The IEEE 802.16 WirelessMAN Standard for Broadband Wireless Metropolitan Area Networks

IEEE Computer Society
Distinguished Visitors Program
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http://WirelessMAN.org

Outline

- Wireless Metropolitan Area Networks
  - Broadband Wireless Access
- IEEE Standards and IEEE 802
- IEEE 802.16 Working Group
- IEEE 802.16 Air Interface Standard
  - IEEE 802.16: Air Interface (MAC and 10 - 66 GHz PHY)
  - P802.16a: Amendment, 2-11 GHz (finished)
    Licensed
    License-Exempt
  - WiMAX Forum coordinating interoperability testing
  - Interoperability documentation in development

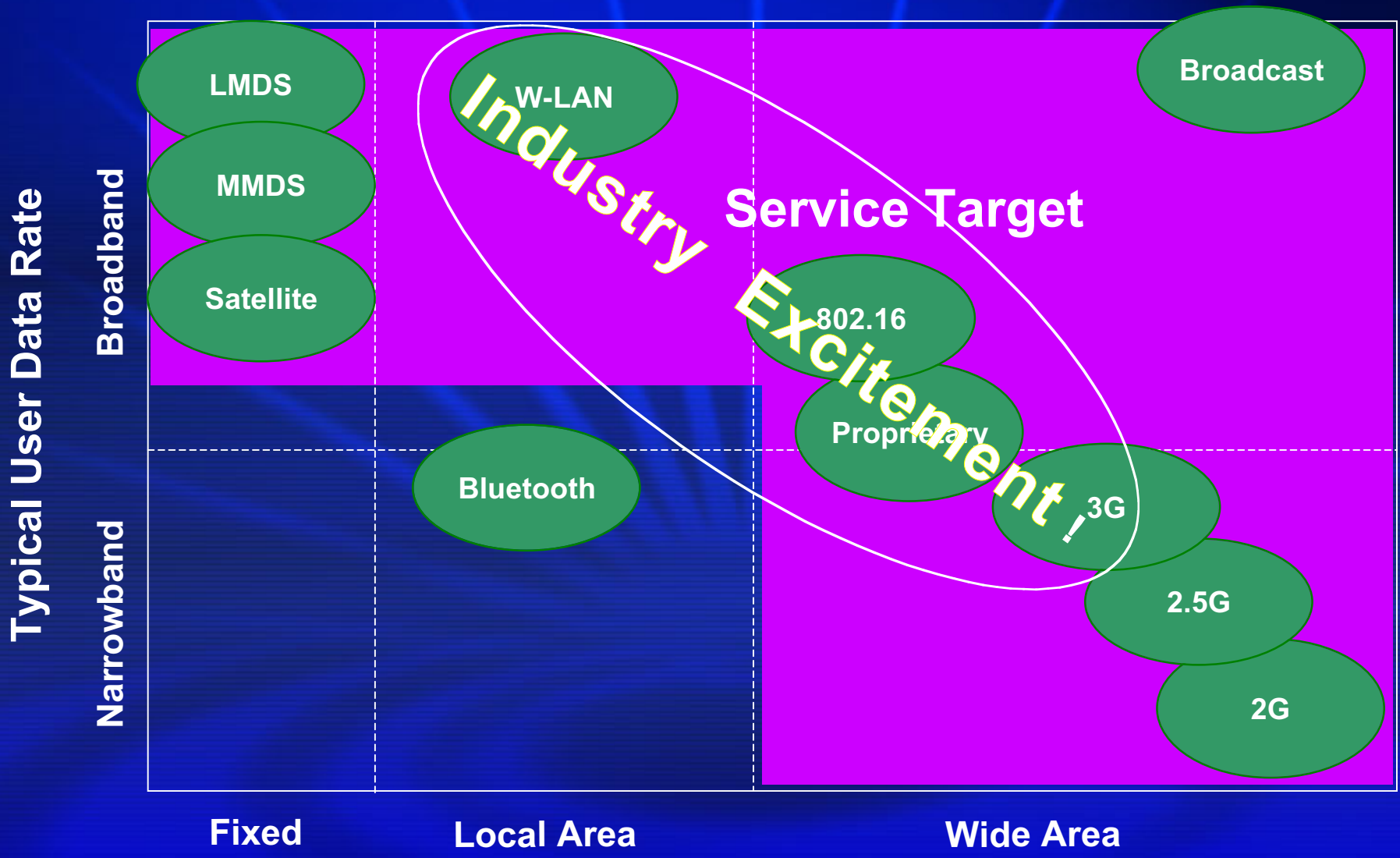
  - P802.16e: Mobile Enhancement
- IEEE Standard 802.16.2 and P802.16.2a
  - Recommended Practice on Coexistence

Broadband Access to Buildings

- The "Last Mile"
  - Fast local connection to network
- Business and residential customers demand it
  - Data
  - Voice
  - Video distribution
  - Real-time videoconferencing
  - etc.
- Network operators demand it
- High-capacity cable/fiber to every user is expensive
  - Construction costs do not follow Moore's Law

Slide by Sriram Viswanathan, Intel Capital

Wireless Access Methodologies



Viswanathan's slides from <http://ieee802.org/16/docs/03/C80216-03_02.zip>

Slide by Sriram Viswanathan, Intel Capital

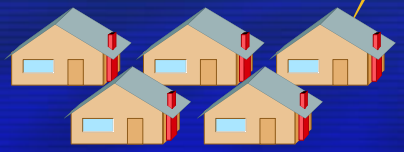
802.16a Last Mile Market Segments

- Market still early stage
- Dramatic product improvements since 1st gen
- 802.16a standard opens door for volume components
- Cooperation & promotion amongst vendors is key

T1 LEVEL SERVICE for ENTERPRISE

FRACTIONAL T1 for SMALL BUSINESS

WIRELESS BACKHAUL for Hotspots



RESIDENTIAL/SOHO BROADBAND

Slide by Sriram Viswanathan, Intel Capital

802.11 Drives Demand for 802.16a

- Wireless broadband key to fast deployment of hotspots where wireline not available
- WLANs within the home or business increase appetite for broadband access

ENTERPRISE 802.11 WLANs

802.16a

802.16a

802.16a

SMALL BUSINESS 802.11 WLANs

RESIDENTIAL AND HOME OFFICE 802.11 WLANs

802.11 HOTSPOTS: Cafes, Campuses Hotels, Airports Conventions Centers, ...

Slide by Sriram Viswanathan, Intel Capital

Today's Wireless Performance

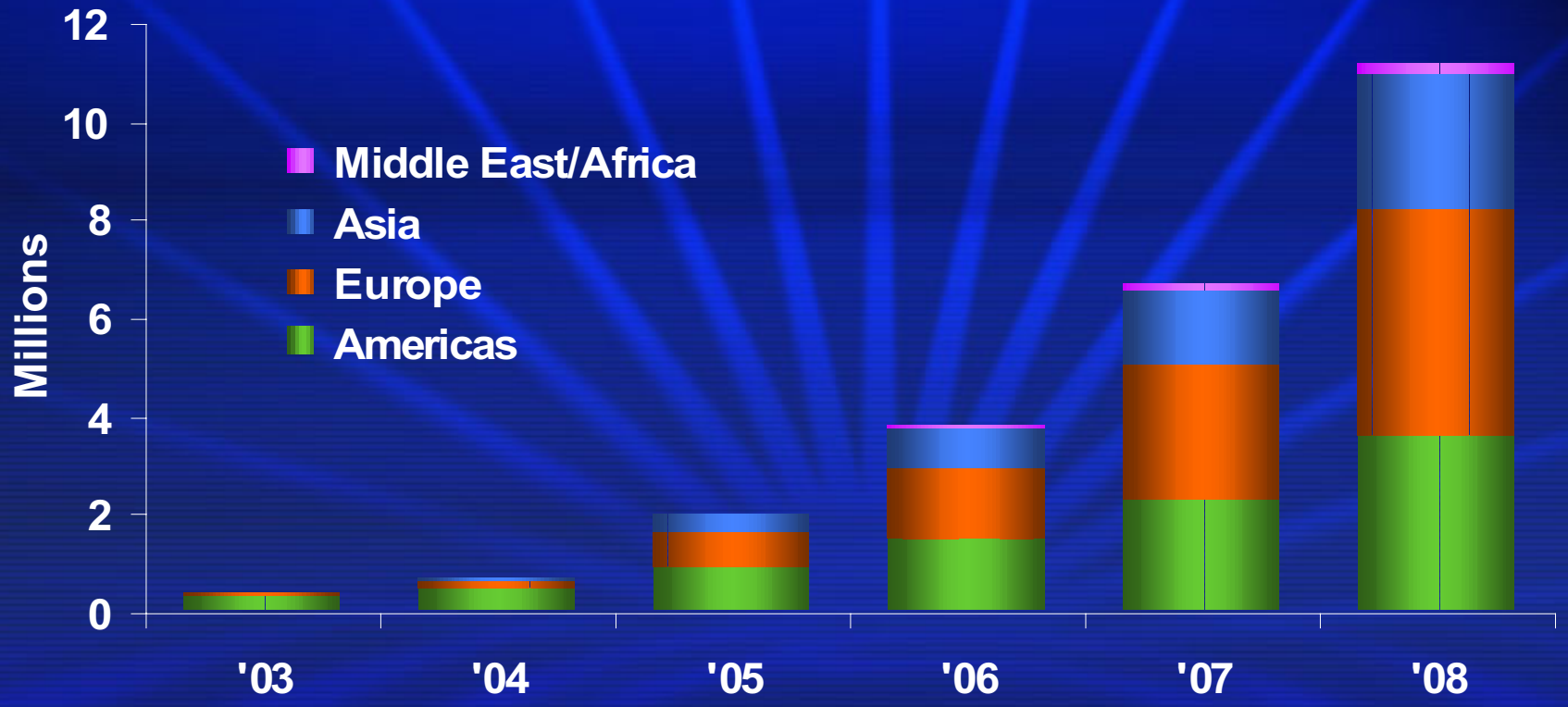
	Channel Bandwidth	Maximum Data Rate	Maximum Bps/Hz
802.11a	20 MHz	54 Mbps	~2.7 bps/Hz
802.16a	10, 20 MHz; 3.5, 7, 14 MHz; 3, 6 MHz	70 Mbps*	~5 bps/Hz
EDGE	200 kHz	384 kbps	~1.9 bps/Hz
CDMA2000	1.25 MHz	~2 Mbps	~1.6 bps/Hz

