Title: 802.16h main concepts, as reflected by IEEE 802.16-05/22

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Purpose:

802.16h main concepts, as reflected by IEEE 802.16-05/22

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Head-ups

- This presentation reflects the draft IEEE 802.16h standard, as contained in the document:
  - IEEE 80216h-05/022
- The security part is not detailed here
  - Security of communication needed for BS-BS and BS-BSIS (BS Identification Server)
- The content of the draft may change during further work

IEEE 802.16h – LE Task Group PAR

- PAR - Title
  - Improved Coexistence Mechanisms for License-Exempt Operation
- PAR - Scope
  - To specify improved mechanisms, as policies and MAC 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
  - Un-coordinated operation (may be regulatory licensed or license-exempt bands) in all the bands in which 802.16-2004 is applicable:
- More info: http://grouper.ieee.org/groups/802/16/le/index.html

Basic Mechanisms - 1

- Defined inside of a “Coexistence Community”
- ACS – Adaptive Channel Selection
  - Coexistence Protocol for managed systems
  - Radio signaling for ad-hoc systems
- Scheduling of interference- free zones in a MAC frame
  - Set of possible rules for initial allocation (for managed systems)
  - Radio signaling for ad-hoc systems
  - Negotiation protocol for flexible interference-free sub-frames assignments

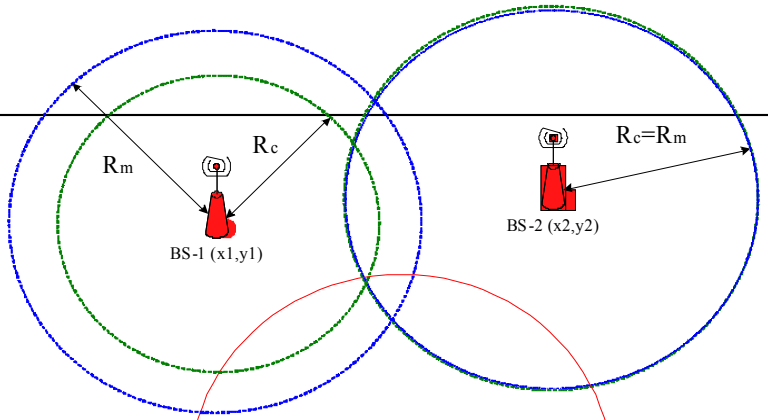
Basic Mechanisms - 2

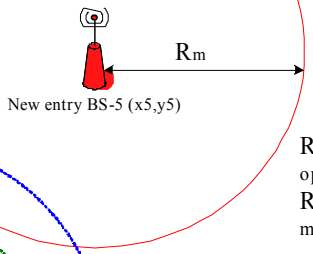
- Interferer identification
  - Using the radio signature at known absolute time
  - Interference-free transmission
  - Allows Power Spectral Density measuring
- Interaction with Ad-hoc systems
  - Ad-hoc systems have to avoid creating interference
  - Simple signaling to mark the “reservation” intervals and announce the scheduling of future transmissions
- Coexistence protocol
  - To control the system functionality
- Coexistence time slot for IP address transmission
  - Energy pulses
  - Sub-frequency pulses

Basic Mechanisms - 3

- Network Architecture
  - Distributed
- Base Station Identification Server
  - BS GPS position
  - BS IP address
  - BS Operator information
  - BS Radio Signature scheduling info
  - BS electrical info: power, etc
- Security
  - IP Sec
  - Key Distribution - Radius

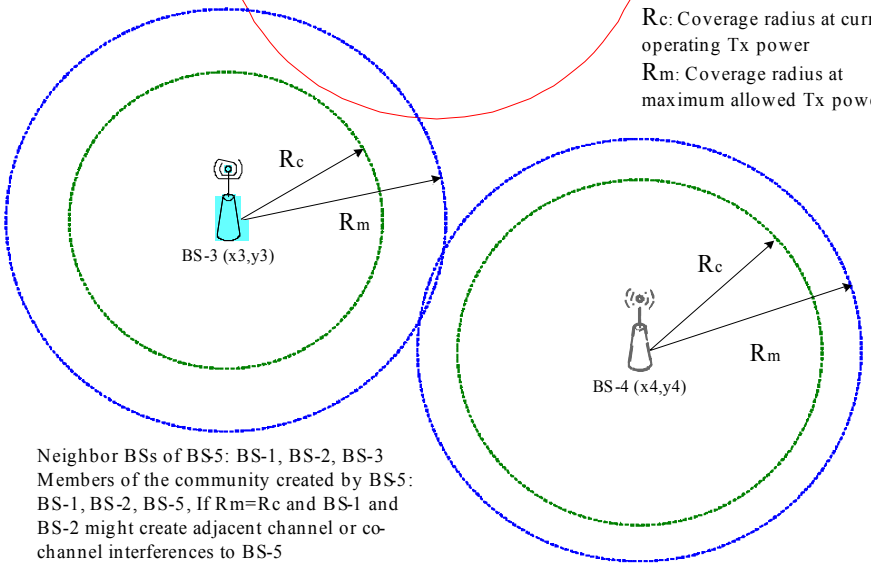
Coexistence Community





BS5 Community

Rc: Coverage radius at current operating Tx power
Rm: Coverage radius at maximum allowed Tx power



Neighbor BSs of BS-5: BS-1, BS-2, BS-3
Members of the community created by BS-5: BS-1, BS-2, BS-5, If Rm=Rc and BS-1 and BS-2 might create adjacent channel or co-channel interferences to BS-5

