

# **IEEE 802.16**

# **Candidate Proposal**

# **for IMT-Advanced**

ITU-R WP 5D Third Workshop on IMT-Advanced  
Focused on Candidate Technologies and  
Evaluation

Dresden, Germany, 15 October 2009

# Outline

- IEEE 802.16 Working Group
  - IEEE Standard 802.16
  - IEEE 802.16m
- IEEE 802.16, ITU, and IMT-Advanced
- IEEE Candidate RIT
  - Description
  - Evaluation
- Conclusion

# IEEE 802.16 is:



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

# IEEE 802.16 Working Group

- Organized under IEEE (an ITU-R Member)
- Initiated in 1998
- Formalized in 1999 (over 10 years old)
- Holds at least six sessions a year
  - Session duration: four days
- Open process
  - Anyone can participate
- Members are people
  - Membership earned by participation
  - Currently: 437 Members, from around the world

# IEEE 802.16 Session Attendance (excluding IEEE 802 Plenary)

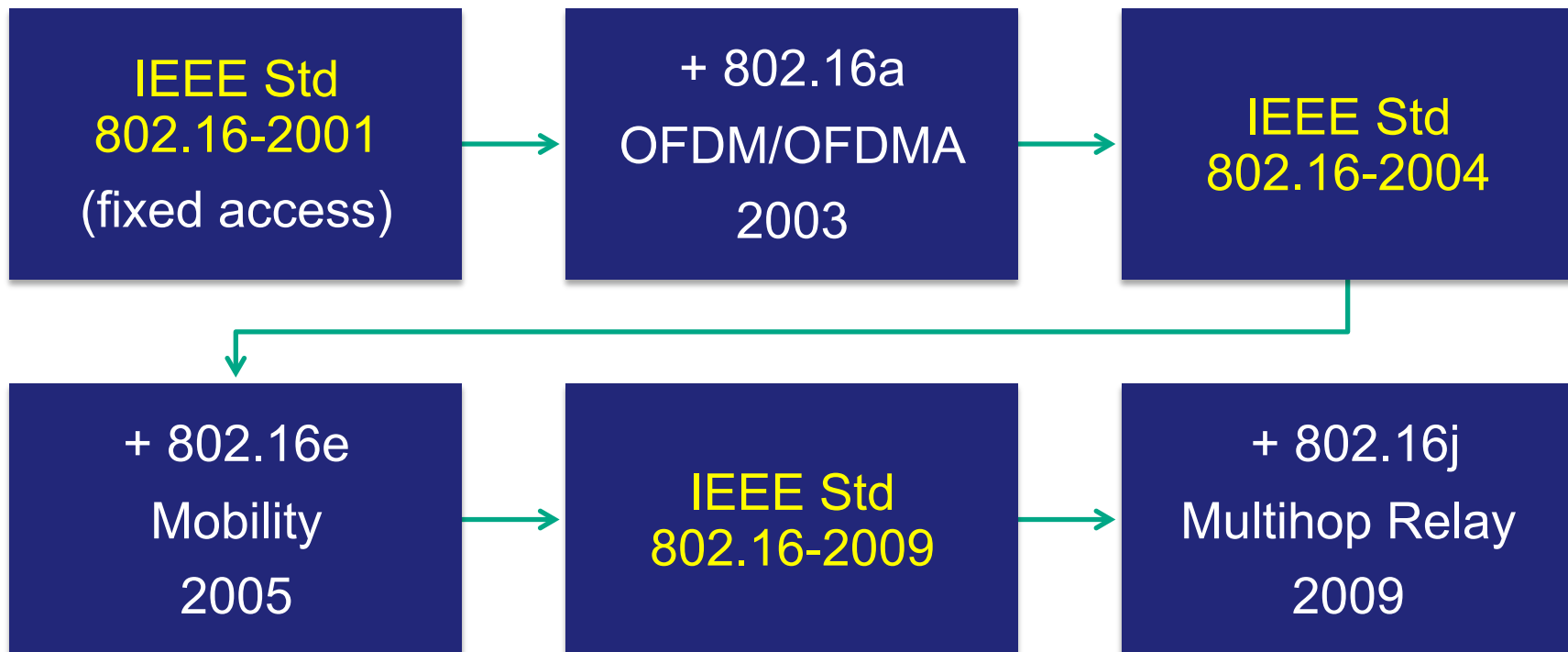
#29	Jan	2004	Canada	131
#31	May	2004	China	228
#33	Sep	2004	Korea	287
#35	Jan	2005	China	313
#37	May	2005	Italy	218
#39	Sep	2005	Taiwan	225
#41	Jan	2006	India	111
#43	May	2006	Israel	122
#45	Sep	2006	Canada	191

#47	Jan	2007	UK	274
#49	May	2007	USA	307
#51	Sep	2007	Spain	288
#53	Jan	2008	Finland	303
#55	May	2008	China	402
#57	Sep	2008	Japan	415
#59	Jan	2009	USA	310
#61	May	2009	Egypt	210
#63	Sep	2009	Korea	257

# IEEE Standard 802.16

- “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”)

# IEEE 802.16: Key Evolution Steps



# IEEE 802.16m Project

- Amendment project, initiated 2006
- “Advanced Air Interface”
  - Amend IEEE 802.16 WirelessMAN-OFDMA specification to provide an advanced air interface
  - meet the cellular layer requirements of IMT-Advanced next generation mobile networks
  - support for legacy WirelessMAN-OFDMA equipment (i.e., backward compatibility)
  - provide performance improvements to support future advanced services and applications



# Participation in IEEE 802.16m Development

- 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: > 2200 documents

# IEEE 802.16m Development Documents

Background documents prior to development of 802.16m draft standard:

- Evaluation Methodology Document (EMD)
- System Requirements Document (SRD)
  - Stage 1
- System Description Document (SDD)
  - Stage 2

# IEEE 802.16m Evaluation Methodology Document (EMD)

- Defines link-level and system-level simulation models and associated parameters for evaluation and comparison of technologies for IEEE 802.16m
- Highly detailed (199 pages)
- Mostly aligned with IMT-Advanced evaluation methodology
- First version: March 2008

# IEEE 802.16m System Requirements Document (SRD)

- High-level system requirements
  - Stage 1 Specification
- Includes advanced features beyond IMT-Advanced requirements
- First version: January 2007
- Current version: September 2009
- IEEE 802.16m requirements will be evaluated according to 802.16m EMD
- IMT-Advanced requirements were evaluated according to IMT-Advanced methodology

# Key 802.16m 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)

# IEEE 802.16m System Description Document (SDD)

- System level description of IEEE 802.16m
  - Stage 2 Specification
- IEEE 802.16m standard is being developed in accordance with SDD
- is maintained and may evolve
- First version: Jan 2008
- Current version: Sept 2009
  - Attached to IMT-Advanced proposal

# IEEE 802.16m SDD: Key Topics

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

# IEEE 802.16m Draft Standard

- Started with an initial working document
- Four revisions of the document toward a draft standard were created
- First draft standard
  - July 2009
  - 514 pages
- Began Working Group Ballot in July 2009



# **IEEE 802.16, ITU, AND IMT-ADVANCED**

# IEEE 802.16 and 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
  - IMT-2000
  - IMT-Advanced

# IEEE 802.16 and 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

# IEEE 802.16 IMT-Advanced Contributions

- 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.
- 5D/356 (Feb 2009) and 5D/443 (May 2009) provided specific notice of intention to submit IMT-Advanced proposal, with additional details.
  - WP 5D response: 5D/TEMP/206
- 5D/542 (October 2009): *Submission of a Candidate IMT-Advanced RIT based on IEEE 802.16*

# IEEE 802.16 and IMT-Advanced Workshops

- ITU-R notification of 802.16m progress toward IMT-Advanced in three Workshops
  - “IEEE 802 Standards for Advanced Wireless Networks,” 1<sup>st</sup> Workshop on IMT-Advanced (Kyoto, 22 May 2007)
  - “Project 802.16m as an IMT-Advanced Technology,” 2<sup>nd</sup> Workshop on IMT-Advanced (Seoul, 7 Oct 2008)
  - Presentation at the 3<sup>rd</sup> Workshop on IMT-Advanced as one of two Technology Proponents (Dresden, 15 Oct 2009)

# **IEEE CANDIDATE RIT**

# Development of IEEE 802.16 IMT- Advanced Proposal

- Solicited input material towards development of candidate RIT:
  - Call for comments and contributions over the past year
  - Correspondence Group between IEEE 802.16 sessions
  - Liaison activity with external organizations (e.g. WiMAX Forum, ARIB, TTA, and WP 5D)
- Contributions received containing calibration/simulation results as well as text for description templates and other elements of the submission from authors affiliated with:
  - Alcatel-Lucent Shanghai Bell, Clearwire, ETRI, Fujitsu, Hitachi, Intel, ITRI, KDDI, LG Electronics, MediaTek, Mitsubishi Electric, Motorola, NEC, Samsung Electronics, Toshiba, UQ Communications, WiMAX Forum, and others.

