802.16 WirelessMAN®

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IEEE 802 Standards Education Workshop:
The World of IEEE 802 Standards
November 30, 2009 | Honolulu, Hawaii, USA

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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)

MENU

- 802.16 is...
  - Working Group
  - Standard
- Latest Significant Activity: 16m
- Standard & ITU
- 16m Details
- Resources & References
- WiMAX Forum
- 802.20
- 802.21

802.16 is...

An IEEE-SA P802 Working Group (WG)

- IEEE 802.16 Working Group on Broadband Wireless Access
- Develops and maintains a set of standards

802.16 is...
A standard

- IEEE Standard 802.16: Air Interface for Broadband Wireless Access Systems
- The WirelessMAN® standard for Wireless Metropolitan Area Networks

MENU

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- 802.20
- 802.21

The 802.16 Working Group
Overview

- Organized under IEEE
- Initiated in 1998; Formalized in 1999 (over 10 years old)
- Holds at least six sessions a year
  - Session duration: four days
  - 64 Sessions to date
- Open&Transparent process
  - Anyone can participate; become a Member

The 802.16 Working Group
Overview (continued)

- Members are individuals; people
- Membership earned by participation
- Currently: 437 Members, from around the world, from dozens of countries

MENU

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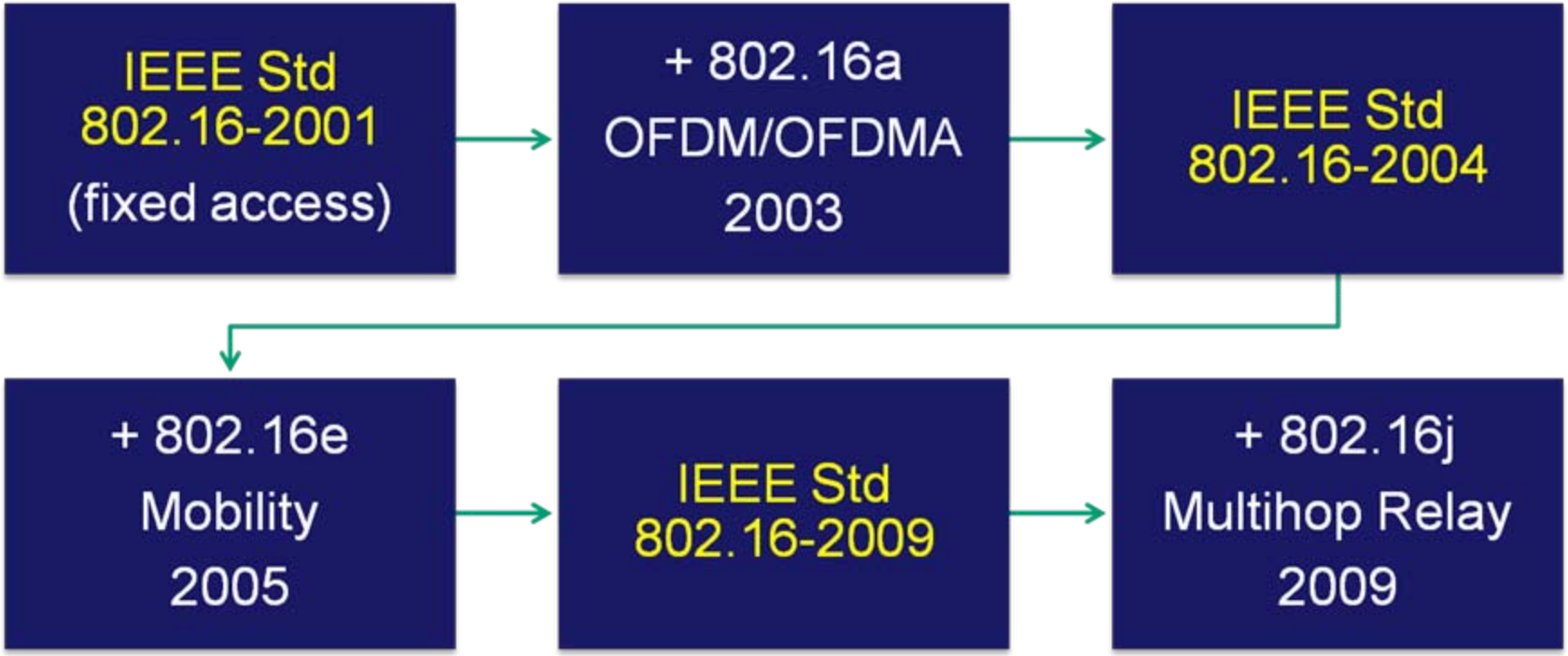
- WiMAX Forum
- 802.20
- 802.21

The 802.16 Standard
Overview

- “Air Interface for Broadband Wireless Access Systems”
- Developed since 1999 by IEEE 802.16 WG
- Evolves by amendments and revision
- Fixed non-line-of-sight OFDMA introduced in 2002
- Mobile-enabled OFDMA introduced in 2005 (“802.16e”)

The 802.16 Standard

Key Evolution Steps



A dozen other Amendments and Corrigenda not shown

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The 802.16 Standard
Latest Significant Activity: 16m

- "Advanced Air Interface" **16m** Amendment project, initiated 2006
- Amend IEEE 802.16 WirelessMAN-OFDMA specification only
- meet the cellular layer requirements of IMT-Advanced next generation mobile networks

The 802.16 Standard

Latest Significant Activity: 16m (continued)

- support for legacy WirelessMAN-OFDMA equipment (i.e., backward compatibility)
- provide performance improvements to support future advanced services and applications

The 802.16 Standard
Latest Significant Activity: 16m (continued)

- Wide participation and interest
  - Over 1200 professionals
  - From about 240 organizations
  - From 23 countries
  - Contributed > 4400 documents to date since project inception

The 802.16 Standard

Latest Significant Activity: 16m (continued)

- Project Process
  - Evaluation Methodology Document (EMD) Done
  - System Requirements Document (SRD)
    - Stage 1 Done
  - System Description Document (SDD)
    - Stage 2 Done
  - Draft Amendment to IEEE 802.16-2009
    - Stage 3 In Process

The 802.16 Standard
Latest Significant Activity: 16m (continued)

- Draft Amendment to IEEE 802.16-2009
  - Stage 3 Draft Status
    - Four versions before P802.16m/D1
    - Current version P802.16m/D2
    - D3 to be published by Dec 4
- Draft Progress and Completion
  - Likely enter Sponsor Ballot in 2010Q2
  - Likely project completion 2010Q4

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The 802.16 Standard & ITU

- IEEE: ITU-R Sector Member
  - "Regional & other International Organizations"
- Relevant ITU-R Engagement
  - Fixed Wireless Access
    - Rec. F.1763: IEEE 802.16 in the Fixed Service
  - Land Mobile Radio
    - Rec. M.1801: IEEE 802.16 in the Mobile Service

The 802.16 Standard & ITU
(continued)

- Relevant ITU-R Engagement (continued)
  - IMT-2000
  - IMT-Advanced

The 802.16 Standard & ITU
(continued)

- Relevant ITU-R Engagement (continued)
  - IMT-2000
    - M.1457 Rev. 7 (2007) adds “OFDMA TDD WMAN”
      - Based on IEEE Std 802.16 (including 802.16e)
      - Implementation profile developed by WiMAX Forum
    - M.1457 Rev. 9 (2009) completed by WP 5D
      - Updates reference to IEEE Std 802.16-2009
      - Includes FDD as well as TDD updates

The 802.16 Standard & ITU
(continued)

- Relevant ITU-R Engagement (continued)
  - IMT-Advanced
    - Contribution 8F/1083 (Jan 2007) notified ITU-R that **802.16m** project is intended for future contributions on IMT-Advanced.
    - IEEE 802.16 Working Group developed many contributions to WP 5D regarding IMT-Advanced process and technical requirements.

The 802.16 Standard & ITU
(continued)

- Relevant ITU-R Engagement (continued)
  - IMT-Advanced (continued)
    - 5D/356 (Feb 2009) and 5D/443 (May 2009) provided specific notice of intention to submit IMT-Advanced proposal, with additional details.
    - 5D/542 (October 2009): Submission of a Candidate IMT-Advanced RIT based on IEEE **802.16m**

The 802.16 Standard & ITU
(continued)

- Relevant ITU-R Engagement (continued)
  - IMT-Advanced (continued)
    - Presentation at the 3rd Workshop on IMT-Advanced as one of two Technology Proponents (Dresden, 15 Oct 2009)
      - 802.16m for both FDD and TDD; targeting meeting all four ITU IMT-Advanced test environments
        - Indoor Hotspot
        - Urban Microcell
        - Urban Macrocell
        - Rural Macrocell

The 802.16 Standard & ITU
(continued)

- Relevant ITU-R Engagement (continued)
  - IMT-Advanced (continued)
    - Cooperating with national standards bodies in support of 802.16 candidate technology
      - Japan, ARIB; Korea, TTA
    - Large commercial support
      - Endorsement of candidate IMT-Advanced RIT based on IEEE 802.16 from 30 multinationals that participate in ITU-R

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The 802.16 Standard

16m Details: SRD Key System 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)

