IEEE 802.16 in IMT-Advanced

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Presenter(s) Name:	Affiliation:	Email Address:
Roger Marks	WiMAX Forum	r.b.marks@ieee.org
Reza Arefi	Intel Corporation	reza.arefi@intel.com
Brian Kiernan	Interdigital Communications, LLC	brian.kiernan@interdigital.com
Ron Murias	Interdigital Communications, LLC	ron@murias.ca
Phillip Barber	Huawei Technologies Co., LTD.	pbarber@huawei.com
Jong Kae Fwu	Intel Corporation	jong-kae.fwu@intel.com
Rakesh Taori	Samsung Electronics	rakesh.taori@samsung.com

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- "At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE."
  - IEEE-SA Standards Board Operation Manual (subclause 5.9.3)

Outline

- IEEE 802.16: Historical Overview
- IMT-Advanced Activities in ITU-R Working Party 5D
- The path to 802.16m
- 802.16m draft history
- WirelessMAN-Advanced Air Interface
  - PHY
  - PHY-MAC (Lower MAC)
  - MAC Data plane
  - Upper MAC
- WirelessMAN-Advanced performance characteristics

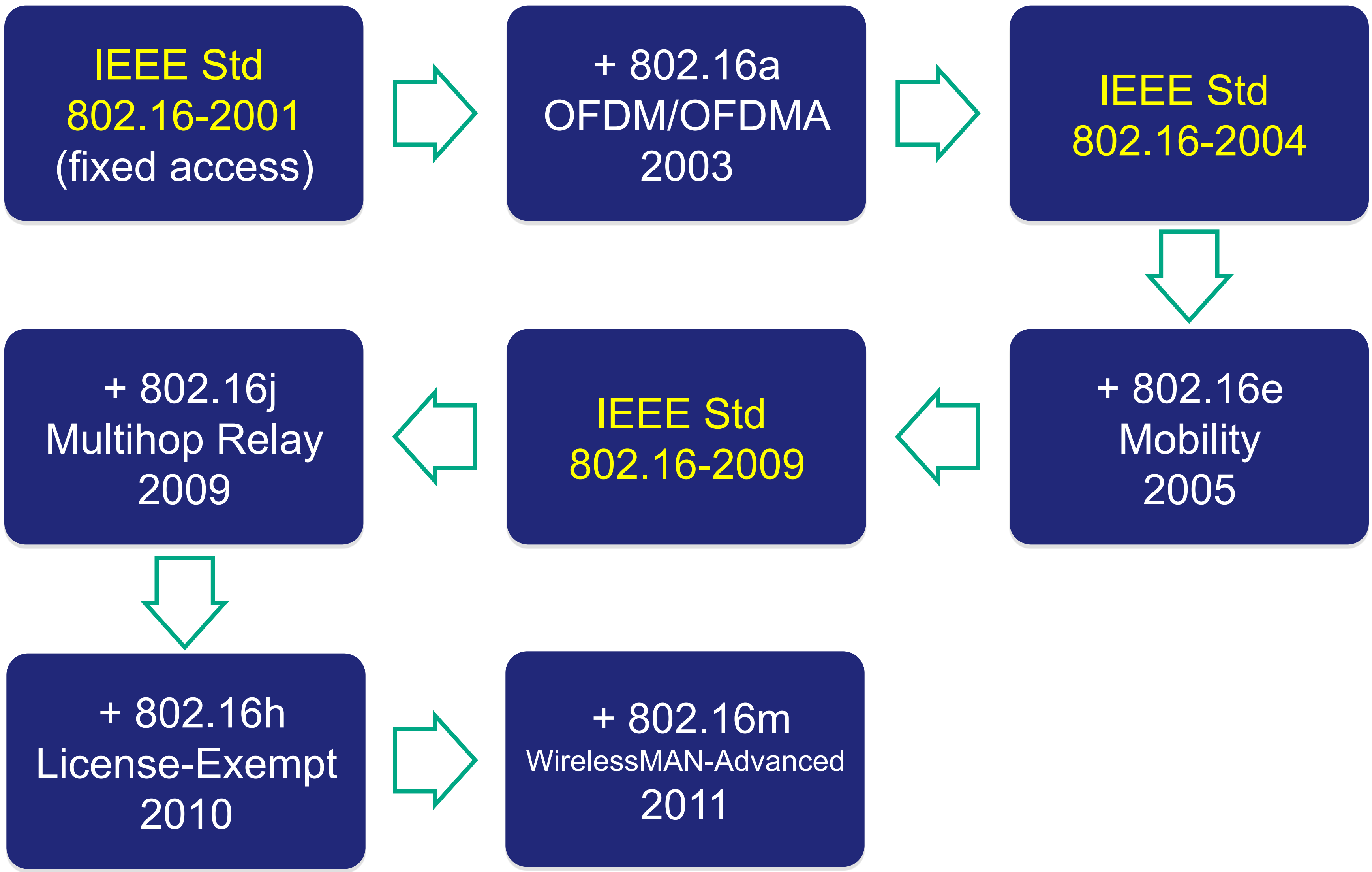
IEEE 802.16 is:

- **A Working Group (WG):**
  - The IEEE 802.16 Working Group on Broadband Wireless Access
  - Meeting since 1999
  - Develops and maintain a set of standards
- **The Working Group's core standard**
  - IEEE Std 802.16: Air Interface for Broadband Wireless Access Systems
  - The WirelessMAN® standard for **Wireless Metropolitan Area Networks**

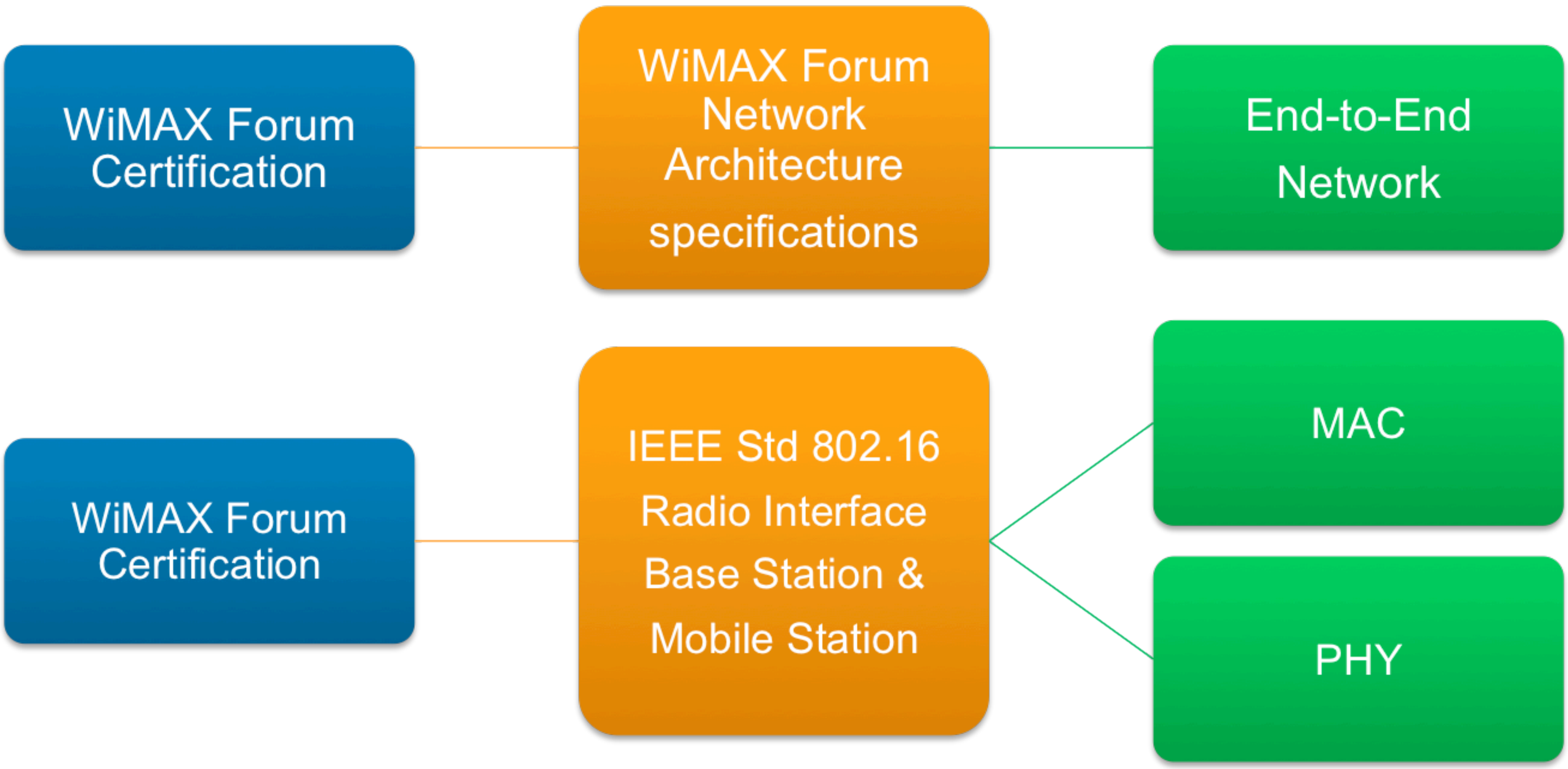
Worldwide Participation

- **Open process; everyone may participate**
- **Current 802.16 WG Membership: 226 people**
- **Actively seeks worldwide applicability**
  - Seeks worldwide participation.
  - Attendees from Australia, Belgium, Brazil, Canada, China, Egypt, Finland, France, Germany, Greece, Hong Kong, India, Ireland, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Pakistan, Romania, Russia, Singapore, Spain, Sweden, Taiwan, Thailand, USA, UK, etc.
- **Major coordination with ITU-R**