# International support for IEEE 802.16 IMT-Advanced Proposal

- Cooperating with national standards bodies
- Relevant contributions to WP 5D Meeting #6; e.g.:
  - 5D/544 (from Japan): *Proposal for candidate radio interface technologies for IMT-Advanced based on IEEE 802.16*
  - 5D/561 (from ARIB, via BR): *ARIB's endorsement of IEEE's proposal submission under Step 3 of the IMT-Advanced process in document IMT-ADV/2(Rev.1)*
  - 5D/563 (from Korea): *Support of candidate RITs for IMT-Advanced*
  - 5D/560 (from TTA, via BR): *Submission of a Candidate IMT-Advanced RIT based on IEEE 802.16*
  - 5D/558 (from 30 members): *Endorsement of candidate IMT-Advanced RIT based on IEEE 802.16*



# IMT-Advanced Requirements

- IEEE is proposing 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	✓
Urban Microcell	✓
Urban Macrocell	✓
Rural Macrocell	✓

# Contents of IMT-Advanced Submission 5D/542

- Part 1: cover page, overview, proposal
- Part 2: background, future plans, IPR statement, version, references
- Part 3: general description, technology description templates: characteristics and link budget
- Part 4: self-evaluation report and compliance templates

# IEEE RIT Proposal: Part 1

- Proposal:
  - *This proposal should be assigned for evaluation, in all four test environments, under Step 4 of the IMT-Advanced terrestrial component radio interface development process in Document IMT-ADV/2(Rev.1), during which time the IEEE 802.16 Working Group will support the activities of the independent evaluation groups per Clause 2 of this contribution. This proposal should also proceed to consideration under Steps 5, 6, and 7.*

# IEEE RIT Proposal: Part 2

- 1 Introduction and background
    - 1.1 IMT-2000 Background
    - 1.2 Prior communications regarding IMT-Advanced Proposal
    - 1.3 IMT-Advanced Workshop Participation
  
  - 2 Continuing Development
    - 2.1 Ongoing Development of 802.16m Project
    - 2.2 Plans for Step 4 of IMT-Advanced development process
    - 2.3 IMT-Advanced Evaluation Group Coordination
  
  - 3 IPR Policy compliance
  
  - 4 Declaration of version
- References
- Abbreviations

# IEEE RIT Proposal: Part 3

5 General description of the RIT

6 Description templates

6.1 Description template – characteristics

6.2 Description template – link budget

Annex 1 – L1/L2 Overhead Calculation

Annex 2 – Stage 2 Specification: IEEE 802.16m System Description Document (SDD)

# IEEE RIT Proposal: Part 4

## 7 Self-evaluation report

7.1 Overview

7.2 Evaluation results

## 8 Compliance templates

8.1 Compliance template for services

8.2 Compliance template for spectrum

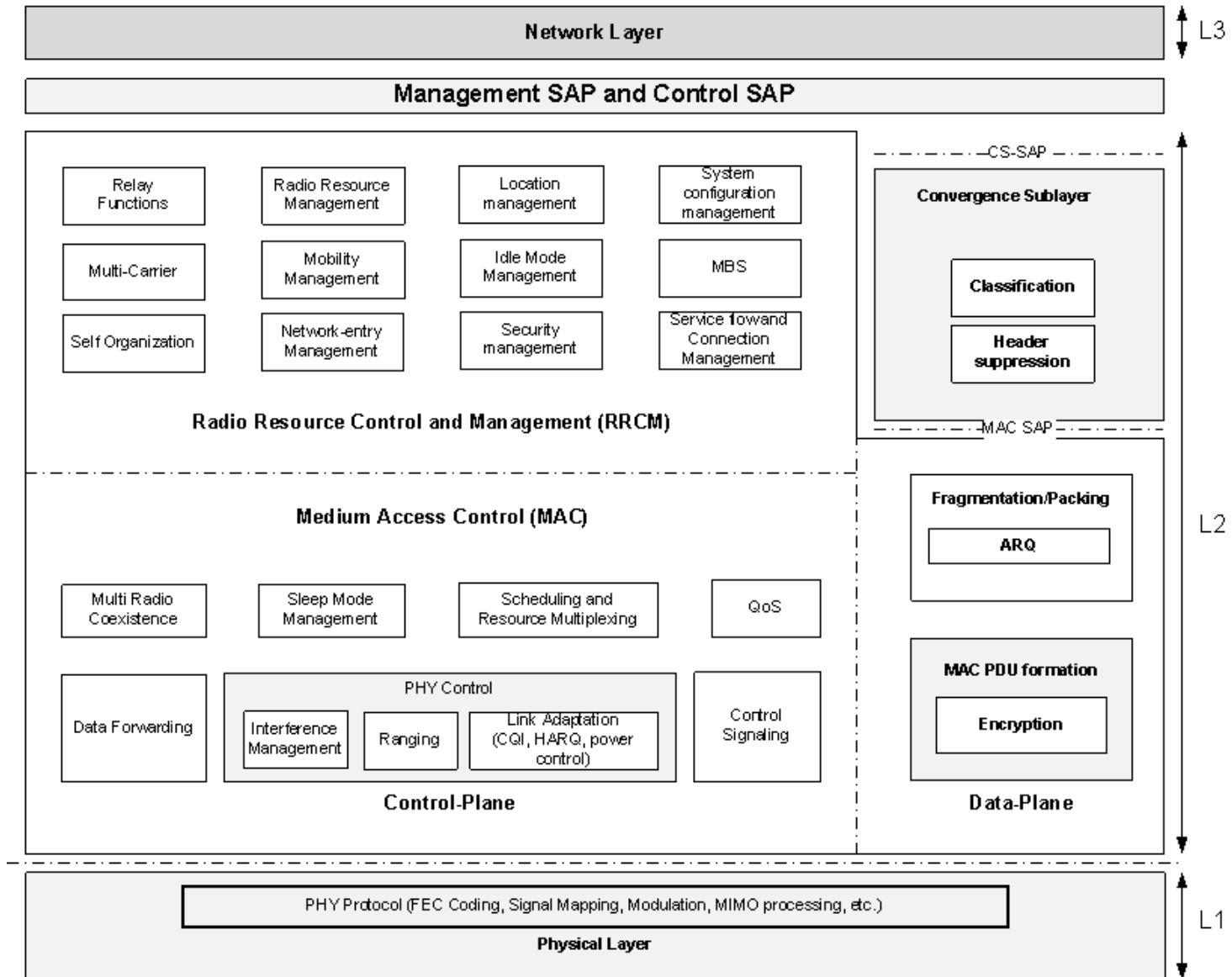
8.3 Compliance template for technical performance

Annex 3 – Simulation Assumptions and Configuration Parameters for  
IMT-Advanced Test Environments

Annex 4 – Details of Simulation Results in the Compliance Template for  
Technical Performance

