The IEEE 802.16 WirelessMAN® Standard for Broadband Wireless Metropolitan Area Networks

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Roger Marks
Physicist
National Institute of Standards and Technology
U.S. Department of Commerce
Boulder, Colorado, USA

Chair
IEEE 802.16 Working Group on
Broadband Wireless Access

Outline

- Wireless Metropolitan Area Networks
  - Broadband Wireless Access
- IEEE Standards and IEEE 802
- IEEE 802.16 Working Group
- IEEE 802.16 Air Interface Standard
  - MAC and PHY, to 66 GHz
  - Revised: June 2004
  - Interoperability documentation in development
  - WiMAX Forum coordinating interoperability testing
  - P802.16e: Mobile Enhancement
  - Other developments

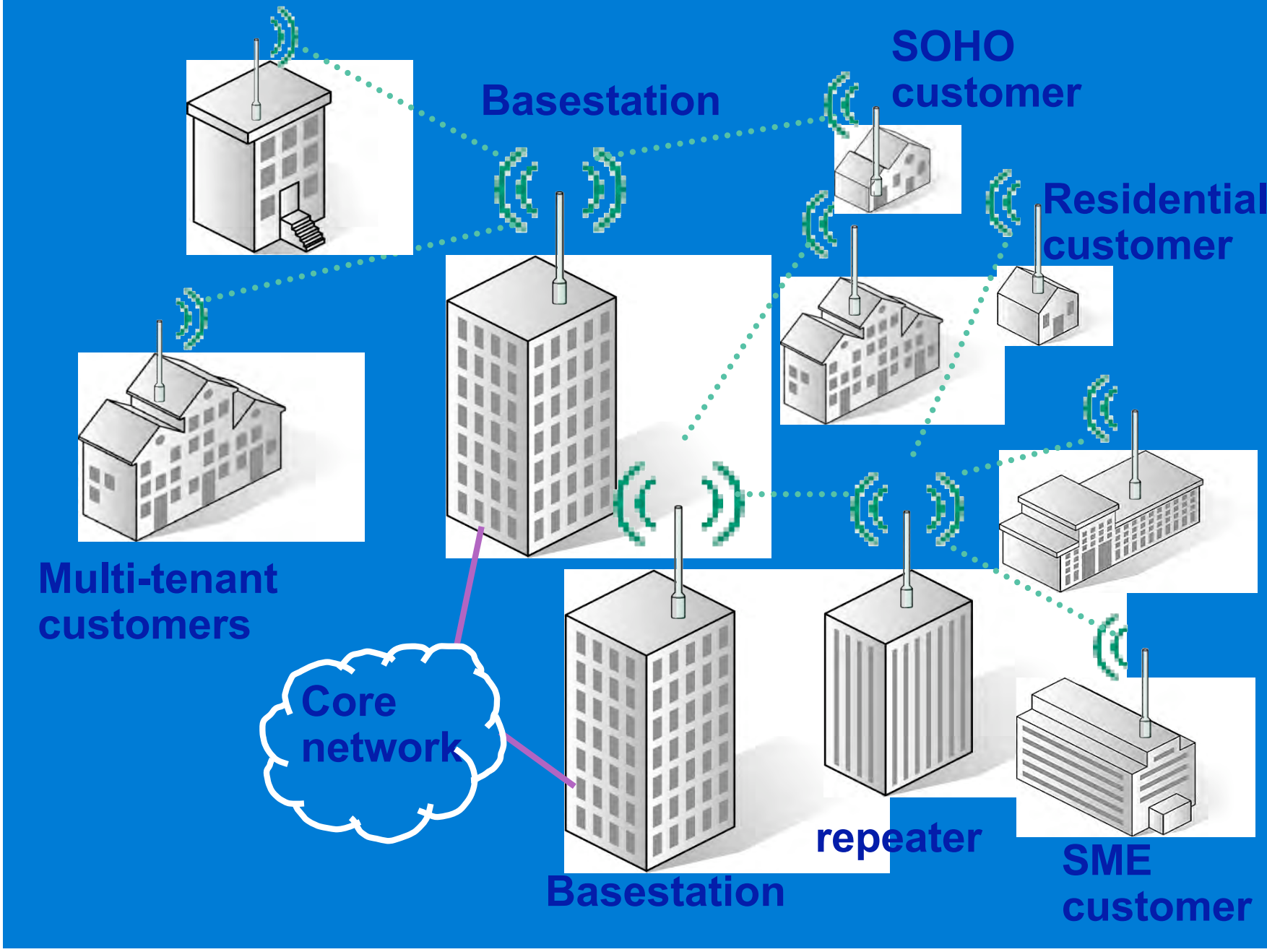
Broadband Access

- The "last mile" (or the "first few kilometers")
  - Fast local connection to network
- Business and individual customers demand it
  - Data, Voice, Two-way Video, Gaming, etc.
- Network operators demand it
- Many users are fixed (static)
  - High-capacity cable/fiber to every user is expensive
  - Construction costs do not follow Moore's Law
  - Most countries lack widespread fixed broadband access
- Many users wish to be mobile

Universal Access

- Most of the world's population has no access to broadband.
- Access to even telephone service is far from universal.
- Rather than create parallel telephone and broadband networks, a broadband network supporting voice may be more economical to deploy.

WirelessMAN: Wireless Metropolitan Area Network



Critical Issues for Broadband Wireless Access

- Access to spectrum on a technology-neutral basis
- Global industry developing technical standards to meet global needs

LMDS Band Allocation
(Local Multipoint Distribution Service)

28 & 31 GHz Band Plan

Two LMDS Licenses per BTA

Block A - 1150 MHz:
27,500-28,350 MHz
29,100-29,250 MHz
31,075-31,225 MHz

Block B - 150 MHz
31,000-31,075 MHz
31,225-31,300 MHz

Legend

* - Primary Service
MSS - Mobile Satellite Service
NON-LTTS - Non-Local Television Transmission Service

Source: Federal Communications Commission

Centimeter-Wave Bands

Non-Line-of-Sight

International

3.5 GHz; 10.5 GHz; etc.

U.S.: Broadband Radio Service

~2.5-2.7 GHZ

Korea

2.3 GHz

License-Exempt Bands

5-6 GHz

2.4 GHz

59-64 GHz

Importance of Global Standards for Broadband Wireless Access Systems

- Reduced costs due to mass production
- Reduced operator risk
- Opportunities for roaming
- Stimulate adoption of technology
- Platform for technical innovation

- Global standards benefit the **users** and the **producers**.

IEEE Standards for Broadband Wireless Access Systems

- Institute of Electrical and Electronics Engineers (IEEE)
  - Global, open process
  - Worldwide participation
  - Producing international standards
- IEEE 802.11™ (short-range: ~100 m):
  - Wireless Local Area Networks
  - Often called "Wi-Fi" for "Wi-Fi Alliance"
- IEEE 802.16 ™ (long-range: ~10 km):
  - Wireless Metropolitan Area Networks
  - Often called "WiMAX" for "WiMAX Forum"
  - or "WiBro" for "Wireless Broadband"

Why IEEE 802®?

Telecom Standardization

- National
- Political

Datacom Standardization

- Global
- Open
- Industry-Driven
- 802 and IETF set the standards

Who are the Members?