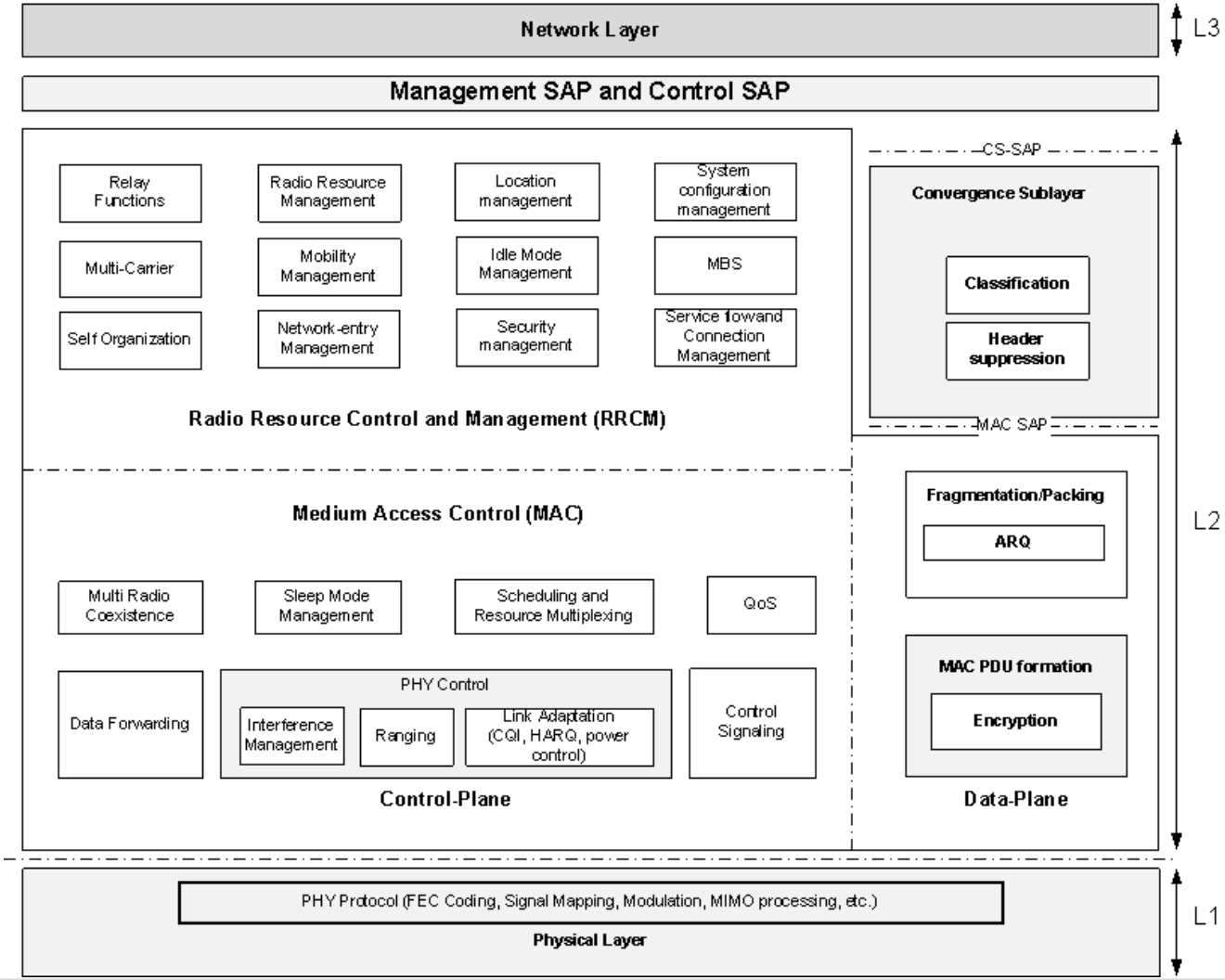
The 802.16 Standard

16m Details: SDD Key Features

- Protocol Structure
- Frequency Bands
- Convergence Sublayer
- Medium Access Control Layer
- Physical Layer
- Location Based Services
- Enhanced Multicast Broadcast Service
- Multi-Hop Relay
- FemtoBS
- Self-organization
- Multi-carrier Operation
- Interference Mitigation
- RF Requirements
- Inter-BS Synchronization