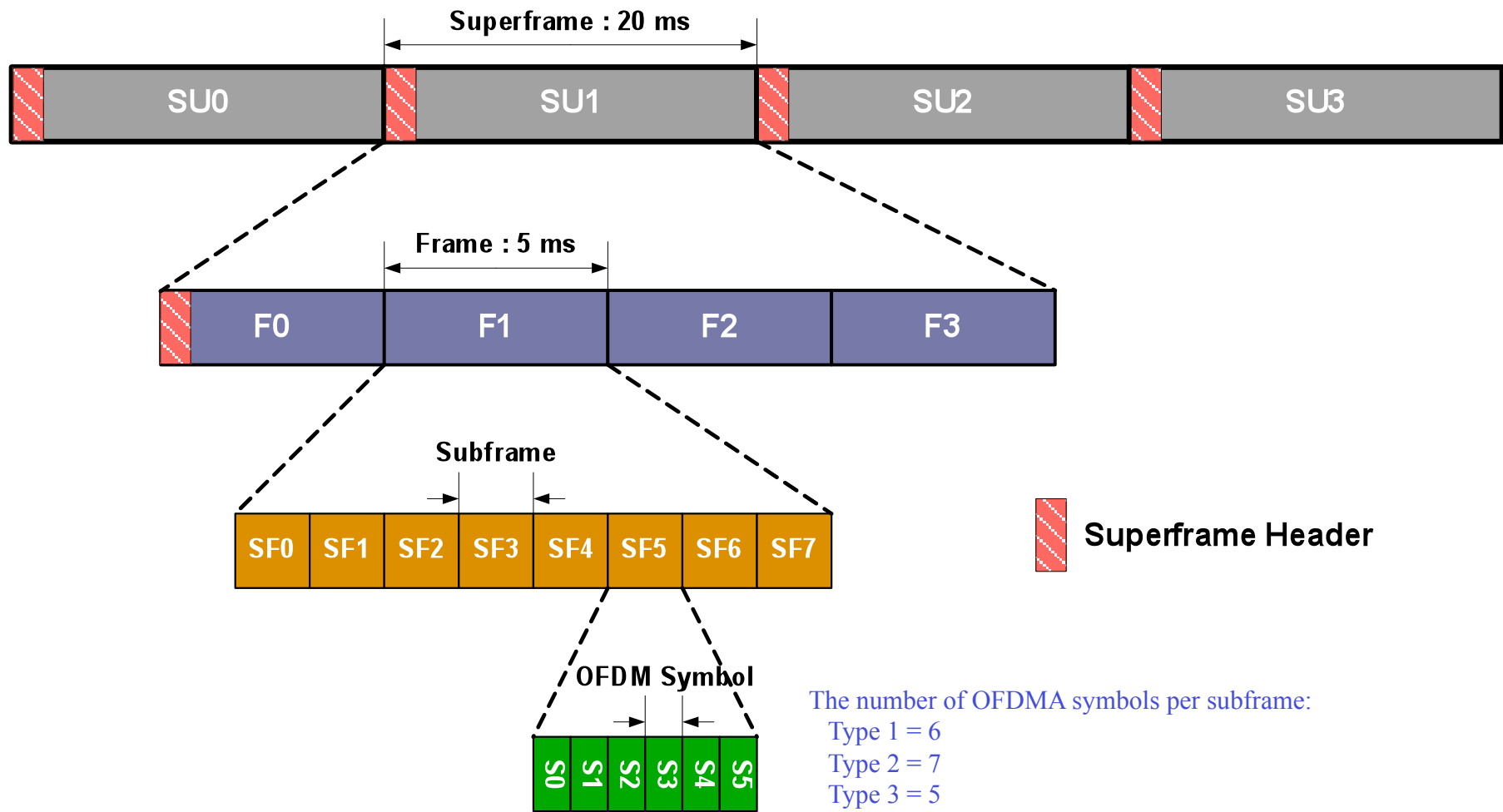
# **IEEE CANDIDATE RIT DESCRIPTION**

# IEEE 802.16m Protocol Structure





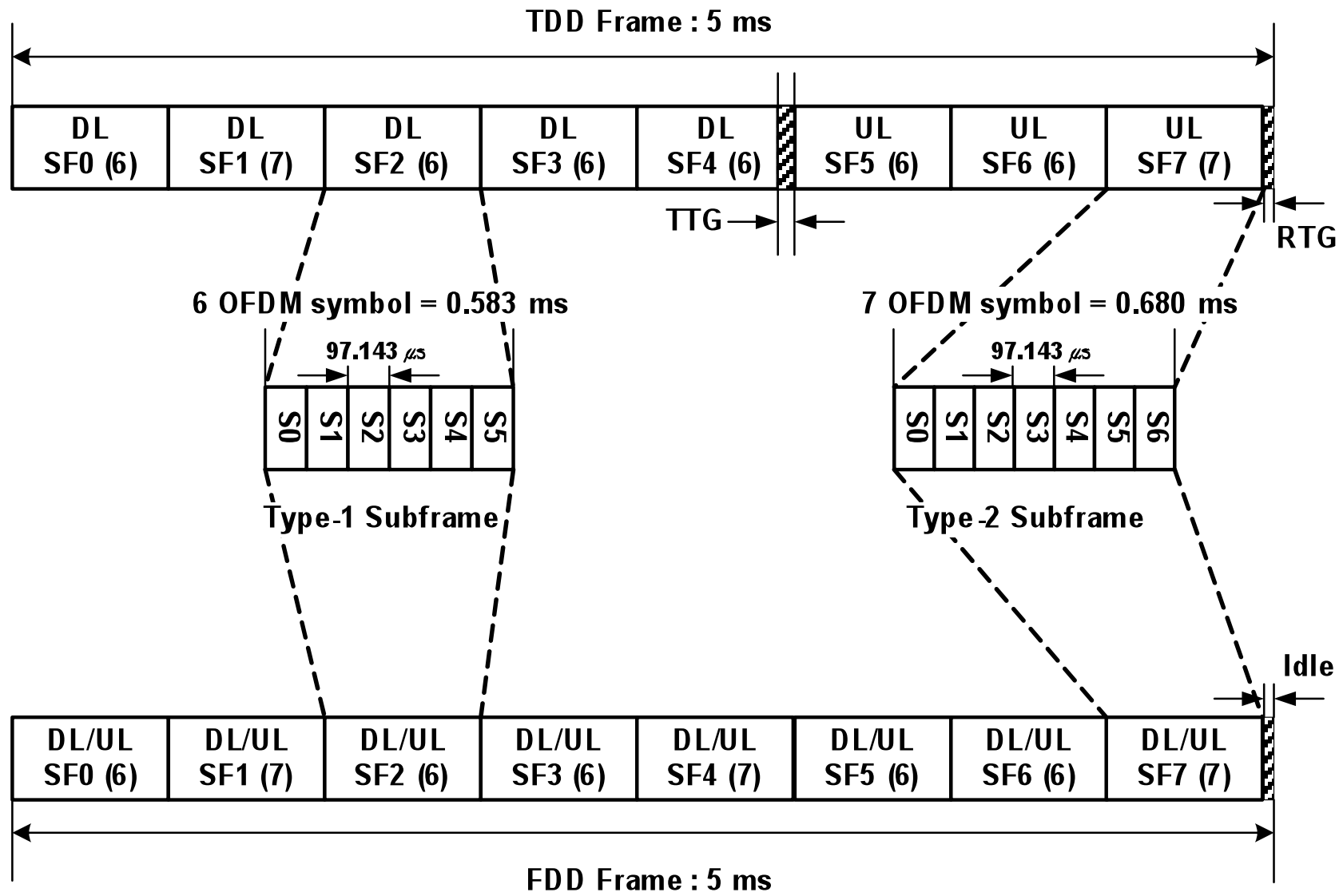
# Frame Structure



The number of OFDMA symbols per subframe:

- Type 1 = 6
- Type 2 = 7
- Type 3 = 5
- Type 4 = 9 (UL only)

# Frame Structure with CP=1/16 (DL/UL=5:3)

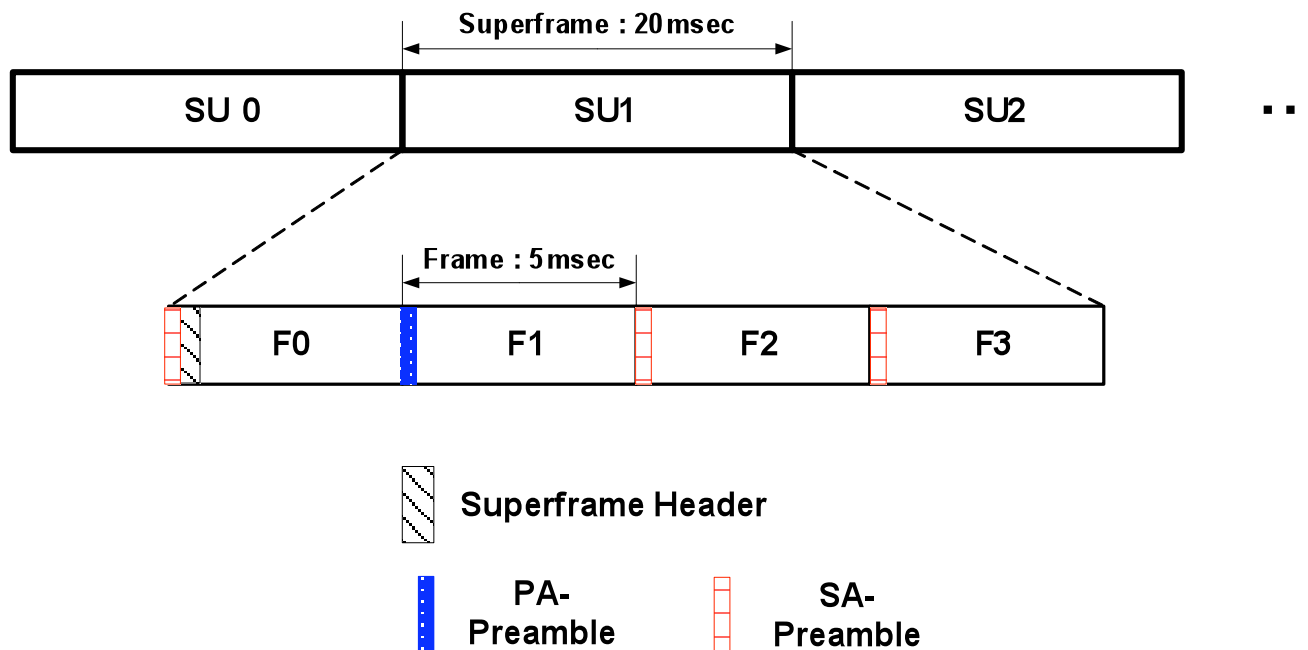


# OFDMA Parameters

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 $T_u$ ( $\mu$ s)		91.429	128	102.4	91.429	91.429
Cyclic prefix (CP) $T_g = 1/8 T_u$	Symbol time $T_s$ ( $\mu$ s)		102.857	144	115.2	102.857
	FDD	Number of OFDMA symbols per frame	48	34	43	48
		Idle time ( $\mu$ s)	62.857	104	46.40	62.857
	TDD	Number of OFDMA symbols per frame	47	33	42	47
		TTG + RTG ( $\mu$ s)	165.714	248	161.6	165.714
CP $T_g = 1/16 T_u$	Symbol Time $T_s$ ( $\mu$ s)		97.143	136	108.8	97.143
	FDD	Number of OFDMA symbols per frame	51	36	45	51
		Idle time ( $\mu$ s)	45.71	104	104	45.71
	TDD	Number of OFDMA symbols per frame	50	35	44	50
		TTG + RTG ( $\mu$ s)	142.853	240	212.8	142.853