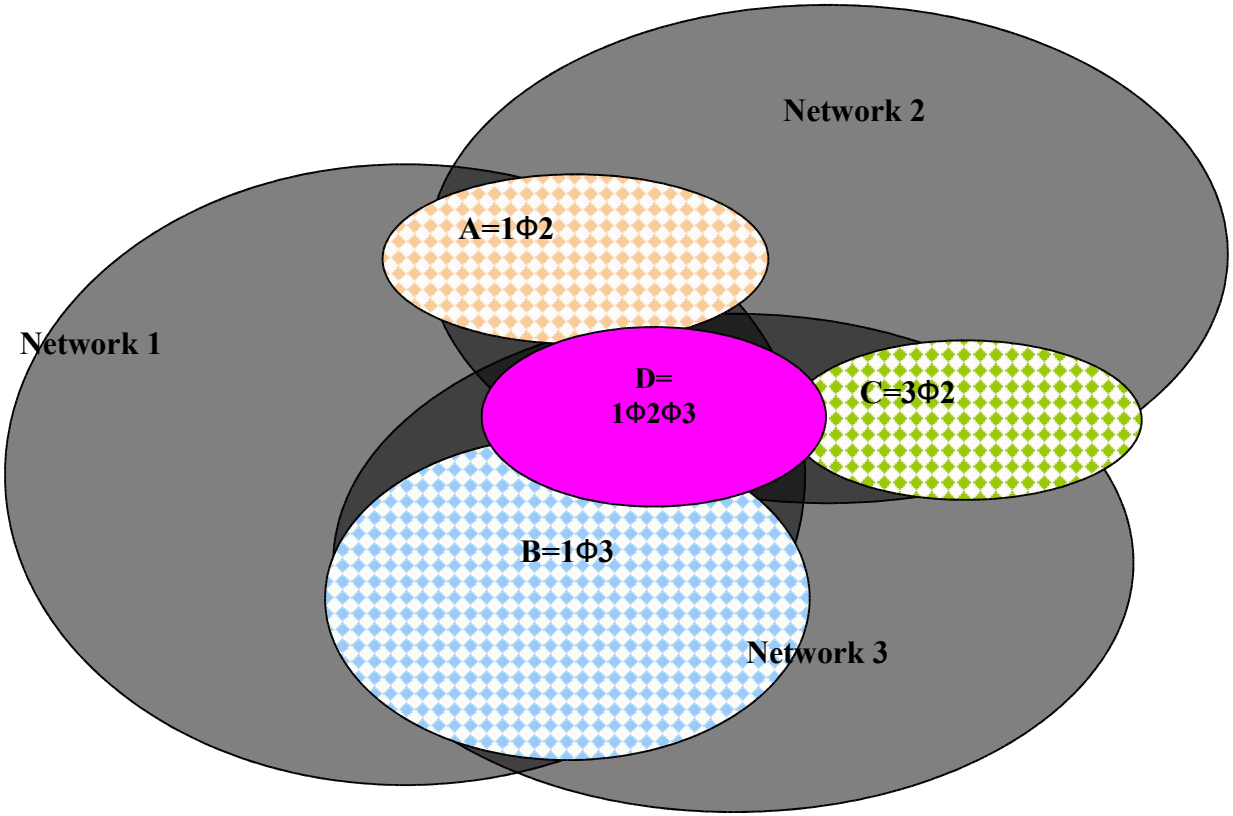
Community entry alternatives

- Two possible process
  - Potential “Master” systems
    - Using the GPS, etc. info in the Coexistence Data Base and the Coexistence Protocol
    - The IP Address of a new BS may be transmitted in the Coexistence TS, using simple signaling (energy pulses in time or frequency domain)
    - Interference assessment based on RF signature
  - Ad-hoc systems
    - Using signaling in the frequency domain
    - Always will be “slaves”

Neighborhood: discovery and maintenance

- Discovery of “neighbors”
  - The new BS asks the “Coexistence Server” to provide the GPS locations of neighbor Base Stations
    - The “Coexistence Server” includes the BS data base
  - Calculate, based on LOS propagation, the possible interferer area and forms it own “interference community”
    - Due to co-channel operation
    - Due to adjacent channel operation
- Maintenance of “coexistence neighborhood
  - The “neighbors” may change when a new BS comes into neighborhood or were the operating frequencies are changed

Interference example

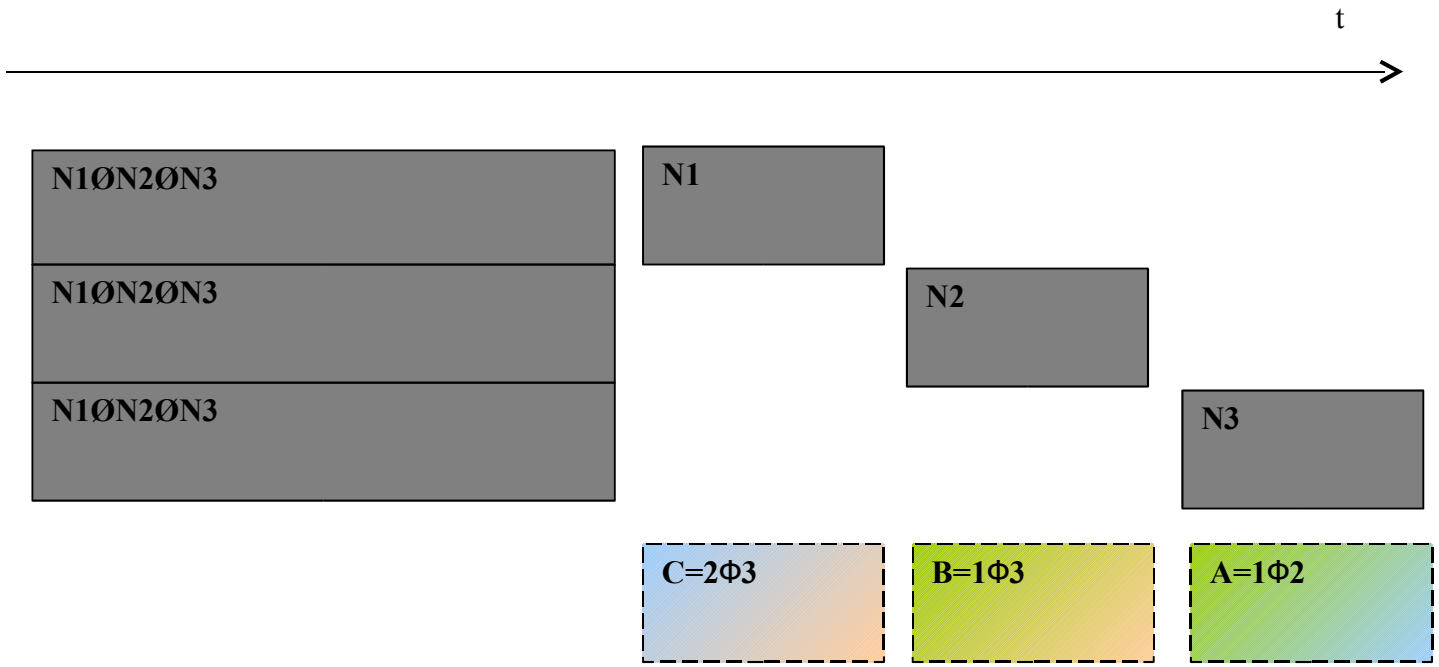


Legend:

Network i

Sub-network j, k not interfering with Network i

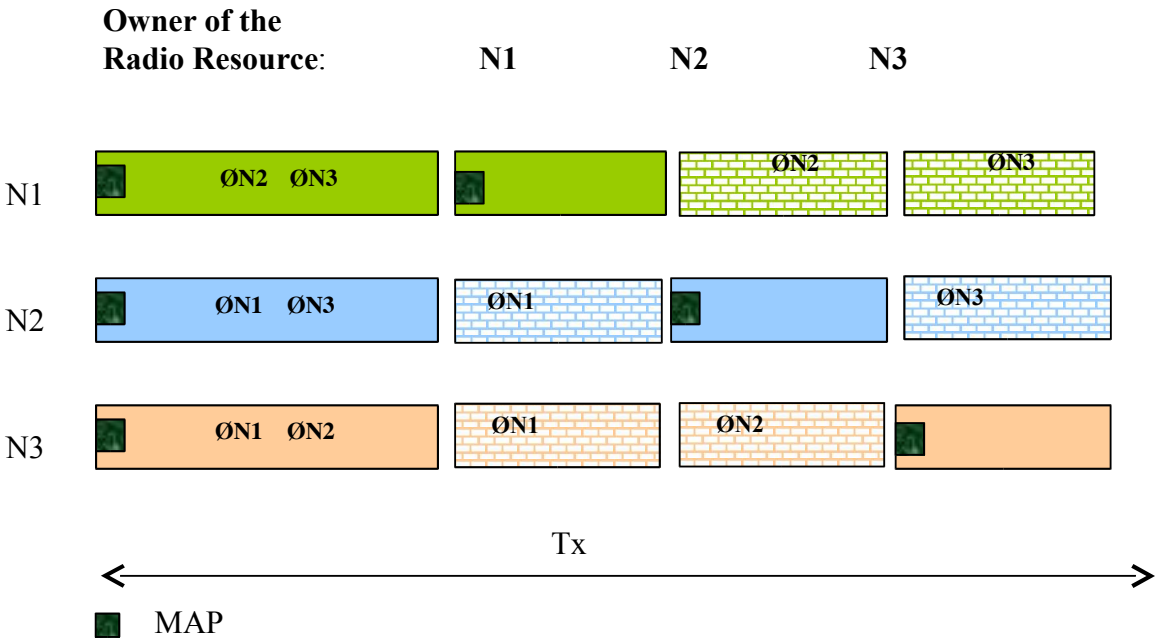
Traffic scheduling



:Conclusion

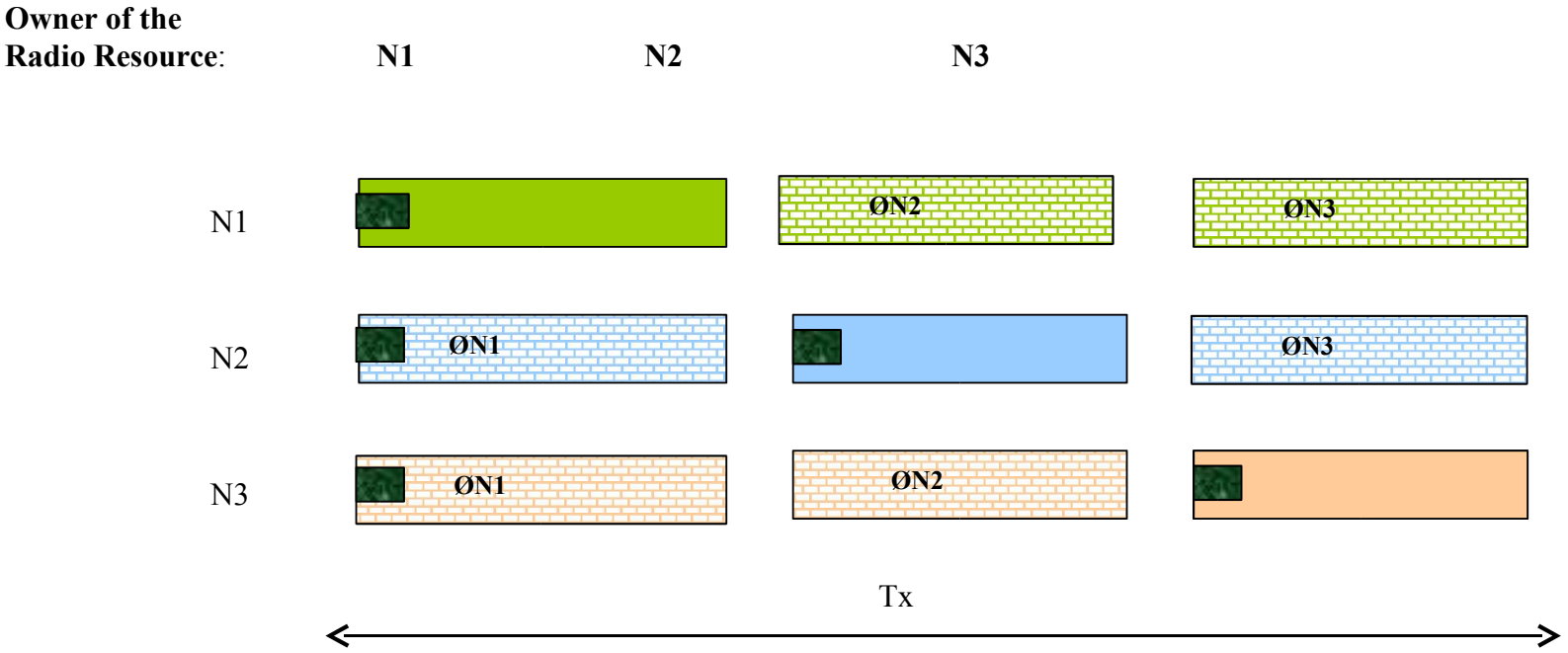
Every system may use 100% of spectrum, with !!!interference avoidance

Scheduling in context of 802.16 – MAC frame



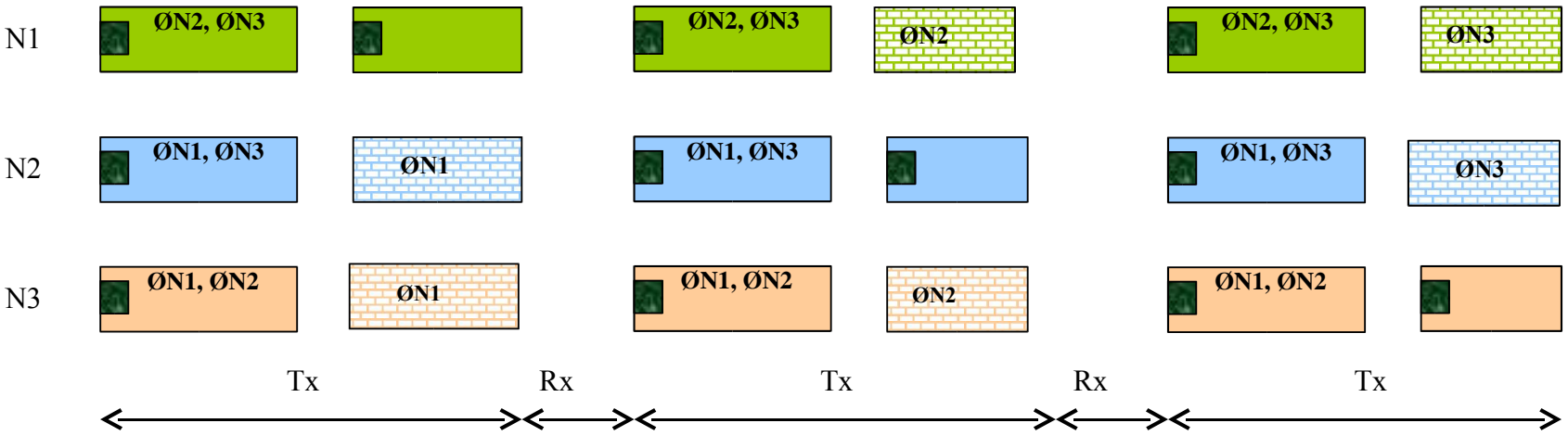
Example: the maximum granted time-frame to be used may be 40% at medium power (non-interference zone) and 20% at maximum power