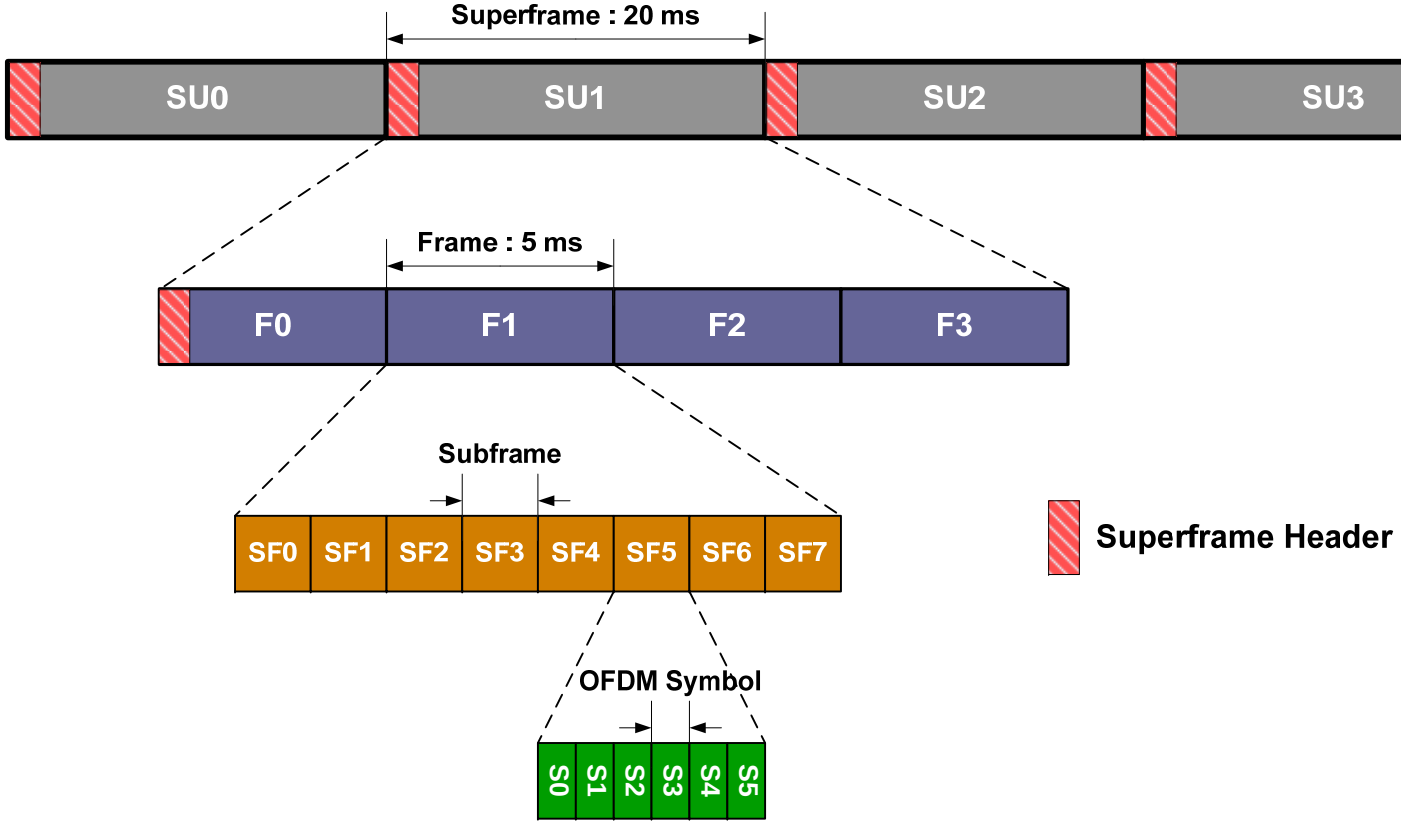
The 802.16 Standard

16m Details: Amendment: Protocol Structure



The 802.16 Standard

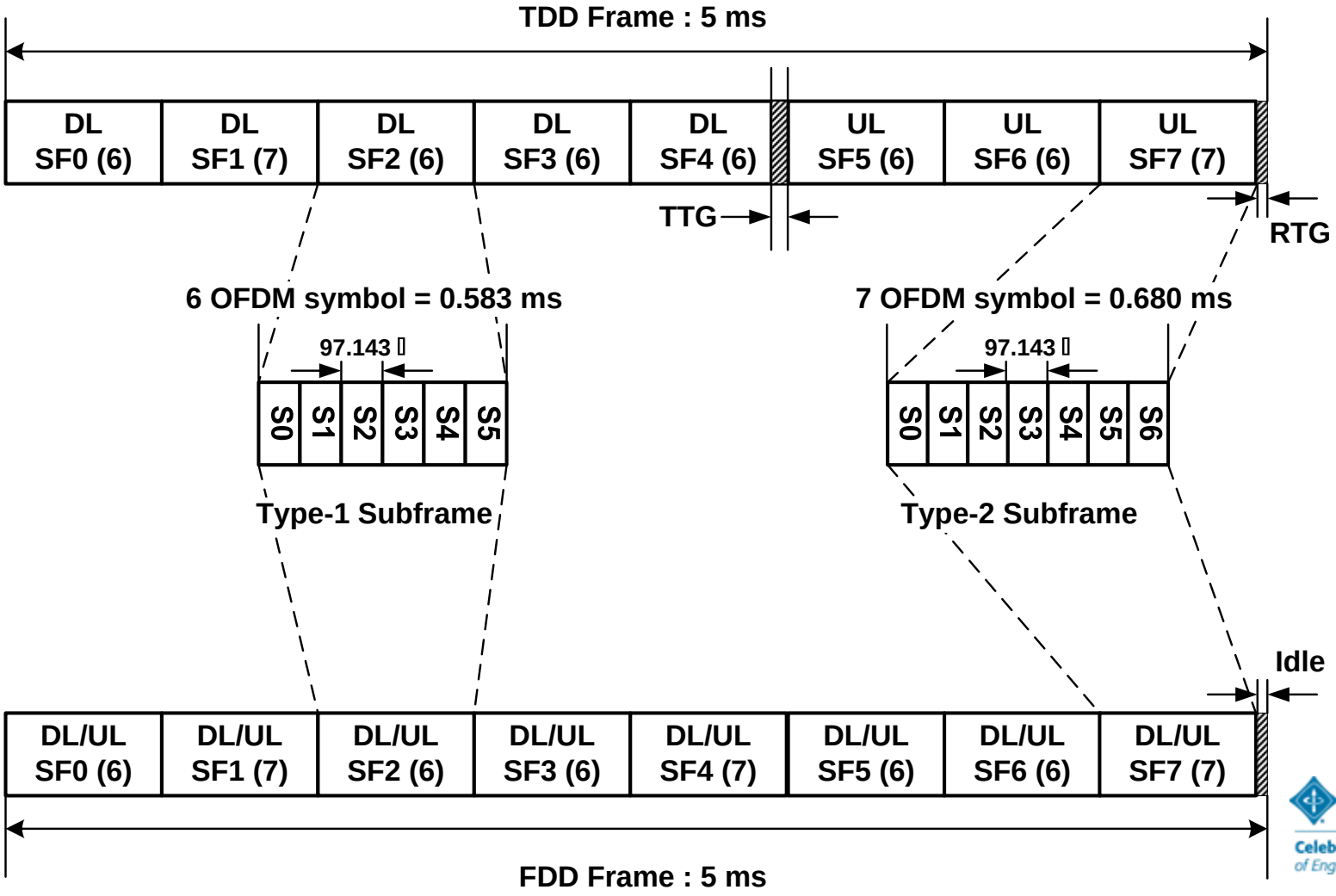
16m Details: Amendment: Frame Structure



- improved voice capacity and reduced channel response latency

The 802.16 Standard

16m Details: Amendment: Frame Detail



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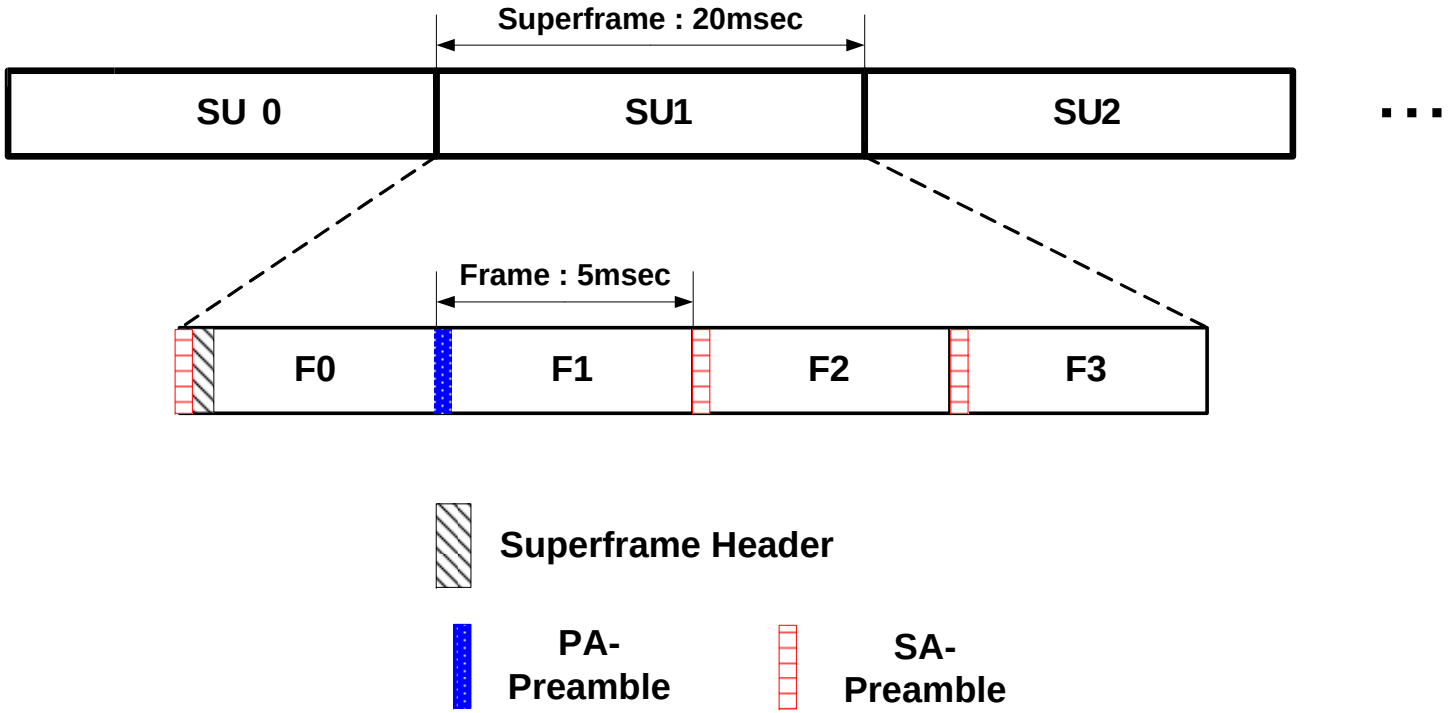
The 802.16 Standard

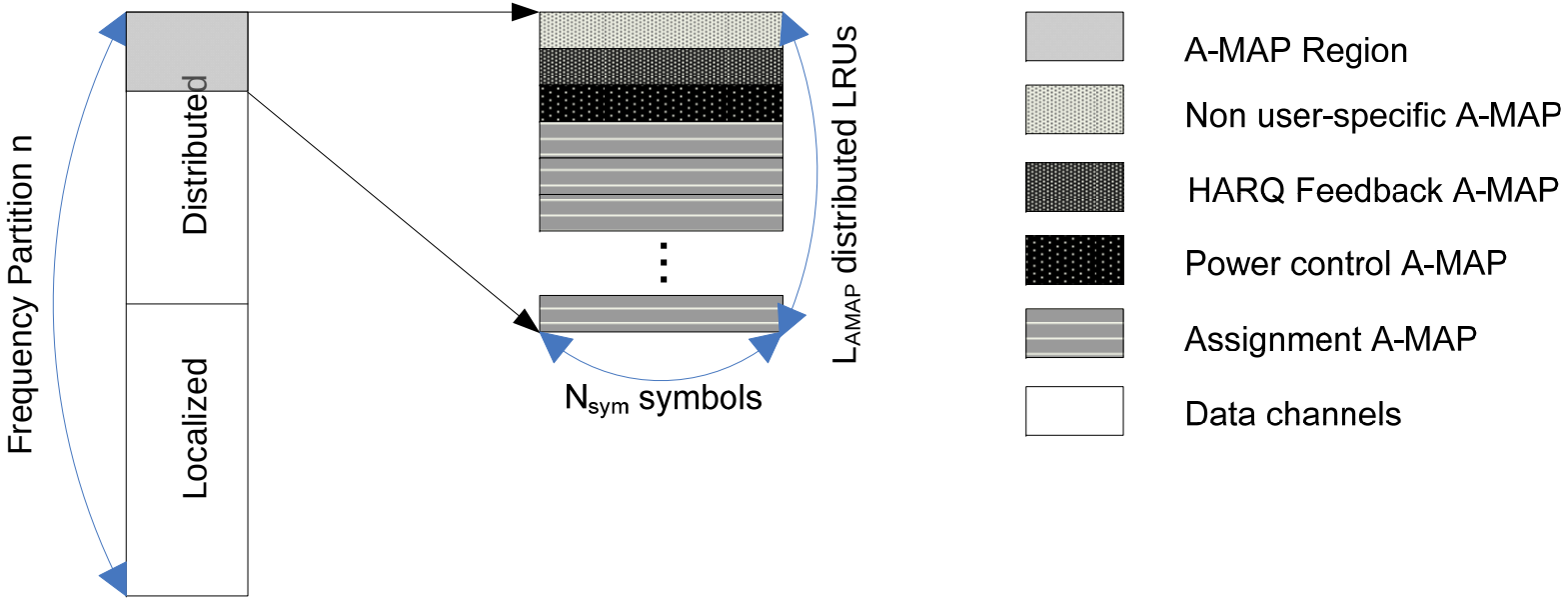
16m Details: Amendment: Preamble



- Primary (PA-) Preamble: For initial acquisition, superframe synchronization, etc.
- Secondary (SA-) Preamble: For fine synchronization, cell identification, etc.