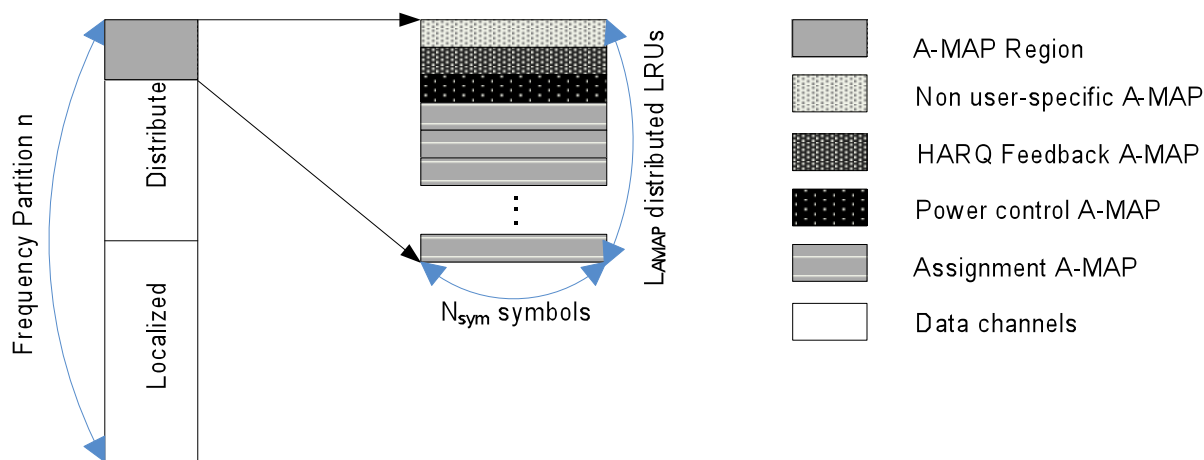
# Preamble

- Preamble is a DL physical channel that provides a reference signal for timing, frequency, frame synchronization, RSSI estimation, channel estimation, cell identification, etc.
  - Primary (PA-) Preamble: For initial acquisition, superframe synchronization, etc.
  - Secondary (SA-) Preamble: For fine synchronization, cell identification, etc.



# DL Control Channel

- **Superframe Header (SFH):** To carry the system configuration information for cell selection and system access
- **Advanced MAP (A-MAP)**
  - **Assignment A-MAP (A-A-MAP):** To contain resource assignment information
  - **HARQ Feedback A-MAP (HF-A-MAP):** To carry HARQ ACK/NACK information for UL data transmission
  - **Power Control A-MAP (PC-A-MAP):** To carry fast power control command to AMS

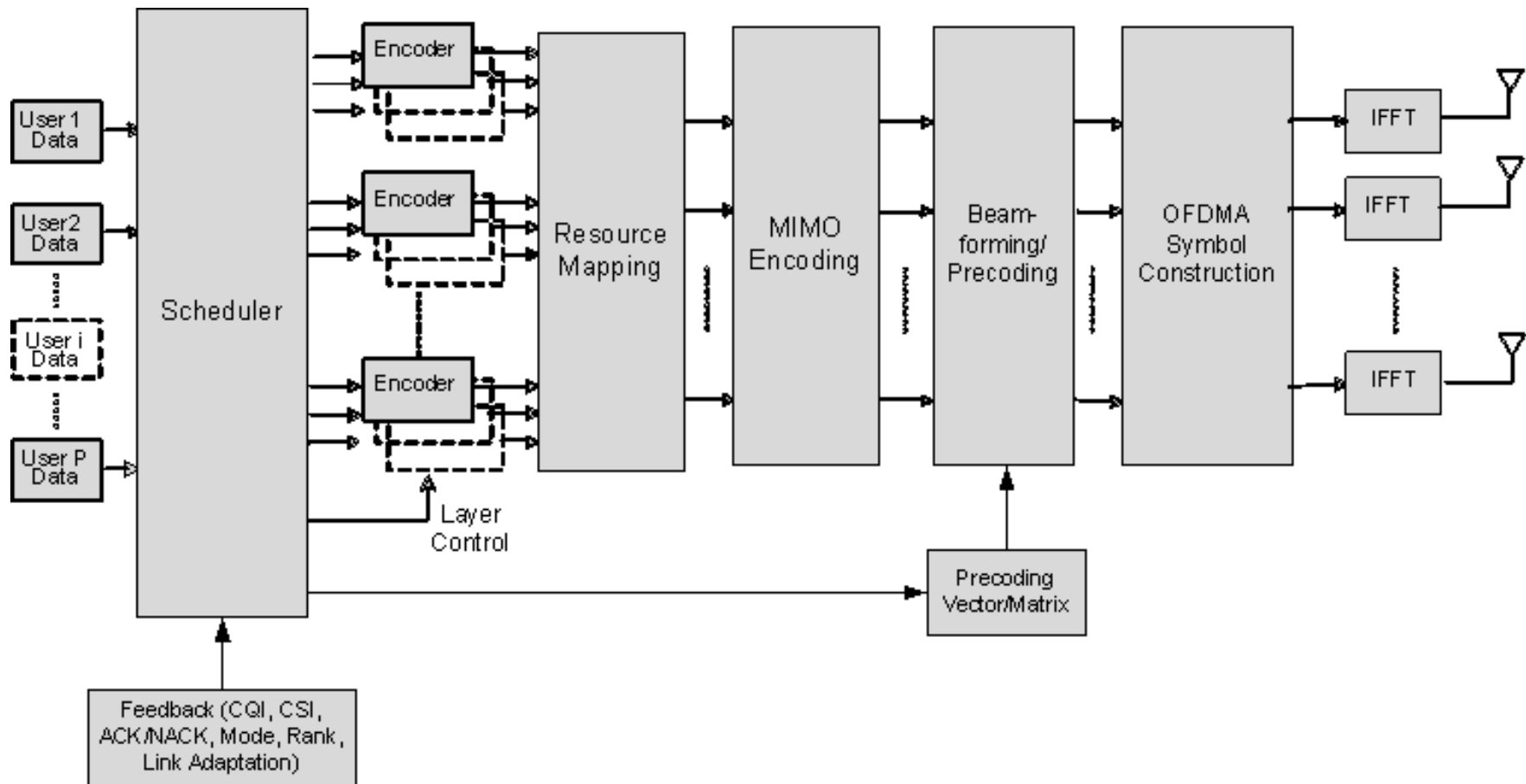


# MIMO

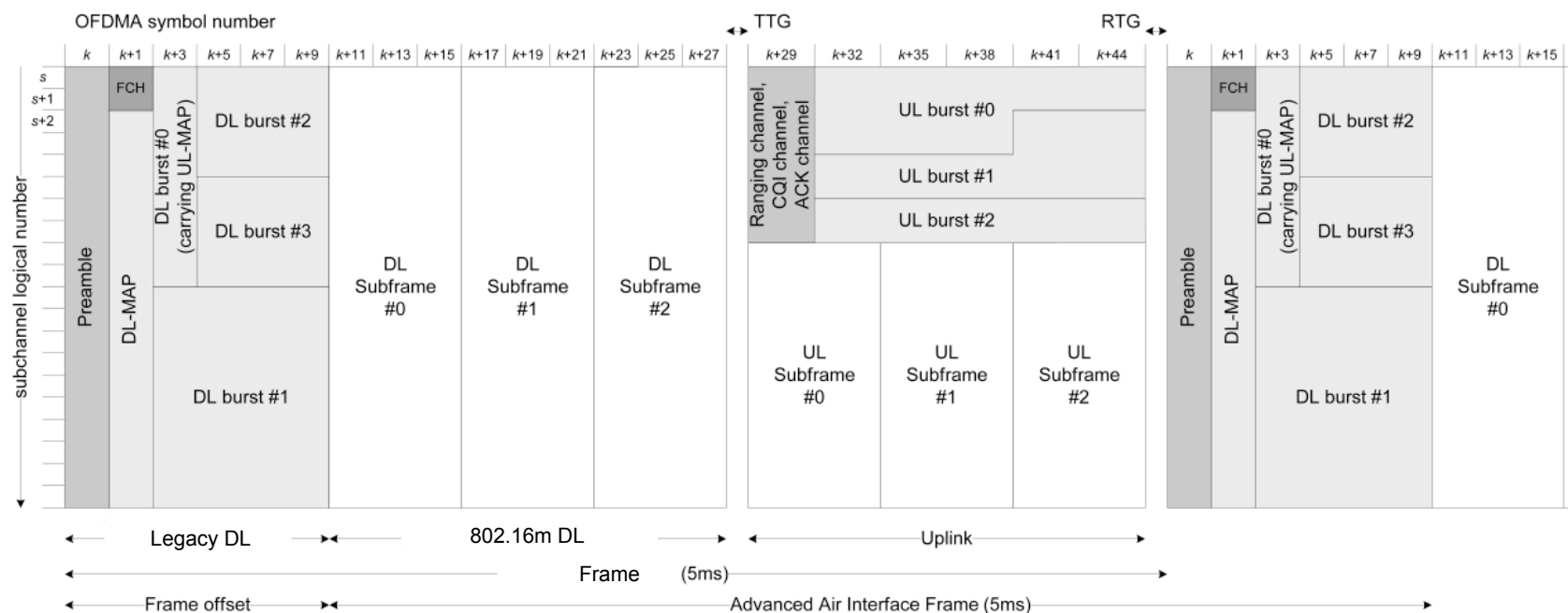
RIT supports various antenna technologies:

- SU-MIMO and MU-MIMO
  - SU-MIMO (Single User): A MIMO transmission scheme in which a single MS is scheduled in one Resource Unit
  - MU-MIMO (Multi-User): A MIMO transmission scheme in which multiple MSs are scheduled in one RU. Multi-user diversity for DL (SDMA) and collaborative Spatial Multiplexing for UL
- Open-loop and closed-loop
  - Open-loop: Transmit diversity with Space-Frequency Block Coding (SFBC) and spatial multiplexing with non-adaptive precoding
  - Closed-loop: Codebook-based precoding and sounding/midamble-based precoding
- Rank and mode adaptation
- Multi-BS MIMO

# Downlink MIMO Architecture



# Legacy Support



IEEE 802.16m RIT provides continuing support for legacy IMT-2000 (OFDMA TDD WMAN) MSs and BSs.