* Assuming a 14 MHz channel and ~ 5 bps/Hz

Slide by Sriram Viswanathan, Intel Capital

802.16 Wireless Access

Worldwide < 11 GHz Subscriber Base by Region (802.16a and Proprietary)



Assumptions

- 802.16a standard is adopted -> reducing customer premise equipment price
- Does not consider Hotspot subscribers

Source: Intex Management Services primary research for Intel, December '02. Based upon April '02 report, "The WW Market for Broadband Wireless Access, 2002".

Slide by Sriram Viswanathan, Intel Capital

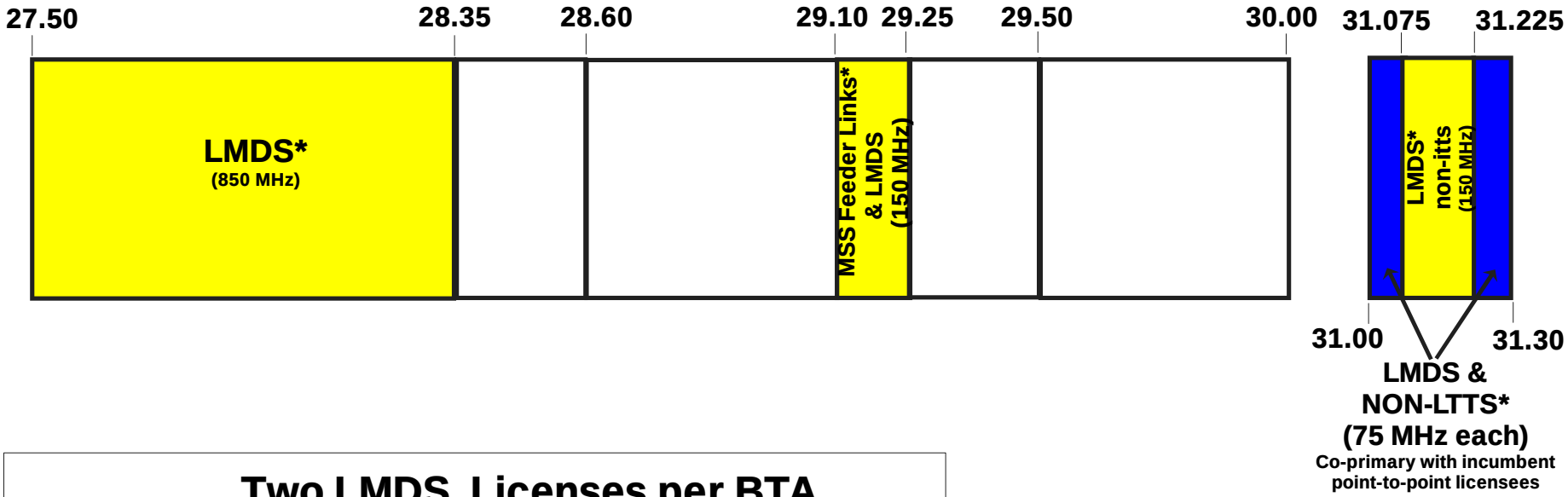
Summary

- Wireless - A spectrum of opportunities
- 802.11 is first key disruption - 802.16 is Next
- Economics don't work for Broadband data over Cellular
- Interoperability/standards critical

Intel is active in the entire ecosystem !

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

Source: Federal Communications Commission

Centimeter-Wave Bands
for Wireless MAN

International
3.5 GHz
10.5 GHz

U.S.: MMDS & ITFS
2.5-2.7 GHZ

Non-Line-of-Sight

License-Exempt Bands
for Wireless MAN

5.725-5.825 GHz
(U-NII)

2.4 GHz License-Exempt:
Wireless LANs

59-64 GHz

Properties of IEEE Standard 802.16

- Broad bandwidth
  - Up to 134 Mbit/s in 28 MHz channel (in 10-66 GHz air interface)
- 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 from 2-66 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 and space-time coding
- Extensions to mobility are coming next.
- Is this 4G?

IEEE 802.16 History

- Project Development: 1998-1999
- Meet every two months:
  - Session #1: July 1999
  - ...
  - Session #22: Hawaii, Nov 2002
  - Session #23: San Jose, Jan 2003
  - Session #24/Mar 2003: Dallas (with 802)
- Future Sessions
  - Session #25/May 2003: Dallas (with 802 wireless)
  - Session #26/July 2003: San Francisco (with 802)

IEEE 802.16 Projects: 10-66 GHz

- Air Interface (MAC and PHY)
  - IEEE Standard 802.16
    - Completed in October 2001
    - Published in April 2002; Now free
  - Followup interoperability projects (unusual in 802)
    - 802.16c (Profiles): published in Jan 2003
    - 1802.16.1 (PICS): approval expected Jun 2003
    - 1802.16.2: (Test Suite Structure & Purposes)
      - Initiated on Dec 2002; WG Ballot underway
    - 1802.16.3: (Radio Conformance Tests)
      - Initiated May 2003
- Coexistence
  - IEEE Standard 802.16.2 (Recommended Practice)
    - Published in September 2001; Now free

IEEE 802.16 Projects: 2-11 GHz

- Air Interface
  - new PHY based on 802.16 MAC
  - IEEE Standard 802.16a
    - Completed in November 2002
    - Approved 29 January 2003; published 1 April 2003
  - Followup interoperability projects
    - P802.16d: first meeting Jan 2003; in WG Ballot
  - Followup air interface project: *mobility*
    - P802.16e: first meeting Jan 2003; Working Doc in review
- Coexistence
  - IEEE Standard 802.16.2a (Recommended Practice)
    - In IEEE ballot
    - Completion expected in March 2003

