Draft IEEE Standard for
Local and metropolitan area networks

Part 16: Air Interface for Fixed Broadband Wireless Access Systems

Amendment for Improved Coexistence Mechanisms for License-Exempt Operation

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Abstract:*Should be based on the scope and purpose of the standard as indicated on the PAR.*

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Introduction

This introduction is not part of IEEE P802.16h, Draft Amendment to IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems - Amendment for Improved Coexistence Mechanisms for License-Exempt Operation.

Participants

This document was developed by the IEEE 802.16 Working Group on Broadband Wireless Access, which develops the WirelessMAN™ Standard for Wireless Metropolitan Area Networks.

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NOTE-The editing instructions contained in this amendment/corrigendum define how to merge the material contained herein into the existing base standard IEEE Std 802.16-2004.

The editing instructions are shown bold italic. Four editing instructions are used: change, delete, insert, and replace. Change is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using strike through (to remove old material) and underscore (to add new material). Delete removes existing material. Insert adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. Replace is used to make large changes in existing text, subclauses, tables, or figures by removing existing material and replacing it with new material. Editorial notes will not be carried over into future editions because the changes will be incorporated into the base standard.

1. Overview

scope: *This amendment specifies improved mechanisms, as policies and medium access control enhancements, to enable coexistence among license-exempt systems based on IEEE Standard 802.16 and to facilitate the coexistence of such systems with primary users.*

applicability: *This amendment improves the coexistence of 802.16 systems in interference environments characteristic of license-exempt operation, including operation in lightly licensed situations where frequencies are not assigned exclusively. Some of the defined procedures could be applied in other cases, which require improved inter-system coexistence.*

1.3 Frequency bands

[change the text as indicate in subclause 1.3.3]

1.3.3 License-exempt and uncoordinated frequencies below 11 GHz ~~(primarily 5-6 GHz)~~

The physical environment for the license-exempt bands and uncoordinated frequencies below 11 Ghz is similar to that of the licensed bands in the same frequency range, as described in 1.3.2. However, the license-exempt nature introduces additional interference and co-existence issues, whereas regulatory constraints limit the allowed radiated power. In addition to the features described in 1.3.2, the PHY and MAC introduce mechanisms such as dynamic frequency selection (DFS) to detect and avoid interference.

Further enhancements to facilitate co-existence for license-exempt and uncoordinated systems in utilizing improved co-existence mechanisms is embodied in MAC enhancements specified in 6.3.15. and recommended practice and high level protocols specified in chapter 15. This mode of operation provides enhancements to the MAC protocol to provide for better interference measurement, reporting and management; together with negotiation for spectrum sharing and is designated WirelessMAN-CX. Additional needs of systems operating in license-exempt bands are addressed in 8.5 and 15.

License-exempt or uncoordinated bands may adopt RF profiling in terms of selecting a known set of RF parameters, such as a band plan. If such a convention is adopted the design, management and inter-working of uncoordinated systems is eased significantly. If no baseline assumptions about other systems sharing the band can be made then complexity is added to both system design and algorithms implemented.

[Insert the following row into table-1:]

Designation	Applicability	PHY	Additional MAC requirements	Options	Duplexing alternative
WirelessMAN-CX	Below 11 GHz license-exemptor when needed for inter-system improved coexistence	Section 8	MAC enhancements for coexistence (6.4)	Those applicable to PHY implemented. Section 15.	TDD

2. References

3. Definitions

[Insert following sections after 3.85:]

3.86 WirelessMAN-CX: The designation used to describe the realization that adds co-existence procedures and recommended practice to systems implemented below 11GHz, in license-exempt bands or whenever improved inter-system coexistence is needed. This designation is PHY independent and adds additional MAC functionality, together with a recommended practice for achieving coexistence.

3.87 Interference Neighborhood: Interference neighborhood is relative to a system (BS and its subscribers). A system (BS and its SSs) will perceive as interference neighbors, all other systems (BSs and their SSs) which create/receive interference to/from it.

3.88 Community: is composed of those systems (BSs and their SSs) which coordinate to resolve their interference.

3.89 Coexistence Community: is composed of those systems (BSs and their SSs) which have resolved their interference and coexist.

3.90 Coexistence Proxy(CXPRX): Coexistence proxy act as a agent to forward the CP message between their BSs with other BSs and terminals in the internet. It shall be used when the IP contact information is transmitted over the air and be optionally used when no IP contact information is transmitted over the air. By using the coexistence proxy in the coexistence coordination process, all the BSs do not know other BSs' IP address, and contact BSs only via coexistence proxy and the BSID information. In order to prevent various attack from the internet, coexistence proxy could utilize various approach to protect the data service of BSs from being influenced.

3.91 Random Temporary Key (RTK): the temporary key generated and sent by the BS, contained in the air signaling, which is required to be contained in the request messages of coexistence protocol sent to this BS. RTK is used to obstruct the coexistence request from the unqualified internet terminals.

3.92 Alternative Channel (ALTCH): The alternative working channel decided by the base station, on which the base station haven't detected any user and also not currently chosen to be the working channel of this base station.

3.93 Coexistence Signaling Interval (CSI): a predefined time slot for the coexistence protocol signaling purpose, especially for the BS to contact its coexistence neighbor BS through one or more coexistence neighbor SSs in the common coverage area.

3.94 Initialization Coexistence Signaling Interval (ICSI): the periodically appointed CSI specially used by IBS to contact its neighbor OBS. When the IBS get the OCSI allocation and start the operating stage, it will ceased from using the ICSI.

3.95 Operation Coexistence Signaling Interval (OCSI): the rest CSI other than ICSI, periodically reallocated to OBSs.

3.96 Coexistence Signaling Interval Number (CSIN): the periodical number of CSI according to the time order. The range of CSIN is from 0 to the number of CSI in one OCSI cycle.

3.97 Coexistence Signaling: the signaling mechanism defined in WirelessMAN-CX to exchange information between wireless systems with or without the same PHY profiles.

3.98 Coexistence Messaging: the messaging mechanism defined in WirelessMAN-CX to exchanged information between wireless systems with the same PHY profiles.

4. Abbreviations and acronyms

[Insert the following abbreviations at appropriate location:]

AH	Authentication Header
ALTCH	Alternative Channel
BSD	Base Station Descriptor
BSIS	Base Station Identification Server
CCD	Candidate Channel Determination
CMI	Coexistence Messaging Interval

CNTI	Cognitive Network Time Interval
CoNBR	Coexistence Neighbor
CR	Cognitive Radio
CR_NOC	Cognitive Radio Network Operations Centre.
CSI	Coexistence Signaling Interval
CSIN	Coexistence Signaling IntervalNumber
CTS	Coexistence Time Slot
CX	Co-eXistence
CXPRX	Coexistence Proxy
DRRM	Distributed Radio Resource Management
DSM	Distribution System Medium
ESP	IP Encapsulating Security Payload
IANA	Internet Assigned Numbers Authority
IBS	Initializing Base Station
ICSI	Initialization Coexistence Signaling Interval
IETF	Internet Engineering Task Force
IPBC	IP address Broadcast
IPsec	Internet Protocol Security
NOC	Network Operation Center
NURBC	Neighborhood Update Request BroadCast
OBS	Operating Base Station
OCSI	Operation Coexistence Signaling Interval
PKM	Private Key Management
PLE	Path Loss Exponent
PSD	Power Spectrum Density
RADIUS	Remote Authentication Dial-in User Service
RTK	Random Temporary Key
SAP	Service Access Point
SSURF	Subscriber Station Uplink Radio Frequency
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
UTC	Universal Coordinated Time
WirelessMAN-CX	Wireless Metropolitan Access Network Co-eXistence

Notes: the IP broadcasting in the airlink is to be reconsidered and call for contribution for modification.

5. Service-specific CS

6. MAC common part sublayer

6.3 Data/Control plane

6.3.2 MAC PDU Format

6.3.2.3 MAC management messages

[Insert the following rows into Table-14. MAC Management messages as indicate.]

Type	Message Name	Message Description	Connection
67	BSD	Base Station Descriptor	Broadcast
68	SSURF	SS Uplink RF Descriptor	Basic
69	MADD	Master Advertisement Discovery Descriptor	Broadcast
70	SADD	Slave Advertisement Discovery Descriptor	Broadcast
71	ADPD	Advertisement Discovery Policy Descriptor	Broadcast
72	BS_CCID_IND	*[Base Station Co-Channel Interference Detection Indication]*	Basic
73	S_CCID_RSP	*[Base Station Co-Channel Interference Detection Response]*	Basic
74-255		reserved	

6.3.2.3.33 Channel measurement Report Request/Response (REP-REQ/RSP)

[Change the text in section 6.3.2.3.33 as indicated:]

If the BS, operating in bands below 11 GHz, requires RSSI and CINR channel measurement reports, or requires neighbor detection reports, it shall send the channel measurements Report Request message. The Report Request message shall additionally be used to request the results of the measurements the BS has previously scheduled. Table 62 shows the REP-REQ message.

The REP-REQ message shall contain the following TLV encoded parameters:

Report Request

The channel measurement Report Response message shall be used by the SS to respond to the channel measurements listed in the received Report Requests. Where regulation mandates detection of specific signals by the SS, the SS shall also send a REP-RSP in an unsolicited fashion upon detecting such signals on the channel it is operating in, if mandated by regulatory requirements. The SS may also send a REP-RSP containing channel measurement reports, in an unsolicited fashion, or when other interference is detected above a threshold value. In cases where specific signal detection by an SS is not mandated by regulation, the SS may indicate 'Unmeasured. Channel not measured.' (see 11.12) in the REP-RSP message when responding to the REP-REQ message from the BS. Especially for a coexistence system, when SS have detected the broadcasting signaling from the coexistence neighbor BS, the SS need to use REP_RSP to report the information to its serving BS in an unsolicited manner. Table 63 shows the REP-RSP message.

[add a new section 6.3.2.3.62 as indicate:]

6.3.2.3.62 Base Station Descriptor (BSD) message

The base station descriptor (BSD) message specifies the base station identification information. This message is sent only in the CMI (see 15.2.1.1.7) claimed by the Base Station and it is intended to be decoded by SSs associated to other systems.

The BSD has two purposes. First, it contains pertinent information related to the base station, allowing foreign (interfered-with) Subscriber Stations to identify it as interference. Secondly, it allows the differentiation

of a CMI from a non-CMI. When it is received, the SS associated with the BS will recognize the interval containing the BSD message as a CMI, and will transmit SSURF messages in response to it. Note that SSURF will use the uplink bandwidth granted only in the CMI, and is not transmitted in the data link.

The length of BSD message is an integral number of bytes. The BSD messages are generated and broadcast within the downlink portion of a CMI every minute by a base station.

A BSD message shall include the following parameters:

IP_Proxy address information: The Coexistence Proxy IP address information provides the IP address of the Coexistence Proxy Server. The encoding of this field is given below in TLV format.

BS EIRP: The BS EIRP field is included within this message to help determine the interference potential. It is signed in units of 1 dBm.

RF Antenna Sector ID: The RF antenna sector ID is used to identify the RF antenna in a base station if multiple RF antennas are used for RF reuse purpose.

Table 108aa—BSD message format

Syntax	Size	Notes
BSD_Message_Format ( ) {		
Management Message Type =TBD	8 bits	
BS EIRP	16 bits	dBm
BSID	48 bits	
BS RF antenna sector ID	8 bits	0-reserved for no RF reuse BS 1-255 for RF reuse BS
IP_Proxy_Address_IE( )	Variable	TLV specific
}		

[add a new section 6.3.2.3.63 as indicate:]

6.3.2.3.63 Subscriber Station Uplink Radio Frequency (SSURF) message

The Subscriber Station uplink radio frequency (SSURF) message is the complement to the BSD message except it is sent on the uplink during the CMI interval claimed by the Base Station to which the SS is registered.

This message if received by foreign (interfered-with) Base Stations, will identify the SS as being an interferer.

A SSURF message shall includes the following parameters to identify a subscriber station:

SS ID: Subscriber station identifier, in the context of this message, identifies the transmitting SS. This SS is the source of co-channel interferences reported in this message.

BS ID: Serving Base Station associated with the SS.

BS Antenna Sector ID: The RF antenna sector ID is used to identify the RF antenna in a base station if multiple RF antenna are used for RF reuse purpose.

BS IP_Proxy address information: The BS IP address information uniquely identifies a associated base station. The encoding of this field is given above in TLV format.

.

Table 108ab—SSURF message format

Syntax	Size	Notes
SSURF_Message_Format( ) {		
Management Message Type =TBD	8 bits	
SS ID	8 bits	
BS ID	48 bits	Associated base station identifier
BS Antenna sector ID	8 bits	
BS IP Proxy_Address_IE( )	Variable	
}		

[add a new section 6.3.2.3.64 as indicate:]

6.3.2.3.64 Master Advertisement Discovery Descriptor (MADD) message

The Master Advertisement Discovery Descriptor (MADD) message specifies the advertisement discovery information sent by the master BS towards the SSs located in the overlapped area of this master cell with the surrounding slave cells. This information is sent by the master BS in MATI in downlink (section 15.6.2.2.6.5) on a given channel (frequency domain). This information is sent every TMATI in the advertisement discovery period TS, and the advertisement discovery sequence occurs very TAD. MADD provides the necessary information to the SSs of the surrounding slave cells to inform the slave BSs about possibilities of radio resources sharing with this master cell.

A MADD message shall include the following parameters:

BSID_M: ID of the master BS.

BS_ IP_Proxy_address_M: The Coexistence Proxy IP address of the master BS.

T_START_M: The Starting time of the period opened for renting by the master cell on that channel.

T_End_M: The Ending time of the period opened for renting by this master cell on that channel.

MRCTN: Minimum number of credit tokens required by the master BS to its share radio resources.

LC: List of other channels (frequency domain) of master cell opened for renting.

-

Table 108ac—MADD message format

Syntax	Size	Notes
MADD_Message_Format( ) {		
Management Message Type =TBD	8 bits	
BSID_M	48 bits	
IP_Proxy_address_M	variable	TLV specific
T_START_M	16 bits	Starting time of the period opened for renting by the master cell (in microseconds)
T_End_M	16 bits	Ending time of the period opened for renting by the master cell (in microseconds)
MRCTN	TBD	Minimum number of credit tokens required by the master BS
LC	TBD	List of other channels (frequency domain) of master cell opened for renting
}		

[add a new section 6.3.2.3.65 as indicate:]

6.3.2.3.65 Slave Advertisement Discovery Descriptor (SADD) message

The Slave Advertisement Discovery Descriptor (SADD) message specifies the advertisement discovery information sent by the slave BS towards the SSs located in the overlapped area of this slave cell with the surrounding master cells. This information is sent by the slave BS in SATI in downlink (section15.6.2.2.6.5) on a given channel (frequency domain). This information is sent every TSATI in the advertisement discovery period TS, and the advertisement discovery sequence occurs very TAD. SADD provides the necessary information to the SSs of the surrounding master cells to inform the master BSs about possibilities of radio resources sharing with this master cell.
A SADD message shall include the following parameters:

BSID_S: ID of the slave BS.

BS_ IP_Proxy_address_S: The Coexistence Proxy IP address of the slave BS.

T_START_S: Starting time from which the slave BS would be interested to rent a period opened for renting (in microseconds).

T_End_S: Ending time of the period the slave BS would be interested to rent (in microseconds).

.

Table 108ad—SADD message format

Syntax	Size	Notes
SADD_Message_Format( ) {		
Management Message Type =TBD	8 bits	
BSID_S	48 bits	
IP_Proxy_address_S	variable	TLV specific
T_START_S	16 bits	
T_End_S	16 bits	
}		

6.3.2.3.66 Advertisement Discovery Policy Descriptor (ADPD) message

The Advertisement Discovery Policy Descriptor (ADPD) message is sent by the slave BS in SATI in down-link (section 15.6.2.2.6.5) on a given channel (frequency domain). ADPD specifies when some SSs (located in the overlapped area between this slave cell and surrounding master cells and getting MADD message from master BS) associated to this slave BS have to report the MADD conveyed in MATI towards this BS.

ADPD message shall include the following parameters:

T_START_S: Starting time from which the slave BS would be interested to rent a period opened for renting (in microseconds). Below this value, the SSs associated to that slave BS are not allowed to report MADD content to their BS.

T_End_S: Ending time of the period the slave BS would be interested to rent (in microseconds). Beyond this value, the SSs associated to that slave BS are not allowed to report MADD content to their BS.

RCTN_MAX: Maximum admissible number of credit tokens per radio resource unit the slave BS will provide to get the radio resources rented by the master BSs. Beyond this value, the SSs associated to that slave BS are not allowed to report MADD content to their BS.

.

Table 108ae—ADPD message format

Syntax	Size	Notes
ADPD_Message_Format( ) {		
Management Message Type =TBD	8 bits	
T_START_S	16 bits	
T_End_S	16 bits	
RCTN_MAX	16 bits	
}		

6.3.2.3.67 BS_CCID_IND message

The subscriber station co-channel interference indication (BS_CCID_IND) message contains co-channel interference information detected at a subscriber station. The source of co-channel interference can be foreign sources such as radars or non-WirelessMAN-CX compliant devices, as well as other WirelessMAB-CX base stations that may or may not be members of the coexistence community.

This is a MAC management message sent by a SS to its home base station when unresolved co-channel interference is detected at a SS. Unresolved co-channel interference typically is interference which is new to the SS and which is not recorded in the SS Interference Table as having been resolved using the Coexistence Protocol by the home base station of the SS. Resolved interference implies that messages destined to the SS will not be corrupted by interference emanating from a foreign WirelessMAN-CX base station. This message is sent either every time (or after a set number of detection instances) the foreign BSD interference is detected and until the interference is resolved.

The message is sent also when non-WirelessMAN-CX systems are detected, such RLAN signals or radars which have higher regulatory priority to the bandwidth.

The length of BSD message is an integral number of bytes.

This BS_CCID_IND MAC management message shall contain the following minimum information to help determine the source and victim of co-channel interference:

BS_ID: The foreign BS identity taken from the BSD message.

IP_ BS Proxy_Address_IE: The proxy IP address associated with a foreign base station, derived from the BSD.

BS RF_Sector_ID: The RF antenna sector ID is used to identify the RF antenna in a base station if multiple RF antenna are used for RF reuse purpose; it is taken from the BSD.

BS EIRP: The EIRP of the interfering Base Station, taken from the BSD.

CMI_ID_XX

The Coexistence Messaging Interval during which the interference was received.

SS_ID: The subscriber station identifier: a 48 bit long field identifying the subscriber station that generated this BS_CCID_IND management message. This subscriber station is a victim of co-channel interference reported in this message.

INT_BSD_Frq: The frequency of interference BSD events detected per CMI cycles (calculated as the number of BSD interference events per N full CMI cycles [1 cycle= 1 min TBD]) . For this specific BSD, as relayed by this BS_CCID_IND message. This value can be set by the home base station to make the SS less responsive to interference detection (such as highly sporadic and transient events).

DFS_LE_PWR_FRQ: This parameter is used to identify the mean RSSI of the radar signals or non-WirelessMAN-CX systems detected in CMI_ID_54. Radar signals may be detected at below DFS threshold values and the value given for their signature will be radar events (pulses) per minute. If non-WirelessMAN-CX systems their signature will be given as number of detected CMI_ID_54 events per N CMI cycles [1 minute=1 Cycle TBD]

.

Table 108af—BS_CCID_IND message format

Syntax	Size	Notes
BS_CCID_IND_Message_Format( ) {		
Management Message Type =TBD	8 bits	
SS_ID	48 bits	Subscriber station ID
DFS_LE_PWR_FRQ	32 bits	Bits 0-3: Device Type Bits 4-15: Device detection specific Bits 16-23: 8 bit mean RSSI Bits 24-31: TBD
INT_BSD_Frq	16 bits	The frequency of interference BSD (or non-WirelessMAN-CX) interference events at set detection power threshold
BS ID	48 bits	Foreign
BS_RF_Sector_id	8 bits	1-255 for RF reuse BS 0 reserved for no RF reuse BS
BS EIRP	8 bits	Nominal EIRP of interfering BS
CMI_ID_XX	8 bits	Coexistence Messaging Interval ID (CMI_ID_54 for non-WirelessMAN-CX)
IP_BS Proxy_Address	Variable	(Proxy IP)
}		

6.3.2.3.68 BS_CCID_RSP message

This message is sent to the SS initiating the BS_CCID_IND message. It is sent by the BS and it is used to indicate whether the interference events identified in the BS_CCID_IND have been resolved. For DFS and non-WirelessMAN-CX responses, other responses will be issued by the network management systems, which can entail moving to other channels, reducing EIRP, etc, at the SS.

BS_CCID_RSP shall contain the following parameters:

BS_ID: The identity of the foreign BS noted in the BS_CCID_RSP. This can be null if the message was originally due to DFS or non-WirelessMAN-CX sources.

RSP_FIELD: The response field indicates:
(1) Interference with foreign BS is/is not resolved
(2) Sub DFS threshold and non-WirelessMAN-CX users noted, no response at present
(3) TBD threshold/response adjustment variables (TBD)

-

Table 108ag—BS_CCID_RSP message format

Syntax	Size	Notes
BS_CCID_RSP_Message_Format( ) {		
Management Message Type =TBD	8 bits	
BS_ID	48 bits	Interfering BS station ID for which this response is sent to SS; set to zero if non-WirelessMAN -CX
RSP_Field	16 bits	The response field indicates: Bit 0: Response to Radar=1 Response to Non-WirelessMAN CX =0 Bit 1-2: 0 - Resolved 1 - Pending Resolution 2 - Adjust threshold 3 - Inhibit Response Bit 3-9: Interference RSSI Power threshold Adjust (-95 to -55 dBm (TBD) Bit 10-15: TBD Threshold for number of inter-ference events per CMI Cycle)
}		

6.3.15 DFS for license-exempt operation

6.3.15.1 Introduction

[Add the following text at the end of section 6.3.15.1.]

Figure h 1 illustrates the flowchart representation of a generic scheme for operation in bands with specific spectrum users. WirelessMAN-CX provides enhanced reporting for specific spectrum users and addresses the need in situations where more than one type of specific spectrum user is operational in a given band.

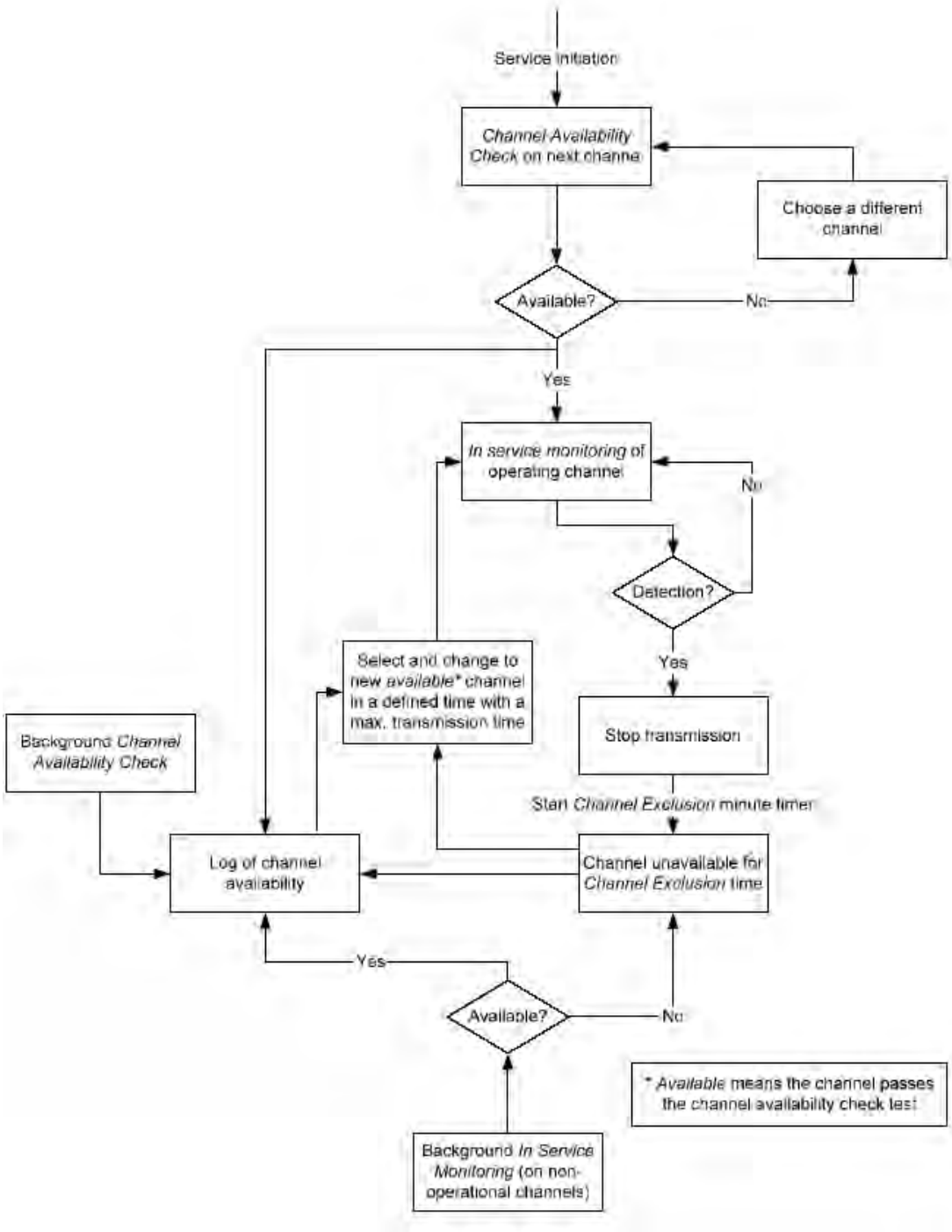


Figure h1—Flowchart showing generic operation in bands with specific spectrum users

[Insert a new section 6.4 :]

6.4 MAC enhancement for coexistence

This section describes MAC enhancements for WirelessMAN-CX in support of license-exempt and uncoordinated bands. Firstly concepts are described which are general to the MAC, after which PHY specific interactions are considered. PHY specific discussion is required since WirelessMAN-CX operation is dependant on the features supported for a given PHY.

[tbc for deriving the appropriate part from clause15 here]

6.4.1 General concepts

This section describes WirelessMAN-CX operation specific to the MAC and support of the PHY from the MAC..

6.4.1.1 Capability Negotiation

A Base Station is made aware of the WirelessMAN-CX capabilities and functionality support by the SS using the field described in section11.7.8.

A mechanism is provided by which WirelessMAN-CX and non-WirelessMAN-CX devices are to interwork. This is an important mechanism for deployment scenarios where regulatory designation of WirelessMAN-CX operation is required. Some examples of how the capability negotiation can be used are given:

- A device with WirelessMAN-CX functionality will need to interwork with infrastructure that knows nothing of WirelessMAN-CX.
- A non-WirelessMAN-CX device will need to interwork with WirelessMAN-CX compliant infrastructure.
- A non-WirelessMAN-CX device shall have the ability to be barred from working in a WirelessMAN-CX network - this is deployment specific.
- A WirelessMAN-CX device shall work in a non-WirelessMAN-network as 'normal' non-WirelessMAN-CX device.

6.4.1.2 Extended channel numbering structure

License-exempt or uncoordinated bands may require or provide scope for the use of a defined channel raster or channel bandwidth. This section provides a means to achieve this, and therefore offer simplification to issues of interference managements. Extended channel numbering provide an enhancement to channelization and definition of channel number for WirelessHUMAN operation in section 8.5.1. This extension provides channelization references beyond the limits of 5-6GHz as defined. The channelization is defined accordingly.

- Extended Channel Number (ExChNr) – 2 byte specific channel number reference.
- Base Channel Reference (BaseChRef) – 1 byte base reference to frequency range or deployment band. This reference maps to an absolute frequency value
- Channel spacing (ChSp) - 2 byte channel spacing value (10kHz increments)

In summary the definition of the *Channel Centre Frequency* is:

*Channel Centre Frequency [MHz] = BaseFrequency(BaseChRef)[MHz] + ((ExChNr+1/2)*ChSp *0.01)[MHz]*

This is shown in a graphical representation in Figure h 2.

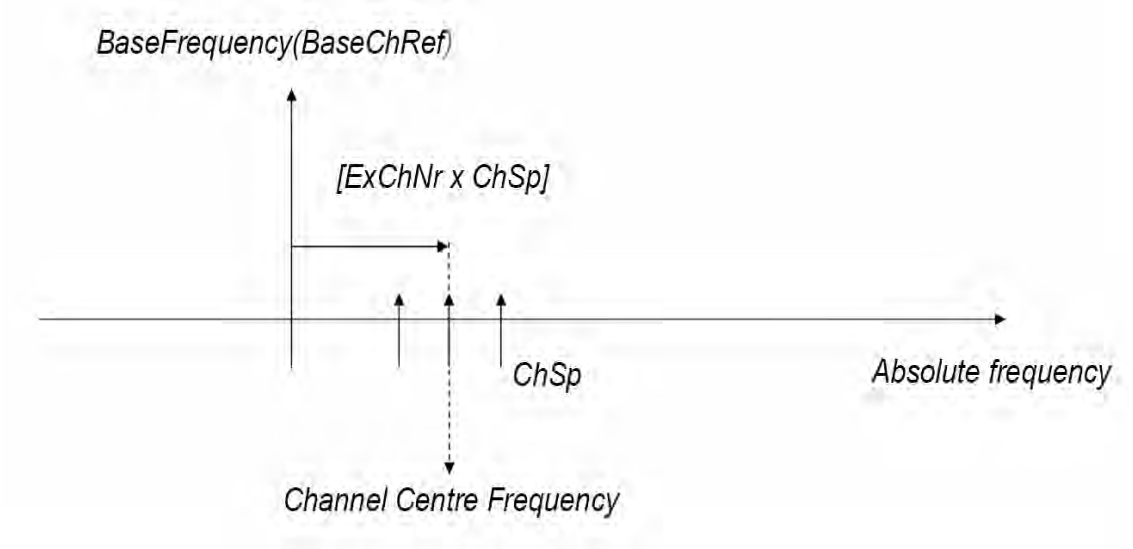


Figure h2—Representation of 'Channel Centre Frequency' calculation.

ExChNr is used in *REP-REQ/REP-RSP* messages while *BaseChRef*, and *ChSp* are communicated at a session setup or reconfiguration.

6.4.1.3 Measurement and Reporting

License-exempt or uncoordinated bands are likely to present an operating environment that has a significantly higher and more dynamic interference profile than licensed bands. Measurement and reporting of the prevailing environment is therefore an important consideration for system operation and stability. Measurement and reporting enhancements provide the ability to:

- Enhance details on environmental knowledge for license-exempt and uncoordinated band operation.
- Provide timely reports for fast link adaptation in an attempt to maintain BER performance.
- Provide bandwidth efficient reports maintain spectral efficiency but also to ensure interference reports are not out-of-date.
- Provide accurate measurements to retain WirelessMAN-CX integrity.
- Provide enhanced reporting for specific spectrum users.

6.4.2 WirelessMAN-CX support for OFDMA PHY

This section provides a description of WirelessMAN-CX support for the WirelessMAN-OFDMA PHY.

6.4.2.1 Co-existence zone (CXZ) for downlink and uplink

The addition of a CXZ provides the means to include all co-existence enhancements in a defined region within the WirelessMAN-OFDMA PHY. It is expected that all co-existence operation will occur within this zone.

6.4.2.2 Measurement and Reporting

In order to meet strict requirement on measurement and reporting in license-exempt and uncoordinated bands enhanced reporting for WirelessMAN-CX is supported through the REP-REQ/REP-RSP MAC messages (see sections 11.11 and 11.12 respectively). Also the use of the WirelessMAN-OFDMA fast feedback channel is used to enhance reporting capabilities. Section 6.3.18.2 discusses periodic CINR report with fast-feedback (CQICH) channel. It is recommended that interference measurements are undertaken on the effective (feedback type=0b01) or physical (feedback type=0b00) CINR measurement for a CXZ permutation zone (Zone permutation=0b110 and report type=1) from pilot subcarriers (measurement type=0). Section 8.4.5.4.12 gives specific details of the CQICH allocation IE.

7. Privacy sublayer

8. PHY

8.4 WirelessMAN-OFDMA PHY

8.4.4 Frame structure

8.4.4.2 PMP frame structure

[change the last paragraph of section 8.4.4.2 into the following text in 802.16 primary standard:]

The OFDMA frame may include multiple zones (such as PUSC, FUSC, PUSC with all subchannels, optional FUSC, and AMC, CXZ, TUSC1, and TUSC2), the transition between zones is indicated in the DL-Map by the STC_DL_Zone IE (see 8.4.5.3.4), CXZ_DL_IE (see 8.4.5.3.11), or AAS_DL_IE (see 8.4.5.3.3). No DL-MAP or UL-MAP allocations can span over multiple zones. Figure 219 depicts the OFDMA frame with multiple zones.

[change figure 219 as following:]

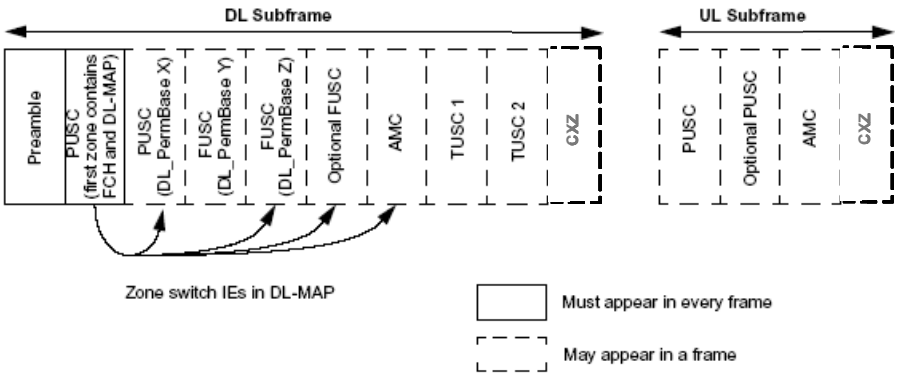


Figure 219—Illustration of OFDMA frame with multiple zones

[insert the following rows to table 277a, section 8.4.5.3.2.1.]

Extended DIUC (hexadecimal)	Usage
09	CXZ_DL_IE
~~09~~ 0A	*reserved*

[Insert a new section 8.4.5.3.28:]

8.4.5.3.28 Co-existence zone (CXZ) downlink IE format

Within a frame, the switch to co-existence operation is marked by using the extended DIUC = 15 with the CXZ_DL_IE(). The CXZ_DL_IE defines a DL CX zone and spans continuous OFDMA symbols. Multiple CXZ zones can exist within the same frame. When used, the CID in the DL_MAP_IE() shall be set to the broadcast CID.

Table 286aa— CXZ downlink IE

Syntax	Size	Notes
CXZ_DL_IE() {		
Extended DIUC	4 bits	CXZ = 0x09
Length	4 bits	Length = 0x01
OFDMA symbol offset	8 bits	Denotes the start of the zone (counting from the frame preamble and starting from 0).
CXZ duration	10 bits	Denotes the duration of the zone
Next CXZ start	12 bits	The time interval, in symbols, until the start of the next downlink CXZ.
}		

[insert following row into table-289a as indicate(section 8.4.5.4.4.1):]

Extended UIUC (hexadecimal)	Usage
0B	CXZ_UL_IE
~~0B~~0C … 0F	*reserved*

[change the row in table 300 as indicate (section 8.4.5.4.12)]

Syntax	Size	Notes
Zone permutation	3 bits	The type of zone for which to report 0b000 - PUSC with 'use all SC = 0' 0b001 - PUSC with 'use all SC = 1' 0b010 - FUSC 0b011 - Optional FUSC 0b100 - Safety Channel region 0b101 - AMC zone (only applicable to AAS mode) 0b110 - CXZ 0b~~110~~111 - Reserved

[Insert a new section 8.4.5.4.29]

8.4.5.4.29 Co-existence zone (CXZ) uplink IE format

Within a frame, the switch to co-existence operation is marked by using the extended UIUC = 15 with the CXZ_UL_IE(). The CXZ_UL_IE defines a DL CX zone spans continuous OFDMA symbols. Multiple CXZ zones can exist within the same frame. When used, the CID in the DL_MAP_IE() shall be set to the broadcast CID.

Table 302w—CXZ uplink IE

Syntax	Size	Notes
CXZ_UL_IE() {		
Extended DIUC	4 bits	CXZ = 0x09
Length	4 bits	Length = 0x01
CXZ zone length offset	8 bits	The length of the uplink CXZ zone.
CXZ duration	10 bits	Denotes the duration of the zone
Next CXZ start	12 bits	The time interval, in symbols, until the start of the next uplink CXZ.
}		

9. Configuration

10. Parameters and constants

[insert a new section 10.5 as indicate:]

10.5 Coexistence specific values

10.5.1 Radio signaling

The absolute time runs on a periodic base of 1800 sec. (30 minutes). For cases when one or more seconds are added/subtracted at the mid-night, the absolute time is supposed to follow those changes. All the values below are repeating based on the relation:

Time = (Absolute time) mod 1800.

The time is expressed as sec: ms, according to the decimal format xxxx:yyy.

Table 345a—parameter of absolute time reference

Absolute time reference	Chapter	Reference	Value
AT1	Radio signaling (15.4.4.1.2)	Start of the first MAC Frame (no. N) including cognitive radio signaling	0003:000, 15:000, 27:000, 39:000, 51:000

AT2	Radio signaling (15.4.4.1.2)	Start of the 2nd MAC Frame including cognitive radio signaling	AT1+0001:000
AT3	Radio signaling (15.4.4.1.2)	Start of the 3rd MAC Frame including cognitive radio signaling	AT1+0002:000
AT4	Radio signaling (15.4.4.1.2)	Start of the 4th MAC Frame including cognitive radio signaling	AT1+0004:000

Table 345b—parameter of radio signaling timer

Timer	Chapter	Reference	Value
T_cogn	Radio signaling (15.4.4.1.2)	Repetition period of the cognitive signaling	12s
Tad_reg	Radio signaling (15.4.4.1.2)	Maximum time-interval in which an ad-hoc unit has to repeat the registration	1800s
T_iptx	Radio signaling (15.4.4.1.2)	Time interval between the start of consecutive CSI slots for the transmission of the IP address using frequency-keyed energy pulses	20ms

11. TLV encodings

11.7 REG-REQ/RSP management message encodings

[Insert the following row into table 369a:]

Type	Parameter
45	WirelessMAX-CX capability
46	Base Channel Reference (BaseChRef)
47	Channel Spacing (ChSp)

11.7.8 SS capability encodings

[insert new subclause 11.7.8.14:]

11.7.8.14 WirelessMAX-CX capability

Name	Type (1 byte)	Length (1 byte)	Value	Scope
WirelessMAX-CX capability	45	1	Bit #0: No WirelessMAX-CX capability Bit #1: WirelessMAX-CX capability Bits #2 - #7: Reserved	REG-REQ
Base Channel Reference (BaseChRef)	46	1	Base Channel Reference in MHz providing base reference to frequency range or deployment band	REG-RSP
Channel Spacing (ChSp)	47	2	Channel Spacing in 10kHz increments.	REG-RSP

11.11 REP-REQ management message encodings

[insert the following entry in the second table of 11.11:]

Coexistence neighbor Interference Report	1.9	1	Bit #0: 1-include information received in BS_NURBC Bit #1: 1-include RSSI of CSI symbols(only valid when bit#0 is set to one) Bit #2: 1-include frame number that start to receive BS_NURBC Bit #3~7: reserved, shall be set to zero
ExChNr	1.10	2	Physical extended channel number (WirelessMAX-CX only)
Extended report type (WirelessMAN-CX only)	1.11	1	Bit #0 = 1: Include summary extended report Bit #1 = 1: Include full extended report Bit #2 = 1: Specific spectrum user extended report Bits #3 - #7: Reserved

11.12 REP-RSP management message encodings

[insert the following entry in the first table of 11.12:]

Coexistence neighbor Report	7	variable	Compound
Extended report type	8	variable	Compound

[insert the following table into 11.12 as indicates:]

Coexistence neighbor Interference Report type	Name	Type	Length	Value
all	CoNBR system count /new neighbour system discovery indication	7.1	1	Bit #0:1-New CoNBR Discovered by BS_NURBC received Bit #1-7:The number of CoNBR that interference to this SS

bit #0=1	Neighborhood update request report IPv4	7.2	12	Bits 15:0 - RTK Bits 63:16 - BSID Bits 95:64 - BS IP address(IPv4) 4bytes IPv4 address of CoNBR interference to this SS, 255. 255. 255. 255 indicate the fail of CRC check.
bit #0=1	Neighborhood update request report IPv6	7.3	24	Bits 15:0£¦RTK Bits 63:16£¦BSID Bits 191:64£¦BS IP address(IPv4) 16bytes IPv6 address of CoNBR interference to this SS, all ones indicate the fail of CRC check.
bit #1=1	BS_NURBC RSSI	7.4	2	1byte RSSI mean (see also 8.2.2, 8.3.9, 8.4.11) for details) 1byte standard deviation
Bit #2=1	Starting Frame Serial Number of BS_NURBC	7.5	3	Bit# 0-24: frame number of BS_NURBC starting frame

REP-REQ Extended report type	Name	Type	Length	Value
Bit #0 = 1 OR Bit #1 = 1 OR Bit #2 = 1	ExChNr	8.1	2	Extended physical channel number to be reported on.
Bit #0 = 1 OR Bit #1 = 1 OR Bit #2 = 1	Start frame	8.2	2	16 LSBs of Frame number in which measurement for this channel started
Bit #0 = 1 OR Bit #1 = 1 OR Bit #2 = 1	Duration	8.3	3	Cumulative measurement duration on the channel in multiples of Ts. For any value exceeding 0xFFFFFF, report 0xFFFFFF
Bit #0 = 1	WirelessMAX-CX interference indicator	8.4	1	Bit #0: Low interference indication Bit #1: Medium interference indication Bit #2: High interference indication Bit #3: Specific spectrum user detected on the channel Bit #4: Channel not measured.
Bit #1 = 1	Zone specific CINR report	8.5	2	1 byte: mean 1 byte: standard deviation
Bit #1 = 1	Zone specific RSSI report	8.6	2	1 byte: mean 1 byte: standard deviation
Bit #2 = 1	Specific spectrum user detection report	8.7	1	Bit #0: Specific spectrum user type #0 Bit #1: Specific spectrum type #1 Bit #2: Specific spectrum type #2 Bit #3: Specific spectrum type #3 Bit #4: Specific spectrum type #4 Bit #5: Specific spectrum type #5 Bit #6: Specific spectrum not known Bit #7: Channel not measured

[insert a new section 11.20 in clause 11 as indicate:]

11.20 BSD and SSURF Message and Encodings

IP_Proxy_Address_IE Encoding:

Name	Type (1 byte)	Length (1 byte)	Value	PHY Scope
ProxyIPv4 Address	1	4	Proxy IP address if IPv4 is supported.	all
ProxyIPv6 Address	2	16	Proxy IP address if IPv6 is supported.	all

There can be one and only one information element in an IP_Address_IE.

12. System profiles

13. 802.16 MIB structure for SNMP

14. Management Interfaces and Procedures

[insert new clause 15:]

15. Mechanism for improved coexistence

[Editor's notes: the figure number and table number is temporarily marked as Figure hxxx. And Table hxxx, these number should be corrected according to WG rules before the draft release]

15.1 General

This clause describes high-level protocols and policies to be used for coordinating the system operation in order to reduce the inter-system interference.

The basic mechanisms for achieving better coexistence are different for managed systems and for ad-hoc system s. It is recognized that the managed systems , generally deployed by operators, should receive a higher priority than the ad-hoc systems .

Three basic mechanisms for achieving coexistence are:

- MAC Frame Synchronization, including Tx and Rx intervals;
- Adaptive channel selection, for finding a less interfered or less used frequency;
- Separation of the remaining interference in the time domain, by using coordinated scheduling and a fairness approach.

For inter-system communication, at infrastructure and radio level, there are defined IP-level messages, MAC level messages and Cognitive Radio Signaling.

Communication using IP-level messages is the most general case and is PHY independent. It allows distributed BS-BS communication as well as communication with a central database. The messages defined for such communication constitute the Coexistence Protocol.

The MAC-level messages are intended for systems using the same PHY profile. These message may convey special information between the BS and its subscribers, or may send messages between systems. In the last case, the communication takes place during the Coexistence Messaging Interval.

The Cognitive Radio signaling uses elements of the existing PHY modes and allows simple communication between different systems. The radio signaling may be used to communicate with ad-hoc systems, or to indirectly transmit contact information for the IP network during the Coexistence Signaling Interval.

[These simple signals are selected in such a way, to allow in the future the extension of these procedures for communication with other systems, not belonging to IEEE 802.16 family.]

Different system parameters, including GPS coordinates and timing, may be shared between systems, through distributed communication between Base Stations grouped in a Coexistence Community.

The level of interference and the interference source may be assessed using the Radio Signatures and the interferer identification procedures.

Interference-free sub-frames are initially created based on the selection of one of three possible rules and control of system power. The Coexistence Protocol includes procedures, which allow the interference- free radio resource re-allocation. Some of these procedures use credit tokens and negotiations, such that the interference-free resources may be dynamically apportioned to support the changing character of the traffic.

The protocols and policies described in this chapter enable operation with reduced interference. The Coexistence Zone provides support at the MAC level for scheduling the interference-free sub-frames.