- 802.16m BS supports a legacy MS while also supporting 802.16m MSs on the same RF carrier, at a level of performance equivalent to that of a legacy BS
- 802.16m MS operates with a legacy BS on the same RF carrier, at a level of performance equivalent to that of a legacy MS
- 802.16m BS supports handover of a legacy MS to and from a legacy BS and to and from 802.16m BS



# **IEEE CANDIDATE RIT EVALUATION**

# Table Legend

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

# Cell Spectral Efficiency

Table 7-5: DL cell spectral efficiency in bit/s/Hz/cell for TDD

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

Table 7-7: DL cell spectral efficiency in bit/s/Hz/cell for FDD

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

Table 7-9: UL cell spectral efficiency in bit/s/Hz/cell for TDD

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

Table 7-11: UL cell spectral efficiency in bit/s/Hz/cell for FDD

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

# Cell Edge User Spectral Efficiency

Table 7-6: DL cell edge user spectral efficiency in bit/s/Hz/cell for TDD

	<i>InH</i>	<i>UMi</i>	<i>UMa</i>	<i>RMa</i>
<i>Cell spectral efficiency</i>	0.260	0.092	0.069	0.093
<i>ITU-R requirement</i>	0.1	0.075	0.06	0.04

Table 7-8: DL cell edge user spectral efficiency in bit/s/Hz/cell for FDD

	<i>InH</i>	<i>UMi</i>	<i>UMa</i>	<i>RMa</i>
<i>Cell spectral efficiency</i>	0.253	0.097	0.069	0.091
<i>ITU-R requirement</i>	0.1	0.075	0.06	0.04

Table 7-10: UL cell edge user spectral efficiency in bit/s/Hz/cell for TDD

	<i>InH</i>	<i>UMi</i>	<i>UMa</i>	<i>RMa</i>
<i>Cell spectral efficiency</i>	0.426	0.111	0.109	0.119
<i>ITU-R requirement</i>	0.07	0.05	0.03	0.015

Table 7-12: UL cell edge user spectral efficiency in bit/s/Hz/cell for FDD

	<i>InH</i>	<i>UMi</i>	<i>UMa</i>	<i>RMa</i>
<i>Cell spectral efficiency</i>	0.444	0.119	0.114	0.124
<i>ITU-R requirement</i>	0.07	0.05	0.03	0.015

# Mobility Requirement

Table 7-15: Mobility requirement data for TDD

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

Table 7-16: Mobility requirement data for FDD

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

# VoIP Capacity

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

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

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

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

# Latency & Handover Interruption Times

- The RIT meets all requirements for latencies and handover interruption times (see Part 4 of the submission)



## Plans for Step 4 (External Evaluation)

- IEEE 802.16 plans to engage with independent evaluation groups, assist in their evaluations, and provide clarifying information.
- IEEE 802.16 hopes to benefit from insights gained by the independent evaluation groups, applying that knowledge to the refinement and improvement of the IEEE 802.16m draft standard.
- IEEE offers to provide independent evaluation groups with access to updated drafts and invite comments.
- IEEE 802.16 IMT-Advanced web site
  - <http://WirelessMAN.org/imt-adv>

# IEEE 802.16m IMT-Advanced Evaluation Group Coordination Meeting

- IEEE 802.16 Working Group invites independent evaluation groups to the “IEEE 802.16m IMT-Advanced Evaluation Group Coordination Meeting.”
  - 13 January 2010
  - San Diego, California, USA, in conjunction with IEEE 802.16 Session #65 <<http://ieee802.org/16/meetings/mtg65>>.
- Overview of the proposal
- Update regarding current status of the 802.16m draft
- Opportunity for independent evaluation groups to exchange views among each other and with members of the IEEE 802.16 Working Group.
- See <<http://WirelessMAN.org/imt-adv>>

# Conclusion

- The IEEE 802.16 WirelessMAN standard has been evolving for 10 years to bring the latest technology to the marketplace.
- IEEE follows an open, worldwide development process.
- IEEE has submitted a complete IMT-Advanced candidate RIT, based on IEEE Project 802.16, including documentation demonstrating that it meets the requirements of Step 3 in all four test environments.
- IEEE looks forward to international cooperation for the success of new ICT access opportunities for all.

# Resources

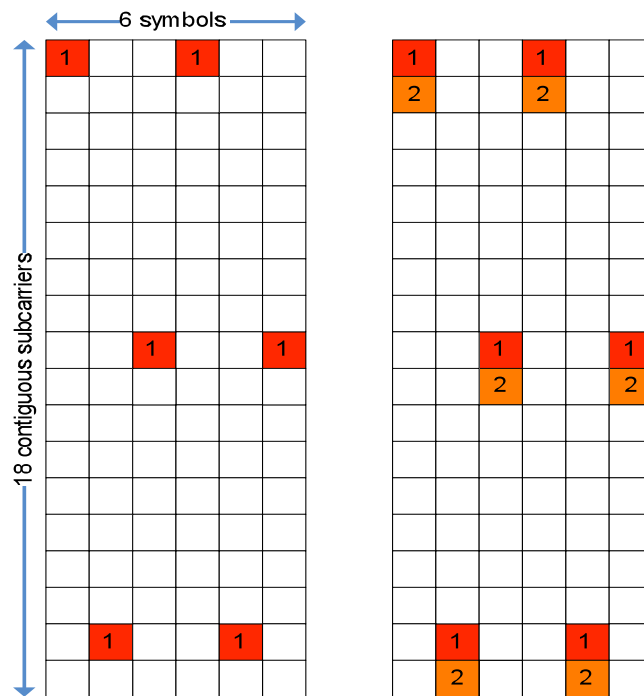
- IEEE 802.16 web site
  - <http://WirelessMAN.org>
- IEEE 802.16 IMT-Advanced web page
  - <http://WirelessMAN.org/imt-adv>

Details of IEEE 802.16m project development and status

# **SUPPORTING SLIDES**

# Pilot Structure

- Transmission of pilot subcarriers in DL and UL is necessary for enabling channel estimation, measurements of CQI such as the SINR, frequency offset estimation, etc.



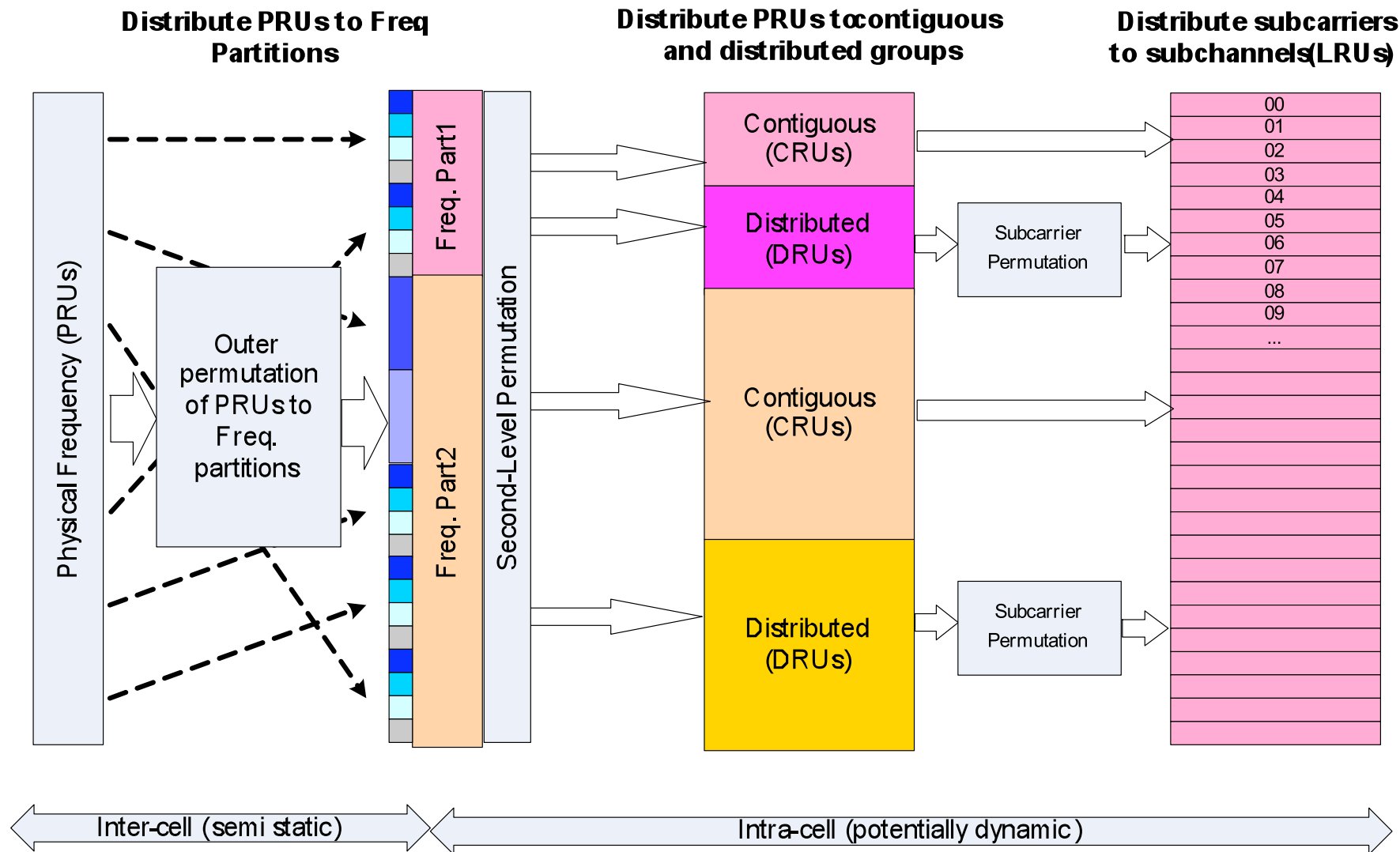
(a)