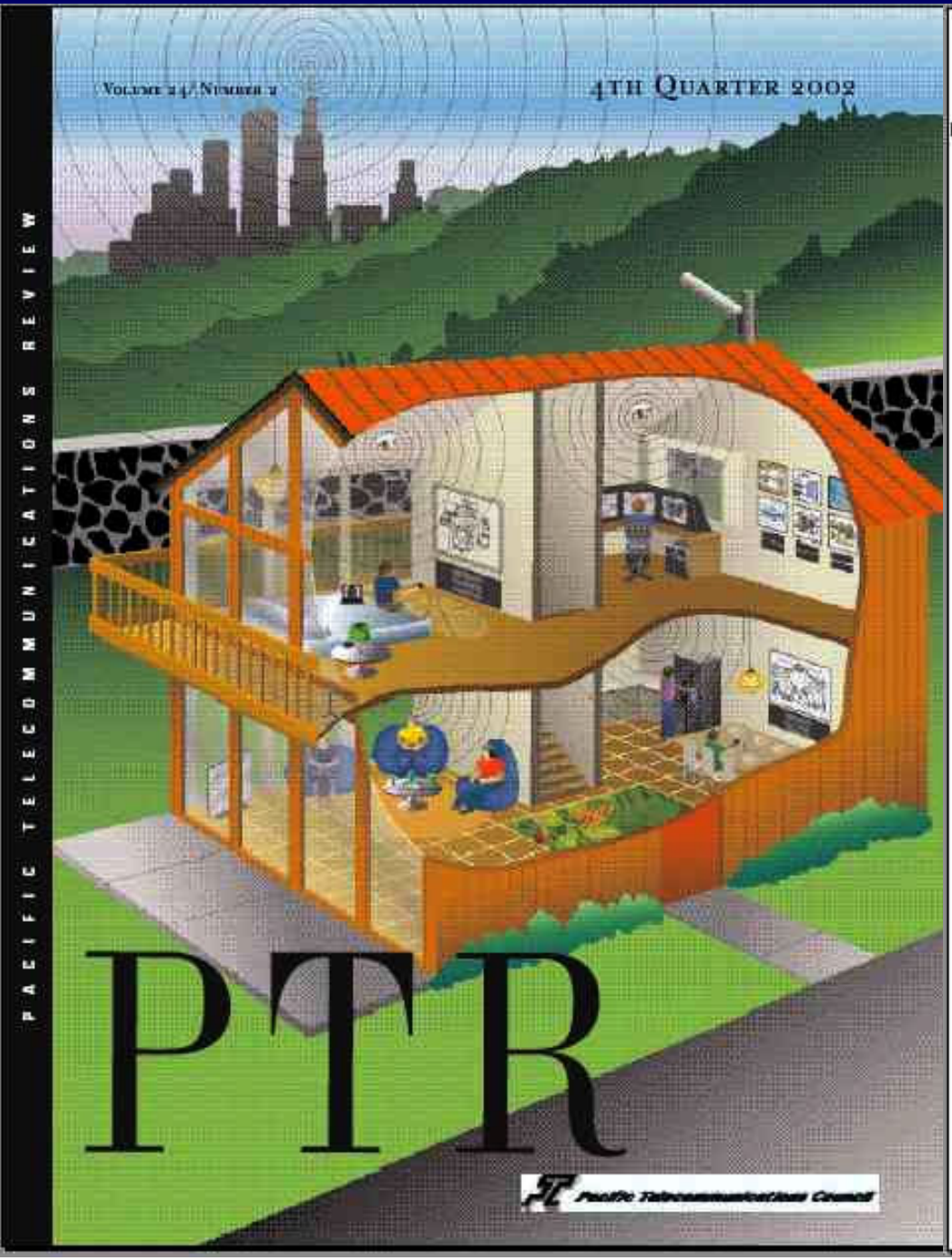
The World Wants Access

- All over the world:
  - Users want access to networks
  - Network operators want access to customers
- Broadband Wireless Access flourishes where:
  - Many users are dissatisfied with their access
  - Network operators need to reach customers

The World Wants Standards

- Standards are at the forefront of world trade
  - World Trade Organization rules accelerating process
  - e.g. Chinese-language MediaView magazine is instituting a monthly column on standards
- In all fields of telecommunications, the world wants standards.
- Broadband Wireless Access is not isolated from this trend.
- Some say that stationary systems don't require standards. But consider:
  - Ethernet
  - DOCSIS

Pacific Telecommunications Council



Contents

The World Wants 802.16 WirelessMAN™ Standards

- Have had attendees from 21 countries (Australia, Canada, China, Finland, France, Germany, Greece, Israel, Italy, Japan, Korea, Netherlands, Norway, Pakistan, Russia, Singapore, Spain, Sweden, Taiwan, UK, USA)
- 2002 meetings in:
  - Finland
  - Korea
  - Canada twice (Vancouver and Calgary)
  - U.S. twice (Hawaii and St. Louis)
- Coordinated European efforts in ETSI

802.16 and ETSI

- Over 50 liaison letters between 802.16 and ETSI
  - (European Telecom Standards Institute)
- ETSI HIPERACCESS
  - Above 11 GHz
  - ETSI began first, but IEEE finished first
  - 802.16 has encouraged harmonization
- ETSI HIPERMAN
  - Below 11 GHz
  - IEEE began first
  - Healthy cooperation
  - Harmonized with 802.16a OFDM

BWA/802.16 Interest within 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" (Prof. Liu Yuan An, Chair)

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.***
- **Principles:**
  - **Support IEEE 802.16**
    - **2-66 GHz**
  - **Propose access profiles for the IEEE 802.16 standard**
  - **Guarantee known interoperability level**
  - **Promote IEEE 802.16 standard to achieve global acceptance**
  - **Open for everyone to participate**
- **Developing & submitting baseline test specs**

Today's *Washington Post*

"Technology companies including Intel, Fujitsu Microelectronics America and Nokia... have joined a new nonprofit corporation to promote a new wireless Internet broadcasting standard called ***802.16***... said the technology could be used as a cheaper way to provide high-speed Internet access to customers than currently available fiber-optic or phone-line networks."

Washington Post, 9 April 2003

Today's *Wall St. Journal*

"A new wireless technology that could one day be used to deliver high-speed Internet access to homes and businesses received the support of several high-profile technology companies… to help certify equipment based on a new wireless technical standard that could help greatly expand the availability of high-speed Internet access… **802.16** technology has a range of as much as 31 miles… '**We believe it's the next big thing in the wireless broadband arena**,' said Margaret LaBrecque, president of the WiMAX group and an Intel manager.

Wall St. Journal, 9 April 2003

EE Times Magazine

"At the Wireless Communications Assoc. conference in San Jose... Sriram Viswanathan, director of Intel Capital's Broadband and Wireless Networking Investments group, declared during his keynote that ***'802.11 [Wi-Fi] is the first key disruption. 802.16 is the next***.'"

"IEEE 802.16 spec could disrupt wireless landscape," *Electronic Engineering Times*, 30 January 2003

IEEE 802

The LAN/MAN Standards Committee

Wired:

- 802.3 (Ethernet)
- 802.17 (Resilient Packet Ring)

Wireless:

- 802.11: Wireless LAN
  - Local Area Networks
- 802.15: Wireless PAN
  - Personal Area Networks {inc. Bluetooth}
- 802.16: WirelessMAN™
  - Metropolitan Area Networks
- 802.20:
  - Vehicular Mobility (new)

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

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

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- Project Development: 1998-1999
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  - Session #24: Dallas, TX, USA, Mar 2003
- Future Sessions
  - Session #25/May 2003: Dallas, TX, USA
    - with 802 wireless groups
  - Session #26/July 2003: San Francisco (with 802)

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

IEEE Standard 802.16: The WirelessMAN-SC™ Air Interface

Published: 8 April 2002

IEEE Std 802.16-2001®

IEEE Standard for
Local and metropolitan area networks

Part 16: Air Interface for Fixed Broadband Wireless Access Systems

Sponsor

LAN/MAN Standards Committee
of the
IEEE Computer Society

and the
IEEE Microwave Theory and Techniques Society

Approved 6 December 2001

IEEE-SA Standards Board

Abstract: This standard specifies the air interface of fixed (stationary) point-to-multipoint broadband wireless access systems providing multiple services. The medium access control layer is capable of supporting multiple physical layer specifications optimized for the frequency bands of application. The standard includes a particular physical layer specification applicable to systems operating between 10 and 66 GHz.

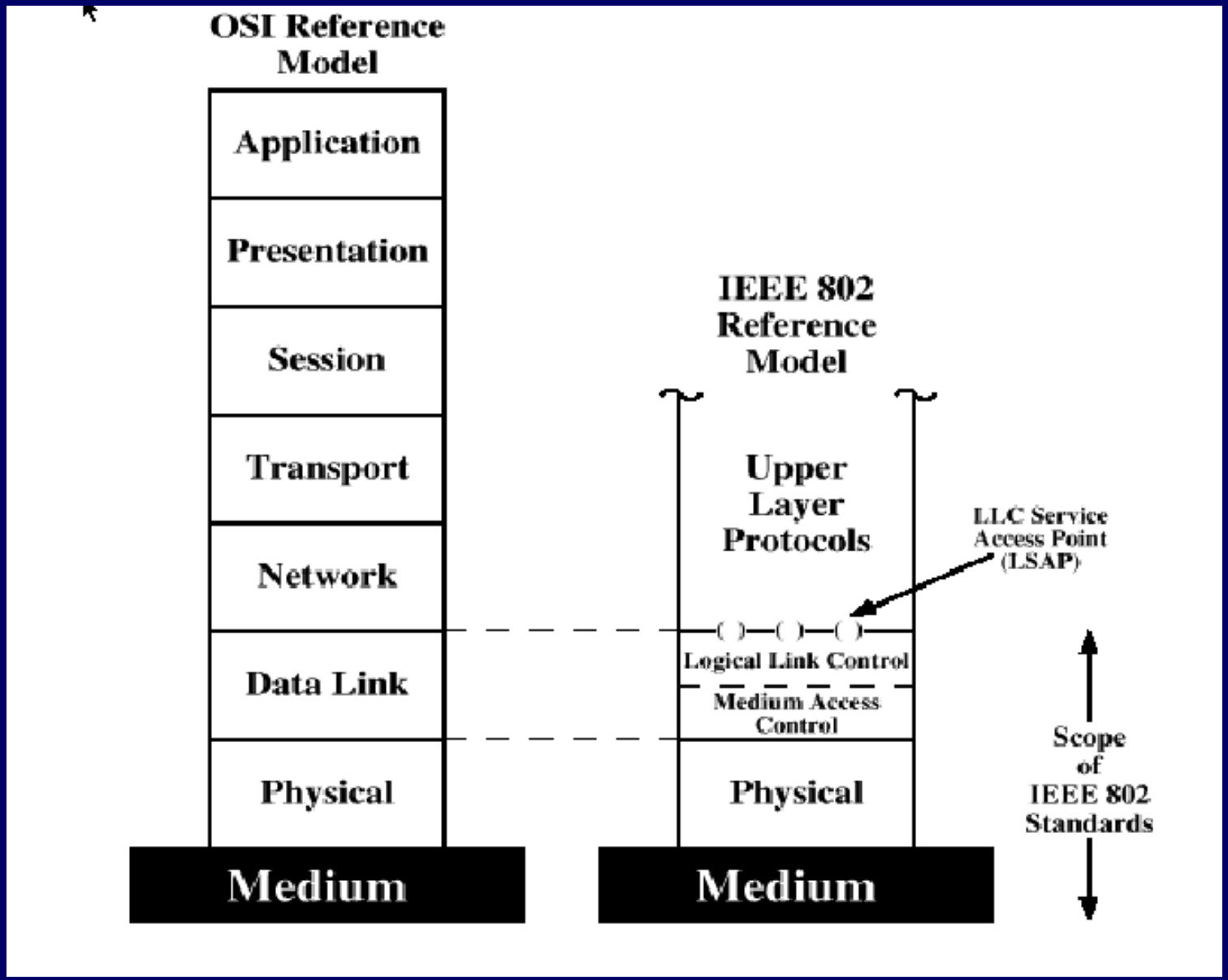
Keywords: fixed broadband wireless access network, metropolitan area network, microwave, millimeter wave, WirelessMAN™ standards