- Telecom Standardization Bodies
  - Governmental Representatives
  - Companies
- IEEE
  - engineers

Properties of IEEE Standard 802.16™

- Broadband
  - Up to ~100 Mbit/s (in principle, at PHY, in 28 MHz channel)
- Supports multiple services simultaneously with full QoS
  - Efficiently transport IPv4, IPv6, ATM, Ethernet, etc.
- Bandwidth on demand (frame by frame)
- MAC designed for efficient used of spectrum
- Comprehensive, modern, and extensible security
- Supports multiple frequency allocations up to 66 GHz
  - ODFM and OFDMA for non-line-of-sight applications
- TDD and FDD
- Link adaptation: Adaptive modulation and coding
  - Subscriber by subscriber, burst by burst, uplink and downlink
- Point-to-multipoint topology, with mesh extensions
- Support for adaptive antennas, space-time coding, MIMO
- Extensions to mobility (nearly finished)
- An element of 4G wireless.

IEEE 802.16 History

- Project Development: 1998-1999
- Meet every two months:
  - #1: July 1999: Montreal Canada 130 people
  - ...
  - #29/Jan 2004: Vancouver Canada 131
  - #30/Mar 2004: Orlando USA 222
  - #31/May 2004: Shenzhen China 228
  - #32/Jul 2004: Portland USA 332
  - #33/Sep 2004: Seoul Korea 287
  - #34/Nov 2004: San Antonio USA 367
  - #35/Jan 2005: Sanya China 313
  - #36/Mar 2005: Atlanta USA 330
  - #37/May 2005: Sorrento Italy 218
  - #38/Jul 2005: San Francisco USA ~300

IEEE 802 Process

- Call for Contributions
  - Specific topics for discussion at next meeting
- Receive and post written contributions
- Discuss and debate at meeting
- Create draft by 75% vote
- Working Group Ballot
- IEEE "Sponsor Ballot"
- Ballot Responses:
  - "Approve" (can include comments)
  - "Disapprove": indicate what needs to be changed to bring about an "Approve" vote

Participation in IEEE 802.16

- *Open process and open standards*
- Anyone can participate in meetings
- Anyone can participate outside of meetings
  - Subscribe to mailing lists and read list archives
  - Post to mailing lists
  - Examine documents
  - Contribute and comment on documents
  - Join the Sponsor Ballot Pool
    - Vote and comment on draft standards
    - Must join the IEEE Standards Association to vote
    - Producers and Users must both be in ballot group

The World Wants 802.16 WirelessMAN® Standards

- Attendees from Australia, Belgium, Brazil, Canada, China, Finland, France, Germany, Greece, Hong Kong, India, Ireland, Israel, Italy, Japan, Korea, Netherlands, Norway, Pakistan, Russia, Singapore, Spain, Sweden, Taiwan, UK, USA
- Regional coordination
  - Europe, Korea, China
- International coordination with ITU

802.16 and ETSI

- Over 50 liaison letters between 802.16 and ETSI
  - (European Telecom Standards Institute)
- ETSI HIPERMAN
  - Below 11 GHz
  - IEEE began first
  - Healthy cooperation
  - Harmonized with 802.16 OFDM
- Cooperation on conformance tests

802.16 and Korea

- Several liaison letters between 802.16 and TTA (Telecommunication Technology Association)
- Korean Ministry of Information and Communication announced (29 July 2004) that Portable Internet Service (WiBro) using the 2.3 GHz spectrum “must comply with IEEE 802.16-2004 and IEEE 802.16e/Draft3 or later versions.”

IEEE 802.16 History in China

- "IEEE 802.16a Broadband Wireless Access (BWA) Standard Development and Internet Application": conference sponsored by BUPT and MII on 24 August 2001 in Beijing "on the specific topic of whether to use 802.16a as the Chinese national standard for fixed broadband wireless access at 3.5 GHz"

IEEE Standards & China

- Delegation of IEEE Standards Association Met with leaders of Standards Administration of China (Beijing, 18 May 2004)
- Met with leaders in Ministry of Information Industry and China Communications Standards Association (Shenzhen, 19 May 2004)

802.16 and ITU

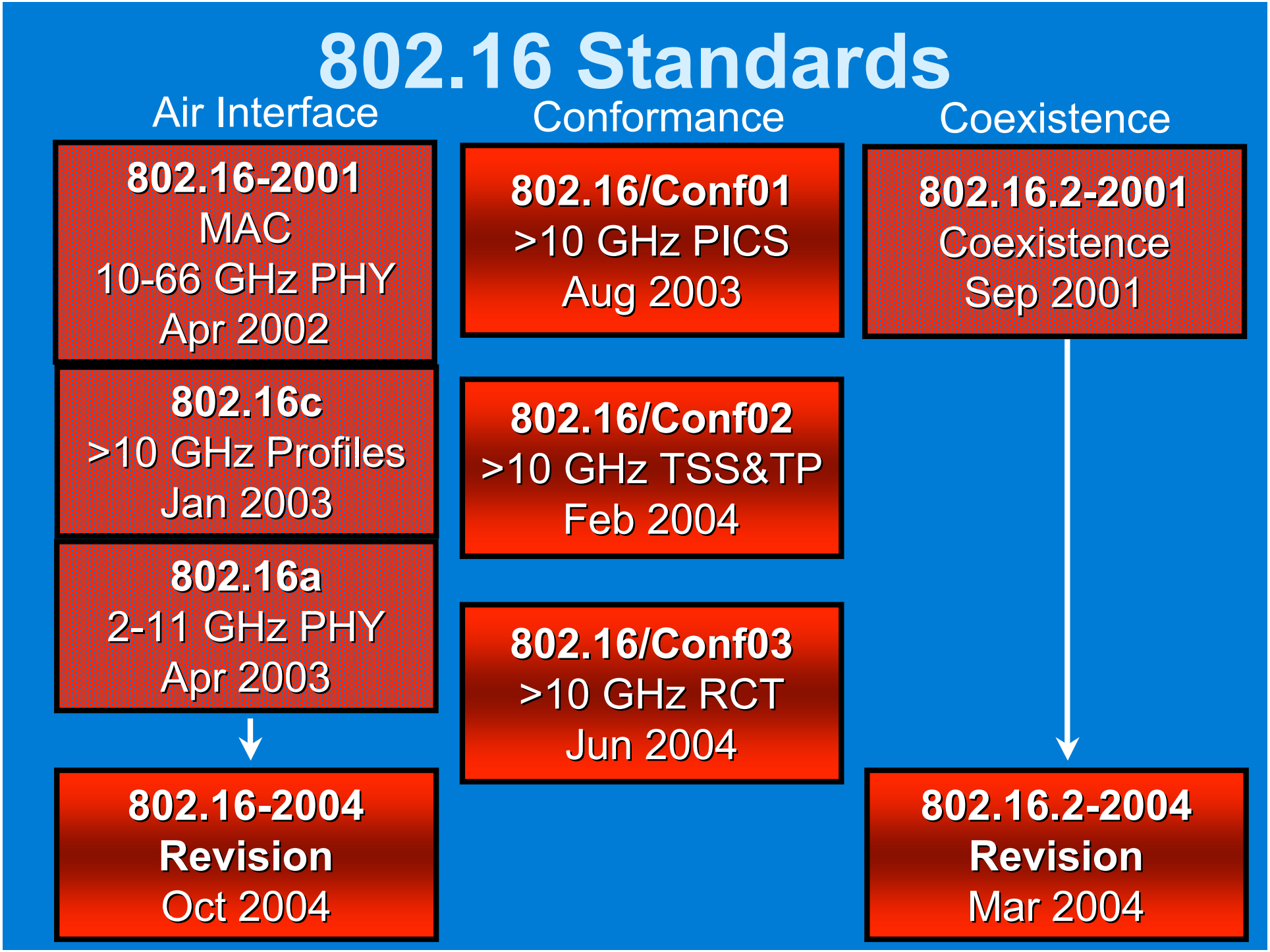
- ITU-T:
  - SG15: network access technologies
    - Leadership meeting
    - Liaison letters
  - SG9: cable television networks
    - Leadership visits
    - Liaison letters
    - PDNR underway: broadband wireless extensions
      - 802.16 invited to contribute
- ITU-R:
  - WP 9B: fixed wireless access
    - Liaison exchanges
    - PDNR: broadband wireless recommendations
      - Based on 802.16's invited input
  - WP 8A: land mobile radio: initiative underway

