Update on IEEE WirelessMAN-Advanced

IEEE 802.16 Working Group

2nd IEEE 802.16 IMT-Advanced Evaluation Group Coordination Meeting

17 May 2010

Beijing, China

Outline

- Updated Status of IEEE P802.16m Draft Standard
- Physical Layer Technology Updates
- MAC Layer Technology Updates
- References

Updated Status of IEEE P802.16m Draft Standard

Status of IEEE P802.16m Draft Standard

- IEEE P802.16m draft standard (Draft 5) is currently in Working Group Letter Ballot comment resolution
- All core and key functional features are completed
- Advanced features such as relay, femtocell, E-MBS, E-LBS, multi-carrier operation, multi-BS MIMO are fully specified
- Next step: Confirmation Ballot of Draft 6 and submission to IEEE for approval ballot, to be concluded by the end of 2010
- No impact as a result of updates on performance results submitted to ITU-R WP 5D
- Final approval of the standard is expected in Q1 2011

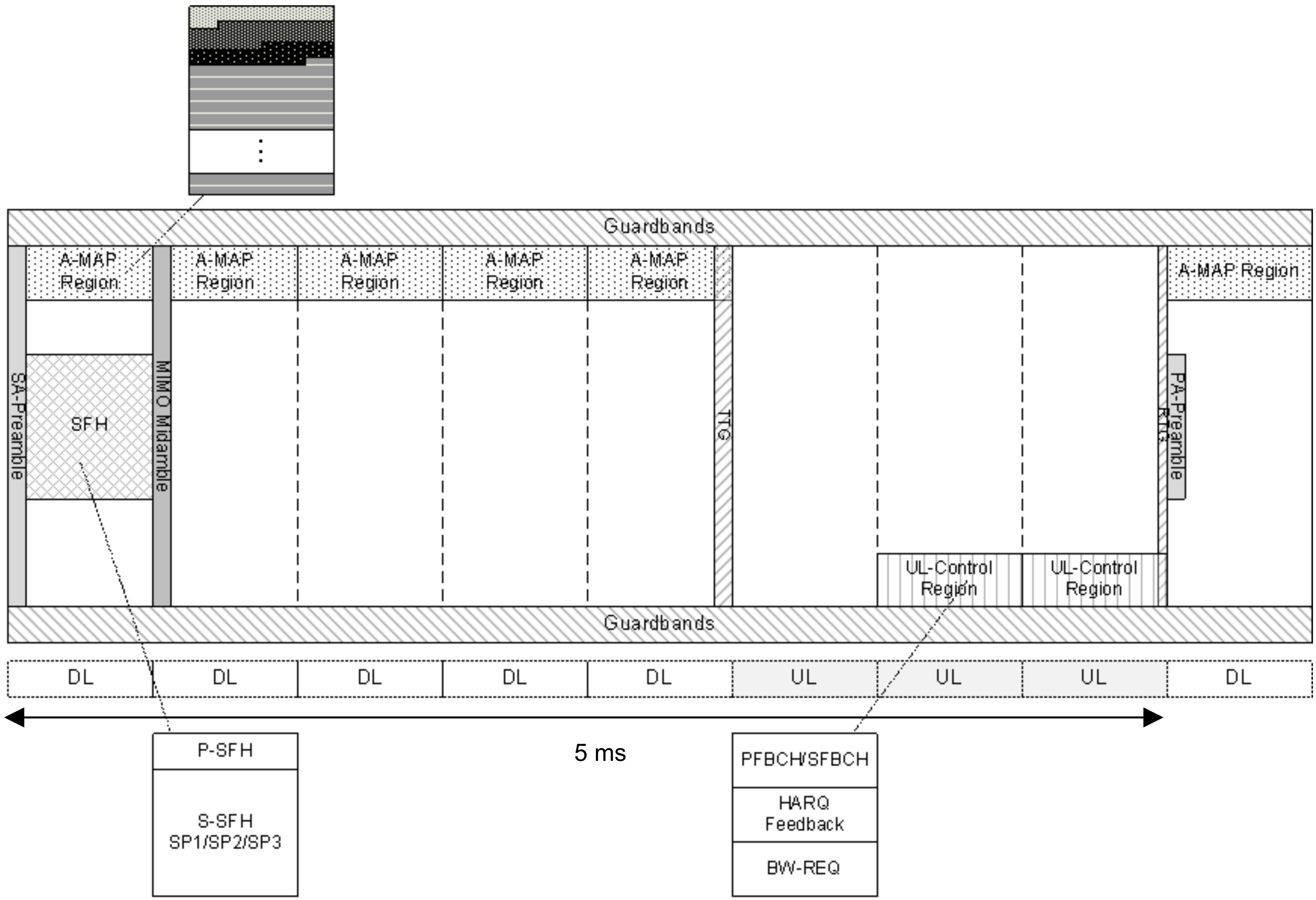
- See IEEE 802.16m Work Plan at IEEE 802.16m-10/0010

Physical Layer Updates

IEEE P802.16m DL/UL Control Channels

<table>
<tr><th></th><th colspan="2">Channels</th><th>Descriptions</th></tr>
<tr><td rowspan="11">DL</td><td rowspan="2">Preamble</td><td>PA-Preamble</td><td>Enable Timing/Carrier acquisition common to all BS’s.</td></tr>
<tr><td>SA-Preamble</td><td>256x3=768 preamble indices for Cell ID</td></tr>
<tr><td colspan="2">MIMO Midamble</td><td>MIMO channel estimation, CQI and PMI estimation
Low PAPR Golay sequence, and Reuse 3</td></tr>
<tr><td rowspan="2">SFH</td><td>Primary Super Frame Header</td><td rowspan="2">Essential system parameters and system configuration information.
Located in the first DL subframe of a superframe</td></tr>
<tr><td>Secondary Super Frame Header</td></tr>
<tr><td rowspan="4">A-MAP</td><td>Assignment A-MAP</td><td>Contain the information such as resource allocation/HARQ/ MIMO
Presents in every DL subframe</td></tr>
<tr><td>Non-User Specific A-MAP</td><td>Contain the resource allocation for Assignment A-MAP</td></tr>
<tr><td>HARQ Feedback A-MAP</td><td>UL HARQ ACK/NACK</td></tr>
<tr><td>Power Control A-MAP</td><td>Power control information</td></tr>
<tr><td rowspan="7">UL</td><td rowspan="3">UL Feedback Channel</td><td>Primary Fast Feedback</td><td>CQI & MIMO Rank</td></tr>
<tr><td>Secondary Fast Feedback</td><td>PMI & Band Selection</td></tr>
<tr><td>UL HARQ Feedback Channel</td><td>DL HARQ ACK/NACK</td></tr>
<tr><td rowspan="2">Ranging Channel</td><td>Non-Synchronized AMSs</td><td>Initial Entry and Handover</td></tr>
<tr><td>Synchronized AMSs</td><td>Periodic uplink time synchronization</td></tr>
<tr><td colspan="2">BW REQ Channel</td><td>3-Step fast & 5-Step robust uplink bandwidth request</td></tr>
<tr><td colspan="2">Sounding Channel</td><td>UL Channel Sounding</td></tr>
</table>