IEEE 802.16 Evolution



WiMAX Forum and IEEE 802.16



Internationalization of IEEE 802.16

- **International Telecommunication Union (ITU)**
  - organized under United Nations
  - membership by national governments
- **Radiocommunication Sector (ITU-R)**
  - private organizations hold memberships
    - Including WiMAX Forum, IEEE, companies
- **802.16 WG seeks "Internationalization"**
  - though it is, in many ways, "international" to begin with
  - strategy since the beginning in 1999
  - ITU-R Liaison Group

IMT-2000: "International Mobile Telecommunications"

- **Under ITU-R Study Group 5/Working Party 5D**
  - known as Working Party 8F before 2008
- **the international cellular standard since ~1998**
  - significant impact on spectrum allocations
- **M.1457-7 (Oct 2007) adds "OFDMA TDD WMAN"**
  - Based on IEEE Std 802.16 (including 802.16e)
  - Implementation profile developed by WiMAX Forum
- **M.1457-9 (2009) added FDD as well**

IMT-Advanced

- **To develop "Beyond IMT-2000" recommendation**
  - "to be developed around the year 2010, capable of supporting high data rates with high mobility, which could be widely deployed around the year 2015 in some countries."
- **"IMT" Spectrum identified at WRC2007**
  - includes "IMT-2000" and "IMT-Advanced"
- **ITU-R Working Party 5D developed background materials and requirements**
  - Announced in July 2008

IEEE 802.16m Project

- **Amendment project, initiated December 2006**
- **Scope:**
  - amend the IEEE 802.16 WirelessMAN-OFDMA specification to provide an advanced air interface for operation in licensed bands
  - meet the cellular layer requirements of IMT-Advanced next generation mobile networks
  - continuing support for legacy WirelessMAN-OFDMA equipment (i.e., backward compatibility)
  - Provide performance improvements to support future advanced services and applications
- **"WirelessMAN-Advanced" air interface**

Participation in IEEE 802.16m

- **Since 802.16m project began, 802.16 WG participation includes:**
  - Over 1200 professionals
  - From about 240 organizations
  - From 23 countries
- **Contributed documents to 802.16m Task Group**
  - 2007: >300 documents
  - 2008: >1500 documents
  - 2009: > 2700 documents
  - 2010: > 1400 documents

IEEE 802.16m – Key Features

- New Subframe-based Frame Structure
- New Subchannelization Schemes and More Efficient Pilot Structures
- New and Improved Control Channel Structures
- Extended and Improved MIMO Modes
- Increased VoIP Capacity
- Multi-Hop Relay
- Femto BS
- Self-organization
- Multi-carrier Operation
- Interference Mitigation
- Multi-BS MIMO
- Improved Intra-RAT and Inter-RAT Handover
- Multi-Radio Coexistence
- Location Based Services
- Enhanced Multicast and Broadcast Service

WirelessMAN-Advanced Proposal for IMT-Advanced

- **IEEE submitted detailed proposal on WirelessMAN-Advanced air interface in Oct 2009**
- **Two other entities submitted proposals of the same technology:**
  - Administration of Japan
  - TTA (Korean SDO)
- **All 3 included self-evaluation demonstrating that all IMT-Advanced requirements are met**
- **Nine worldwide experts groups conducted extensive technical studies that support results**

IMT-A Requirements

- **IEEE proposed a single RIT (inclusive of TDD and FDD) to meet or exceed all IMT-Advanced requirements in all test environments**

Test Environment / Deployment Scenario	Proposal Meets IMT-Advanced Requirements
Indoor Hotspot (InH)	✓
Urban Microcell (UMi)	✓
Urban Macrocell (UMa)	✓
Rural Macrocell (RMa)	✓

Performance Requirements

Requirements	IMT-Advanced	802.16m SRD
Peak spectral efficiency (b/s/Hz/sector)	DL: 15 (4x4) UL: 6.75 (2x4)	DL: 8.0/15.0 (2x2/4x4) UL: 2.8/6.75 (1x2/2x4)
Cell spectral efficiency (b/s/Hz/sector)	DL (4x2) = 2.2 UL (2x4) = 1.4 (Base coverage urban)	DL (2x2) = 2.6 UL (1x2) = 1.3 (Mixed Mobility)
Cell edge user spectral efficiency (b/s/Hz)	DL (4x2) = 0.06 UL (2x4) = 0.03 (Base coverage urban)	DL (2x2) = 0.09 UL (1x2) = 0.05 (Mixed Mobility)
Latency	C-plane: 100 ms (idle to active) U-plane: 10 ms	C-plane: 100 ms (idle to active) U-plane: 10 ms
Mobility b/s/Hz at km/h	0.55 at 120 km/h 0.25 at 350 km/h	Optimal performance up to 10 km/h “Graceful degradation” up to 120 km/h “Connectivity” up to 350 km/h Up to 500 km/h depending on operating frequency
Handover interruption time (ms)	Intra frequency: 27.5 Inter frequency: 40 (in a band) 60 (between bands)	Intra frequency: 27.5 Inter frequency: 40 (in a band) 60 (between bands)
VoIP capacity (Active users/sector/MHz)	40 (4x2 and 2x4) (Base coverage urban)	60 (DL 2x2 and UL 1x2)

Mobility Requirements

Table 7-15: Mobility requirement data for TDD

Test environment	*Median SINR (in dB)*	*Achieved spectral efficiency (in bit/s/Hz) LOS*	*Achieved spectral efficiency (in bit/s/Hz) NLoS*	*ITU-R Required spectral efficiency (in bit/s/Hz)*
InH (10 km/h)	*16.6*	*3.76*	*3.41*	*1.0*
UMi (30 km/h)	*5.0*	*1.81*	*1.50*	*0.75*
UMa (120 km/h)	*4.3*	*1.72*	*1.30*	*0.55*
RMa (350 km/h)	*5.6*	*1.70*	*1.23*	*0.25*

Table 7-16: Mobility requirement data for FDD

Test environment	*Median SINR (in dB)*	*Achieved spectral efficiency (in bit/s/Hz) LOS*	*Achieved spectral efficiency (in bit/s/Hz) NLoS*	*ITU-R Required spectral efficiency (in bit/s/Hz)*
InH (10 km/h)	*16.6*	*3.86*	*3.56*	*1.0*
UMi (30 km/h)	*5.0*	*1.72*	*1.51*	*0.75*
UMa (120 km/h)	*4.3*	*1.63*	*1.34*	*0.55*
RMa (350 km/h)	*5.6*	*1.61*	*1.27*	*0.25*

WirelessMAN-Advanced Accepted as IMT-Advanced

- **ITU-R's Working Party 5D, in its meeting of 13-20 October 2010, approved the "WirelessMAN-Advanced" technology of IEEE 802.16m as an IMT-Advanced technology.**
  - "met all of the criteria established by ITU-R for the first release of IMT-Advanced" and was "accorded the official designation of IMT-Advanced."
- **WP 5D accepted an offer from three parties (IEEE, ARIB, TTA) to have IEEE complete and submit the full detailed specification of the technology at the following WP 5D meeting in April 2011.**
- **Anticipating approval of IEEE Std 802.16m by IEEE-SA on 31 March 2011**
- **WiMAX Forum's Release 2 will take advantage of the WirelessMAN-Advanced air interface.**

WirelessMAN-Advanced Transpositions

- **In the IMT-Advanced standard:**
  - The WirelessMAN-Advanced air interface will be specified via IEEE Std 802.16 and the 802.16m amendment.
- **Three SDOs authorized to develop "transpositions" of WirelessMAN-Advanced standard**
  - ARIB (Japan), TTA (Korea), WiMAX Forum
  - Adoptions of IEEE standards.
  - Will be incorporated by reference into IMT-Advanced.
- **IEEE 802.16 convening meeting of the "WirelessMAN-Advanced Transposing Organizations" (WATO) starting 15 March 2011.**

IMT-Advanced Schedule

- 2010-10: approved two technologies for IMT-Advanced
- 2011-04: Review of detailed specifications of two technologies
- 2011-09: Transpositions due
- 2011-10: Final WP 5D agreement on IMT-Advanced standard
- 2011-11: Final Study Group 5 agreement
- 2012-02: ITU-R approval at Radiocommunication Assembly

Is IMT-Advanced = 4G?