WiMAX Forum

- WiMAX: Worldwide Interoperability for Microwave Access
- Mission: *To promote deployment of BWA by using a global standard and certifying interoperability of products and technologies.*

- 317 Member companies, and growing
  - Support IEEE 802.16 standard
  - Propose and promote access profiles for IEEE Std 802.16
  - Certify interoperability levels both in network and the cell
  - Achieve global acceptance
  - Promote use of broadband wireless access overall

802.16 Standards



Active 802.16 Projects

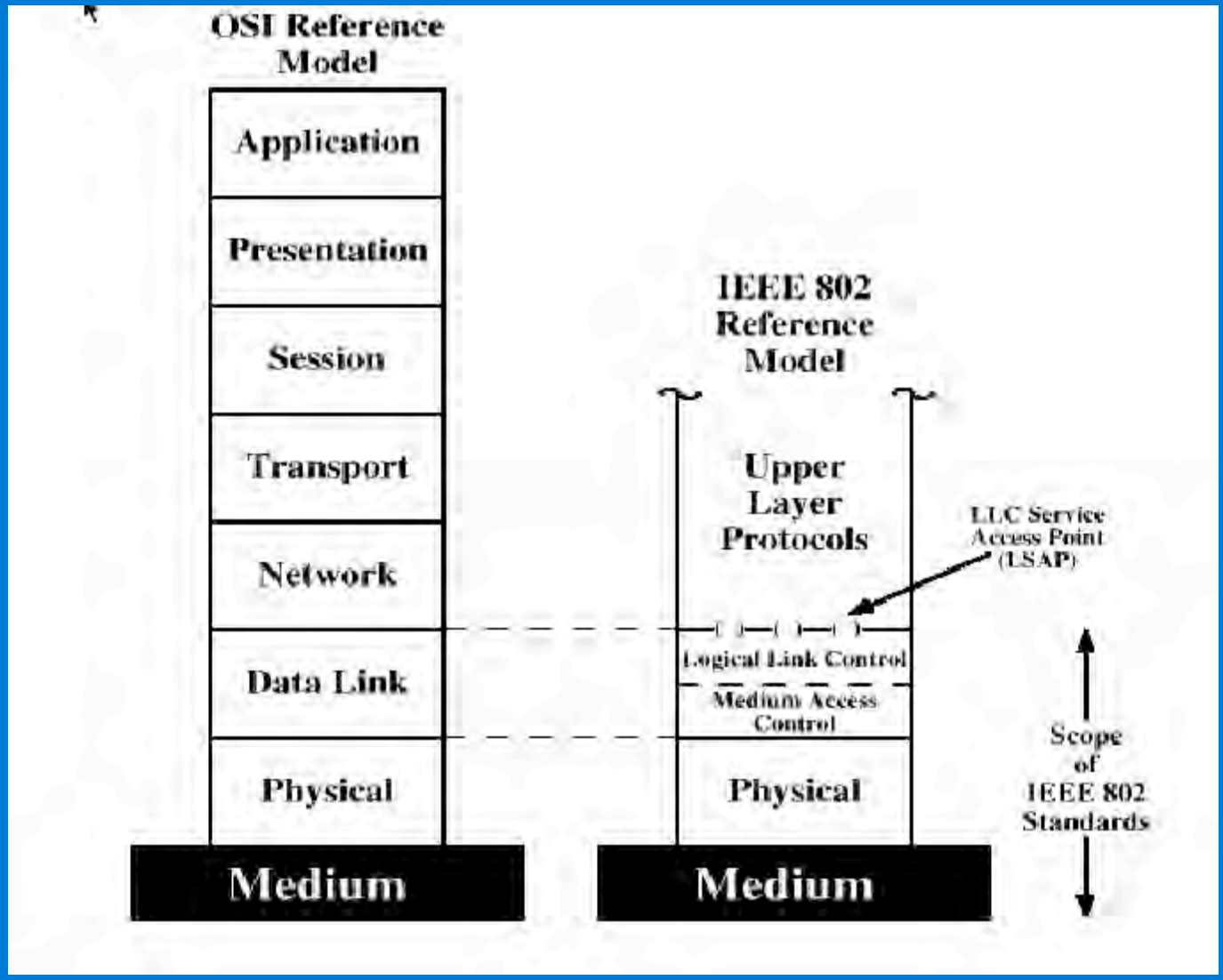
Air Interface	Conformance	Management
P802.16e Mobile Done: Aug 2005?	**P802.16/Conf04** <11 GHz PICS in ballot	**P802.16f** MIB (fixed only) Done: Aug 2005?
P802.16/Cor 1 Maintenance Done: Aug 2005?		**P802.16g** Management Plane Procedures & Services Start: Aug 2004
P802.16h LE Coexistence Start: Dec 2004		

IEEE Standard 802.16: WirelessMAN™ Air Interface

Point-to-Multipoint Wireless MAN: not a LAN

- Base Station (BS) connected to public networks
- BS serves Subscriber Stations (SSs)
- Provide SS with first-mile access to networks
  - SS can serve a building (business or residence)
  - SS can serve a Wireless LAN AP
  - SS can serve a PDA, etc.
- Compared to a Wireless LAN:
  - Multimedia QoS, not only contention-based
  - Many more users
  - Much higher data rates
  - Much longer distances