Scheduling in context of 802.16 – MAC frame, alternative approach



Example:the minimum time to be used is 33% at any power

Scheduling in context of 802.16 – repetitive MAC Frame



Example for granted times:

- 60% maximum power and 40% average power / frame
- 20% maximum power and 40% average power in a multi-frame

Scheduling the interference free intervals

- Sharing the same MAC frame, first approach
  - Disadvantage: long MAC frame duration
  - Advantage: better multiplexing in time
- Sharing the same MAC frame, alternative approach
  - Advantage: suitable for high-interference environment
  - Disadvantages: long frame duration - All BSS-SS links suffer from high delay
- Repetitive sharing
  - Advantage: short MAC frame duration, easier to negotiate the splitting between the common grant and the grant per network, in a frame
  - Disadvantage
    - links affected by interference have long delays
- Who decides?
  - The operators in the covered area

Community entry process for BS

- Listen phase
  - Identify the interference on all possible frequency channels and sub-frames
- **Real-time, adaptive** channel and sub-frame selection
  - Chose the operation frequency with minimum interference
  - Select a minimum-interference sub-frame
  - Announce all the Base Stations using the sub-frame as Master to **listen** the Radio Signature and **asses the level of interference**
    - maximum power, maximum power density and in all the used directions;
    - Dedicated time-slot, no other transmitter will operate
  - Ask for permission to use the sub-frame
  - If permission NOT granted, try another frequency channel and/or another sub-frame
- If not possible to find one, ask for creation of a new Master sub-frame

Community entry process for SS

- Listen phase (frequencies, sub-frames)
  - Assume that the interference is reciprocal;
  - Build database for possible working 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;*
- Interference assessment phase
  - 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 its Base Station to *find another sub-frame for its operation.*

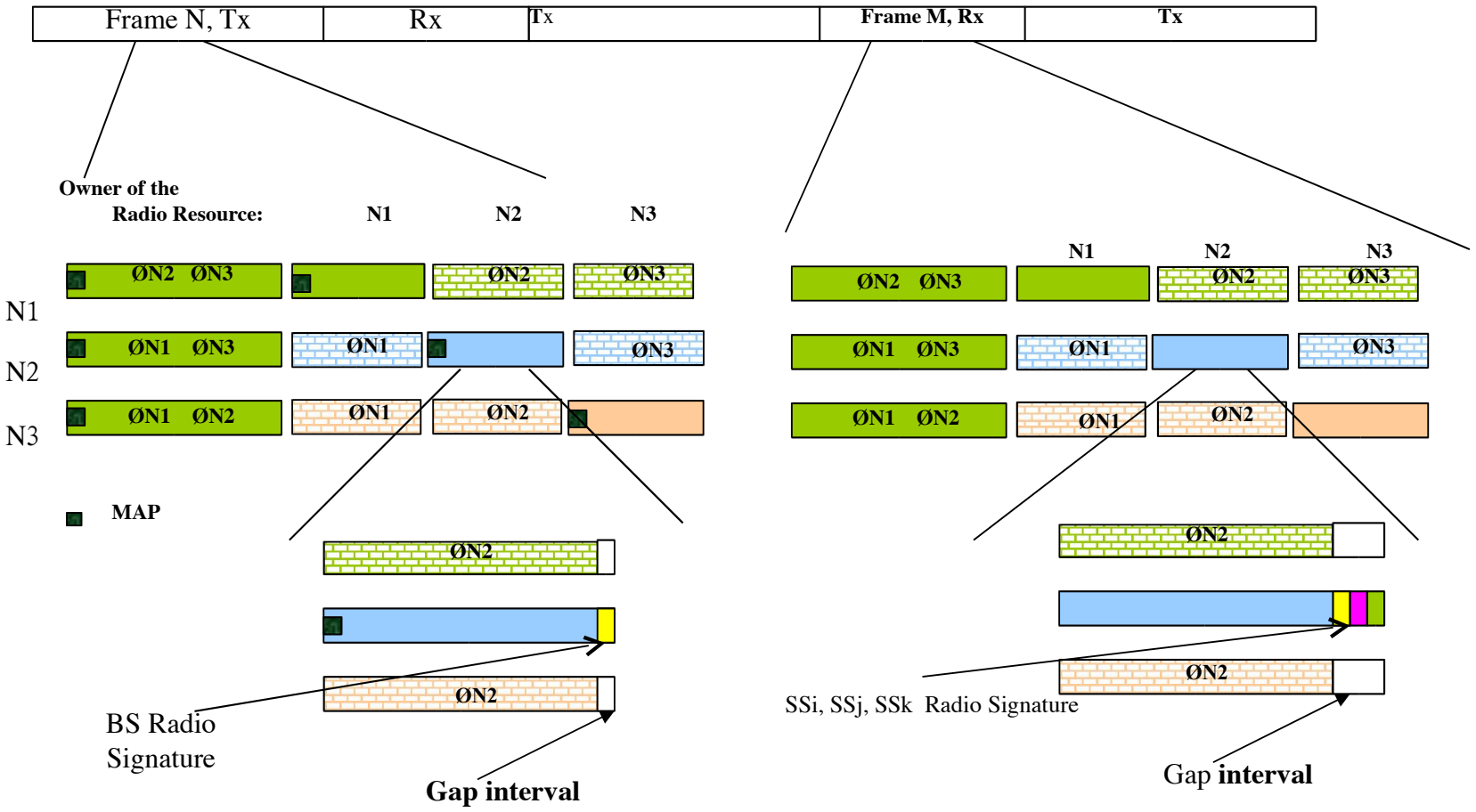
Creation of a new sub-frame

- Requesting BS to send IP messages to all BS members of the community, and indicate:
  - 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 BSs 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

Interferer identification

- The interferers will be identified by their radio signature, for example a short preamble for OFDM/OFDMA cases
- The radio signature consists 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 particular transmissions times are kept in the BS-data bases.