The following table shows a list of the coexistence mechanisms for WirelessMAN-CX. The mechanisms are classified with collaborated and non-collaborated. Collaborated means information exchanges between the systems in the mechanism, while non-collaborated means the systems do not exchange information in the mechanism:

Table h1—coexistence mechanism list for WirelessMAN-CX

Applicable	**1: with wired IP communication available**	**Yes**				**No**			
Condition	**2: same PHY profile**	**Yes**		**No**		**Yes**		**No**	
	3: in signaling/messaging range*	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**
non-collaborative	dynamic frequency selection(DFS)6.3.15	✓	✓	✓	✓	✓	✓	✓	✓
mechanism	GPS timing recovery(GPS/UTC)	✓	✓	✓	✓	✓	✓	✓	✓
collaborative	IP network message(CP message)15.2.2.3	✓	✓	✓	✓				
mechanism	coexistence proxy(CXPRX)15.2.1.1.6	✓	✓	✓	✓				
	coexistence signaling (CSI/ radio signature)15.2.1.1.3/4/5	✓		✓		✓		✓	
	coexistence messaging(CMI/CCD) 15.2.1.1.7	✓				✓			
	sub frame sharing(master sub frame)	✓	✓	✓	✓	✓		✓	
	channel reallocation(ACS)	✓	✓	✓	✓	✓		✓	
	credit token	✓	✓	✓	✓				

15.1.1 Component and Relationship

System: the BS and its associated SSs form a system

Neighbor Relationship: neighbor is a kind of relationship between two systems, when the BS in at lest one of these two systems make interference higher than certain threshold to at lest one SS in another system, or at lest on of the SSs in at lest one of these two systems make interference higher than certain threshold to the BS in another system.

The Figure h 3 shows some examples of neighbor relationship formed by bidirectional interference. In the Figure h 3, system A have neighbor relationship with system B, system C and system D, vice versa, system B have neighbor relationship with system A, so do system C and system D.

The Figure h 4 is an example of neighbor relationship formed by unidirectional interference., system E and system F have neighbor relationship with each other, although all the interference between the two systems is caused by system E. The interference from the SSs in one system to the SSs in another system, and from the BS in one system to the BS in another system is ignored, for the reason that they have been avoid by transmit/receive synchronization.

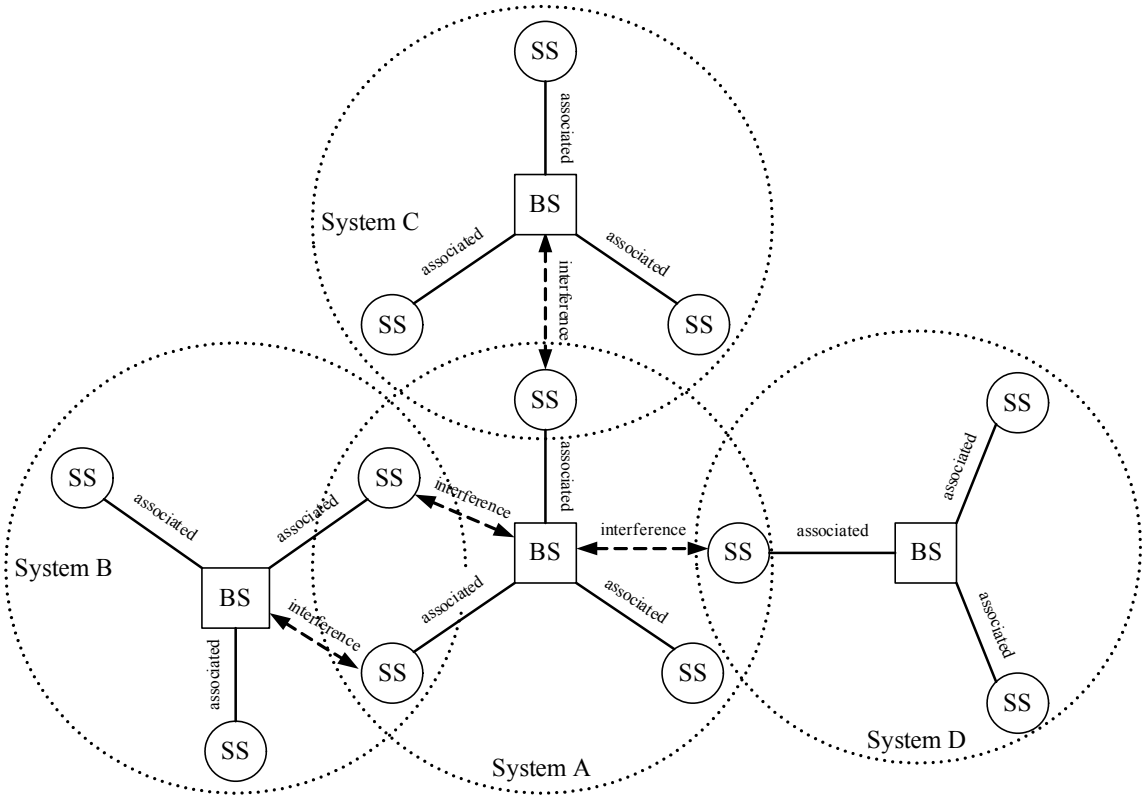


Figure h3—Neighbor relationship formed by bidirectional interference

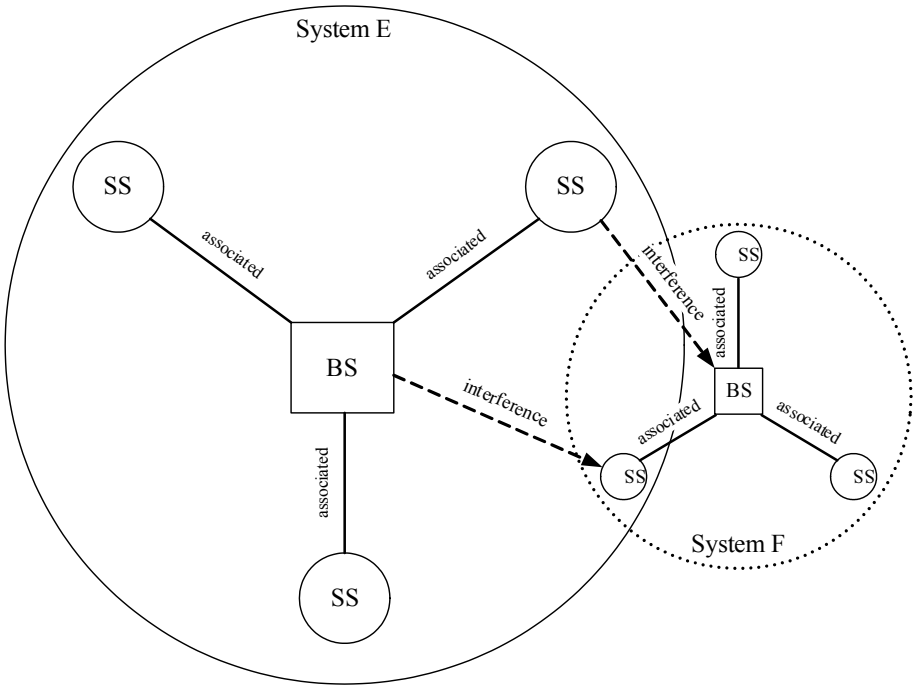


Figure h4—Neighbor relationship formed by unidirectional interference

Neighbor: another system should be called a neighbor system of the system, when it have the neighbor relationship with this system,

Interference Victim System: the system is an interference victim system, when there is BS or SS in this system which is interfered by the system's neighbor system, and the interference is higher than a certain threshold. The interference victim system could be an interference source system to its neighbor system at the same time(eg. system A/B/C/D in Figure h 3), or only an interference victim system of its neighbor system(eg. system F in Figure h 4).

Interference Source System: the system is an interference source system, when there is BS or SS in this system which make interference to the system's neighbor system, and the interference is higher than a certain threshold. The interference source system could be an interference victim system to its neighbor system at the same time(eg. system A/B/C/D in Figure h 3), or only an interference source system of its neighbor system(eg. system E in Figure h 4).

Interference Victim BS/SS: the BS/SS in an interference victim system is an interference victim BS/SS, when the BS/SS is interfered by the SS/BS in this system's neighbor system, and the interference is higher than a certain threshold. The interference victim system could be an interference source BS/SS to the SS/BS in its neighbor system at the same time(eg. BS in system A/B/C and the interference victim SSs in system A/B/C/D in Figure h 3), or only an interference victim BS/SS of the interference source SS/BS in its neighbor system(eg. interference victim BS/SS in System F in Figure h 4).

Interference Source BS/SS: the BS/SS in an interference source system is an interference source BS/SS, when the BS/SS make interference to the SS/BS in the system's neighbor system, and the interference is higher than a certain threshold. The interference source BS/SS could be an interference BS/SS to the SS/BS in its neighbor system at the same time(eg. BS in system A/B/C and the interference source SSs

in system A/B/C/D in Figure h 3), or only an interference source system of its neighbor system(eg. Interference source BS/SS in system E in Figure h 4).

Interference Neighborhood: Interference neighborhood is relative to a system. A system will perceive as interference neighbors, all other systems which create/receive interference to/from it. The Figure h 5 shows some examples of neighborhood.

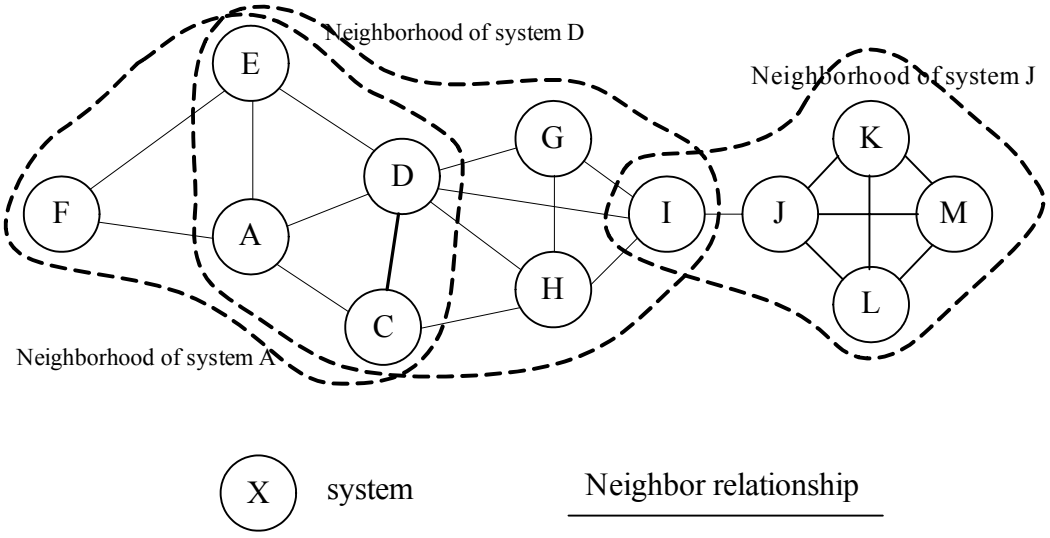


Figure h5—Concept of neighborhood

Community: *[notes: description needed.]*

15.2 Interference detection and prevention – general architecture

15.2.1 Operational Principles and Policies

15.2.1.1 General Principles

The approaches for interference resolution are based on separating the interference in the frequency and time domains.

The separation of interference in the frequency domain is undertaken first, followed bythe separation of remaining interference in the time domain, using procedures of the Coexistence Protocol. The Coexistence Protocol is defined at the IP level and is mainly intended for BS-BS communication.

In order to obtain the IP address of the Base Stations within the Coexistence Neighborhood, a number of procedures are defined, based on operator coordination, or on indirectly transmitting the contact information for the IP network.

The operators can exchange information tables containing the deployment information, such as GPS coordinates, IP address of the CX entity in the Base Station, etc.

Operators may also maintain a common database, including both deployment information and an IP identifier for allowing the operation of a technology-independent coexistence approach. In this case, it is assumed that:

1) Every Base Station includes a data base, base on which the Base Station standing for its system negotiate with other systems in the community; the BS data-base contains information necessary for spectrum sharing, and includes the information related to the Base station itself and the associated SSs; a Base Station and the associated SSs form a system. Other Base Stations can send queries related to the information in the database to the DRRM entity, located in a Base Station (see Figure h 30).The base station shall represent its system in the cooperation with other systems when communicating over the backbone. It is possible to use the subscriber station to relay the control messages in some situations. The base station locations may be obtained by GPS or other positioning systems, however there is no need to register the subscriber locations;

2) In some cases there is country/region data base, which includes, for every Base Station, the following parameters:

- o Operator ID
- o Base Station ID
- o Base Station GPS coordinates
- o IP identifier

The local Radio Administration may have, for light licensing procedure, its own database, generally not including the Base Station ID and IP identifier information.

There is a server that manages the write/reading of this Data Base, using the WirelessMAN-CX standardized procedures; the server and the country/region data base can be hosted by one of the operators or a trusted entity, like the local Radio Administration.

Otherwise, if the region/country database is not available, the base stations should try to find its neighbor and the community topology in a coordinatively distributed fashion.

3) All the Base Stations forming a community will have synchronized MAC frames and frame number.

4) A community will be limited to a reasonable size.

5) All Base Stations and their systems will as a first step be equipped with a spectrum detection and monitoring capability that prevents co-channel utilization of the same spectrum.

6) All base stations are synchronized to a GPS clock. The start of all MAC frame and other transaction are referenced to the rising edge of this clock.

7) All non-WirelessMAN-CX systems, operating in the LE bands, will be provided with the opportunity to signal their presence to WirelessMAN-CX systems within the dedicated CMI slot.

8) The WirelessMAN-CX systems will recognize the use of radar and other systems having higher priority to LE spectrum.

9) Every system will have a guaranteed minimum access time for the interference free use of the radio resource, being able to receive with minimum interference and to transmit at the needed powers for allowing communication between its Base Station and the remote subscribers.

Figure h 6 illustrates an example of three overlapping radio systems and illustrates a possible implementation of the guaranteed radio resource principle.

The overlapping radio systems create different interference zones based on the spatial distance between transmitters and receivers. As example of BS to SS interference,, the radio receivers in Zone A have interference between system 1 and system 2.

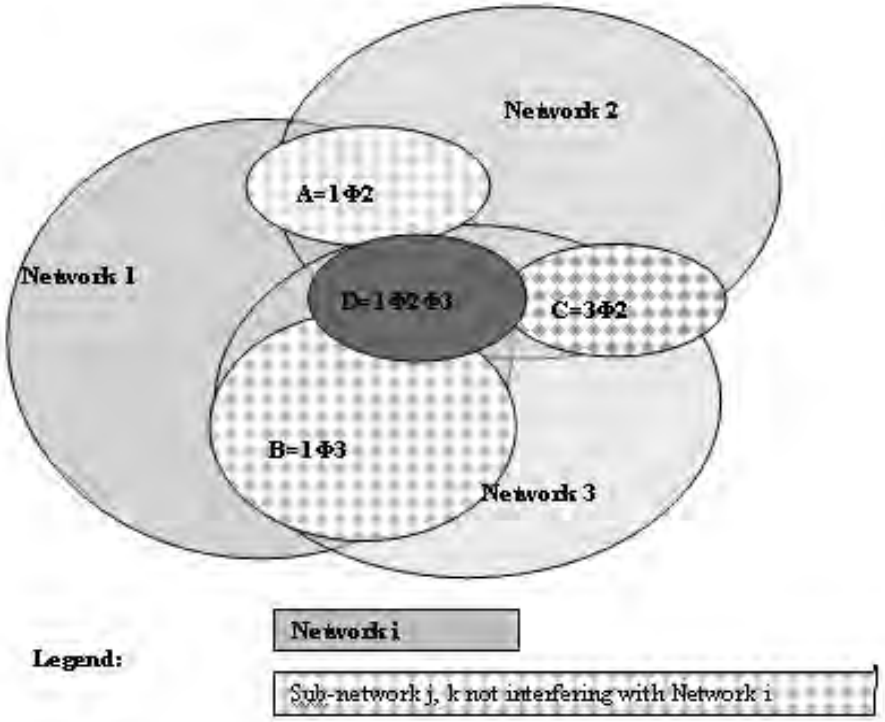


Figure h6—Interference due to overlapping networks

The operation of the three systems in Figure h 6 assume the following different situations:

Zones in which the systems 1,2and 3 do not interfere;

- Zone A: systems 1 and 2 interfere;
- Zone B: systems 1 and 3 interfere;
- Zone C: systems 3 and 2 interfere;
- Zone D: systems 1 and 2 and 3 interfere.

Now lets suppose that we split the time frame in 3 sub-frames (being 3 different systems), so that every system will receive an interference free interval for operation as shown in Figure h 7.

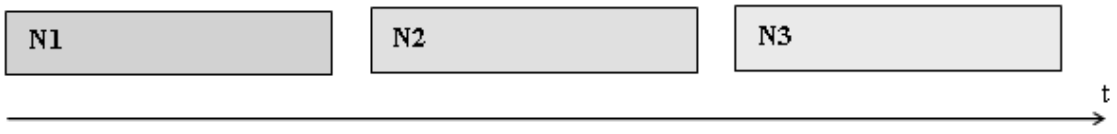


Figure h7—Equal splitting of radio resource between networks

Another possible approach shown in Figure h 8 will be to set an operating time for not interfering (noted ?) situations, and split equally between the three systems the remaining resource, like shown below. It can be seen that non-interfering traffic may be scheduled in parallel, resulting a much better radio resource usage.

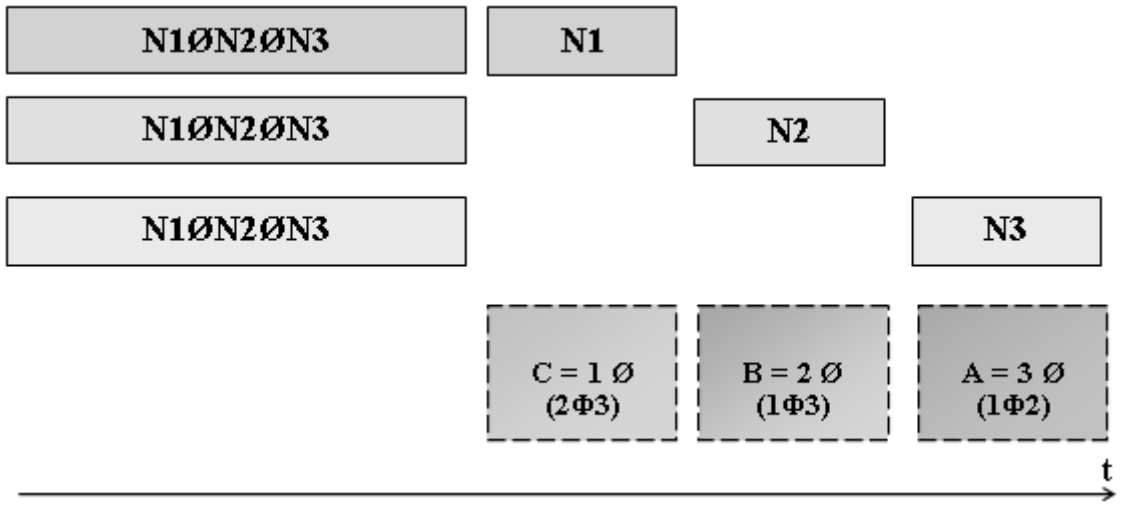


Figure h8—Usage of the spectrum by every system

Taking as example system1, it can be seen that this system operates in all the sub-frames, achieving in the same time interference-free operation and good spectral efficiency.

However, the systems working in the same time with the system having the control of the radio resource, shall use power control, sectorization or beam-forming in order to not create interference to that system.

Systems working in parallel at the start of the frame may need to use reduced transmitted power, to avoid creating interference to each other.

15.2.1.1.1 Cooperation with other systems

A system may need more bandwidth, as time allocated resource, for its BS communication with the SSs, than available for its operation in the assigned interference-free time interval. In this case, the specific network may request from one or more adjacent systems to reduce their interference free transmission intervals. The other systems will consider the request, and when possible will accept the request, by indicating an agreed new interference-free operating interval. The duration of each sub-frame may be negotiated through inter-network communication and using the common DRRM policy.

15.2.1.1.2 Scheduling of interference free intervals in the context of IEEE 802.16 MAC

A number of repetitive scheduling approaches are presented below, for Tx synchronized intervals. Same approach is valid for Rx intervals.

— *Type 1*: The MAC frame, for each Tx and Rx part, is split into N+1 sub-frames:

  - One for non-interfering traffic
  - Every other one to be used by a single BS or more non-interfering BSs which are assuming the Master role

— *Type 2*: The MAC frame, for each Tx and Rx part, is split into N sub-frames, every one to be used by a single BS or more non-interfering BSs which are assuming the Master role during a sub-frame

— *Type 3*: The MAC frame is split into two sub-frames: one for non-interfering traffic and one in which a single BS or more non-interfering BSs are assuming the Master role; each Base Station will assume the Master role after M frames

The duration of each sub-frame, in a given community, is calculated as follows:

For type 1:

— $T_{Tx\_sub\text{-}frame} = T_{TxMAC / (N+1)}$

— $T_{Tx\_sub\text{-}frame} = (T_{TxMAC} - T_{Txsh}) / N$

— $T_{Rx\_sub\text{-}frame} = T_{RxMAC} / (N+1)$

— $T_{Rx\_sub\text{-}frame} = (T_{RxMAC} - T_{Rxsh}) / N$

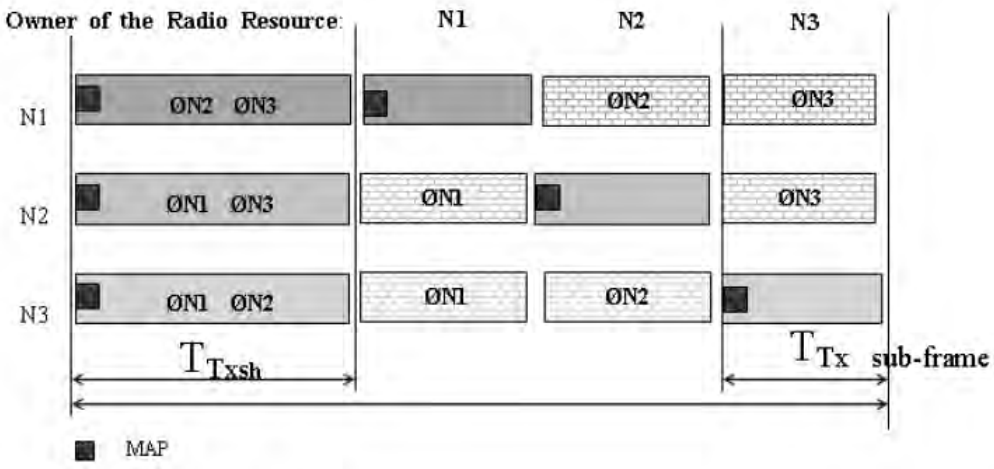


Figure h9—Sub-frame structure type1

For type 2:

— $T_{Tx\_sub\text{-}frame} = T_{TxMAC / N}$

— $T_{Rx\_sub\text{-}frame} = T_{RxMAC / N}$

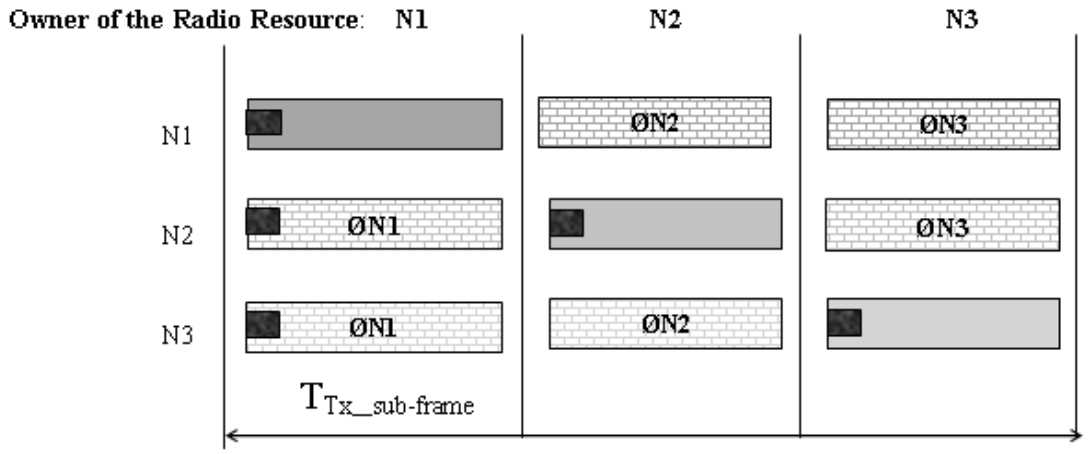


Figure h10—Sub-frame structure type 2

For type 3:

— $T_{Tx\_sub\text{-}frame} = T_{TxMAC} / 2$

— $T_{Tx\_sub\text{-}frame} = T_{TxMAC} - T_{Txsh}$

— $T_{Rx\_sub\text{-}frame} = T_{RxMAC} / 2$

— $T_{Rx\_sub\text{-}frame} = T_{RxMAC} - T_{Rxsh}$

and the repetition interval is equal with $N*T_{MAC}$,

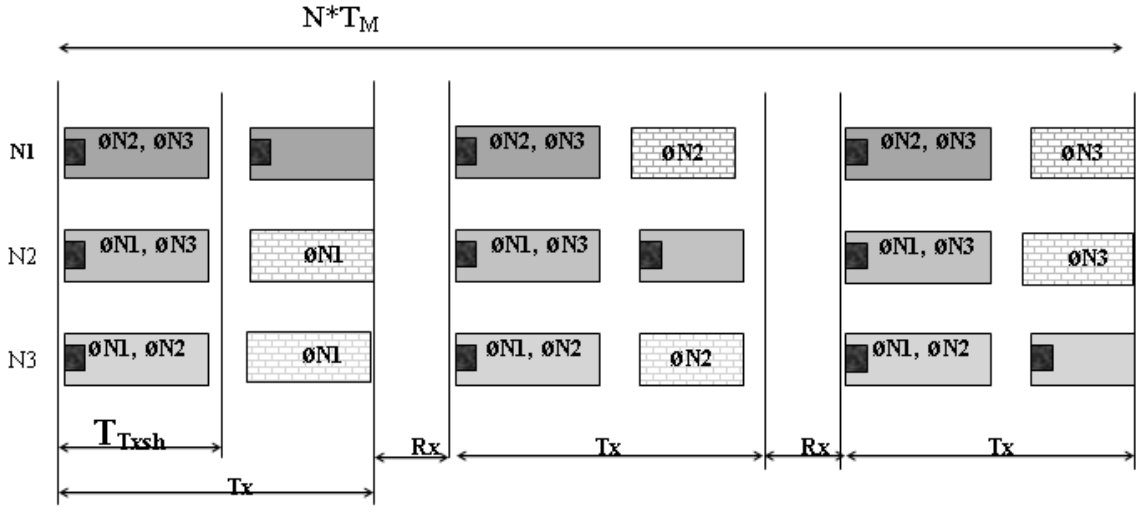


Figure h11—Sub-frame structure type 3

where:

— T_{MAC}, T_{TxMAC}, T_{RxMAC} are the durations of the respectively the MAC frame, Tx interval and Rx interval of the MAC frame;

— T_{Txsh}, T_{Rxsh} are the durations of the shared sub-frame. In the above relations, the meaning of Tx or Rx is relative to the usage of the MAC Frame by a Base Station.

During the Master sub-frame the Base Stations which have the Master role may use their maximum power;

During every Master sub-frame, the Base Stations will create a slot, possibly not overlapping with another slot of a coexistence neighbor Base Station, during each every transmitter (BS or associated SS) will send a predefined signal; this signal, called "radio signature", will be used to measure the interference created by that transmitter.

- The "radio signature slot" for a Base Station will be created during its Tx Master sub-frame, every B MAC-frames;
- The "radio signature slot" for a Subscriber Station will be created during the Rx Master sub-frame;
- UL MAP and suitable UIUC for scheduling the "radio signature" are t.b.d.
- During "radio signature" intervals, all the other BSs and SSs shall use a GAP interval;
- The Base Station shall take care to provide enough transmit opportunities for the active SSs.

The figure below shows the possible allocation of the "radio signature" transmission opportunity for a given system, using for example the Type 1 repetitive pattern, with a focus on Network 2.

The Network 2 will transmit its Base Station radio signatures from time to time (every N MAC intervals); different radio signatures will be sent for every used power/sub-channelization/OFDMA sub-channel/ spatial direction combination. During these intervals the other Base Stations will schedule a GAP interval, in order to identify solely one Base Station. Base Stations using the same MAC sub-frame as Master sub-frames shall schedule the transmission of their "radio-signatures" in such a way that will not interfere one with the other.

The transmission of "radio-signatures" used by the active SSs will take place during the Master sub-frame, from time to time (a timer shall be defined). The repetition period and the duration of the signature transmission shall be a parameter in the BS Data Base. The active SSs will provide a signature for every used power/ OFDMA/sub-channelization/ direction partition.

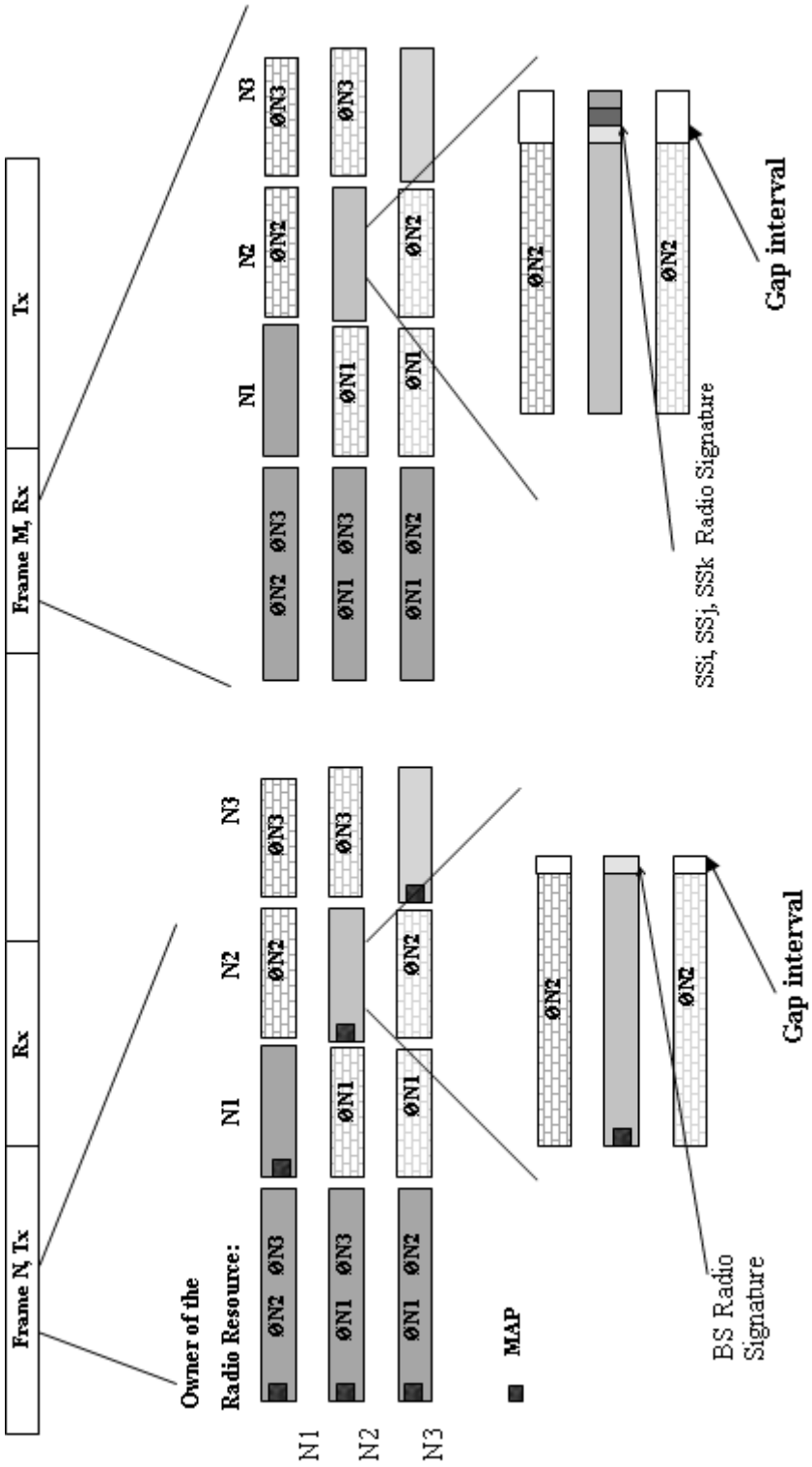


Figure h12—Allocation of slots for BS and SS radio signature

The BS data base will include:

- Operator ID
- Base Station ID
- MAC Frame duration (same for a community)
- Shared Tx and Rx sub-frame durations (same for a community)
- Type of sub-frame allocation (same for a community)
- MAC Frame number and sub-frame number chosen for the Master sub-frame (same for a community)
- Repetition period for Base Station radio-signature, measured in MAC-frames
- *Repetition interval between two Master sub-frames*, measured in MAC-frames
- *List of other used sub-frames*, in the interval between two Master sub-frames
- Time_shift from the Master sub-frame start, duration and the repetition information for the Base Station radio-signature transmission
- Time_shift from the Master sub-frame start, duration and the repetition information for the Subscriber Station radio-signature transmission
- *Time_shift from the Master sub-frame start and duration for network entry of a new Base Station*, which is evaluating the possibility of using the same Master slot.
- BS power relative to radio-signature, in the used sub-frames, in the interval between two Master subframes;
- For every active SS: SSID and its attenuation relative to radio-signature power, in the used sub-frames,in the interval between two Master sub-frames;
- For every coexistence neighbor BS: the BSID, the IP address of the coexistence neighbor and other profile information, and the SSs it interfered to, (and the SSs belong to it that interfered by the database owner BS.tbd.)
- For every BS in the same community: the contact IP address and the interference situation between this BS and other BS, including the interference situation with the DB owner.
- For every SS registered: the interference situation, the number of interference source, the IP address and RSSI of each source detected by the SS.

At the MAC level, the Master sub-frame is scheduled by using the Coexistence Zone.

The following figures show examples of the usage of the CXZ and the relation with the Master sub-frame types 1 and 3:

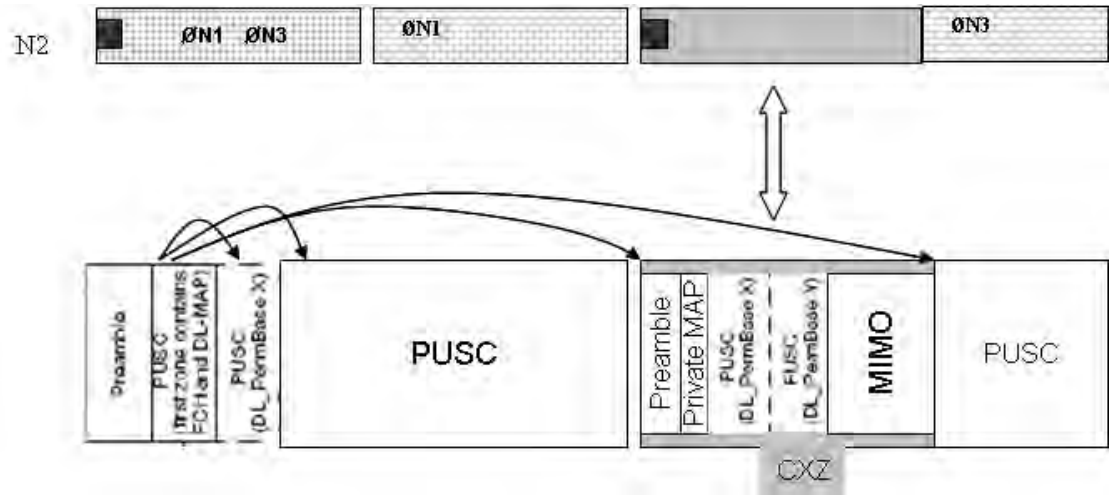


Figure h13—Relation between Master sub-frame type 1 and the CXZ

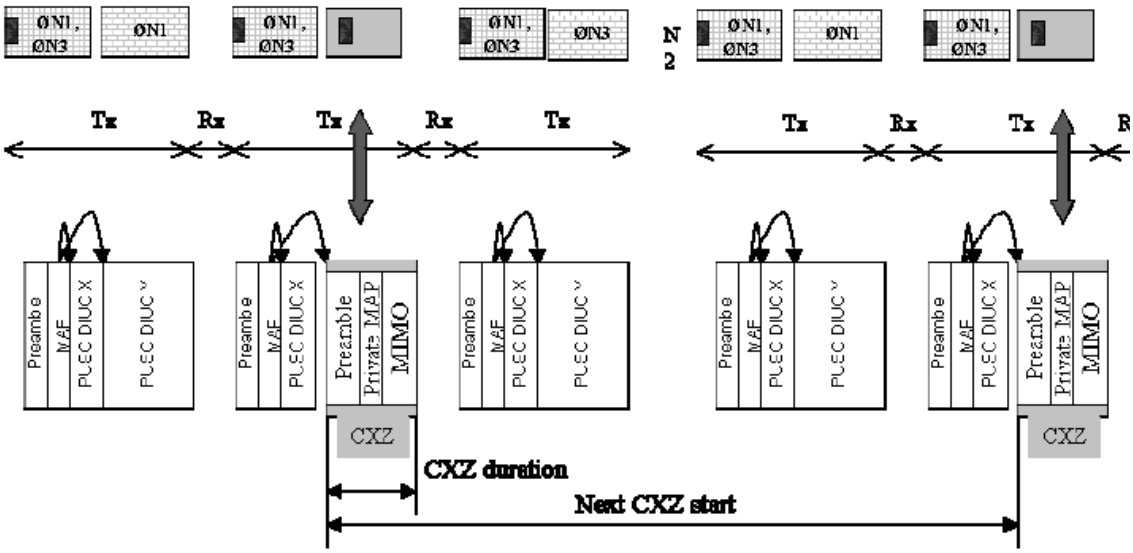


Figure h14—Relation between Master sub-frame type 3 and the CXZ

15.2.1.1.3 Coexistence Signaling Interval

The CSI (Coexistence Signaling Interval) is a predefined time slot in which the BS may contact its coexistence neighbor BS through one or more coexistence neighbor SSs in the common coverage area. For the Initializing BS (IBS), the periodical CSI is called the ICSI (Initialization Coexistence Signaling Interval) and is used by IBS to contact its neighbor Operating BS(OBS). By coordination with the other BS, the IBS will get its periodical OCSI (Operation Coexistence Signaling Interval) which is allocated only for this BS, and start the operating stage, hence ceased from using the ICSI.

Every CSI have its number, called CSIN (Coexistence Signaling Interval Number), that's a periodical number according to the time order.

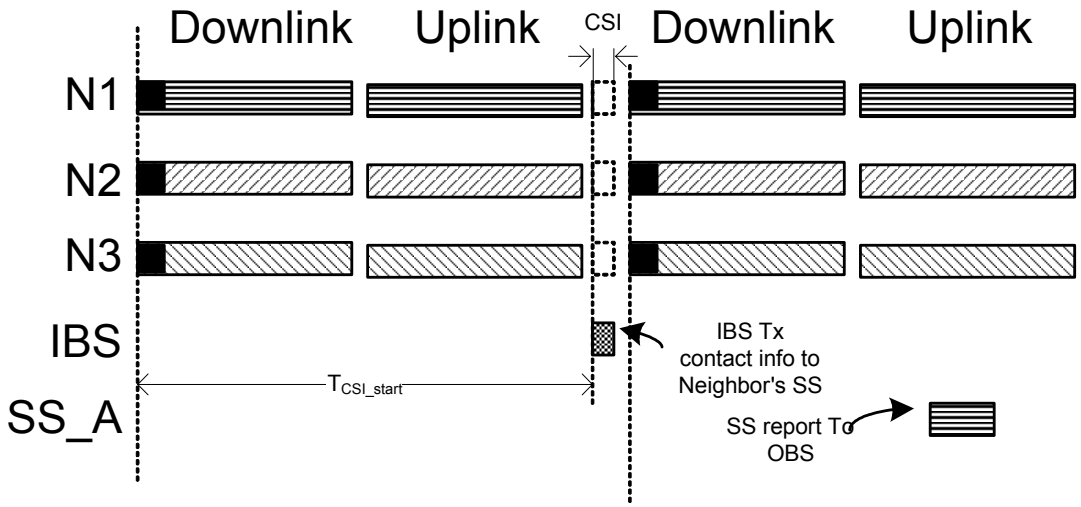


Figure h15—Timing of Coexistence Signaling Interval

In order to not break the downlink PDU and, and to reduce the overhead of more preamble and gaps, CSI slots shall be located before RTG/TTG in the TTD frame structure or before the preamble of downlink frame in FDD frame structure. To unify the location in these two kind of frame duplex, CSI slots in FDD frame shall be put into the downlink structure right before the preamble, and shall be located right before RTG in TDD frame.

The CSI/ICSI parameters need to be unified in a particular region, and to be well known by the BSs. So that each BS could know the exact time to transmit the broadcasting message in its initialization. The parameters include:

— $\mathbf{T_{CSIstart}}$: CSI starting time from the beginning of the frame (ms)

— $\mathbf{T_{CSIdurat}}$: CSI duration time (ms)

— $\mathbf{N_{CSIstart}}$: CSI starting frame number frames

— $\mathbf{N_{CSIintv}}$: number of frames in CSI interval

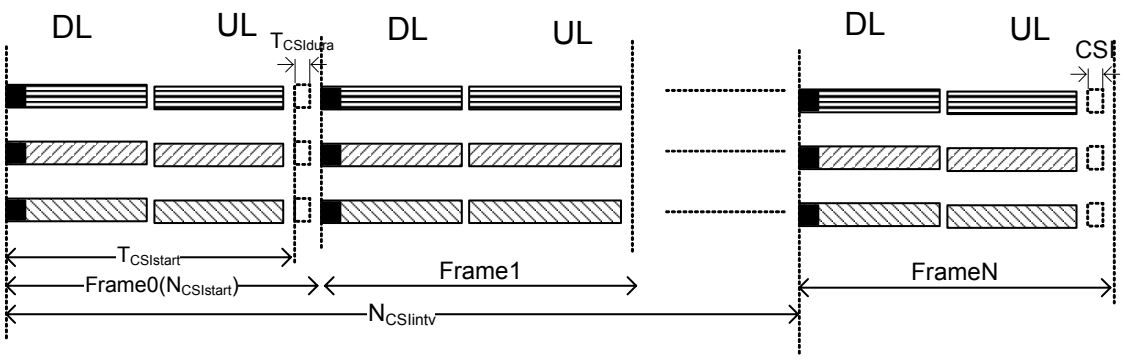


Figure h16—CSI parameters

— N_{ICSI_Cycle}: ICSI cycle counted in CSI cycles

— N_{OCSI_Cycle}: OCSI cycle counted in ICSI cycles

Assuming NCSIintv =4, NICSI_Cycle =4, NOCSI_Cycle =2, an example of the timing indication is illustrated in Figure h 17. The first IBS come into a environment without occupation of any OCSI, using ICSI to broadcasting coexistence signaling, become OBS1 and choose OCSI1 as the OCSI occupied for its system. Afterwards IBS2 starts up and uses ICSI to broadcasting coexistence signaling, finding its neighbor system of OBS1, and find OCSI1 occupied by it, IBS2 choose OCSI2 as its OCSI for its system and become OBS2 after the initializing phase. (also see 15.3.1.1.1) For IBS2, the occupation of OCSI1 by OBS1 can be aware by detected signaling from the system of OBS1, or to be informed by the CP message as the feedback of the IBS2's broadcasting signaling from OBS1's system.

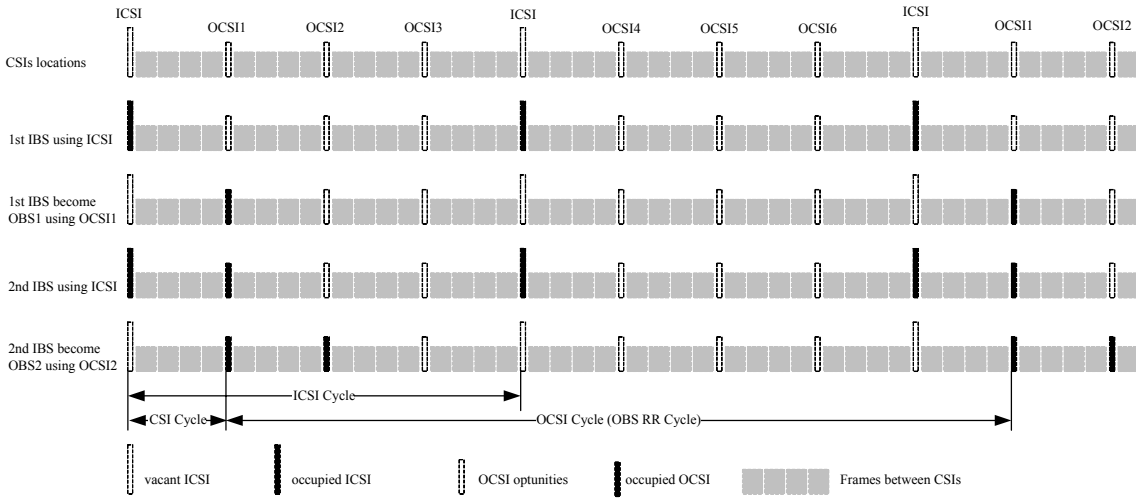


Figure h17—ICSI/OCSI occupation and timing example

15.2.1.1.4 Energy Symbols Used in the CSI

The symbols in the CSI slots are broadcast by the BS and received by the SS in coexistence neighbor network. The modulation technology on interference source and victim system should be one of the following: SCa, OFDM or OFDMA, and could be different between the interference source system and interference victim system. The band of the the source and victim shall have overlapped part, and the bandwidth could be different.