Scope of 802 Standards



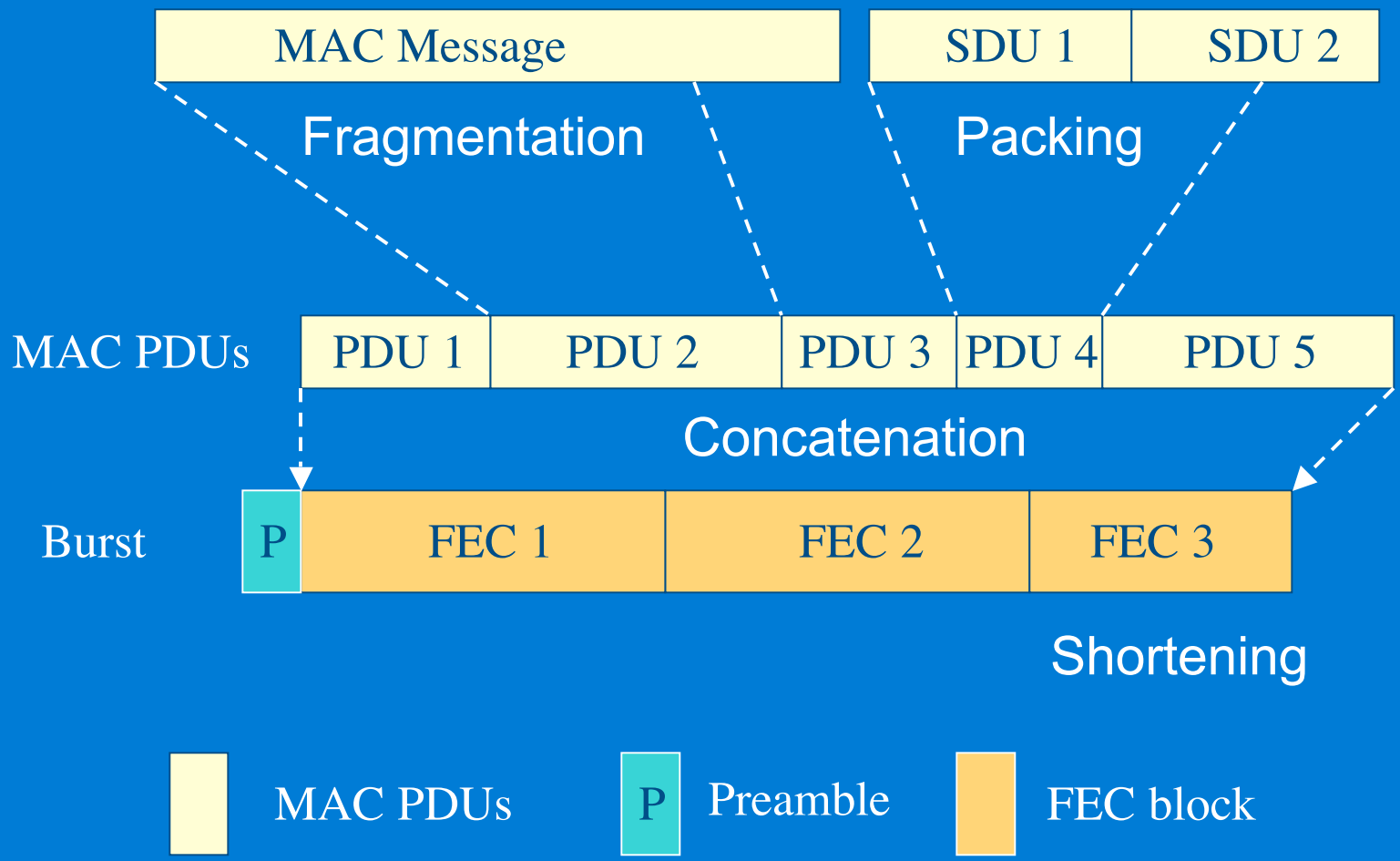
802.16 MAC: Overview

- Point-to-Multipoint Metropolitan Area Network
- Connection-oriented
- Supports difficult user environments
  - High bandwidth, hundreds of users per channel
  - Continuous and burst traffic
  - Very efficient use of spectrum
- Protocol-Independent core (ATM, IP, Ethernet, …)
- Balances between stability of contentionless and efficiency of contention-based operation
- Flexible QoS offerings
  - CBR, rt-VBR, nrt-VBR, BE, with granularity within classes
- Supports multiple 802.16 PHYs (SC, OFDM, OFDMA)
- ARQ/HARQ for link reliability
- Adaptive Antenna System (AAS) and MIMO support
- Dynamic Frequency Selection (DFS) (license-exempt)

P802.16e MAC: Mobility Support

- Handover messaging
- Support of Make-Before-Break and Soft Handover
- Sleep Mode
- Idle Mode (Paging)
- Advertisement of neighborhood
- Scanning for neighbors
- Efficient network re-entry process

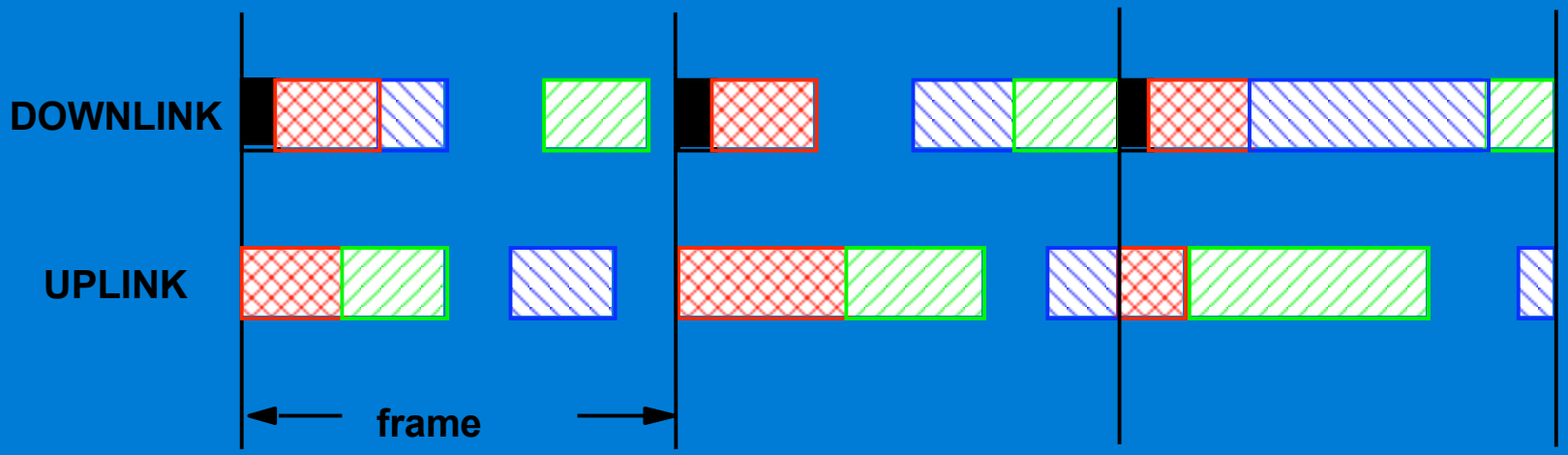
MAC PDU Transmission



Multiple Access and Duplexing

- On DL, SS addressed in TDM stream
- On UL, SS allotted a variable length TDMA slot
- Time-Division Duplex (TDD)
  - DL & UL time-share the same RF channel
  - Dynamic asymmetry
  - SS does not transmit/receive simultaneously (low cost)
- Frequency-Division Duplex (FDD)
  - Downlink & Uplink on separate RF channels
  - Static asymmetry
  - Half-duplex SSs supported
    - SS does not transmit/receive simultaneously (low cost)