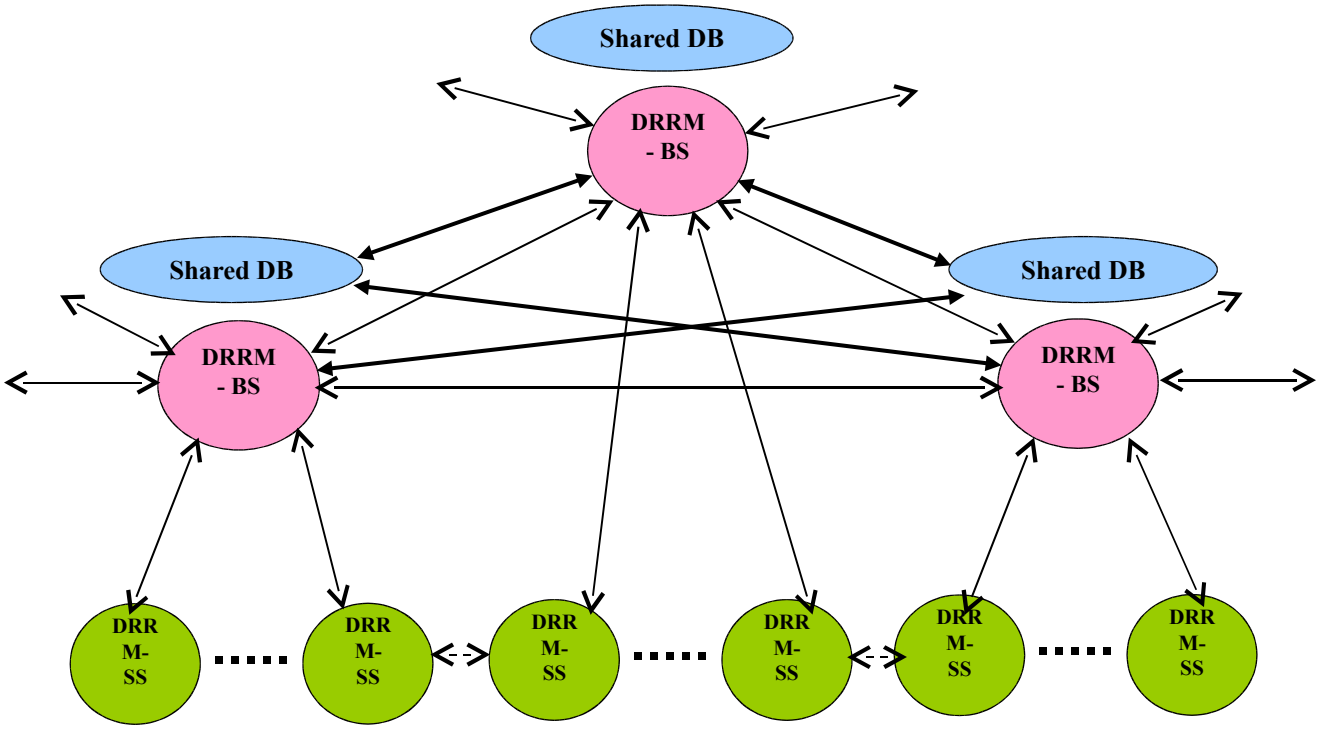
Sending the Radio Signature



Controlling interference during Master sub-frames

- A BS can request slave systems to reduce their power/ stop operating during its Master sub-frames
- The Base Station data base shall keep the following information regarding the usage of 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:
  - Reduce_Power_Request
  - Stop_Operating_Request