The symbol in the CSI slot is defined only in the power and time aspect, and could use any one of the modulation technology and any band that are available in the equipment. The length of the energy symbol shall be 1/N of the CSI length, here N is a natural number that is specified by the region/country regulator.

There is four kinds of symbols:<SOF>,0/null,1,<EOF>, to be used to form any frame in CSI and to carry the information.

— <SOF>: Start Of Frame, indicating the data portion will start at the following symbol.

— 0/null: Binary code 0 used to compose the data portion, same with null symbol.

— 1: Binary code 1 used to compose the data portion.

— <EOF>End Of Frame, indicating the data portion ended at the last symbol

Each symbol is divided into two equal length parts. For each part, there are two kinds of power keying level defined, H (high) and L (low). The BS uses the maximum power to transmit in the H(high) portion so that the SS can detect higher RSSI, and the BS is silent in the Low(L) portion and the SS can detect lower RSSI at that time.

The format of each of the four kinds of symbols is shown in the table below:

Table h2—CSI symbol Format

format		signification
Part1	Part2	
L	H	<SOF>
H	L	<EOF>
L	L	0
H	H	1

The receiving SS shall follow up the CSI timing and decode each symbol continuously in every symbol space. So that it can acquire the information transmitted by the source system. The SSs shall verify the symbol by this aspect of RSSI and time. One CSI consists of one or multiple symbols with the same length, and the number of symbols in each CSI slot is standardized in region/country.

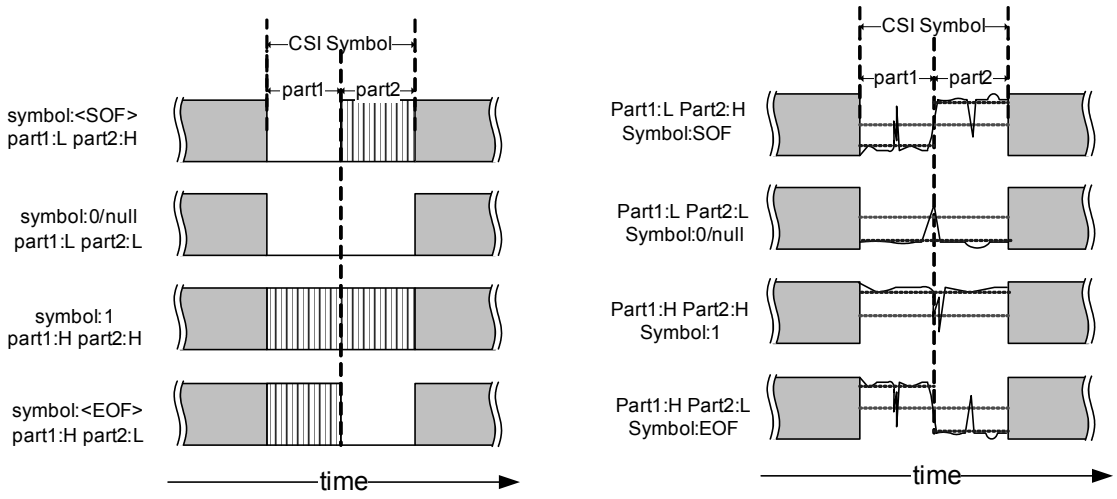


Figure h18—CSI symbol transmission and receiving

15.2.1.1.5 CSI Frame Structure

The CSI frame is broadcasted from the base station to the coexistence neighbor's subscriber station.within serialized CSI slots fragmentally. The CSI frame consists of power keying energy symbols as the basic element and carry the information from BS to the coexistence neighbor's SS. The CSI frame has the <SOF> symbols and <EOF> symbols as the boundary of slots when there is more than 4 symbols in each CSI slot. Two consecutive <SOF> and <EOF> indicate the signaling frame boundary. Each CSI frame shall have 8 bits cyclic redundancy check(CRC) (Polynomial "X8+X2+X+1") appendant to check the validity of the information carried in the CSI frame. In case when the last slot of the signaling frame have not been used up with the CRC and <EOF>, Pad is filled with symbol one between the CRC and double <EOF>, . CSI frame should be continuously carried in the serialized CSI slots during the whole CSI frame structure. The basic structure is shown below:

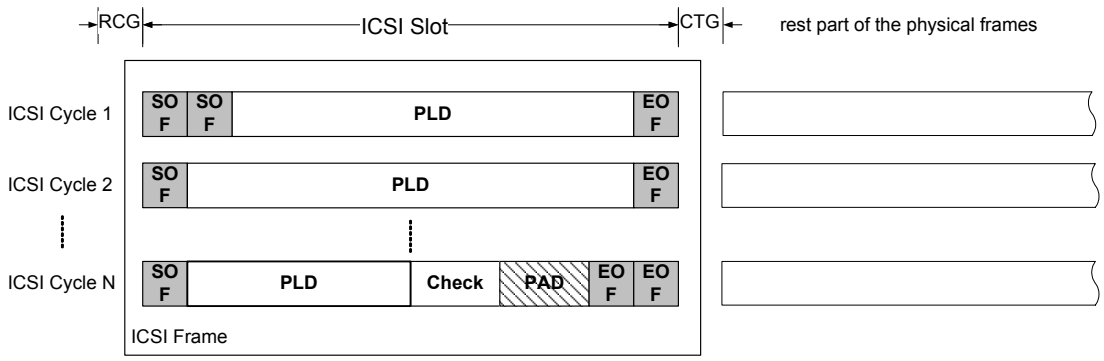


Figure h19—CSI frame construction with no less than 4 symbols in one slot

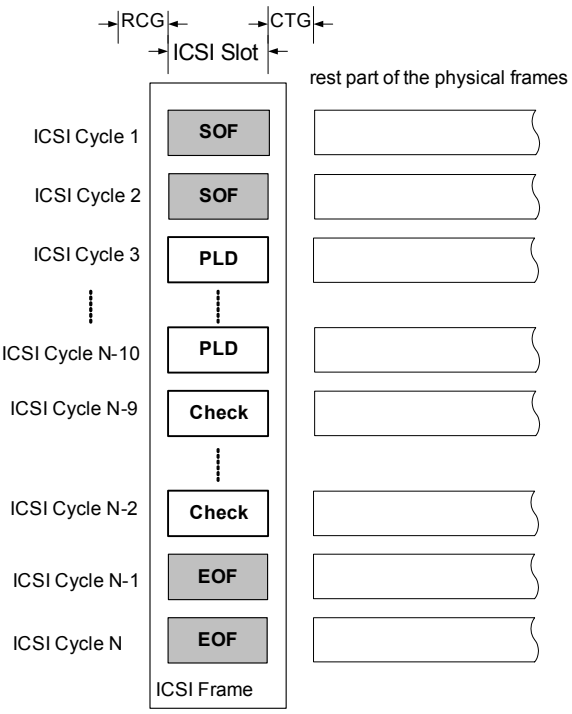


Figure h20—CSI frame construction with 1 symbol in 1 slot

The subscriber station of coexistence neighbor cannot get correct timing offset because of no ranging process between the SS and IBS, so RCG(Receive-CSI gap) and CTG(CSI-Transmission gap) should be engaged in the CSI slot for reliable sampling in SS.

The PLD (payload) part of the CSI frame should be divided into TLV aspect. TYPE indicate the type of the payload, LENGTH correspond to the number of symbols/bits contained in the VALUE portion. (TYPE and LENGTH is 1 octet each.)

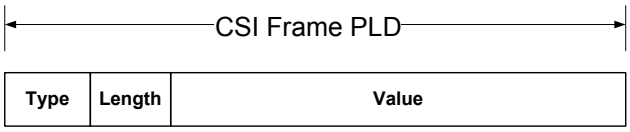


Figure h21—CSI frame PLD

The SS should keep monitoring the RSSI to detect <SOF> in ICSI interval. <SOF> flag can be detected according to the energy power value against the timing, When power of symbol in first half part of window is significantly lower than the second part, one <SOF> is expected to have been received, and the SS will pick a value in the middle of the two value as a threshold for the following symbols. The following symbols in this frame should using this threshold as criterion. If a following symbol shows lower in the first part and higher in the second than the threshold, it will consider as succeeded in detecting another <SOF>. A CSI frame considered to start here. When all the symbols in the frame are received and verdict correctly, and received consecutive two <EOF> at the end using the similar method as the <SOF> , the whole signaling frame is received correctly and the information inside will be extracted and reported. .

Symbols between the two consecutive <SOF> and the two consecutive <EOF> are reassembled into CSI frame while the pad is dropped while the check is passed. If the check is failed, the signaling frame will be reported with error indication and no value part of the payload will be reported. The whole CSI symbol sequence will be ignored if no consecutive two <SOF> was detected.

When there is more than 4 symbols in each CSI slots, there will be a <SOF> and an <EOF> at the beginning and the end of the slots respectively. All the <SOF> and <EOF> will be dropped when reassembling the payload of the CSI frame.

15.2.1.1.6 Coexistence proxy

Every BS shall use its coexistence proxy to exchange CP message while they send/receive signaling containing the IP contact information over the air, so that other BSs will not know the IP address of this BS from the signaling over the air. The coexistence proxy should have a stand alone physical port and an IP address to connect into the internet using either direct link or internal interface. The coexistence proxy could be a module of the BS or a stand alone server .

A coexistence proxy can also optionally be used to forward the CP message between BSs when IP address of the BS is not transmitted over the air, so that the proxy will act as a agent between the BSs with other BSs and terminals in the internet. In the coexistence coordination process, by using coexistence proxy, all the BSs know other BSs' coexistence proxy's IP address instead of the IP address of the BS's, and contact them only via coexistence proxy and the BSID information. In order to prevent various attack from the internet, proxy could utilize various approach to protect BSs without influence the data service of BSs. *[Proxy could limit the forwarding bandwidth from one IP address or to one BSID. Proxy could qualify or block the message using various approach.]*

15.2.1.1.7 Coexistence Messaging Interval

[the following part of this section is taken from C802.16h-06_010r1, content below and above need to be harmonized.]

A Coexistence Messaging Interval (CMI) is a reserved physical frame used for the coexistence protocol signaling purposes. The CMI is used with systems having the same profile (15.2.2.3.1) and synchronized MAC frames. The position of the CMI and the subsequent IEEE 802.16 MAC frames are synchronized to a GPS timing signal (15.6.2.1.1). Furthermore, the CMI are identified by UTC time stamps (15.6.2.1.1.3). For example, the beginning of the first CMI is at HH:MM:00 UTC, the second CMI is at HH:MM:06 UTC, etc. The beginning of every CMI is specified by a UTC message (time stamp) (Figure h 22).

The CMI is used by WirelessMAN-CX systems (BSs and their SSs) to mediate their co-channel coexistence. The CMI will be an opportunity for systems (BSs and their SSs) to indicate to other systems (BSs and their SSs) the extent of the interference they can cause; newly arriving interfering base stations (IBS) will use the CMI to make themselves known to established communities of operating base stations (OBS). Newly entering SS will make their presence known when they are detected by base stations to which they are not associated (see Section ***TBD***). Sporadic interference from BS or SS will also be detected by the same process.

A Coexistence Community can consist of a maximum of 9 systems ***(TBD)***. Each system claims a unique CMI by a process outlined in Section 15.2.1.3.1. There are a total of 10 CMI which repeat every minute (***TBD***), but since CMI_ID 54 is reserved for noise measurement and foreign system identification purposes, there are only 9 CMI available to the Coexistence Community. A system must broadcast its BSD and

SSURF messages once a minute on its CMI; when it does this all other members of the Coexistence Community remain silent and monitor to detect the extent of the interference that is caused by this.

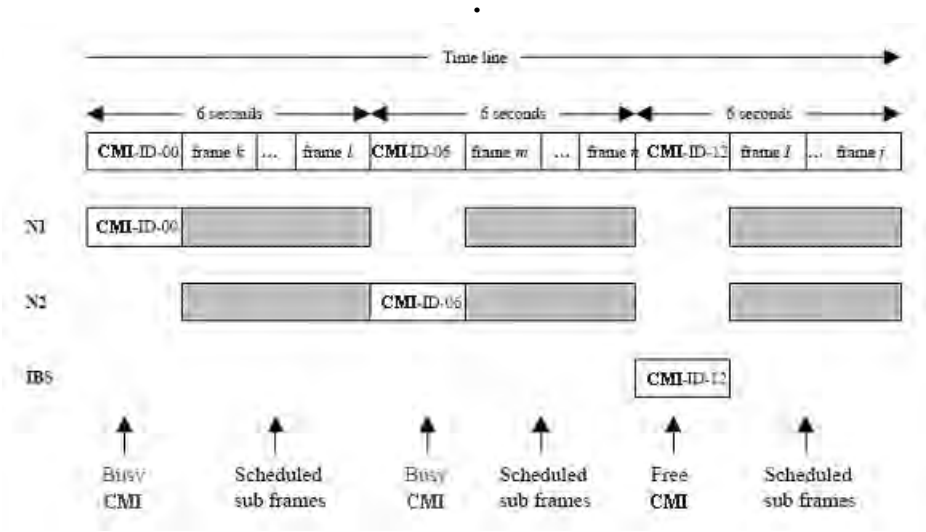


Figure h22—CMI Timing

15.2.1.2 Interference Control

Interferer control uses identification obtained from the radio signature

— A receiver will listen to the media during the radio signature slot and will find out which are the strongest interferes; by then scanning the BS data bases it will be possible to identify, due to the knowledge of the frame number, sub-frame number and offset, which BS is the interferer associated; based on time-shift information, the Base Station will be able to identify the Subscriber Station ID. During the allocated radio-signature transmit opportunity no other radio transmitters will operate.

Interference reduction

— A BS has the right to request any interferer to reduce its power by P dB, for transmissions during the time in which a Base Station is a Master; if the requested transmitter cannot execute the request, it has to cease the operation during the Master sub-frame of the requesting Base Station; this applies also for systems using the sub-frame as a Master

Sharing the Master time

— A Base Station will indicate in the data base *what portion of the sub-frame time, separately for Tx and Rx, is actually used*

— Other systems, which do not interfere one with each other, may use that time interval

Target acceptable interference levels during Master sub-frames:

For the Base Station and its SS, using the Master sub-frame: min. 14dB above the noise + interference level (16QAM 1/2) ***[note: we should define the interference criteria; the existing one may be too stringent and not necessary for short links]***

15.2.1.3 Community Entry of new BS

To enter the existing community of its neighborhood, a new BS without any associated SS contacts its-neighbors and coordinates using the IP network. The new BS should synchronize to the timing of the CSI and ICSI in the air before using ICSI to broadcast the BS_NURBC (see 15.5.6.2.1) signaling to make its neighbor know its arrival and its contact information.

ICSI is used by IBS to establish communication with its neighbor BSs. Initializing BS (IBS) shall use ICSI slot to broadcast its coexistence proxy's IP address and the BSID of IBS, by sending a message and/or cognitive radio signaling. The coexistence neighbor operating BS finds the initializing coexistence neighbor in IP network via its coexistence proxy after receiving the SS report for this signaling. In order to obstruct coexistence request from an unqualified internet terminal (such as a terminal far away or some terminal without any capability of WirelessMAN-CX air signaling which have known the static BSID and IP address information, the BS should use a RTK (Random Temporary Key) in the broadcast signaling. To qualify the request of CP message, the RTK sender requires the request CP message sent back later via IP network to contain this random temporary key. Then the IBS and OBS begin further negotiation via their coexistence proxy for coexistence protocol. After coordination with the neighbors in the community, IBS will get periodical interference free OCSIs, and become OBS, after that, it will cease from using the ICSI.

The BS_NURBC (see 15.5.6.2.1) broadcasting procedure is unidirectional, only from the BS to the SSs in common coverage of the BS and its neighbors', and the SSs shall report all the useful information to their OBSs they associated to. The SSs that succeed in receiving the signaling should report the content of BS_NURBC and the frame number of the starting frame of BS_NURBC, the SSs which fail to received the broadcasting signaling but get BS_NURBC as interference in the CSI should report the error status and the starting frame number of receiving the interference in CSI. IBS use ICSI to broadcast BS_NURBC signaling, the content in the signaling will enable its neighbor systems to communicate with the IBS in the IP network to coordinate by coexistence protocol. By the IP address of IBS's coexistence proxy and the BSID reported from the SSs with RTK, the OBSs will then communicate with the IBS in the IP network via their coexistence proxy, and go further coordinate using IP network. And by checking the frame number in the report, OBS determines if the SSs that report the error status in BS_NURBC receiving have got the same interference source, then OBS will update the database and reply to the SSs which have send the error report.(see Figure h 23.)

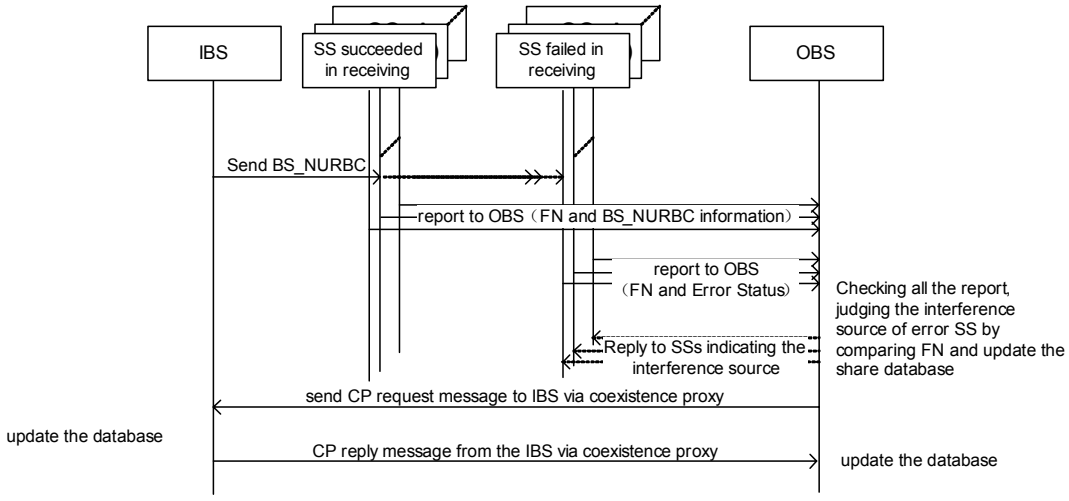


Figure h23—IBS entering the community by neighborhood update request broadcasting

A new entering BS knows the IP address of its coexistence proxy. By receiving the broadcasted IP address of its IBS's coexistence proxy and the BSID of IBS, all the neighbor OBSs which have get the contact infor-

mation of IBS should start to communicate with this IBS using CP message through internet via coexistence proxy. After receiving the CP request message from OBS, the OBS's coexistence proxy will then transform the source IP address into the IP address of the proxy, and forward the CP request message to the destination coexistence proxy which serves IBS. The IBS's coexistence proxy should get the destination BSID by parsing the CP request message, and map it into IBS's IP address. If the BSID is in the coexistence proxy service list and finds the corresponding IP address, the coexistence proxy should forward the qualified CP request message to the IBS. By receiving the CP messages from its neighbor systems, the IBS can discover its neighbor systems and continue on further negotiation and communication using the IP network through the coexistence proxies. Vice versa, IBS should send the CP reply message to the OBS via the coexistence proxy after receiving and processing the CP request message.

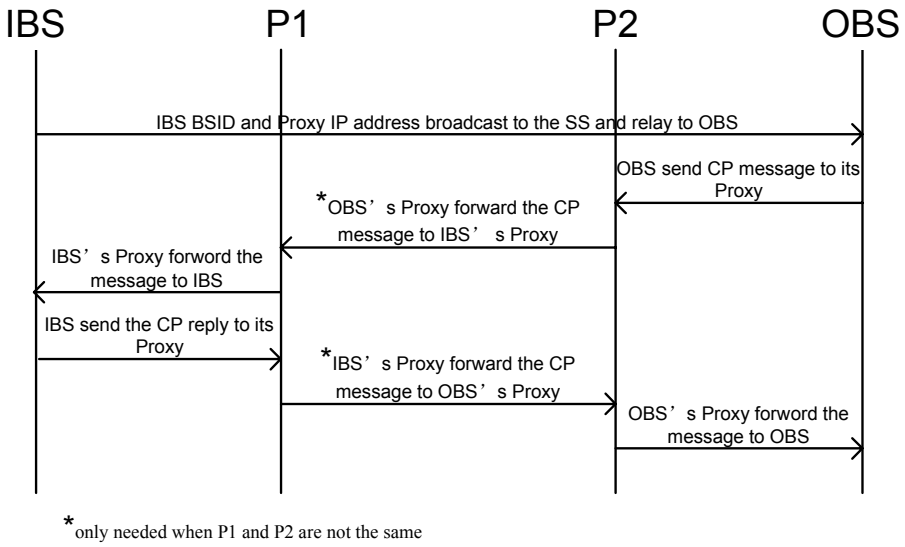


Figure h24—IBS entering the community with proxy

Figure h 25 explains how one new entry BS discovers its coexistence neighbor BSs. The new entry BS-5 uses its GPS coordinates (x5, y5) and its maximum coverage radius in LOS, Rm, at allowed maximum transmission power. A BS is *potential* coexistence neighbor BS of another BS if:

— In co-channel operation the LOS maximum coverage area resulting for the allowed maximum transmission power overlaps one with each other. As depicted in Figure h 25,the regional LE DB will return BS-1, BS-2 and BS-3 as the *potential* coexistence neighbor BSs of the new entry BS.

— In first or alternate adjacent channels operation, the BS should consider the attenuation of the transmitted power, corresponding to the actual operation channels of different Base Stations

Once a LE BS has learnt its *potential* coexistence neighbor topology from the regional LE DB, it evaluates the coexisting LE BSs and identifies which BSs might create interferences. The Adaptive Channel selection will select the actual operating frequency, such that the probability of interference will be minimized. Each LE BS tries to form its own community. By including the coexistence neighbor BSs that create interferences to the associated SSs The members of community will change when the working frequency of any BSs changes or new interfering coexistence neighbor BS comes in.

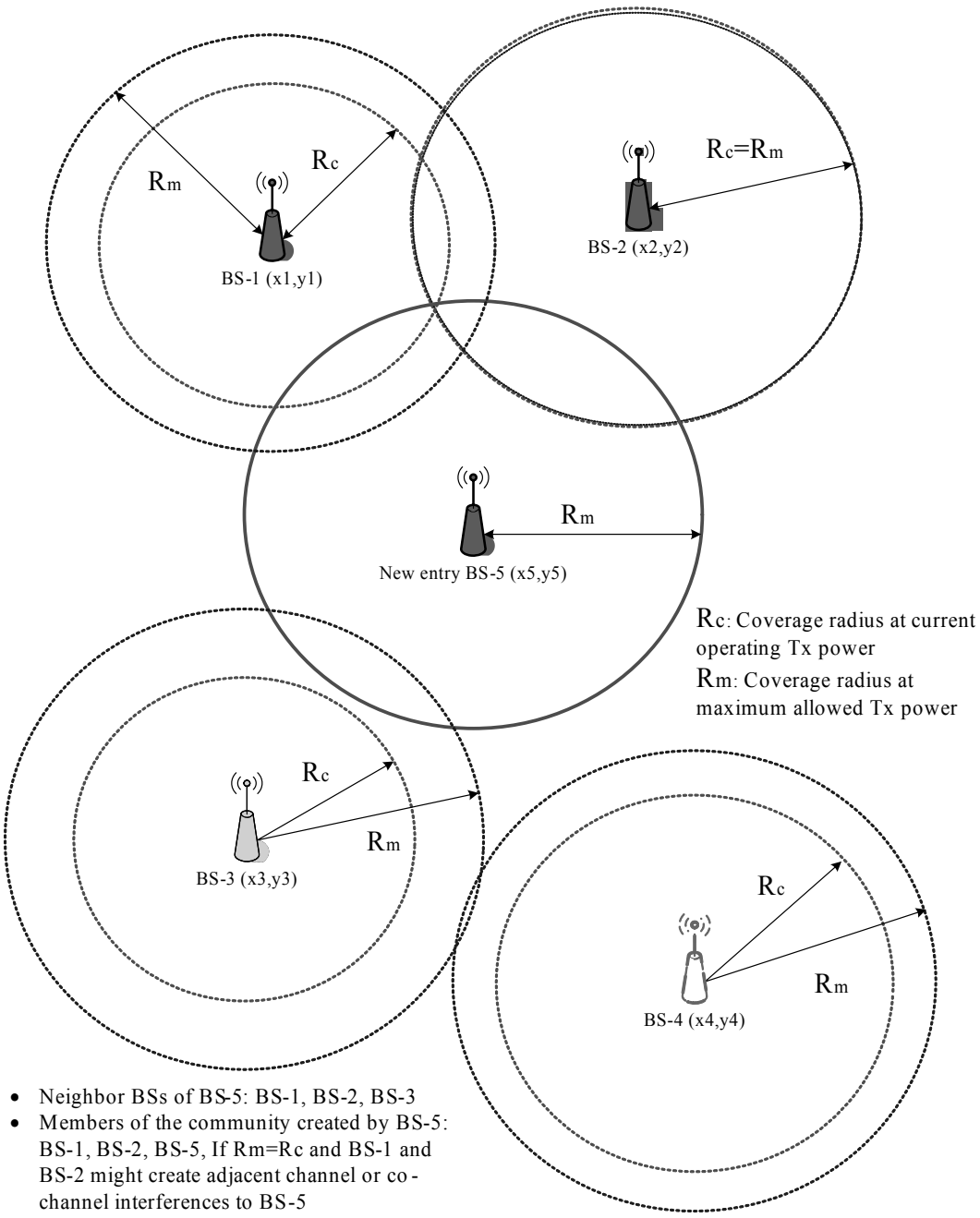


Figure h25—WirelessMAN-CX neighbor BSs discovery and definition of coexistence neighbor and community

Within a regional LE DB, a LE BS can construct its coexistence neighbor topology and acquire the IP addresses of its coexistence neighbor securely.

In any case that the new coming BS could not find the region LE DB, it should start a ad-hoc method to find the neighbor topology. The entering BS uses the coexistence time slot to broadcast its IP address to the reachable SSs in the neighbor network. Once the SSs received this signaling, they will report to their serving BS one by one unsolicitedly, the information of the new BS and the interference status that they record during the receiving will be reported to there serving BS.

The serving BS will get all the information from the related SSs and saved the useful content to their database. After that, the serving BS will contact new BS using the IP address reported by the SS and transfer the parameter of its own to the new coming one with authorization and negotiation, thereafter the serving BS will also get the parameter and other corresponding information from the new coming BS.

In general, the coexistence detection, avoidance and resolution are performed in two stages, initialization stage and operating stage.

(1) *Initialization stage*

In initialization stage the BSs may avoid the co-channel or adjacent channel interference by scanning the available frequencies. But this method cannot avoid the hidden neighbor system problem, i.e. the BS that cannot be heard directly but may have overlapping service coverage. Thus, with the knowledge of coexistence neighbor topology the IBS can detect the hidden neighbor systems and can, therefore, avoid the possible interferences from neighbors.

Alternatively, if the country/region database is not valid in this phase, the initializing BS will use the initialization coexistence signaling interval (ICSI) to broadcast its contact information to its coverage using its maximum power. In this way, the SSs in the reachable zone of the new BS's interference will receive the signaling and forward the contact information to its serving BS. And after the neighbor BSs get the address via the SSs' reports, they will contact with their new coming neighbor via IP network and updating the database on both side. Thus, in ad-hoc fashion, it will solve the hidden neighbor problem by the SSs in the neighbor system. Therefore, using the information that the IBS has got from its neighbor, IBS can get the information of the relative collaborative systems in potential community.

If the IBS finds that there is no "free" channel exist, the information in the distributed database can be used to figure out with whom it should negotiate with. IBS may decide whether a "free" frequency can be allocated for itself by channel reallocation within community, If IBS can figure out optimized channel distribution in the community, which made every member in the community could occupy a exclusive channel, IBS can contact the BSs in the community which need to reallocate the channel and negotiate, after confirmed by every candidate BS, IBS will vacate a exclusive channel for its system. After that it should send a CP message to the candidate BS to indicate the succeeding, all the candidate BS should then continue operation on the new channel. Otherwise, if IBS can't get a "free" frequency after the effort of reallocation, the IBS should try to share a frequency with some of its neighbors.

Similar to the channel allocation, the IBS will then first try to find a vacant sub-frame in the potential channels using the information inside the distributed database, when failed IBS will then try to vacate an exclusive existing sub-channel by sub-frame distribution optimization if supported. If a exclusive existing sub-channel is not available, IBS will then try to negotiate with the systems inside the community to create a new sub frame. While all these attempt failed, the IBS will not be able to get any interference free resource in its interference situation. These procedures are described in Figure h 26.

(2) *Operating stage*

In the operating stage, the BS has SSs associated with it, however, untilthe operating system parameters are determined., the co-channel or adjacent channel interference from LE BSs of different network may still occur due to the detection of interference from primary user. Channel switching of coexistence neighbor systems or the entry of new coexistence neighbor BS might make the community so crowded that there is no enough channels. If the LE BS finds that there is no "free" channel at that moment, synchronous channel switching maybe executed, or the coexistence neighbor topology provides the guidelines of with whom it should negotiate to share the channel. *[detailed procedures are to be defined]*

Figure h 26 shows the initialization procedures for the 802.16 LE BSs. Note that the procedures that BS tries to create a Master slot or channel switching are also applicable for operating stage. The detailed negotiation and update procedures are described in section 15.5.2and 15.6.1.4.

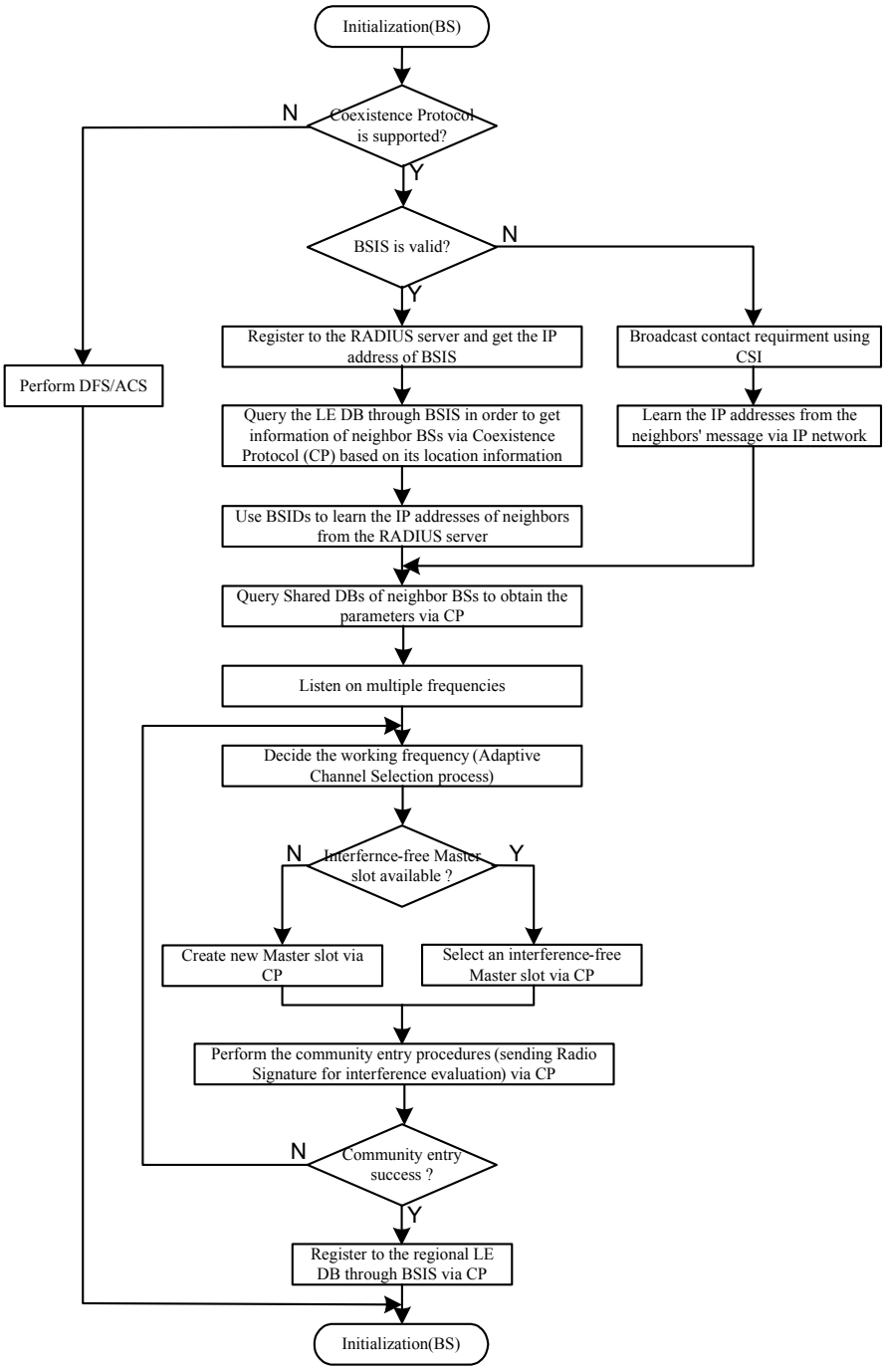


Figure h26—Initialization procedures — BS

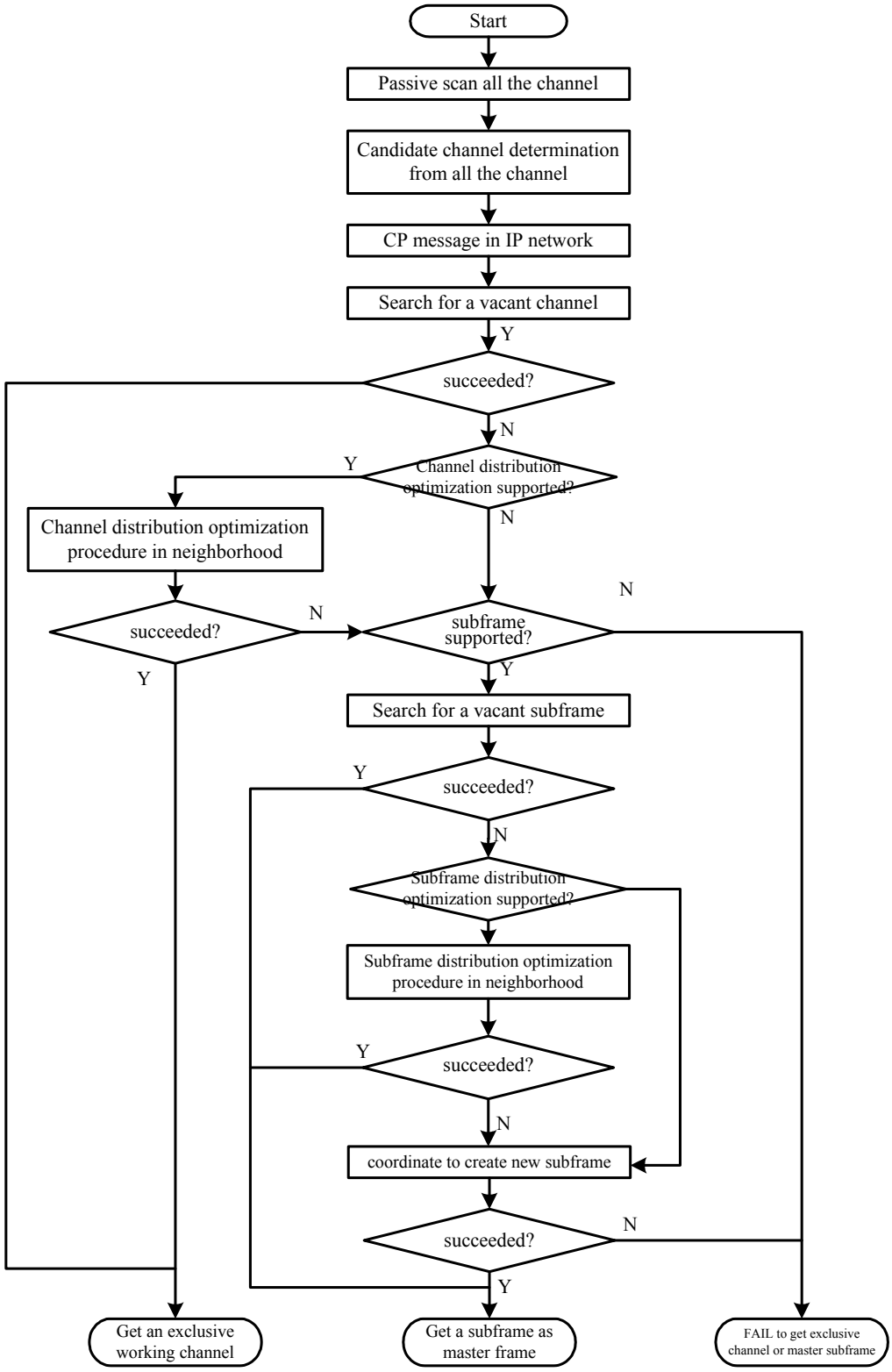


Figure h27—Initialization procedures - BS radio resource allocation

[Note: the following text needs further consideration]

— The first phase of the Community Entry is to judge the validity of country/region data base. If the country/region Root RADIUS serveris valid(t.b.c: what means valid?),, the processfurther queries Root RADIUS server:

  - o Get the BSISs from the country/region Root RADIUS server;
  - o Read the data base maintained by BSIS via Coexistence Protocol;
  - o Identify which Base Stations might create interference, based on the location information;
  - o The IBS learn the IP identifier for those Base Stations;

  Otherwise:

  - o New BS uses the interference free slot to broadcast the message containing the contact request and/or the cognitive radio signal transmitting the IP address
  - o The SS in the common coverage will forward the information to its operating base station. using REP_RSP message
  - o The operating BS update its database and send feedback informationto the IBS, using the IP network
  - o learn the IP identifier of the coexistence neighbor BS from the message sent by the coexistence neighbor BS via IP network

— Build the local image of the relevant information in the community BS's, by copying the info in those BSs

— Listen on multiple frequencies

  - o Identify the level of interference on each frequency channel;

— Decide the working frequency (ACS – Adaptive Channel Selection process);

  - o If no interference detected on some channels, select one randomly as working channel;
  - o If interference detected by IBS or OBS network on all channels, then IBS should decide whether an optimized channel distribution can allocate an exclusive channel for each BSs including IBS in community.
  - o If every BS in community can be allocated an exclusive channel without interfering with others, that means default interference-free Master slot is available for this initializing BS.

— If available, select an interference-free Master sub-frame; if not, use the procedure for creating new Master sub-frames;

— Search the Base Station data base for finding the BSs using the selected Master sub-frame;

— Request those Base Stations, by sending IP unicast messages, to listen during the BS_entry slot in order to evaluate the interference from the new Base Station;

— Use the allocated slots for transmitting the "radio signature" at maximum power, maximum power density and in all the used directions;

— Ask for permission of the Base Stations, using the sub-frame as Masters, to operate in parallel and use the same sub-frames;

— If all of them acknowledge, the Base Station acquires a "temporary community entry"status; the final status will be achieved after admission of the SSs;

— If no free Master slot sub-frame is found, use the procedure for creating new Master slotssub-frames.

15.2.1.3.1 Entry of a new BS into a Interference Neighborhood and the Creation of a Coexistence Community Using GPS/UTC Time Synchronization and Common System Profile

In applications where the Coexistence Messaging Intervals (CMI see 15.2.1.1.7) are synchronized to a GPS (or similar precision timing reference) and are given UTC time stamps (Figure h 22), entry of a new Base Station (IBS) will be undertaken in 4 steps, with the IBS:

(a) Monitoring the CMI Intervals,
(b) Selecting an Empty CMI interval,
(c) Claiming an empty CMI interval,
(d) Membership in a Coexistence Community.

Prior to entry into a Community of Operating Base Stations (OBS) it is assumed that the IBS will have undertaken Candidate Channel Determination (Section 15.4.2.1.1) and has selected a candidate channel, is synchronized to a downlink GPS signal and can derive a UTC time stamp, and has no operational SS yet deployed. It is assumed that the IBS is deployed within an Interference Neighborhood: ie: active interference from existing Operating Base Stations is present. It is also assumed that the community which entered is WirelessMAN-CX compliant and uses a common (same) profile. The IBS entry process is shown in Figure h 28,Figure h 29 shows aspects of the entry procedure with signalling.

(a) Monitoring the CMI

Having tuned to the candidate channel, the IBS monitors and determines the level of activity on each CMI by demodulating the uplink SSURF (Sec 6.3.2.3.62) messages and storing their parameters in its Base Station Information Table(See Table h 3). All demodulated SSURF messages will be from SSs that will interfere with the BS on the uplink and eventually, coexistence will have to be arranged with each of the OBS controlling these SSs via the Coexistence Protocol (CP). Each CMI from CMI-ID-00 to CMI-ID-54 is monitored. Each CMI is monitored for 5 CMI cycles or minutes (***TBD***). If CMI-ID-54 has detectable power in it, the channel will be construed as occupied by a non-IEEE 802.16 system (See 15.3.1.1.3.1) which may also be synchronized to the GPS/UTC. The channel will be abandoned if CMI-ID-54 is occupied (See 15.3.1.1.3). The signalling seen by an IBS is shown in Figure h 29.

(b) Selection of an Empty CMI

The monitored CMI in which no (demodulated) SSURF messages are received becomes a candidate CMI, and is considered empty. Empty CMI indicate that it is still possible for the IBS to create a new Coexistence Community including the OBS (only a maximum of 9 (***TBD***) co-channel systems can be accommodated by a single channel. Full loading is indicated when all 9 (***TBD***) CMI are occupied by the systems forming a Coexistence Community).

During each candidate CMI a RSSI (see 8.4.11.2) will be undertaken by the IBS during the uplink duration. RSSI is undertaken to determine the presence or absence of low level (un-demodulated) uplink SSURF messages. Each candidate CMI is monitored in this manner over a duration of 10 CMI cycles or minutes (***TBD***). An interval will be considered as useable and chosen if the mean RSSI power measurement in it is no greater than ([N] +3 dB) (***TBD***); where [N] is the thermal noise floor of the IBS receiver as determined by the Candidate Channel Determination process (See 15.4.2.1.1).

The absence of uplink SSURFs means that the CMI is free of uplink (and possibly downlink occupancy). The particular CMI is now considered as being ready for claiming.

(c) Claiming Procedure.

The purpose of the claiming process is to make all adjacent OBS aware of the presence of the IBS. This process results in the delimitation of the Interference Neighborhood, that is, identification of all the adjacent systems that will see interference from the IBS. Claiming is undertaken by having the IBS broadcast its

BSD during an empty CMI. Since all the OBS (both base stations and their SS) are silent and are monitoring the downlink on each CMI other than their own, the broadcast BSD message will likely be detected during what was previously an empty CMI (see discussion on undetected broadcasts below).

To begin the claiming procedure the IBS broadcasts at maximum EIRP a BSD (see 6.3.2.3.62) message. This message, when received by SS belonging to adjacent OBS systems that form the Interference Neighborhood, will result in those SS informing their associated base stations (OBS) of the presence of a new base station (the IBS). The SS inform their BS of this by using a MAC message called the BS_CCID_IND . This MAC message contains the Proxy IP address of the IBS, which was extracted by the SS from the interfering BSD message. Now having the proxy IP address, the OBS respond back to the IBS via a backhaul IP link, informing the IBS that it has been detected and is a de facto interferer on the co-channel RF downlink. Having received this communication from the OBS, the IBS will now have discovered the systems in the Interference Neighborhood, and as part of this discovery process now has the identities of the adjacent OBS. The OBS identities are included in the IBS Information Table (see Table h 3). The IBS continues its BSD broadcast routine until no new OBS make themselves evident to the IBS. The IBS continues its BSD broadcasts every CMI cycle (every minute), and does so as long as it confirms to itself that it has formed a Coexistence Community with adjacent systems.

(d) Membership in the Coexistence Community

All of the adjacent systems with which the IBS creates or sustains interference to/from become listed in the BS Information Table (See Table h 3) of the IBS. This table contains the BS_IDs and related IP addresses derived either from uplink SSURF messages that the IBS demodulated during its monitoring phase (above (a)) or from the BS_CCID_IND and IP messages that it received via the IP backhaul from the OBS as part of the claiming procedure ((c) above).

Communication and negotiation with each OBS listed in the BS Information Table is undertaken via the ***[TBD]*** Coexistence Protocol (CP). Coexistence entails allocation of uplink and downlink transmission intervals in a manner that eliminates co-channel interference amongst users that would otherwise experience it and sustain degraded communications. This is done by parsing uplink and downlink intervals and establishing master subframes (see Sec 15.2.1.1.2). Each OBS that the IBS has listed in its BS Information Table as an interfering network must partake in such a resolution procedure. By undertaking this process the IBS thus creates a Coexistence Community for itself, and consequently becomes accommodated by the neighbouring networks of its interference neighbourhood. If the IBS for some reason cannot resolve all the interference it creates or sustains, then the entry process is repeated on a new channel taken from the rankings provided by the CCD procedures (see 15.4.2.1.1). In doing so the IBS would then abandon the CMI that it claimed in (c). If the CP process is successful, then the IBS (now OBS) continues its claim to the CMI, thereby now informing all other systems of its active presence in the Coexistence Community.