Point-to-Multipoint Wireless MAN: not a LAN

- Base Station (BS) connected to public networks
- BS serves Subscriber Stations (SSs)
  - SS typically serves a building (business or residence)
  - provide SS with first-mile access to public networks

- Compared to a Wireless LAN:
  - Multimedia QoS, not only contention-based
  - Many more users
  - Much higher data rates
  - Much longer distances

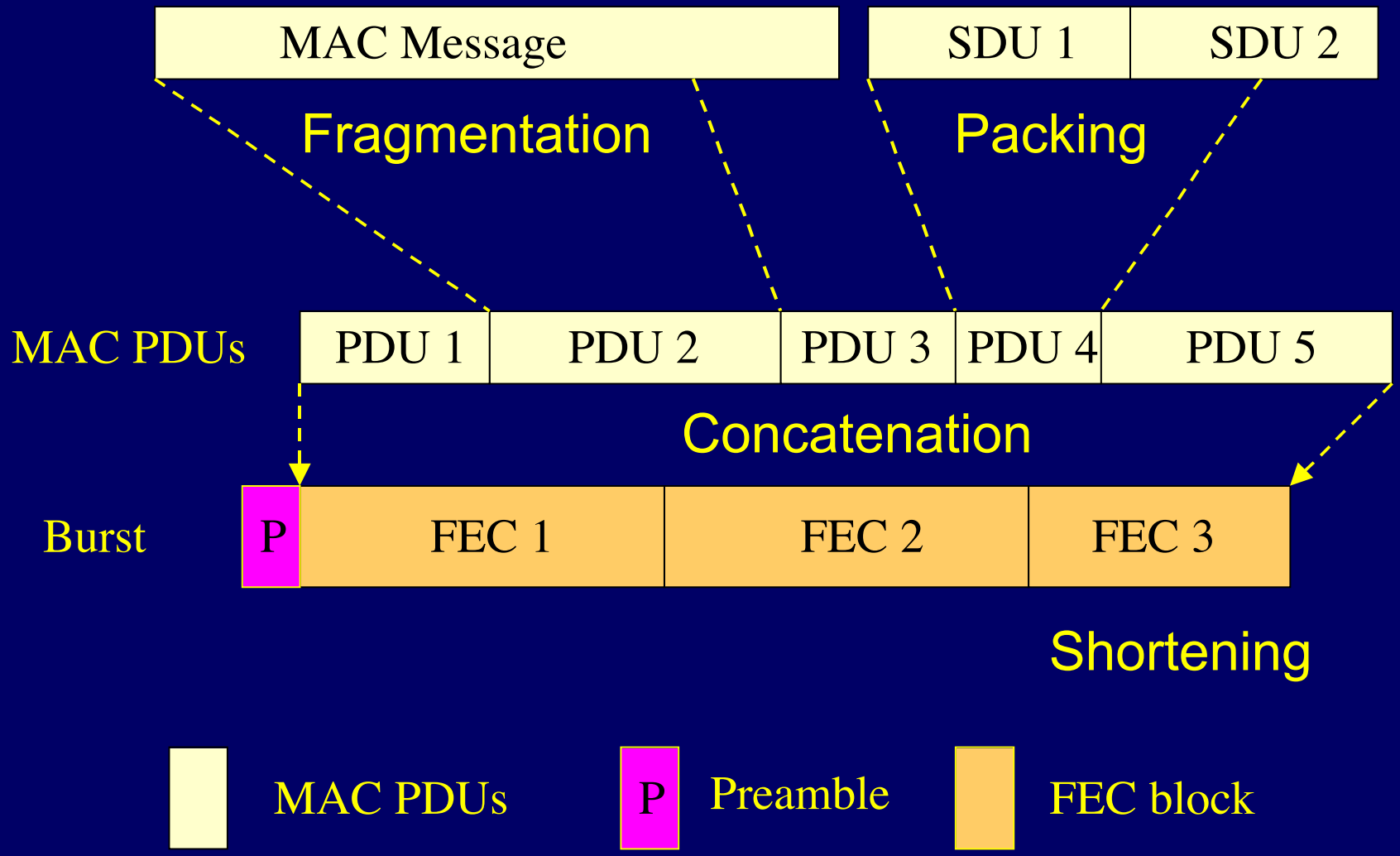
Scope of 802 Standards



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

MAC PDU Transmission

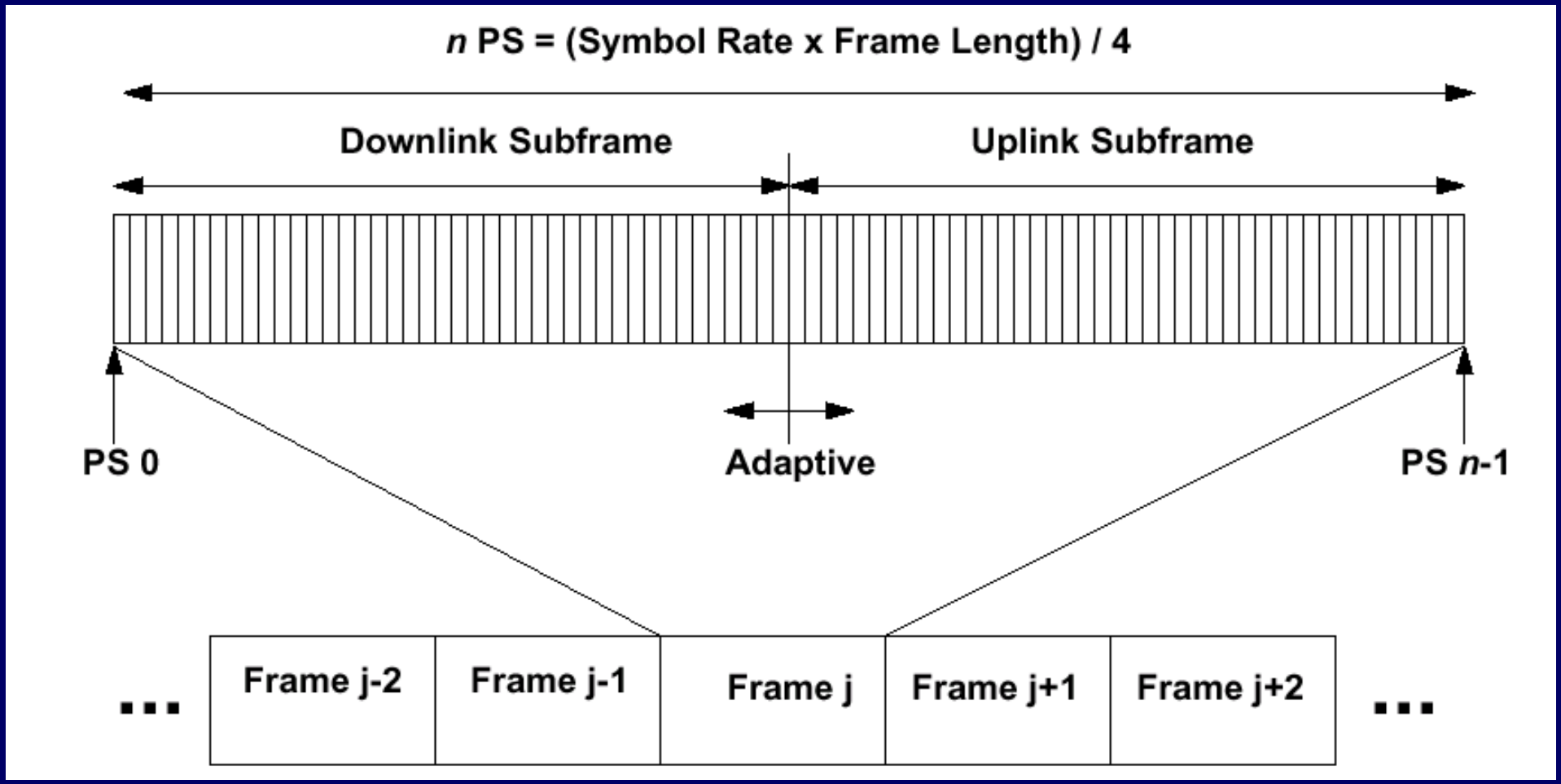


Multiple Access and Duplexing

- 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)