Burst FDD Framing



Broadcast

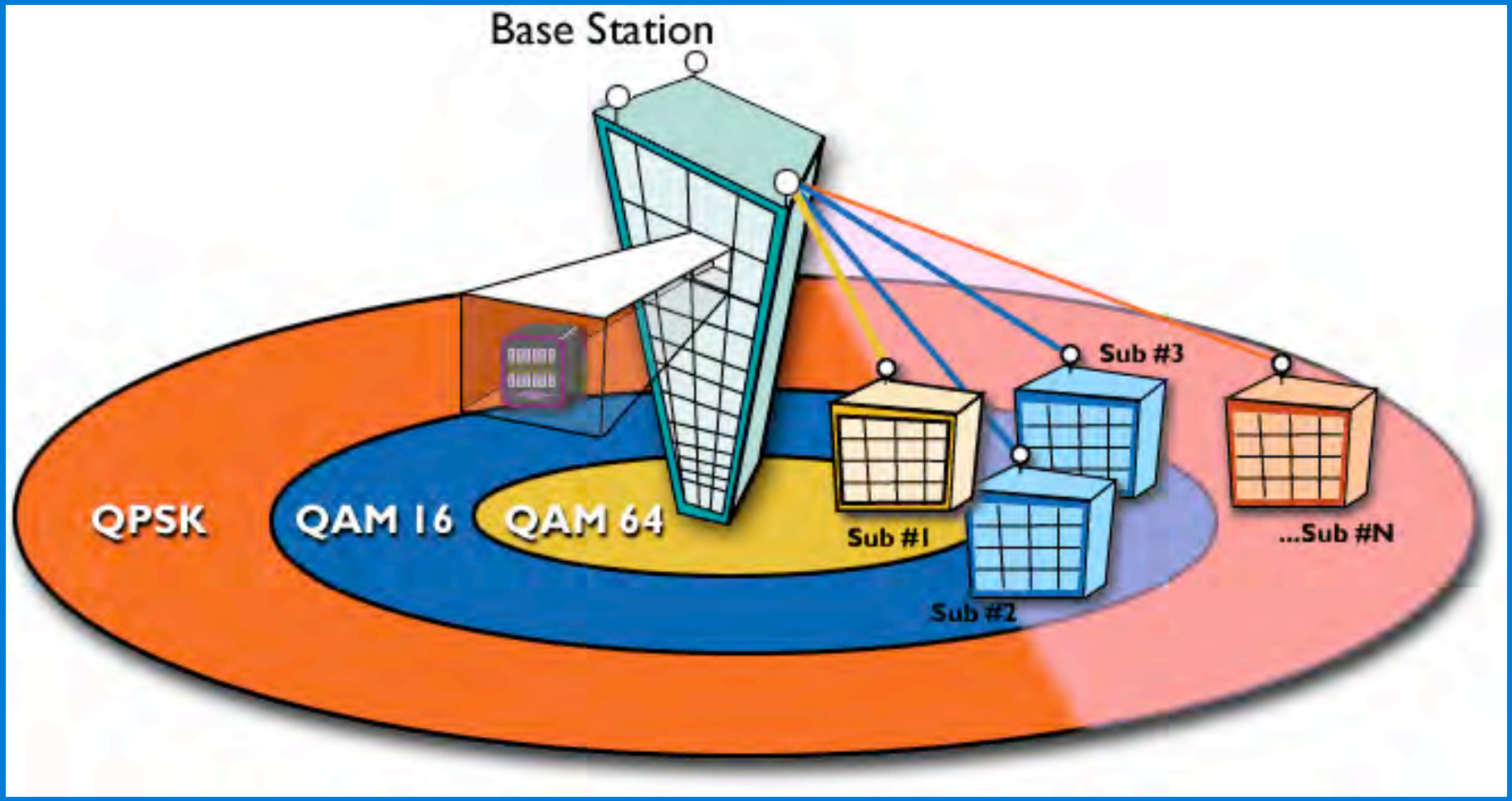
Half Duplex Terminal #1

Full Duplex Capable User

Half Duplex Terminal #2

Allows scheduling flexibility

Adaptive PHY

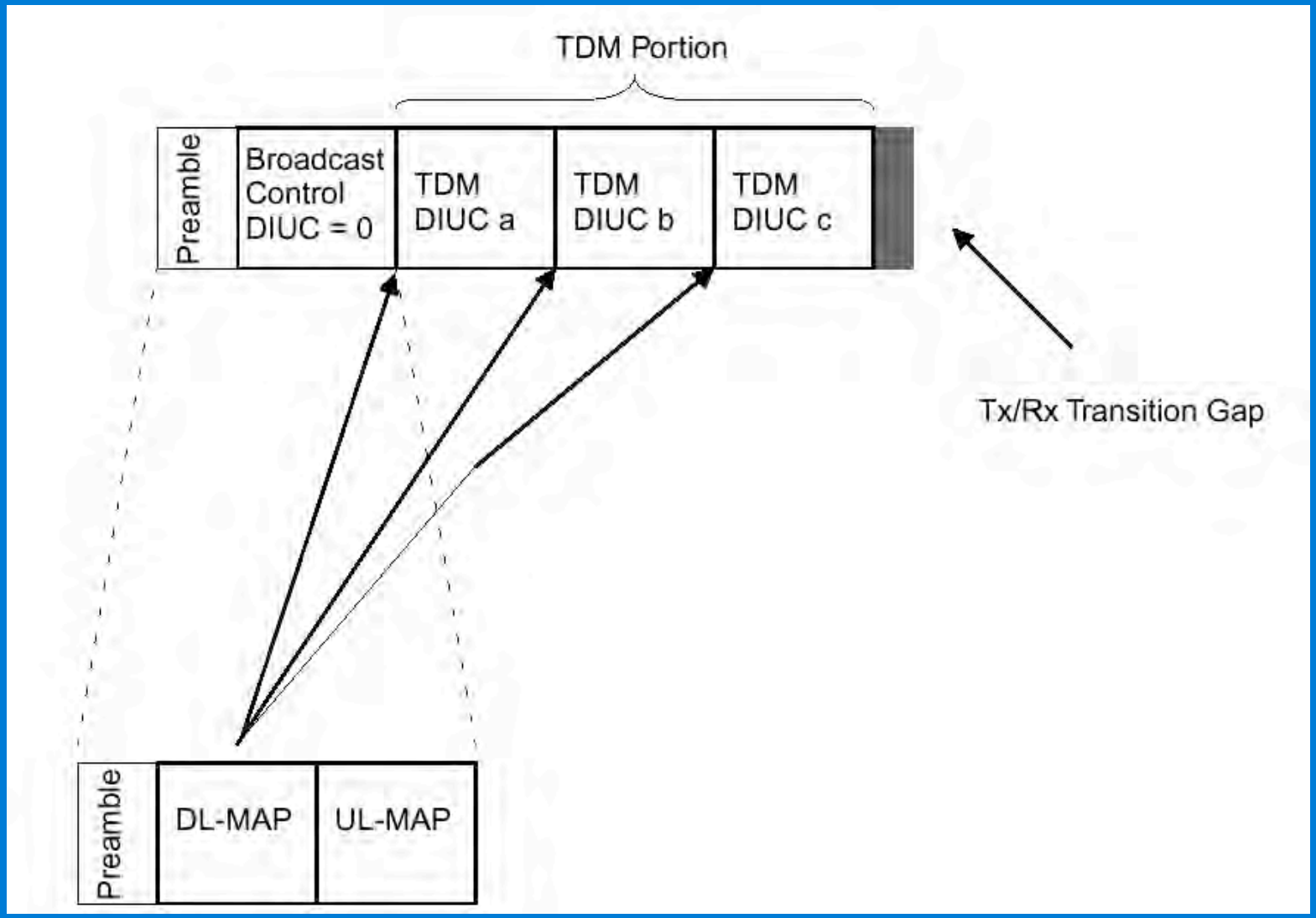


(burst-by-burst adaptivity not shown)