The 802.16 Standard

16m Details: Amendment: Frame Header



- Superframe Header (SFH)
  - To carry the system configuration information for cell selection and system access
- Advanced MAP (A-MAP): RU Assignment A-MAP; HARQ Feedback A-MAP; Power Control A-MAP

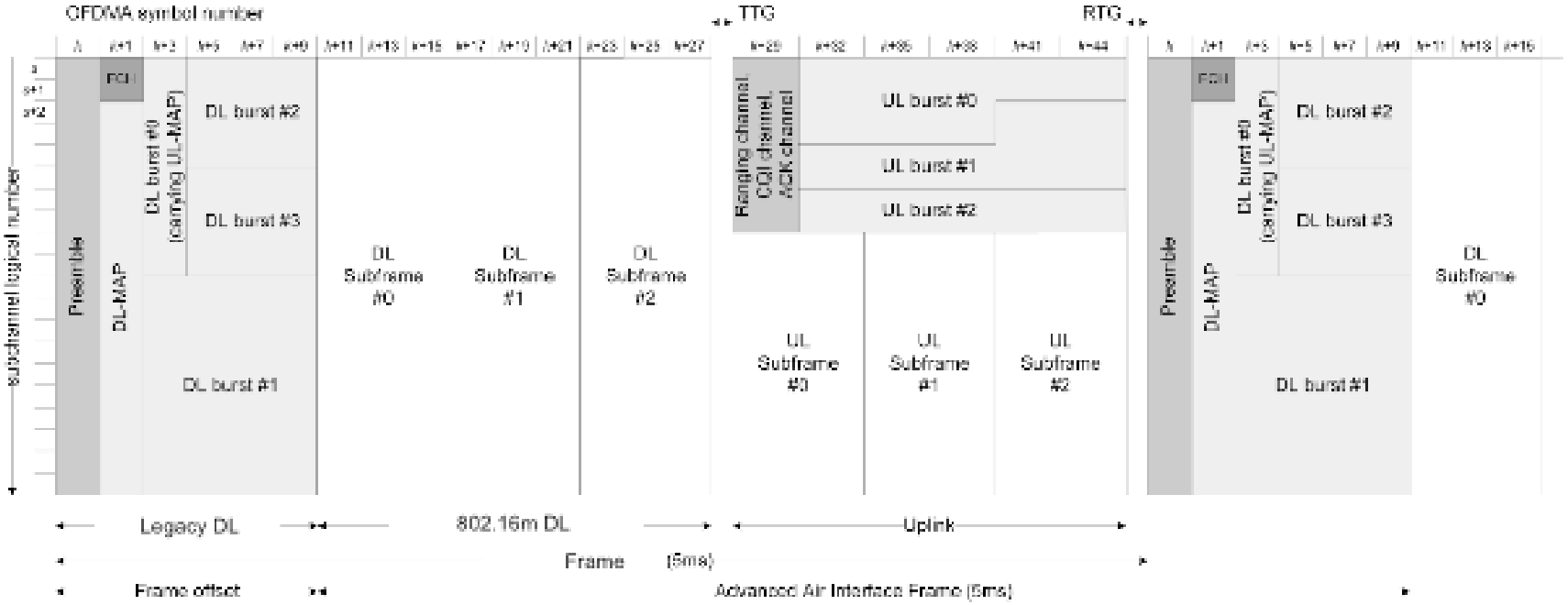
The 802.16 Standard

16m Details: Amendment: Numerology

Nominal channel bandwidth (MHz)			5	7	8.75	10	20
Sampling factor			28/25	8/7	8/7	28/25	28/25
Sampling frequency (MHz)			5.6	8	10	11.2	22.4
FFT size			512	1024	1024	1024	2048
Subcarrier spacing (kHz)			10.937500	7.812500	9.765625	10.937500	10.937500
Useful symbol time T_u (μs)			91.429	128	102.4	91.429	91.429
Cyclic prefix (CP) T_g = 1/8 T_u	Symbol time T_s (μs)		102.857	144	115.2	102.857	102.857
	FDD	Number of OFDMA symbols per frame	48	34	43	48	48
		Idle time (μs)	62.857	104	46.40	62.857	62.857
	TDD	Number of OFDMA symbols per frame	47	33	42	47	47
		TTG + RTG (μs)	165.714	248	161.6	165.714	165.714
CP T_g = 1/16 T_u	Symbol Time T_s (μs)		97.143	136	108.8	97.143	97.143
	FDD	Number of OFDMA symbols per frame	51	36	45	51	51
		Idle time (μs)	45.71	104	104	45.71	45.71
	TDD	Number of OFDMA symbols per frame	50	35	44	50	50
		TTG + RTG (μs)	142.853	240	212.8	142.853	142.853

The 802.16 Standard

16m Details: Amendment: Legacy Support



- IEEE 802.16m RIT provides continuing support for legacy IMT-2000 (OFDMA TDD WMAN) MSs and BSs.
- 802.16m BS/MS supports a legacy BS/MS at a level of performance equivalent to that of a legacy BS

The 802.16 Standard

16m Details: Amendment: PHY&MAC Improvements

- Advanced MIMO
- Reduced Overhead Resource Mapping
- Multi-carrier Operation
- Advanced Interference Mitigation
- Multi-RAT service
- Co-located Multi-RAT Coexistence
- Inter-BS Synchronization
- Enhanced MBS
- Multi-Hop Relay
- FemtoBS
- Self-organization
- Enhanced LBS
- Improved Privacy and Security

The 802.16 Standard

16m Details: Amendment: PHY&MAC Improvements (continued)

- Improved Scalability and Flexibility in QoS
- Improved HARQ Integration
- Improved Control Message Integrity
- Enhanced Power Conservation Operation in All Modes
- Emergency Services and Notification support

The 802.16 Standard

16m Details: Amendment: Performance

Designation	Test environment	Deployment scenario
InH	Indoor	Indoor Hotspot
UMi	Microcellular	Urban micro-cell
UMa	Base coverage urban	Urban macro-cell
RMa	High speed	Rural macro-cell

The 802.16 Standard

16m Details: Amendment: Performance

Table 7-5: 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

Table 7-7: 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

Table 7-9: 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

Table 7-11: 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

The 802.16 Standard

16m Details: Amendment: Performance

Table 7-13: VoIP capacity (users/sector/MHz) for TDD

Test environment	DL	UL	Minimum {DL, UL}	ITU-R required
Indoor (InH)	140	165	140	50
Microcellular (UMi)	82	104	82	40
Base coverage urban (UMa)	74	95	74	40
High speed (RMa)	89	103	89	30

Table 7-14: VoIP capacity (users/sector/MHz) for FDD

Test environment	DL	UL	Minimum {DL, UL}	ITU-R required
Indoor (InH)	139	166	139	50
Microcellular (UMi)	77	102	77	40
Base coverage urban (UMa)	72	95	72	40
High speed (RMa)	90	101	90	30

The 802.16 Standard
16m Details: Amendment: Performance

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

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- 802.21

802.16 WirelessMAN®
Resources & References

- IEEE 802.16 Website
  - http://WirelessMAN.org
- IEEE 802.16 IMT-Advanced web page
  - http://WirelessMAN.org/imt-adv
- IEEE 802.16 Candidate Proposal for IMT-Advanced
  - L802.16-09/0114r4

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WiMAX Forum®…

WiMAX Forum Vision:
Global adoption of WiMAX as the broadband wireless Internet technology of choice anytime, anywhere

WiMAX Forum Seeks to Achieve this Vision By:

- Promoting WiMAX to ensure spectrum availability and a favorable regulatory environment.
- Delivering a trusted certification process to achieve global interoperability.
- Publishing technical specifications based on recognized standards.
- Promoting the brand and technology to establish WiMAX as the worldwide market leader for broadband wireless

WiMAX Forum®

- WiMAX Forum <http://wimaxforum.org> is an international consortium of hundreds of leading companies from around the world
- certifies broadband wireless products based upon IEEE Std 802.16, promoting compatibility and interoperability
- dedicated to the global adoption of WiMAX as the broadband wireless Internet technology of choice anytime, anywhere
- Over 150 WiMAX Forum certified Products
  - from 25 BS vendors and 42 SS vendors
- 518 deployments in 146 countries
  - coverage of more than 430 Million people

WiMAX Forum, IEEE, and IMT

- WiMAX Forum partners with IEEE in supporting *IMT-2000 OFDMA TDD WMAN* radio interface in ITU-R
  - Approved in 2007
  - Updated to include FDD in 2009 (awaiting adoption)
- Endorses IEEE proposal to include 802.16m in ITU-R's IMT-Advanced standard
  - Issued supportive announcement
  - Coordinated ecosystem news conference
  - Developed supporting contribution to ITU-R and enlisted 50 companies to co-sign

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802.20 Mobile Broadband Wireless Access (MBWA) Working Group

- Base standard IEEE 802.20-2008
- Two standards in one
  - TDD UMB design substantially based on 3GPP2/TIA FDD UMB
    - 3GPP2 C.S0084-0-000 thru C.S0084-0-009
  - Separate and unrelated 625kiloHertz-spaced MultiCarrier (625k-MC) enhancements to ATIS High Capacity-Spatial Division Multiple Access (HC-SDMA)
    - ATIS-070004.2005

802.20 Mobile Broadband Wireless Access (MBWA) Working Group

- Current projects
  - PICS
  - Minimum Performance Requirements
  - MIB
  - Virtual Bridging