Illustration of IEEE P802.16m Overhead Channels



Updated Peak Spectral Efficiency

Parameter	TDD mode	FDD mode
Bandwidth, MHz	20	2x20 = 40
FFT Size, points	2048	
Cyclic Prefix Ratio	1/16	
Number of streams	DL: N_S = 4 streams UL: N_S = 2 streams	
Subframe types (w/o overhead symbols)	6 type-1 (6 symbols), 2 type-2 (7 symbols)	5 type-1 (6 symbols), 3 type-2 (7 symbols)
Number of physical resource units (PRUs)	N_{PRU} = 96	
Number of pilots per PRU	DL, 4 streams, subframe type-1: 16, DL, 4 streams, subframe type-2: 16 DL, 4 streams, subframe type-3: 16, UL, 2 streams, subframe type-1: 12 UL, 2 streams, subframe type-2: 14	
Number of data subcarriers per PRU for different subframe types	DL, 4 streams, type-1: $N_{Data-T1}$=18x6 – 16 = 92 , DL, 4 streams, type-2: $N_{Data-T2}$=18x7 – 16 = 110 DL, 4 streams, type-3: $N_{Data-T3}$=18x5 – 16 = 74 , UL, 2 streams, type-1: $N_{Data-T1}$=18x6 – 12 = 96 UL, 2 streams, type-2: $N_{Data-T2}$=18x7 – 14 = 112	
DL overhead symbols:	DL: One symbol for A-Preamble DL: One symbol for MIMO-Midamble	
DL:UL Ratio	1:1	NA
Number of symbols per subframe of the frame (with taking into account overhead)	DL: {1+5},7,{1+5},6 UL: 6,6,6,7	DL: {1+5},7,6,6,7,6,{1+5},7 UL: 6,7,6,6,7,6,6,7
Number of subframe types (with taking into account overhead)	DL: N_{SF-T1} = 1, type-1 subframes N_{SF-T2} = 1, type-2 subframes N_{SF-T3} = 2, type-3 subframes UL: N_{SF-T1} = 3, type-1 subframes N_{SF-T2} = 1, type-2 subframe	DL: N_{SF-T1} = 3, type-1 subframes N_{SF-T2} = 3, type-2 subframes N_{SF-T3} = 2, type-3 subframes UL: N_{SF-T1} = 5, type-1 subframes N_{SF-T2} = 3, type-2 subframes
Total number of data subcarriers per frame	$N_{DATA} = N_{PRU} (N_{SF-T1}N_{Data-T1}+N_{SF-T2} N_{Data-T2} + N_{SF-T3}N_{Data-T3})$	
	DL: N_{DATA} = 33600 = 96x(1x92+1x110+2x74) UL: N_{DATA} = 38400 = 96x(3x96+1x112)	DL: N_{DATA} = 72384 = 96x(3x92+3x110+2x74) UL: N_{DATA} = 78336 = 96x(5x96+3x112)
Coding rate, FEC_{RATE}	1 (uncoded transmission)	
MCS 64QAM, N_b, bit/symbol	6	
Frame Duration, T_{FRAME}, ms	5	
Peak Throughput Definition	$PEAK_{THR} = N_{DATA}\ N_S\ N_b\ FEC_{RATE}$	
Peak DL Throughput, Mbit/s	161.28	347.44
Peak UL Throughput, Mbit/s	92.16	188.01
DL Peak spectral efficiency, bit/s/Hz	16.13	17.37
UL Peak spectral efficiency, bit/s/Hz	9.21	9.4

Updated L1/L2 Overhead

Assumption	Overhead	Minimum Fraction of Radio Frame Resources	Maximum Fraction of Radio Frame Resources
10 MHz Bandwidth CP = 1/8 DL 2×2 Antenna Configuration	L1 Overhead	0.3104	0.3104
	Total Overhead (L1/ L2)	0.3532	0.4380
20 MHz Bandwidth CP = 1/16 DL 4×2 Antenna Configuration	L1 overhead	0.2824	0.2824
	Total overhead (L1/ L2)	0.3029	0.3441

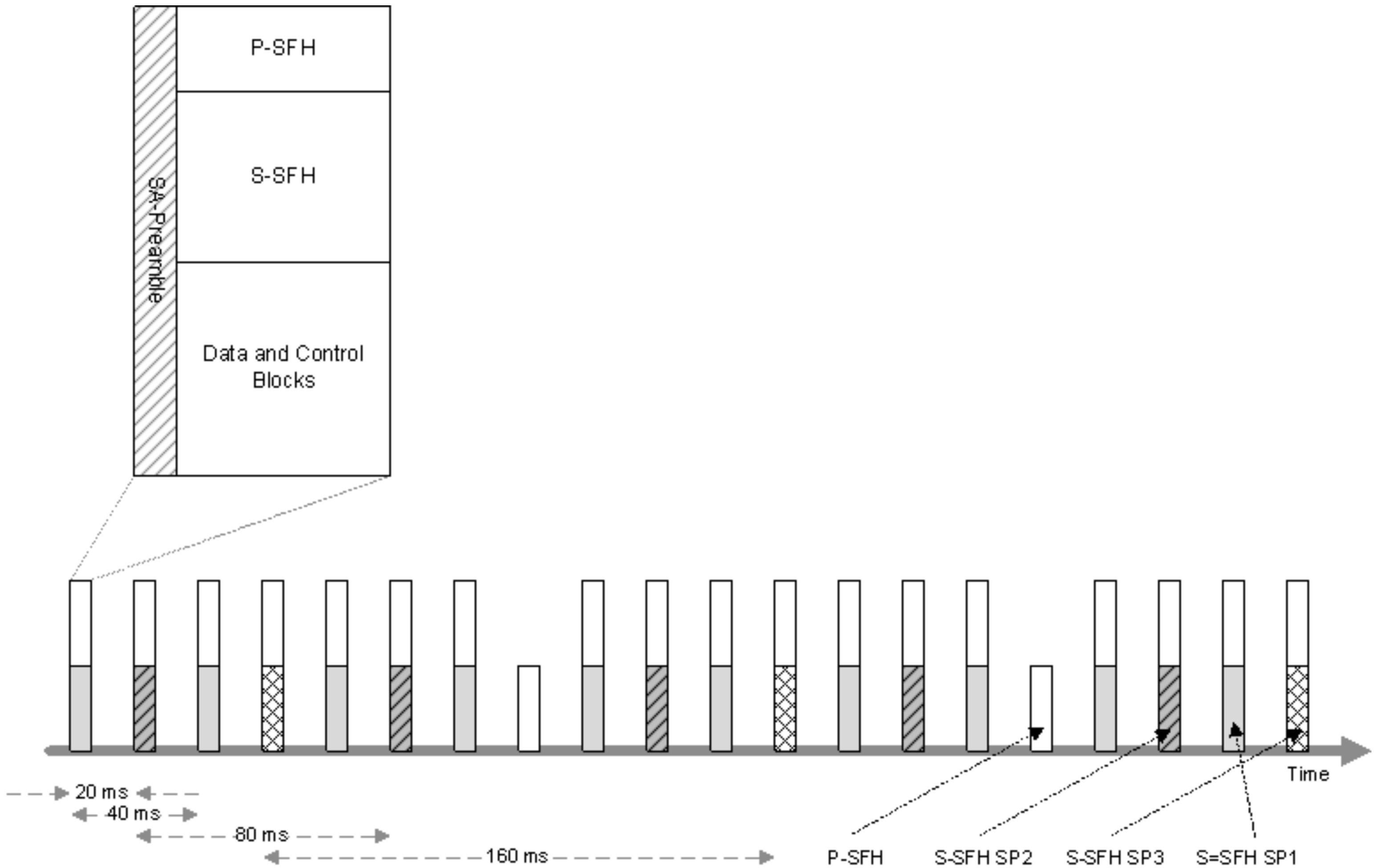
A-MAP Region

- An A-MAP region is composed of one or all of the following A-MAPs: non user-specific A-MAP, HARQ feedback A-MAP, power control A-MAP, and assignment A-MAP.
- There is one A-MAP region in the reuse-1 or highest-power reuse-3 frequency partition.
- An A-MAP region occupies a number of contiguous DLRUs.
- There is one A-MAP region in each DL subframe.
- Information in the A-MAP region is coded and transmitted using SFBC.
- If FFR configuration is used, either the reuse 1 partition or the highest-power reuse 3 partition may have an A-MAP region.
- In a DL subframe, non user-specific, HARQ feedback, and power control A-MAPs are in a frequency partition called the primary frequency partition.
- The primary frequency partition can be either the reuse 1 partition or the highest-power reuse 3 partition, which is indicated by ABS through SFH.
- SFBC used to transmit information in the A-MAP region

Superframe header (SFH)

- Superframe header transmitted with 20 ms periodicity
- Allocation size is limited in a rigid manner (5 MHz logical bandwidth)
- Transmitted in the first subframe of the superframe, fixed permutation (One frequency partition, all DRU) and always at start of the subframe.
- Contains P-SFH and/or S-SFH
  - Primary superframe header (P-SFH)
    - Always transmitted
    - Defines repetition of secondary SFH
    - ~20 bits, TBCC, QPSK with code rate of 1/24
  - Secondary superframe header (S-SFH)
    - Always transmitted if changed. Otherwise periodicity is likely to aim latency requirement.
    - Consists of 3 types of sub-packets. Each optimized for different activity. SP1 optimized for NW re-entry, SP2 optimized for initial NW entry and NW discovery and SP3 contains remaining information.
    - ~100 bits, TBCC, QPSK with optional code rates of: 1/4 ,1/12 or 1/24.