Adaptive Burst Profiles

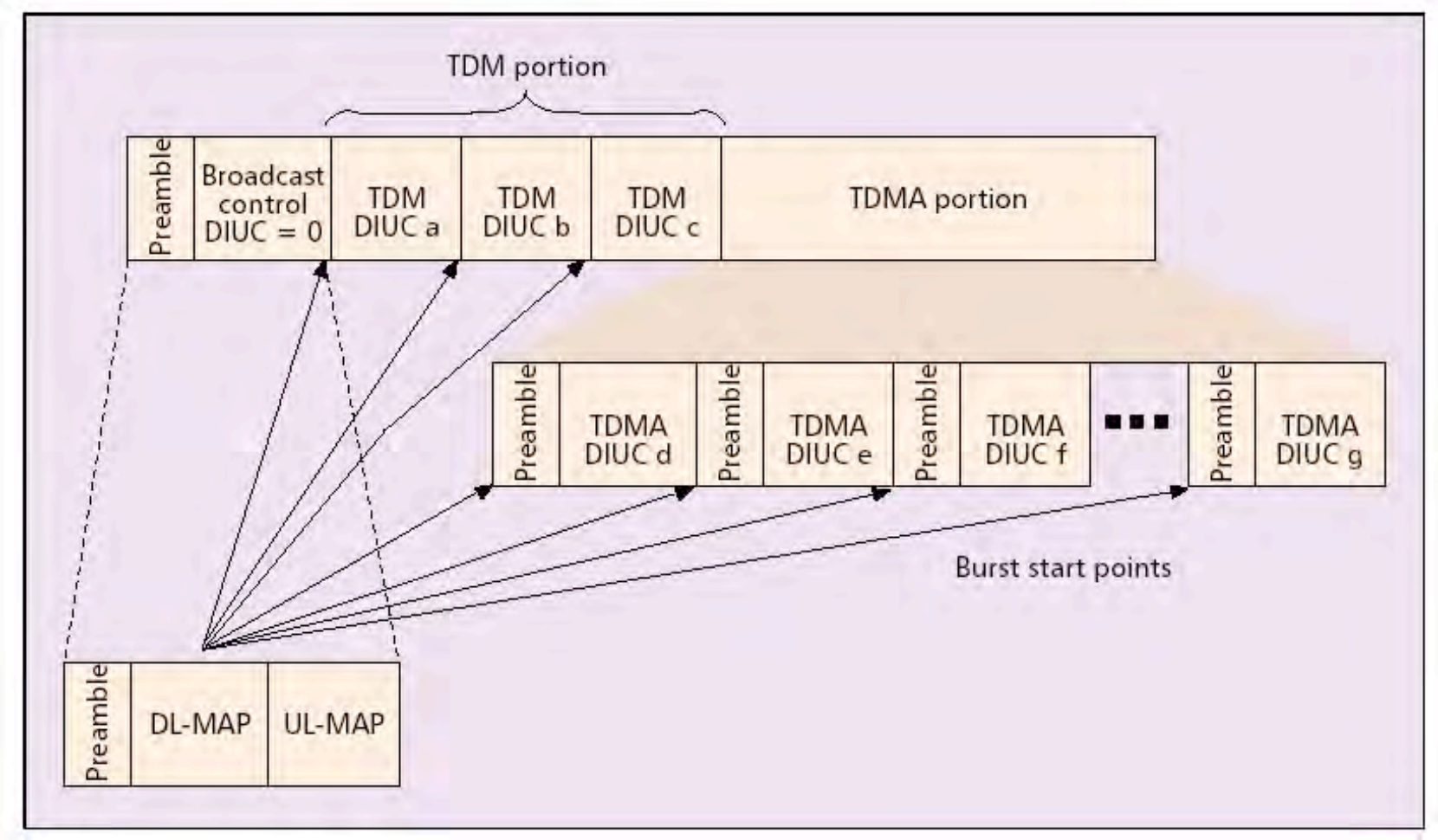
- Burst profile
  - Modulation and FEC
- Dynamically assigned according to link conditions
  - Burst by burst, per subscriber station
  - Trade-off capacity vs. robustness in *real time*
- Roughly doubled capacity for the same cell area
- Burst profile for downlink broadcast channel is well-known and robust
  - Other burst profiles can be configured “on the fly”
  - SS capabilities recognized at registration

TDD Downlink Subframe



DIUC: Downlink Interval Usage Code

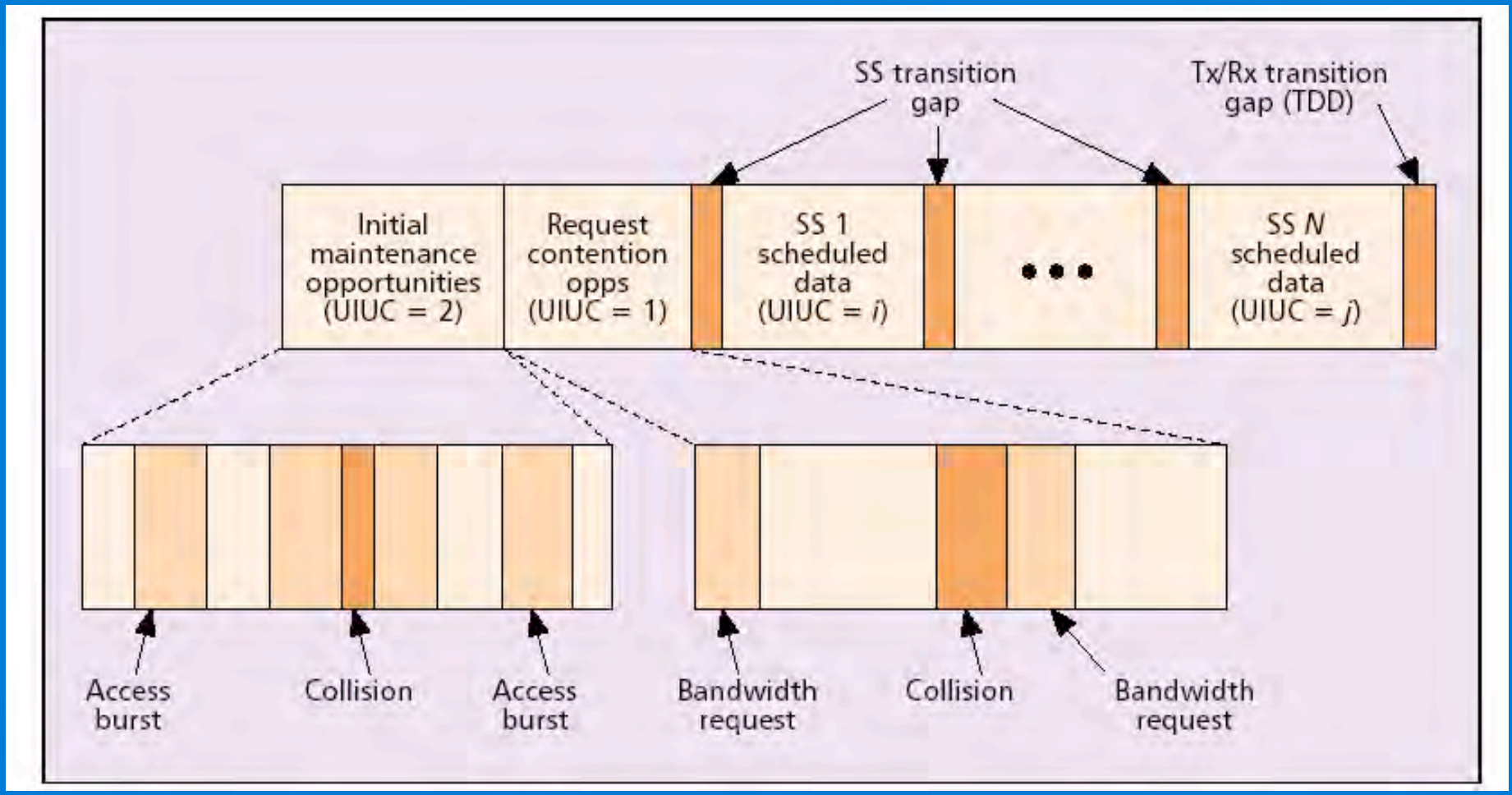
FDD Downlink Subframe



TDMA portion: transmits data to some half-duplex SSs (the ones scheduled to transmit earlier in the frame than they receive)