802.16h network architecture



Inter-BS communication

SS-SS Communication

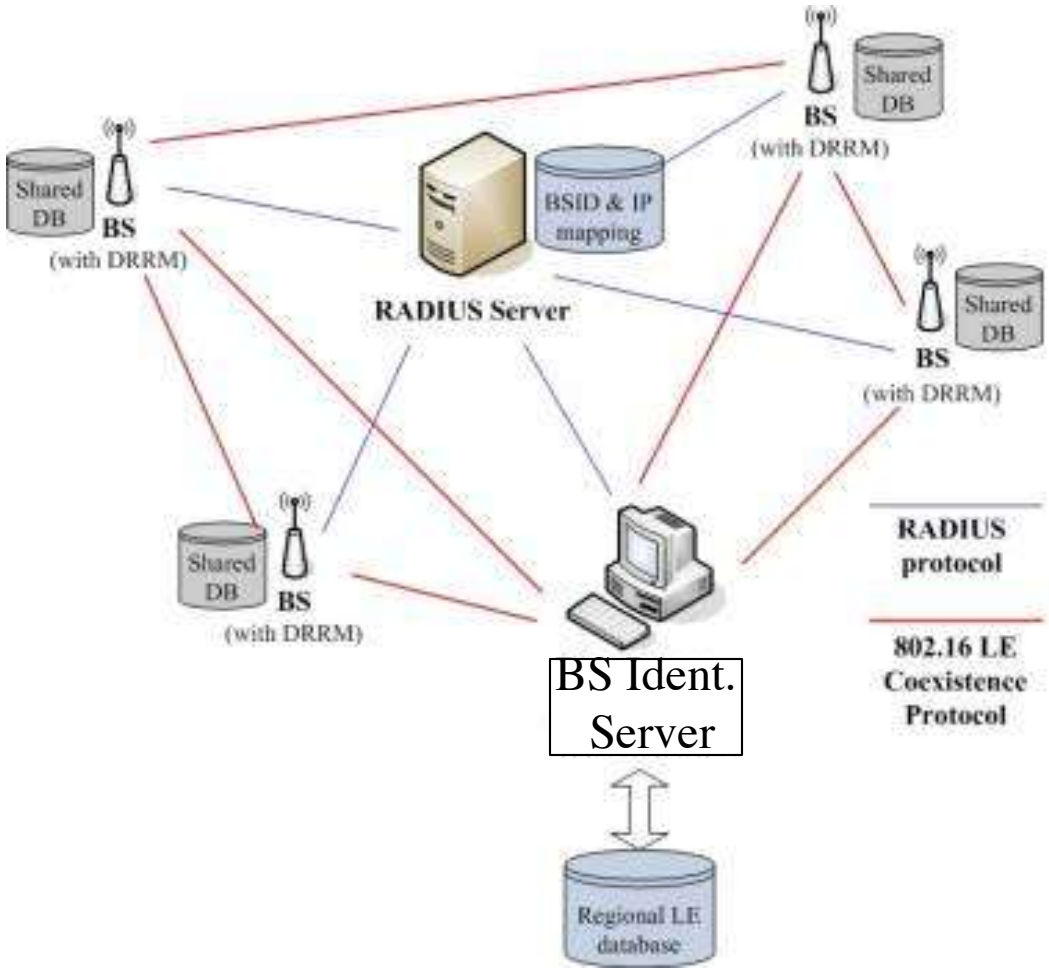
BS to Shared Data Base Communication

Inter-BS communication

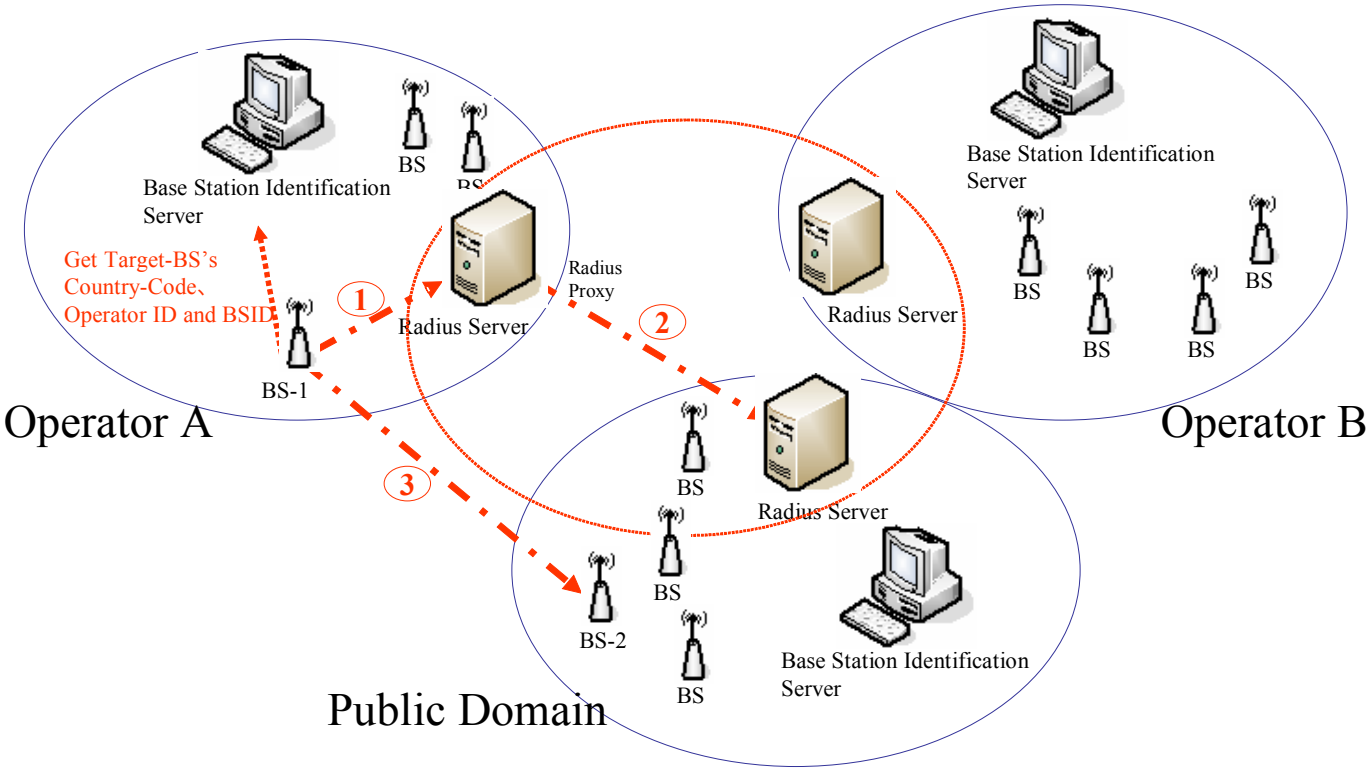
DRMM – Distributed Radio Resource Management

MIB – Management Information Base

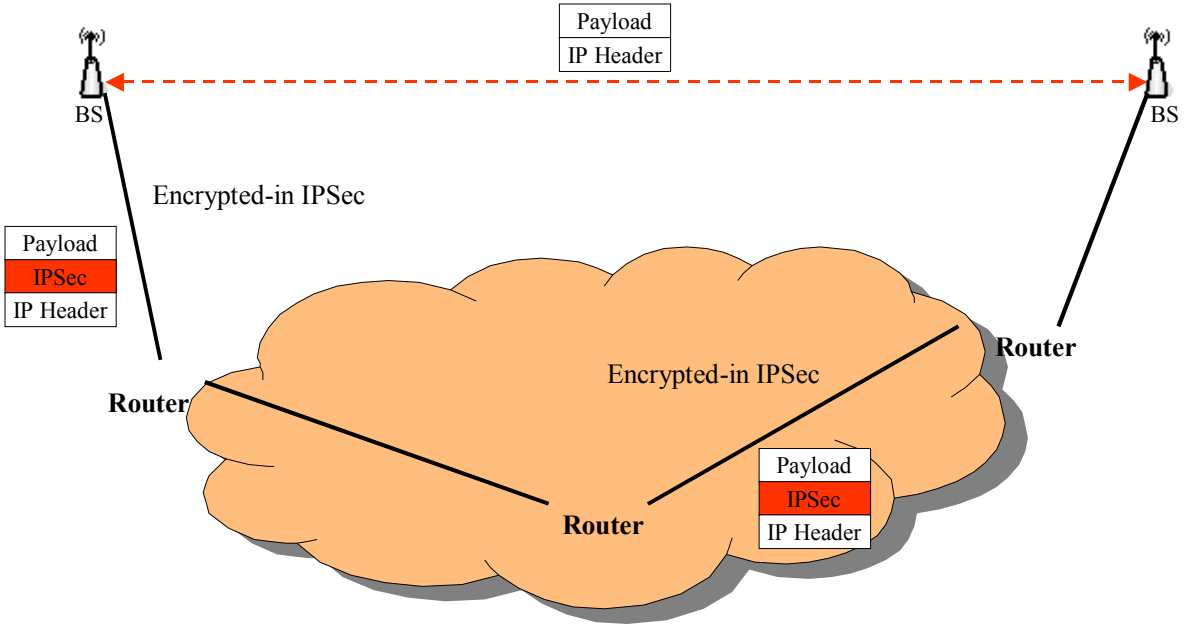
802.16h inter-network communication and Security architecture



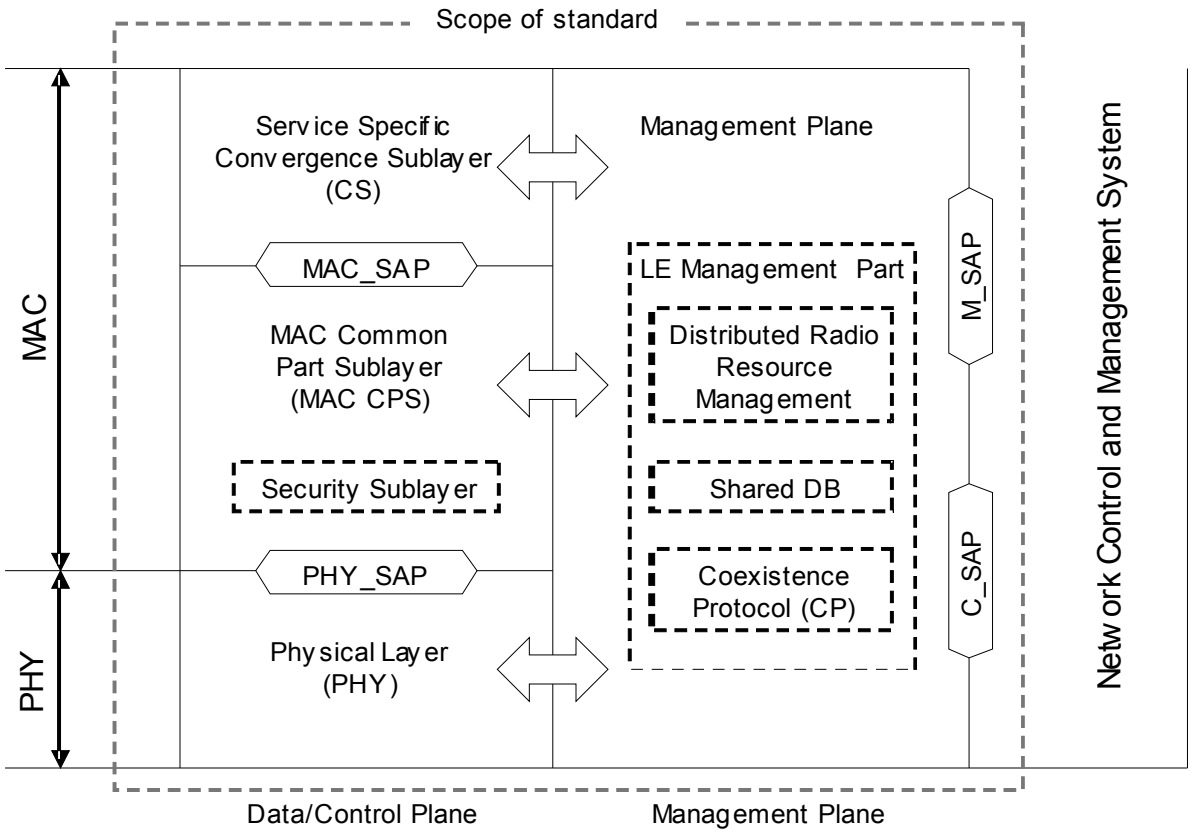
Network architecture for multi-operator and multi-Radius Servers