Undetected BSD Broadcasts/Undetected Uplink SSURF messages:

The BSD and SSURF messages are sent at the lowest, most robust modulation rate specified for IEEE 802.16 transmissions. However, because of the statistical variation in the propagation channel whose variance can exceed 10 dB, there is a finite probability that eventually such signals shall eventually exceed demodulation threshold levels and be detected. The time to achieve this is ***TBD***. Furthermore, below threshold signals can be detected by power detectors or detection techniques that will provide indication of signals below demodulation thresholds. These techniques can be instituted either as part of the RF system or in parallel with the demodulation process.

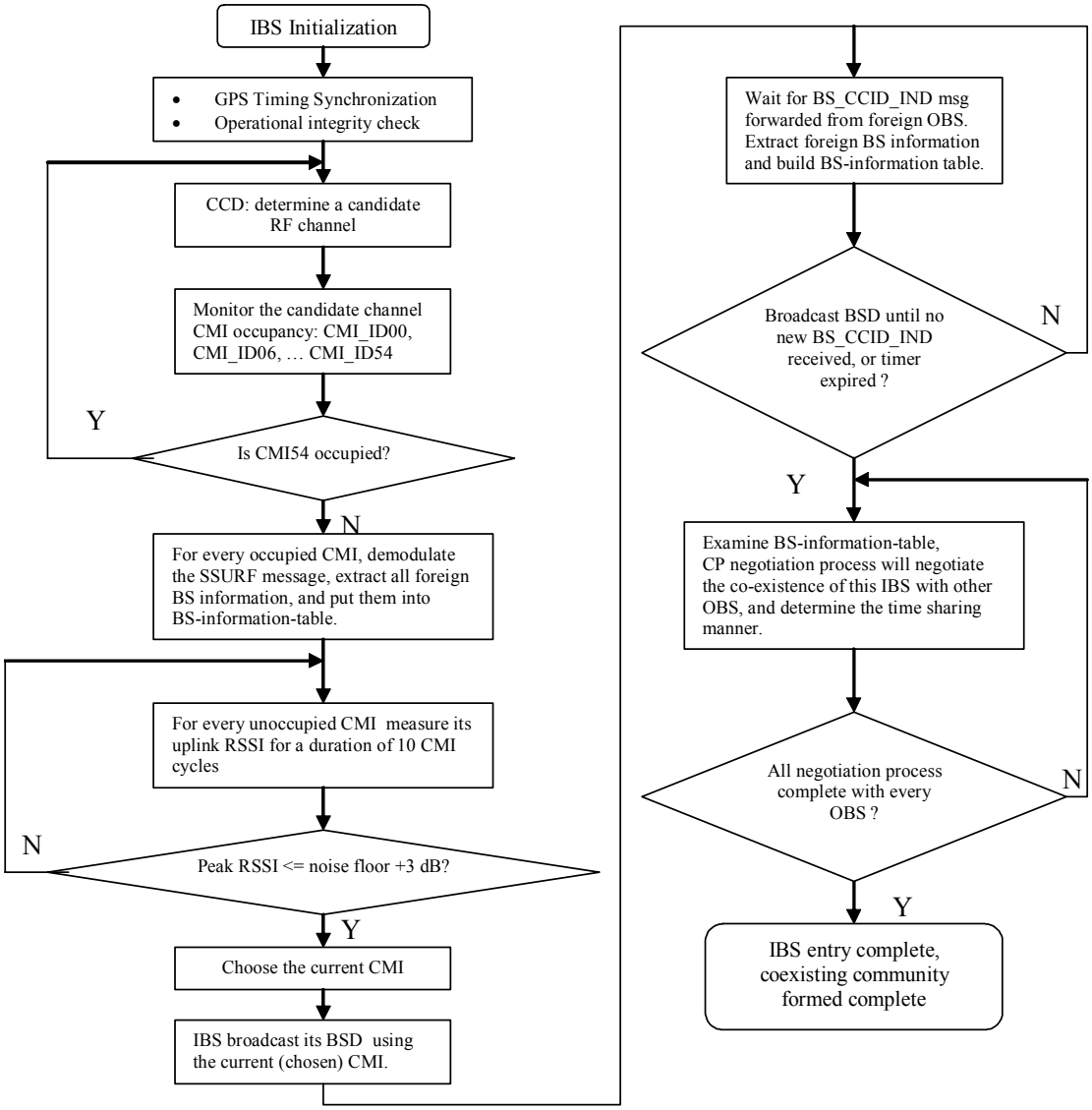


Figure h28—IBS community entry process

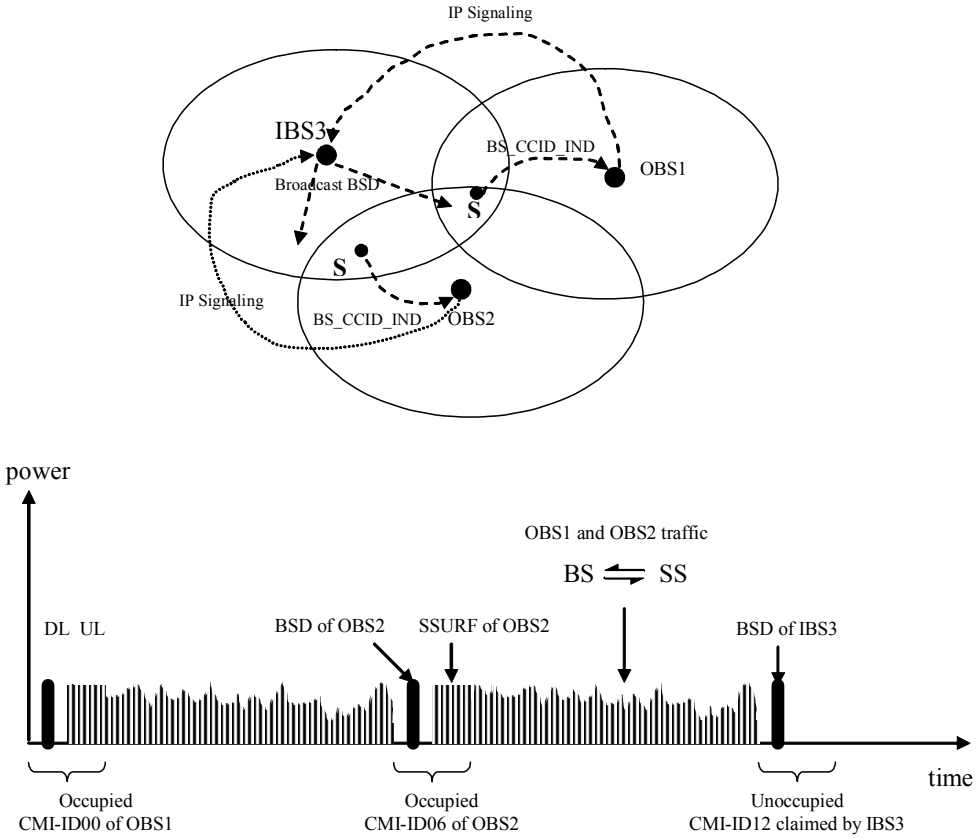


Figure h29—IBS3 Entry Signalling

15.2.1.4 Network and Community Entry for SS

- Start listening;
- Determine interference intervals;
- Assume that the interference is reciprocal;
- Build database for possible working slots and sub-frames;
- Wait for the Base Station community entry and start of operation;
- At BS request, s*end a list of the above identified time intervals;*
- If an old Base Station will perceive interference from the new SSs, it will *ask the new Base Station to find another sub-frame for that SS operation;*
- If the SS will sense interference, will request their Base Station to *find another sub-frame for operation as Master.*

15.2.1.5 BS regular operation

The regular operation of BS includes:

- **Radio resource allocation and re-allocation:** including channel allocation and sub frame allocation.

- **SS traffic Scheduling:** The traffic of each served SS should be scheduled into the corresponding sub-frame/resource based on the SSs' interference situation. Traffic of SSs in the interference free zone could be scheduled into any available sub-frame/resource of the serving BS, and traffic of SSs in the interference zone should useonly corresponding master subframe/resource of the serving BS.
- **System power controlling:** Set Tx power levels in order to use the minimum power levels for both BS and SSs;
- **Interference situation identification:** The BS needs to keep updated information for all BS in the community including the coexistence neighbor BS, and the information of the served SSs in the own network. The information includes the profile and the interference situation of the stations. The interference situation information includes the interference status, the interference source and corresponding RSSI, the interference victims founded, etc.
- **Distributed database maintenance:** Update and maintain database when other BS's join the network.

15.2.1.6 Operational dynamic changes

15.2.1.7 Creation of a new sub-frame

If none sub-frame can be used, a *new Base Station may request the addition of another sub-frame.* The effect of such a request will be the reduction of operating time for those Base Stations that interfere with the new Base Station. However, all the others, that do not interfere one with each other and with the new one, may work in parallel and use the same operating time.

A Base Station will request the creation of a new sub-frame by:

- Sending IP messages to all BS members of the community, and indicating:
  - The interfering operator ID and BS ID
  - The MAC frame-number in which the addition of a new sub-frame will take place.
- All the requested *BSs will acknowledge the request*, by
  - Sending back a message having as parameters:
  - Frame-number for the change (must be the same as the requested one
  - Master sub-frame number for the new BS (SF = Sfold+1).
  - If are missing acknowledges, those BS will be asked again, for another M attempts, after that will be considered that they are not working;
  - At the above specified MAC frame number, a new sub-frame partition will take place, by inserting in the sub-frame calculation relation N=N+1
  - The BSs will up-date the own SSs about the change
- Start to use the created Master sub-frame.

15.2.1.8 Controlling interference during master sub-frame

15.2.1.8.1 Interferer identification

The interferers will be identified by their radio signature, for example a short preamble for OFDM/OFDMA cases. The radio signature consist of:

- Peak power
- Relative spectral density
- Direction of arrival.

Every transmitter will send the radio signature during an interference-free slot. The time position of this slot (frame_number, sub-frame, time-shift) will be used for identification.

In IBS's coexistence neighbor discovery phase, the IBS's contact information and RTK shall be broadcast using the BS_NURBC frame with pulse energy keying. And this shall be detected by coexistence neighbor's SS in the IBS's coverage (see ANNEX C.1 case 3) and reported to its serving BS.

The BSID is used to identify the coexistence neighbor BS by the receiver SS. And also be the identifier of the BS for its coexistence neighbor BS.

15.2.1.8.2 Interference to BS

The BS of the system which experience interference from the SSs in the neighbor systems can control the interference, using the following procedures:

- Identification of the source of interference, using the procedures defined above;
- Request for transmit power reduction. If the sources of the interference are identified, the BS should send message to the BSs of the interfering systems, asking them to drop the power of the specified transmitter inside the neighbor systems by P dB.
- Request for stoping the operation. Alternatively, the BS could send message to the BSs of the interference source systems, asking the interference source system to stop operating during this BS's master slot.

The interference status information of this BS in the system and the interference status information in the coexistence message from its neighbor systems should be stored and updated regularly into the database of this system.

15.2.1.8.3 Interference to SS

- Report to BS about experienced interference
- List of frame_number, sub-frame, offset, IP address of source BS (if detected)
- BS start process for interference reduction with feedback from the SS.

15.2.1.9 Controlling interference during not-interfering traffic sub-frames

The Base Station data base shall keep the following information regarding the usage of " non-interfering sub-frame" or Master sub-frames belonging to other systems:

- BS power, relative to the radio signature ***power***, when using each of the sub-frames;
- List of SSs and their power, relative to the radio signature ***power***, when using each of the sub-frames.

The received power during other sub-frames can be obtained by using the radio signature measurement and suitable calculations, according to data-base information on used powers. Messages as Stop_Operating_Request and Reduce_Power_Request can be used for controlling the interference levels.

15.2.1.10 Power Control

Every network will strive to reduce its transmit powers to the minimum, such that the C/I+N will be sufficient to allow the operation at the minimum common rate, considered as QPSK1/2 for all the 802.16 systems; an exception from this rule is possible only when a network is operating during its interference-free period. The power control mandatory algorithm will be defined in chap. ***[t.b.c.]***

15.2.1.11 Coexistence with non-WirelessMAN wireless access systems

The principles in section 15.2.1.9 are also applicable to non-WirelessMAN systems, like IEEE 802.11. During every WirelessMAN MAC frame, a IEEE 802.11 system may find that a sub-frame may be used, due to the low created interference levels. In the case that no operation in parallel is possible, the new system will ask for the creation of a new Master sub-frame. The Coexistence Protocol, working at IP level, will allow the communication between systems using different PHY/MAC standards.

The scheduled use of the MAC frame is possible by using the IEEE 802.11 PCF mode.

15.2.2 Shared distributed system architecture

15.2.2.1 Architecture

The architecture for Radio Resource Management in the context of this clause it is a distributed one and allows communication and exchange of parameters between different systems. A system consists from a base station and its associated subscriber stations and its coexistence proxy.

Every base station includes a distributed radio resource management (DRRM) entity, to apply the spectrum sharing policies, and a data base (DB) to store the shared information regarding the actual usage and the intended usage of the radio resource.

A subscriber station may include an instance of DRRM, adapted to SS functionality. in The two figures, Figure h 30 and Figure h 31 illustrate the two System Architecture alternatives.

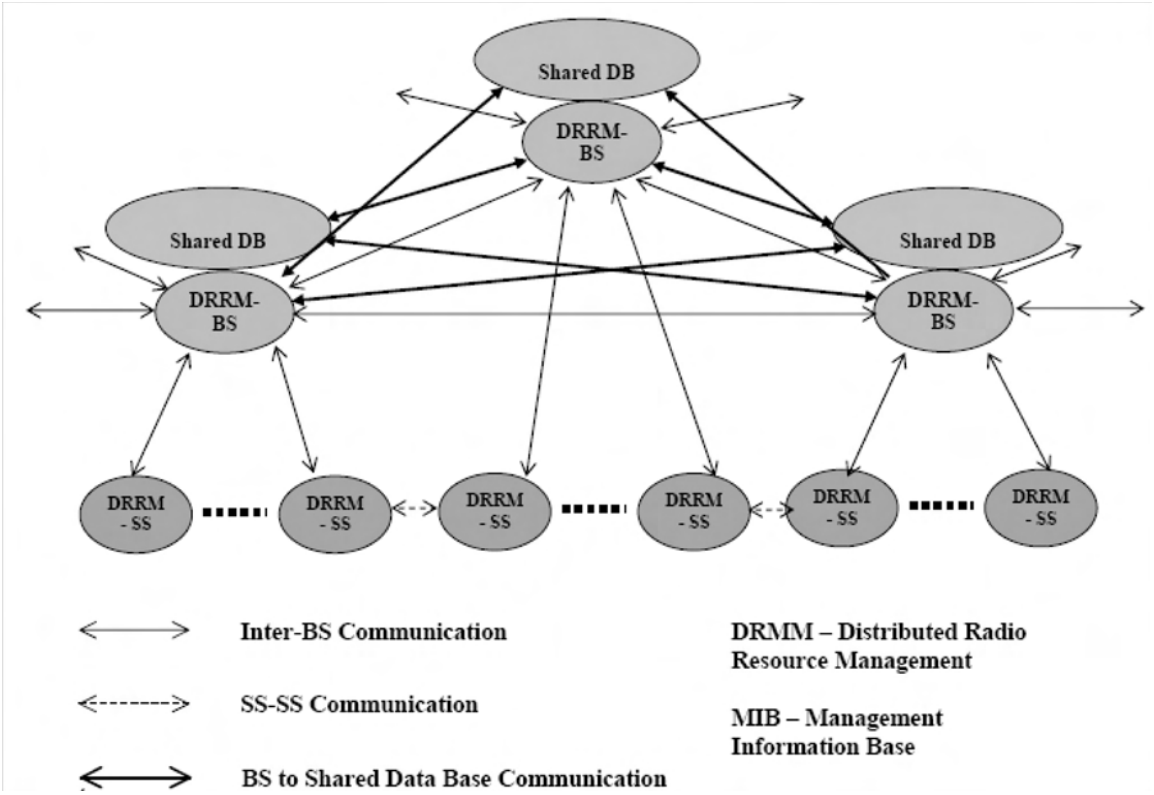


Figure h30—System Architecture type 1

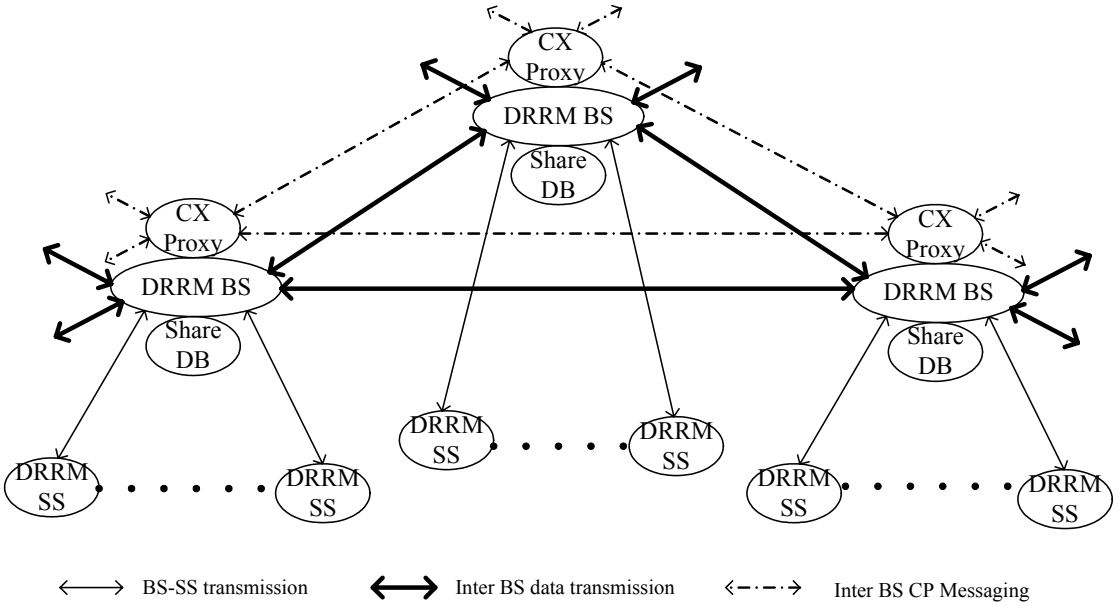


Figure h31—System Architecture type 2

Figure h 32 and Figure h 33_shows the IEEE 802.16 LE type1 and type2 inter-network communication architecture:

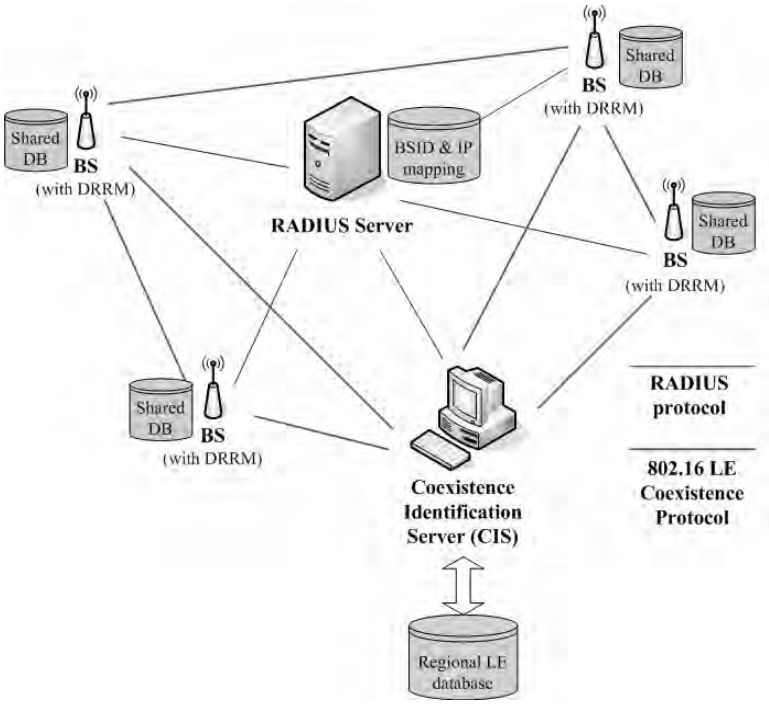


Figure h32—Network Architecture Type 1

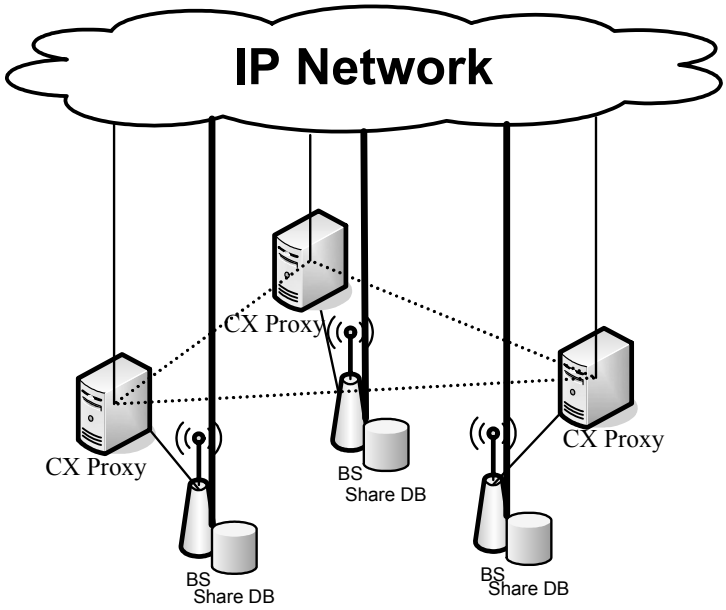


Figure h33—Network Architecture Type 2

General architecture includes the components operating over IP-based network:

For network architecture type 1:

- The RADIUS Server- The Base Station Identification Server (BSIS), ~~described in detail in section xxx -~~ The BSs cooperating with the Distributed Radio Resource Management (DRRM) procedure RADIUS server to maintain the address mapping of wireless medium addresses of BSs (their BSID) and medium addresses of BSIS to their IP addresses.

For the network architecture type 2:

- The coexistence proxy of every base station maintains the mapping of the IP address and the BSID of their serving BSs. All the CP messages between the different systems should be sent and received via their coexistence proxies instead of directly between the base stations. So the IP address will not be known outside the system. The coexistence proxy will forward the CP messages for the base station.

15.2.2.2 Inter-network communication

The inter-network communication consists in:

- Inter-netwo*rk messages*
  - Base Station to/from Base Station
  - Base Station to/from Subscriber Station to/from foreign Base Station; the subscriber Station is used as relay of signaling, if the two Base Stations are hidden one from the other
- Open access to DRRM Data Base (*optionally via coexistence proxy when between systems*):
  - To read the parameters of the hosting Base Station
  - *To request c*hange of the hosting Base Station operating parameters.

15.2.2.3 Coexistence Protocol

[Note: the security part is a temporary text adopted from contribution C802.16h-05/11r1 and is subject to further discussion.]

In order to obtain a coexistence neighbor topology, the Base Station accesses the database(see 15.3.2.5) and registration to peer, negotiation for Shared RRM etc. using the Coexistence Protocol (CP). Figure h 34 describes the coexistence protocol architecture for WirelessMAN-CX systems.. The protocol architecture indicates that DRRM, Coexistence Protocol and Shared DB belong to the LE Management Part located in management plane and the CP messages (see 15.5.2) will be exchanged over IP network. Thus, the DRRM in the LE Management Part uses the Coexistence protocol to communicate with other BSs and with Regional LE DB in order to interact with MAC or PHY. Figure h 35 illusttrates the LE BS architecture with the Coexistence Protocol. The gray indicates area where there is an absence of connection between blocks. The Distribution System Medium (DSM) is another interface to the backbone network. Note that is architecture is only for reference. Similarly, Figure h 36 illustrates the BSIS architecture which is co-located regional LE database. The Coexistence Protocol (CP) services are accessed by the LE Management Entity through the CP SAP. The service primitives are described in [Apppendix?] t.b.d. A BS uses the Coexistence Protocol, which is similar to PKM protocol, to perform the coexistence resolution and negotiation procedures. There are two types of messages to support Coexistence Protocol:

(1) CP-REQ: BS->BS or BS->BSIS

(2) CP-RSP: BS->BS or BSIS->BS

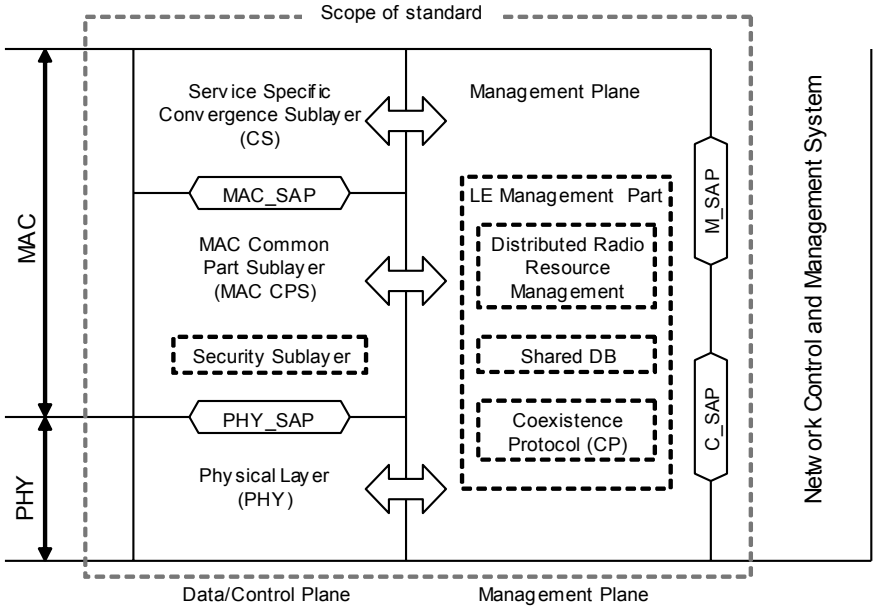


Figure h34—WirelessMAN-CX BS Protocol architecture Model

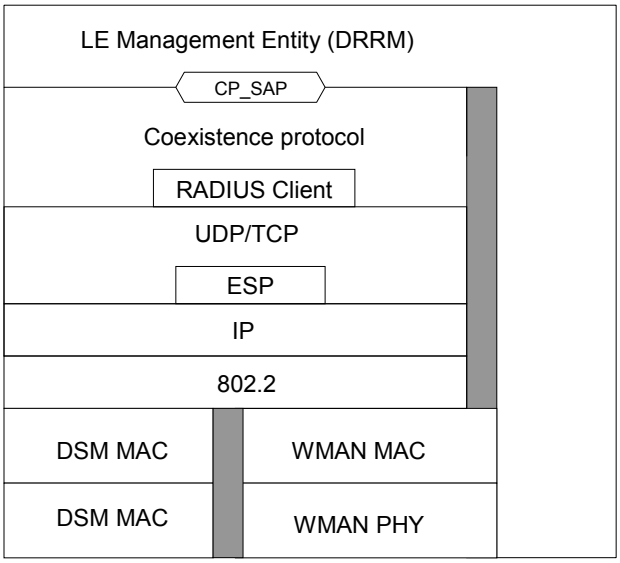


Figure h35—LE BS architecture with Coexistence Protocol

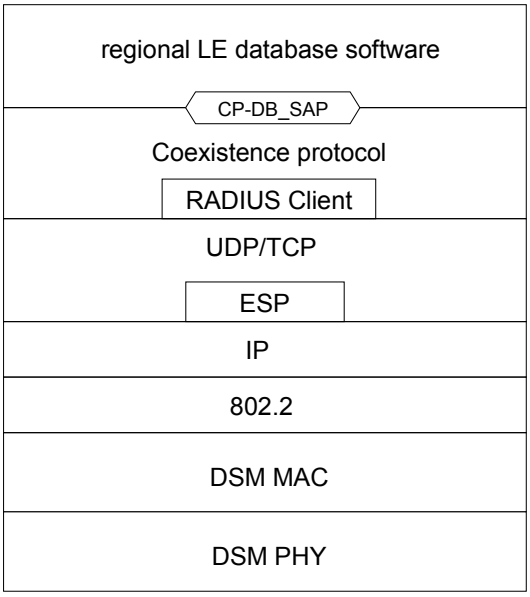


Figure h36—BSIS architecture with co-located regional LE database

15.2.2.3.1 Same PHY Profile

For systems using the same PHY Profile in this standard, the profile elements are:

— Mandatory channel spacing for LE system in[tbd.] MHz will be[tbd.] MHz;

— PHY mode option:

- o WirelessMAN-OFDM (256 FFT points)
  Mandatory profiles for operation in the LE 5725-5850 MHz band will be:
  - — profM3_pmp,profP3_10,profC3_23,TDD,profR13
- o WirelessMAN OFDMA 2k (in future 128, 512, 1k) FFT points
- o *WirelessMAN* SCa,

the inter-system communication will be undertaken using messages over the air, as specified in this standard.

15.2.2.3.1.1 Coexistance Messaging Interval (CMI) Use for Same Profile Systems

The CMI is the duration of the MAC frame (20 msec) and consists of an uplink and downlink intervals of equal size (10 msec) (TBD). Downlink messages carry information (BSD messages) unique to the identity of the base station controlling the system to which the particular CMI is associated. Uplink messages carry information (SSURF messages) unique to the subscriber stations within the system and base station associated with the same CMI. During a CMI all other systems, not associated with the particular CMI, remain silent and receive only.

Every BSD (section 6.3.2.3.62) sent downlink has a BS_ID associated with it. This BS_ID tag can be used as an interference identification tag as well. The message contains the UL-MAP, which addresses specific SS to send their SSURF messages. The duration of the BSD message is typically 1 msec (TBD).

There is only one downlink BSD PDU in the CMI and it is transmitted at random starting point within the downlink time interval of the CMI. The rationale for the random placement of the BSD within the downlink subframe is to handle the possibility that two or more potentially interfering base stations inadvertently choose the same CMI. Such base stations and the respective networks they control may coexist peacefully without causing interference to each other because of hidden SS or having no SS in the common coverage area. Essentially, such networks do not form an interference community because they do not interfere with each other. However, when the hidden SS or new SS enters into the common coverage area, co-channel interference will be detected at the new SS resulting in a situation that impacts the neighboring base stations having a common CMI.

A BSD collision occurs in this situation and this is resolved by randomizing the start times of downlink sub frame PDU and uplink SSURF messages in the CMI. This reduces the possibility that two networks, sharing the same CMI will overlap in their downlink and uplink BSD or SSURF transmissions. Realize that the downlink slot will be 10 msec wide and that the downlink sub frame BSD PDU itself is only < 1 msec. For the worst BSD collision case, there are n base stations in the common coverage area, the successful (non-overlapping) BSD transmission probability is

$$p = 1 - \frac{1}{m} \bullet \frac{1}{m} \bullet C_n^2 = 1 - \frac{1}{m} \bullet \frac{1}{m} \bullet \frac{n!}{(n-2)! \bullet 2!} \qquad \textit{(h1)}$$

Where $m = \frac{t}{td}$. Assume the CMI downlink duration time length is t which is the uplink portion of a physical frame (physical frame duration is varying from 2, 2.5, 4, 5, 8, 10, 12.5, to 20ms), the BSD downlink PDU time duration is d t , which is typically < 1 msec.

15.2.2.3.2 Mixed-PHY Profile communication

In the case of different PHY Profiles the coexistence communication will be done at IP Level. Every Base Station needs to know the IP address of the DRRM of the Base Stations in its area, by provisioning or/and by using a regional data base approach or/and by using cognitive radio signaling.

15.3 Interference identification

In order to coordinate with the neighbor systems, the system should be aware of its interference situation and identify the victims and sources around it. Based on this the systems can proceed with further Interference prevention (section 15.4) procedures.

When able to exchange information between the WirelessMAN-CX system and the neighbor systems, may use collaborative mechanisms and become aware of the identity of the interferer, otherwise it can not know the identity of the interference victims or sources. In the latter case it will only be possible to use non-collaborative mechanisms (15.2.1.1) and procedures to coexist, such as interference power detection, DFS and so on. This section defines the identification procedures based on information exchange using signaling and messages.

15.3.1 Identification of the interference situations

The BS in the system takes responsiblity for gathering and maintaining all the interference information of the system and determines the resource allocated for its own system use. The interference identification is determined by the power detection, CSI signaling decoding, CMI messaging receiving, CP message received.

All the corresponding interference information should be stored in the distributed database *[as SS and BS interference tables]* for each system (see 15.3.2.4) and maintained regularly. The distributed database have the information relative to all the systems in the neighborhood or other community.

The Interference information gathering approaches include:

1) using interference power detection to measure the basic interference situation in the candidate channels

2) signaling decoding in candidate channels (15.3.1.1.1)

3) receiving messages in candidate channels

4) exchanging system information using CP message in the IP network

IP address information may be aquired by the following metods:

1) the initializing BS uses a configured IP contact list, the list is either read from a region centralized server or from a off-line address list;

2) by decoding the contact information from the signaling/messaging sent by the neighbor system.

The detail of the CP message exchanged in the initializing procedure is shown in section 15.5.2.

15.3.1.1 Interferer identification

The interferers will be identified by their radio signature, for example a short preamble for OFDM/OFDMA cases. The radio signature consist of:

- Peak power
- Relative spectral density
- Direction of arrival.

Every transmitter will send the radio signature during an interference-free slot. The *time position of this slot (frame_number, sub-frame, time-shift)* will be used for identification.

The transmitted power of non-interfering radio transmitters using a Master sub-frame will be known from the BS data base, indicating their power attenuation relative to the radio signature, for every used sub-frame.

15.3.1.1.1 Interference Identification & Resolution via CSI Detection

Downlink CSI is used by the BSs to broadcast signaling to the neighbor systems. These signals are used for Interference identification and resolution. In order not to collide with the other neighboring interferers, the coordinated community should prevent neighboring BSs from using the same CSI.

There is one ICSI for IBS in an ICSI cycle, in the example figure below, each ICSI cycle have 4 CSIs and CSIN 0/4/8/12 indicate the CSI number of ICSI. The other CSI is leave to OBS as OCSI, as shown in Figure h 37. Every OBS need to obtain an OCSI allocation in one OCSI cycle, which is formed by multiple ICSI cycle so that IBS can get more opportunity then OBS. There are 4 ICSI cycles inside one OCSI cycle and 4 CSI in each ICSI cycle in the example, so that there is 4 ICSI interval for the IBS and 12 interval for up to 12 OBSs.

Notice that the CSI allocation MAP should indicate all the CSI allocation in the uncoordinated channel as unusable. The uncoordinated channel information can be gathered in the DFS procedure or by the failure of coordination procedure in the interfered channel.

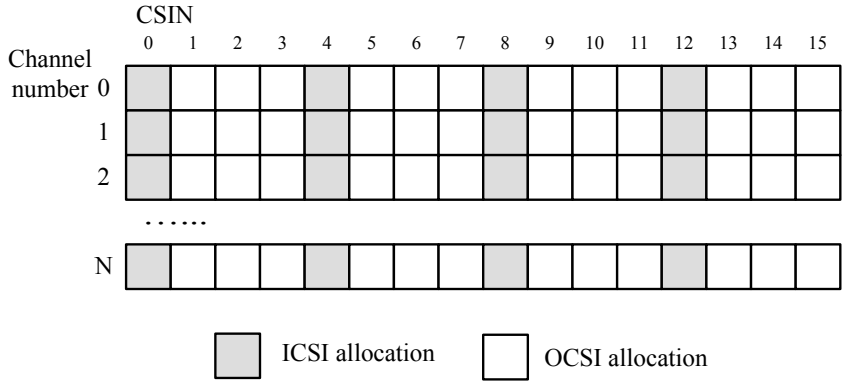


Figure h37—format of ICSI/OCSI allocation MAP

In the initialization phase of a BS, before the BS has an OCSI allocation, the BS should use ICSI to advertise its arrival in the air at every candidate channels sequentially one by one. The neighbor OBS will then send their current OCSI allocation and current sub frame allocation to the IBS using CP message. After the IBS chooses the working channel for its radio link, the IBS shall choose a vacant CSIN for OCSI in this channel and inform other neighbors about this choice. Then, this BS will start using this OCSI allocation as its exclusive CSI allocation.

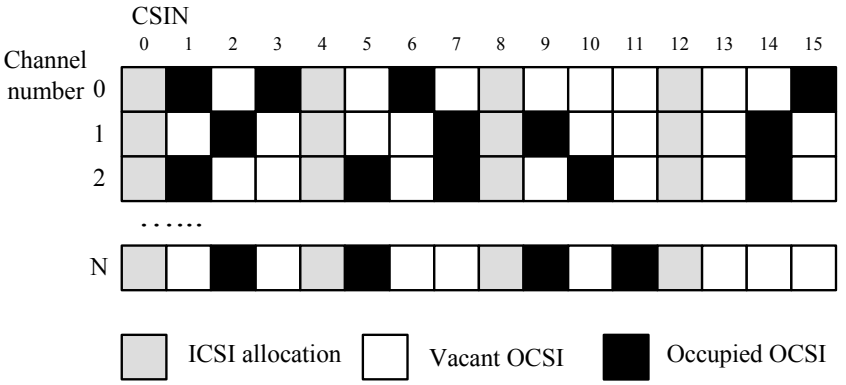


Figure h38—Example of CSI allocation MAP in one BS's database

Figure h 38 illustrates an example of the CSI allocation MAP of one BS during his initialization phase by collecting the CP message information from his neighbors. Assume this BS chooses channel 0 as its working channel, it can then choose any one of the CSIN 2,5,7,9,10,11,13,14 as its OCSI allocation number. Every BS will have its own CSI allocation map indicating the current situation of CSI occupancy by the neighbors in the working channel and potential neighbors in the potential working channel. The CSI allocation MAP table of potential working channel will be used when BS move to another channel in cases. The CSI allocation MAP of the BS should be updated in time when any changes have been informed by its neighbors in the working channel and potential neighbors in the potential working channel.

In the OCSI mapping table, every neighbor in working channel or potential neighbor in potential channel is mapped to one OCSI allocation, every OCSI allocation will indicate its occupant or vacancy. By inquiring

the mapping table of the OCSI allocations to the BSs, one BS can recognize the source of the interference or signaling in each OCSI allocation.

The initializing BS uses the OCSI allocation table to find out its neighbors in the working channel. By the contact information it acquired from the CP message, the IBS will then use CP message to negotiate for interference resolution with its neighbors.

15.3.1.1.2 Interference from other networks specified in this standard

[Editors note: CCD content may need to be moved into 15.3.1.1. All interferer identification mechanism should be introduced into 15.3 .]

15.3.1.1.3 Interference from Non-IEEE 802.16 systems.

Non-IEEE802.16 systems can make coexistence using collaborative mechanism or non-collaborative mechanism. When sharing information and coordinating with WirelessMAN-CX system using CP messaging or signaling, non-IEEE802.16 systems, such as IEEE802.11 systems, can share the same band of spectrum or doing radio resource distribution optimization using the collaborative mechanism (summarized in 15.2.1.1) with WirelessMAN-CX systems. Otherwise, only non-collaborative mechanism can be use on coexistence between IEEE802.16 and non-IEEE802.16 systems.

15.3.1.1.3.1 Non-IEEE 802.16 Systems (BSs and their SSs) capable of GPS/UTC Timing Recovery

Other wireless systems not specified in this standard using the LE bands that that are capable of GPS/UTC timing recovery can monitor the CMI intervals to determine the existence of co-channel IEEE 802.16 users. Monitoring the intervals and undertaking CCI measurements over CMI cycles will allow these other systems to determine the occupancy on a channel and avoid settling on it. *[NOTE THAT BS AND SS MAY NOT BE DEFINED IN OTHER SYSTEMS.]*

Additionally, [CMI_ID54] [tbd.] will be left unoccupied by IEEE 802.16 systems. Non -IEEE 802.16 systems occupying the same LE spectrum can insert downlink and uplink power bursts [tbd.] into this interval. Such energy shouldbe detected by the IEEE 802.16 systems which will consequently avoid use of the given channel.

15.3.1.1.3.2 Non-IEEE 802.16 Systems not capable of GPS/UTC Timing Recovery

The majority of co-channel interferers will be systems and devices that cannot perform rudimentary of signaling specified for IEEE 802.16 coexistence and channel detection. To deal with such interferers the WierelessMAN_CX systems in this standard will have to opt for avoidance of such users. To facilitate this avoidance, both the BS and SS will have the ability to undertake [Power Spectral Density mappings] of selected bandwidth and disseminate such information as part of their [tbd.] inter-network messaging.

Sections 15.5.2.32. and 15.5.2.34 describe the instructions and formatting that will be used by the LE systems to undertake [PSD] measurements of contented spectrum. These measurements should be undertaken by a BS prior to occupancy of spectrum space and they can be undertaken throughout the operational period of a network to determine encroachments and to identify other spectrum that may have to be used in the event of uncontrolled interference arising in the occupied spectrum. The [PSD] measurements will be undertaken by the SS as well and this sensor information will be sent to the BS. [PSD] measurement information

forms part of the data base that is exchanged between networks as part of their mutual spectrum management tasks. SSURF messages [tbd.] could be used to transport spectrum information.

15.3.1.2 Grouping of interfering/not-interfering units

The system need the grouping of interfering/not interfering units of all the systems in the community and all the SSs in native system for various purpose.

For all the neighbor systems (which shows the aspect of interference victim or source in any one of the candidate channel), the initializing BS will group them all as its potential interfering system before choosing the operation channel. When the initializing BS have allocated the operation channel, only the neighbor system which are interfering in current channel are grouped as interfering neighbor system. The interfering neighbor system should share the same band of spectrum by coordinating into different master sub frame or controlling the power spectrum density etc. The other neighbor systems are to be maintained in the database, for the case of such as channel reallocation coordination.

For all the SSs inside the native systems, the BS need to group them into interfering or not-interfering ones, so that the BS can schedule their data traffic into different sub frame to prevent interference. The not interfering SS can use either the interference free sub frame or the master sub frame for their data traffic, while the data traffic of interfering SS can only be tied up into the master sub frame of the native systems.

15.3.2 Identification of spectrum sharers

15.3.2.1 Regulations

15.3.2.2 Messages to disseminate the information

15.3.2.3 Avoid false-identification situations

15.3.2.4 Information table in distributed database

The following tables specify the fields (TLVs) to be included in the BS data base, and containning information relative to its own operation (see Table h 3) and to the operation of the base stations in the community (see Table h 4). Table h 5 specifies the information (TLV) to be included in the SS data-base.