- Need preamble to re-sync (carrier phase)

Typical Uplink Subframe (TDD or FDD)

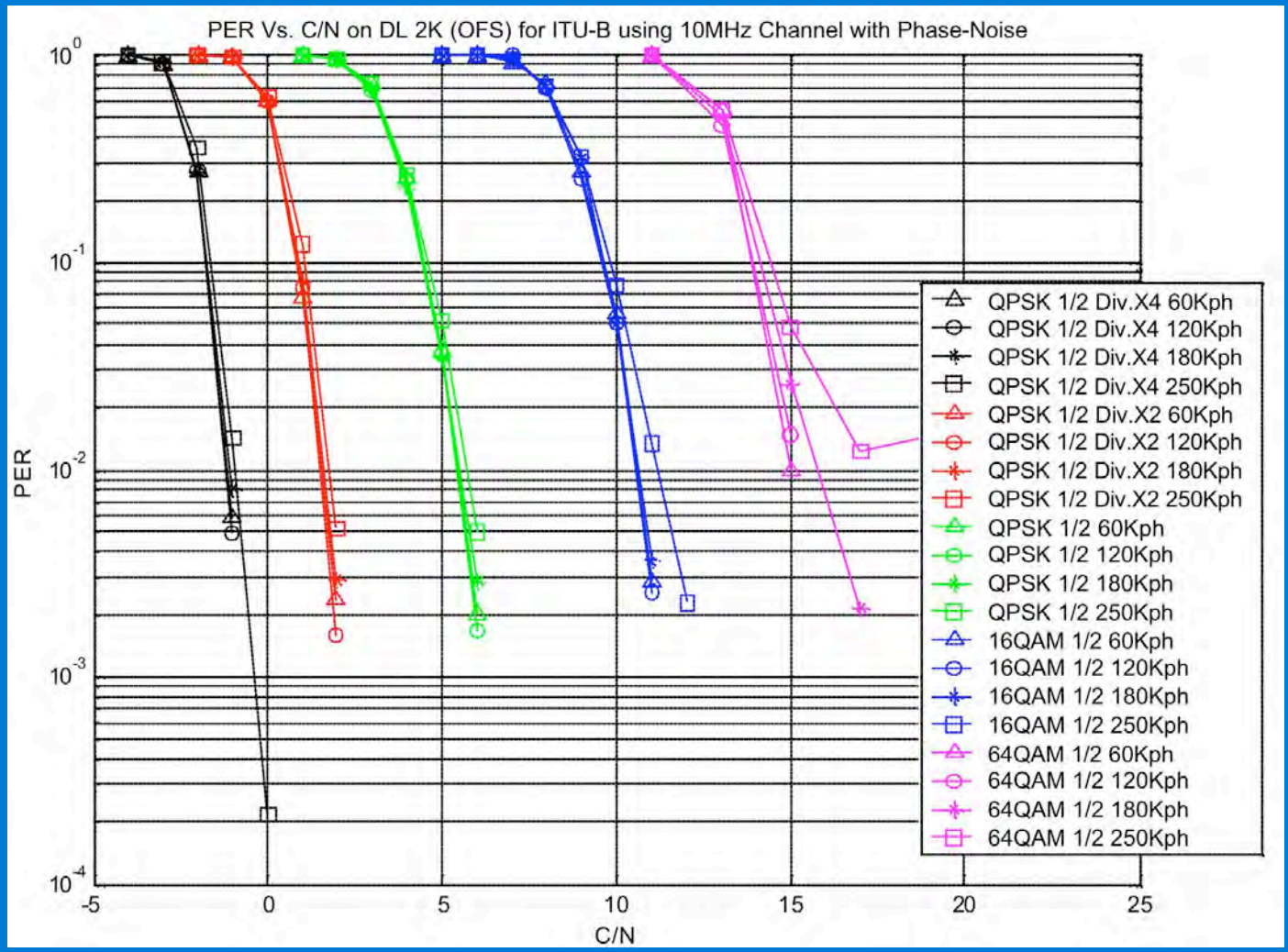


<11 GHz PHY Alternatives: Different Applications, Bandplans, and Regulatory Environments

- OFDM (WirelessMAN-OFDM Air Interface)
  - 256-point FFT
- OFDMA (WirelessMAN-OFDMA Air Interface)
  - 2048-point FFT
  - Scalable to 1024, 512, 128
- Single-Carrier (WirelessMAN-SCa Air Interface)
  - Can use Frequency-Domain Equalization

PHY in Mobile Application

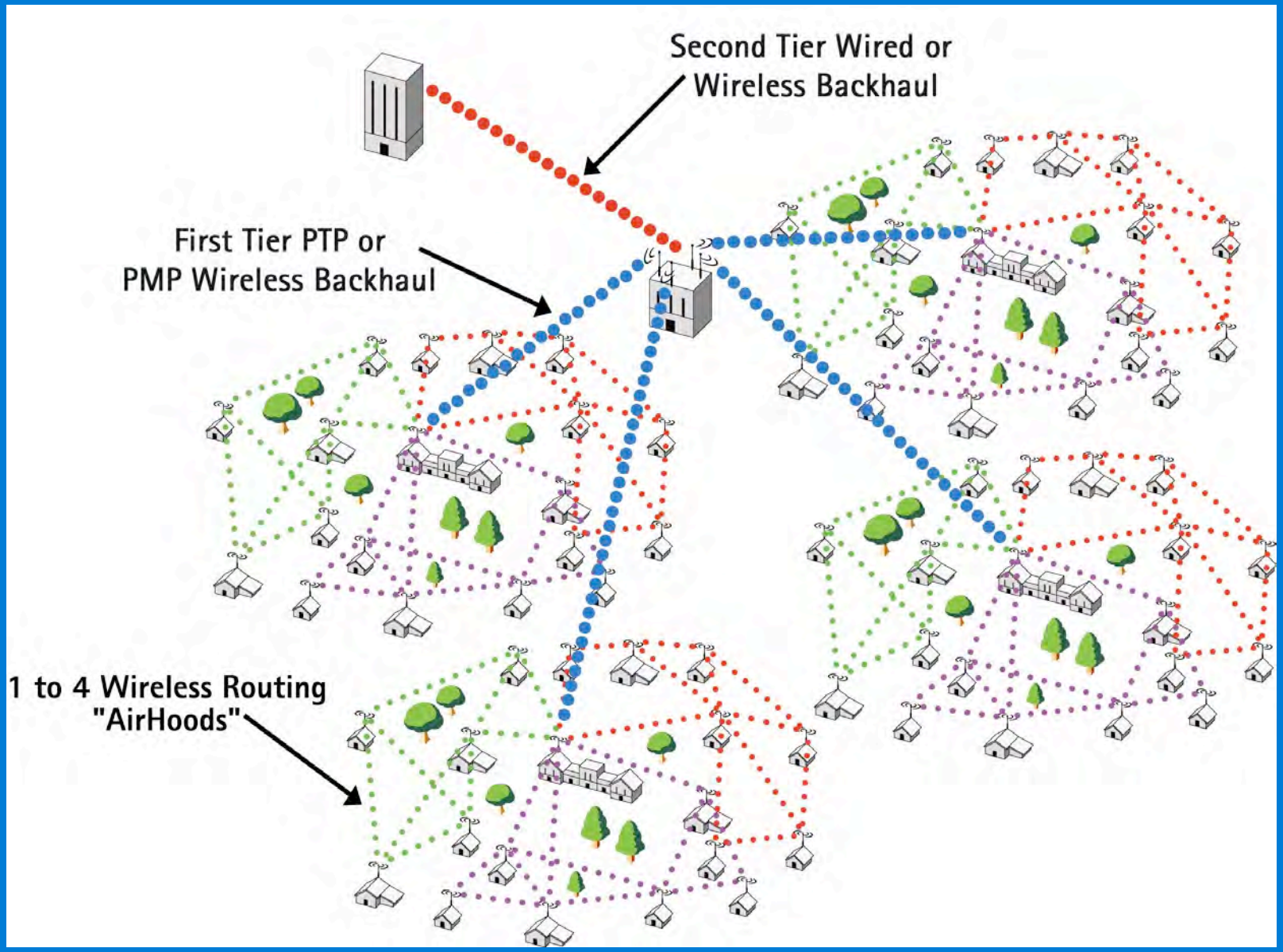
Source: "Applying scalability for the OFDMA PHY Layer," Contribution IEEE C802.16e-04/47r2((Y. Segal, I. Kitroser, Y. Leiba, Z. Hadad)