Encryption of Information



Base Station Protocol Architecture

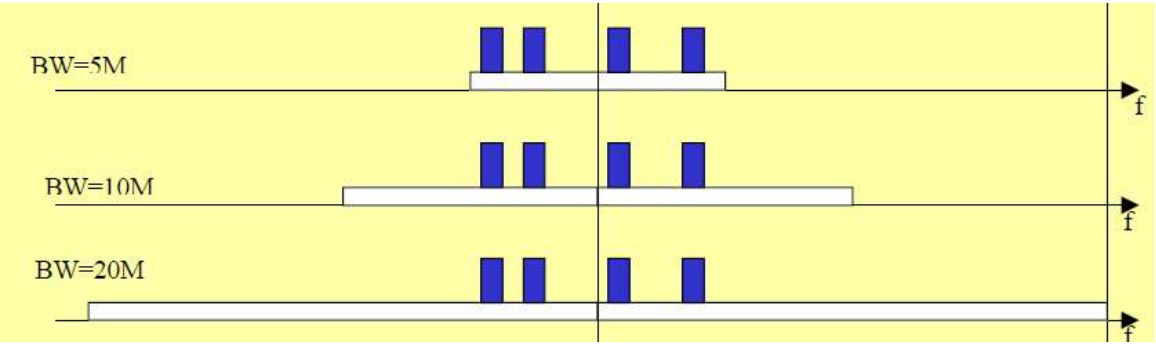


Ad-hoc systems registration to Community

- Systems already registered to a Community, BS and RS (Repeater) using will transmit in:
  - MAC Frame N:
    - Signals to reserve MAC frame Tx/Rx intervals by indicating:
      - MAC Tx_start, MAC Tx_end, MAC Rx_start, MAC Rx_end
    - the MAC frame N is indicated in the BS data-base and these procedures will repeat after Ncogn MAC frames;
  - MAC Frame N+1:
    - Signals to 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
  - MAC Frame N+2:
    - will be indicated the position of the time-slots Master sub-frames, to be used starting with the MAC Frame N+3 for registration. The start of the "Rx_slot" signal will indicate the start of the slot.

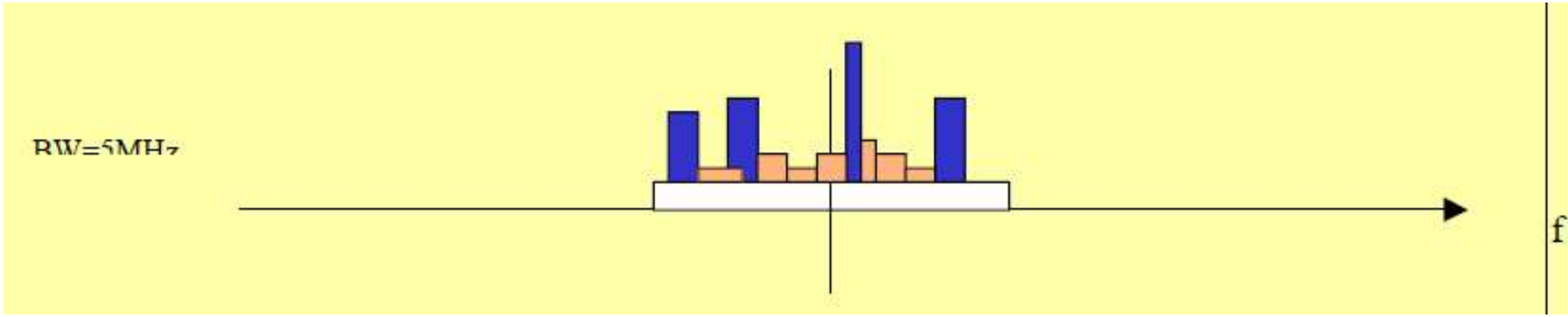
Signaling

- Split the narrowest channel to be used (as defined in 802.16 Profiles) into 32 energy bins, as follows:
  - For 256FFT, to 8 sub-carriers/bin
  - For 512 FFT, to 16 sub-carriers/bin
  - For 1024FFT, to 32 sub-carriers/bin
  - For 2048FFT, to 64 sub-carriers/bin.



Message sending

- Send an 802.16h MAC message
  - the MAC header will use 1 symbol and the MAC PDU will use another symbol;
  - the power distribution for different bins will be with at least 5dB higher for a bin marked in Table 1x with “H” than for bin marked with “L”.
  - May be needed to disable the interleaver



Message coding

Bin number /Signal number	**6**	**8**	**10**	**12**	**14**	**18**	**20**	**22**	**24**	**26**
1 (802.16h Cognitive MAC 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 (CTS_Start)	H	L	L	L	H	L	H	L	L	H
8 (CTS_Continuation)	L	H	H	L	L	H	L	H	L	L
9	L	L	H	H	L	L	H	L	H	L

Ad-hoc systems registration to Community - cont

- Ad-Hoc systems
  - MAC frame N+4 – to be used by ad-hoc transmitters for sending their radio signature
- Master systems
  - Send NACK signals if are interfered by Ad-hoc systems
- Ad-Hoc systems
  - If allowed to use the Master sub-frame, start operating
  - If not, look for another frequency and another sub-frame

Using signaling to transmit the IP address of a new Base Station

- IP address is used for BS communication with other BSs in Community
  - If there is a BSIS, a new BS can initiate the communication
    - Transmitting the IP address by signaling is NOT needed
  - Use the Coexistence Time-Slot
    - Interference free
- 2 methods:
  - Energy pulses in time domain
  - Energy pulses in frequency domain