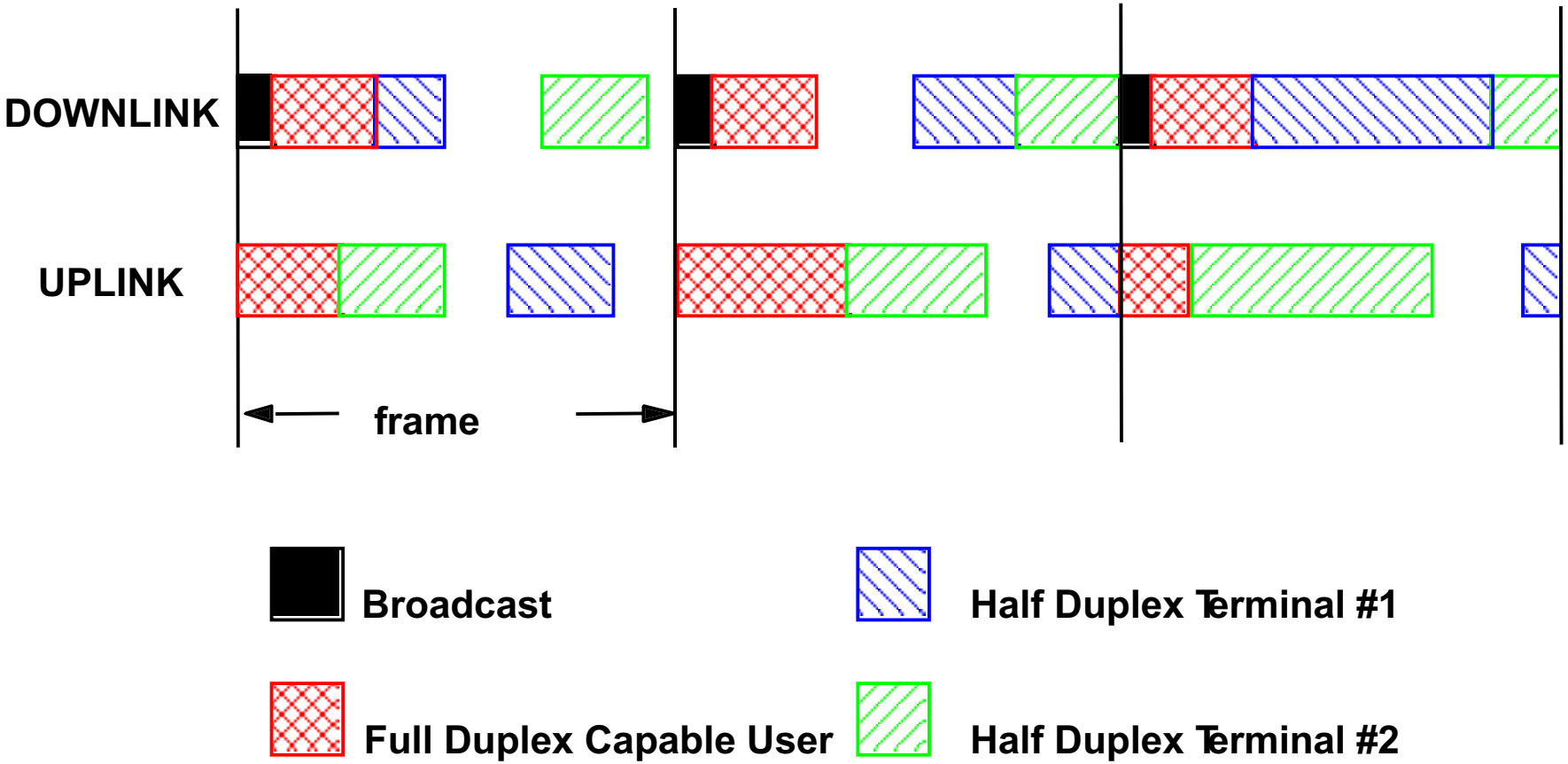
TDD Frame (10-66 GHz)