802.20 Mobile Broadband Wireless Access (MBWA) Working Group

- TDD UMB
  - DL OFDMA, UL CDMA/OFDMA based air interface PHY

802.20 MBWA
TDD UMB Layering Architecture

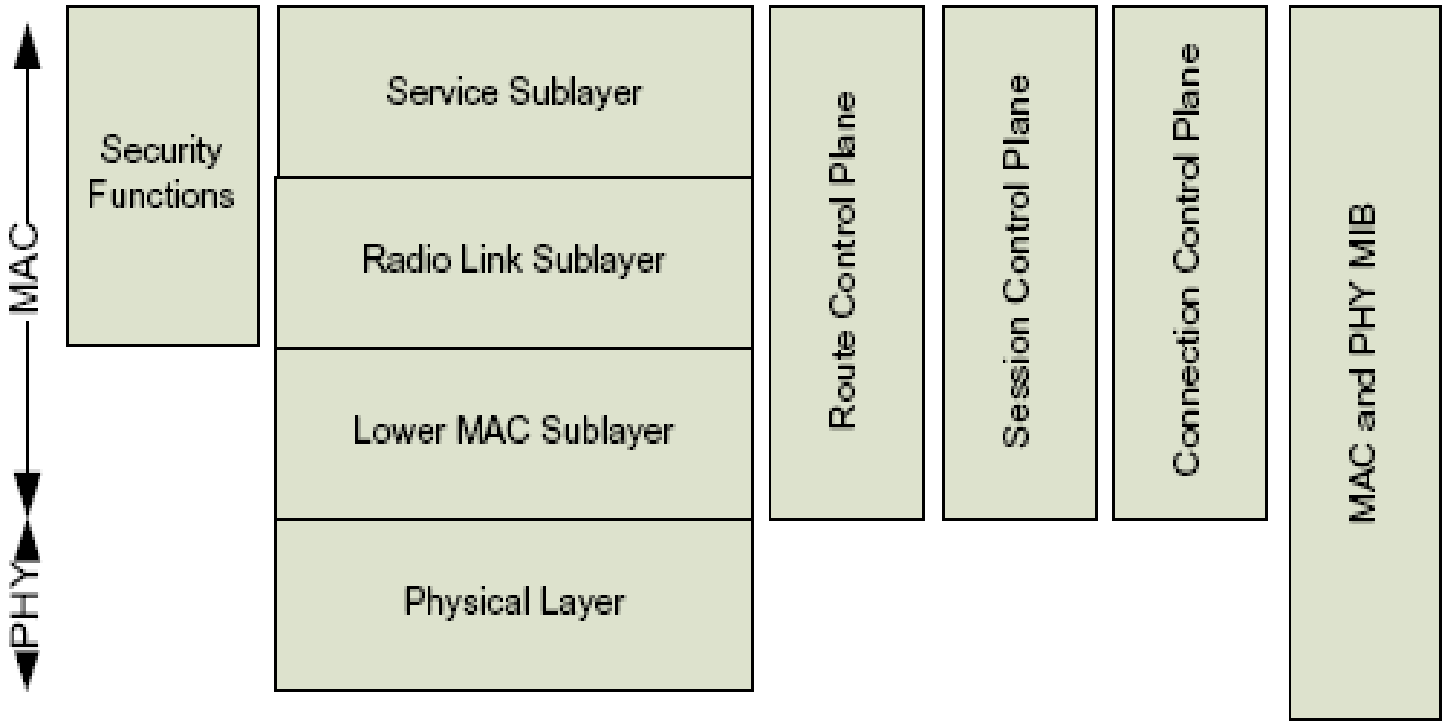

Figure 2 — Unicast Route Layering Architecture

802.20 MBWA

TDD UMB FL Superframe Structure

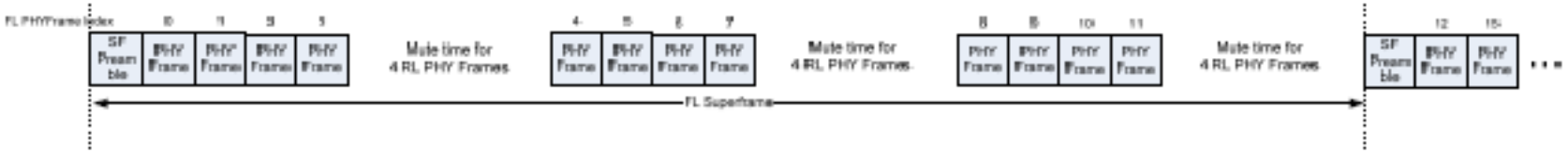

Figure 82 — TDD44 Forward Link Superframe Structure

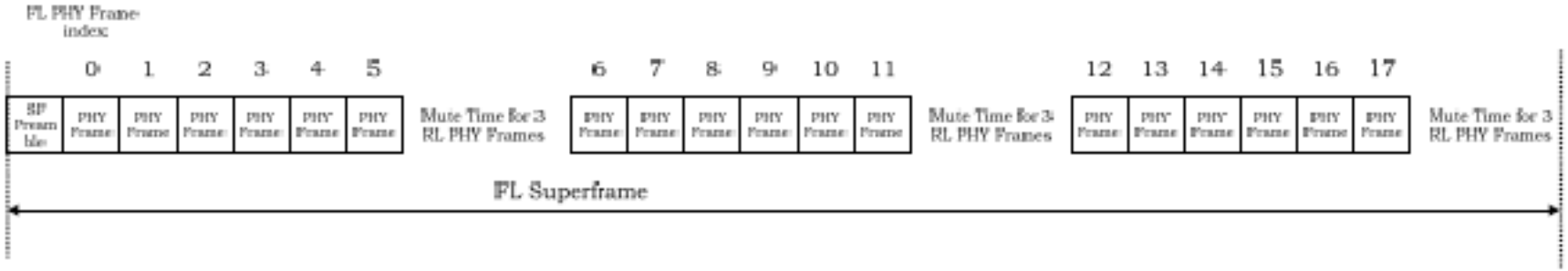

Figure 83 — TDD63 Forward Link Superframe Structure

802.20 MBWA

TDD UMB FL Symbol Numerology

Table 154 — Forward Link Orthogonal Frequency Division Multiplexing Symbol Numerology

Parameter	FFT Size $N_{FFT} = 512$	$N_{FFT} = 1024$	$N_{FFT} = 2048$	Units
Chip Rate $1/T_{CHIP}$	4.9152	9.8304	19.6608	Mcps
Subcarrier Spacing $1/(T_{CHIP}N_{FFT})$	9.6	9.6	9.6	kHz
Bandwidth of Operation	2.5–5	5–10	10–20	MHz
Cyclic Prefix Duration $T_{CP} = N_{CP}N_{FFT}T_{CHIP}/16$ $N_{CP} = 1, 2, 3, \text{or } 4$	6.51, 13.02, 19.53, or 26.04	6.51, 13.02, 19.53, or 26.04	6.51, 13.02, 19.53, or 26.04	µs
Windowing Guard Interval $T_{WGI} = N_{FFT}T_{CHIP}/32$	3.26	3.26	3.26	µs
Orthogonal Frequency Division Multiplexing Symbol Duration $T_s = N_{FFT}T_{CHIP}(1 + N_{CP}/16 + 1/32)$ $N_{CP} = 1, 2, 3, \text{or } 4$	113.93, 120.44, 126.95, or 133.46	113.93, 120.44, 126.95, or 133.46	113.93, 120.44, 126.95, or 133.46	µs

802.20 MBWA

TDD UMB FL Superframe Numerology

Table 155 — Forward Link Orthogonal Frequency Division Multiplexing Superframe Numerology

Parameter		Value	Units
$N_{PREAMBLE}$ = Number of Orthogonal Frequency Division Multiplexing Symbols in the Superframe Preamble		8	
N_{FRAME} = Number of Orthogonal Frequency Division Multiplexing Symbols in a Forward Link PHY Frame		8	
Duplexing Mode = TDD44	Number of FL PHY Frames in a Superframe	12	
	Guard time between a FL PHY Frame and the subsequent RL PHY Frame ($T_{g,TDD,F} = 3N_{FFT}T_{CHIP}/4$)	78.13	µs
	Guard time between a RL PHY Frame and the subsequent FL PHY Frame ($T_{g,TDD,R} = 5N_{FFT}T_{CHIP}/32$)	16.28	µs
	Superframe Duration ($T_{SUPERFRAME}$) for N_{CP} = 1, 2, 3, or 4	23.07, 24.37, 25.67, 26.98	ms
Duplexing Mode = TDD63	Number of FL PHY Frames in a Superframe	18	
	Guard time between a FL PHY Frame and the subsequent RL PHY Frame ($T_{g,TDD,F} = 3N_{FFT}T_{CHIP}/4$)	78.13	µs
	Guard time between a RL PHY Frame and the subsequent FL PHY Frame ($T_{g,TDD,R} = 5N_{FFT}T_{CHIP}/32$)	16.28	µs
	Superframe Duration ($T_{SUPERFRAME}$) for N_{CP} = 1, 2, 3, or 4	25.80, 27.26, 28.72 or 30.18	ms