Table h3—Information table for the BS containing this database

Syntax	Size	Notes
This BS information table(){		
BSID	48bits	
Operator ID	?bits	
IP version	1bits	0-IPv4 1-IPv6
(IP version = 0){		
IPv4 address	32bits	IPv4 address of this BS
CXPRX IPv4 address	32bits	CXPRX IPv4 address
}		

Else{		
IPv6 address	128bits	IPv6 address of this BS
CXPRX IPv6 address	128bits	CXPRX IPv6 address
}		
RTK	16bits	Random Temporary Key
Extended Channel Number (ExChNr)	16bits	2 byte base reference to frequency range or deployment band. This reference maps to an absolute frequency value.
Base Channel Reference (BaseChRef)	8bits	1 byte specific channel number reference
Channel spacing (ChSp)	16bits	2 bytes channel spacing value (10kHz increments)
Master resource ID	8bits	Sub-frame number
OCSI ID	8bits	CSIN of OCSI allocation
Negotiation status	8bits	Bit0: get communication in the IP network Bit1: be registered in Bit2: registered to Bit3: done for resource sharing(if neighboring) Bit4-7: tbc.
CSI parameter(){		Regulated by region/country
Tcsi_start	16bits	In microseconds
Tcsi_duration	8bits	In microseconds
Period of frames	8bits	frames
Starting frames offset	16bits	frame serial number of the first frame that CSI presented
Length of Symbols	8bits	In microseconds, need to be 1/n of Tcsi_duration
ICSI cycle	8bits	ICSI cycle counted in CSI cycles
OCSI cycle	8bits	OCSI cycle counted in ICSI cycles
}		
Number of CoNBRs	8bits	m:The number of coexistence neighbors of this BS
for (i= 1; i <= m; i++) {		
BSID	48bits	
(Tbc.)	(Tbc.)	(Tbc.)
}		
Profile(){		
Band		
PHY mode(){		
Modulation		
Working Channel ID	8bits	Identifier of the working channel of this BS.
Number of alternative Channels	8bits	p: The number of alternative channels to which this BS can switch without interference.
For(i = 1; i <= p; i++){		
Alternative Channel ID	16bits	Identifier of the alternative channel.
}		
(Tbc.)		
}		
Maximum power	8 bits	dbm
Number of registered SS	12bits	n
for (i = 1; i <= n; i++) {		
SSID	48bits	
(tbc.)	(tbc.)	(tbc.)
}		
(tbc.)	(tbc.)	(tbc.)
}		
}		

Table h4—Information table for the systems inside the neighborhood or community

Syntax	Size	Notes
BS information table(){		
Index	16bits	
BSID	48bits	
Operator ID	?bits	
RTK	16bits	Random Temporary Key
IP version	1bits	0-IPv4 1-IPv6
(IP version = 0){		
CXPRX IPv4 address	32bits	CXPRX IPv4 address
}		
Else{		
CXPRX IPv6 address	128bits	CXPRX IPv6 address
}		
Sector ID	8bits	
Extended Channel Number (ExChNr)	16bits	2 byte base reference to frequency range or deployment band. This reference maps to an absolute frequency value.
Base Channel Reference (BaseChRef)	8bits	1 byte specific channel number reference
Channel spacing (ChSp)	16bits	2 bytes channel spacing value (10kHz increments)
Master resource ID	8bits	Sub-frame number
OCSI ID	8bits	CSIN of OCSI allocation
Negotiation status	8bits	Bit0: get communication in the IP network Bit1: be registered in Bit2: registered to Bit3: done for resource sharing(if coexistence neighboring) Bit4-7: tbc.
Coexistence neighboring	1bit	Coexistence neighbor with this BS? 1-yes 0-no
BS GPS coordinates	TBD	GPS coordinates of this Base Station
BS RF antenna sector ID	8bits	Identifier of antenna creating this sector
BS nominal EIRP	TBD	Nominal EIRP of this Base Station
BS PSD Vector	TBD	PSD as determined by this BS of all available channels using RSSI scanning process
BS antenna azimuth	TBD	Azimuth orientation of this Base Station's antenna
BS antenna beamwidth	TBD	Azimuth Beam width of this Base Station's antenna
If (Coexistence neighbor){		
Number of victim SSs	16bits	n:The number of victim SSs of this coexistence neighbor, in this network
for (i = i; i <= n; i++) {		
SSID	48bits	
RSSI	16bits	1byte RSSI mean (see also 8.2.2, 8.3.9, 8.4.11) for details) 1byte standard deviation
}		
(Tbc.)	(Tbc.)	(Tbc.)
}		
Number of Coexistence neighbors	8bits	m:The number of coexistence neighbors of this BS
for (i= 1; i <= m; i++) {		
BSID	48bits	

Working Channel ID	16bits	Identifier of the working channel of this neighbor.
Escape Channel Flag	1bit	Flag indicates this neighbor has one or more escape channels.
(Tbc.)	(Tbc.)	(Tbc.)
}		
Profile(){		
Band		
PHY mode(){		
Modulation		
Working Channel ID	16bit	Identifier of the working channel of this neighbor.
alternative Channel Flag	1bit	Flag indicates this neighbor has one or more alternative channels.
(Tbc.)		
}		
Maximum power	8 bits	dbm
Number of registered SS	12bits	
(tbc.)	(tbc.)	(tbc.)
}		
If (CMI Interval used) {		
Number of coexistence neighbors		
For (i=0; i<=n; i++) {	TBD	All Co-existing neighbor BS information. This is the list of foreign BS, which may be causing interference to this BS and its SS
Foreign BSID	TBD	BS_ID of this foreign BS
Foreign BS IP address	TBD	IP address of this foreign BS
Foreign BS CMI-ID	TBD	CMI_ID of this foreign BS
Number of foreign SSs causing Co-channel interfering	TBD	Number of SS associated with this foreign BS causing interference to this BS
For (j=0; j<=m; j++) {	TBD	All SSs associated with this foreign BS, which cause co-channel interference
Interfering SSID	TBD	SS_ID of this SS causing interference to this BS
CMI Interfering occurrence	TBD	Number of instances where interference recorded.
RSSI of interfering SS	TBD	RSSI of this interfering SS
SS interference resolved	1 bit	Has the interference caused by this SS been resolved by use of the CP between this BS and the foreign network?
}		
}		
}		
(tbc.)	(tbc.)	(tbc.)
}		

Table h5—Information table for the SSs inside the system containing this database

Syntax	Size	Notes
SS information table(){		
Index	16bits	
SSID	48bits	
SS location	TBD	Optional
SS GPS location	TBD	Optional
SS antenna beam width	TBD	Beam width of this SS antenna
SS nominal uplink EIRP	TBD	Nominal EIRP of this SS
SS PSD vector	TBD	Power Spectral Density determined by the SS by RSSI process scanning all available channels

Interference status	1bit	Interfered by coexistence neighbor? 1-yes 0-no
If (Interfered){		
Number of source BSs	8bits	n:The number of interference source of coexistence neighbor
for (i = 1; i<= n; i++) {		
BSID	48bits	
BS_NURBC detected	1bits	1-yes 0-no
If (BS_NURBC detected){		
IP version	1bits	0-IPv4 1-IPv6
(IP version = 0){		
CXPRX IPv4 address	32bits	the v4 IP address of the CXPRX reported by the SS
}		
Else{		
CXPRX IPv6 address	128bits	the v6 IP address of the CXPRX reported by the SS
}		
IBS BSID	48bits	The BSID reported by SS
RTK	16bits	RTK in the BS_NURBC reported by SS
Sector ID	?bits	Reported by SS
Frame number	24bits	Reported by SS
Error Status	?bits	0 -no error 1 - not capable to decode the energe pulse symbol.; 2 - not able to find the eligible <SOF>; 3 - not able to find the eligible <EOF>; 4 - not able to pass the CRC check for message;
(tbc.)	(tbc.)	(tbc.)
}		
RSSI	16bits	1byte RSSI mean (see also 8.2.2, 8.3.9, 8.4.11 for details) 1byte standard deviation
(tbc.)	(tbc.)	(tbc.)
}		
(tbc.)	(tbc.)	(tbc.)
}		
If (CMI frame used) {		
Associated BS ID	TBD	BS_ID to which this SS is associated
Associated BS RSSI	TBD	Mean RSSI of BS downlink to which this SS is associated
Associated BS RSSI Var	TBD	Variance of RSSI of downlink
Associated BS BER	TBD	BER of downlink
Number of foreign BSs	TBD	Number of foreign BS this SS has detected via BSD
For (I=0; I <=n; I++) {		
Foreign BS ID	TBD	BS_ID of this foreign BS as determined from its BSD
Foreign BS EIRP	TBD	EIRP of this foreign BS as determined from its BSD
Foreign BS antenna sector ID	TBD	Antenna sector ID of this foreign BS as per BSD
Foreign BS Proxy IP address	TBD	Proxy IP address of this foreign BS as per BSD
Foreign BSD occurrence ratio	TBD	Defined as the ratio of demodulated foreign BSD messages to CMI cycles. A metric indicating severity of interference caused by this foreign co-channel BS.
Interference resolution	1 bit	An indication that interference from this foreign BS has been resolved by the CP.
CMI-ID	TBD	CMI_ID of this foreign BS

}		
}		
(tbc.)	(tbc.)	(tbc.)
}		

15.3.2.5 Using centralized server

[Note: overlapping chapter]

15.3.2.5.1 Base Station Identification Server

[Note: The following part from 3.2.4.1 is a temporary text adopted from contribution C802.16h-05/11r1 and is subject to further discussion. A call for comment from security experts is open to comment on this text.]

The *Base Station Identification Server* (BSIS) acts as an interface between 802.16 LE BSs and the regional LE DB which stores the geographic and important operational information, e.g. latitude, longitude, BSID etc., of the LE BSs belonging to the same region. It converts the actions carried in PDUs received from the 802.16 LE BSs to the proper formats, e.g. SQL (Structured Query Language) string, and forwards the strings to the regional LE DB, which can be any available database software. BSIS converts the query results from the regional LE DB to the proper format, e.g. TLV encodings, and replies to the requested BSs. Figure h 32 shows the general architecture of inter-network communication across 802.16 LE systems. BSIS acts as a peer of 802.16 LE BSs in this architecture. The BSID of regional BSIS is well known among the 802.16 LE systems within certain domain. The messages exchanged between the LE BSs and the BSIS will be revealed in the next section.

[Note that the interface between BSIS and regional LE DB is out of scope.]

15.3.2.5.2 Information table in centralized database

[notes: Centralized server should contain the information necessary for system's neighbor discovery procedure, and should describ the content here.]

15.4 Interference prevention

This subclause describes the methods of preventing the interference, based on the information of the interference that the system had identified (section 15.3).

15.4.1 Dynamic Frequency Selection – DFS

15.4.1.1 Frequency selection for regulatory compliance

15.4.2 Adaptive Channel Selection – ACS

This section describes the method of Adaptive Channel Selection (ACS) to prevent interference. The first step is to attempt to identify a vacant channel using the gathered information from the system and the neigh-

bor systems (see 15.3.2). If a vacant channel is not found, the BS then tries to obtain an exclusive channel by optimization of channel distribution (see 15.6.1& 15.6.1.4).

Success of either step will enable the BS start working with an exclusive working channel. If no vacant channel can be found, then the BS will attempt the channel sharing coordination procedure.

15.4.2.1 Adaptive Channel Selection between systems based on the WirelessMAN-CX

15.4.2.1.1 Candidate Channel Determination (Using GPS/UTC Synchronized CMI and Common Profile)

Candidate Channel Determination (CCD) is the process used by WirelessMAN-CX systems (using a synchronized CMI and common profile) where a base station monitors a band to which it has access and selects, within that band, a channel having minimal use and occupancy by neighboring wireless systems. This process is used, for example, by an IBS prior to undertaking entry into a Coexistence Community. Since a base station can only receive uplink traffic, this process relies on the monitoring uplink transmission intervals and the measurement of interference signal power [I] and noise power [N]. Each candidate channel will be ranked in terms of its (I/N) ratio. Those channels with the lowest ratio or ideally a ratio of 1 will be selected for use by the base station and be candidates for entry by an IBS, since such channels will have the lowest amount of discernable activity on them, hence likely have lower interference.

[I] and [N] will be determined using the RSSI measurement capability of the base station receiver as detailed in Section 8.4.11.2. After synchronization to the GPS and initialization of the base station operating parameters, the base station will select a channel and undertake noise floor measurements on CMI_ID54, which is unoccupied by WirelessMAN-CX networks but may be used by non-WirelessMAN-CX networks (15.3.1.1.3.1).

CMI_ID54, in situations when it is unoccupied, will be free from all WirelessMAN-CX transmissions and will provide an interval allowing the measurement of the receiver thermal noise floor [N]. The thermal noise floor is the noise power spectral density of the received channel (No) multiplied by the channel bandwidth. Measurements will be undertaken long enough to determine whether [N] has Gaussian characteristics. Characteristics not deemed as Gaussian and/or RSSI measurements that are 3 db (TBD) higher than a predetermined [N] value (which can be provided a priori as a Receiver Noise Figure estimate within RSSI measurement algorithm in the base station receiver) will be indicators that channel may be occupied by non-WirelessMAN-CX users. In this instance the value of the mean RSSI will be taken as the [I] created by the occupying non-WirelessMAN-CX network and the given channel will be discarded from further consideration. Otherwise, the measurement will provide a value for [N].

[I] measurements will be undertaken by calculating the mean signal strength and variance due to uplink SSURF messages summed over intervals CMI_ID00 to CMI_ID48. The number of CMI cycles to be measured will be a variable (***TBD***) set for the base station by the operator. Measurement of the RSSI will be done in accordance with Section 8.4.11.2, with care being taken to ensure that valid signals are being measured, even at close-to noise floor levels. The mean RSSI and variance calculated for the summed CMI intervals of the channel will be construed as interference values [I] and [Var I] for the channel.

The channels are then ranked, with the channel having the lowest I/N and smallest [Var I] measurements likely selected for IBS entry into a Coexistence Community. Figure h 39 shows the CCD process.

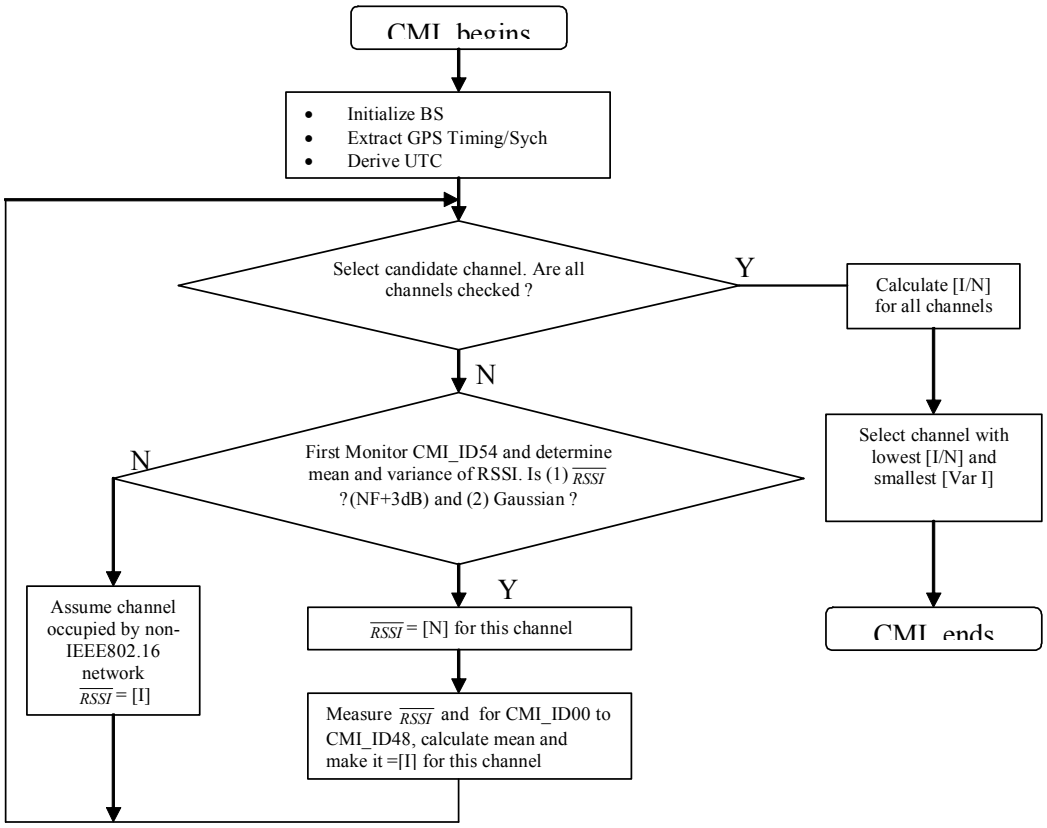


Figure h39—CCD Process

15.4.3 Adaptive Sub frame Selection - ASFS

[notes: description for adaptive sub frame selection needed here, the procedure here is similiar to ACS.]

15.4.4 Pro-active cognitive approach

15.4.4.1 Signaling to other systems

15.4.4.1.1 Ad-hoc systems - operating principles using Radio signaling

In order to reduce the interference situations, in deployments in which there exist a combination of systems using this Coexistence Protocol and 802.16 ad-hoc systems, the 802.16 ad-hoc systems will apply the Adaptive Channel Selection procedures and use radio signaling procedures to interact with systems using a Coexistence Protocol. The ad-hoc systems obtain a temporary Community registration status, that has to be renewed from time to time.

15.4.4.1.2 Registration

The WirelessMAN-CX pro-active radio approach defines signals and procedures for the reservation of the activity intervals and registration of ad-hoc systems. The operational procedures are described below:

— WirelessMAN-CX Community registered systems, using a Coexistence Protocol, will reserve the MAC frame Tx/Rx intervals by using, during the MAC Frame N, starting at the absolute time AT1, radio signals to indicate the MAC Tx_start, MAC Tx_end, MAC Rx_start, MAC Rx_end. These signals are transmitted by Base Stations and Repeaters. These procedures will repeat after T_cogn seconds; the values of these parameters are specified in section 10.5; No regular data transmission should take place 20 ms from the start of AT1 (the maximum IEEE802.16 MAC frame duration).

— During the MAC frame starting at the absolute time AT2, cognitive signals will indicate the beginning and the end of Master sub-frames, by transmitting signals indicating by their transmission start the Tx_start, Tx_end, Rx_start, Rx_end for the specific sub-frame; these signals are transmitted by Base Stations, Repeaters and those SSs which experiences interference, at intervals equal with Ncog MAC Frames; no regular data transmission should take place 20 ms from the start of AT2 (the maximum IEEE802.16 MAC frame duration).

— The MAC frame starting at the absolute time AT3 is the beginning of a registration interval using the cognitive signaling; the registration interval has the duration of Tcr_reg seconds; The ad-hoc transmitters shall use during the MAC frame starting at the absolute time AT3, the marked master sub-frames for sending their radio signature. The radio signature will be used for the evaluation of the potential interference during the Master slot, to systems which use the sub-frame as Master systems.

  - o The radio signature will consist of a preamble and a MAC header, sent on the working channel and using the same power and sub-carrier allocation, as used in the regular data transmission mode;
  - o The sub-frame starting at Tx_start is slotted, each slot having the duration of 100us. The tramsmission of a radio signature will start at a slot boundary, as perceived by ad-hoc systems. No ranging assumptions were taken in the assessment of the slot duration.
  - o An ad-hoc radio unit (BS, Repeater or SS) will send this signal using a random access mode for Tcr_reg seconds, using the sub-frame intended for their regular transmission (BSs and SSs use different sub-frames for transmission).
  - o The ad-hoc transmitters will have to use the registration procedures every Tad_reg seconds.
  - o No regular data transmission should take place 20 ms from the start of AT3 (the maximum IEEE802.16 MAC frame duration).

— Registration replay

  - o The radio units using the Master sub-frame will send a NACK signal, during the MAC Frame starting at the absolute time AT4, and using the same sub-frame as used by the unacceptable transmitter, if they appreciate that the ad-hoc transmitter will cause interference. Typically, to a registration signal sent during a DL sub-frame, the NACK will be sent by one or more SSs, while to a registration signal sent during UL sub-frame, the NACK signal will be sent by a Base Station.
  - o The NACK signal indicates that the requesting ad-hoc device cannot use the specific sub-frame, while using the requesting radio signature
  - o Same device may try again, if using a different radio signature (for example, lower power).

- Lack of response indicates that the registration is accepted for transmission during the specific sub-frame.
- No regular data transmission should take place 20 ms from the start of AT4 (the maximum IEEE802.16 MAC frame duration).

15.4.4.1.3 Selection of suitable reception sub-frames

An ad-hoc unit will identify suitable reception sub-frames, by using the ACS and Registration process in a repetitive way, searching for a suitable operation frequency. The practical interference situations, with synchronized MAC Frames are BS-SS and SS-BS interference. Assuming similar transmit powers, the above mentioned process will have as result finding Master sub-frames in which the path attenuation between interfering units is maximized.

15.4.4.1.4 Signaling procedures using frequency-keyed energy pulses

The signaling and message exchange between an ad-hoc system and systems which are members of a Community use frequency-keyed pulses. The frequency-keyed energy pulses use for every single sub-channel the preambles defined for subchannelization in the chapter 8.3.3.5.3. Every energy bin is mapped to a OFDM sub-channel (see Table 211-OFDM symbols parameters), as shown in the Table h 6. The channels using sub-carriers at band edge or in the center are avoided.

The following figures show the desired spectral density for radio signaling. Independent of the actual channel width, the preambles are sent using the narrowest channel possible in the band. In the following example, in which channels of 5, 10 and 20MHz may be used, the narrowest channel is 5MHz and any other system will be able to detect the preambles, which are not attenuated by any radio filter.The narrowest channel will be centered in the frequency domain around the actually used channel center.

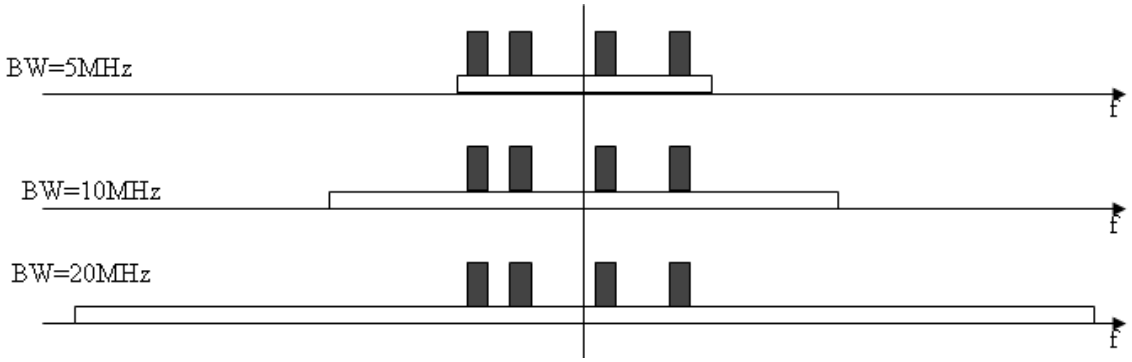


Figure h40—Desired spectral densities for different channel BWs

In Table h 6 the radio signal is defined to minimize the inter-correlation properties.

Table h6—Radio signal definition

Bin number /Signal number	6	8	10	12	14	18	20	22	24	26
Sub-channel number (1..31)	7	9	11	13	15	17	25	27	29	31
1 (Header)	H	L	L	H	H	L	L	L	H	L

2 (Tx_start)	L	H	L	L	H	H	L	L	L	H
3 (Rx_start or Rx_slot)	H	L	H	L	L	H	H	L	L	L
4 (Tx_end)	L	H	L	H	L	L	H	H	L	L
5 (Rx_end)	L	L	H	L	H	L	L	H	H	L
6 (NACK)	L	L	L	H	L	H	L	L	H	H
7 (CSI_Start)	H	L	L	L	H	L	H	L	L	H
8 (CSI_Continuation)	L	H	H	L	L	H	L	H	L	L
9	L	L	H	H	L	L	H	L	H	L

15.4.4.1.5 Using the coexistence slot for transmitting the BS IP identifier

The radio signaling described in section 15.4.4.1.4 may be also used for the transmission of the BS_NURBC message (see 15.5.6.2.1), when there is no active Base Station Identification Server.

The transmission is done in consecutive coexistence time slots, spaced apart by Tiptx seconds. The first CSI in the series starts with CSI start signal, while the CSI in the series contains the Tx_end signal, the continuation in sequential CSI slots starts with the CSI_Continuation, as defined Table h 6. Between these signals is transmitted the IP identifier of the BS and a 8bit CRC, the L.S.B (least significant bit) for each field being transmitted first. The transmission of the above information uses only the preambles for the sub-channels 6,8,10,12,14,18,20,22,24,26 (10bits / symbol), the L.S.B. corresponding to the lowest sub-channel number.

The transmission of an IPV4 address will require 1+ (32+8)/10 + 1 = 6 symbols and the transmission of an IPv6 address will require 1+ceil((128+8)/10) +1 = 16 symbols.

15.4.4.1.6 Coexistence with non-IEEE 802.16 systems

In continuation we provide a review of the main mechanisms that can be used for providing better spectrum sharing with non-IEEE802.16 systems, other than those considered as "preferred spectrum users".

The Candidate Channel Selection, presented as useful for the detection of the co-channel interference, can be used in a much larger scale for interference determination. A slot is reserved for non-IEEE802.16 systems, which may, in the future, to signal their presence in a controlled mode to IEEE802.16 systems.

The Signaling to Ad-hoc Systems, by using a simple, well-known PHY transmission, with increased power on the used sub-carriers, provide a better level of penetration. These transmissions may be detected in the future by non-IEEE802.16 systems, and used by them for choosing an optimal operation channel and to further isolate the interference in time domain.

For non-IEEE802.16 systems, these mechanisms are complementary: the first will allow to non-IEEE802.16 systems to signal their presence to IEEE802.16 systems, while the second will permit to non-IEEE802.16 systems to:

— Detect the potential interference to be caused by IEEE802.16 systems in both frequency and time domain

— Select the operating channels and time intervals, such that will avoid to interfere with IEEE802.16 systems.

15.4.4.2 Recognition of other systems

15.5 Transmission of information

15.5.1 Sequencing and Retransmission

The CP is a request-response protocol. In any particular message exchange, one party acts as the initiator (sends a request) and the other party acts as the responder (sends a response message).

The initiator sets the Message ID in the header to any value in the first message of the CP association, and increases the Message ID by one for each new request using serial number arithmetic. Retransmissions do not increment the Message ID. The responder sets the message ID in the response to the value of the message ID in the request.

The initiator is always responsible for retransmissions. The responder only retransmits a response on seeing a retransmitted request; it does not otherwise process the retransmitted request.

The retransmitted requests/responses are exact duplicates of previous requests/responses. The initiator must not send a new request until it receives a response to the previous one. Packets with out-of-sequence Message IDs are considered invalid packets and are discarded.

The initiator must retransmit after a configurable interval until either it gets a valid response, or decides after a configurable number of attempts that the CP association has failed. (Since the retransmission algorithm is implementation-dependent, it is not defined here.)

15.5.2 Coexistence Protocol (CP) messages (CP-REQ/ CP-RSP)

The Coexistence Protocol employs two MAC message types: CP Request (CP-REQ) and CP Response (CP-RSP), as described in Table h 7.

Table h7—CP MAC messages

Type Value	Message name	Message description
0	CP-REQ	Coexistence Resolution and Negotiation Request
1	CP-RSP	Coexistence Resolution and Negotiation Response

These MAC management messages are exchanged between peers, e.g. BS and BSIS or BS and BS or BS and SS., and distinguish between CP requests (BS -> BS/BSIS/SS or SS-> BS) and CP responses (BS/BSIS/SS -> BS or SS->BS). Each message encapsulates one CP message in the Management Message Payload. Coexistence Protocol messages exchanged between the BS and BS or between BS and BSIS or between BS and SS shall use the form shown in Table h 8.

Table h8—CP message format

Syntax	Size	Notes
CP _Message_Format() {		
Version of protocol in use	*4* bits	1 for current version
Code	8 bits	See Table h 9

Management Message Type	16bits	0-CP-REQ 1-CP-RSP
Length of Payload	*16*bits	
Confirmation Code	8 bits	0-OK/success 1-Reject-other 2-Reject-unrecognized-configuration-set-ting 3-Reject-unknow-action 4-Reject-authentication-failure 5-255 Reserved
Alignment	4 bits	
AssociationID	*??*bits	
CP Message Seq_ID	8 bits	
TLV Encoded Attributes	variable	TLV specific
}		

A detailed description of the parameters is the following:

Version of protocol in use

This standard specification of the protocol is version 1.

Code

The Code is one byte and identifies the type of CP packet. When a packet is received with an invalid Code, it shall be silently discarded. The code values are defined in Table h 9.

Length of payload

The length of payload in bytes .

CP Message Sequence Identifier (CP Message Seq_ID)

The CP Message Sequence Identifier field is one byte. A BS/BSIS uses the identifier to match a BS/BSIS response to the BS's requests. The BS shall increment (modulo 256) the Identifier field whenever it issues a new CP message. The retransmission mechanism relies on TCP. The Identifier field in a BS/BSIS's CP-RSP message shall match the Identifier field of the CP-REQ message the BS/BSIS is responding to.

Association identifier(Association ID)

The Association ID is used to uniquely identify a CP connection between an initiator and responder.

It is a parameter used to uniquely assign or relate a response to a request. The association identifier used on the responder and initiator MUST be a random number greater than zero to protect against blind attacks and delayed packets.

When the initiator sends subsequent messages, it uses the responder's association identifier in the Association ID field; when the responder sends a message it uses the initiator's association identifier in the Association ID field.

Confirmation Code

The Confirmation Code is the appropriate CC for the entire corresponding CP-RSP.

Attributes

CP attributes carry the specific authentication, coexistence resolution, and coexistence negotiation data exchanged between peers. Each CP packet type has its own set of required and optional attributes. Unless explicitly stated, there are no requirements on the ordering of attributes within a CP message. The end of the list of attributes is indicated by the LEN field in the MAC PDU header.

Table h9—CP message codes

Code	CP Message Name	CP Message Type	Protocol type	Direction
0	Reserved	—	—	—
1	Identify Coexistence Request	CP-REQ	TCP	BSIS->BSIS
2	Identify Coexistence Response	CP-RSP	TCP	BSIS->BSIS
3	CoNBR Topology Request	CP-REQ	TCP	BS-> BSIS
4	CoNBR Topology Reply	CP-RSP	TCP	BSIS->BS
5	Registration Request	CP-REQ	TCP	BS-> BSIS
6	Registration Reply	CP-RSP	TCP	BSIS->BS
7	Registration Update Request	CP-REQ	TCP	BS-> BSIS
8	Registration Update Reply	CP-RSP	TCP	BSIS->BS
9	De-registration Request	CP-REQ	TCP	BS-> BSIS
10	De-registration Reply	CP-RSP	TCP	BSIS->BS
11	Add Coexistence Neighbor Request	CP-REQ	TCP	BS->BS
12	Add Coexistence Neighbor Reply	CP-RSP	TCP	BS->BS
13	Update Coexistence Neighbor Request	CP-REQ	TCP	BS->BS
14	Update Coexistence Neighbor Reply	CP-RSP	TCP	BS->BS
15	Delete Coexistence Neighbor Request	CP-REQ	TCP	BS->BS
16	Delete Coexistence Neighbor Reply	CP-RSP	TCP	BS->BS
17	Get_Param_Request	CP-REQ	UDP	BS->BS
18	Get_Param_Reply	CP-RSP	UDP	BS->BS
19	Evaluate_Interference_Request	CP-REQ	UDP	BS->BS
20	Evaluate_Interference_Reply	CP-RSP	UDP	BS->BS
21	Work_In_Parallel_Request	CP-REQ	UDP	BS->BS
22	Work_In_Parallel_Reply	CP-RSP	UDP	BS->BS
23	Quit_Sub_Frame_Request	CP-REQ	UDP	BS->BS
24	Quit_Sub_Frame_Reply	CP-RSP	UDP	BS->BS
25	Create_New_Sub_Frame_Request	CP-REQ	UDP	BS->BS(MC?)
26	Create_New_Sub_Frame_Reply	CP-RSP	UDP	BS->BS
27	Reduce_Power_Request	CP-REQ	UDP	BS->BS
28	Reduce_Power_Reply	CP-RSP	UDP	BS->BS
29	Stop_Operating_Request	CP-REQ	UDP	BS->BS
30	Stop_Operating_Reply	CP-RSP	UDP	BS->BS
31	SS_CCID_IND	CP-REQ	UDP	BS->BS
32	SS_CCID_RSP	CP-RSP	UDP	BS->BS
33	PSD_REQ	CP-REQ	UDP	BS->BS
34	PSD_RSP	CP-RSP	UDP	BS->BS
35	Channel Switch Negotiation Request	CP-REQ	TCP	BS->BS
36	Channel Switch Negotiation Reply	CP-RSP	TCP	BS->BS
37	Channel Switch Request	CP-REQ	TCP	BS->BS

38	Channel Switch Reply	CP-RSP	TCP	BS->BS
39-255	reserved			

Formats for each of the CP messages are described in the following subclauses. The descriptions list the CP attributes contained within each CP message type. The attributes themselves are described in each message. Unknown attributes shall be ignored on receipt and skipped over while scanning for recognized attributes. The BS/BSIS shall silently discard all requests that do not contain ALL required attributes. The BS shall silently discard all responses that do not contain ALL required attributes.

[Note: The following security part is a temporary text adopted from contribution C802.16h-05/11r1 and is subject to further discussion. A call for comment from security experts is open to comment on this text.]

The following Type-Length-Value (TLV) types may be present in the CP payload depending on the Message_Type:

Table h10—TLV types for CP payload

Type	Parameter Description
tbc	Operator ID
tbc	BS-ID
tbc	BS GPS coordinates
tbc	BS IP Address
tbc	MAC Frame duration
tbc	Type of sub-frame allocation
tbc	MAC Frame number chosen for the Master sub-frame
tbc	Sub-frame number chosen for the Master sub-frame
tbc	Repetition interval between two Master sub-frames, measured in MAC-frames
tbc	Time shift from the Master sub-frame start of the Base Station radio-signature transmission
tbc	Duration information for the Base Station radio-signature transmission
tbc	Repetition information for the Base Station radio-signature transmission
tbc	Time shift from the Master sub-frame start of the Subscriber Station radio-signature transmission
tbc	Duration information for the Subscriber Station radio-signature transmission
tbc	Repetition information for the Subscriber Station radio-signature transmission
tbc	List of other used sub-frames, in the interval between two Master sub-frames
tbc	Slot position
Tbc	Country Code
Tbc	Operator contact - phone
Tbc	Operator contact – E-mail
Tbc	PHY mode
Tbc	Maximum coverage at Max. power
Tbc	Current Tx power

15.5.2.1 Identify Coexistence Request message

The BSIS requests to the foreign BSIS with geographical information of the requesting LE BS.

Code: 1

Attributes are show in Table h 11

Table h11—Identify Coexistence Request message attribute

Attribute	Contents
Operator identifier	The operator ID of the BSIS.
Country code	The country code of the BSIS
Latitude	The latitude information of the BS.
Longitude	The longitude information of the BS.
Altitude	The altitude information of the BS.
Maximum coverage at Max. power	The maximum radius at maximum allowed/designed power that the BS intends to detect its coexistence neighbors.

15.5.2.2 Identify Coexistence Reply message

The BSIS responds to the foreign BSIS to Identify Coexistence Request with a Identify Coexistence Reply message.

Code: 2

The query results is in the format of Coexistence Neighbor Topology Parameter Set, each result will contain the attributes shown in Table h 12. Each BSID TLV indicates start of new result.

Table h12—Coexistence neighbor Topology Parameter Set

Attribute	Contents
BSID	The BSID of the requested BS.
Operator identifier	The operator ID.
Operator contact - phone	The phone number in ASCII string of the operator.
Operator contact – E-mail	The E-mail address in ASCII string of the operator.
Country code	The country code of the BS
PHY mode	The PHY modes of the requested BS.
Latitude	The latitude information of the BS.
Longitude	The longitude information of the BS.
Altitude	The altitude information of the BS.
Maximum coverage at Max. power	The maximum radius at maximum allowed/designed power that the BS intends to detect its coexistence neighbors.

15.5.2.3 Coexistence Neighbor Topology Request message

This message is sent by the BS to the BSIS to request its coexistence neighbor topology with its geometric information.

Code: 3

Attributes are shown in Table h 13.

Table h13—Coexistence Neighbor Topology Request message attribute

Attribute	Contents
Latitude	The latitude information of the BS.
Longitude	The longitude information of the BS.
Altitude	The altitude information of the BS.

Maximum Coverage at Max. power	The maximum radius at maximum power that the BS intends to detect its coexistence neighbors.

15.5.2.4 Coexistence neighbor Topology Reply message

The BSIS responds to the BS' to Coexistence neighbor Topology Request with a Coexistence neighbor Topology Reply message.

Code: 4

Specification of the query results of coexistence neighbor topology from BSIS specific parameters.

The query results is in the format of Coexistence Neighbor Topology Parameter Set, each result will contain the attributes shown in Table h 14. Each BSID TLV indicates start of new result.

Table h14—Coexistence neighbor Topology Parameter Set

Attribute	Contents
BSID	The BSID of the requested BS.
Operator identifier	The operator ID.
Operator contact - phone	The phone number in ASCII string of the operator.
Operator contact – E-mail	The E-mail address in ASCII string of the operator.
Country code	The country code of the BS
PHY mode	The PHY modes of the requested BS.
Latitude	The latitude information of the BS.
Longitude	The longitude information of the BS.
Altitude	The altitude information of the BS.
Maximum coverage at Max. power	The maximum radius at maximum allowed/designed power that the BS intends to detect its coexistence neighbors.

15.5.2.5 Registration Request message

This message is sent by the BS to the regional LE DB to perform the registration.

Code: 5

Attributes are shown in Table h 15.

Table h15—Registration Request message attributes

Attribute	Contents
BSID	The BSID of the requested BS.
Contact IP address	The IP address of BS or Coexistence Proxy
Operator identifier	The operator ID.
PHY mode	The PHY modes of the requested BS. Containing Modulation mode, working channel ID, alternative Channel Flag etc.
<optional>:Operator contact - phone	The phone number in ASCII string of the operator.
<optional>:Operator contact – E-mail	The E-mail address in ASCII string of the operator.
<optional>:Country code	The country code of the BS
<optional>:Latitude	The latitude information of the BS.

<optional>:Longitude	The longitude information of the BS.
<optional>:Altitude	The altitude information of the BS.
<optional>:Operational Range at Max. Power	The maximum operational radius of the BS at Max. power.

15.5.2.6 Registration Reply message

The BSIS responds to the BS' to Registration Request with a Registration Reply message.

Code: 6

No Attributes.

15.5.2.7 Registration Update Request message

This message is sent by the BS to the regional LE DB to update the registration.

Code:7

Attributes are shown in Table h 15.

15.5.2.8 Registration Update Reply message

The BSIS responds to the BS' to Registration update Request with a Registration update Reply message.

Code: 8

No Attributes.

15.5.2.9 De-registration Request message

This message is sent by the BS to the BSIS to perform de-registration.

Code: 9

Attributes are shown in Table h 16.

Table h16—De-registration Request message attributes

Attribute	Contents
BSID	The BSID of the request BS.

15.5.2.10 De-registration Reply message

The BSIS responds to the BS' to De-registration Request with a De-registration Reply message.

Code: 10

No Attributes.

15.5.2.11 Add Coexistence Neighbor Request message

This message is sent by the BS to the coexistence neighbor BS to request to add it to coexistence neighbor list.

Code: 11

Attributes are shown in Table h 17.

Table h17—Add Coexistence Neighbor Request message attributes

Attribute	Contents
BSID	The BSID of the requested BS.
Contact IP address	The IP address of the requested BS or Coexistence Proxy of the requested BS.
Operator identifier	The operator ID.
PHY mode	The PHY modes of the requested BS. Containing Modulation mode, working channel ID, alternative Channel Flag etc.
<optional>:Country code	The country code of the requested BS.
<optional>:Latitude	The latitude information of the BS.
<optional>:Longitude	The longitude information of the BS.
<optional>:Altitude	The altitude information of the BS.
<optional>:Current Tx power	Current Tx power of the BS.
<optional>:Operational Range	The operational radius of the BS.
<optional>:PHY specific parameters	The PHY specific encodings.

15.5.2.12 Add Coexistence Neighbor Reply message

The BSIS responds to the BS' to Add Coexistence Neighbor Request with an Add Coexistence Neighbor Reply message.

Code: 12

No Attributes.

15.5.2.13 Update Coexistence Neighbor Request message

This message is sent by the BS to the coexistence neighbor BS to request to update its neighbor list.

Code: 13

Attributes are shown in Table h 18.

Table h18—Update Coexistence Neighbor Request message attributes

Attribute	Contents
BSID	The BSID of the requested BS.
PHY mode	The PHY modes of the requested BS.
Latitude	The latitude information of the BS.
Longitude	The longitude information of the BS.
Altitude	The altitude information of the BS.
Operational Range	The operational radius of the BS.
PHY specific parameters	The PHY specific parameters.

15.5.2.14 Update Coexistence Neighbor Reply message

The BSIS responds to the BS' to Update Coexistence Neighbor Request with an Update Coexistence Coexistence neighbor Reply message.

Code: 14

No Attributes.

15.5.2.15 Delete Coexistence Neighbor Request message

This message is sent by the BS to the coexistence neighbor BS to request to delete form its coexistence neighbor list.

Code: 15

Attributes are shown in Table h 19.

Table h19—Delete Coexistence Neighbor Request message attrubutes

Attribute	Contents
BSID	The BSID of the requested BS.

15.5.2.16 Delete Coexistence Neighbor Reply message

The BSIS responds to the BS' to Delete Coexistence Neighbor Request with a Delete Coexistence Neighbor Reply message.

Code: 16

No Attributes.

15.5.2.17 Get_Param_Request message

Messages between BSs, used to request the list of parameters

Code:17

Parameters: list of the BS parameters

15.5.2.18 Get_Param_Reply message

Messages between BSs, reply to the Get_Param_Request

Code:18

Parameters: list of the BS parameters

15.5.2.19 Evaluate_Interference_Request message

A message sent by a new BS wishing to use an existing Master sub-frame, to the BSs already acting as Masters, requesting them to evaluate its interference

Code:19

Parameters: tbc.

15.5.2.20 Evaluate_Interference_Reply message

A message sent by the existing Master BSs, reply to the Evaluate_Interference_Request.

Code:20

Parameters: tbc.

15.5.2.21 Work_In_Parallel_Request message

A message sent by a new BS to request the use an existing Master sub-frame

Code: 21

Parameters: tbc.

15.5.2.22 Work_In_Parallel_Reply message

A message sent by a existing Master BS in response to the Work_In_Paraller_Request message.

Code: 22

Parameters: tbc.

15.5.2.23 Quit_Sub_Frame_Request message

A message sent by an old Base Station, in order to request the new Base Station to cease the operation as Master in the current sub-frame

Code:23

Parameters: tbc.

15.5.2.24 Quit_Sub_Frame_Reply message

A message sent by an new Base Station, in response to the old Base Station's Quit_Sub_Frame_Request message.

Code:24

Parameters: tbc.

15.5.2.25 Create_New_Sub_Frame_Request message

A message sent by a BSs to all the community BSs, to request the creation of a new Master sub-frame; the message will include: interfering BSIDs and the frame-number in which the change will take place

Code:25

Parameters: tbc.

15.5.2.26 Create_New_Sub_Frame_Request message

A message sent in response to the Create_New_Sub_Frame_Request message.

Code:26

Parameters: tbc.

15.5.2.27 Reduce_Power_Request message

A message between a BS and an interfering BS requesting to reduce the power of the specified transmitter (identified by frame_number, sub-frame, time-shift) by P dB

Code: 27

Parameters: tbc.

15.5.2.28 Reduce_Power_Reply message

A message by an interfering BS in response to the Reduce_Power_Reply message.

Code: 28

Parameters: tbc.

15.5.2.29 Stop_Operating_Request message

A message sent by a Master BS to the BSs operating in its Master sub-frame, but not being Masters for this sub-frame, requesting to cease using this sub-frame in parallel

Code: 29

Parameters: tbc.

15.5.2.30 Stop_Operating_Reply message

A message sent by the BSs operating in its Master sub-frame,in response to the Stop_Operating_Request message.

Code: 30

Parameters: tbc.

15.5.2.31 SS_CCID_IND message

A message sent by SSs to indicate co-channel interference detected.

Code: 31

This is a message sent by an interfered-with BS to the master BS or its peer BS when co-channel interference due to an interfering SS is detected. This message shall contain the following information to determine the source of the co-channel interference and its RF emission characteristics. This information is extracted from the SSURF messages sent by the interfering SS.

— **SS_ID**:The interfering subscriber station identity , as derived from the SSURF.

— **BS_ID _Source**: The identity of the base station associated with the interfering SS, as derived from the interfering SSURF

— **EIRP**: EIRP of the interfering base station, as derived from the interfering SSURF.

— **M_RSSI**: Mean RSSI of the interfering SSURF.

— **Base Station RF Antenna Sector ID**: Antenna sector ID of interfering BS system associated with the interfering SS.

— **BS_ID_Victim**: Identity of interfered-with Base Station.

— **CMI_ID**: The Coexistence Messaging Interval during which the interference was received.

— **INT_SSURF_Frq**: The frequency of interference SSURF events detected per CMI cycles (calculated as the number of detected SSURF interference events per N full CMI cycles [1 cycle= 1 min TBD]) . This value relates to the severity of the interference from the foreign SS

SS_CCID_IND TLV encoding are provided in the following table

Table h20—SS_CCID_IND TLV encoding

Name	Type (1 byte)	Type (1 byte)	Value (Variable length)	PHY scope
SS_ID	1	6	Foreign Interfering SS ID derived from SSURF	
BS_ID	2	6	Foreign Base Station ID detected at SS Derived from foreign SSURF	
EIRP	3	1	Nominal EIRP of interfering signal () or the per burst EIRP	
CMI_ID	4		Common messaging interval ID	
M_RSSI	5	2	Mean RSSI of detected and identity interference (SSURF)	
INT_SSURF_FRQ	6	2	frequency of interference SSURF events.	
Base station RF antenna sector ID	7	1	The RF antenna sector identifier for a base station. 1-255 for FDD only 0- reserved for TDD only	
BS_ID	8	6	ID of BS generating this message; the interfered-with BS ID	

None of above TLV in this message is repeatable.

15.5.2.32 SS_CCID_RSP message

A “set” message to SS.

Code: 32

This CP message is usually sent in response to a SS_CCID_IND to inform the interfered-with base station on the status of the interference resolution being undertaken at the foreign base station. Since there may be longer timed negotiations being undertaken as a consequence of the SS_CCID_IND message; this message may be used to indicate to the interfered-with BS a wait time. In most instances the message will indicate a resolution to the uplink interference , achieved by scheduling uplink transmissions from the foreign subscriber station.

— **RES**: Information to the inquiring base station (originating SS_CCID_IND) on the status of the resolution of identified interference. This could be a number of options: interference resolved (rescheduling of SS uplink traffic to non-interference zone); lowering EIRP or modulation of SS; unresolved (due to inability to find uplink rescheduling zones) etc.

— **CNTI_BS_TBD**: Pending scheduling changes, as part of CP {TBD}

The message shall have the following information:

SS_CCID_RSP TLV encoding are provided in the following table

Table h21—SS_CCID_RSP TLV encoding

Name	Type (1 byte)	Type (1 byte)	Value (Variable length)	PHY scope
BS_ID	1	6	Foreign Base Station ID detected at SS Derived from foreign SSURF	All
SS_ID	2	6	Foreign SS generating interference.	
EIRP	3		EIRP of Foreign BS	
RES	4	2	Resolution status pertaining to original SS_CCID_IND; Either resolved, pending, unresolved. {TBD}	
CNTI_BS_TBD	5	4	Pending CP scheduling changes directed to BS (TBD)	

None of above TLV in this message is repeatable.

15.5.2.33 PSD_REQ message

A"set" message to start PSD (power spectrum density) sampling

Code: 33

All co-channel interference that is created cannot necessarily be demodulated or decoded correctly, allowing the extraction of Tagged information from interference frames. Additionally, some users of license-exempt spectrum may not comply with any of the IEEE standards and be impossible to identify. In this event it is useful for a to be able to monitor the LE spectrum to determine available spectrum "white space" and determine sub-detection interference. "Snapshots" of spectrum space are useful to CR systems, especially when new base stations or terminals are installed and are searching for unoccupied spectrum.

This is a "set" message, it is requests a BS or SS to sample PSD (power spectrum density) data for next "get" message. Since sampling PSD data will take some time, depending on environment, nature of bursty users, the following "get" message shall wait long enough for BS/SS to complete the PSD data sampling.

There shall be only one scalar MIB object defined for this operation.

15.5.2.34 PSD_RSP message

A “get” message to get PSD (power spectrum density) data table.