Frame duration: 1 ms

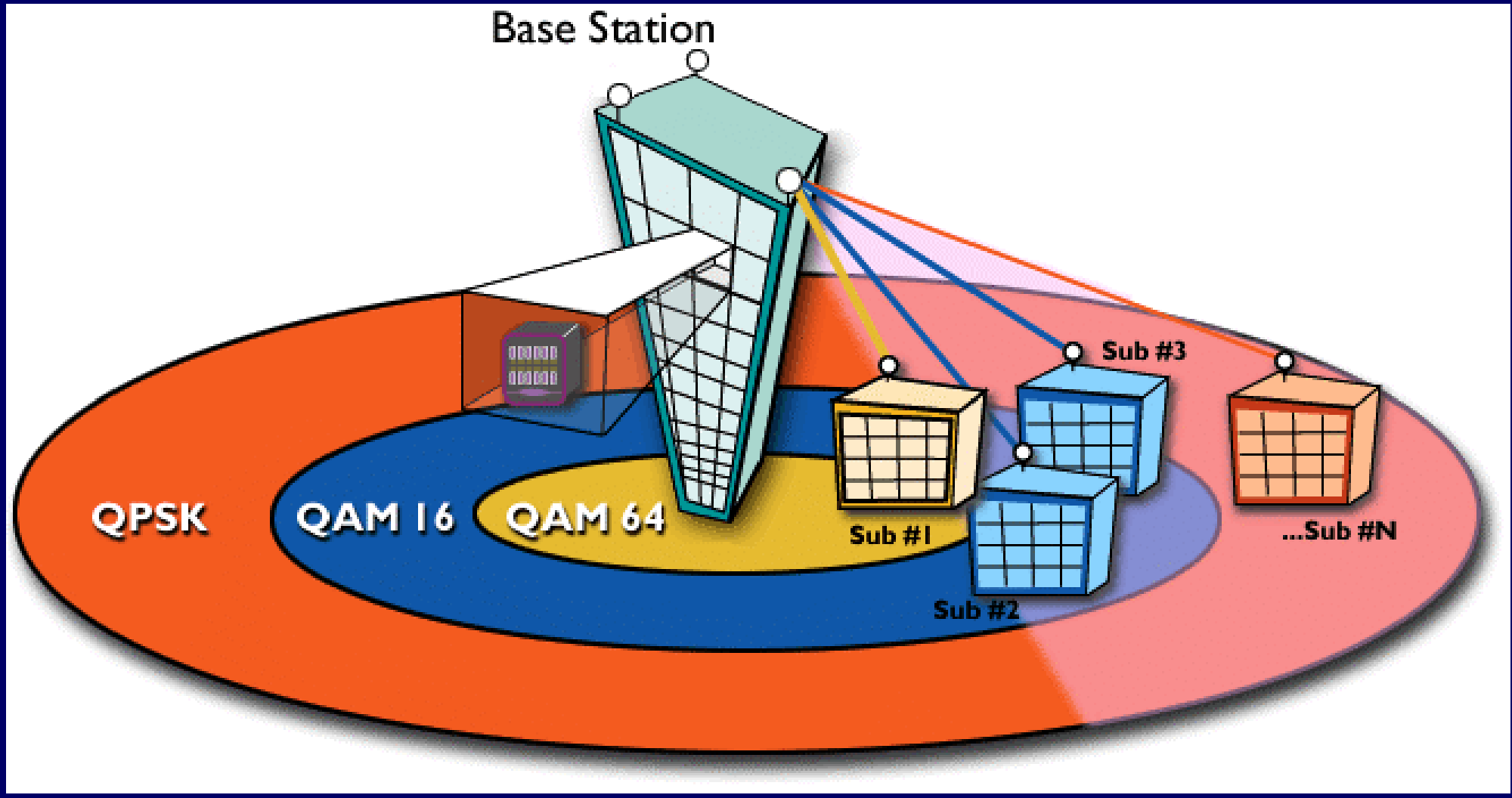
Physical Slot (PS) = 4 symbols

Burst FDD Framing



Allows scheduling flexibility

Adaptive PHY

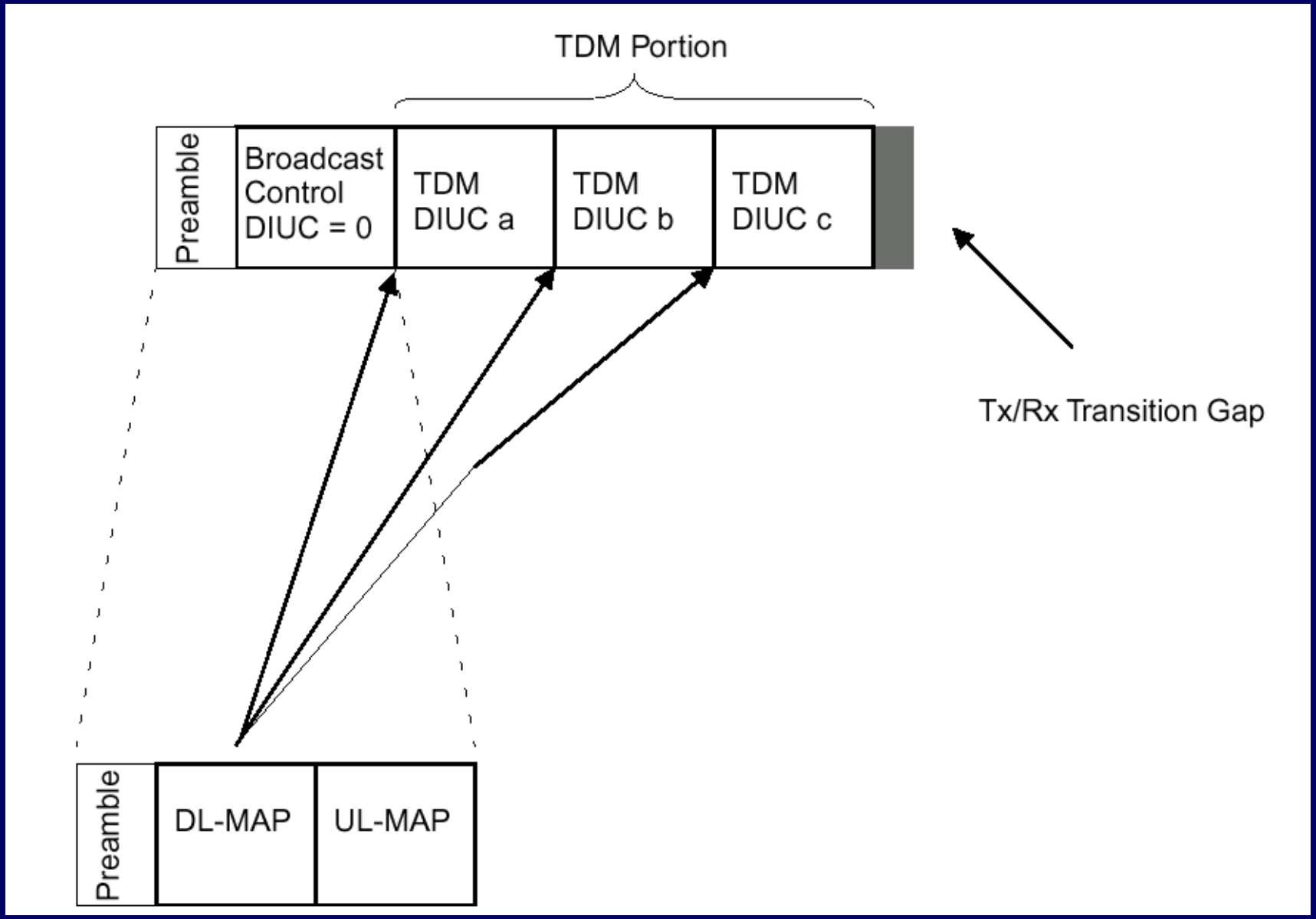


(burst-by-burst adaptivity not shown)

Adaptive Burst Profiles

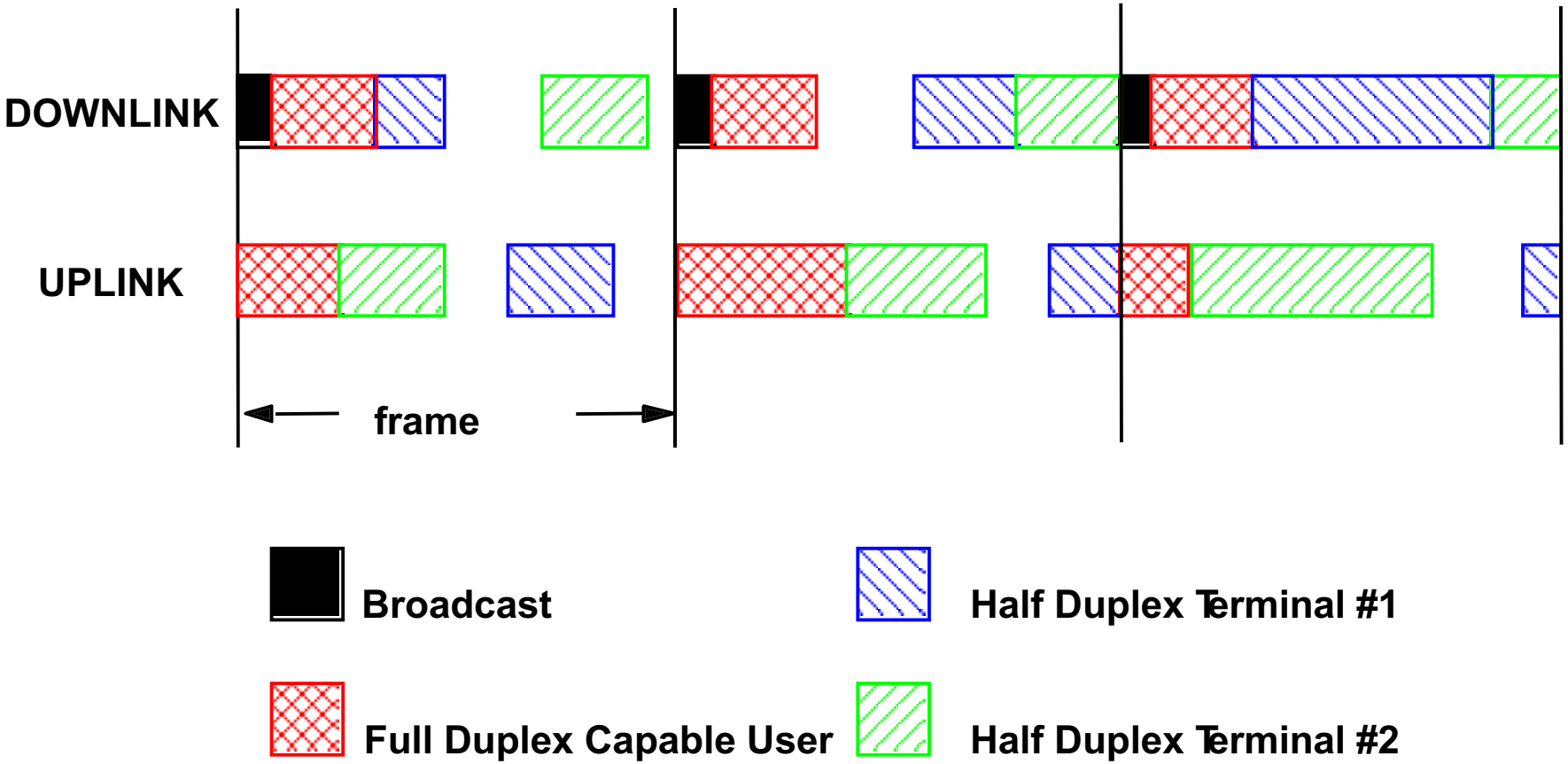
- Burst profile
  - Modulation and FEC
- Dynamically assigned according to link conditions
  - Burst by burst, per subscriber station
  - Trade-off capacity vs. robustness in *real time*
- Roughly doubled capacity for the same cell area
- Burst profile for downlink broadcast channel is well-known and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