- **No.**
- **“Unique name” (“IMT-Advanced”) for systems beyond IMT-2000. The term “4G” is not used.**
- **On 21 Oct 2010, ITU announced that WirelessMAN-Advanced and LTE-Advanced were “accorded the official designation of IMT-Advanced,” suggesting also that “IMT-Advanced” is the “true 4G.”**
- **On 6 Dec 2010, ITU clarified its position on 4G:**
  - 4G is “undefined”.
  - “4G may also be applied to” forerunner technologies, such as WiMAX

802.16m Development Process

- **Not your "normal" IEEE 802 standards development situation:**
  - Known established "drop dead' date for Standard completion
  - Well defined set of formal externally established requirements
  - Final standard to be evaluated by multiple International independent groups against those requirements
  - Evaluation criteria, scenarios and methodologies pre-established by international consensus

802.16m Development Process

- **Not your "normal" IEEE 802 standards development process:**
  - Multiple document creation via a staged development process:
    - Detailed WorkPlan and schedule continually updated to measure progress and set deadlines
      - Initial: http://ieee802.org/16/tgm/docs/80216m-07_001r1.pdf
      - Final: http://ieee802.org/16/tgm/core.html#10_0010 (2010-03-18)
  - WorkPlan called for development of multiple documents which defined the Standard development:

802.16m Development Process

- **"TGm will develop the following documents as part of 802.16m standardization process**:
  - **System Requirements Document (SRD)**
    - **http://ieee802.org/16/tgm/core.html#07_002**
    - A set of possible deployment scenarios and applications of the 802.16m standard.
    - A set of performance targets and features that 802.16m compliant systems shall meet or exceed.
  - **Evaluation Methodology Document (EMD) http://ieee802.org/16/tgm/core.html#08_004**
    - A complete set of parameters, models, and methodologies for the link-level and system-level simulations that allow fair evaluation/comparison of various technical proposals.
    - Channels Models: A set of spatial channel model parameters are specified to characterize particular features of MIMO radio channels to be used for simulating technical proposals for the future 802.16m standard.

802.16m Development Process

- **System Description Document (SDD)**
- **http://ieee802.org/16/tgm/core.html#09_0034**
  - Architecture and design of the 802.16m air interface amendment
  - Captures the core technical concepts behind the features included in the amendment
  - Will enable analysis and/or simulations for characterizing the coarse level performance benefits of the air interface in association with the Evaluation Methodology Document
- **802.16m amendment (Working Document and IEEE Drafts)**
- **802.16 IMT-Advanced Proposal**

802.16m Development Process

- **All Document development tightly linked by an agreed-to self-imposed Configuration Control procedure (CCP):**
  - http://ieee802.org/16/tgm/core.html#09_0008
- **Established "Process for maintaining the Project 802.16m System Requirements Document (SRD), the System Description Document (SDD) and the Evaluation Methodology Document (EMD) after approval.**
- **Created a strict Change Control Process for these documents to limit the amount of unnecessary changes in the amendment as it was being developed.**

The 802.16m draft history

- **Document history:**
  - 4 “Amendment Working Document” (AWD) drafts
  - 6 Working Group Ballot drafts
  - 6 Sponsor Ballot drafts
- **Final: D12**
  - 1086 pages
  - 237 figures
  - 345 tables
  - New Clause 16
  - New ASN.1 Annex

Creating the Draft

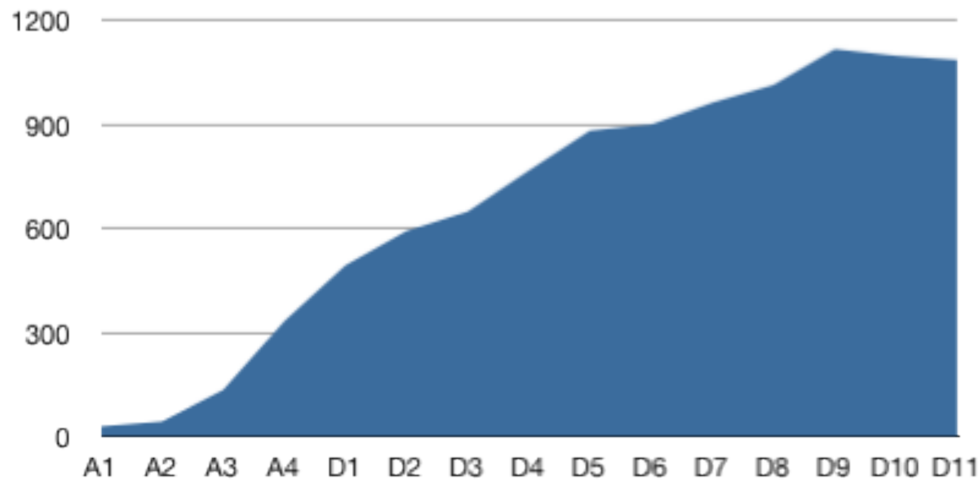
- **AWD work: lone editor**
  - Commentary database
  - FrameMaker
  - 50-200 new pages each round (average 75)
  - Ad hoc file backups
- **Multiple Editor Model**
  - Initially, each editor converted Word contributions to FrameMaker format
  - Chief Editor copy/paste to the Draft
  - Comments implemented by the Chief editor
  - Faster implementation, but no improvement to the error rate

Editorial Group

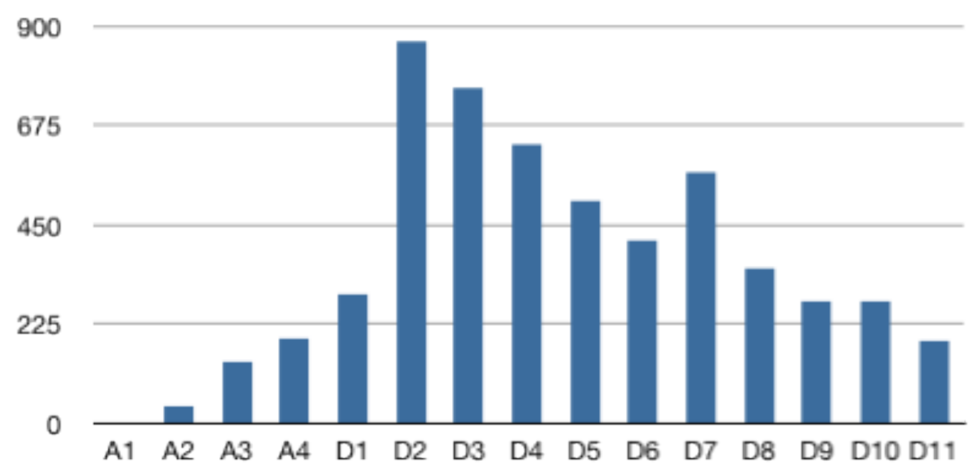
- **Break the document source into "large-ish" subclauses**
- **Software Development Model:**
  - SVN repository
  - Team of 6-10 editors
  - Domain experts focus on subclauses in line with their expertise
  - Time zone differences enabled almost 24-hour editing
  - Unofficial draft created and internally circulated prior to release
- **Benefits**
  - Doubled productivity
  - 33% reduction in re-work
  - Built-in backups with revision roll-back
  - Every change is traceable to an editor and comment

802.16m Draft Highlights

Number of Pages



Number of Implemented Comments



Other Improvements (wish list)

- **Document structure database (in progress)**
- **Better Tools**
  - LaTeX?
    - Much larger pool of editors
    - Plain text based – revision control and concurrent editing is easier

802.16m PHY

802.16m Physical Layer Features

Feature Aspects	802.16e+Mobile WiMAX Release 1 relevant aspects	802.16m Enhancements	Remarks
Multiple Access Technology	OFDMA both on the Down Link (DL) and Up Link (UL)	OFDMA on the DL and UL. Same numerology is followed for full backward compatibility	Tone dropping also supported for odd bandwidths.
MIMO/Beam forming (BF)	Single User MIMO and Beam forming as separate modes	Multi-User MIMO, Single User MIMO, Transformation Codebook, Differential Codebooks and Long Term Beam forming DL: 2x2, 4x2, 4x4, 8x4 UL: 1x2, 2x2, 2x4, 4x4, 4x8	Unified MIMO/BF Architecture
Frame Structure	Variable size DL and UL Subframes	Fixed size DL and UL subframes of 6 symbols and 20ms Superframe composed of four 5ms frames	Less control channel overhead. Lower latency.
Symbol Structure	PUSC and AMC permutations in different symbols.	Sub-band/Mini-band and Distributed permutation in same symbols possible. Optimal pilot density & interlaced pilots	Backward Compatibility and mixed mode co-existence
Control Channels	Very Flexible control channels with many options	Structured control channels with reduced flexibility for higher efficiency and better throughput performance. Improved VoIP performance	Control info. Divided based on time relevance into SFH, AMAP
HARQ	Asynchronous Chase HARQ for DL and UL.	DL Asynchronous HARQ and UL Synchronous HARQ with CTC-IR to enable <10ms one-way air interface latency	HARQ RTT as low as 1 frame.
Interference Mitigation	Segmented PUSC based Frequency Re-use and Scheduling based mitigation	Explicit Fractional Frequency Reuse support, CL and OL power control schemes and also Multi-BS MIMO	Multi-BS coordination, TPC and Tx BF