Timing of the P/S-SFH (System Configuration)

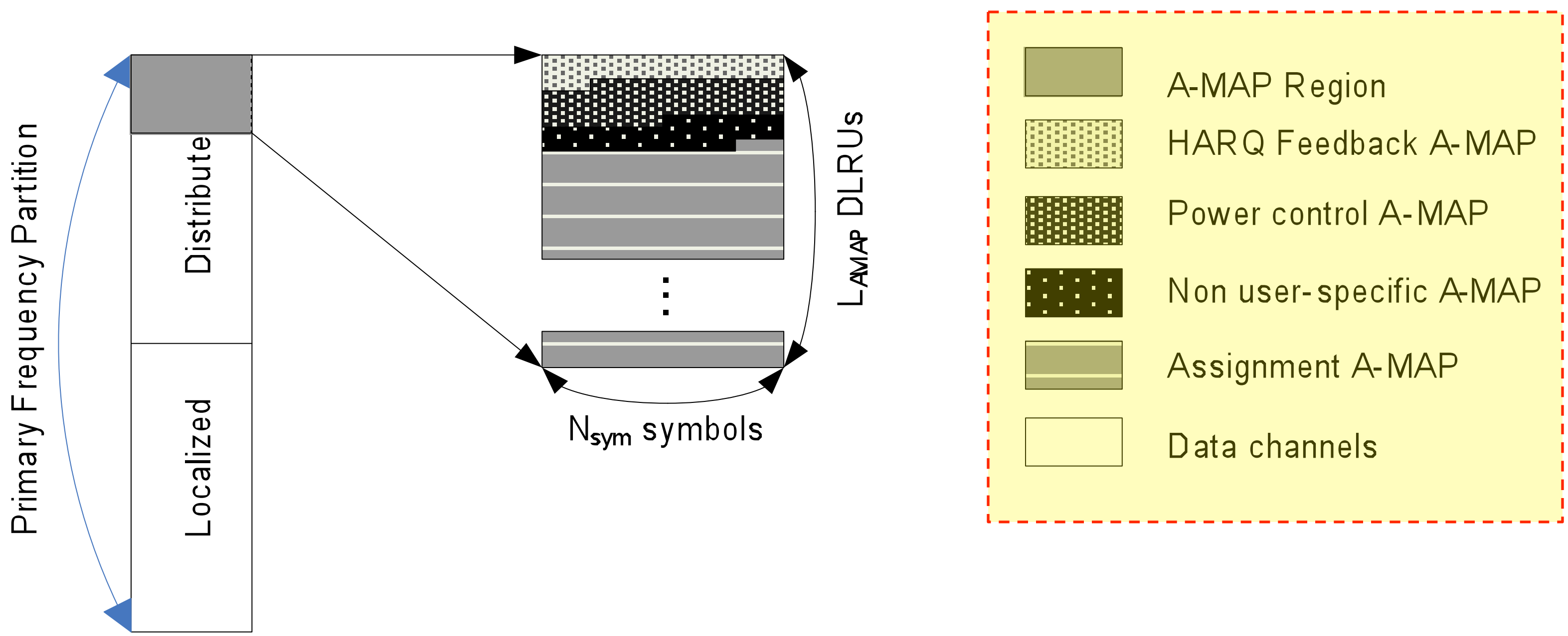


A-MAP Physical Channel Design

- HARQ Feedback A-MAP
  - HARQ feedback A-MAP uses 8 tone-pairs as a cluster. Each cluster can carry up to 4 HARQ Feedback A-MAP IEs.
  - 8 LSB of the STID are used to scramble the repeated HARQ Feedback A-MAP IE before modulation for error handling.
- Power Control A-MAP
  - Power Control A-MAP uses 2 or 4 tone-pairs (a Power Control A-MAP cluster) to transmit up to 2 Power Control A-MAP IEs.
- Non-user specific A-MAP
  - Coded with 1/12 TBCC if the A-MAP region is in the reuse 1 partition, or with 1/4 TBCC if the A-MAP region is in the reuse 3 partition.
  - It has 12 information bits
- Assignment A-MAP
  - Each Assignment A-MAP occupies one or multiple logical units called MLRUs (56 tones) in an A-MAP region. MCS can be either 1) QPSK ½, ¼ or 2) QPSK ½, 1/8

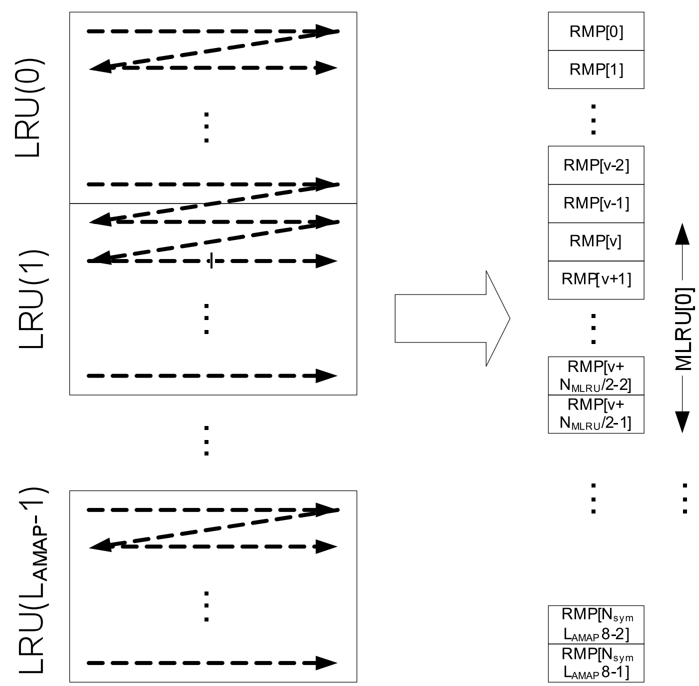
A-MAP Region Location and Structure

A-MAP	A-MAP	A-MAP	A-MAP				
DL SF0	DL SF1	DL SF2	DL SF3	UL SF4	UL SF5	UL SF6	UL SF7



A-MAP Physical Channel Tone-Selection

- A-MAP physical channels are formed by selecting tone-pairs from DLRUs in the A-MAP region.
- Tone-pairs of DLRUs in the A-MAP region are rearranged into a one-dimensional array in the time first manner. An A-MAP channel are formed by tone-pairs in a segment of the array.