TDD Downlink Subframe



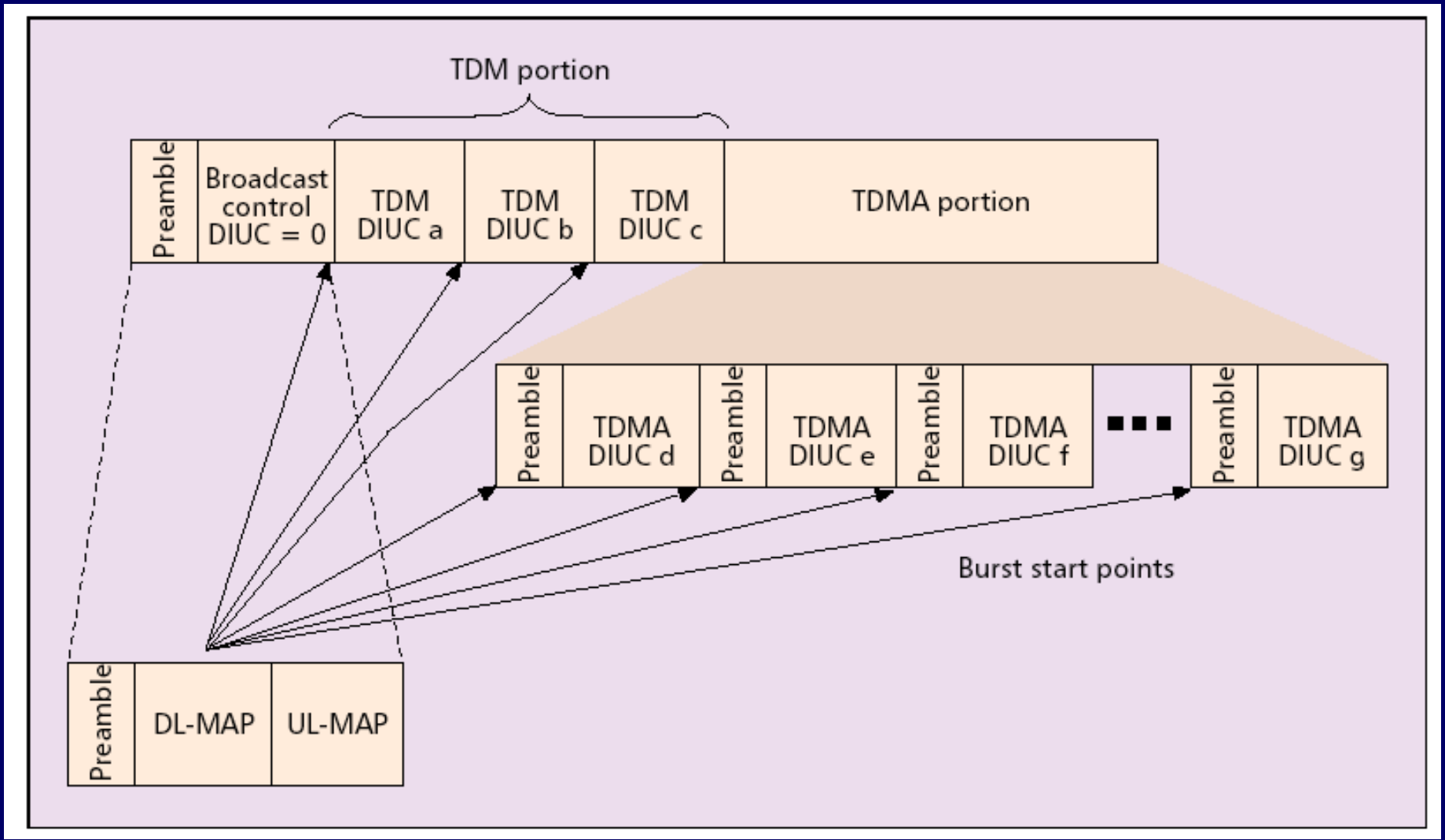
DIUC: Downlink Interval Usage Code

Burst FDD Framing



Allows scheduling flexibility

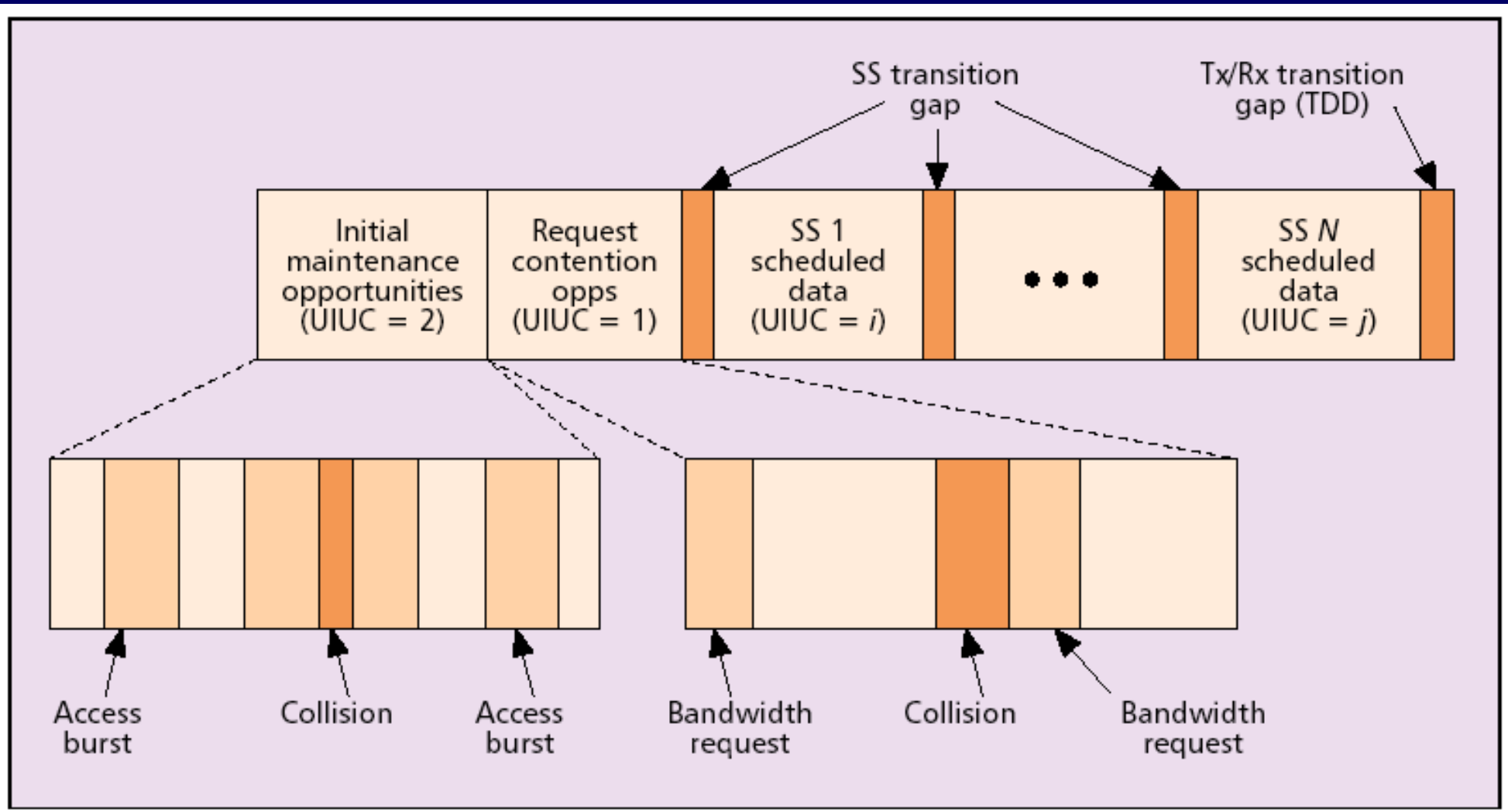
FDD Downlink Subframe



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)



Interoperability Testing for WirelessMAN-SC™ (10-66 GHz)

- IEEE P802.16c (Detailed System Profiles)
  - Published 15 January 2003
  - specifies particular combinations of options
  - used as basis of compliance and interoperability testing
    - MAC Profiles: ATM and Packet
    - PHY Profiles: 25 & 28 MHz; TDD & FDD
- Test Protocols
  - PICS (P1802.16.1 in ballot)
  - Test Suite Structure & Test Purposes (started)

Amendment Project
IEEE P802.16a

Medium Access Control Modifications and Additional Physical Layer Specifications for 2-11 GHz