Code: 34

This is a “get” response message, MIB objects shall be defined accordingly; it shall contain the following values for a complete PSD:

— Antenna Parameter List containing attributes of antenna undertaking PSD

— X-min, the lower bound of channel frequency (in kilohertz)

— X-max, the upper bound of channel frequency (in kilohertz)

— Resolution bandwidth

— Power spectrum density measurement

Resolution bandwidth is scalar, it is used together with X-max and X-min to determine how many PSD values are collected and contained in the STRUF_REP message (i.e.).

$$(X_{max} - X_{min}) / (resolutionBandwidth) + 1 \qquad (h2)$$

Upon reception of this message, CR_NMS will stamp the message based on the arrival time and translate the information into internal format and store it into database.

Here is an example of PSD display:

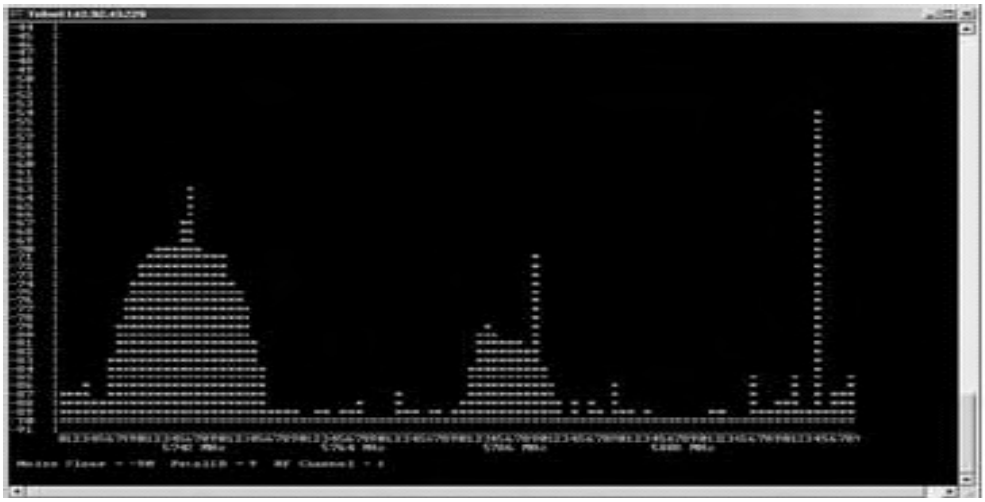


Figure h41—Example of PSD Display

15.5.2.35 Channel Switch Negotiation Request message

This message is send by BS to another coexistence BS in the community to negotiate to switch to a certain target channel.

Code: 35

Parameters: tbc.

15.5.2.36 Channel Switch Negotiation Reply message

A message sent by BS, reply to Channel Switch Negotiation Request message about whether it agree or refuse to switch.

Code: 36

Parameters: tbc.

15.5.2.37 Channel Switch Request message

This message is send by BS to another coexistence BS in the community to request to switch to an alternative channel.

Code:37

Parameters:

Table h22—Channel Switch Request message attributes

Attribute	Contents
Operator ID	The Operator identifier of requesting BS.
BSID	The requesting BS identifier
Requested BSID	BS identifier of the requested BS
Working Channel ID	The current working channel ID of the requested BS
Rolling back indication	0: to switch to one of the alternative channels 1: to switch back to the channel before the last channel switching request
FSN	Frame sequence number to switch channel

15.5.2.38 Channel Switch reply message

A message sent by BS, reply to Channel Switch Request message indicating the result of the channel switching.

Code: 38

Parameters:

Table h23—Channel Switch Reply message attributes

Attribute	Contents
Operator ID	The Operator identifier of requesting BS.
BSID	The requesting BS identifier
Requested BSID	BS identifier of the requested BS
Acknowledge	0: rejection for fail in switching 1: succeeded in switching

Target working channel ID (new working channel)	The channel ID of the requested BS will switch to
FSN	Frame sequence number of the channel switching

15.5.3 Message Validity Check

A message is only accepted if all the following holds true:

- Message version *field = 1*.
- Association ID must match a current association
- All messages received by peer have R bit in flag set to zero
- All responses received by authenticator have R bit in flag set to one.
- Message opCode is valid
- Message length equals size of payload
- Message ID must match the expected sequence number
- The payload contains only those TLVs expected given the value of the opCode
- *All TLVs within the payload are well-form*ed, TLVs marked as mandatory are recognized.

15.5.4 Fragmentation

CP does not provide support for fragmentation.

15.5.5 Transport Protocol

CP uses UDP as the transport protocol with port number[tbd.]. All messages are unicast.

15.5.6 Using dedicated messages

15.5.6.1 Common PHY

15.5.6.2 Between BS and SS

15.5.6.2.1 BS Neighborhood Update Request BroadCasting (BS_NURBC)

The BS_NCRBC message is broadcast by the initializing BS or the operating BS in order to update the neighbor list in the database. This message is sent from the BS to the SS in the coexistence neighbor systems. It uses the CSI frame to carry the IP address information of its coexistence proxy and the BSID from the BS to the SS, and the IP & BSID information shall be reported by the SS to its serving coexistence neighbor BS. The serving coexistence neighbor BS should communicate to the initializing BS in the IP network via the coexistence proxy, and proceed with further coexistence negotiation.

An *RTK (Random Temporary Key)* shall be randomly generated in the BS and broadcast using BS_BURBC. The neighbor BS which sends the CP request message needs to carry the RTK in the message. This will prevent the BS from being easily attacked by someone far away without any WirelessMAN-CX airlink capability which have know the static contact information. Table h 24 lists the TLV encoding for the BS_NURBC message.

Table h24—BS_NURBC message TLV encoding

Name	Type(1byte)	Length	Value (Variable length)
NURBC_V4	0	12	Bits 15:0 - RTK Bits 63:16 - BSID Bits 95:64 - BS IP address(IPv4)
NURBC_V6	1	24	Bits 15:0 - RTK Bits 63:16 - BSID Bits 191:64 - BS IP address(IPv6)

15.6 Common policies

15.6.1 How to select a “free” channel (for ACS and DFS)

IBS should listen for candidate frequencies during the selection of a working frequency. If the interference level is greater than the detection threshold, which is the required strength level of a received signal within the channel bandwidth, the channel is considered as an interfered channel.

Moreover, IBS should try to figure out whether it interfere with other systems in each of these candidate channels. By the feedback messages received after the signaling broadcasting, the IBS will collect the information of its interference victims on each channel.

If there is neither interference detected nor interference victims found in some channel by IBS, the channel is marked as "free" channel of IBS. Otherwise, the IBS should figure out whether an "free" channel can be vacated by optimized channel distribution, as described in 15.6.1.4.

Process of ACS is shown in Figure h 42. ACS results in two kinds of conclusion, "free" channel is validated with or without channel distribution optimization, or no "free" channel.

If a "free" channel is validated, it means default interference-free master slot is to be used, otherwise, IBS need to share the channel with coexistence neighbors, as described in 15.2.1.7.

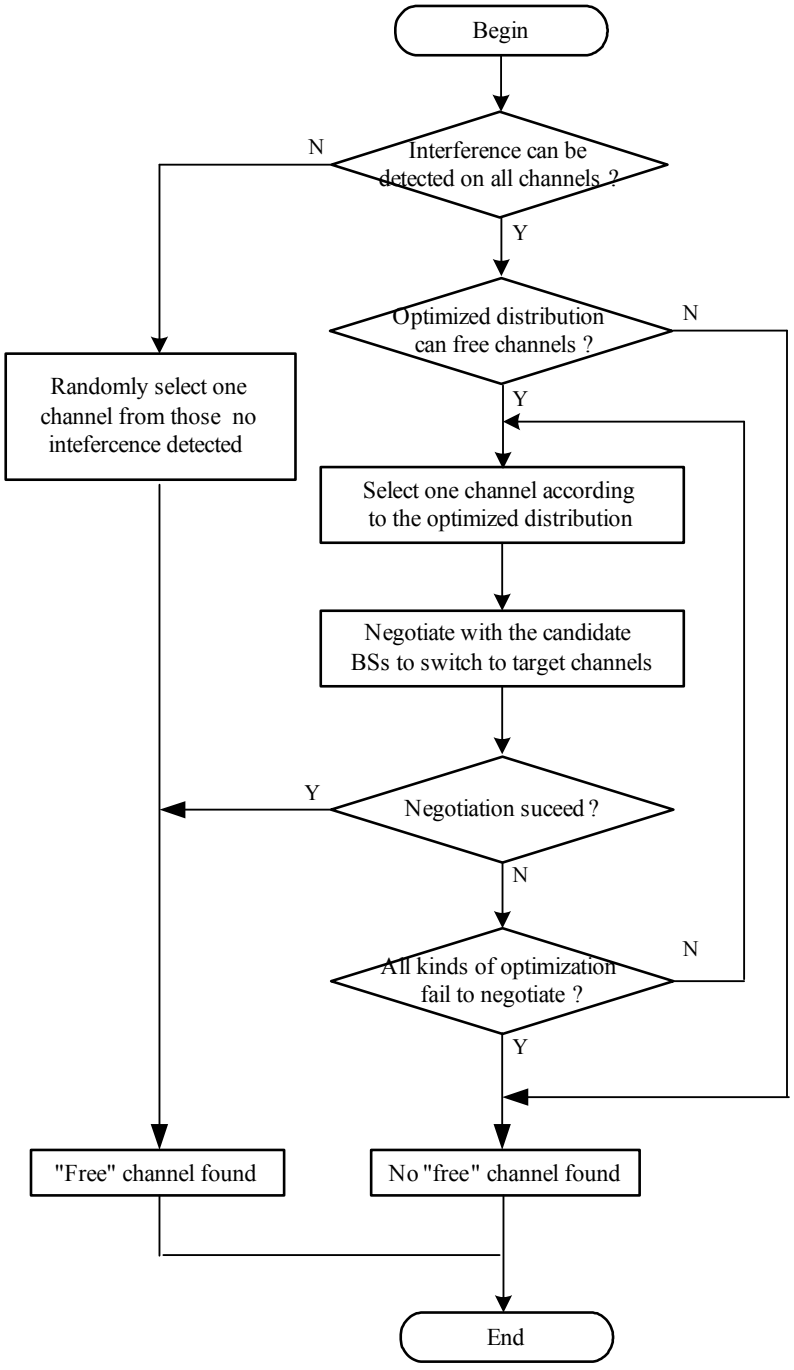


Figure h42—Process of ACS

15.6.1.1 Acceptable S/(N+I)

15.6.1.2 Acceptable time occupancy

15.6.1.3 Capability of sharing the spectrum

15.6.1.4 Optimization of Channel Distribution

In the initialization phase of an IBS, IBS's neighbors will send their current working channel ID, OCSI allocation and subframe allocation to the IBS using CP messages, as well as a flag of having alternative channels. The IBS maintains the channel information of all neighbors in BS information table.

When IBS cannot find any free channels at the initialization, IBS should try to optimize channel distribution to vacate a free channel for IBS by switching some neighbors' working channels to others.

First, the IBS picks up all the channels that all neighbors operating on it have got alternative channels, and sorts them according to the number of neighbor systems working on it.

Second, the IBS selects one of the channel used by the fewest BS, and considers this channel its potential working channel. The neighbors working on the selected channel are then negoeiated.

Third, to negotiate with every neighbor BS working on this channel, IBS should send channel switch request message. Neighbor OBS which have received this message should select one of its alternative channels as the their target working channel, and try to move its working channel to that channel as long as the request is valid. After the working channel switch to its alternative channel, the neighbor OBS should acknowledge to IBS by sending back a channel switch reply message with success indication, otherwise it should show rejection to IBS by sending back channel switch reply message with fail indication. If IBS received any rejection from the neighbors which IBS have sent the request, IBS should cancel the request by sending another message with the indication for the neighbors to back to the channel they used before the IBS's channel switching request.

Finally, when IBS receives from the neighbor OBS all positive acknowledged messages, it means the channel distribution optimization procedure has succeeded to vacate a channel for IBS. And IBS should use it as working channel afterwards. Otherwise, IBS should try to vacate the next potential channel.

If all the potential channels can not be vacated to become IBS's working channel, channel distribution optimization procedure is failed, and IBS shall try to share one channel with some of its neighbors.

With succeeding of the optimization procedure, list of alternative channels of relative BSs should be updated if their neighbors have changed their working channels. For IBS, it should broadcast to all its neighbors that it will working on the selected channel, and all its neighbors should add IBS as its new neighbor in BS information table, and exclude IBS's target working channel in the list of alternative channel. For the neighbor OBSs moved away from this channel, they also should notify their change to all their neighbors for the channel switching, so their neighbors can update the database according to the change.

The above process of channel selection optimization is shown in Figure h 43.

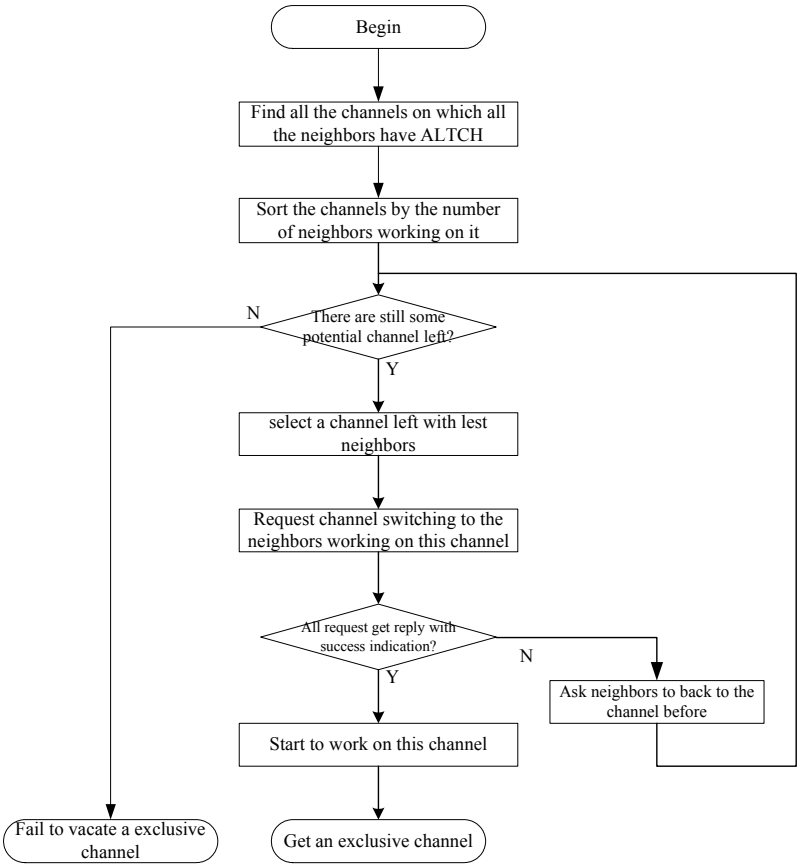


Figure h43—Process of channel distribution optimization

15.6.2 Interference reduction policies

15.6.2.1 BS synchronization

15.6.2.1.1 Synchronization of the WirelessMAN-CX Networks

All base stations forming a community of users sharing common radio spectrum will use a common clock to synchronize their MAC frames. The common clock will be available to all outdoor WirelessMAN-CX networks. Such a clock can be provided by global navigational systems such as GPS (Annex 2) or can be distributed by other mean . Every BS upon activation, will as a first step ensure the derivation of the common system clock.

15.6.2.1.1.1 Network Time Interval

All synchronized WirelessMAN-CX base stations will either synthesize or derive a 1 pps clock broadcast by a global navigational system or other means. The 1 sec duration is called the Network Time Interval (NTI). The rising edge of the 1 pps synchronization pulse will be considered as the start of the NTI. The 1pps pulse will have a stability of +/- 100 XX microseconds, as measured from rising edge to rising edge.

15.6.2.1.1.2 Granularity of the NTI

The NTI will be comprised of 1000 1 Millisecond slotsNTI_S unit that will be used by both TDD and FDD networks to negotiate times and durations of co-channel occupancy. Negotiation for access time to common spectrum will be specified in terms of the NTI_S unit 1 millisecond units. Occupancy times will be specified in terms of time from the beginning of the NTI and in terms of negotiated number of NTI_S unit1 millisecond intervals.

15.6.2.1.1.3 UTC Standard Time

The common clock specified in 15.7.2.1.1 will provide a Universal Coordinated Time (UTC) signal to all WirelessMAN-CX networks, making all networks synchronized to this referenced time stamp. WirelessMAN-CX base stations will use the UTC time standard for coordinating and identifying specific NTI intervals.

15.6.2.1.2 Ad-hoc

15.6.2.2 Shared Radio Resource Management

15.6.2.2.1 Fairness criteria

15.6.2.2.1.1 Power control

15.6.2.2.1.2 Mutual tolerance

15.6.2.2.2 Distributed scheduling

15.6.2.2.2.1 Assignments

15.6.2.2.3 Distributed power control

15.6.2.2.4 Distributed bandwidth control

15.6.2.2.5 Beam-forming

15.6.2.2.6 Credit token based coexistence protocol

Spectrum sharing between several networks (NW) can be achieved through the sharing of a common MAC frame between the different NWs as exampled by Figure h 44. In such a MAC frame structure, dedicated portions (denoted as “master NW sub-frames”) of the frame are periodically and exclusively allocated to a NW (denoted as the “master NW”) respectively in the forward and reverse link. The terminology used hereafter defines a slave NW as a NW that may operate during the other master NWs sub-frames. With respect to this definition, the slave NW sub-frames are the time intervals operating in parallel of the master NWs sub-frames.

Additional flexibility can be provided by such a frame structure if The length of each master sub-frame(interference free sub-frame) can be dynamically adjusted as a function of the spatial and temporal traffic load variations of each NWas stated in section 15.2.1.1.1.

To achieve this, this section proposes the dynamic coordination of the frame structure sharing between BSs when several master NWs compete to share this common shared MAC frame.

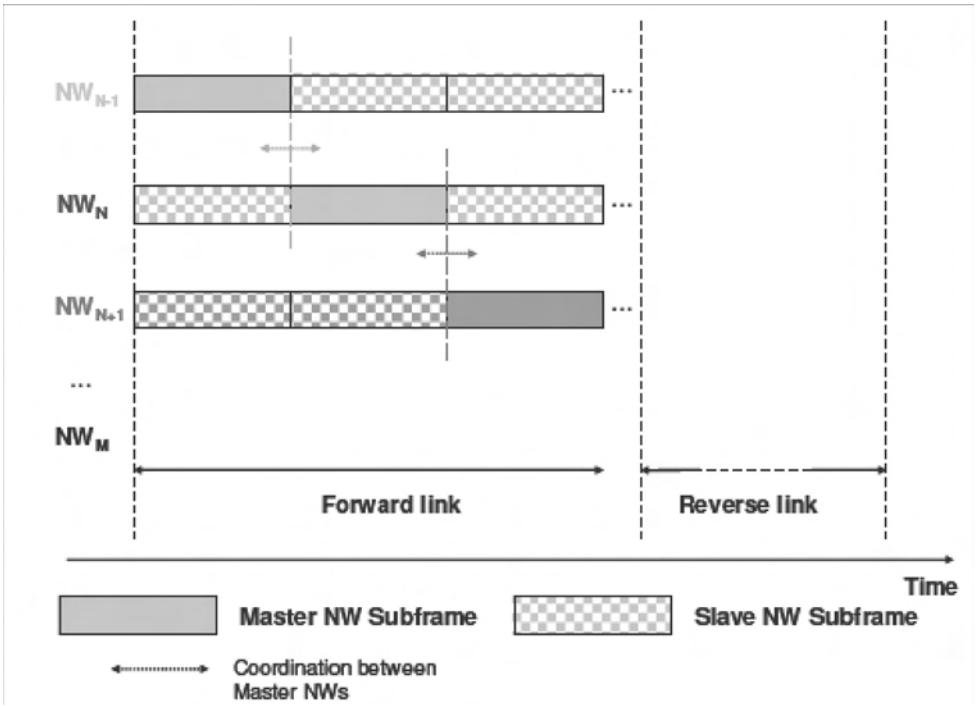


Figure h44—Example of TDD based MAC frame sharing structure between M NWs

15.6.2.2.6.1 General principle

In order to solve contention access channel and resources scheduling issues between NWs, the first step consists in defining credit tokens and designing appropriate reserve price auctioning and bidding mechanisms. Then, on the basis of the credit tokens based mechanisms usage, the second step consists in managing dynamically(temporally) the bandwidthrequests and grants mechanisms for the sharing of the master sub frames within the common MAC frame.

Based on the credit tokens transactions (selling, purchase and awarding), these two steps provide the mechanisms to enable spectrum efficiency and a fair spectrum usage in a real time fashion, while ensuring both the master and slave NWs QoS. These two steps enable to manage spectrum sharing between master NWs themselves. The result is the dynamic shaping of the MAC frame structure sharing as a function of the space

time traffic intensity variations, and the dynamic credit tokens portfolio account of the master NWs. The transaction mechanisms are detailed in the following sections.

15.6.2.2.6.2 Credit tokens assignment and usage principles

— Each NW is initially allocated with a given credit tokens account.

— Negotiation for spectrum sharing between NWs is based on credit tokens transactions.

— Credit tokens transactions occur dynamically between a seller (master NW owner of the radio resources during the active master sub-frame) and one or several bidders (the other master NWs).

— The negotiation occurs dynamically between master NWs to agree the length of each master sub-frame as a function of the spatial and temporal traffic load variations need of each master NW.

15.6.2.2.6.3 Negotiation between master NWs

15.6.2.2.6.3.1 Definition and notation

— BSN denotes the BS belonging to the master NWN.

— BSk denotes the BS belonging to the slave NWk.

— Each BSk can dynamically make a bid BS_CT(n)k at the nth iteration. This bid corresponds to the amount of credit tokens per time unit corresponding to the BSk during the nth iteration of the auctioning/bidding phase.

— Resource scheduling is carried out by an auction like mechanism. The auction type used for the scheduling is dynamic in time. Starting from the reserved price auction RPA, the price of auction is successfully raised (at each iteration n) until the winning bidders remain.

15.6.2.2.6.3.2 Dynamic credit tokens based scheduling cycle

The contribution proposes a dynamic scheduling cycle between one BSN of master NWN and several BSk of different slave NWk. For the sake of simplicity, the cycle is illustrated (Figure h 45 and Figure h 46) for one BSN and one BSk of a given slave NWk. The cycle is composed of different phases, and each phase can be composed of several sequences as follows.

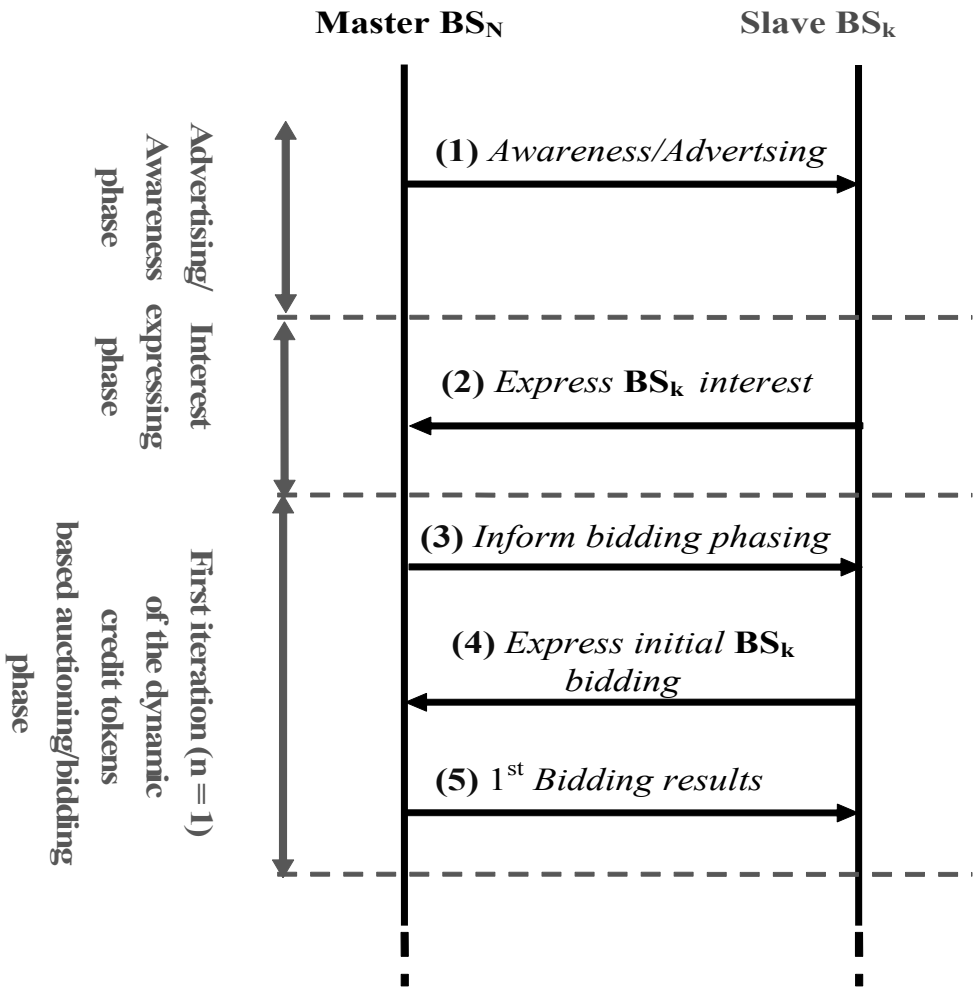


Figure h45—Dynamic (iterative) credit tokens based scheduling cycle – (sequences (1) to (5))

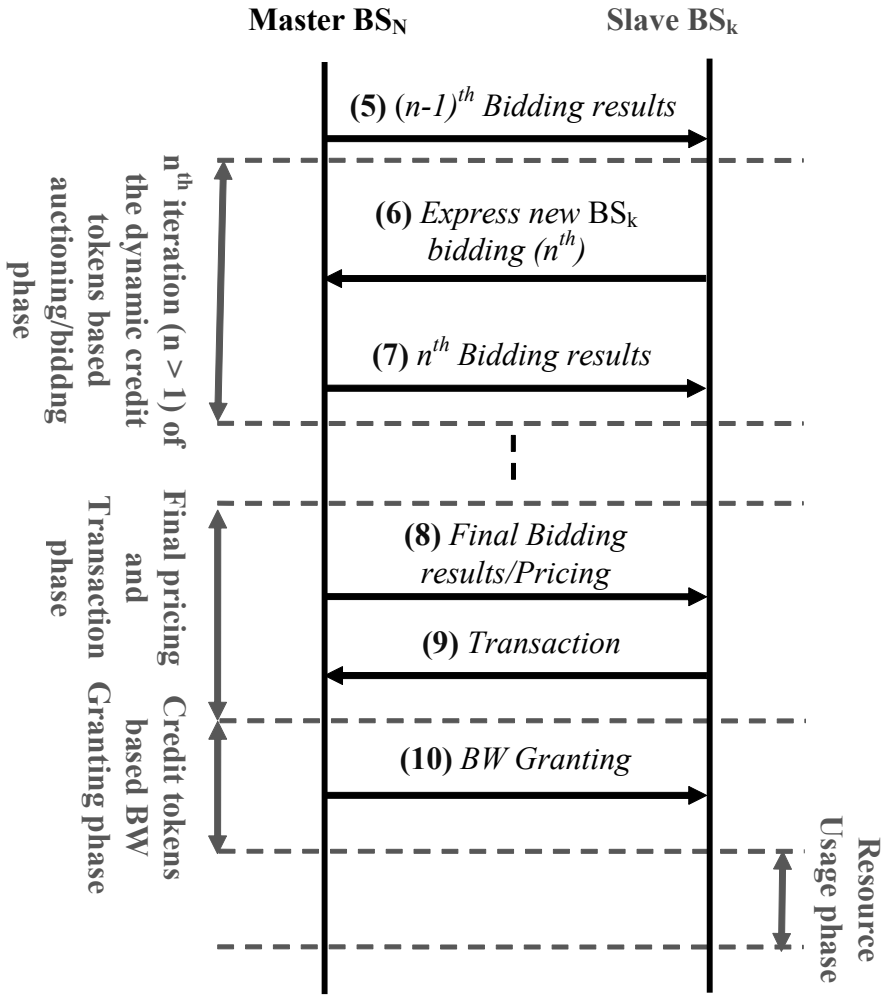


Figure h46—Dynamic (iterative) credit tokens based scheduling cycle – (sequences (5) to (10))

15.6.2.2.6.3.3 Negotiation mechanisms between master NWs

For each of the phase of the credit tokens based scheduling cycle presented in section 15.7.2.2.6.3.2, this section 15.7.2.2.6.3.3 describes the details of the enhanced mechanisms.

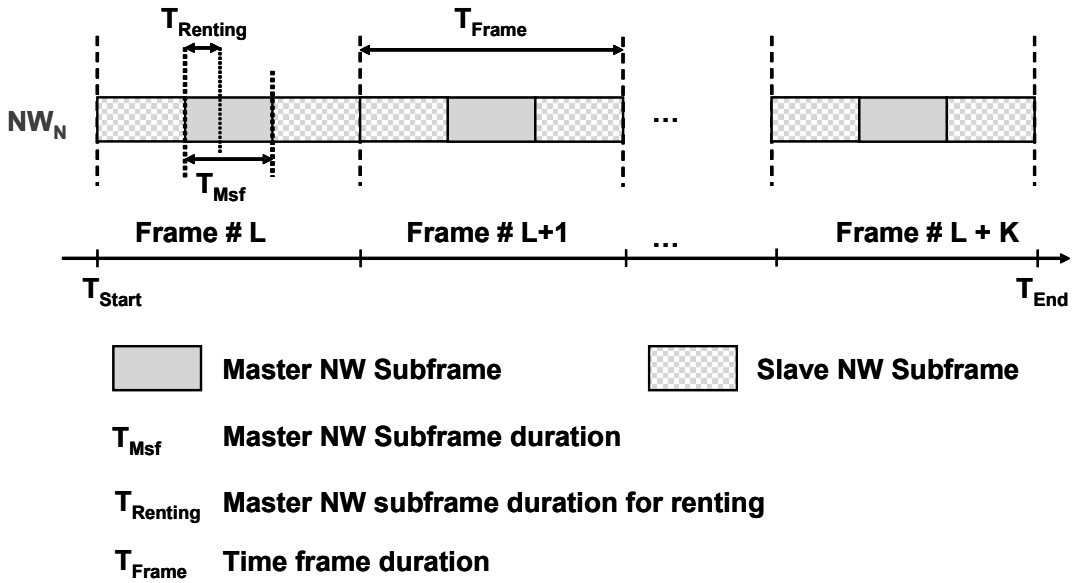


Figure h47—Simplified MAC frame structure illustrating master NW sub-frame renting principle and associated notations

Advertising/Awareness phase

This phase is composed of the single sequence (1) as follows:

— The master NW_N (seller) advertises that its periodic assigned master sub-frame is open for renting (Figure h 47) from starting time $\mathbf{T_{Start}}$ to ending time $\mathbf{T_{End}}$ for a fraction ($\mathbf{T_{Renting}}/\mathbf{T_{Msf}}$) of its master sub-frame duration $\mathbf{T_{Msf}}$. $\mathbf{T_{Renting}} = \mathbf{T_{End\ Renting}} - \mathbf{T_{Start\ Renting}}$.

— The master NW_N proposes a reserve price auction **RPA** for this renting. The **RPA** is expressed as a number of credit tokens per time unit.

Interest expressing phase

This phase is composed of the single sequence (2) as follows: each BSk informs the master BSN about its willingness (or not) to participate to the bidding. If the BSk is interested, it communicates its idk to the master BSN.

First iteration (n = 1) of the credit tokens based auctioning/bidding phase

This phase is divided into 3 sequences as follows:

— In sequence (3), the master BS_N provides the following information to the slave BS_ks that have expressed the interest to participate to the bidding:

  o $\mathbf{T_{Start\ Bidding}}$: time from which the bidding phase will start,

  o $\mathbf{T_{End\ Bidding}}$: time at which the bidding phase will end ($\mathbf{T_{End\ Bidding}} < \mathbf{T_{Start}}$),

  o Note: For this first iteration (n = 1), the initial $\{\mathbf{id_k}\}$ is noted $\{\mathbf{id^{(1)}_k}\}$.

— In sequence (4), each BS_k provides the following information to BS_N: $\mathbf{BID^{(1)}_k} = \{\mathbf{BS\_CT^{(1)}_k}, \mathbf{x_k}, \mathbf{T_{Start\ k}}, \mathbf{T_{End\ k}}\}$ where:

  - $\mathbf{BS\_CT^{(1)}_k}$ is the amount of bided credit tokens per time unit proposed by BS_k for the first iteration,
  - x_k is the fraction of $T_{Renting}$ for which bid $\mathbf{BS\_CT^{(1)}_k}$ applies for,
  - $[T_{Start\ k}, T_{End\ k}]$ is the time interval for which bid $\mathbf{BS\_CT^{(1)}_k}$ applies for. $[\mathbf{T_{Start\ k}}, \mathbf{T_{End\ k}}] \subset [\mathbf{T_{Start}}, \mathbf{T_{End}}]$.

— In sequence (5), BS_N performs the following action:

  - Given the set of intervals $\{[\mathbf{T_{Start\ k}}, \mathbf{T_{End\ k}}]\}$ received from different bidders $\{\mathbf{id^{(1)}_k}\}$, BS_N partitions $\{[\mathbf{T_{Start}}, \mathbf{T_{End}}]\}$ into contiguous time segments $\{\mathbf{TS_m}\}$. Each $\mathbf{TS_m}$ corresponds to a time window (integer number of $\mathbf{T_{Frame}}$) in which a subset of intervals of $\{[\mathbf{T_{Start\ k}}, \mathbf{T_{End\ k}}]\}$ overlap.
  - The different bidders $\{\mathbf{id^{(1)}_k}\}$ assigned to a given $\mathbf{TS_m}$ are identified by $\{\mathbf{id^{(1)}_{k,m}}\}$. $\{\mathbf{id^{(1)}_{k,m}}\}$ compete for each $\mathbf{TS_m}$. Each involved bidder $\mathbf{id^{(1)}_{k,m}}$ competes with his respective $\mathbf{BID^{(1)}_k}$.
  - Then, for each $\mathbf{TS_m}$, the master BS_N calculates the payoff $\mathbf{P^{(1)}_k} = \mathbf{BS\_CT^{(1)}_k} * \mathbf{x_k} * \mathbf{T_{Renting}} * \mathbf{N_{Frame\ m}}$ for each bidder k, and searches the subset $(\{\mathbf{id^{(1)}_{k,m}}\}_{selected})$ of $\{\mathbf{id^{(1)}_{k,m}}\}$ such as $sum(\mathbf{x_k}) = \mathbf{1}$ and $sum(\mathbf{P^{(1)}_k})$ is maximal. $\mathbf{N_{Frame\ m}}$ is the number of frames within $\mathbf{TS_m}$ ($\mathbf{N_{Frame\ m}} = \mathbf{TS_m}/\mathbf{T_{Frame}}$).
  - For each $\mathbf{TS_m}$, BS_N informs all $\{\mathbf{id^{(1)}_{k,m}}\}$ about $\mathbf{P^{min,\ (1)}_m}$ and $\mathbf{P^{max,\ (1)}_m}$ where $\mathbf{P^{min,\ (1)}_m}$ is the minimal payoff from $\{\mathbf{id^{(1)}_{k,m}}\}_{selected}$ and $\mathbf{P^{max,\ (1)}_m}$ is the maximal payoff from $\{\mathbf{id^{(1)}_{k,m}}\}_{selected}$ during the first iteration. With this approach, each BS_k is directly informed whether it has been selected or not, and has some information on how far it is from $\mathbf{P^{min,\ (1)}_m}$ while still having some information on $\mathbf{P^{max,\ (1)}_m}$. This approach enables to keep the privacy of competing $\{\mathbf{id^{(1)}_{k,m}}\}$ on $\mathbf{TS_m}$.

n^{th} iteration of the credit tokens based auctioning/bidding phase

This phase is composed of 2 sequences as follows:

— In sequence (6):

  - If $\mathbf{P^{(1)}_k} < \mathbf{P^{min,\ (1)}_m}$, this means that BS_k has not been selected for being granted the resources he has bided for during the first iteration n = 1. More generally speaking, for n>1, if $\mathbf{P^{(n-1)}_k} < \mathbf{P^{min,\ (n-1)}_m}$, this means that BS_k has not been selected for being granted the resources he has bided for during the $(n-1)^{th}$ iteration.
  - If $\mathbf{P^{(n-1)}_k} < \mathbf{P^{min,\ (n-1)}_m}$ and if BS_k is still interest to be allocated with the additional resources he initially requested for, it can propose a new $\mathbf{BS\_CT^{(n)}_k}$ for the n^{th} iteration. Then, BS_k computes the new $\mathbf{P^{(n)}_k} = \mathbf{BS\_CT^{(n)}_k} * \mathbf{x_k} * \mathbf{T_{Renting}} * \mathbf{N_{Frame\ m}}$ where $\mathbf{x_k}$,$\mathbf{T_{Renting}}$ and $\mathbf{N_{Frame\ m}}$ are fixed for all n on $\mathbf{TS_m}$.
  - If $\mathbf{P^{(n)}_k} > \mathbf{P^{(n-1)}_k}$ and $\mathbf{P^{(n)}_k} > \mathbf{P^{min,\ (n-1)}_m}$, BS_k expresses its interest to keep on participating in the bidding with the new bid $\mathbf{P^{(n)}_k}$. In that case, it informs BS_N with its new (update) value of $\mathbf{BS\_CT^{(n)}_k}$. In case $\mathbf{P^{(n)}_k} = \mathbf{P^{(n-1)}_k}$ or $\mathbf{P^{(n)}_k} < \mathbf{P^{min,\ (n-1)}_m}$, BS_k leaves the bidding phase and will not be granted with the additional resources he asked for.

— In sequence (7), BS_N updates $\{\mathbf{id^{(n-1)}_{k,m}}\}$ into $\{\mathbf{id^{(n)}_{k,m}}\}$. Based on the new received biddings $\{\mathbf{BS\_CT^{(n)}_k}\}$ for each $\mathbf{TS_m}$, the master BS_N calculates the new payoff $\mathbf{P^{(n)}_k} = \mathbf{BS\_CT^{(n)}_k} * \mathbf{x_k} * \mathbf{T_{Renting}} * \mathbf{N_{Frame\ m}}$ for each bidder k who still participates to the bidding. Then, for each $\mathbf{TS_m}$,

BS_N searches the subset ($\{\mathbf{id^{(n)}_{k,m}}\}_{selected}$) of $\{\mathbf{id^{(n)}_{k,m}}\}$ such as sum($\mathbf{x_k}$) = **1** and sum($\mathbf{P^{(n)}_k}$) is maximal. Next, BS_N performs the same actions as in sequence (5): for each $\mathbf{TS_m}$, BS_N informs all $\{\mathbf{id^{(n)}_{k,m}}\}$ about $\mathbf{P^{min,\,(n)}_{\ m}}$ and $\mathbf{P^{max,\,(n)}_{\ m}}$ where $\mathbf{P^{min,\,(n)}_{\ m}}$ is the minimal payoff from $\{\mathbf{id^{(n)}_{k,m}}\}_{selected}$ and $\mathbf{P^{max,\,(n)}_{\ m}}$ is the maximal payoff from $\{\mathbf{id^{(n)}_{k,m}}\}_{selected}$ during the n^{th} iteration.

Final pricing and credit tokens transaction phase

This phase is composed of two sequences as follows:

— In sequence (8):

  o As long as $\mathbf{T_{End\ Bidding} - T_{Start\ Bidding}} > 0$ (i.e. the bidding phase duration has not yet elapsed), n is increased and the credit tokens based bidding phase mechanisms of the previous paragraph "***n^{th} iteration of the credit tokens based auctioning/bidding phase***" are applied.

  o When $\mathbf{T_{End\ Bidding} - T_{Start\ Bidding}} = 0$, bidding phase is over. None BS_k can propose a new bid. $\{\mathbf{id^{(n\ final)}_{k,m}}\}_{selected}$ is derived. At this point, BS_N derives the clearing price auction $\mathbf{BS\_CPA_k}$ (expressed as a number of credit tokens per time unit) for each $\mathbf{TS_m}$ and each k from $\{\mathbf{id^{(n\ final)}_{k,m}}\}$. For each k and m, $\mathbf{BS\_CPA_k}$ can correspond to the $\mathbf{BS\_CT^{(final)}_k}$, or for example can follow another price auction method.

— In sequence (9), eack BS_k is requested to pay $\mathbf{Pr_k} = \mathbf{BS\_CPA_k} * \mathbf{x_k} * \mathbf{T_{Renting}} * \mathbf{N_{Frame\ m}}$ to be allowed to use the resources it won on its corresponding $\mathbf{TS_m}$. Provided that $\mathbf{Pr_k}$ does not exceed the credit tokens account of BS_k, the token transaction between BS_N and each BS_k is performed.

Credit tokens based bandwidth granting phase

This phase is composed of the single sequence (10). During this phase, BS_N grants the resource to each BS_k who has successfully performed the credit transaction operation in sequence (9).

Resource usage phase

After BS_k has been granted with the resources, BS_k can use them during during $\boldsymbol{x_k * T_{Renting}}$ time unit of NW_N and for $\mathbf{N_{Frame\ m}}$ frames from the beginning on its corresponding $\mathbf{TS_m}$.

15.6.2.2.6.4 Inter BSs communication

The credit tokens mechanisms (section 15.6.2.2.6.3) require inter BSs communication between different NWs. This inter BS communications is necessary to exchange the parameters related to the credit tokens based negotiation cycle.

The primitive parameters include: T_{Start}, T_{end}, $T_{End\_Renting}$, $T_{Start\_Renting}$, $T_{Msf,}$ MRCTN, id_k, $BS\_CT^{(n)}_k$, x_k,, T_{Start_k}, T_{End_k}.

The derived parameters include: TS_m, $\{id^{(n)}{}_{k,m}\}_{selected}$, $P^{min,\,(n)}{}_m$, $P^{max,\,(n)}{}_m$.

These parameters are stored into the regional LE DB and into the local database of each LE BS of the shared distributed system architecture (section 15.2.2).

The information exchange about these parameters between these databases and the RADIUS/BSIS servers is performed by IP based wired using the co-existence protocol (CP). Thisinter BS communication is supported by the inter system messages defined in the shared distributed system architecture (section 15.2.2).

The inter BS communications to support the signaling messages related to the awareness/advertisement sequence of the credit tokens based co-existence protocol can also be implemented by secured over the air mechanisms described in section 15.6.2.2.6.5.

15.6.2.2.6.5 Radio Resources Sharing Opportunities Advertisement Discovery

Over the air signaling for the first phase (advertisement) of the negotiation cycle would be also of great support to facilitate urgent (critical time) radio resources sharing opportunities discovery between IEEE WirelessMAN-CX systems themselves, but also between IEEE WirelessMAN-CX systems and non IEEE WirelessMAN-CX systems. This section describes signaling discovery procedures so that:

- Master BSs can advertise periodically to the neighbouring slave BSs about their offers of radio resources for renting. This enables the slave BSs to be aware of master BSs' offers.

- Slave BSs can inform periodically the surrounding cells about their search of radio resources sharing opportunities for renting. This enables slave BSs to inform the master BSs that they are looking for temporally some additional radio resources.

Specific master BS and slave BS downlink time intervals (TBD) are used to support the over the air advertisement discovery messages in support of the credit tokens based negotiation. These messages, not yet defined, are temporary called respectively MATI (Master Advertisement Time Interval) and SATI (Slave Advertisement Time Interval).

Usage of the advertisement discovery MAC frame structure

The usage of MATI and SATI is described in this paragraph.

- The MATIs are dedicated to master BS transmissions in downlink.

- Each MATI is used by a master BS in downlink for broadcasting. At a given time, each MATI can only be used by a single BS among the co-existence neighbourhood. However, a same MATI can be used by different BSs at different times.

- Each master BS can use any MATI provided it is not already used by any other MATI BS of the co-existence neighbourhood.

- MADD (Master Advertisement Discovery Descriptor) message is sent in MATI (Section 6.3.2.3.64).

- The MATIs are ranked in each *Advertisement discovery sequence* in such a way that the first MATI is assigned to the master BS whose renting period will occur first (i.e. min of the T_Start_M), the second MATI is assigned to the master BS whose renting period will occur in second, and so on. Re-ranking is updated dynamically each time a new master BS is arriving. This mechanism avoids the SSs of the slave cells (see paragraph "*Advertisement discovery from master cell by slave cell*" below) to scan all MATIs when the slave cells have to find very shortly some available resources to rent. In this manner, they have directly knowledge of the next available resources they can propose credit tokens for.

- Each master cell releases the MATI it is using when its negotiation starting time has elapsed. This enables new arriving master cells to use this MATI (eventually after the re-ranking) to advertise incoming channels reuse opportunities.

- The SATIs are dedicated to slave BS transmissions in downlink.

- Each SATI is used by a slave BS in downlink for broadcasting. Each SATI can only be used by a single BS among the co-existence neighbourhood. However, a same SATI can be used by different slave BSs at different times.

- Each slave BS can use any SATI provided it is not already used by any other slave BS of the co-existence neighbourhood.

SADD (Slave Advertisement Discovery Descriptor) message is sent in SATI (Section 6.3.2.3.65).

- A "master" SS is a SS belonging to a master cell. A "slave" SS is a SS belonging to a slave cell.

- The MATI and SATI time positions are known by the "master" and "slave" SSs.