Assignment A-MAP Group Size Signaling

- Assignment A-MAPs in an A-MAP region are grouped together based on the MCS levels. The size of each Assignment A-MAP group is signaled through non-user specific A-MAP. Therefore AMS does not need to blindly decode an MLRU using different MCSs

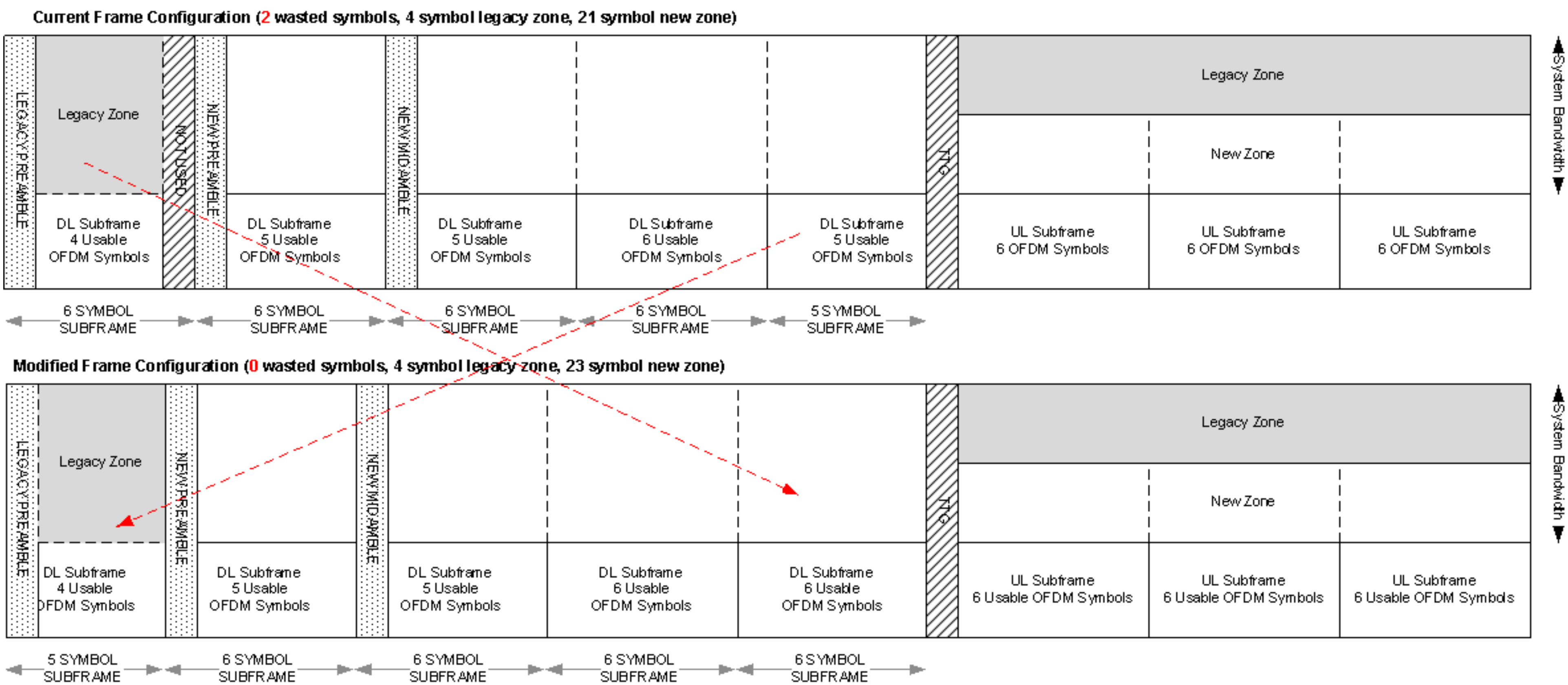
- The number of AMS detection trials is determined by the group sizes as shown above as an example

Mixed-Mode Operation of IEEE P802.16m
General Principles

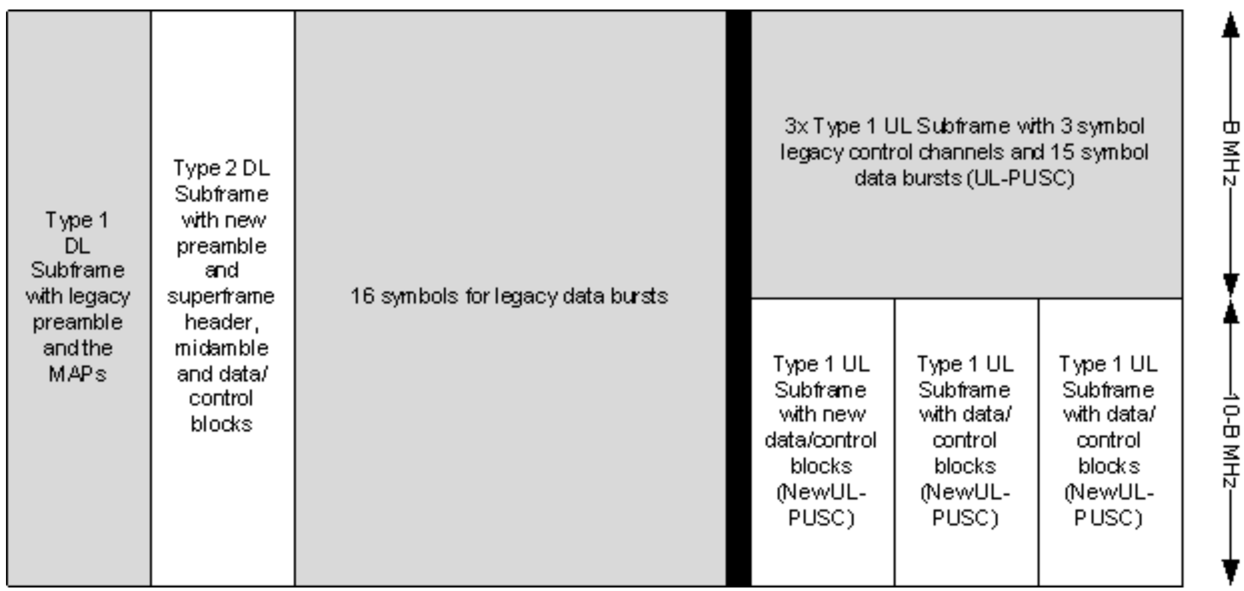
- The legacy and new systems can simultaneously operate on the same RF carrier by dynamically sharing in time and/or frequency the radio resources over the frame.
- There are two approaches to support mixed mode operation of IEEE 802.16m and IEEE 802.16e
  - TDM of the DL zones and FDM of the UL zones (when UL PUSC is used in legacy UL)
  - TDM of the DL zones and TDM of the UL zones (when AMC is used in legacy UL)
- The UL link budget limitations of the legacy are considered in both UL approaches by allowing the legacy allocations to use the entire UL partition across time. The legacy and new allocations are frequency division multiplexed across frequency in both approaches.
- The synchronization, broadcast, and control structure of the two systems are mainly separated and these overhead channels present irrespective of the relative load of the network (i.e., the percentage of legacy and new terminals in the network). The size of the MAPs increase with the number of users.
- In TDD duplex scheme, the frame partitioning between DL and UL and the switching points are synchronized across the network to minimize inter-cell interference.
- The frame partitioning in IEEE 802.16m (superframe/frame/subframe) is transparent to the legacy BS and MS.
- The new BS or MS can fall back to the legacy mode when operating with a legacy MS or BS, respectively.
- While a number of upper MAC functions and protocols may be shared between legacy and new systems, most of the lower MAC and PHY functions and protocols are different or differently implemented.

Mixed-Mode Operation of IEEE P802.16m

In order to improve the throughput of both 802.16m and the legacy systems in the mixed-mode operation, the frame structure for the legacy support was modified.