802.16m Frame Structure

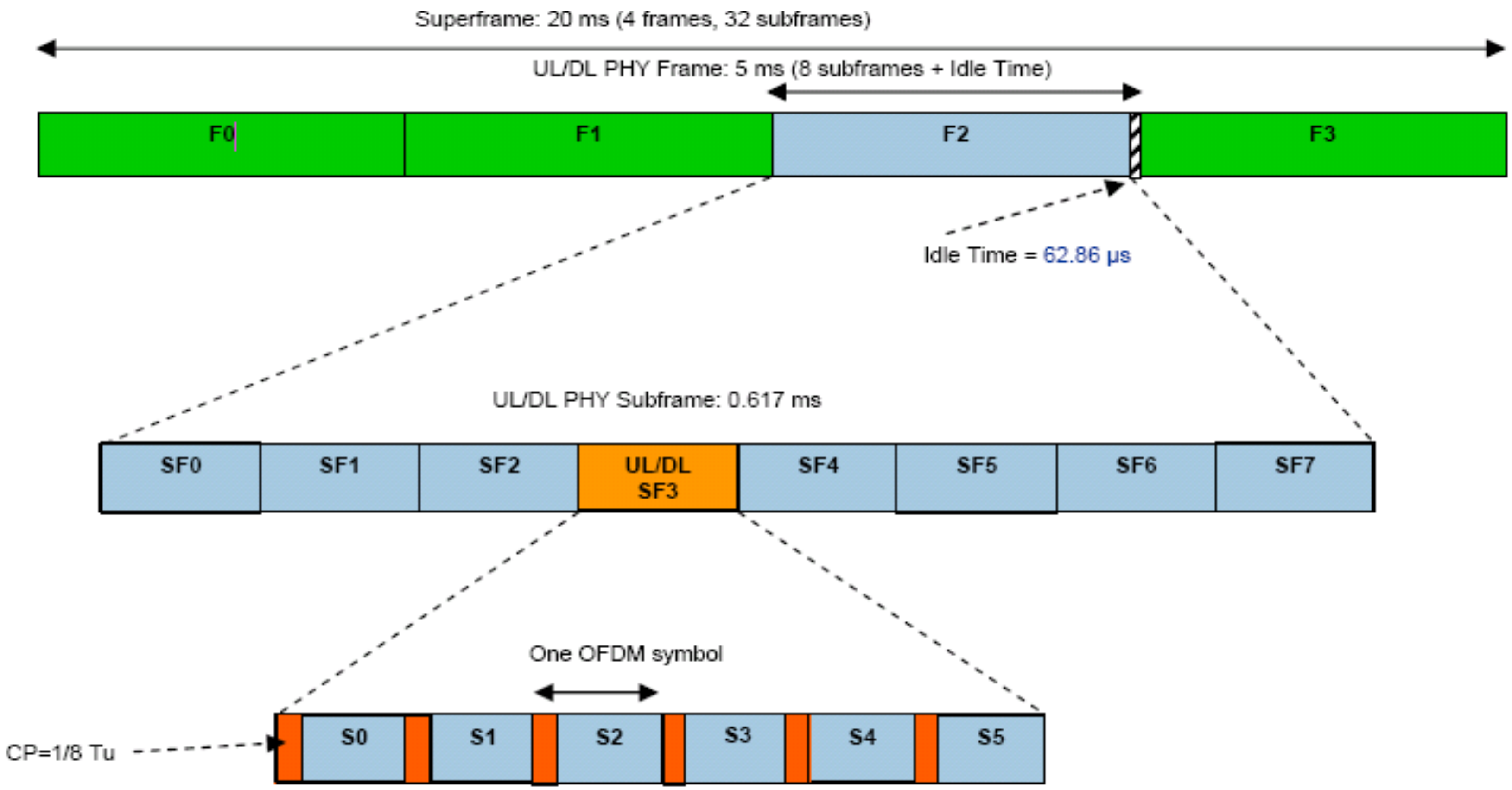
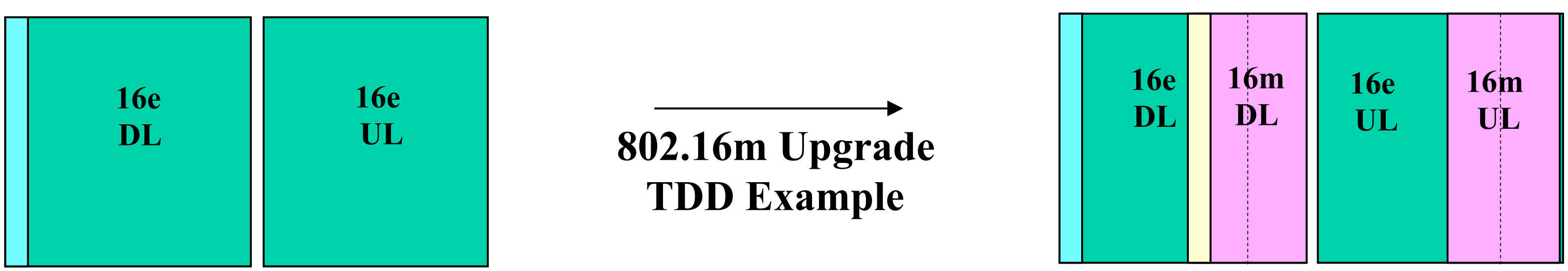


Figure 18 Frame structure with type-1 subframe in FDD duplex mode ($CP=1/8\ T_u$)

- Hierarchical structure of super-frame, frame and subframe to support (1) flexible scheduling and (2) low latency.
- A-MAP on each subframe

802.16m Backward Compatibility

- **802.16m uses the same 802.16e OFDMA numerology**
- **802.16m extends the same 802.16e frame structure**
- **802.16m network upgrade possible on same 802.16e RF carriers**
- **802.16e and 802.16m terminals can co-exist on the same network**
- **802.16e/16m zones can be adjusted system wide based on traffic**
- **Greenfield 802.16m only deployments also possible for new networks**

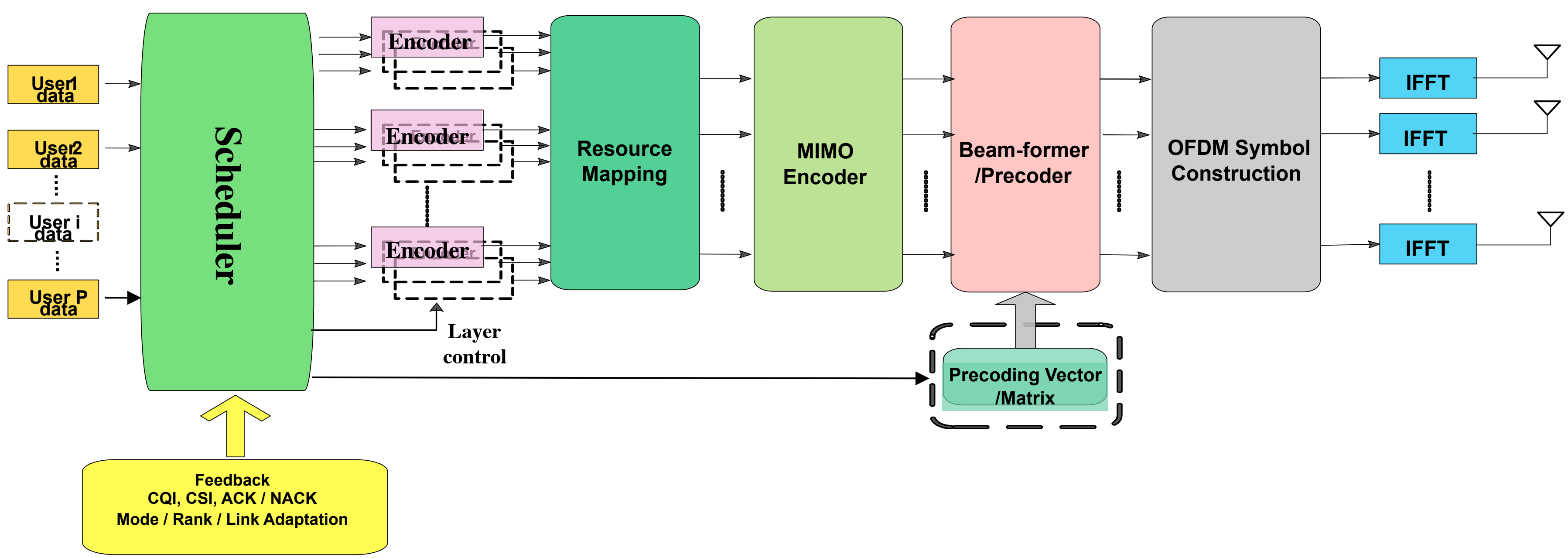


802.16e TDD Network

802.16m Upgraded TDD Network on same RF carrier

802.16m Single/Multi-User MIMO

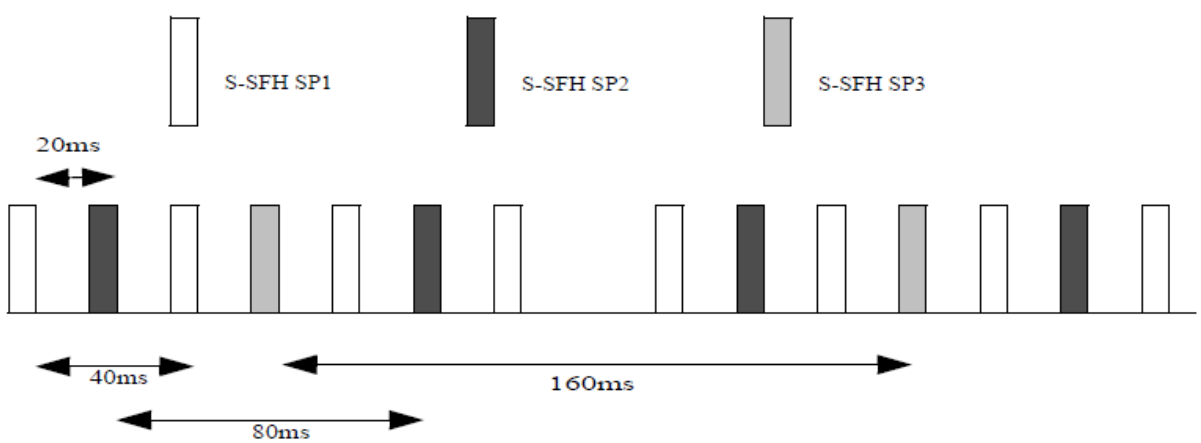
- Unified Single/Multi-user MIMO Architecture
- Multiple Streams: DL: 2x2, 4x2, 4x4, 8x4; UL:1x2, 2x2, 2x4, 4x4
- Open-loop and Closed-loop schemes
- Transmit Beamforming with rank/mode adaptation capability.
- Multi-cell MIMO techniques