(b)

Pilot patterns used for 1 and 2 DL data streams

- Unified pilot pattern design – whether pilot is common or dedicated
- Equal pilot density per stream
- For 1 & 2 streams, the pilot overhead is 5.6% per stream
- Equal number of pilots for each PRU of a data burst assigned to one MS

# Resource Mapping



PRU=Physical Resource Unit; LRU=Logical Resource Unit

# Advanced Interference Mitigation

## 802.16m provides

### ▪ Interference-aware BS co-ordination:

BS exchange information across network backbone to manage radio resources such that inter-cell interference is minimized

### ▪ Fractional frequency reuse:

Multiple reuse settings possible within a cell to improve cell edge capacity and/or average cell capacity. Ex. cell-edge users are assigned reuse 3, while cell-center users benefit from reuse 1

### ▪ Interference aware scheduling:

Scheduler allocates resources based on interference aware CQI metrics

### ▪ Uplink power control:

Subscribers adjust transmit power based on interference caused to other cells

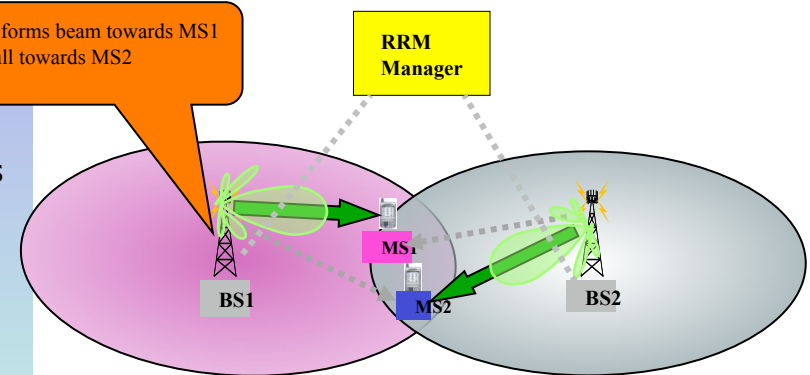
### ▪ Interference randomization:

Transmitted signal is randomly spread the across entire frequency band such that aggregate interference from multiple transmitters on the average looks like Gaussian white noise

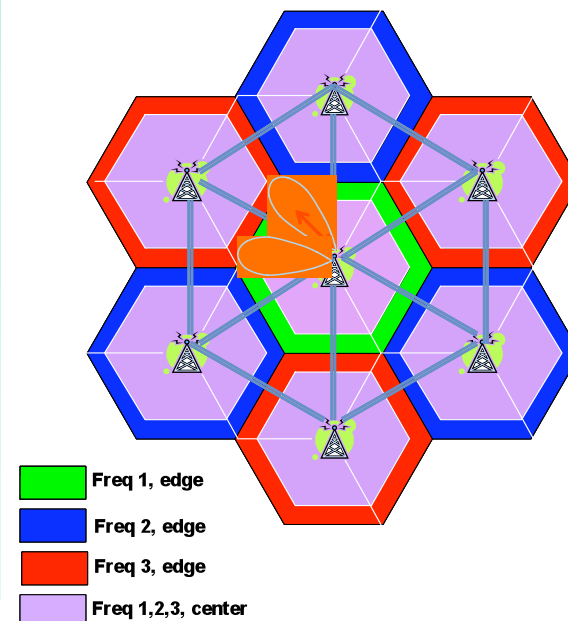
### ▪ TX Beamforming:

Transmitter forms spatial beams & nulls to improve SINR particularly for cell-edge users

BS1 forms beam towards MS1  
& null towards MS2



TX Beamforming

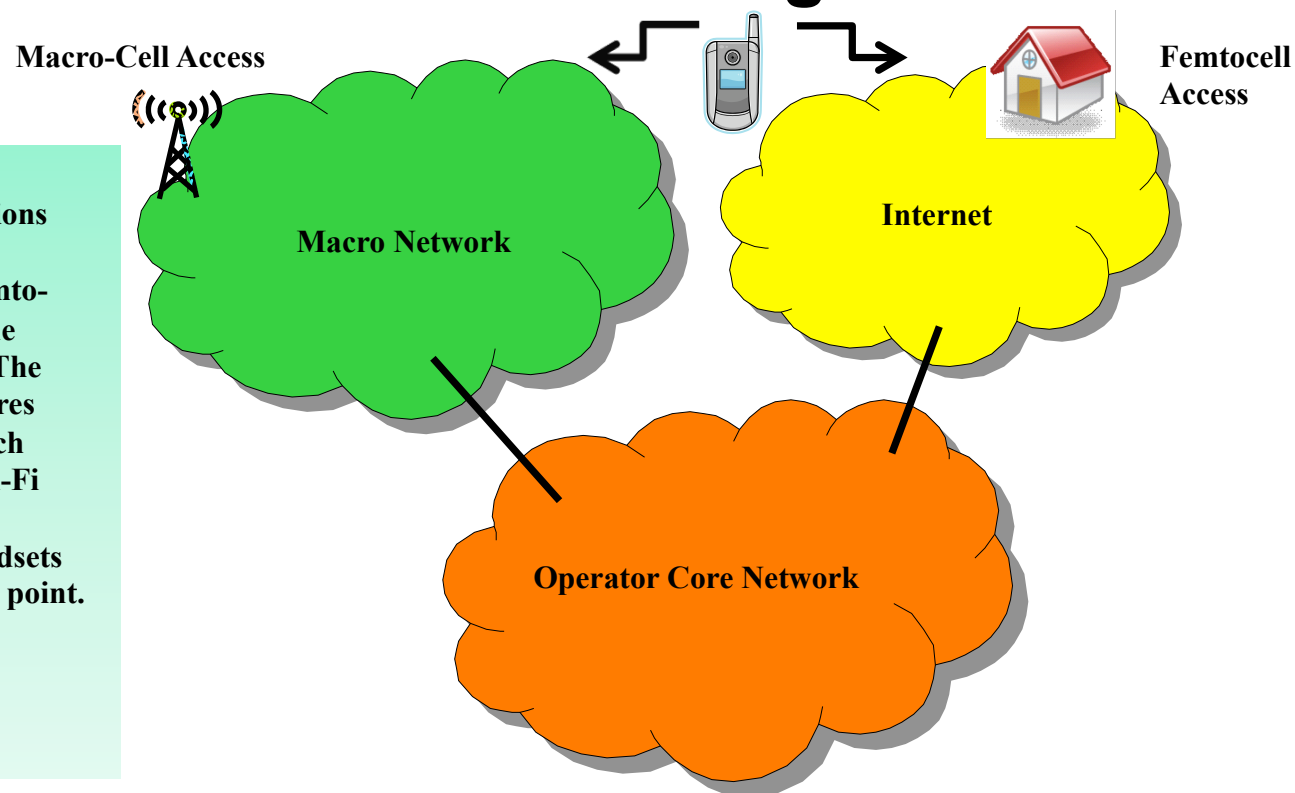


Fractional Frequency Reuse



# Support of Femtocells and Self-Organization

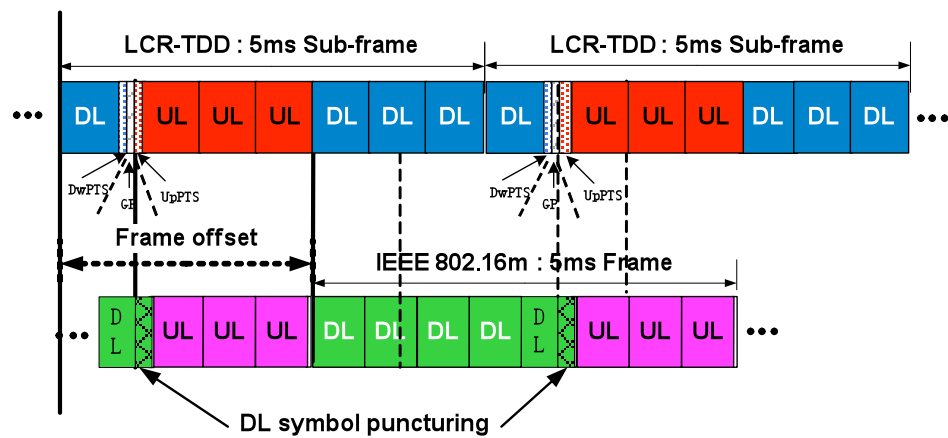
Femto-cells are low power cellular base stations deployed in homes. Mobile stations can be used inside homes with the home broadband connection as backhaul. Femto-cells are an alternative way to deliver the benefits of [Fixed Mobile Convergence](#). The distinction is that most FMC architectures require a new (dual-mode) handset which works with existing home/enterprise Wi-Fi access points, while a femto-cell-based deployment will work with existing handsets but requires installation of a new access point.