Mixed-Mode Operation of IEEE P802.16m



Frame Configuration with minimum 802.16m resource usage

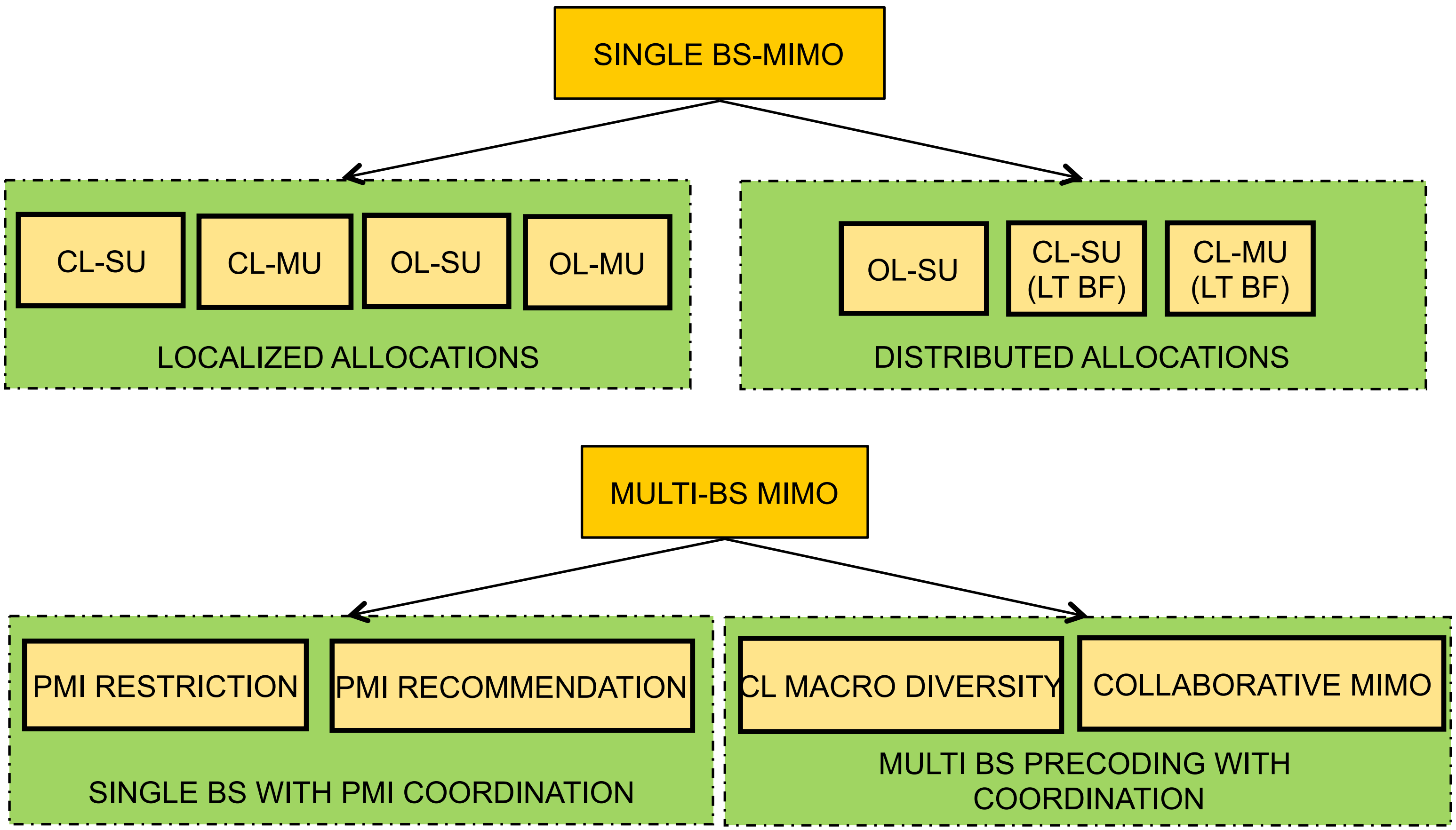
L1/L2 Overhead in Mixed Mode Operation

Overhead Components	IEEE 802.16e		IEEE 802.16m		Mixed Mode	
CP=1/8, BW=10 MHz, DL 2x2 MIMO	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
L1 overhead	0.393	0.393	0.3104	0.3104	0.331	0.346
L1/L2 Overhead	0.446	0.568	0.3532	0.4380	0.404	0.512

The new system has lower L1/L2 overhead relative to the legacy system for a fully-loaded cell.

The mixed-mode operation has also lower L1/L2 overhead relative to the legacy system. New subchannelization schemes, symbol structure, control channel structure design have helped reduce the L1/L2 overhead and increase reliability of the system.