802.16m Lower MAC

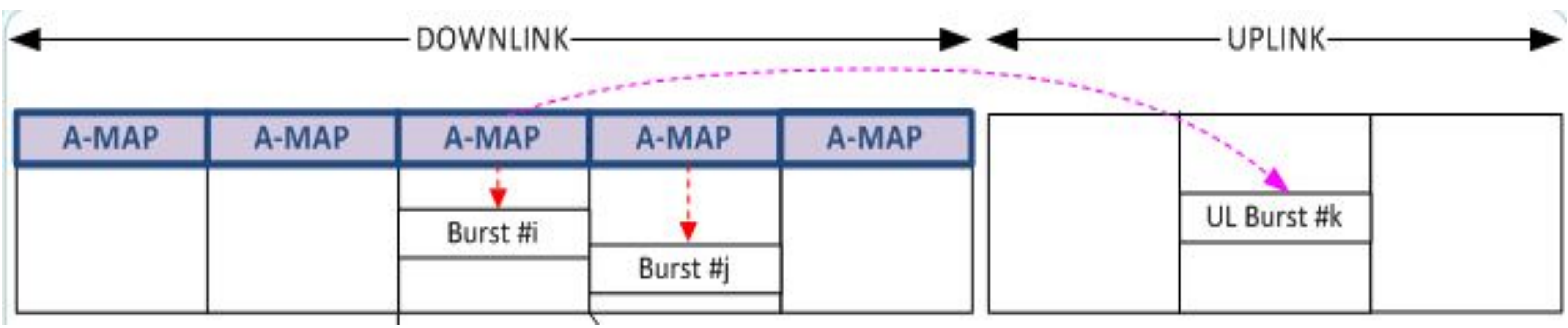
Reduced Overhead Downlink Control

- **DCD/UCD transmissions were large, and therefore infrequent**
- **Approach**
  - Categorization of information based on purpose (Network entry, re-entry,…)
  - Adequate periodicity for the various categories of information
  - Appropriate mix of dedicated channels and MAC messages
- **Subpacketization**
  - Defined Primary SFH (P-SFH) and Secondary SFH (S-SFH) .
  - Subpackets (SP1, SP2, SP3) carried in the S-SFH.



Versatile and Efficient Resource Allocation

- **DL/UL MAPs in 802.16e were broadcast every 5 ms.**
  - Low granularity, low flexibility and not particularly power efficient
- **16m mechanisms**
  - Separate coding (maximizing link adaptation efficiency)
  - Shorter MAP relevance (shorter latency, and increased flexibility and granularity)
  - FDM Multiplexing with data burst (Efficient power boosting)

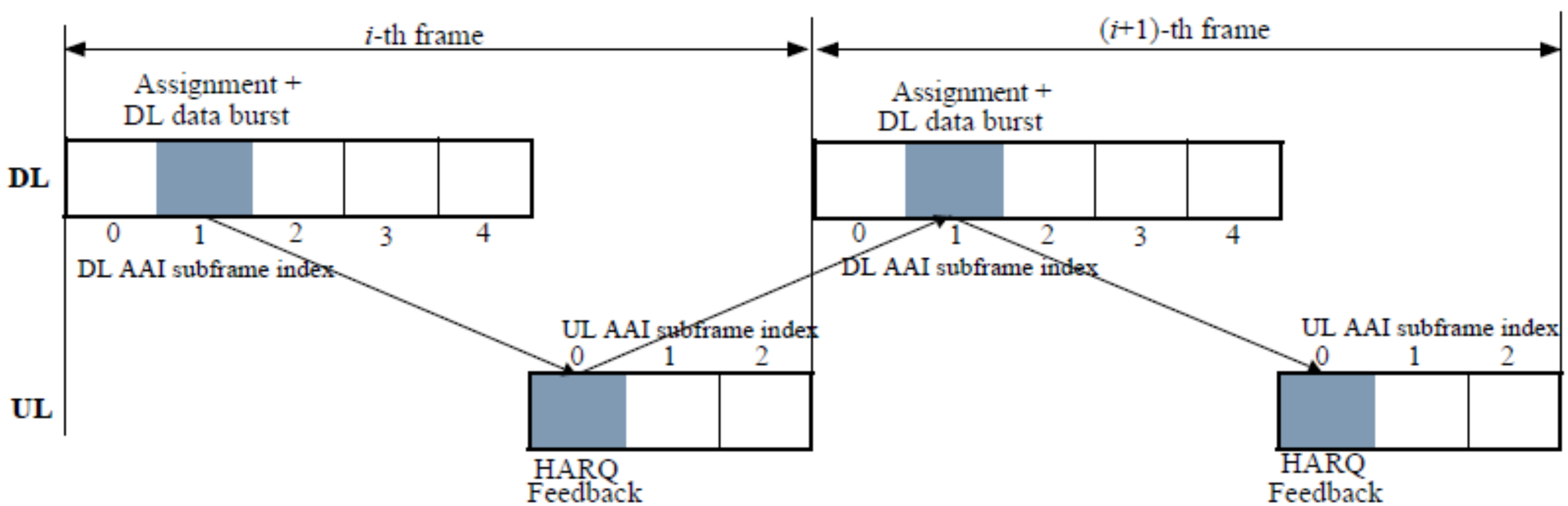


Native Low Latency Support

- **Enhanced HARQ protocol using the new subframe based structure**

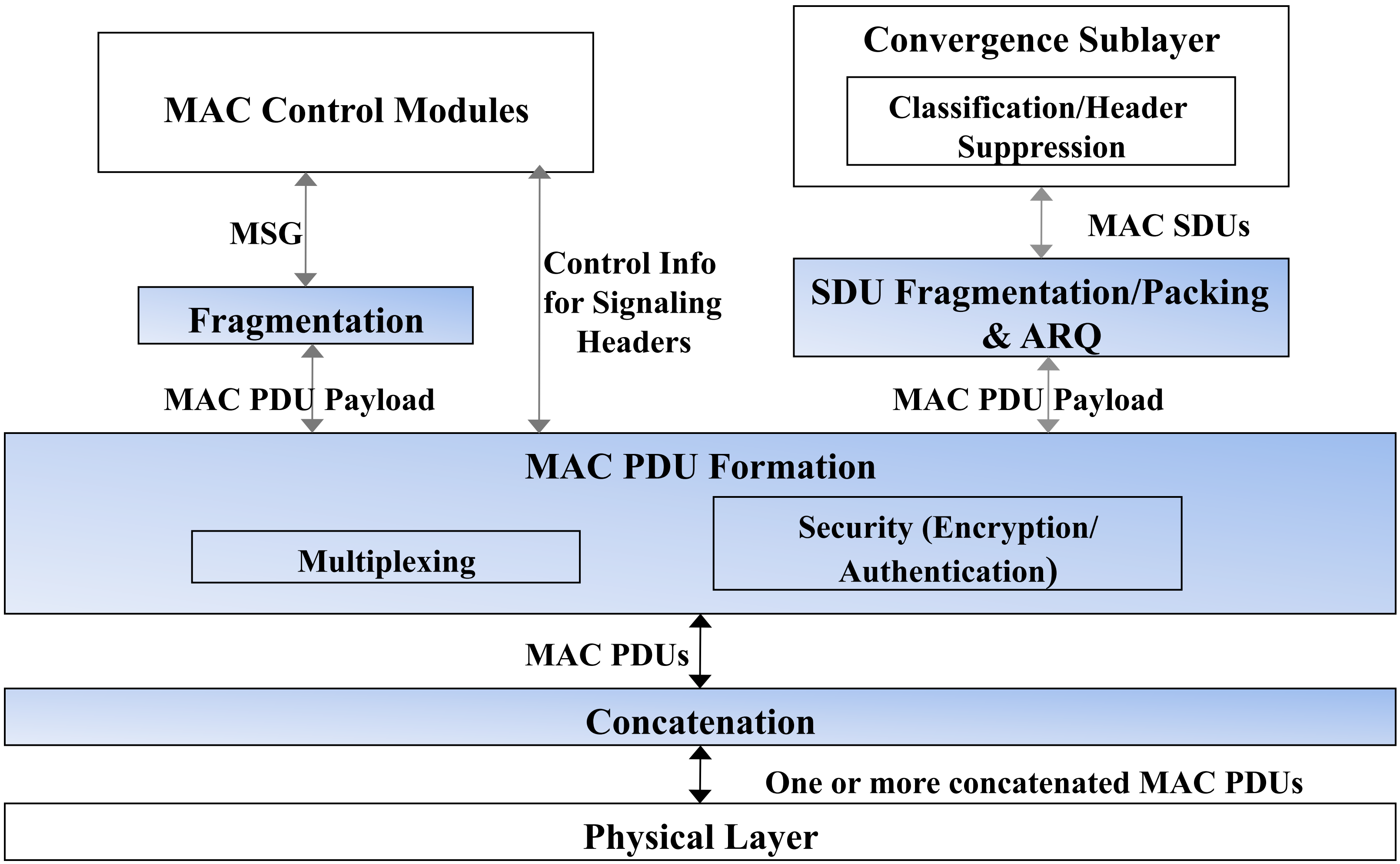
- **Low data/control latency**
  - Assignment A-MAP (scheduling) is transmitted every DL subframe
  - 5ms (1 frame) latency is achived

- **Low signaling overhead**
  - A-MAP, data, and HARQ feedback locations are pre-assigned.