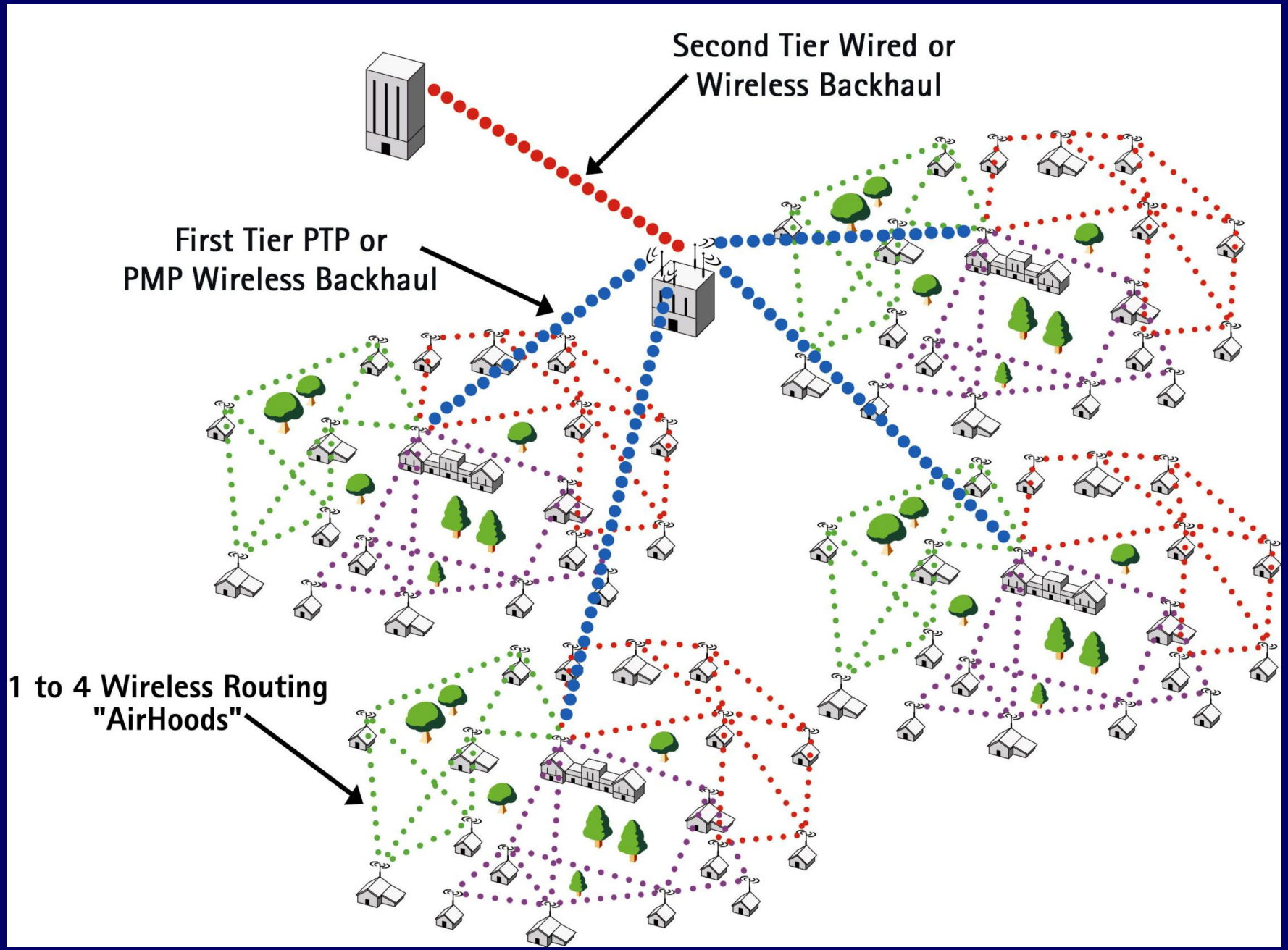
802.16a PHY Alternatives: Different Applications, Bandplans, and Regulatory Environments

- OFDM (WirelessMAN-OFDM Air Interface)
  - 256-point FFT with TDMA (TDD/FDD)
- OFDMA (WirelessMAN-OFDMA Air Interface)
  - 2048-point FFT with OFDMA (TDD/FDD)
- Single-Carrier (WirelessMAN-SCa Air Interface)
  - TDMA (TDD/FDD)
  - BPSK, QPSK, 4-QAM, 16-QAM, 64-QAM, 256-QAM
  - Most vendors will use Frequency-Domain Equalization

Key 802.16a MAC Features

- OFDM/OFDMA Support
- ARQ
- Dynamic Frequency Selection (DFS)
  - license-exempt
- Adaptive Antenna System (AAS) support
- Mesh Mode
  - Optional topology
  - Subscriber-to-Subscriber communications
  - Complex topology and messaging, but:
    - addresses license-exempt interference
    - scales well
    - alternative approach to non-line-of-sight

Mesh-based WirelessMAN



Source: Nokia Networks

What's Next ?

- Compliance documentation
- Mobility
- Potential new 802 project on common 802 handoff framework

802.16 Summary

- The IEEE 802.16 WirelessMAN Air Interface, addresses worldwide needs
- The 802.16 Air Interface provides great opportunities for vendor differentiation, at both the base station and subscriber station, without compromising interoperability.
- Interoperability tests are coming.
- Mobility is the next major enhancement.

Free IEEE 802 Standards

- Since May 2001, IEEE 802 standards have been available for free download.
- See:

http://WirelessMAN.org

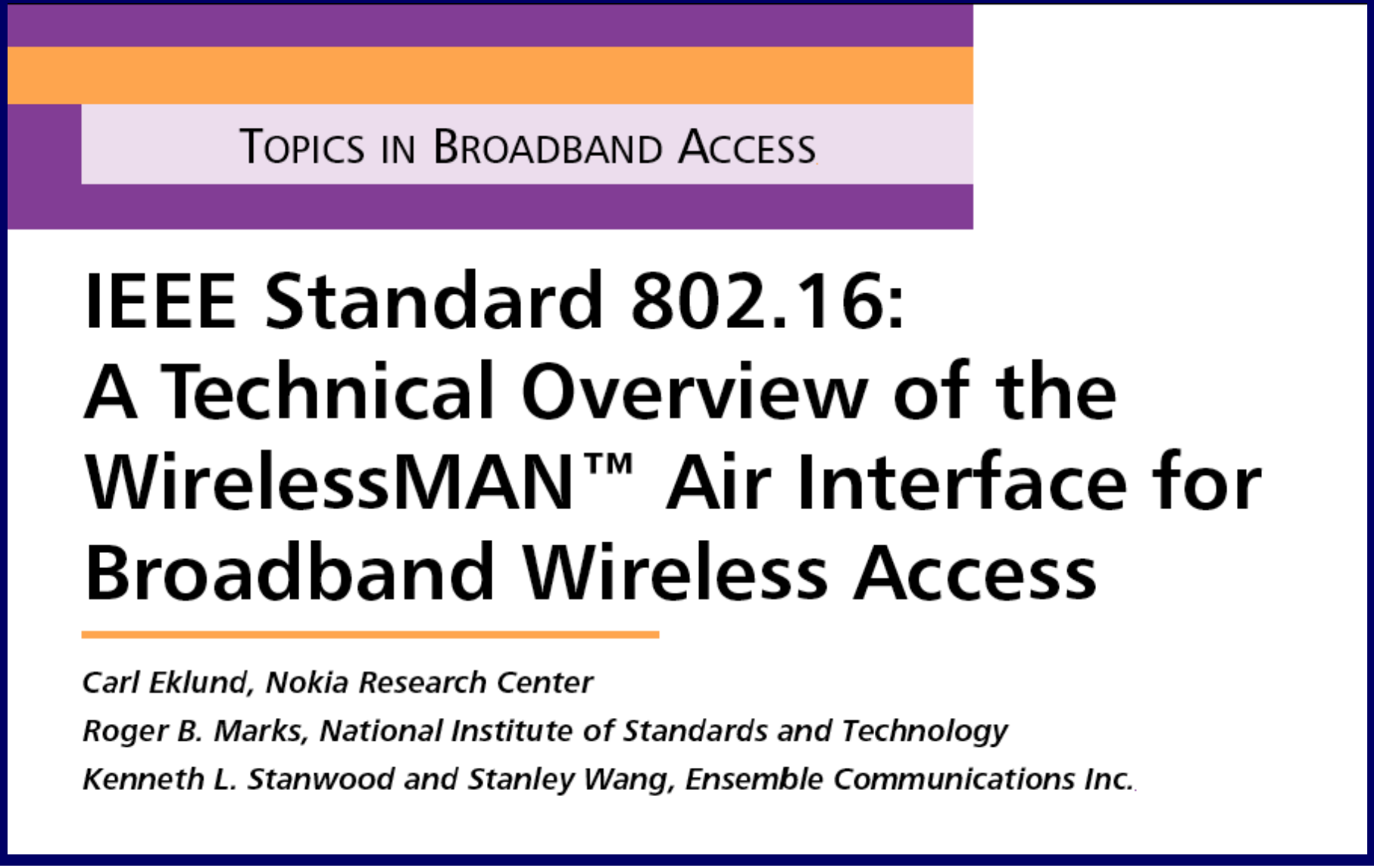
beginning six months after publication

- IEEE Std 802.16.2 is now free
- IEEE Std 802.16 is now free

IEEE Standard 802.16: Tutorial

***IEEE Communications Magazine*, June 2002**

(available on 802.16 web site)



Conclusion

IEEE 802.16 WirelessMAN standards are:

- **open in development and application**
- **addressed at worldwide markets**
- **engineered as optimized technical solutions**
- **significantly complete**
  - **With test spec documents in development**
- **being enhanced for expanded opportunities**

IEEE 802.16 Resources

IEEE 802.16 Working Group on Broadband Wireless Access

info, documents, tutorials, email lists, etc:

http://WirelessMAN.org