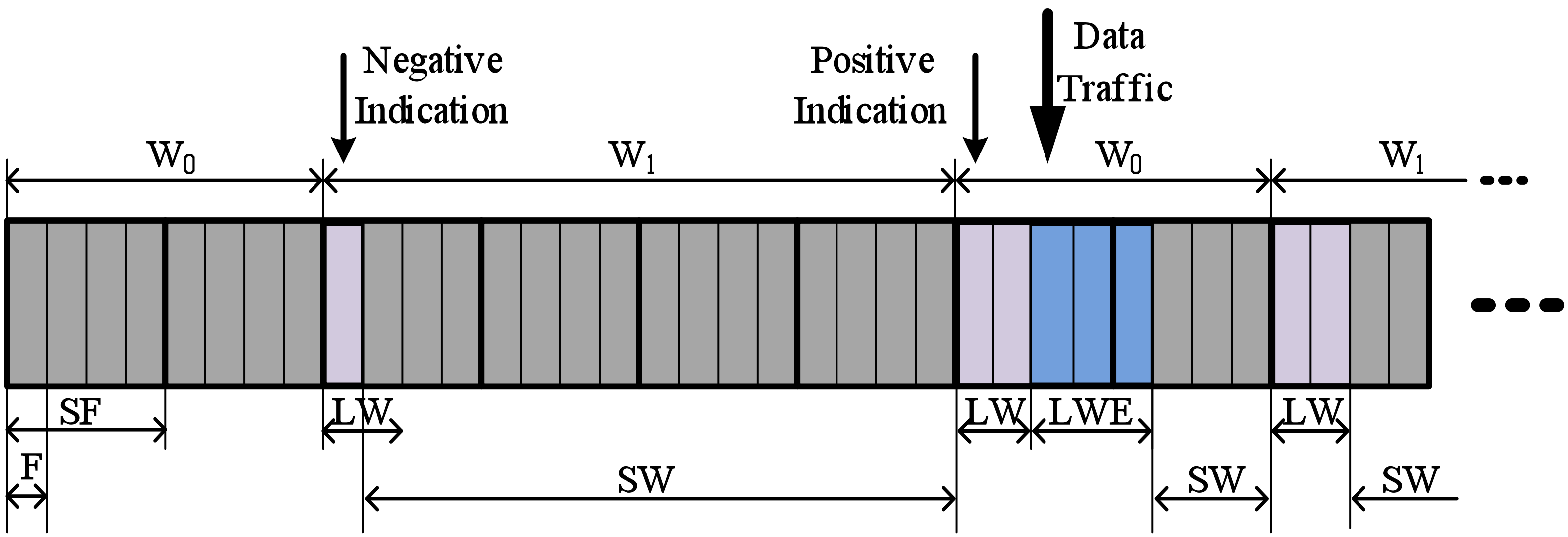
IEEE P802.16m DL/UL MIMO Modes



See section 16.5 of IEEE P802.16m/D5 for the multi-BS MIMO specification

MAC Layer Updates

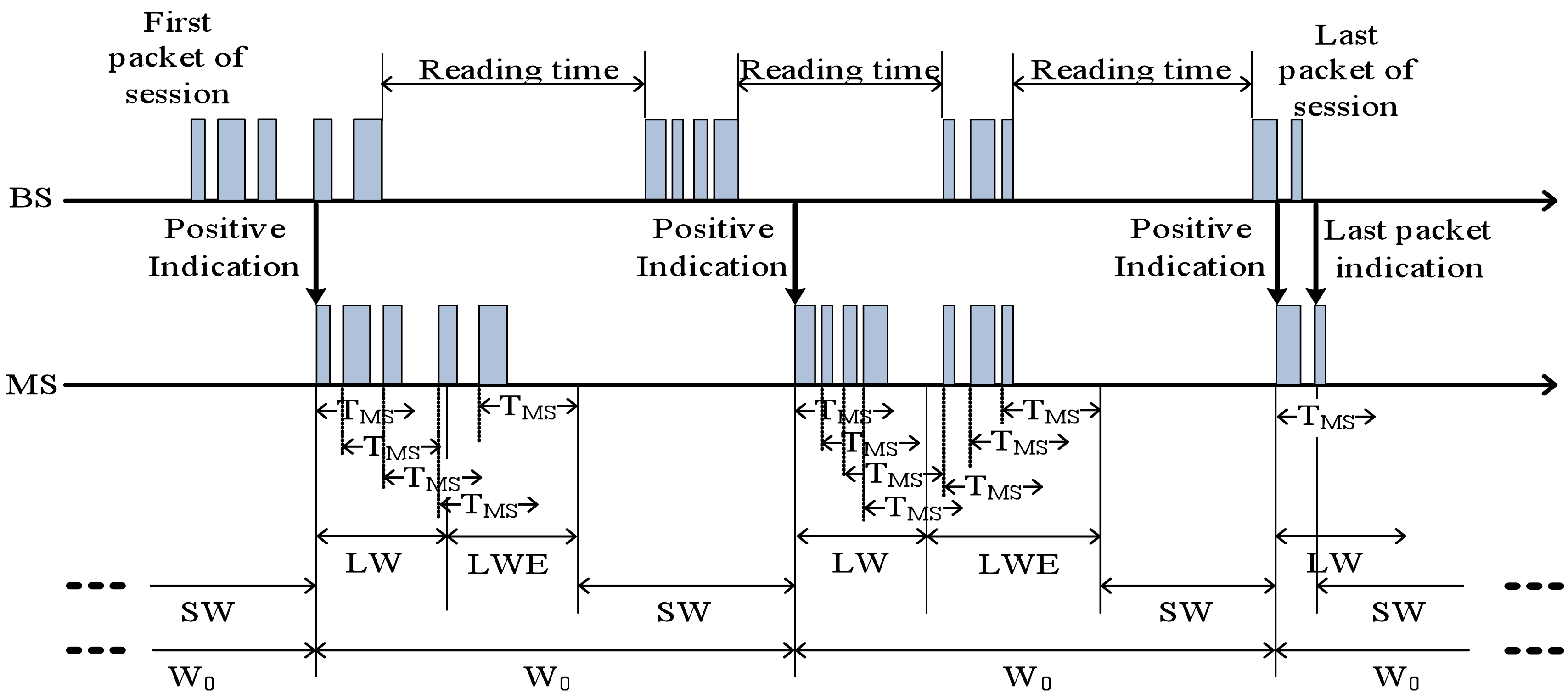
Sleep Mode Operation



W_0: Initial Sleep Cycle
W_i: i^{th} Sleep Cycle
W_L: Final Sleep Cycle
LW: Listening Window
LWE: Listening Window Extension
SW: Sleep Window

Sleep Cycle Update :
- Best effort traffic
  $W_i = \min(2 * W_{i-1}, W_L)$
- Real time traffic
  $W_i = W_0$

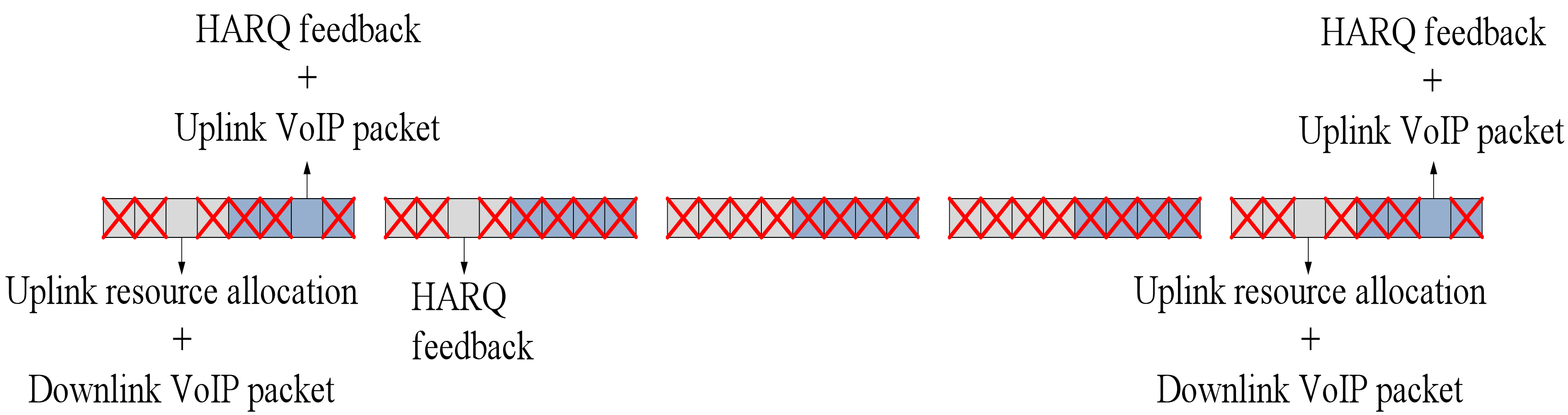
Sleep Mode Operation for HTTP Traffic - Example



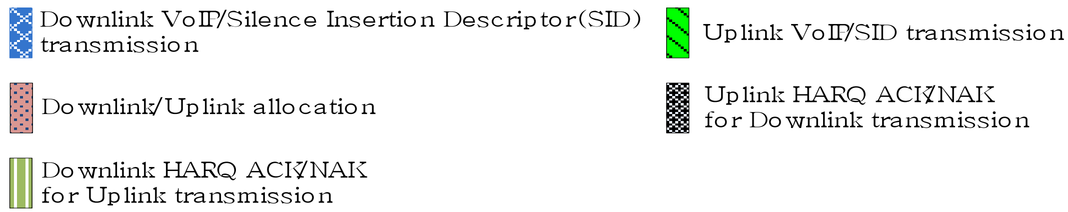
W_0: Initial Sleep Cycle
SW: Sleep Window

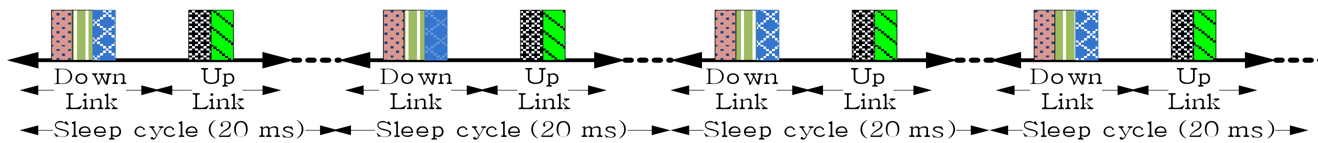
LW: Listening Window
LWE: Listening Window Extension
T_{MS}: MS Inactivity Timer