802.20 MBWA

TDD UMB Superframe Preamble

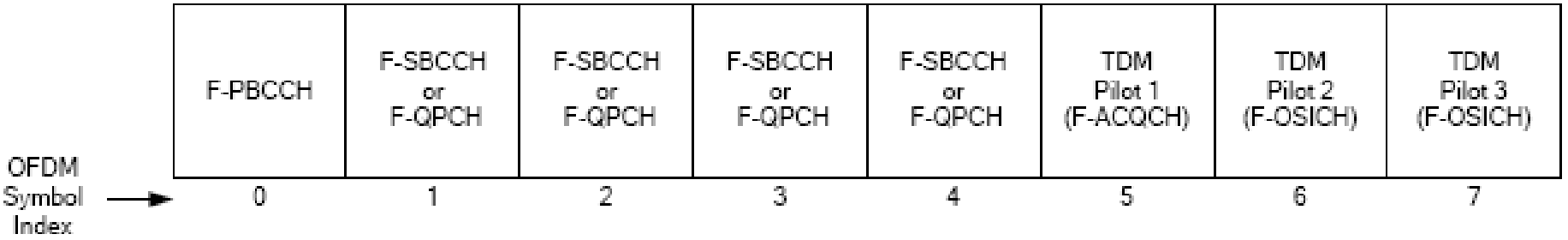

Figure 84 — Superframe Preamble Structure

802.20 Mobile Broadband Wireless Access (MBWA) Working Group

- References
  - http://grouper.ieee.org/groups/802/20/

- IEEE 802.20-2008

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802.21 Media Independent Handover (MIH) Working Group

- Base standard IEEE 802.21-2008
- Current projects
  - Security Extensions
  - Handovers for Downlink only Technologies

802.21-2008

- 802.21 ‘Shim’ Layer
  - event service (MIES)
  - command service (MICS)
  - information service (MIIS)
- Provide Inter-RAT services
  - Service continuity
  - Quality of service
  - Network discovery
  - Network selection
  - Power management
  - Handover policy

802.21-2008

- Management and control messaging primitives; enabled technology specific
- L2.5 Protocol defined

802.21-2008
Communication Model

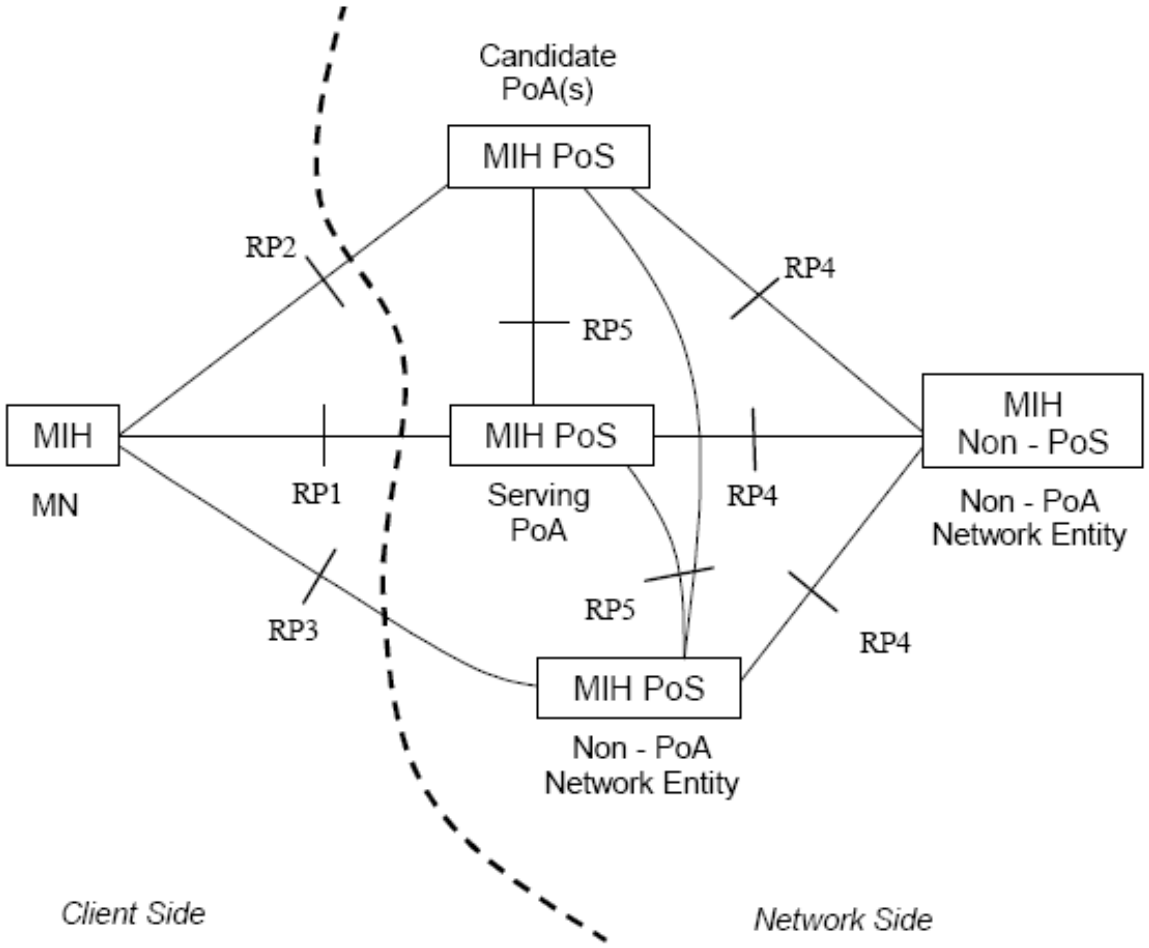
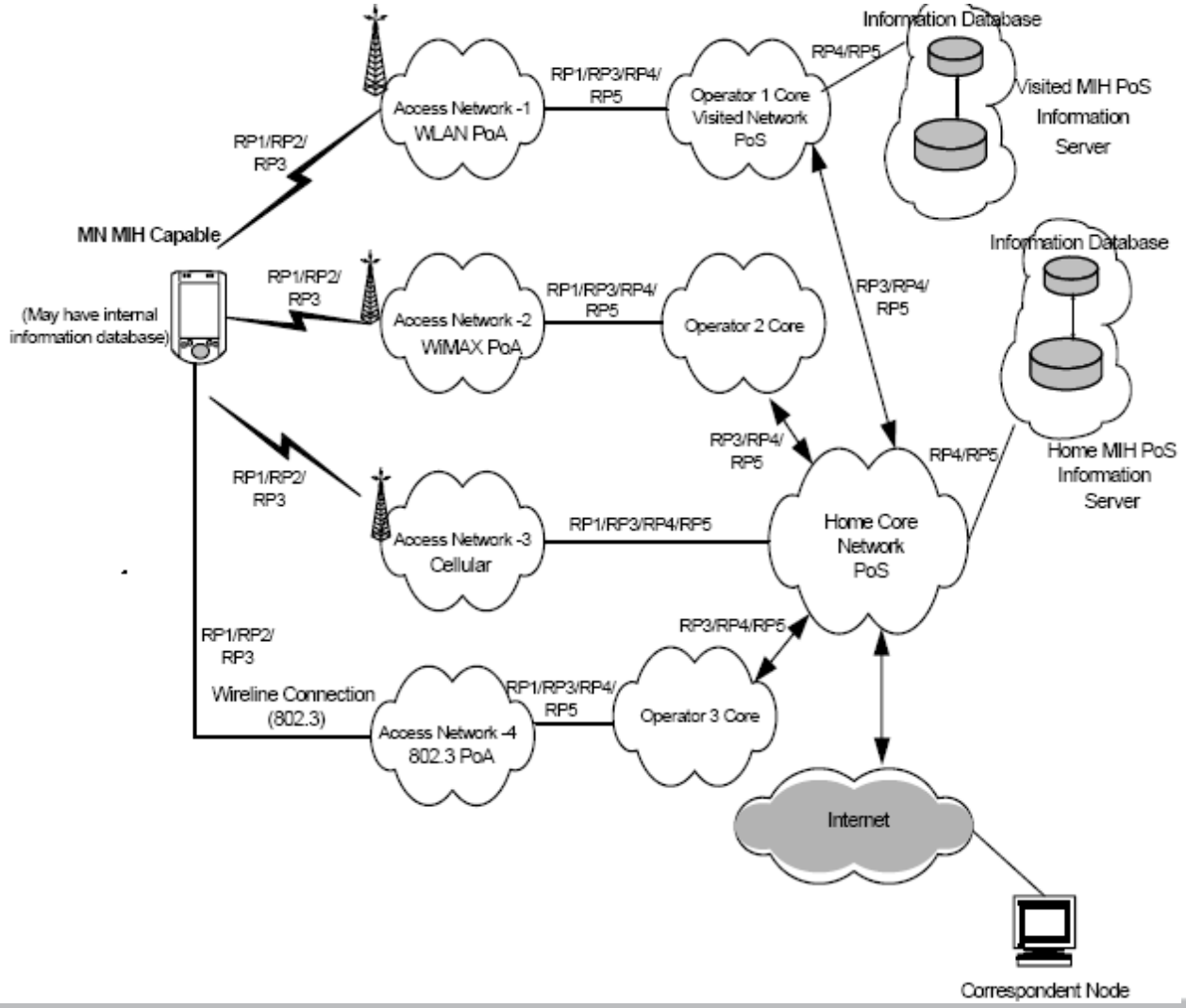


Figure 2—MIHF communication model

802.21-2008
Network Model



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802.21-2008
Protocol Reference Model