Compliance Documentation (10-66 GHz only, so far)

- IEEE P802.16c (System Profiles)
  - specifies particular combinations of options
  - used as basis of compliance testing
    - MAC Profiles: ATM and Packet
    - PHY Profiles: 25 & 28 MHz; TDD & FDD
- IEEE Std 802.16/Conformance0X
  - PICS (01)
  - Test Suite Structure & Test Purposes (02)
  - Radio Conformance Tests (03)
  - [04: PICS for <11 GHz]

Mesh-based WirelessMAN



Source: Nokia Networks

802.16 Summary

- The IEEE 802.16 WirelessMAN Air Interface, addresses worldwide needs
- The 802.16 Air Interface provides great opportunities for vendor differentiation, particularly at the base station, without compromising interoperability.
- The air interface is suitable for mobile subscriber stations, and enhancements for mobile use are nearly complete.
- Standardized network management functions will be defined.
- Compliance tests will be defined.

Free IEEE 802 Standards

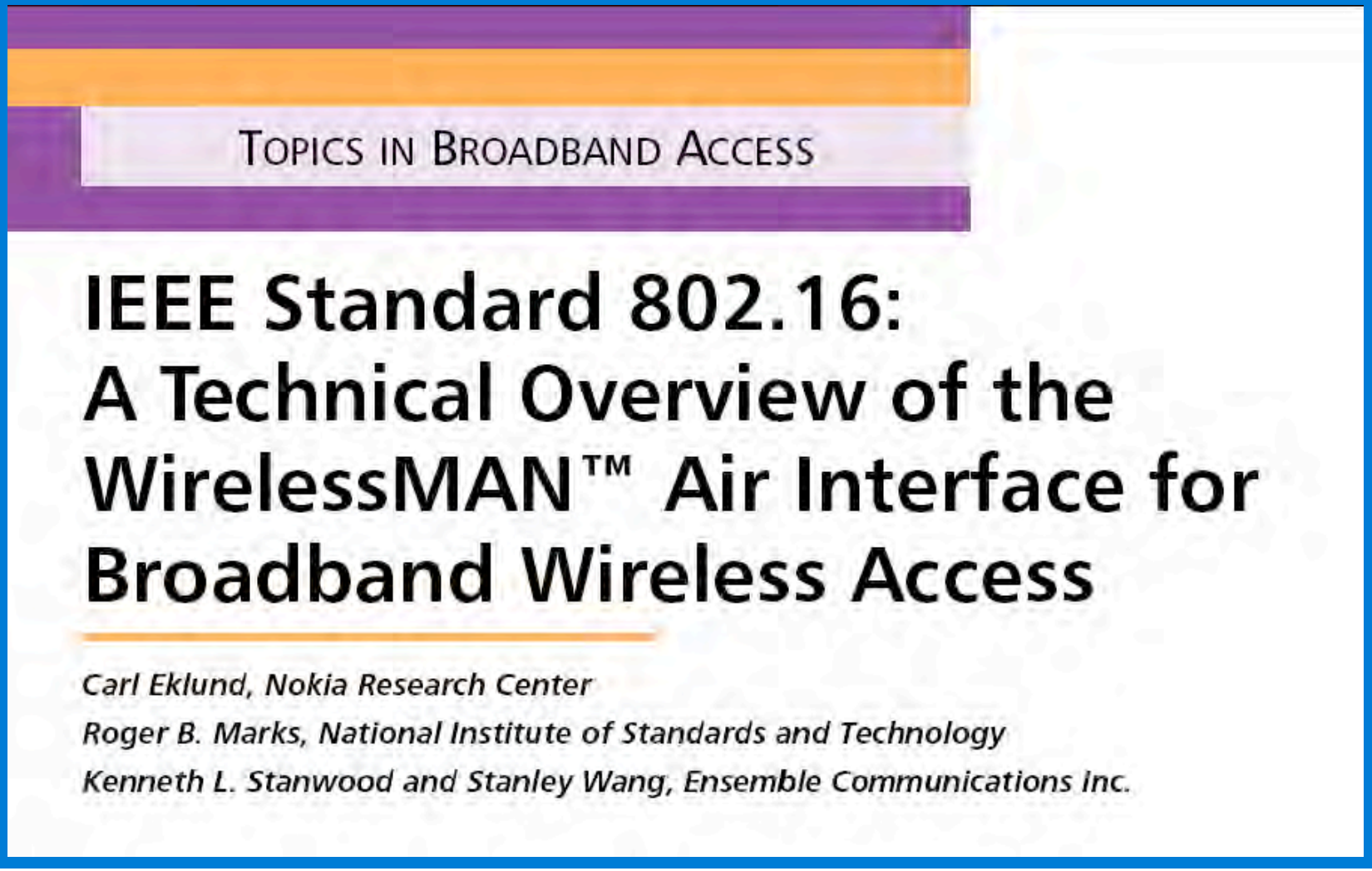
- Since May 2001, IEEE 802 standards have been available for free download, beginning six months after publication.
- See:

http://WirelessMAN.org

- You will find:
  - IEEE Std 802.16-2001, 802.16a, 802.16c
  - IEEE Std 802.16.2-2004
  - IEEE Std 802.16/Conformance 01 & 02

IEEE Standard 802.16: Tutorial

IEEE Communications Magazine, June 2002
(available on 802.16 web site)



IEEE 802.16 Resources

IEEE 802.16 Working Group on Broadband Wireless Access

info, documents, tutorials, email lists, etc:

http://WirelessMAN.org