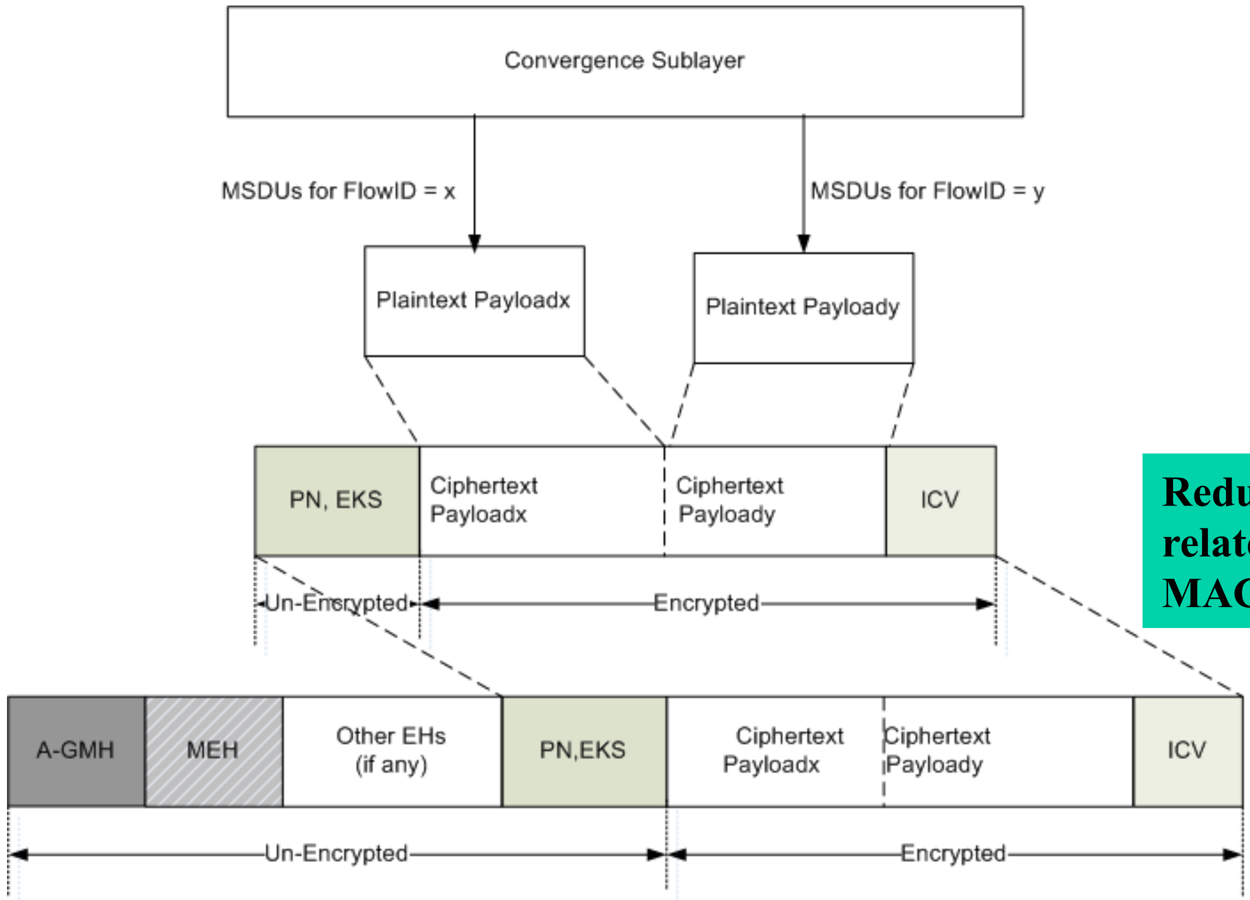


802.16m Data Plane operation

Efficient MAC PDU Formation



Introducing Multiplexing to Reduce Overhead

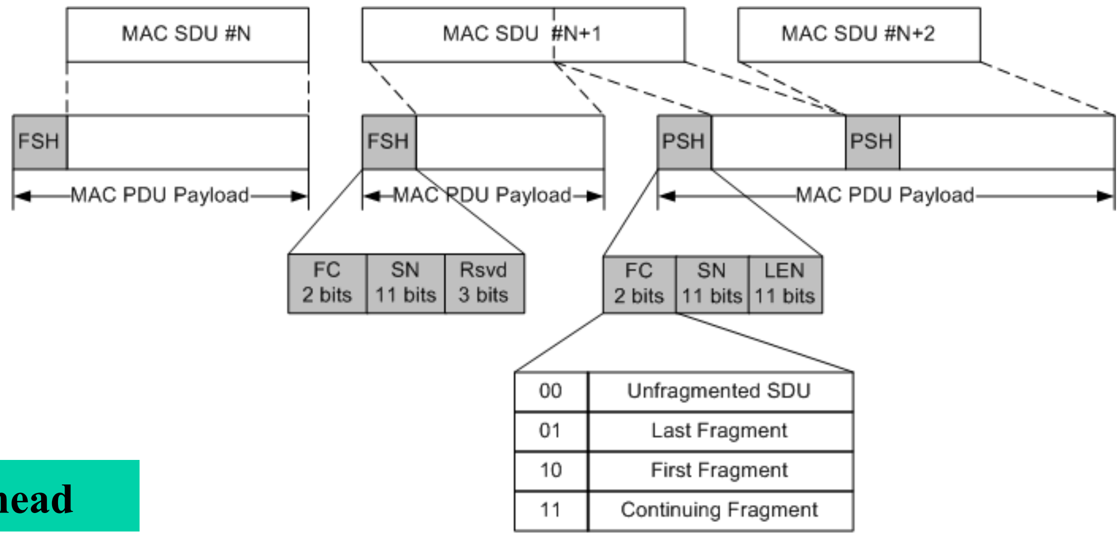


Reduced overhead related to security and MAC header

Multiple connections' payload associated with same security association are multiplexed and encrypted together in a MAC PDU.