## 802.16m provides

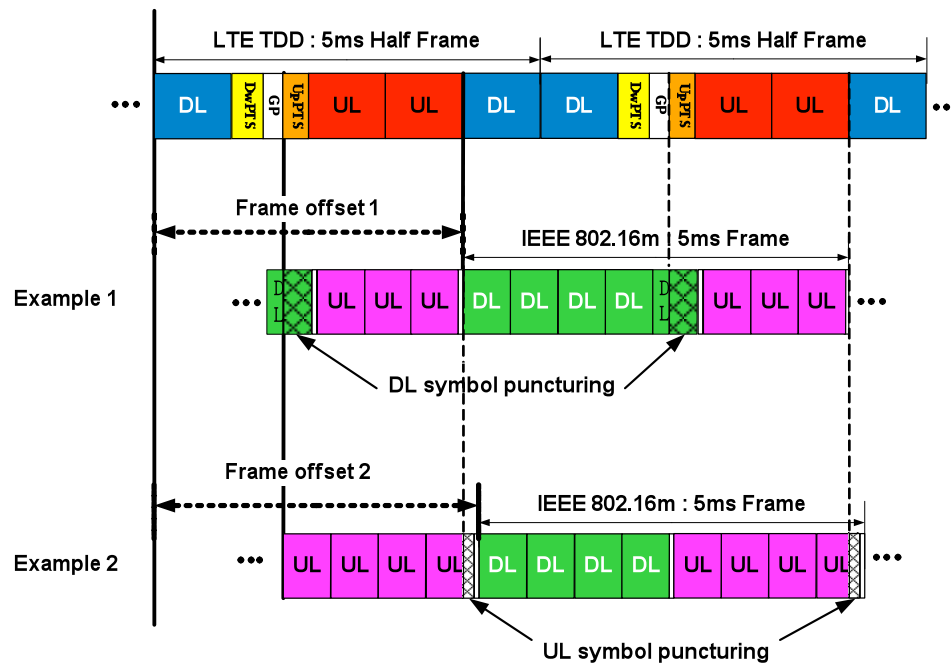
- 1) Very high data rates and service continuity in smaller cells including indoor pico cells, femto cells, and hot-spots. The small cells may be deployed as an overlay to larger outdoor cells.
- 2) Self-configuration by allowing real plug and play installation of network nodes and cells, i.e. self-adaptation of the initial configuration, including the update of neighbor nodes and neighbor cells as well as means for fast reconfiguration and compensation in failure cases.
- 3) Self-optimization by allowing automated or autonomous optimization of network performance with respect to service availability, QoS, network efficiency and throughput.

# Multi-RAT Operation and Handover



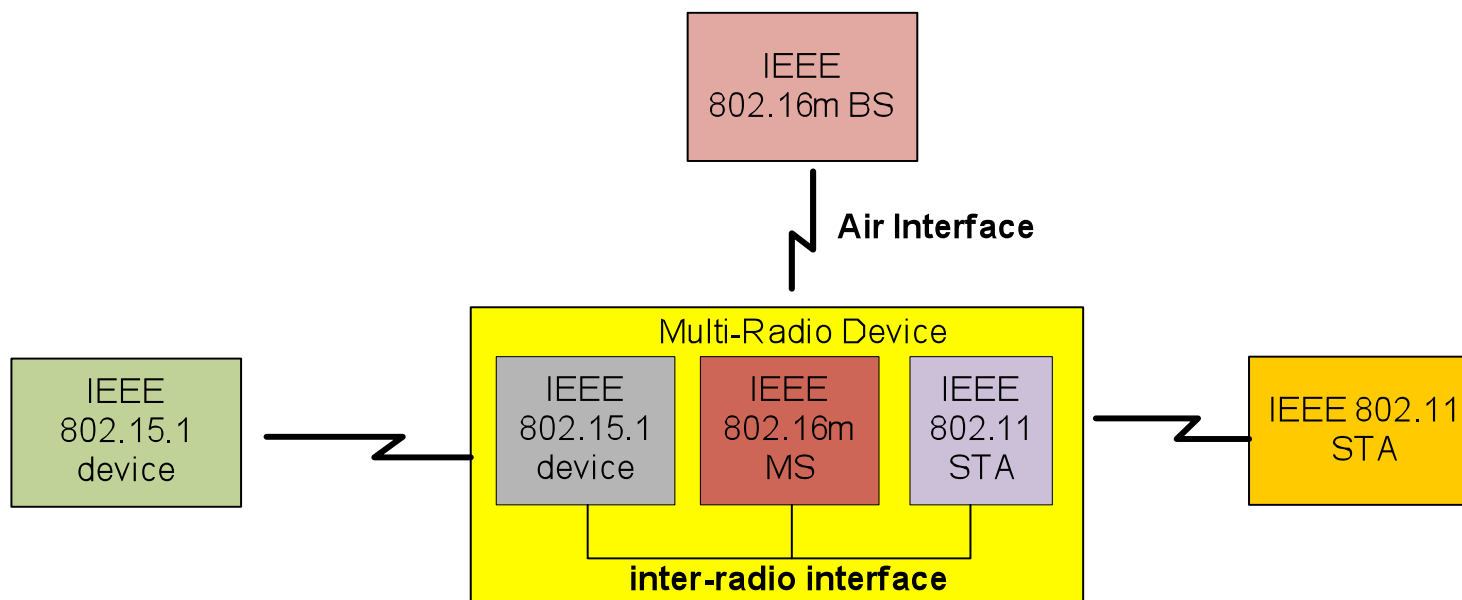
Adjacent Channel Coexistence with UTRA LCR-TDD (TD-SCDMA)

**802.16m supports interworking functionality to allow efficient handover to other radio access technologies including 802.11, GSM/EDGE, UTRA (FDD and TDD), E-UTRA (FDD and TDD), and CDMA200**



Adjacent Channel Coexistence with E-UTRA (TD-LTE)

# Multi-Radio Coexistence Support



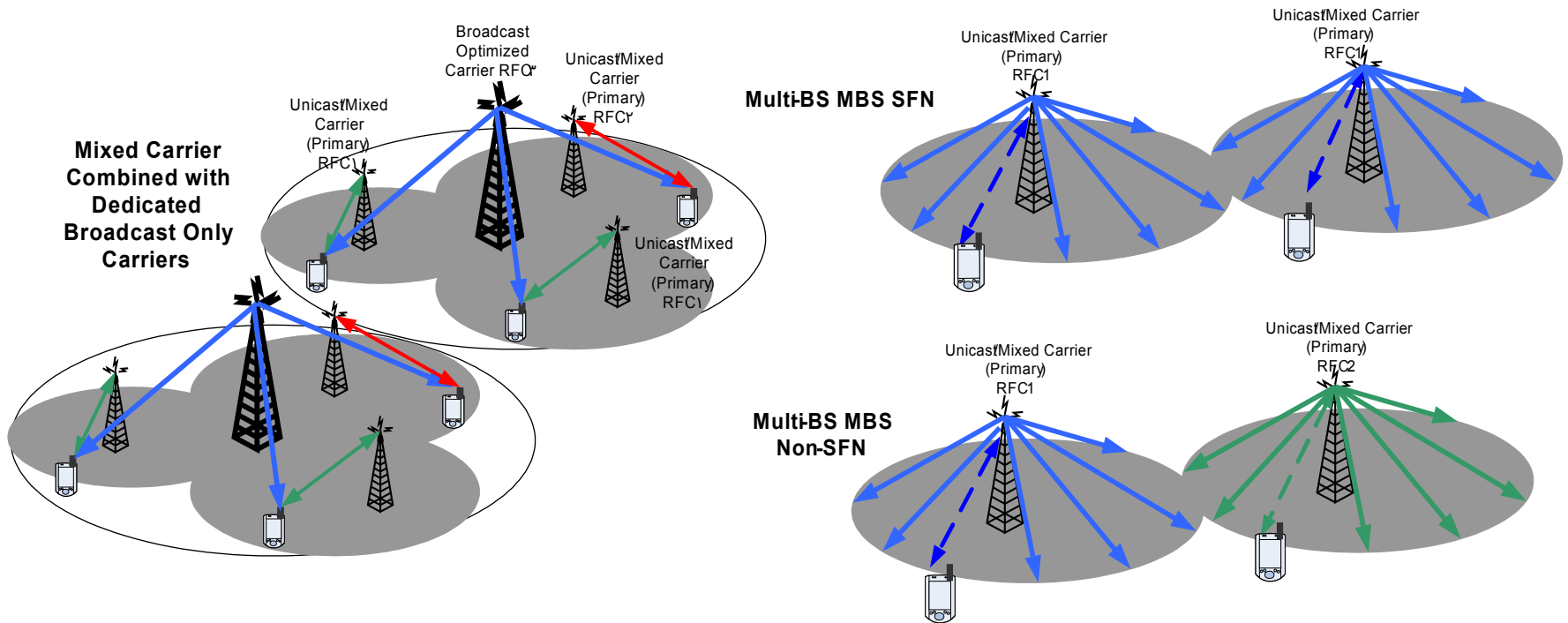
Multi-Radio Device with Co-Located 802.16m MS, 802.11 STA, and 802.15.1 device

**802.16m provides protocols for the multi-radio coexistence functional blocks of MS and BS to communicate with each other via air interface.**

**MS generates management messages to report its co-located radio activities to BS, and BS generates management messages to respond with the corresponding actions to support multi-radio coexistence operation.**