- There are no direct RF communications between the master and slave BSs. The master-slave BS communications are performed via master and slave SSs which act as RF bridges to convey the information as follows:

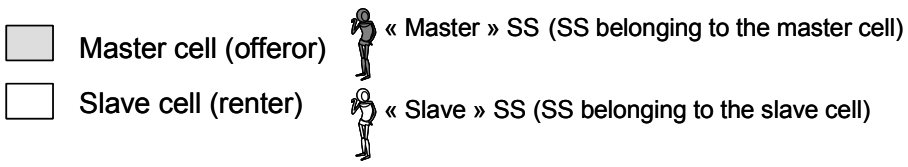
  o A "slave" SS performs the RF bridge between its slave BS and the master BS (provided the coverage of the master cell overlaps with the slave cell area, and this slave SS is located in the overlapping area).

  o A "master" SS performs the RF bridge between its master BS and the slave BS (provided the coverage of the slave cell overlaps with the master cell area, and this master SS is located in the overlapping area).

- Slave SSs in the overlapped (master/slave) cell area listen to the MATIs. Master SSs in the overlapped (master/slave) cell area listen to the SATIs.

15.6.2.2.6.5.1 Mechanisms enabling the discovery and the exploitation of the master cells originated advertisement discovery messages by the slave cells

This paragraph describes the mechanisms enabling the discovery and the exploitation of the master cells originated advertisement discovery messages by the slave cells. The terminology used in the following is:



These mechanisms are described by the different steps as illustrated in the following:

1- Policy instructions to the slave SSs by the slave BS

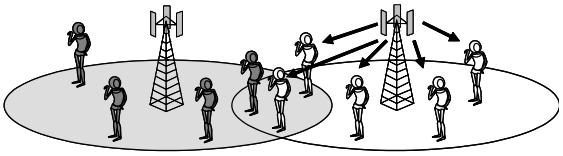


Figure h48—Policy instructions to the slave SSs by the slave BSs

- During this step, the slave BS initially instructs (by broadcasting) its SSs (in red) about the behaviours they have to adopt when some of these SSs get the messages from the different MATIs.

- The behaviour is instructed by the ADPD (Advertisement Discovery Policy Descriptor) message (section 6.3.2.3.66) specifies when some SSs (located in the overlapped area between this slave cell and surrounding master cells and getting MADD message from master BS) associated to this slave BS have to report the MADD information conveyed in MATI towards this slave BS.

- The slave SSs that can hear the MATIs and meeting the requirements sent in ADPD are the only SSs that are allowed to make the RF bridge between the master and slave cells. This means, the policy rules the transmissions from any slave SS towards the slave BS when these SSs are mandated to get feedback about the MATIs proposals. This mechanism avoids having incessant transmissions from the slave SSs towards the slave BS when the MATIs are not aligned with the slave BSs strategy. This saves bandwidth. Any policy can be established. Moreover, the policy can be adapted dynamically in time by the slave BS.

2- Detection and identification of the MATIs content by the slave SSs

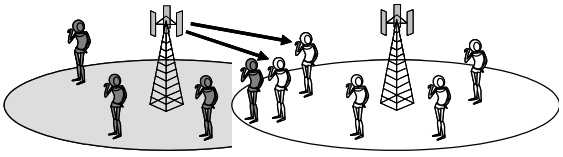


Figure h49—Detection and identification of the MATIs content by the slave SSs

- During this step, the slave SSs in the overlapping area between the master cell and their slave cell listen to the different MATIs sequentially. For each master cell, these slave SSs can get the information sent in the MADD message (Section 6.3.2.3.64).

- Provided the MADD message information received and the ADAP message received about the policy (section 6.3.2.3.66) established by the slave BS, the slave SS is able to decide whether it has to transmit this information to the slave BS or not.

3- Relaying of the MATIs content to the slave cell by the slave SSs

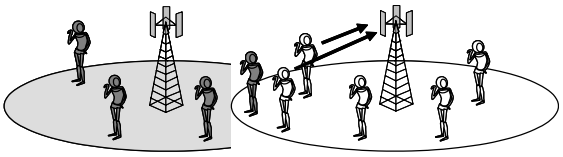


Figure h50—Relaying of the MATIs content to the slave cell by the slave SSs

- In case the policy requirements are met, the information collected by the slave SS is conveyed to the slave BS. The information the slave SS sends to its BS is the content of the MADD message.

- In order to ensure this information is appropriately received by the slave BS, the information is sent by several slave SSs (e.g. 2 slave SSs circulate this information to the slave BS in Figure h 50). This ensures both reliability and security check.

Note: In case the policies requirements sent in ADAP are not met, the slave SSs do not transmit the information. However, it would be possible for the slave SS to convey the information about the list LC (message included in MADD) to its slave BS since it will provide it some further information about other radio resources renting opportunities on other channel (frequency domain). This decision to send the LC information can be ruled by the policy.

4- Master BS - Slave BS communication through the backhaul

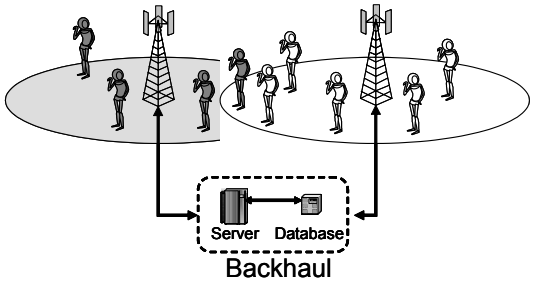


Figure h51—Master-Slave BS communication through the backhaul

After step 3, the slave BS knows the IP_Proxy_address_M (Section 6.3.2.3.64) associated to the master cell. Accordingly, the communications between master and slave cells (BSs) is performed through the backhaul to make the negotiation (Figure h 51) with the co-existence protocol (CP). The remaining phases of the credit tokens based negotiation cycle is performed via this backhaul with IP based communications using server(s) and database(s).

15.6.2.2.6.5.2 Mechanisms enabling the discovery and the exploitation of the slave cells originated requests discovery messages by the master cells

This paragraph describes the mechanisms enabling the discovery and the exploitation of the slave cells originated request discovery messages by the master cells. The terminology used in the following is the same as in the previous paragraph.

These mechanisms are described by the different steps illustrated as follows:

1- Detection and identification of the SATIs content by the master SSs

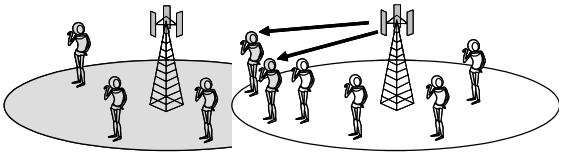


Figure h52—Detection and identification of the SATIs content by the master SSs

During this step (Figure h 52), the master SSs in the overlapping area between the master cell and their slave cell listen to the different SATIs sequentially. For each slave cell, these master SSs can get the information contained in the SADD message.

2- Relaying of the SATIs content to the master cell by the master SSs

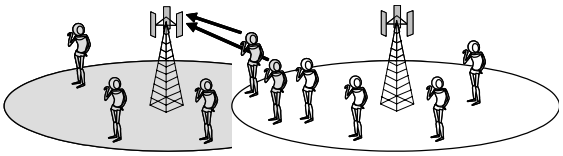


Figure h53—Relaying of the SATIs content to the master cell by the master SSs

- The SADD message information is reported by the master SS to its master cell (Figure h 53).

- In order to ensure this information is appropriately received by the master BS, the information is sent by several masters (e.g. 2 master SSs convey this information to the master BS in Figure h 53). This ensures both reliability and security check.

3- Master BS - Slave BS communication through the backhaul

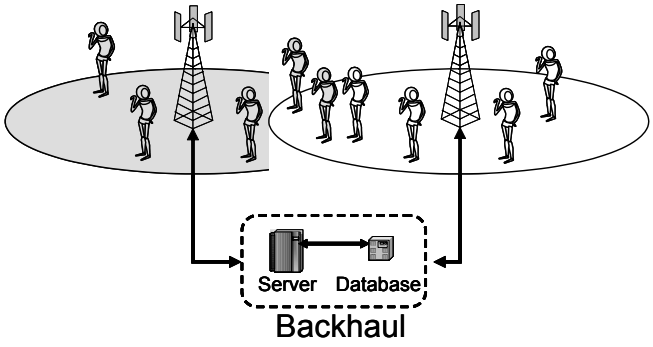


Figure h54—Master BS - Slave BS communication through the backhaul

After step 2, the master BS knows the IP_Proxy_address_S (Section 6.3.2.3.65) of the slave cell. Accordingly, the communications between master and slave cells (BSs) is performed through the backhaul to make the negotiation (Figure h 54) with the co-existence protocol (CP). The remaining phases of the credit tokens

based negotiation cycle is performed via this backhaul with IP based communications using a server and database.

15.6.2.2.7 Legitimate Request for Bandwidth and Transmission Time

An WirelessMAN-CX network that is a member of a community of networks granted access to shared spectrum resources only if it forms an actual network comprised of at least one base station and one subscriber station and supports a bi-directional link.

15.6.2.2.8 Coverage Area

15.6.2.2.9 Direction of Coverage Area

15.6.2.2.10 Bandwidth Utilization

Annexes

Annex A

(informative)

Mechanism of security in coexistence –reference

A.1 General Principal

The access to Data Bases is secured by authentication and possibly encryption

[Note: the security part is a temporary text adopted from contribution C802.16h-05/11r1 and WirelessMAN-CX is calling for comments]

Figure h A1 shows the IEEE 802.16 LE inter-network communication architecture:

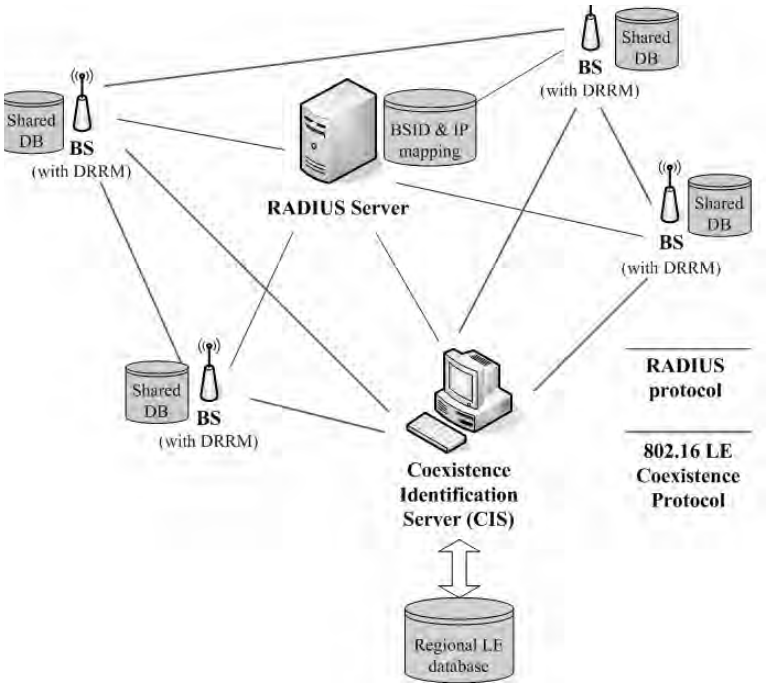


Figure h-A1—Network Architecture

General architecture includes the components operating over IP-based network:

- The RADIUS Server- The Base Station Identification Server (BSIS), ~~described in detail in section xxx -~~ The BSs cooperating with the Distributed Radio Resource Management (DRRM) procedureRADIUS server performs two primary functions. The first one is to authenticate 802.16 LE BSs and BSIS. Keyed-Hashing for Message Authentication (HMAC) with Message Digest 5 (MD5) (RFC2869:2000) is adopted for authentication. The second one is to maintain the address mapping of wireless medium addresses of BSs (their BSID) and medium addresses of BSIS to their IP addresses. This mapping is to distribute the keys for ESP used by BSs belonging to different networks.

BSIS maintains the geographic and operational information such as latitude, longitude and the BSID of LE BSs within certain management domain. BSs operating under LE system shall first query the foreign BSISs which are geographically close to the local BSIS and find the coexistence neighbor BSs while starting up, following the Coexistenceprotocol (detailed description in section 15.2.2.3). After the successful query procedure, the BS can obtain the BSIDs of the coexistence neighbor BSs. Intercommunication between BSs belonging to different networks is permitted after the BS acquires coexisting neighbor's Pairwise Masterkey. and PMK-index for ESP.

Considering the IP network firewalls and different filtering rules, we should find a common security solution to make BSs/BSISs data connection transparent under almost common network management cases. IPSec is used to IPv4 and also included in IPv6 for the IP-Layer security solution. And all BSs/BSISs don't just reside in the same network environment. The data connections should go through some routers/firewalls and need to follow a common security rules.

Figure h A2 shows the BSs/BSISs connections encrypted in IPSec. Based on IPSec, all data connections between BSs/BSISs could pass through firewalls and routers unless some firewalls block IPSec connections.

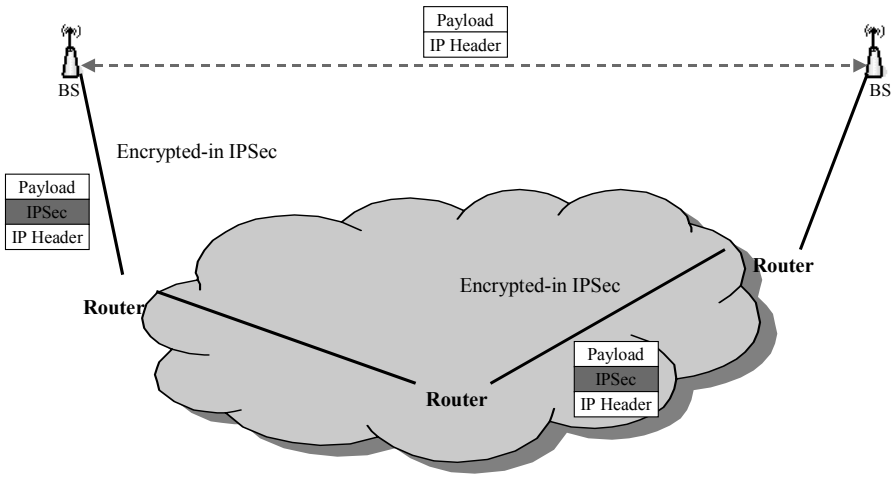


Figure h-A2—BSs/BSISs connection encrypted in IPSec

Figure h A2 demonstrates the IEEE 802.16 LE inter-network communication architecture under multi-Operators with multi-RADIUS Servers.

If BS-1 wants to communicate with BS-2, it must get BS-2's Country's Code, Operator ID and BSID from local BSIS first. And then work as the following steps

(1) BS-1 send RADIUS-Access-Request frame with BS-2's Country's Code, Operator ID and BSID to local RADIUS-Server

(2) Local RADIUS-Server will act as RADIUS-Proxy and transfer this RADIUS-Access-Request to the target RADIUS-Server

(3) Target RADIUS-Server will response RADIUS-Access-Accept with Pairwise-Master-Key and PMK-index for BS-1 and Security-Block for BS-2

(4) Local RADIUS-Server will generate Security-Block including Pairwise-Master-Key and PMK-index from target Raidus-Server

(5) BS-1 will receive RADIUS-Access-Accept from its local RADIUS-Server and get the Pairwise-Master-Key PMK-index and ESP Authentication/Transform IDs in Security-Block for BS-1

(6) BS-1 will act as a PKM-initiator to send Session-Key-Start to BS-2 with Security-Block for BS-2

(7) BS-2 will calculate the ESP-Key-Stuffs with Pairwise-Master-Key, choose the ESP Authentication/ Transform IDs supported by BS-2 and response Session-Key-Request to BS-1

(8) BS-1 will also calculate the ESP-Key-Stuffs with Pairwise-Master-Key to verify Key-Signature, compare ESP Authentication/Transform IDs support by BS-2 with current settings supported by BS-1 and response Session-Key-Response to BS-2

(9) BS-2 will verify Key-Signature and response Session-Key-Accept to BS-1

(10) After the above procedures, BS-1 and BS-2 could communicate in IPSec with the ESP-Key-Stuffs generated dynamically

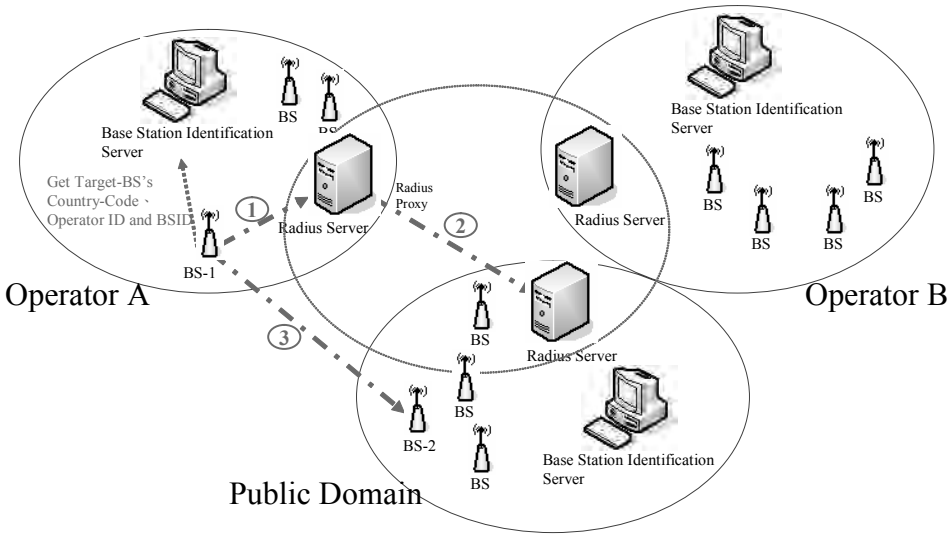


Figure h-A3—Network Architecture under multi-Operators with multi-RADIUS Servers

The following figure shows the each connection of BSs/BSISs will be encrypted in individual Session-Key in IPsec

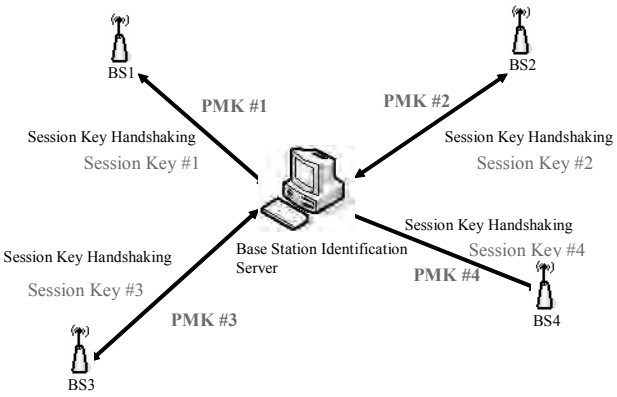


Figure h-A4—Individual Session-Key

For the BSs/BSISs, each connection with different BSs/BSISs will use individual Session-Key in IPsec. Those Session Keys would be generated from PKM-Handshaking with Pairwise-Master-Keys between each pair BSs/BSISs. The re-key procedures also don't need RADIUS-Servers and just use Pairwise-Master-Keys.

A.2 Coexistence Protocol

[Note: the security part is a temporary text adopted from contribution C802.16h-05/11r1 and is subject to further discussion.]

In order to get the coexistence neighbor topology, perform registration to the database and registration to peer, negotiation for Shared RRM etc. will be used a Coexistence Protocol (CP). Figure h A5 describes the WirelessMAN-CX protocol architecture. The protocol architecture indicates that DRRM, Coexistence Protocol and Shared DB belong to LE Management Part located in management plane and the messages will be exchanged over IP network. Thus, DRRM in LE Management Part uses the Coexistence protocol to communicate with other BSs and with Regional LE DB and interact with MAC or PHY. Figure h A5 is LE BS architecture with Coexistence Protocol. The gray area indicates area where there is an absence of connection between blocks. DSM is Distribution System Medium which is another interface to the backbone network. Note that is architecture is only for reference. Similarly, Figure h A5 is the BSIS architecture with co-located regional LE database. Other architectures are not being illustrated. The Coexistence Protocol services are accessed by the LE Management Entity through CP SAP. The service primitives are described in t.b.d A BS uses the Coexistence Protocol, which is similar to PKM protocol, to perform the coexistence resolution and negotiation procedures. There are two types of messages to support Coexistence Protocol:

(1) CP-REQ: BS->BS or BS->BSIS

(2) CP-RSP: BS->BS or BSIS->BS

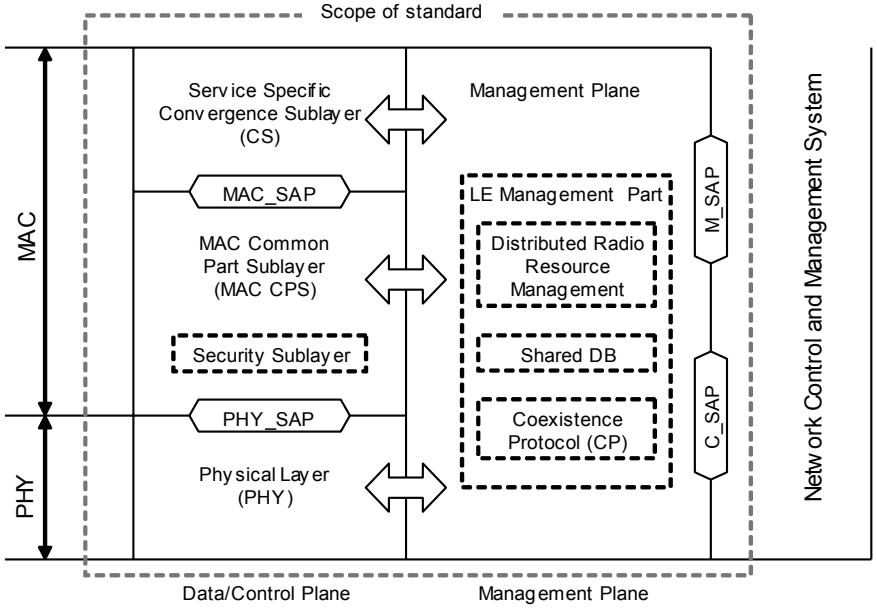


Figure h-A5—WirelessMAN-CX BS Protocol architecture Model

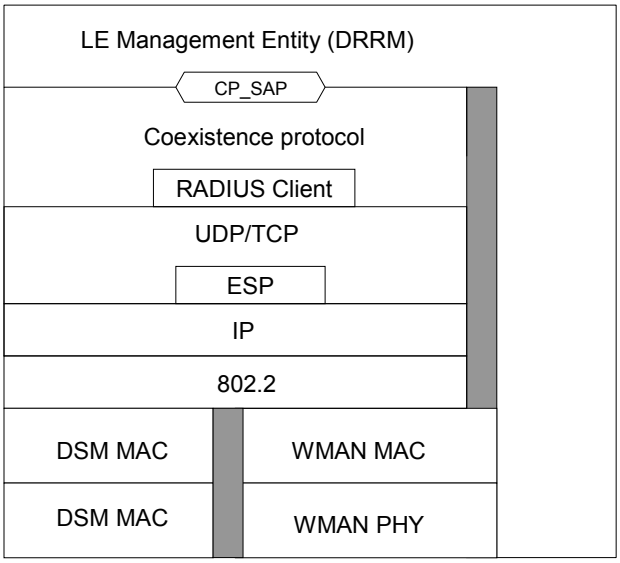


Figure h-A6—LE BS architecture with Coexistence Protocol

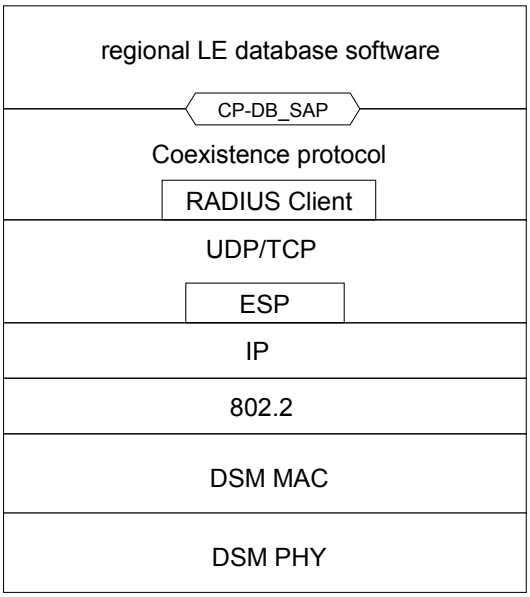


Figure h-A7—BSIS architecture with co-located regional LE database

To use the Coexistence Protocol, which is similar to PKM protocol, to perform the coexistence resolution and negotiation procedures a BS sends a CP-REQ to another BS or BSIS and waits for the CP-RSP.

Before any data can be exchanged between BS and BS/BSIS, security association must be setup first. IEEE 802.16 LE security associations between peers are established through RADIUS server. Any BS wants to communicate with another BS or BSIS shall first send a *RADIUS Access-Request* to request the establishment of the security association between originated BS and terminated BS/BSIS. RADIUS server replies a *RADIUS Access-Accept*, which includes security information for ESP operation, to the BS. At this point, only *virtual* security association is established between the peers. The BS sends the Security Block for the peer, which it received from the RADIUS Server, as a CP-REQ packet with message type *Send-Security-Block*. This is the first message in the Coexistence Protocol TCP exchange between the BS and BS or BS and BSIS. The peer returns CP-RSP packet with message type *Send-Security-Block*. At this point both sides have the information to encrypt all further packets for this exchange between the BS and BS or BS and BSIS.

The UDP port number assigned by IANA to be opened for the CP for transmission and reception of CP packets is *TBD*.

The TCP port number assigned by IANA to be opened for the CP for transmission and reception of CP packets is *TBD*.

A.3 Base Station Identification Server

[Note: The following part from 3.2.4.1 is a temporary text adopted from contribution C802.16h-05/11r1 and is subject to further discussion. A call for comment from security experts is open to comment on this text.]

The *Base Station Identification Server* (BSIS) acts as an interface between 802.16 LE BSs and the regional LE DB which stores the geographic and important operational information, e.g. latitude, longitude, BSID etc., of the LE BSs belonging to the same region. It converts the actions carried in PDUs received from the 802.16 LE BSs to the proper formats, e.g. SQL (Structured Query Language) string, and forwards the strings to the regional LE DB, which can be any available database software. BSIS converts the query results from the regional LE DB to the proper format, e.g. TLV encodings, and replies to the requested BSs. Figure h A7 shows the general architecture of inter-network communication across 802.16 LE systems. In this architecture, the 802.16 LE systems (BSs and BSIS) from different networks set up security association (including BS and BS, BSIS and BSIS) with each other by utilizing the services provided by the RADIUS server. BSIS acts as a peer of 802.16 LE BSs in this architecture. The BSID of regional BSIS is well known among the 802.16 LE systems within certain domain.In summary, ESP with RADIUS can discover a Rogue BS or BSIS. The messages exchanged between the LE BSs and the BSIS will be revealed in the next section. Note that the interface between BSIS and regional LE DB is out of scope.

A.4 RADIUS Protocol Usage

For future interoperability consideration, similar mechanisms are maintained. Secure exchange of 802.16 LE signaling information can be achieved after successful procedures of the RADIUS protocol. To include RADIUS support, the RADIUS server and the BS/BSIS RADIUS client must be configured with the shared secret key and with each other's IP address. Each BS/BSIS acts as a RADIUS client and has its own shared secret key with the RADIUS server. The shared secret key may be different from that of any other BS/BSIS.

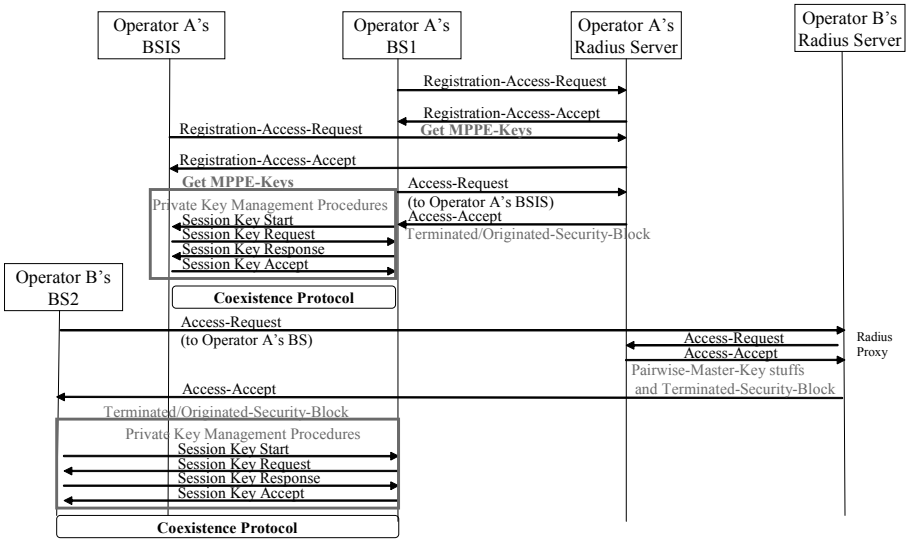


Figure h-A8—RADIUS protocol example

Figure h A8 shows the RADIUS protocol message exchange sequence. At starting up, each BS or BSIS must send a RADIUS-BS/BSIS-Registration-Access-Request (shown in Table h A1) to the RADIUS server for authentication purpose and leave the address mapping (BSID to IP) information in the server. At this time, the RADIUS server will retain the following information of registered BS or BSIS:

a) Wireless medium address of BS (BSID) or medium address of BSIS,

b) MPPE-Keys in RADIUS-BS/BSIS-Registration-Access-Request/Accept Procedures

c) IP address or DNS name,

d) Cipher suites supported by the BS or BSIS for the protection of Coexistence Protocol communications,

e) and Pairwise-Master-Key for BS or BSIS to establish Session-Key-Handshaking procedures

Same as [2], Microsoft Point-to-Point Encryption (MPPE) (RFC 2548:1999) key is introduced. The MS-MPPE-Send-Key, which could be got in the RADIUS-BS/BSIS-Registration-Access-Accept message (shown in Table h A1) and RADIUS-BS/BSIS-Access-Accept message (shown in Table h A1), is used for encrypting the security blocks in the RADIUS-BS/BSIS-Access-accept message for PKM-target and PKM-initiator. A registration access reject message may be issued due to a BS not supporting the ESP Transform or ESP Authentication algorithm selected for use in securing the following intercommunication, or for other RADIUS configuration reasons not discussed here.

Once a BS wants to get the knowledge of coexistence neighbor topology, it must first send RADIUS-BS/BSIS-Access-Request message (shown in Table h A1) to the RADIUS server in order to acquire the regional BSIS's IP address. The wireless medium addresses of regional BSIS, similar to BSID, well known by all BSs supporting LE operation, is sent in the RADIUS-BS/BSIS-Access-Request message to the RADIUS server for looking up IP address of the BSIS. Upon receiving the request message, the RADIUS server will respond with a RADIUS-BS/BSIS-Access-Accept message (shown in Table h A1) if the BS is a valid member which is allowed to perform inter-communication. The RADIUS-BS/BSIS-Access-Accept message would contain Originated-BS-Security-Block(for BS encrypted in MPPE-Send-Key from current RADIUS-BS/BSIS-Access-Request/Accept message) and Terminated-BS/BSIS-Security-Block(for BSIS encrypted in MPPE-Send-Key from BSIS's RADIUS-BS/BSIS-Registration-Access-Request/Accept message). Security-Block (shown in Table h A1) contains Pairwise Master Key IndexPairwise-Master-KEYKey Lifetime-the list of ESP Authentication/Transform IDs for initiator-send/receive for establishing a secure connection with the BSIS .

After querying process between the BS and the regional BSIS in Coexistence Protocol, the BSIS will respond to the BS with possible coexistence neighbor BSs candidates and their BSIDs. The BS, then, tries to establish secure connections with the coexistence neighbor BSs after evaluating the coexistence relationships with these candidates. The BS sends RADIUS-BS/BSIS-Access-Request message to local RADIUS server for Originated/Terminated-BS/BSIS-Security-Blocks. After getting Security-Blocks from RADIUS-BS/BSIS-Access-Accept messages, the BS establishes secure connections with each evaluated coexistence neighbor BS.

An access reject message may be issued due to a BS or the regional BSIS not supporting the ESP Transform or ESP Authentication algorithm selected for the following intercommunication, or for other RADIUS configuration reasons not discussed here.

Table h-A1—Security Block Format

Element ID	Length	Information
1	1	Pairwise Master Key Index for BS/BSIS (0-255)
2	32	Pairwise-Master-KEY
3	4 * number	The list of ESP Authentication IDs corresponding to the ESP Authentication algorithms for initiator-send

4	4 * number	The list of ESP Transform IDs corresponding to the ESP transforms for initiator-send
5	4 * number	The list of ESP Authentication IDs corresponding to the ESP Authentication algorithms for initiator-receive
6	4 * number	The list of ESP Transform IDs corresponding to the ESP transforms for initiator-receive
7	4	Pairwise-Master-KEY Lifetime

The Security-Block would be encrypted in 32-bytes MPPE-Send-Key with the following manner ('+' indicates concatenation):

b(1) = MD5(MPPE-Send-Key+BSID) c(1) = p(1) xor b(1) C = c(1)

b(2) = MD5(MPPE-Send-Key+BSID + c(1)) c(2) = p(2) xor b(2) C = C + c(2)

. .

. .

. .

b(i) = MD5(MPPE-Send-Key+BSID + c(i-1)) c(i) = p(i) xor b(i) C = C + c(i)

Break plain text into 16 octet chunks p(1), p(2)...p(i), where i = len(P)/16. Call the ciphertext blocks c(1), c(2)...c(i) and the final ciphertext C. Intermediate values b(1), b(2)...c(i) are required. The resulting encrypted String field will contain c(1)+c(2)+...+c(i).

For Originated Security Block, the encrypted MPPE-Send-Key is from “RADIUS-Access-Request/Accept”.For Terminated Security Block, the encrypted MPPE-Send-Key is from “RADIUS-Registration-Access-Request/Accept”.

A.5 Privacy Key Management protocol usage

The PKM protocol would provide a flexible and easy-to-maintain key exchange mechanism. The PKM is based on the Pairwise-Master-Key to provide a symmetric key for the PKM-Initiator and PKM-Target side.

The following figure shows the PKM Session-Key-Handshaking procedures

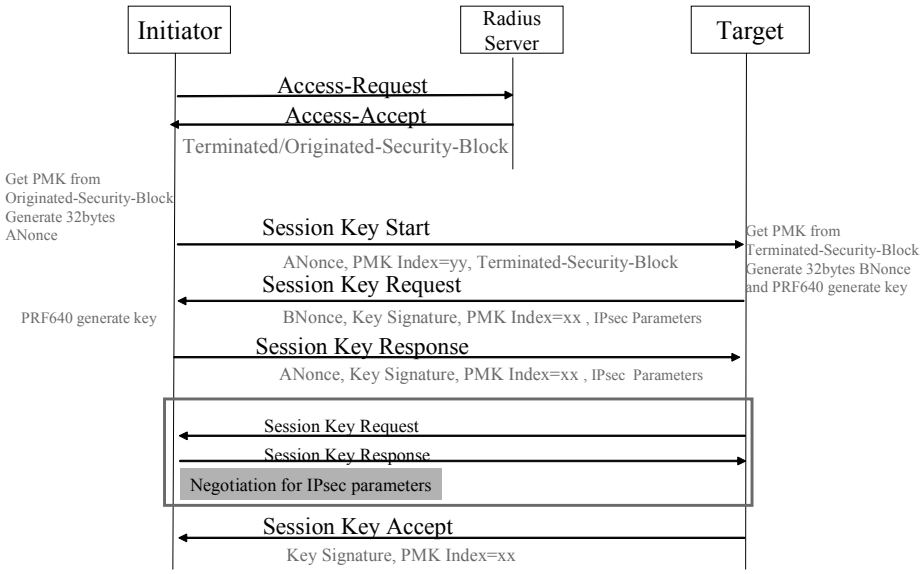


Figure h-A9—PKM Session-Key-Handshaking procedures

The PKM-Initiator will need to get the Pairwise-Master Key in Originated-BS-Security-Block from RADIUS-Server. And then perform the following steps

1) PKM-Initiator would get Pairwise-Master-Key-IndexPairwise -Master-KeyESP Authentication/Transform IDs and Key-Lifetime in originated Security-Block in RADIUS-BS/BSIS-Access-Accept message and then generate a random 32-bytes ANonce.
2) PKM-Initiator would will send Session-Key-Start message to PKM-Target with "ANonce""Pairwise-Master-Key-Index" and "Terminated Security-Block".
3) After receiving Session-Key-Start message, PKM-Target would generate a random 32-bytes BNonce. And perform the PRF640 algorithm to generate the 640-bits Key. Keep the first 512-bits ESP-Transform/Authentication Keys and use the last 128-bits M-Key as the HMAC-MD5 key to generate 16-bytes Key-Signature.
4) PKM-Target would will send Session-Key-Request message to PKM-Initiator with "BNonce""Pairwise-Master-Key-Index" and " ESP Authentication/Transform IDs"(PKM-Target chosen).
5) After receiving Session-Key-Request message, PKM-Initiator would perform the PRF640 algorithm to generate the 640-bits Key. Keep the first 512-bits ESP-Transform/Authentication Keys and use the last 128-bits M-Key as the HMAC-MD5 key to generate 16-bytes Key-Signature to verify the Key-Signature field on the Session-Key-Request message. If it is wrong, PKM-Initiator would perform silent-drop and doesn't response any message. If it is correct, PKM-Initiator would prepare the Session-Key-Response message and use HMAC-MD5 generate Key-Signature filed.
6) PKM-Initiator would will send Session-Key-Response message to PKM-Target with "ANonce""Pairwise-Master-Key-Index" and " ESP Authentication/Transform IDs"(PKM-Initiator chosen) .
7) After receiving Session-Key- Response message, PKM-Target would check the ANonce value if equal to the previous ANonce value in Session-Key-Start message and use HMAC-MD5

generate Key-Signature filed to verify the Key-Signature field. Compare the values of ”ESP Authentication/Transform IDs” to make sure the security parameters.

8) After the above, PKM-Target will send Session-Key-Accept with Key-Signature filed to PKM-Initiator to verify.

9) The following IPsec connection will use the first 512-bits ESP-Transform/Authentication Keys from PRF640 as keys and perform the ESP-Transform/Authentication algorithms from chosen ESP Authentication/Transform IDs.

The following figure shows the PKM Session-Key Re-Key procedures

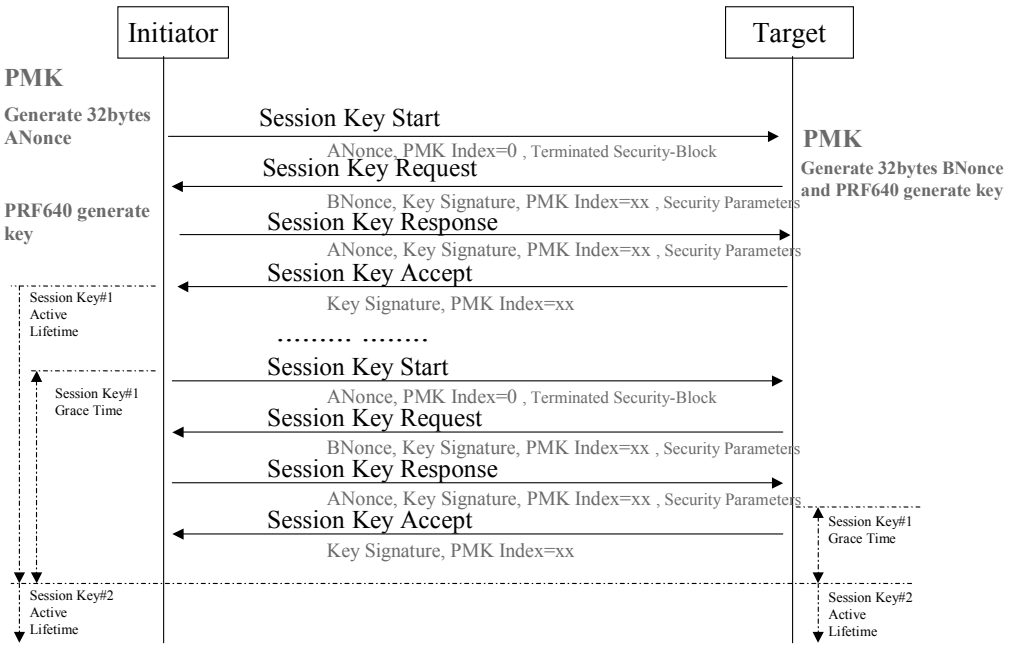


Figure h-A10—PKM Session-Key Re-Key procedures

Each Session-Key would set a Key-Lifetime, and PKM-Initiator could set a Session-Key grace time to perform Session-Key-Handshaking for the next new Session-Key#2 to be generated until the end of the key lifetime. The Session-Key#1 could use up its lifetime and then activate the Session-Key#2. If each side use the Session-Key#2 first in IPsec connection, it could also activate the Session-Key#2. If the lifetime of Session-Key#1 use up, the PKM-Initiator doesn’t perform the Session-Key Re-Key procedures. PKM-Target would disconnect the IP connection until the Session-Key#2 generated.

The following figure shows the PKM Session-Key Re-Key procedures with the PMK update

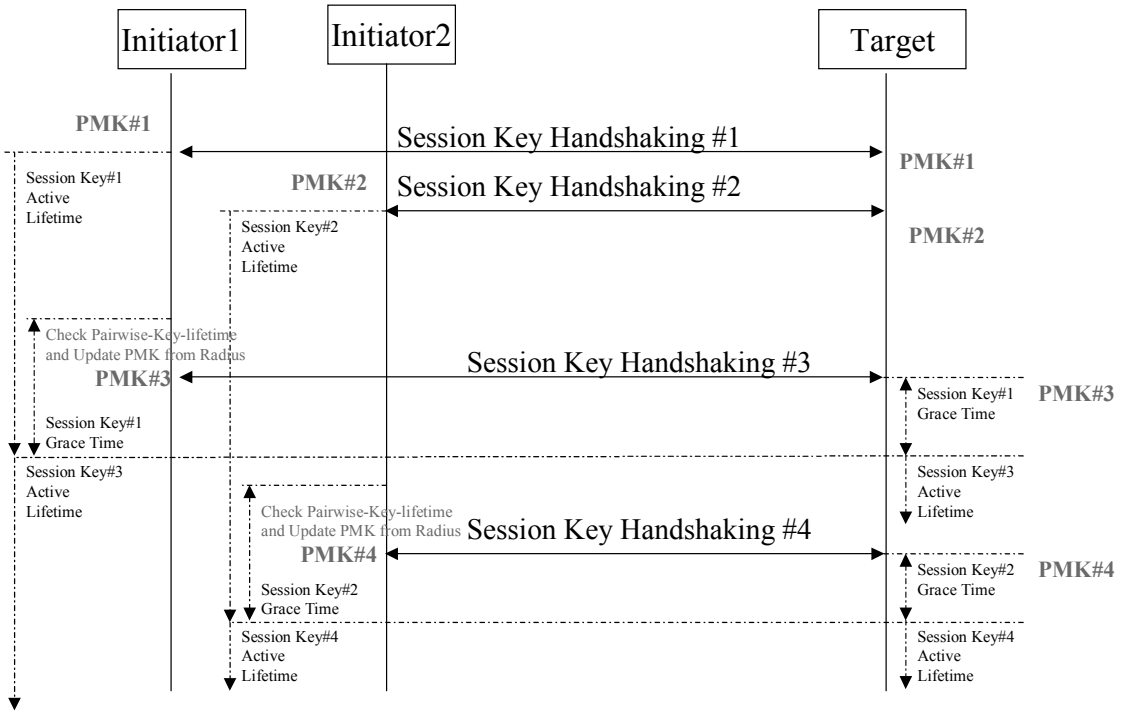


Figure h-A11—PKM Session-Key Re-Key procedures with the MK update of PKM-Target

The PKM-Initiator will check the current Pairwise-Key-Lifetime if still valid. If the PKM-Initiator detects the Pairwise-Key-Lifetime used up, it would perform RADIUS-BS/BSIS- Access-Request/Accept procedures to get the latest Pairwise-Master-Key in Security-Blocks from RADIUS-Server.

Each Pairwise-Master-Key would set a Pairwise-Master-Key-Lifetime, and BSs/BSISs could set a Pairwise-Master-Key grace time to perform Access-Request/Accept procedures for the new Pairwise-Master-Key until the end of the Pairwise-Master-Key lifetime. If the lifetime of Pairwise-Master-Key use up, the originated BSs/BSISs don't perform the Access-Request/Accept procedures, the terminated BSs/BSISs should discard the connections.

The following figure shows the 640-bits Key generated by PRF640

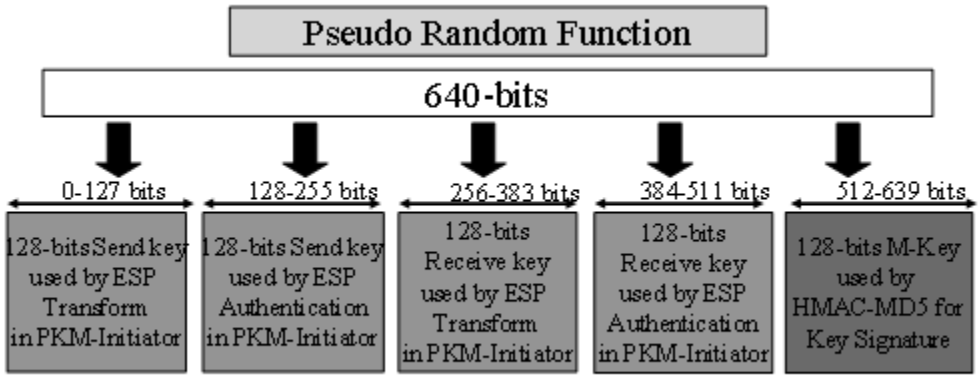


Figure h-A12—the 640-bits Key generated by PRF640

The BSs/BSISs get Pairwise-Master-Key from RADIUS-Servers and generate 32-bytes Nonce value to derive 640-bits key as follows

PRF-640(PMK, "BS-BSIS key expansion", Min(BS1ID,BS2ID) || Max (BS1ID,BS2ID)|| Min(ANonce,BNonce) || Max(ANonce,BNonce))

Where

PRF-640 (K,A,B) =

for i=0 to 4 do

R=R|HMAC-SHA-1(K, A|0|B|I)

return LeastSignificant-640-bits(R)

and "|" denotes bitstring concatenation

A.6 Security consideration

In this model, data traffic is protected by using IPsec.