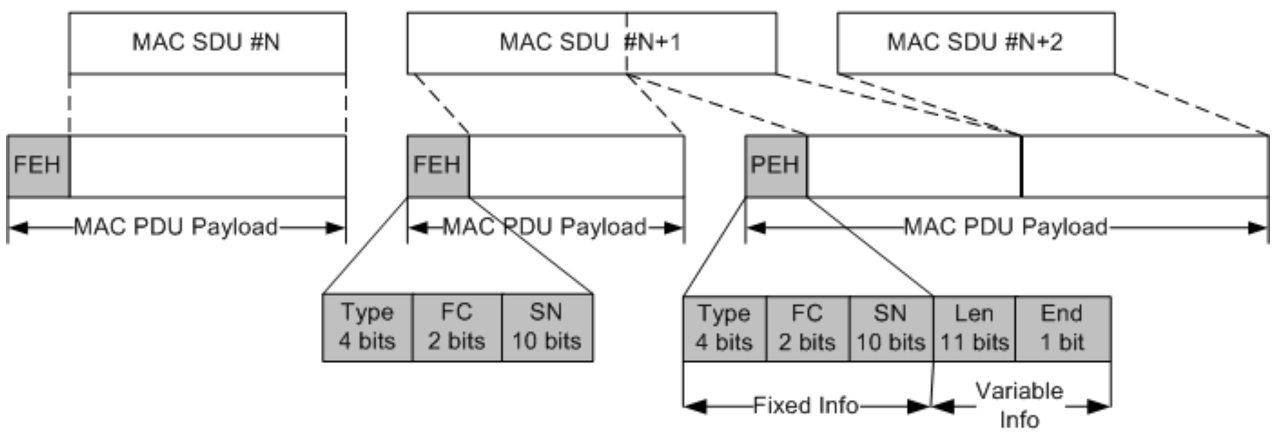
More efficient Packing Mechanism

802.16e Scheme



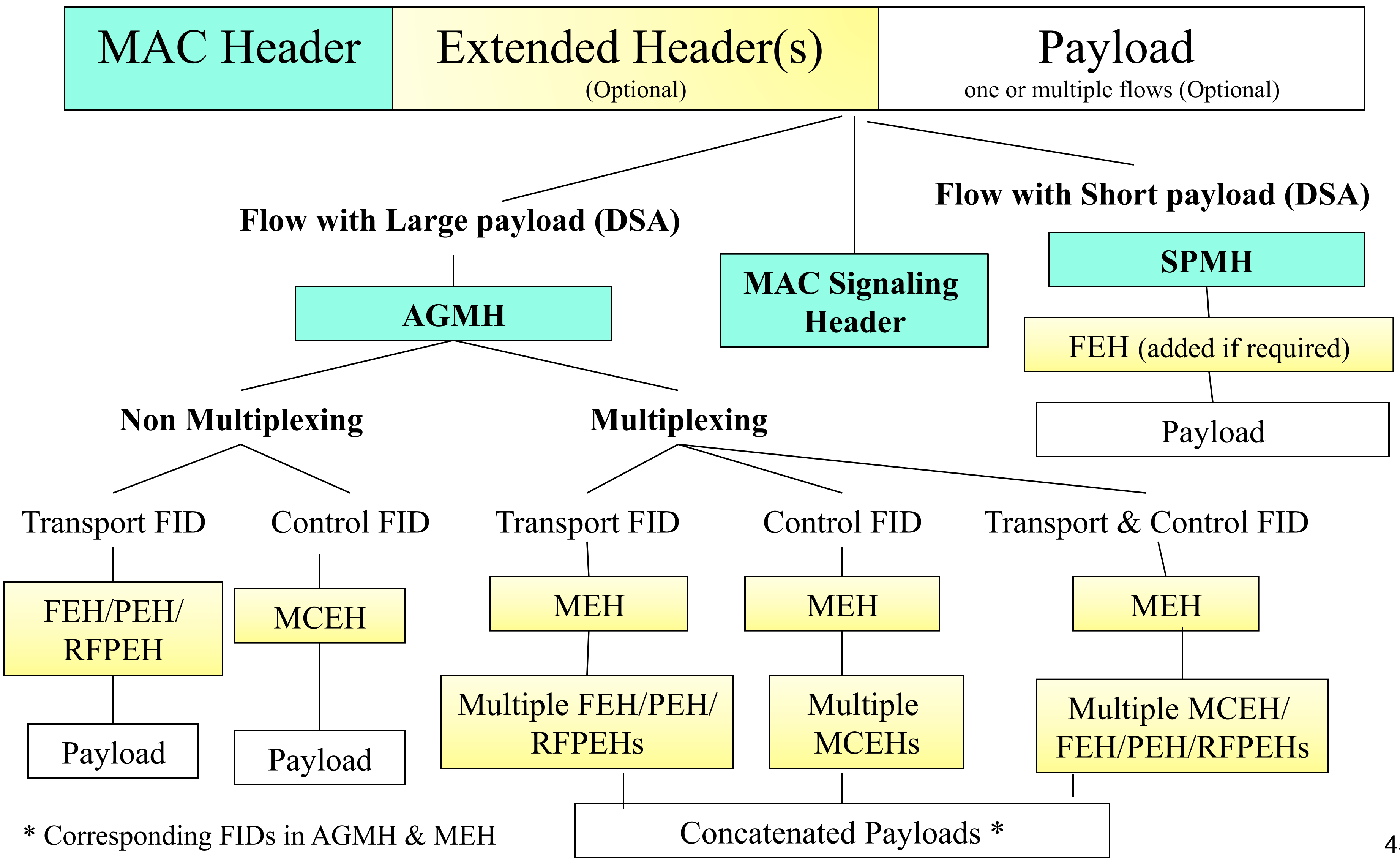
Reduced Packing Overhead

802.16m Scheme



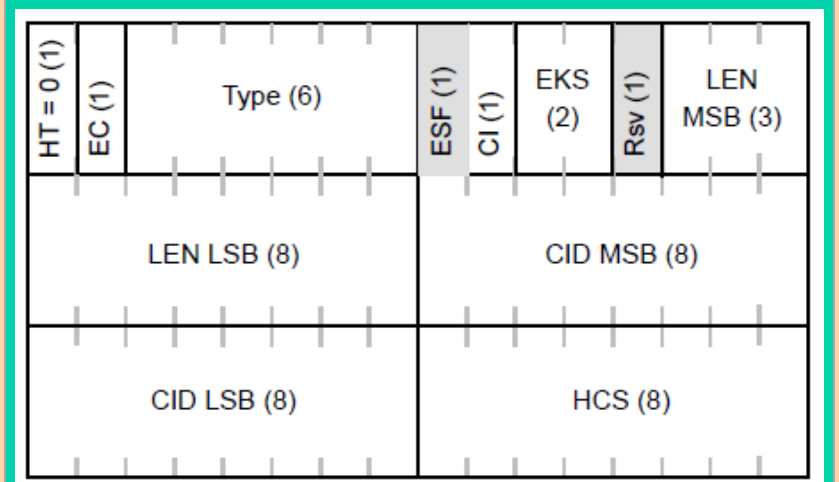
* if 'n' SDU/SDU fragments are packed in MPDU payload then (Len, End) fields are added 'n-1' times in FPEH

802.16m MAC PDU Formats



Connection Specific MAC Header

- 16e Generic MAC Header (6 bytes)



- 16m : Connection Specific MAC header

FlowID (4)	EH (1)	MSB_Length (3)
LSB_Length (8)		

- AGMH, SPMH, Signaling header
  - AGMH: Generic MAC header (2 Bytes)
  - SPMH: For short packets e.g. VoIP (2 Bytes)
  - Signaling header: For control information e.g. BW request (Variable size)

High Throughput ARQ mechanism

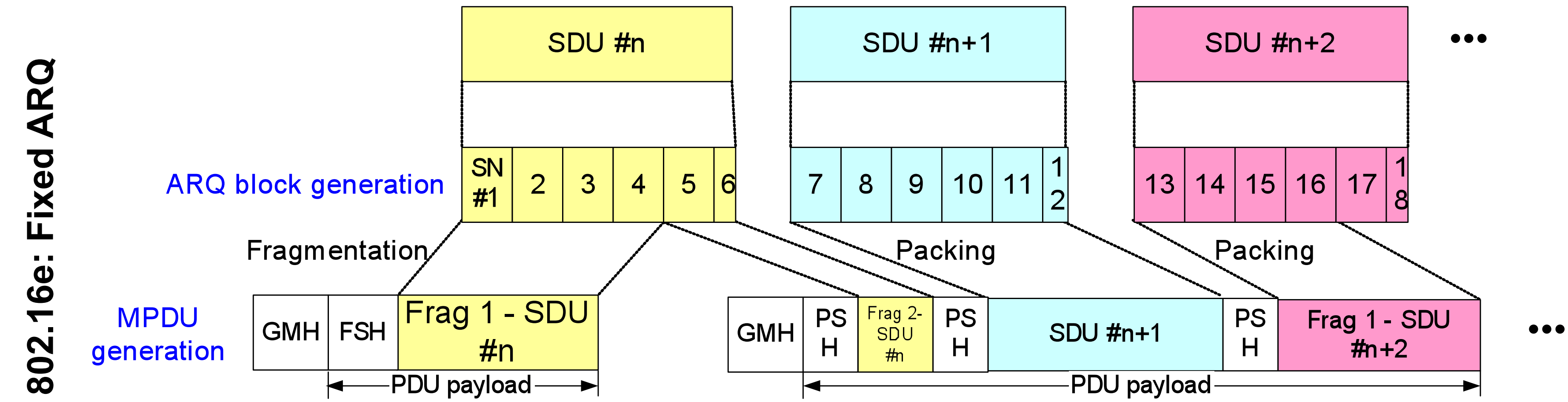


Figure 1. 16e ARQ block and MPDU generation for Initial transmission

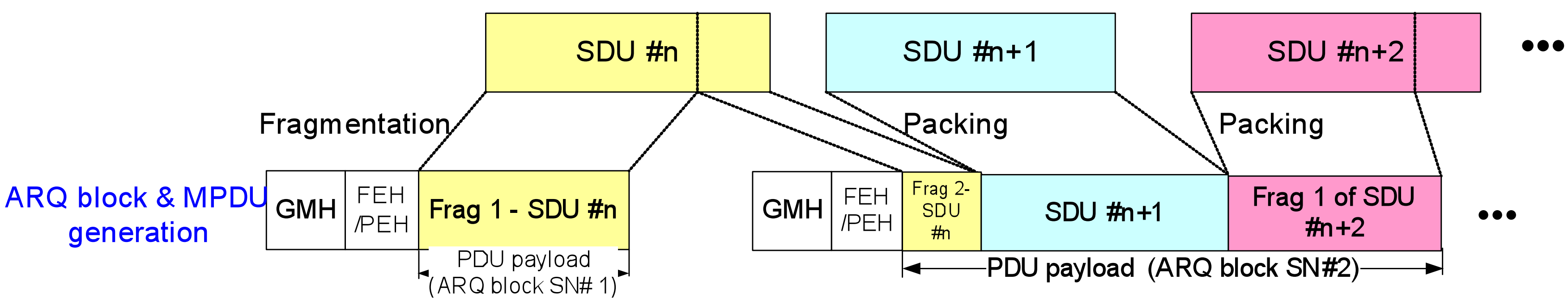


Figure.2. 16m ARQ block and MPDU generation for Initial transmission

802.16m: Variable ARQ

Variable sized ARQ blocks allow better adaptation to channel conditions and remove the throghput bottlenecks caused by the fixed size ARQ blocks

Reliable MAC message transmission

- **All Control messages are fragmentable**
  - Large message can be fragmented to support reliable transmission in Uplink
  - “SN” in MCEH is defined for supporting message fragmentation
- **All unicast Control messages apply HARQ process**
  - HARQ supports PHY level-retransmission
  - Retransmission timer starts when a message is transmitted and stops when a response message is received
- **Generic Message ACK for added reliability**
  - Defined Message ACK extended header
  - Transmitter can poll MSG-ACK to know if message is arrived correctly (MCEH)
  - Message ACK is transmitted after all fragments of message are completely received.
  - Used when:
    - When message retry timer value is quite large
    - One-way message acknowledgement (like HO-IND message)