Sleep Mode Operation for VoIP - Example

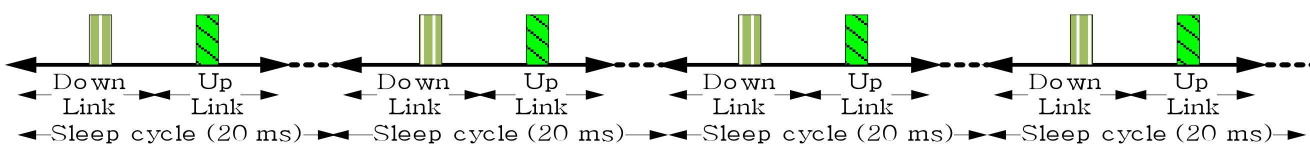


Sleep Mode Operation for VoIP - Example

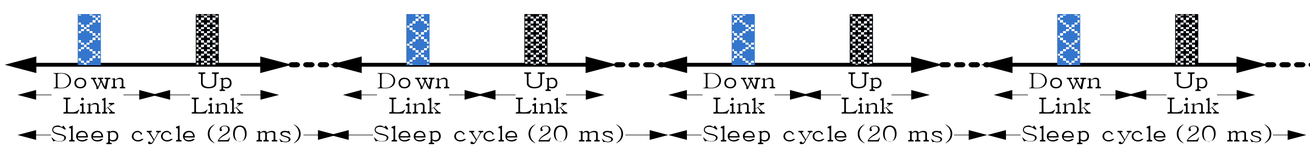




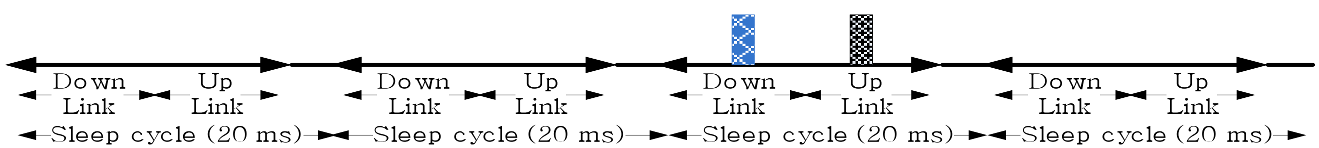
Scenario 1: No Persistent Allocation is used and there is both Downlink and Uplink VoIP traffic