The IP Security Protocol provides cryptographically based security for IPv4. The protection offered by IPsec is achieved by using one or both of the data protection protocols (AH and ESP). Data protection requirements are defined in the Security Policy Database (SPD). IPsec assumes use of version 2 of the Internet Key Exchange protocol , but a key and security association (SA) management system with comparable features can be used instead.

A.7 RADIUS Protocol Messages

The following messages are listed to support RADIUS protocol:

Note that[tbd.] means To Be Defined.

— *RADIUS-*BS*/BSIS-Registration-Request (BS/BSIS* RADIUS *server): A startup BS/BSIS sends this message for authentication purpose.*

Table h-A2—RADIUS-BS/BSIS-Registration-Access-Request

Attribute number	Attribute name	Value
1	User-Name	BSID. The BSID should be represented in ASCII format, with octet values separated by a "-". Example: "00-10-A4-23-19-C0".
4	NAS-IP-Address	BS's IP Address
6	Service-Type	Coexistence-Protocol-Register (value =[tbd.], ex. IAPP-Register, value = 15)
26 26-TBD	Vendor-Specific-Attribute (VSA) Supported-ESP-Authentica-tion-Algorithms	 The list of ESP Authentication IDs corresponding to the ESP Authentication algorithms supported by this BS (See Table h A7)
26-TBD	Supported-ESP-Transforms	The list of ESP Transform IDs corresponding to the ESP transforms supported by this BS (See Table h A6
32	NAS-Identifier	BS's NAS Identifier
80	Message-Authenticator	The RADIUS message's authenticator

According to RFC 2865:2000, other RADIUS attributes may be included in the RADIUS-BS/BSIS-Registration-Access-Request packet in addition to the ones listed in Table h A3.

— RADIUS-*BS/BSIS-Registration-Accept (RADIUS server BS/BSIS): After RADIUS server verifies the valid membership, it will respond with this accept message.*

Table h-A3—RADIUS-BS/BSIS-Registration-Access-Accept

Attribute number	Attribute name	Value
1	User-Name	BSID.
6	Service-Type	Coexistence-Protocol -Register (value =[tbd.], ex. IAPP-Register, value = 15)
26 26-TBD	Vendor-Specific-Attribute (VSA) Supported-ESP-Authenti-cation-Algorithms	 The list of ESP Authentication IDs corresponding to the ESP Authentication algorithms approved by Radius Server
26-TBD	Supported-ESP-Trans-forms	The list of ESP Transform IDs corresponding to the ESP transforms approved by Radius Server
27	Session-Timeout	Number of seconds until the BS should re-issue the registration Access-Request to the RADIUS server to obtain new key information.
80	Message-Authenticator	The RADIUS message's authenticator

According to RFC 2865:2000, other RADIUS attributes may be included in the RADIUS-BS/BSIS-Registration-Access-Accept packet in addition to the ones listed in Table h A4.

— RADIUS-BS/BSIS-Access-Request (BS/BSIS RADIUS server): The BS sends this message to request for inter-communication with another coexistence neighbor BS or a regional BSIS.

Table h-A4—RADIUS-BS/BSIS- Access-Request

Attribute number	Attribute name	Value
1	User-Name	User-Name must include Country-CodeOperator ID and Regional BSIS's WM address or coexistence neighbor BS's BSID
4	NAS-IP-Address	Original BS's IP Address (the BS sending this request message)
6	Service-Type	CS/BSIS-Check (value =[tbd.], ex. IAPP-AP-Check, value = 16)
61	NAS-Port-Type	Wireless – Other (value = 18)
80	Message-Authenticator	The RADIUS message's authenticator

According to RFC 2865:2000, other RADIUS attributes may be included in the RADIUS-BS/BSIS-Access-Request packet in addition to the ones listed in Table h A5.

RADIUS-BS/BSIS-Access-Accept (RADIUS server BS/BSIS): After verifying that the coexistence neighbor BS is valid member, RADIUS server will respond with the security blocks necessary for establishing a secure connection between the coexistence neighbor BS and requesting BS or between BSIS and requesting BS.

Table h-A5—RADIUS-BS/BSIS- Access-Accept

Attribute number	Attribute name	Value
1	User-Name	User-Name must include Country-CodeOperator ID and Regional BSIS's WM address or coexistence neighbor BS's BSID
8	Framed-IP-Address	IP Address of Regional BSIS or coexistence neighbor BS.
26 26-TBD 26-TBD	Vendor-Specific-Attribute (VSA) Originated-BS-Security-Block Terminated-BS/BSIS-Security-Block	 Security Block encrypted using originated BS's MPPE-SEND-KEY, to be decrypted and used by the original BS Security Block encrypted using coexistence neighbor BS's MPPE-SEND-KEY (or BSIS's), to be decrypted and used by the coexistence neighbor BS (or BSIS)
80	Message-Authenticator	The RADIUS message's authenticator

According to RFC 2865:2000, other RADIUS attributes may be included in the RADIUS-BS/BSIS-Access-Accept packet in addition to the ones listed in Table h A6.

Table h-A6—ESP Transform identifiers

Transform identifier	Value	Reference
RESERVED	0	[RFC2407]
ESP_DES_IV64	1	[RFC2407]
ESP_DES	2	[RFC2407]
ESP_3DES	3	[RFC2407]
ESP_RC5	4	[RFC2407]
ESP_IDEA	5	[RFC2407]
ESP_CAST	6	[RFC2407]
ESP_BLOWFISH	7	[RFC2407]
ESP_3IDEA	8	[RFC2407]
ESP_DES_IV32	9	[RFC2407]

ESP_RC4	10	[RFC2407]
ESP_NULL	11	[RFC2407]
ESP_AES-CBC	12	[RFC3602]
Reserved for privacy use	249-255	[RFC2407]

Table h-A7—ESP Authentication algorithm identifiers

Transform identifier	Value	Reference
RESERVED	0	[RFC2407]
HMAC-MD5	1	[RFC2407]
HMAC-SHA	2	[RFC2407]
DES-MAC	3	[RFC2407]
KPDK	4	[RFC2407]
HMAC-SHA2-256	5	[Leech]
HMAC-SHA2-384	6	[Leech]
HMAC-SHA2-512	7	[Leech]
HMAC-RIPEMD	8	[RFC2857]
RESERVED	9-61439	
Reserved for privacy use	61440-65535	

A.8 Privacy Key Management protocol messages

The PKM protocol procedures contain 4 message actions, and each-side could check the code value of the begin of PKM message to recognize which *action need to perform this moment. The meaning of codes for PKM message as follows*

— *0* = Session Key Start

— 1 = Session Key Request

— 2 = Session Key Response

— 3 = Session Key Acce*pt*

The PKM message uses TLV format *to add the following attributes*

Table h-A8—Session Key frame TLV

Type	Length	Value Information
1	32	Nonce
2	8	Replay Counter
3	8	Key lifetime in seconds
4	16	Key Signature
5	4	Security Parameter Index
6	4 * number	The list of ESP Authentication IDs corresponding to the ESP Authentication algorithms for initiator-send supported by this BS
7	4 * number	The list of ESP Transform IDs corresponding to the ESP transforms for initiator-send supported by this BS
8	4 * number	The list of ESP Authentication IDs corresponding to the ESP Authentication algorithms for initiator-receive supported by this BS
9	4 * number	The list of ESP Transform IDs corresponding to the ESP transforms for initiator-receive supported by this BS

10	33 + 4*n	Security Block

The Length field contains a 16-bits value to record the whole frames size starting from Code field, with the ESP-Transforms-and-Authentication-Algorithms-Codes field filled in if present.

The PMK-Index field contains a 8-bits value to record the current Pairwise-Master-Key-Index each PKM-side used. If the PKM-Target detects the PMK-Index different of PKM-Initiator, it must update the latest Pairwise-Master-Key.

The Replay-Counter field contains a 64-bits random number (such as 64-bit NTP timestamp) and does not repeat within the life of the Master-Key material.

The Key-Lifetime field contains a 64-bits value to record the Session-Key lifetime in seconds.

The Key-Signature field contains an HMAC-MD5 message integrity check computed over the Session-Key-Frame starting from Code field, with the ESP-Transforms-and-Authentication-Algorithms-Codes field filled in if present, but with the Key Signature field set to zero. The M-Key is used as the HMAC-MD5 key.

The Security-Parameters-Index field contains a 32-bits value to assign to the IPsec Security Association (including the encryption and authentication keys, the authentication algorithm for AH and ESP, the encryption algorithm for ESP, the lifetime of encryption keys…etc in this session). PKM-Initiator/Target could check the SPI value in ESP-Header to detect to use which SA for this IPsec connection.

The following figure shows the Session-Key-Start message format

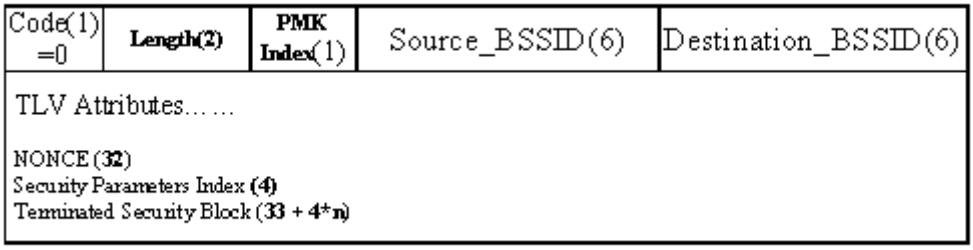


Figure h-A13—Session-Key-Start message format

The following figure shows the Session-Key-Request message format

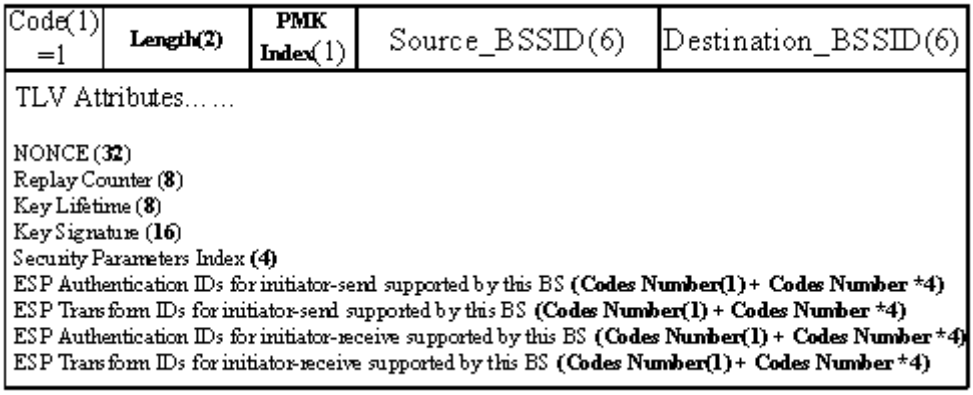


Figure h-A14—Session-Key-Request message format

The following figure shows the Session-Key-Response message format

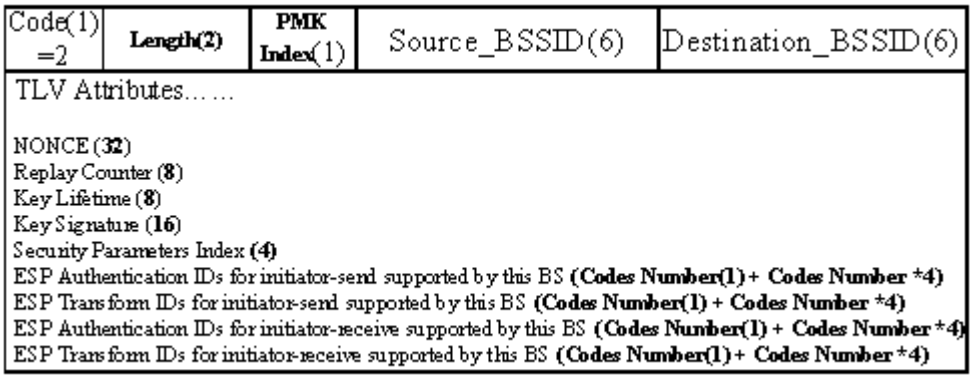


Figure h-A15—Session-Key-Response message format

The following figure shows the Session-Key-Accept message format

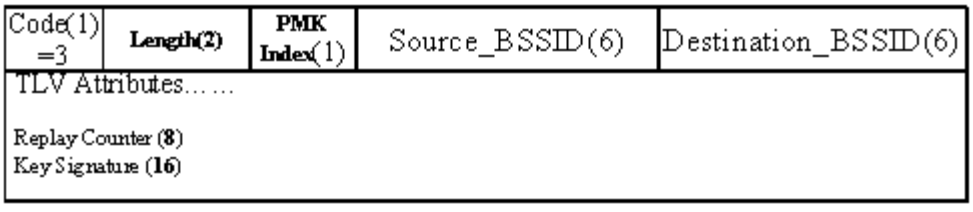


Figure h-A16—Session-Key-Accept message format

Annex B

(informative)

GPS Timing and Base Station Synchronization

Every WirelessMAN-CX systems should be synchronized to a globally distributed reference timing system that is capable of allowing the network Base Stations to synthesize a 1 pps NTI and a UTC time stamp. The Global Positioning System (GPS) is capable of providing these temporal references to the Base Stations that are equipped with GPS receivers.

The Base stations equipped with a GPS receiver arecapable of receiving a UTC synchronized 1 pps timing signal. The clock pulses derived from a GPS receiver are accurate to +/- 100 usec and the derived pulses typically have rise times within +/- 2.5 nsec.Figure h B1 shows a typical GPS 1 sec pulse and its duration (Trimble Inc. Palisade output).

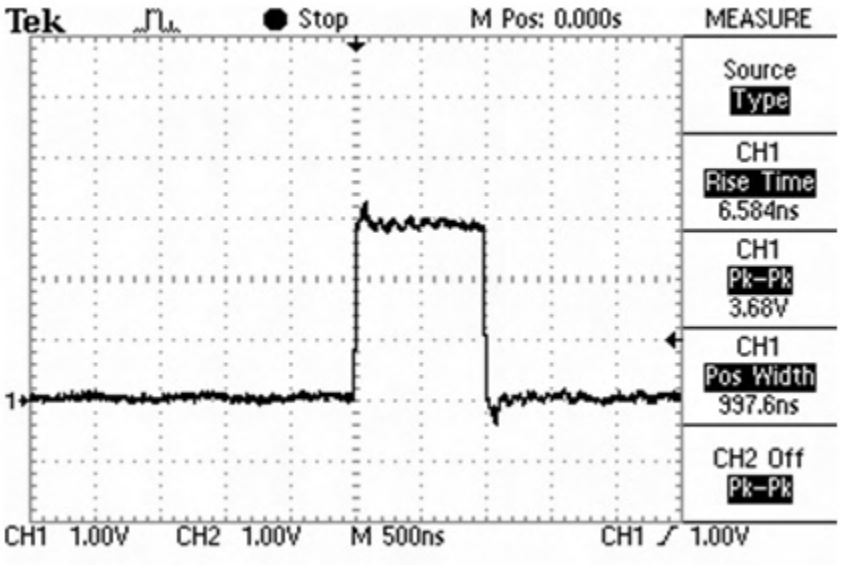


Figure h-B1—GPS 1pps Pulse

The availability of a globally distributed clock will result in a common temporal unit that can be used in negotiating access times to spectrum shared by a community of ad-hoc users. Non- WirelessMAN-CX networks having different architectures and messaging signals could also use a common 1 second interval for synchronization of their networks. This would conceivably allow communication between all IEEE 802.16 networks in a synchronized manner, to facilitating the exchange of information related to coexistence and spectrum sharing.

The one second reference time is appropriate because it is distributed directly by the GPS. WirelessMAN-CX networks typically have frames on the order of several to tens of milliseconds, which is a granularity that could allow several to several tens of networks to negotiate coexistence subintervals within the 1 second span. Additionally, for IP networks, the 1 second interval is of a length sufficient to accommodate inter-router TCP/IP latency, especially over networks that are likely to be close to each other, such as ad-hoc licence exempt systems.

Annex C

(informative)

interference scenario case study

C.1 Base Station initialization scenario case study

See to the figure below:

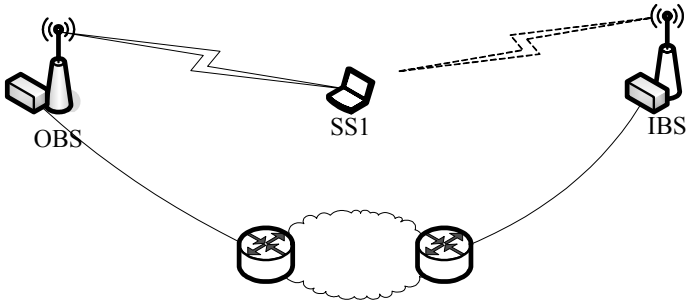


Figure h-C1—Enviorment of initializing basestation

Suppose OBS and SS1 are part of an operating network, SS1 has a stable air link with OBS and OBS has a wired link. Now assume that IBS comes into this area and already has a wired link IBS could contact OBS if he knows the IP address of OBS., Unfortunately IBSdoes not know OBS'sIP address and there may be no regulatory server to ask for help. Notice also that the IBS will not have any SS attached before IBS itself has finished initialization.

There are three kinds of situations that may exist in both SS2BS and BS2SS interference/signaling:

— No interference/signaling detectable

— Interference/signaling detectable but signaling is not decodable

— interference detected and the signaling is decodable

The following designations will be used to illustrate these three cases in Figure h C2

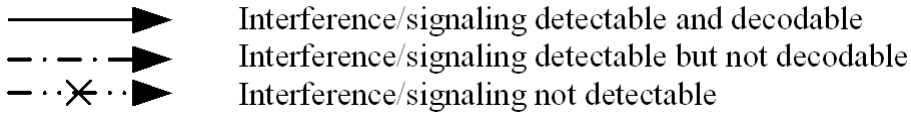


Figure h-C2—Legend of arrow indicating interference direction

[note: based on the synchronization assumption, the BS/BS and SS/SS interference could be ignored.]

The possible cases are:

- Case1x: IBS interference/signaling can not detected by SS1
  - Case1a: the IBS can not detect the signal from the operating network
  - Case1b: the IBS can detect the signal from the operating network, but not decodable
  - Case1c: the IBS can detect and decode the signaling from the operating network
- Case2x: IBS interference/signaling can detected by SS1 but not decodable
  - Case2a: the IBS can not detect the signal from the operating network
  - Case2b: he IBS can detect the signal from the operating network, but not decodable
  - Case2c: the IBS can detect and decode the signaling from the operating network
- Case3x: IBS interference/signaling can detected and decoded by SS1
  - Case3a: the IBS can not detect the signal from the operating network
  - Case3b: the IBS can detect the signal from the operating network, but not decodable
  - Case3c: the IBS can detect and decode the signaling from the operating network

These cases are shown in Figure h C4

1)The red tick signifies that one of the BS may know the IP address of another BS by receiving the signaling from the air; The red cross signifies that the BS can not know the IP address of another BS by the signaling from the air.

2)The red dot line in one side means that from this side, the station can decode the signaling from the transmitter; The red dash line means from this side, the station can detect but can not decode; and the read solid line means the station can not sense transmitter.

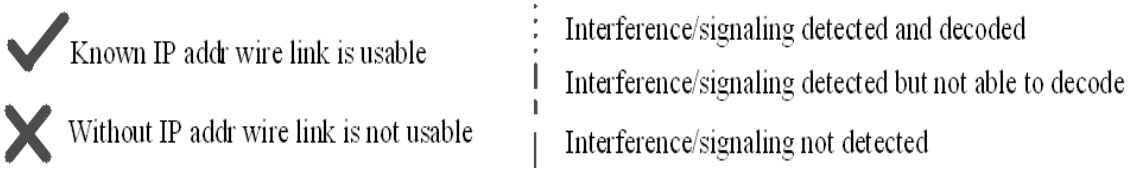


Figure h-C3—Legend of line indicating interference situation and symbols indicating wire-link usability

Case 1x:

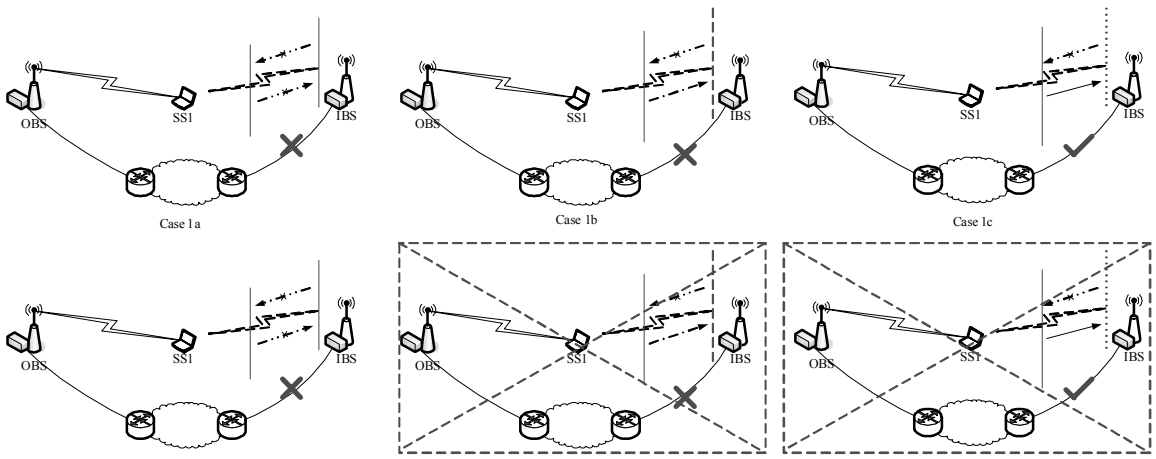


Figure h-C4—case 1x study

[Note: although logically case 1b and 1c could happen, these cases are not normally exist, because the channel propagation are symmetric in both direction, but the BSs' transmition power are normally higher than the SSs'. So when the IBS couldn't been detected by SS1, the IBS will not detect SS1's signal also.]

In these cases IBS doesn't interference with SS1, which means that the OBS's network does not need to contact the IBS. This Case 1x is not a target initialization scenario for WirelessMAN-CX base station .

Case 2x:

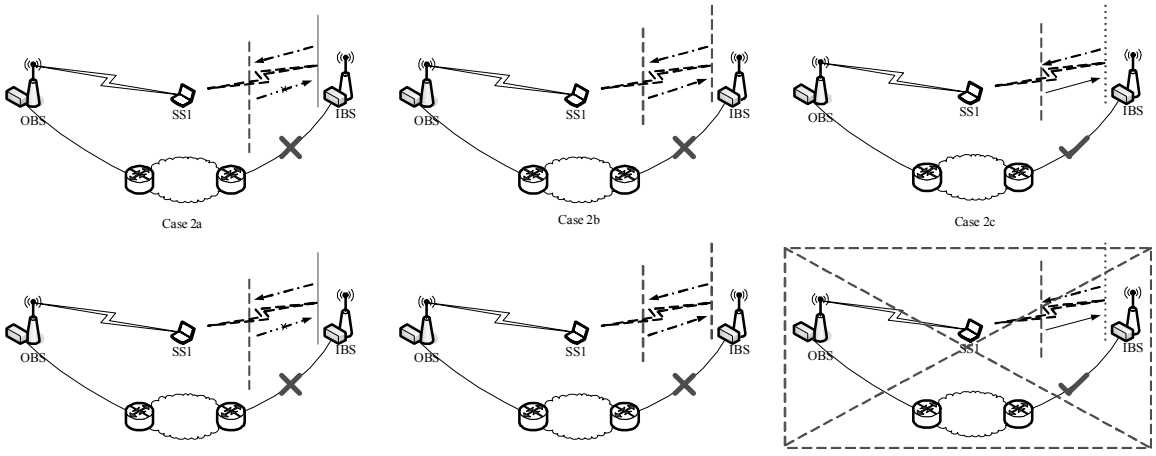


Figure h-C5—case 2x study

[Note: case 2c normally doesn't happen for the same reason with case 1b & 1c.]

In case 2x, , IBS's signaling may be detected by SS1, but SS1 cannot decode the signaling. IBS may interfere to SS1, but SS1 can not identify the interferer, so SS1 can not inform the OBS who is the interferer, so the OBS could not contact IBS for cooperation. Case 2x is the worst case for WirelessMAN-CX.

This worst case problem is due tothe difference of SNR conditions between decodable signaling and troubling interference. The condition could be specified by a SNR requirement, the lower SNR required for the signaling, the lower probability to have this problem; another approach may help was introduced to the working document 15.2.1.1.3 in the meetings before is shown in IEEE C802.16h-05/041,and we could easily understand it in the following figure.

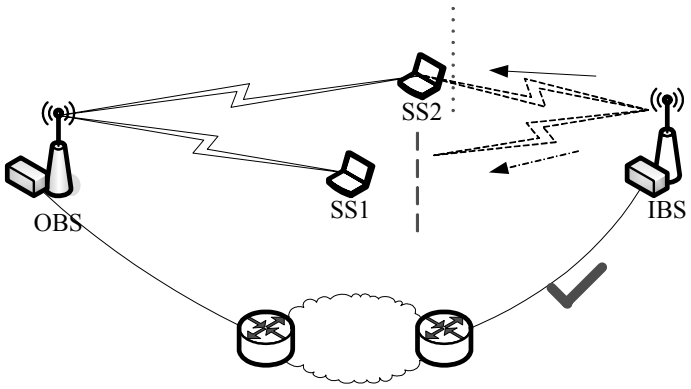


Figure h-C6—Enhanced mechanism dealing with case 2x

Some SSs (eg. SS1 in the Figure h C6) interfered by IBS can not decode the information contained in the broadcast signaling while some SSs decode it at the same time (eg. SS2 in the Figure h C6). All these interfered SS will report to OBS for the signaling. Dealing with all the report, OBS will try to figure out the interferer of the SSs which can not decode the signaling by report message of other SS at the same time, and make use of the interference time/frame_number inside each report message.

We could not absolutely get rid of the difference of the signal requirement between to be decoded and to interfere the transceiver , so we can not totally get rid of the possibility of the SSs to be not able to decode the signaling while being interfered, all we could do is to make the bad effect as little as possible. I don't understand this solution. Once in operating network all the interfered SSs could not decode the signaling, we have no chance to tell who is coming to interfere the network, and this operating network may need to switch/escape to another channel.

Case 3x:

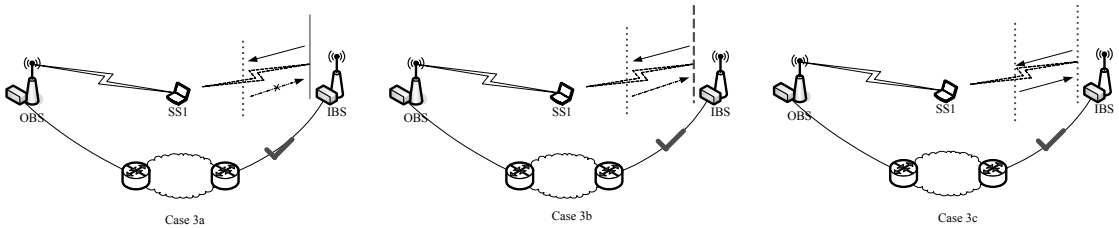


Figure h-C7—case 3x study

Case 3x is the most applicable use of WirelessMAN-CX solution. The common condition of Case3x is that SS can decode the IBS signaling. It's understood that if we don't depends on the IBS signaling transmition, in case 3a and 3b, operation network will not be able to find IBS in the core network. And the only way we

may enable the operating network to do this is using the SS to relay the signaling which is managed to contain the IP address information.

One security issue of CP message between BSs through IP network is roused, how to qualify that the message is from a neighbor station. The BS should make sure that the sender system of the message received its signaling broadcasted. It means that the send system of the CP message should have air interface which can receive and decode the air signaling, nevertheless the system is close enough in distance so that it can receive and decode the signaling send in the air by the BS. If BS send only static information in the signaling, it will not be able to find out if the CP message sender is really its neighbor or just someone who have got the static information unexpected before. This security issue may be mitigated by checking the instant random key and frame numbering in the contact requirement message sent by the OBS. That may prevent the IBS being cheated by someone faraway or by someone which is not able to control or access the WirelessMAN-CX air link. We may need to think about this approach if we have no other choice to meet the cooperation contact requirement in case 3a and 3b.

For the sake of Case 2a and 3a, it's not logical to randomly choose the periodically silent CSI to occupy by the IBS, otherwise in the CSI which the IBS choose will cause collusion and make the initializing procedure not effective. Instead, it's needed to have a predefined periodical ICSI among all the CSI, and every IBS know the timing of ICSI as well. And the rest CSI will be used as OCSI and reallocated periodically to carry the signaling such as radio signature by the OBSs.

C.2 Interference Scenario Case Studies for Synchronized WirelessMAN-CX Systems conforming to a Common PHY Profile.

A case study for WirelessMAN-CX systems is provided. These systems are assumed to conform to the same PHY profile (Section15.2.2.3.1), they are synchronized to a universal time standard such as GPS and can support CMI timing and signaling as outlined in Sections 15.2.1.1.7 and 15.2.2.3.1.1.

In the Common PHY profile concept the following system features are given:

(1) Each System (consisting of a base station (BS) and its subscriber stations (SS)) claims a special interval in time called a CMI in which the BS sends a unique identifier called a BSD and the SS send unique identifiers called SSURF messages. Only one system in a Coexistence Neighborhood can transit during its CMI, all other systems remain quiet and monitor.

(2) All systems are universally synchronized to a common timing standard such as GPS; the beginning of a CMI is universally known. Additionally, the sub-frame sizes in the Time Division Duplexing (TDD) access scheme are all exactly the same across all networks (another common PHY characteristic).

(3) The BSD and SSURF messages can be demodulated and their RSSI values can be determined by systems with which they interfere, hence the rationale for the common PHY and the ability to quantify interference as it occurs on a per burst basis.

(4) Every Subscriber Station and Base Station contains an Interference Table in which is registered the RF emission characteristics, locations, and identities (as IP addresses, SS_ID, BS_ID, etc.) of all the interferers that the SS or BS have ever detected. The table also contains an indication as to whether the interference has been resolved by the Coexistence Protocol (CP) or not. These tables also contain the statistics pertaining to the interference detected, such as its frequency of occurrence, mean RSSI, etc.

(5) Every Subscriber Station and Base Station uses a special series of MAC and CP messages to resolve and indicate interference. The MAC messages are specifically for interference detected at the Subscriber Station and are called BS_CCID_IND and BS_CCID_RSP. These messages detail foreign BS interference detected by the SS. The Coexistence Protocol messages are specifically for interference detected at the Base Station and are called SS_CCID_IND and SS_CCID_RSP. These messages detail foreign SS interference detected by the BS.

There are 4 interference scenarios seen by WirelessMAN-CX systems when they are in an Interference Neighbourhood. It is assumed co-channel interference is at a nominal level where it is capable of being demodulated; it is detected. Interference below such levels, which is sporadic and changes with the variations in the propagation environment, is only occasionally detectable. It is assumed that the SSURF and BSD messages are received at S/N levels to make them at least occasionally detectable as interference. These scenarios assume the interference, when it occurs, is at least occasionally detectable and trigger the responses that are described (ie just one instance of sporadic interference will trigger a response). In more sophisticated control scenarios it will be possible to adjust the levels at which responses are triggered. For example, very occasional sporadic interference may not be worth considering and responses will be inhibited, as long as such unresolved interference is minimal.

Scenarios:

1. New interference is detected by a subscriber stations of one system with the interference generated by base stations of another system (the foreign system). Both systems are independent but form a Coexistence Community, (see Section 15.2.1.1 Definitions). The interference now generated, for example, can be of one in which a hidden SS which becomes exposed to the foreign BS because of some physical change in the coverage area; for example, the removal of a tree that once hid the affected SS or the erection of a metal clad building. This scenario can also happen when a new SS is installed. See Figure h C8.

2. New interference is detected by a base station which is a member of a Coexistence Community. This interference is generated by a foreign subscriber station which is also a member of the same community. This scenario is equivalent to the one discussed in (1) above, but from the BS perspective. The physical changes discussed in (1) could give rise to the scenario described here.

3. New interference is detected at the SS and originates from foreign base stations which are not members of the Coexistence Community of the SS. The SS and foreign BS are initially not Coexistence Neighbors in this scenario. Figure h C9 shows this scenario.

4. New interference is detected at the base station which originates from a foreign SS which in not a member of the Coexistence Community of the base station.. The foreign SS and its BS are initially not Coexistence Neighbors in this scenario. This is equivalent to scenario (3) but from the BS perspective.

Interference Resolution Process

Scenario 1 [Figure h C8]:

— Subscriber Stations have a SS Interference Table (Section 15.3.2.4 Table h 5). Additionally, each system in the Coexistence Community has a unique CMI associated with it. During the CMI of the foreign system, the interfering (foreign) BS transmits a downlink BSD message (Section 6.3.2.3.62) which is received as interference at the SS. Since it is new interference (caused by the removal of a tree, for example), the SS will demodulate the interfering BSD and extract its contents.

— Since the interference is new and the BSD from the foreign BS is not registered in the SS Interference Table, the SS will then create a new entry in the table for the foreign BS, labeling it as new unresolved interference. The SS then sends a BS_CCID_IND message to its home BS, indicating the identity of the interfering BS.

Since the interfering BS is part of the Coexistence Community, the home BS will have negotiated non-interfering intervals between itself and the interfering BS (this being done previously via the Coexistence Protocol — See 15.2.1.1.2). If this were not the case, the two base stations would negotiate scheduling via the CP protocol. This undertaken successfully, the home BS will then schedule downlink transmissions directed to the reporting (interfered-with) SS to a time interval that is free of downlink interference from the interfering BS. This being done, the BS then sends a BS_CCID_RSP message to the SS, indicating that interference is resolved (this actually meaning that the BS transmissions to the SS will not be interfered because of scheduling).

— The SS, on receiving the BS_CCID_RSP from its BS, now assumes that downlink interference has been resolved. The SS then updates its SS Interference Table and will not send BS_CCID_IND messages whenever it detects the BSD of foreign BS. The SS will only listen for its downlink messages only during specifically scheduled intervals within the downlink subframe which are interference free and to which it has been assigned by its home BS.

Scenario 2.

— All Base Stations have a BS Interference Table (Section 15.3.2.4 Table h 3). Additionally, each WirelessMAN-CX system in the Coexistence Community has a unique CMI associated with it. During the CMI of the foreign system the interfering (foreign) SS transmits an uplink SSURF message (See 6.3.2.3.63) which is received as interference at the BS. The SSURF contains information about the identity of the interfering SS and the BS which controls it.

— The interfered-with BS compares this information with the information it has in its BS Interference Table. The BS will determine that (a) the interference is from a new interfering SS and (b) that the interfering SS is registered to a system which is a known Coexistence Neighbor. Since both WirelessMAN-CX Systems are Coexistence Neighbors, they have interference free intervals scheduled amongst themselves. A SS_CCID_IND message is then sent by the interfered-with BS to the BS controlling the interfering SS, indicating a need to resolve the uplink interference. This message is sent via the backbone IP network; usually to the proxy IP address of the interfering BS (this address being registered in the Interference Tables).

— The BS of the interfering system, having received a SS_CCID_IND message realizes that one of its SS is causing unresolved interference. Since this interference is being caused to a Coexistence Neighbor system with which interfering-free scheduling exists; the interfering BS schedules that particular SS to only transmit during non-interfering intervals.

— A SS_CCID_RSP message is sent back via the IP backbone to the interfered-with BS, indicating a resolution of the uplink interference and that the SS causing the interference is scheduled only to transmit on the uplink during previously negotiated non-interfering intervals.

— The BS Interference Table at the previously interfered-with BS is updated to show the resolved status and the interference is deemed resolved. The interfered-with BS will now not send SS_CCID_RSP messages when it receives SSURF from the interfering SS.

Scenario 3 [Figure h C9]:

— Interference from the foreign BS will be detected at the SS during the CMI of the foreign BS. Since the foreign BS (and its system) is not registered as a known interferer to the SS (by not being in the SS Interference Table), the SS will then create a new entry in the table for the foreign BS. By using the proxy IP address of the foreign BS extracted from the BSD of the foreign BS, the interfered-with SS sends a BS_CCID_IND message to its home BS thus indicating the identity of the interfering BS. At this point the interference is registered as detected and unresolved by the SS.

— The foreign BS is considered as an Interference Neighbour by the home BS. The home BS on receiving the BS_CCID_IND then contacts the interfering BS via the IP and initiates the Coexistence Protocol (CP) between the two BS. The negotiation necessitates the creation of a downlink slot which the interfering BS can use without interfering the SS. The home BS also needs to reschedule its downlinks also to accommodate this change. The process can result in changes to EIRP and scheduling and the creation of spatial isolation (if smart antennas are used), for example.

— On completing a successful CP negotiation the home BS will schedule its downlink messages to the SS during the interference free intervals. The interfering BS will accommodate this by appropriated modifying (or ceasing) its downlink transmissions during such intervals. A BS_CCID_RSP message is sent to the SS by the home BS, indicating a resolution of the interference.

— The SS, on receiving the BS_CCID_RSP from its BS, now assumes that downlink interference has been resolved. The SS then updates its SS Interference Table and will inhibit any further interference responses due to detection of the foreign BS's BSD messages. The SS now has specific downlink intervals in which it will look for traffic destined to itself. All other intervals are ignored.

— As a consequence of this process, the formerly interfering BS is now a member of a Coexistence Community that includes both BSs. Both BSs update their BS Interference Tables so that new interference can be more easily resolved now that the CP has established interference free intervals for the BSs.

Scenario 4:

— Interference from the foreign SSURF will be detected during the interfering system's CMI. Interference is detected at the BS.

— The SSURF message will be decoded by the BS which will determine that the interference originates from a system not registered in its BS Interference Table. The proxy IP address of the foreign BS controlling the interfering SS is derived from the SSURF. The interfered-with BS sends a SS_CCID_IND message to the foreign BS indicating that interference was received from its SS, thus there is a need to negotiate uplink coexistence.

— Both BS undertake the Coexistence Protocol and mutually determine interference free uplink slots which the foreign SS can use. The interfered-with BS will also modify (or altogether cease) its use of these slots for its uplink traffic

— On completion of the CP, both BSs update their Interference Tables to contain the characteristics of each other, such as location, IP address, emission characteristics, etc.

— The two base stations and their associated SS are now members of a Coexistence Community.

— The interfering BS sends a SS_CCID_RSP message via the IP backbone; indicating that it has completed its rescheduling, and that the interfering SS is now only transmitting uplink data during non-interfering slots.

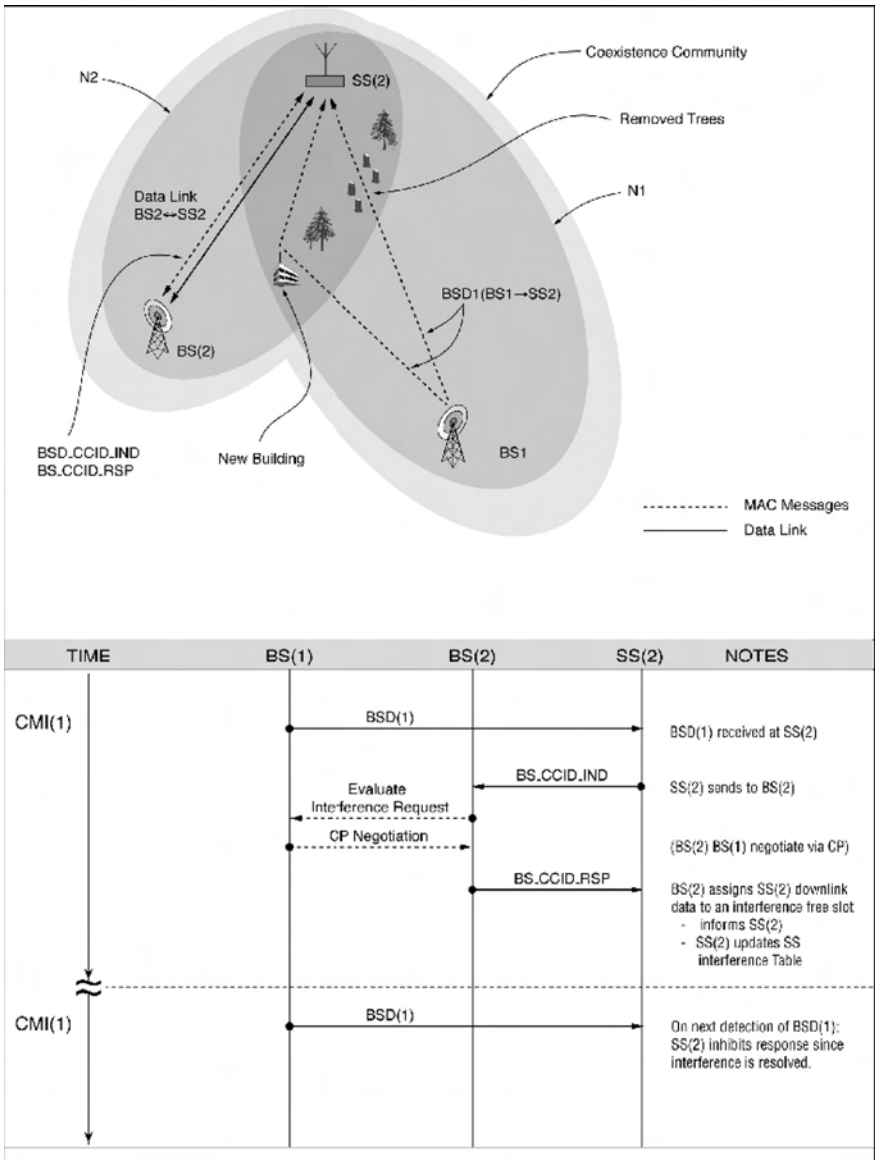


Figure h-C8—BS_CCID_IND BS_CCID_RSP procedure case 1

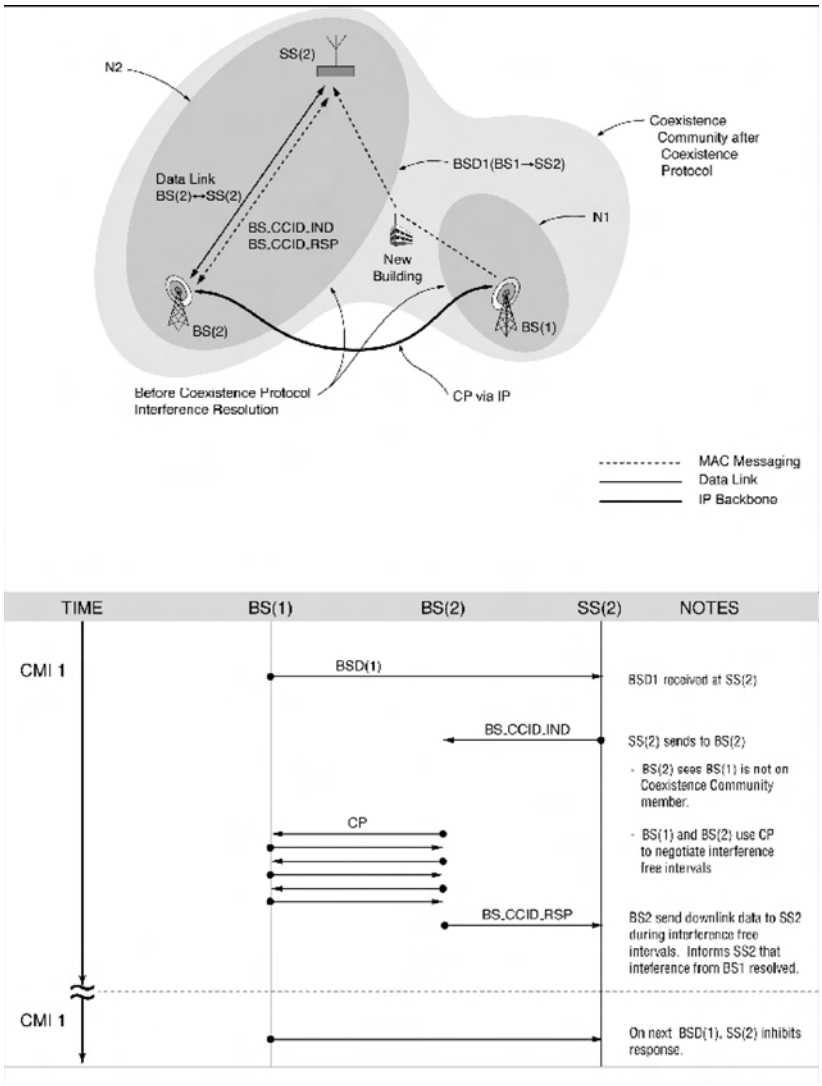


Figure h-C9—BS_CCID_IND BS_CCID_RSP procedure case1