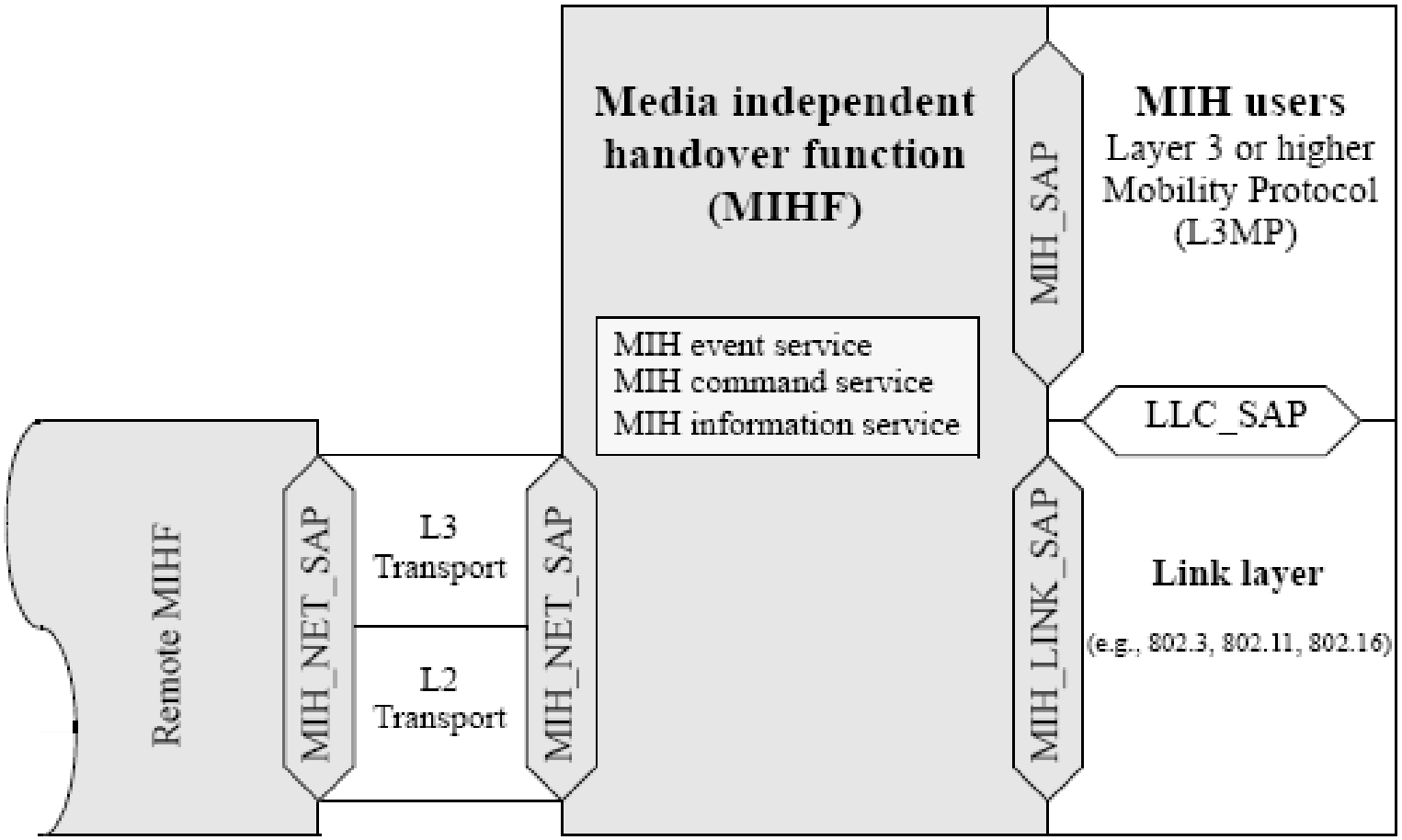

Figure 4—General MIHF reference model and SAPs

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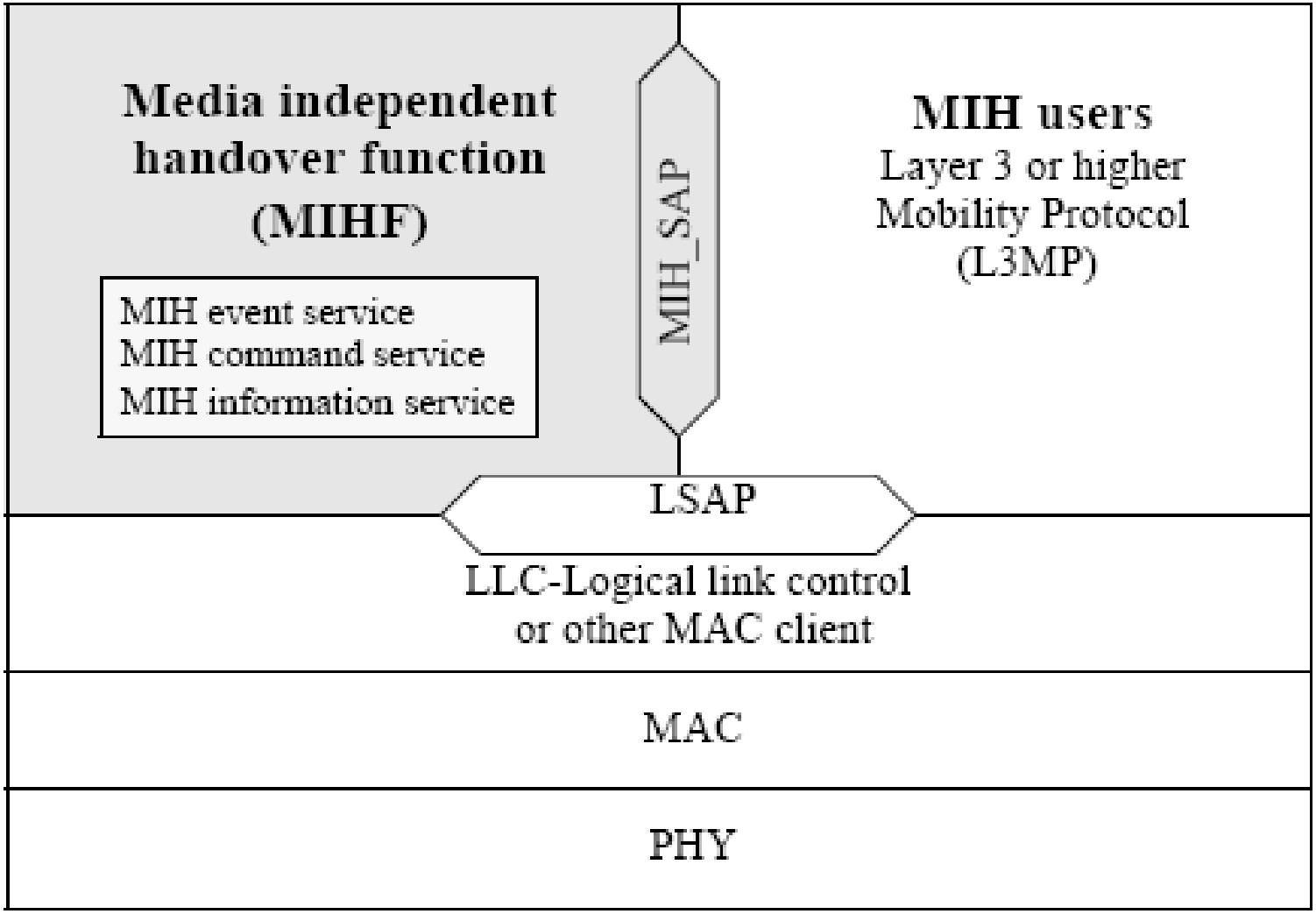
Protocol Reference Model for 802.3



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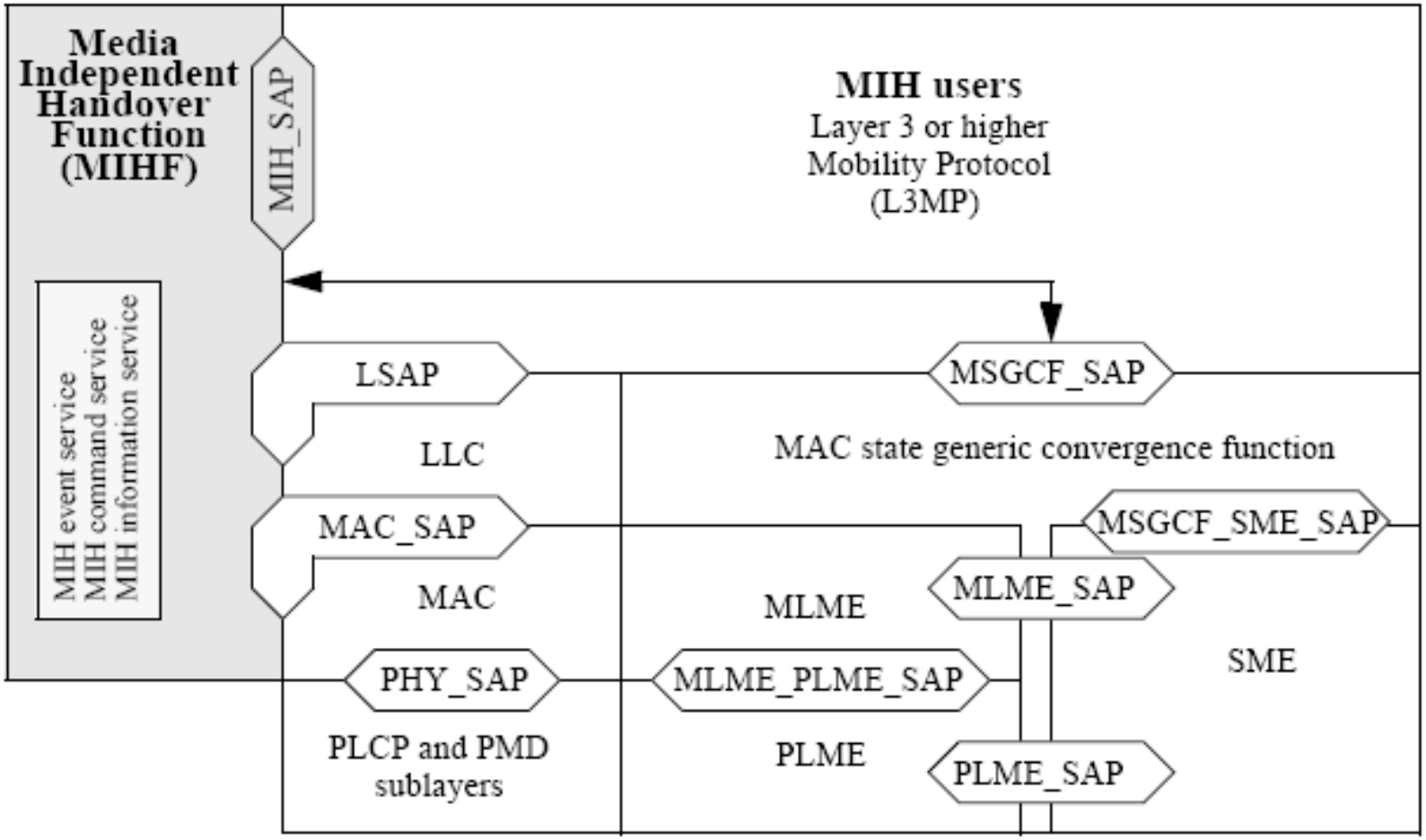
Protocol Reference Model for 802.11