IP address transmission using energy pulses in time domain

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

IP address transmission using energy pulses in frequency domain

- Transmission is done in consecutive coexistence time slots, every NIptx MAC frames.
- First CTS in the series starts with CTS start signal,
- Next CTS starts with CTS_Continuation
- IP identifier of the BS and a 8bit CRC:
  - Uses only the bins 6,8,10,12,14,18,20,22,24,26 (10bits / symbol), the L.S.B. corresponding to the lowest frequency

Coexistence Protocol Messages - 1

1	Identify Coexistence Request	LE_CP-REQ	TCP	BSIS->BSIS
2	Identify Coexistence Response	LE_CP-RSP	TCP	BSIS->BSIS
3	CoNBR Topology Request	LE_CP-REQ	TCP	BS-> BSIS
4	CoNBR Topology Reply	LE_CP-RSP	TCP	BSIS->BS
5	Registration Request	LE_CP-REQ	TCP	BS-> BSIS
6	Registration Reply	LE_CP-RSP	TCP	BSIS->BS
7	Registration Update Request	LE_CP-REQ	TCP	BS-> BSIS
8	Registration Update Reply	LE_CP-RSP	TCP	BSIS->BS

Coexistence Protocol messages - 2

9	De-registration Request	LE_CP-REQ	TCP	BS-> BSIS
10	De-registration Reply	LE_CP-RSP	TCP	BSIS->BS
11	Add Coexistence Neighbor Request	LE_CP-REQ	TCP	BS->BS
12	Add Coexistence Neighbor Reply	LE_CP-RSP	TCP	BS->BS
13	Update Coexistence Neighbor Request	LE_CP-REQ	TCP	BS->BS
14	Update Coexistence Neighbor Reply	LE_CP-RSP	TCP	BS->BS
15	Delete Coexistence Neighbor Request	LE_CP-REQ	TCP	BS->BS
16	Delete Coexistence Neighbor Reply	LE_CP-RSP	TCP	BS->BS
17	Get_Param_Request	LE_CP-REQ	UDP	BS->BS
18	Get_Param_Reply	LE_CP-RSP	UDP	BS->BS

Coexistence Protocol messages - 3

19	Evaluate_Interference_Request	LE_CP-REQ	UDP	BS->BS
20	Evaluate_Interference_Reply	LE_CP-RSP	UDP	BS->BS
21	Work_In_Parallel_Request	LE_CP-REQ	UDP	BS->BS
22	Work_In_Parallel_Reply	LE_CP-RSP	UDP	BS->BS
23	Quit_Sub_Frame_Request	LE_CP-REQ	UDP	BS->BS
24	Quit_Sub_Frame_Reply	LE_CP-RSP	UDP	BS->BS
25	Create_New_Sub_Frame_Request	LE_CP-REQ	UDP	BS->BS(MC?)
26	Create_New_Sub_Frame_Reply	LE_CP-RSP	UDP	BS->BS
27	Reduce_Power_Request	LE_CP-REQ	UDP	BS->BS
28	Reduce_Power_Reply	LE_CP-RSP	UDP	BS->BS
29	Stop_Operating_Request	LE_CP-REQ	UDP	BS->BS
30	Stop_Operating_Reply	LE_CP-RSP	UDP	BS->BS

Coexistence Protocol Messages - 4

31	BS_CCID_IND	LE_CP-REQ	UDP	BS->BS
32	BS_CCID_RSP	LE_CP-RSP	UDP	BS->BS
33	SS_CCID_IND	LE_CP-REQ	UDP	BS->BS
34	SS_CCID_RSP	LE_CP-RSP	UDP	BS->BS
35	PSD_REQ	LE_CP-REQ	UDP	BS->BS
36	PSD_RSP	LE_CP-RSP	UDP	BS->BS
37-255	*reserved*			

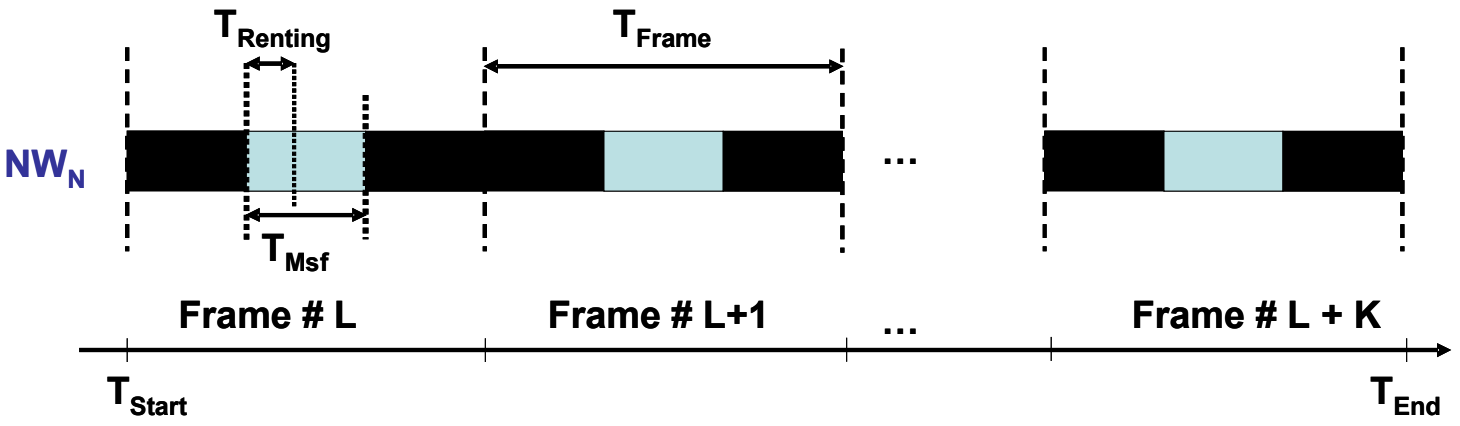
Coexistence Protocol Message Format

Syntax	Size	Notes
CP _Message_Format() {		
Version of protocol in use	4 bits	*1 for current version*
Code	8 bits	See table x
Management Message Type	16bits	- LE_CP-REQ - LE_CP-RSP
Length of Payload	16bits	
Confirmation Code	8 bits	0-OK/success 1-Reject-other 2-Reject-unrecognized-configuration-setting 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
}		

Negotiation of interference free intervals

- Credit Token based
- Allows to use the available interference-free zones
  - A Master may offer leasing for a given duration
    - advertise
  - A number of Slaves may bid
  - Every time-interval has a number of associated tokens
- Procedures to be defined

Leasing master time



Master NW Subframe

Slave NW Subframe

T_{Msf} Master NW Subframe duration

$T_{Renting}$ Master NW subframe duration for renting

T_{Frame} Time frame duration

Conclusion

- Protocol-based coexistence
  - Improve the coexistence beyond what masks or spatial isolation can do
  - Allow better spectral efficiency
  - Allow better QoS
  - Allow lower power consumption
- Multiple applications
  - 5.8GHz, 3.65GHz, TV bands
  - Licensed, but uncoordinated bands
  - Distributed radio resource management inside a system