802.16m Upper MAC Mechanisms

802.16m MAC

- Enhanced HO modes and efficiency
- Legacy mobile 802.16-to-16m HO
- Multi-RAT service
- Co-located Multi-RAT Coexistence
- ASN.1 control message formatting
- Improved Privacy and Security
- Improved QoS
- Enhanced Power Conservation
- Inter-BS Synchronization
- Enhanced MBS
- Multi-Hop Relay
- FemtoBS & SON
- Enhanced LBS

802.16m Handover Improvement

- **BBE and EBB Handover Modes**
  - Reductions in handover control messaging and CDMA signaling
  - Control messaging latency reduction
  - State-change control messaging reliability improvement
  - New make-before-break mode
- **Results are overall improved handover reliability and decreased overhead**

802.16m Legacy mobile 802.16-to-16m HO

- **LZone and MZone concepts in a 16m frame**
  - LZone looks, feels like a Legacy 16 mobile channel
  - Dual-mode mobile subscriber device conducts HO through LZone operation in 16m ABS
  - Dual-mode MS/AMS may transition back/forth from LZone and MZone
  - OR Dual-mode MS/AMS may handover directly from legacy 16 BS to 16m MZone ABS; for instance for an ABS that operates only MZone, no legacy LZone

Multi-RAT service

- Other Radio Access Technology availability advertised
- Further RAT details accessed via other information service, for instance 802.21
- Inter-RAT scanning threshold triggers
- Support for both single- and dual-radio
- Optimized Inter-RAT handover supported
- Col-located Multi-RAT service
  - 802.16m resource scheduling perforation scheme to assure co-located other-RAT collocated radios may receive un-interfered other-RAT channel access

802.16m ASN.1 control message formatting

- MAC control messages using ASN.1 notation, Packed Encoding Rules (PER) with byte unaligned option
- Standardized protocol for formatting
- Reduces message size by about 40%

802.16m Improved Privacy and Security

- Device privacy introduced: session based pseudo-ID used instead of true MAC Address
- Revised key hierarchy that uses derived TEK instead of transferred TEK to cipher data
- Introduces optional cipher on MAC control messages; supplements legacy authentication method
- Reduced overall cipher overhead on data and control

802.16m Improved Scalability and Flexibility in QoS

- Adaptive grant polling service (aGPS) method introduced
- Two pre-negotiated QoS parameter sets
- Trigger and method for parameter set invokation transition
- Helpful for flows with QoS types that have detectable and differentiated QoS state transitions; for instance certain types of Fixed Rate voice codecs

802.16m Enhanced Power Conservation Operation in All Modes

- Idle Mode operation with increased parameter operation; reduces need for mobile to re-attach and adjust operating parameters
- New deregistration with context retention (DCR) mode; facilitates re-attachment without location update requirement, no network or air resource reservation
- Simplified sleep mode operation

802.16m Performance Results

Performance: Cell Spectral Efficiency

DL cell spectral efficiency in bit/s/Hz/cell for TDD

	InH	UMi	UMa	RMa
Cell spectral efficiency	6.93	3.22	2.41	3.23
ITU-R requirement	3.0	2.6	2.2	1.1

DL cell spectral efficiency in bit/s/Hz/cell for FDD

	InH	UMi	UMa	RMa
Cell spectral efficiency	6.87	3.27	2.41	3.15
ITU-R requirement	3.0	2.6	2.2	1.1

UL cell spectral efficiency in bit/s/Hz/cell for TDD

	InH	UMi	UMa	RMa
Cell spectral efficiency	5.99	2.58	2.57	2.66
ITU-R requirement	2.25	1.8	1.4	0.7

UL cell spectral efficiency in bit/s/Hz/cell for FDD

	InH	UMi	UMa	RMa
Cell spectral efficiency	6.23	2.72	2.69	2.77
ITU-R requirement	2.25	1.8	1.4	0.7

Performance: VoIP Capacity

VoIP capacity (users/sector/MHz) for TDD

	DL	UL	Minimum {DL, UL}	ITU-R required
InH	140	165	140	50
UMi	82	104	82	40
UMa	74	95	74	40
RMa	89	103	89	30

VoIP capacity (users/sector/MHz) for FDD

	DL	UL	Minimum {DL, UL}	ITU-R required
InH	139	166	139	50
UMi	77	102	77	40
UMa	72	95	72	40
RMa	90	101	90	30

Peak Spectral Efficiency

Peak Spectral Efficiency (bit/s/Hz)			
		RIT	Required
FDD	DL	17.79	15
	UL	9.40	6.75
TDD	DL	16.96	15
	UL	9.22	6.75

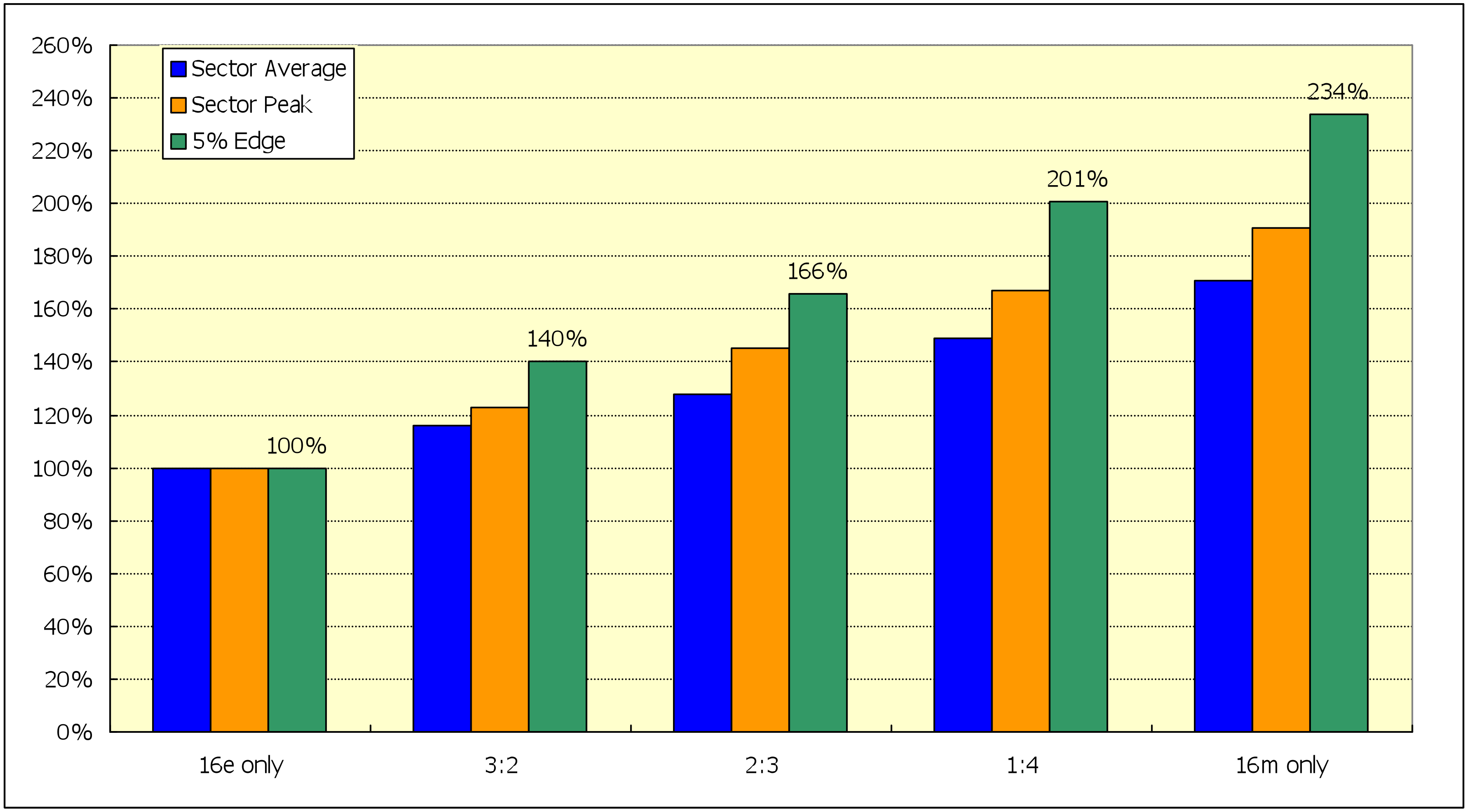
Significant Improvement in Peak Rates

	802.16e (From [1])	802.16m (From [2])
Bandwidth, CP	10MHz, 1/8	20MHz, 1/16
Streams	DL:2, UL:2	DL:4, UL:2
Overhead	3 symbols + pilot	1 symbol + pilot
TDD DL : UL	2 : 1	2 : 1
DL MCS	64QAM, 5/6	64QAM, 1
UL MCS	16QAM, 3/4	64QAM, 1
DL Peak [Mbps]	40.32	**226.1**
UL Peak [Mbps]	10.08	**61.5**

[1] "Mobile WiMAX – Part I: A Technical Overview and Performance Evaluation", June, 2006, WiMAX Forum

[2] "Submission of a Candidate IMT-Advanced RIT based on IEEE 802.16", ITU-R IMT-ADV/4

Performance in Mixed Mode



DL sector throughput comparison for 802.16e:802.16m ratio

– DL:UL=5:3, 10MHz channel bandwidth, 4 x 2 MIMO

Resources

- **IEEE 802.16 web site**
  - http://WirelessMAN.org