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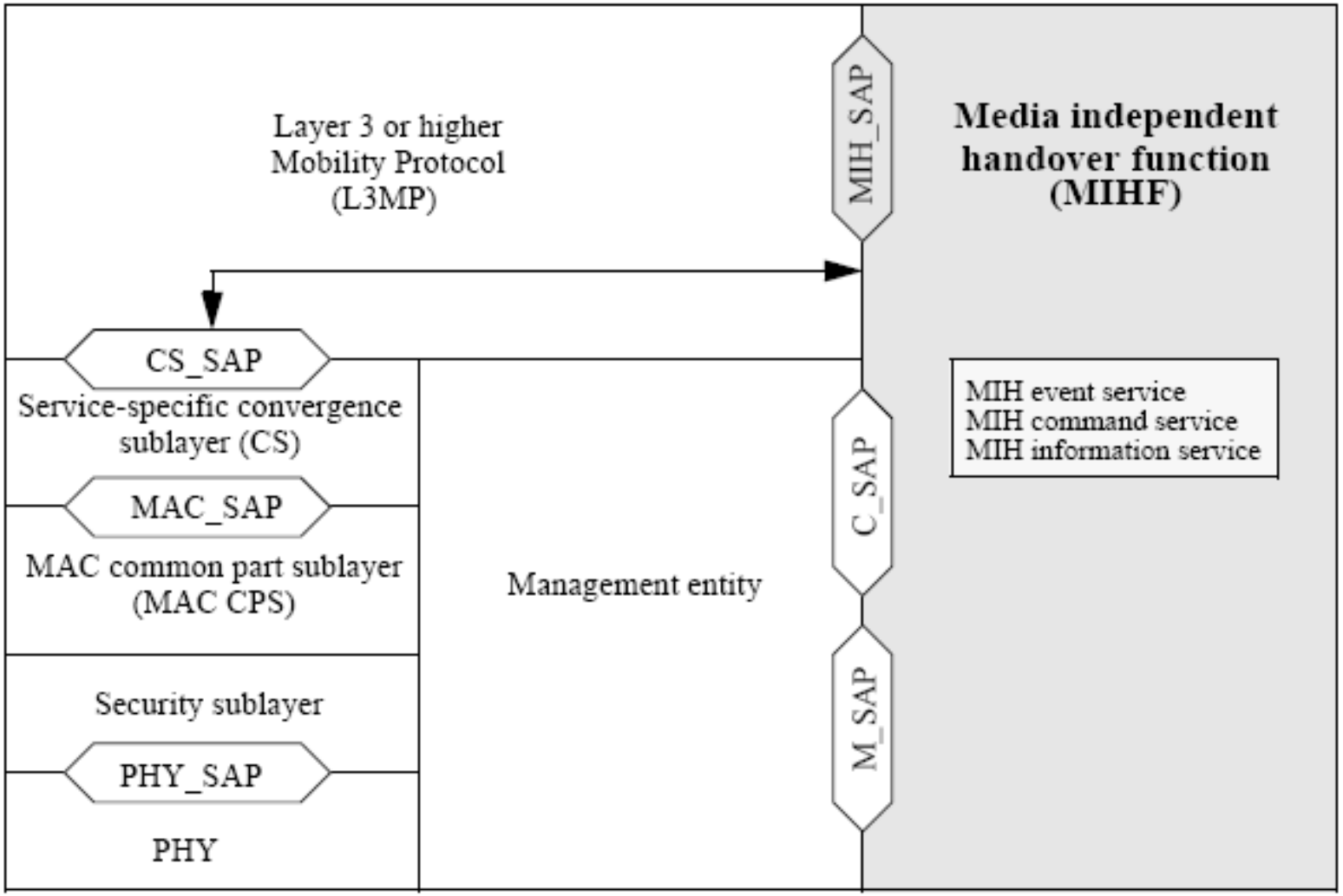
Protocol Reference Model for 802.16



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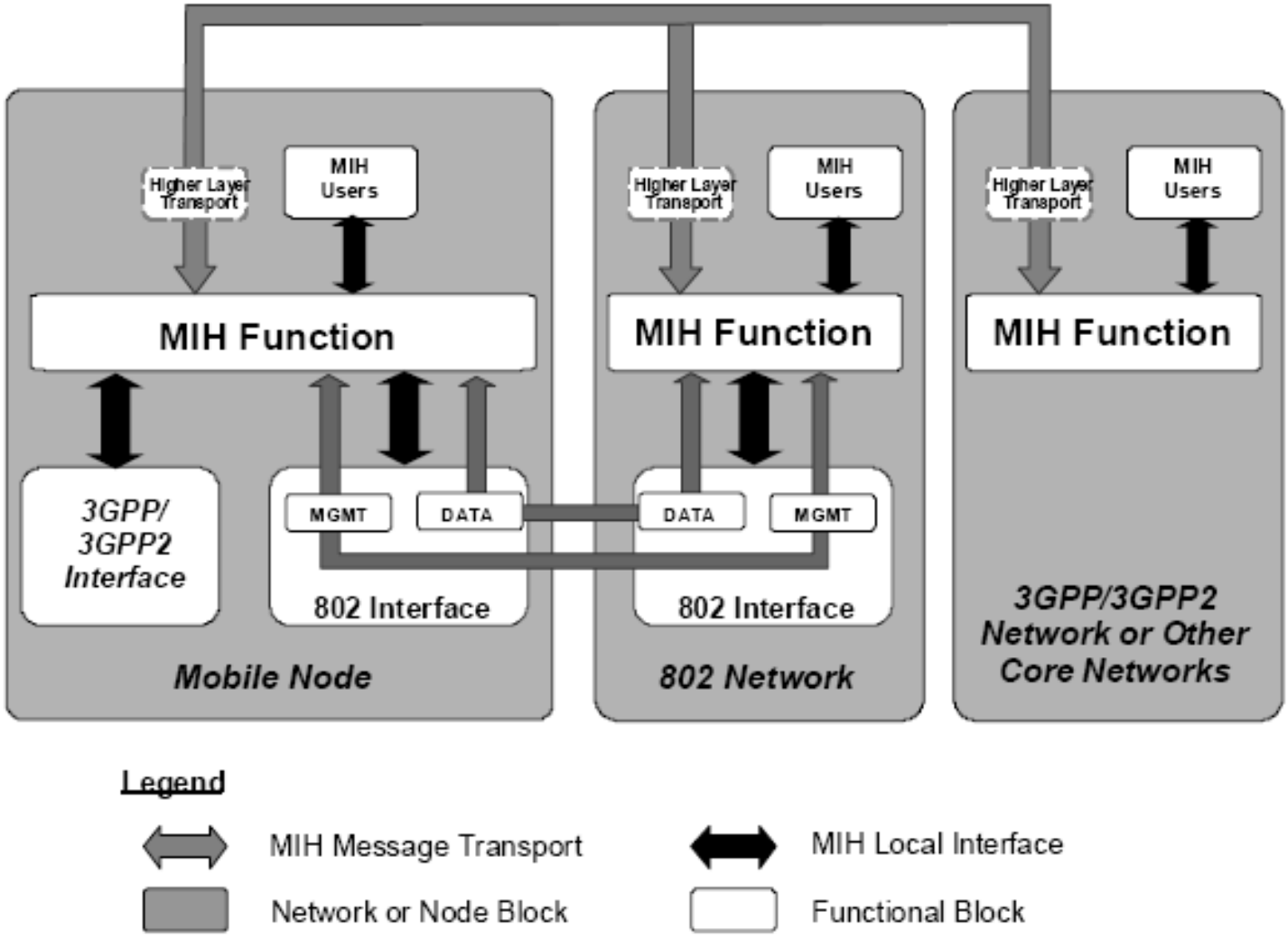
MIHF Relationship Model



802.21 Media Independent Handover (MIH) Working Group

- References
  - http://grouper.ieee.org/groups/802/21/

- IEEE 802.21-2008