Scenario 2: Persistent Allocation is used and there is Uplink VoIP traffic

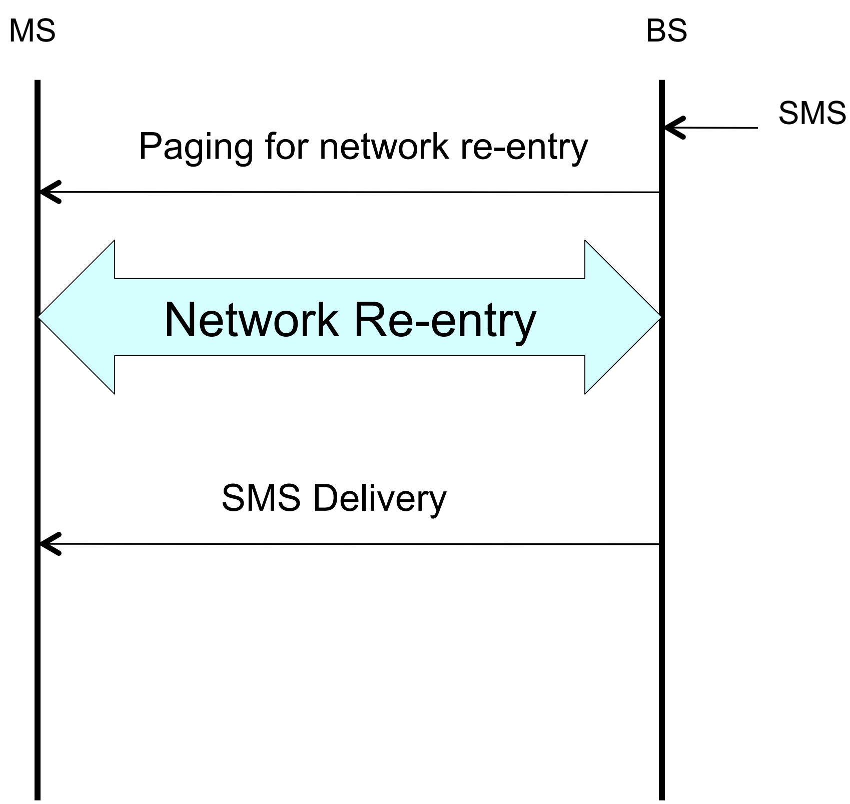


Scenario 3: Persistent Alloocation is used and there is Downlink VoIP traffic

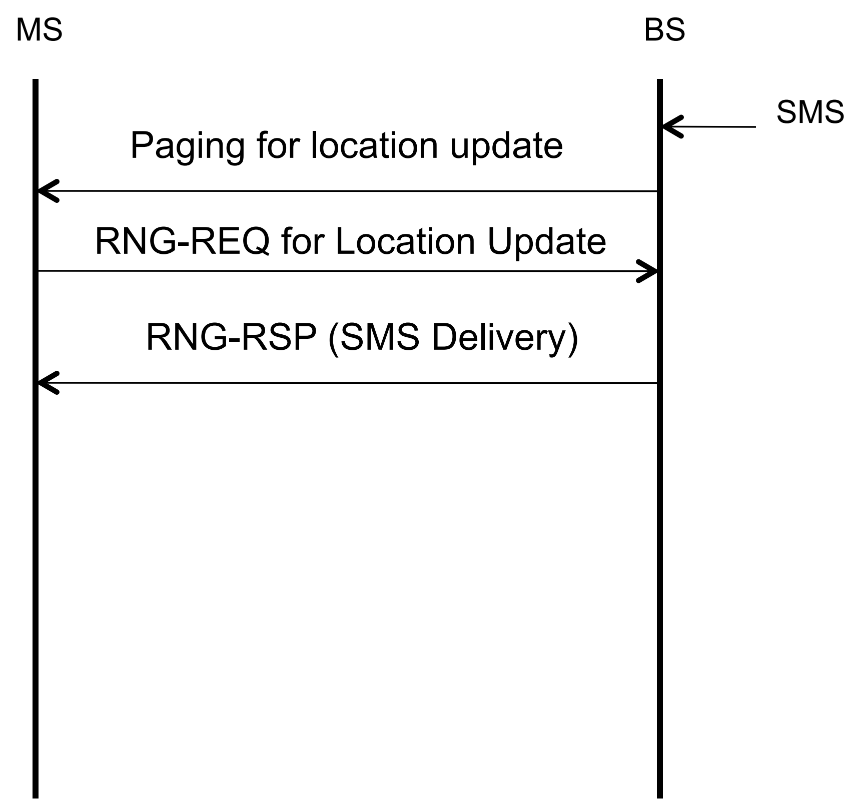


Scenario 4: Persistent Allocation is used and there is Downlink SID packet

SMS Delivery in Idle Mode



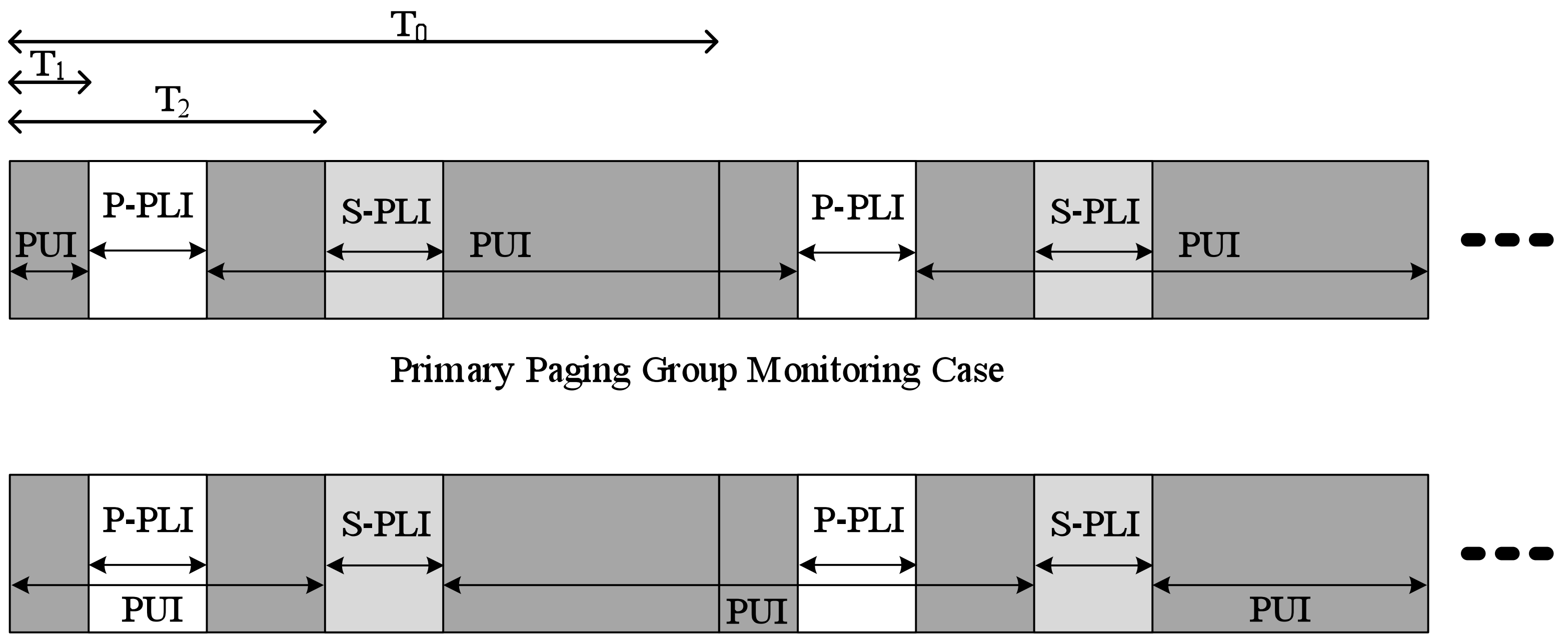
Normal SMS Delivery



IEEE 802.16m SMS Delivery

The new scheme shortens the process for delivery of SMS by around 20 to 30 ms

Idle Mode Operation for Multiple Paging Group



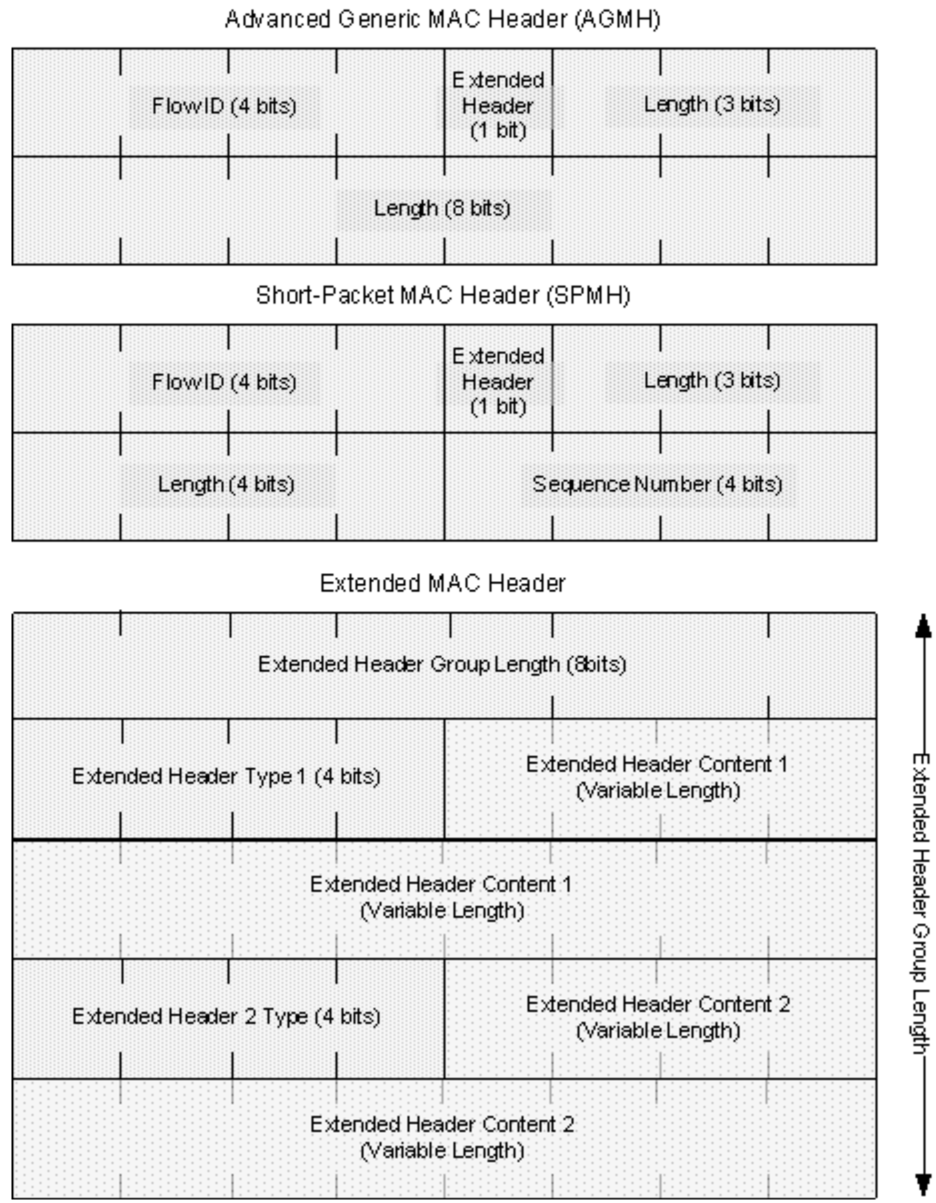
Secondary Paging Group Monitoring Case

T_0: PAGING_CYCLE
T_1: Primary PAGING_OFFSET
T_2: Secondary PAGING_OFFSET

PUI: Paging Unavailable Interval
P-PLI: Primary Paging Listening Interval
S-PLI: Secondary Paging Listening Interval

MAC Headers

- Advanced Generic MAC Header AGMH) for data transmission
- Extended Header (optional)
- AGMH is 2 Bytes in size
- Short-Packet MAC Header (SPMH) for small payloads
- Signaling Header (MAC header with no payload for signaling)



Deregistration with Content Retention (DCR) Mode

- Deregistration with content retention mode is a mode in which an AMS is deregistered from the network while its context is kept in a network entity until the Context Retention Timer is valid.
- While the Context Retention Timer is valid, the network retains AMS's information which is used to expedite AMS's network reentry.
- New mode, where the AMS can store context in the network even after power off or network exit
  - This stored context helps in optimizing network entry significantly next time
  - Significantly more power save as the AMS is off for a long time (as long as authentication keys are valid)
  - No requirement for paging and location update
- Usage models
  - Quick on connectivity to WiMAX network
  - Inter-RAT HO

Migration to IEEE WirelessMAN-Advanced Air Interface without Impacting the Legacy Network

- The migration to IEEE 802.16m RAN may be done without impacting the deployed legacy network elements.
- The ABS should be able to connect to legacy access and core network elements. If the ABS is connected to legacy network, the ABS shall communicate to the AMSs that it is attached to the legacy network and the AMSs shall function in accordance to legacy network requirements.
- Some examples include:
  - AMS privacy via AMSID* shall not be used. AMS provides actual MAC address in the AAI_RNG-REQ message for network entry/re-entry and idle mode location update. ABS provides the hash of the actual MAC address in the AAI_PAG-ADV message.
  - Features such as DCR, multiple paging groups per AMS shall not be supported.

References

Core Documents

1. P802.16m Project Authorization (PAR)
2. P802.16m Five Criteria
3. IEEE 802.16m Work Plan
4. IEEE 802.16m System Requirements Document (SRD)
5. IEEE 802.16m System Description Document (SDD)
6. IEEE 802.16m Evaluation Methodology Document (EMD)
7. System Evaluation Details for IEEE 802.16 IMT-Advanced Proposal (SED)
8. Candidate IMT-Advanced RIT based on IEEE 802.16 (IEEE Contribution to ITU-R Working Party 5D)

Additional Resources

1. IEEE 802.16 IMT-Advanced Candidate Proposal Page http://ieee802.org/16/imt-adv/index.html
2. IEEE P802.16m Drafts http://ieee802.org/16/pubs/80216m.html