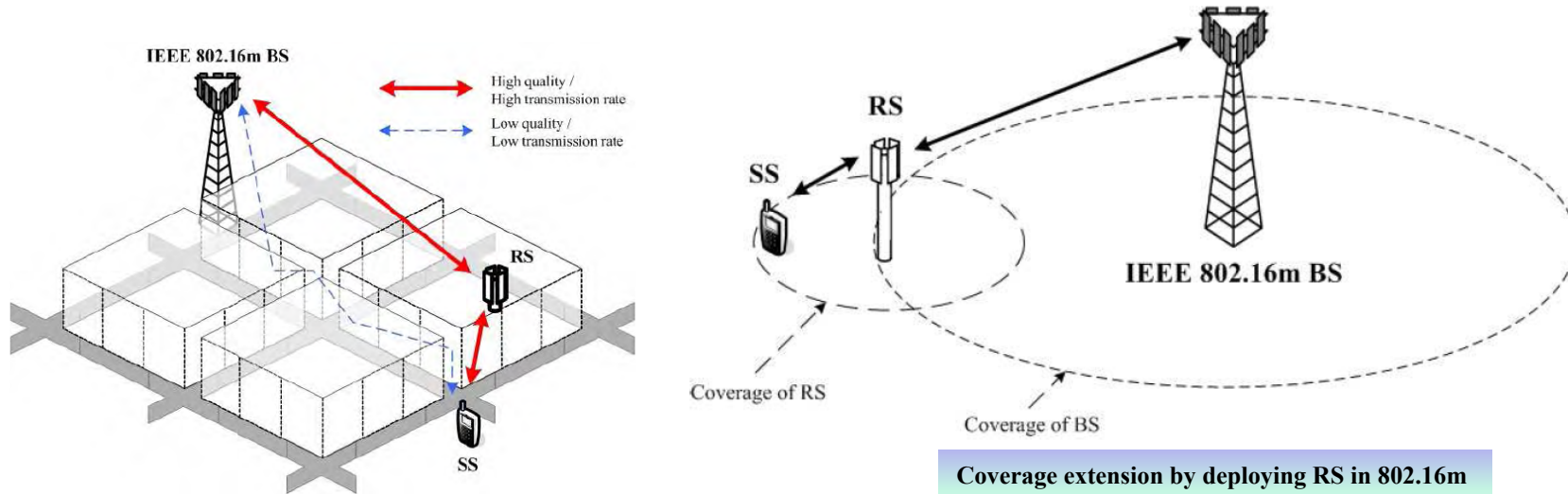
**The multi-radio coexistence functional block at BS communicates with the scheduler functional block to operate properly according to the reported co-located coexistence activities.**

# Enhanced Multicast and Broadcast Service



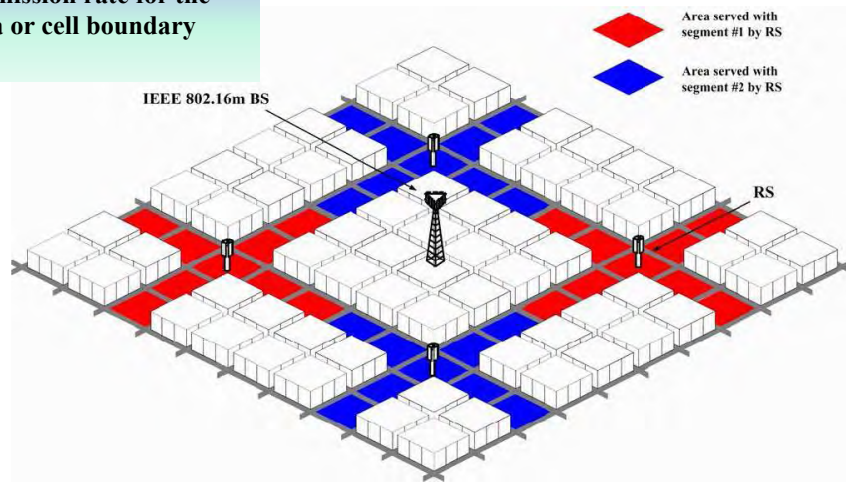
**eMBS can be multiplexed with unicast services or deployed on a dedicated carrier**

# Multihop Relay-Enabled Architecture



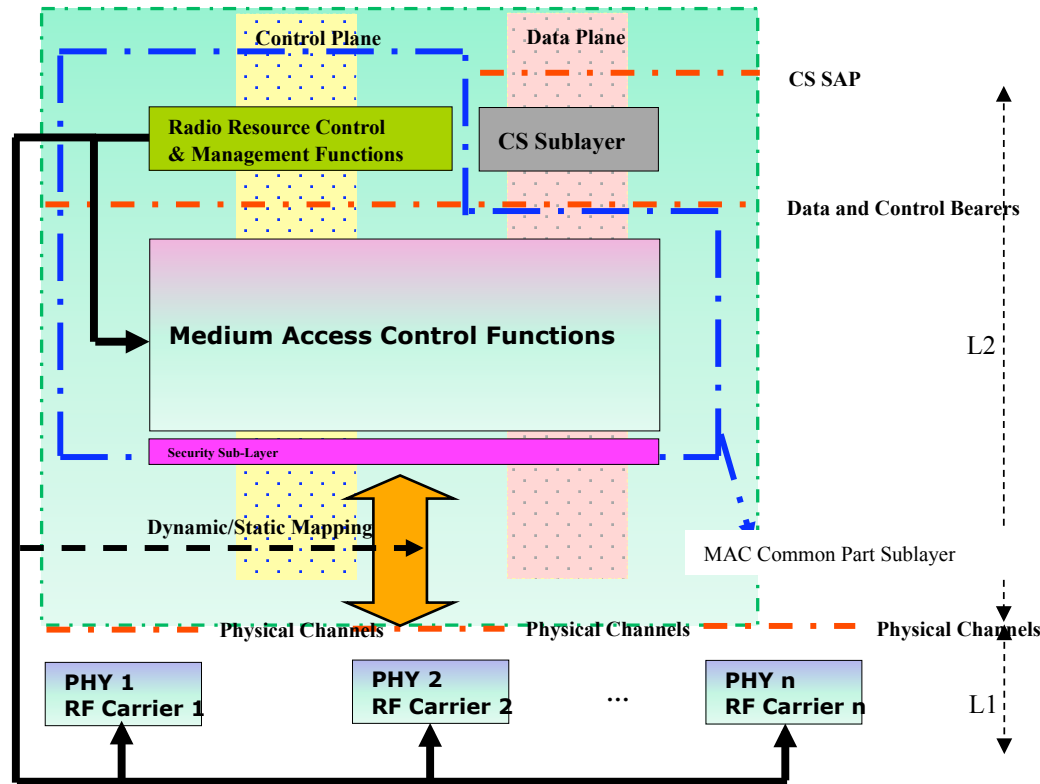
Relays can enhance transmission rate for the MS located in shaded area or cell boundary

Coverage extension by deploying RS in 802.16m network

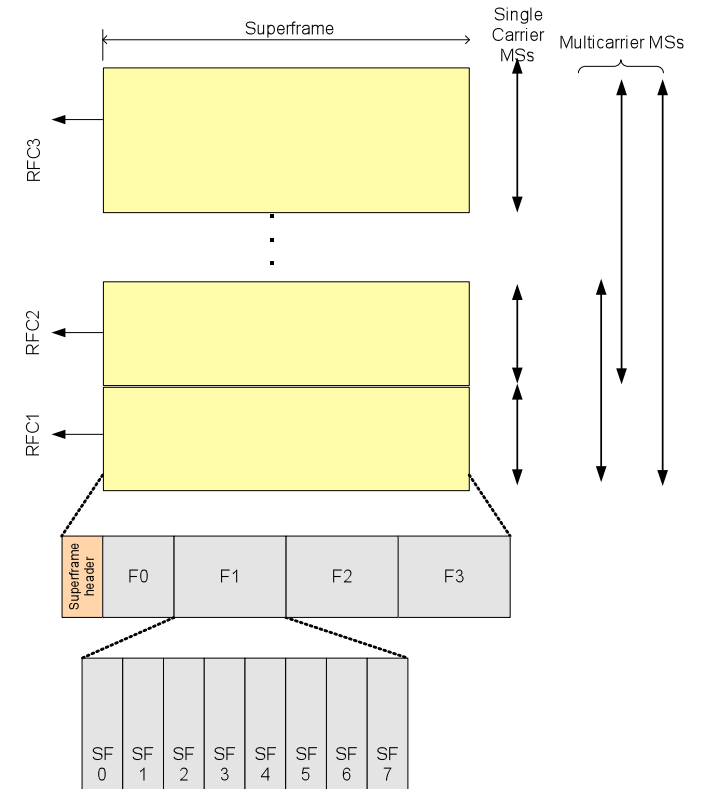


More aggressive radio resource reuse by deploying RS in 802.16m network

# Multi-Carrier Support



A generalized protocol architecture for support multicarrier operation with single MAC entity



Support of multi-carrier operation in 802.16m basic frame structure

Some MAC messages sent on one carrier may also apply to other carriers. The RF carriers may be of different bandwidths and can be non-contiguous or belong to different frequency bands. The channels may be of different duplexing modes, e.g. FDD, TDD, or a mix of bidirectional and broadcast only carriers. Support of wider bandwidths (up to 100 MHz) through aggregation across contiguous or non-contiguous channels. The RF carriers can be fully or partially configured.