

IEEE 802.16 Working Group on Broadband Wireless Access

<http://WirelessMAN.org>



The IEEE 802.16 WirelessMAN Standard for Broadband Wireless Metropolitan Area Networks

IEEE Computer Society

Distinguished Visitors Program

Oakland/East Bay Chapter: 24 July 2003

Roger B. Marks

(US) National Institute of Standards and Technology

Boulder, Colorado, USA

Chair, IEEE 802.16 Working Group

<http://WirelessMAN.org>

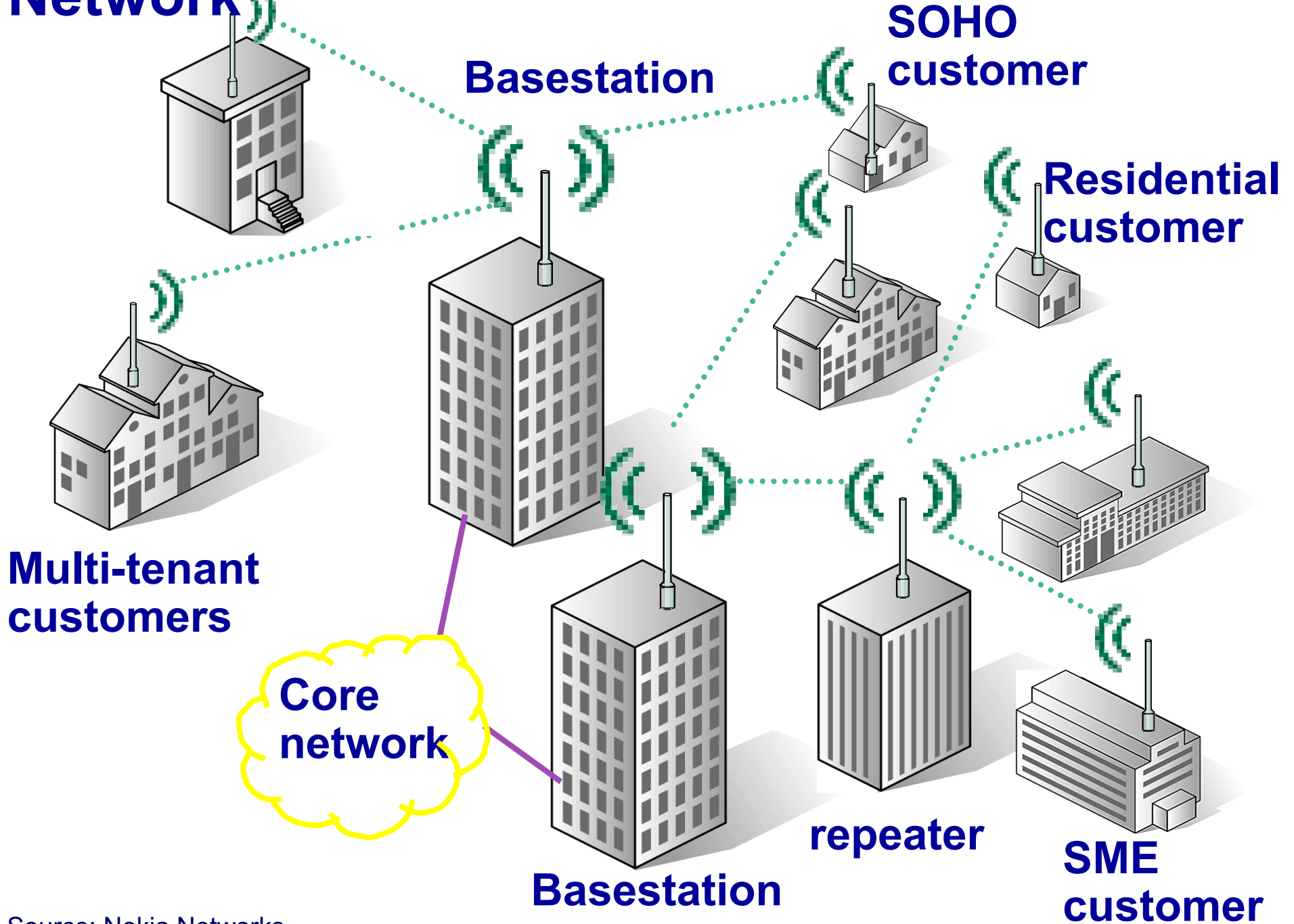
Outline

- 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

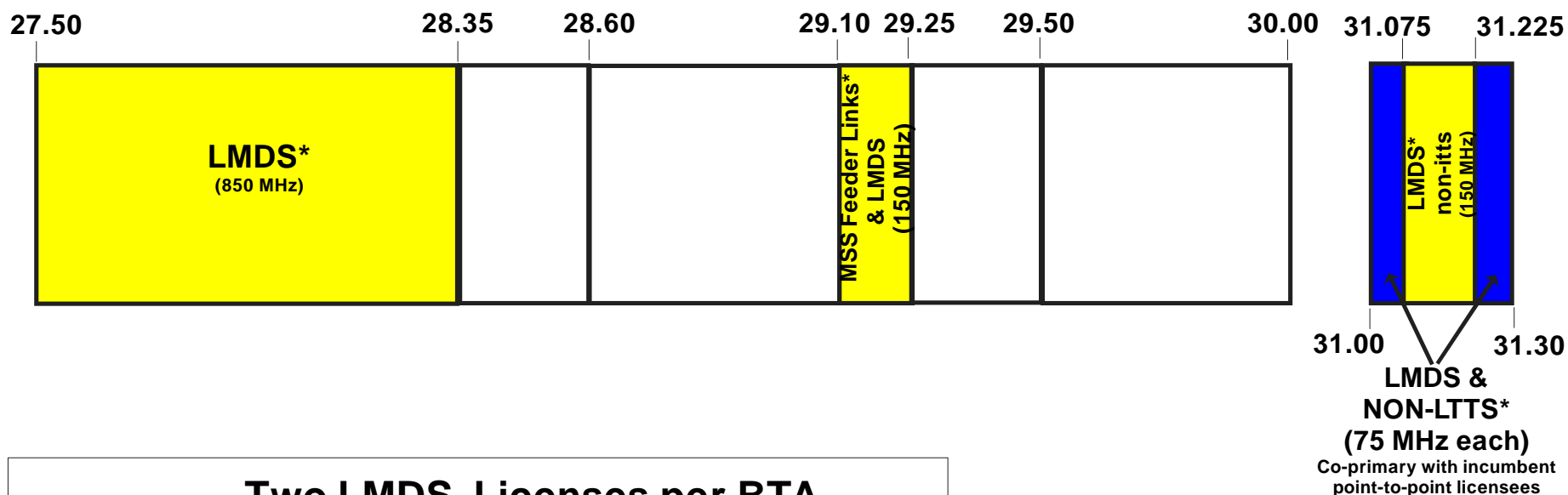
- **The “Last Mile”**
 - Fast local connection to network
- **Business and residential customers demand it**
 - Data
 - Voice
 - Video distribution
 - Real-time videoconferencing
 - etc.
- **Network operators demand it**
- **High-capacity cable/fiber to every user is expensive**
 - Construction costs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

WirelessMAN: Wireless Metropolitan Area Network



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

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

9

- **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 use of spectrum**
- **Comprehensive, modern, and extensible security**
- **Supports multiple frequency allocations from 2-66 GHz**
 - OFDM 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/Ft. Worth (with 802)**
 - **Session #25/May 2003: Dallas/Ft. Worth (802 wireless)**
 - **Session #26/July 2003: San Francisco (with 802)**
- **Future Sessions**
 - **Session #27/Sept 2003: Denver**
 - **Session #27/Nov 2003: Albuquerque**

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

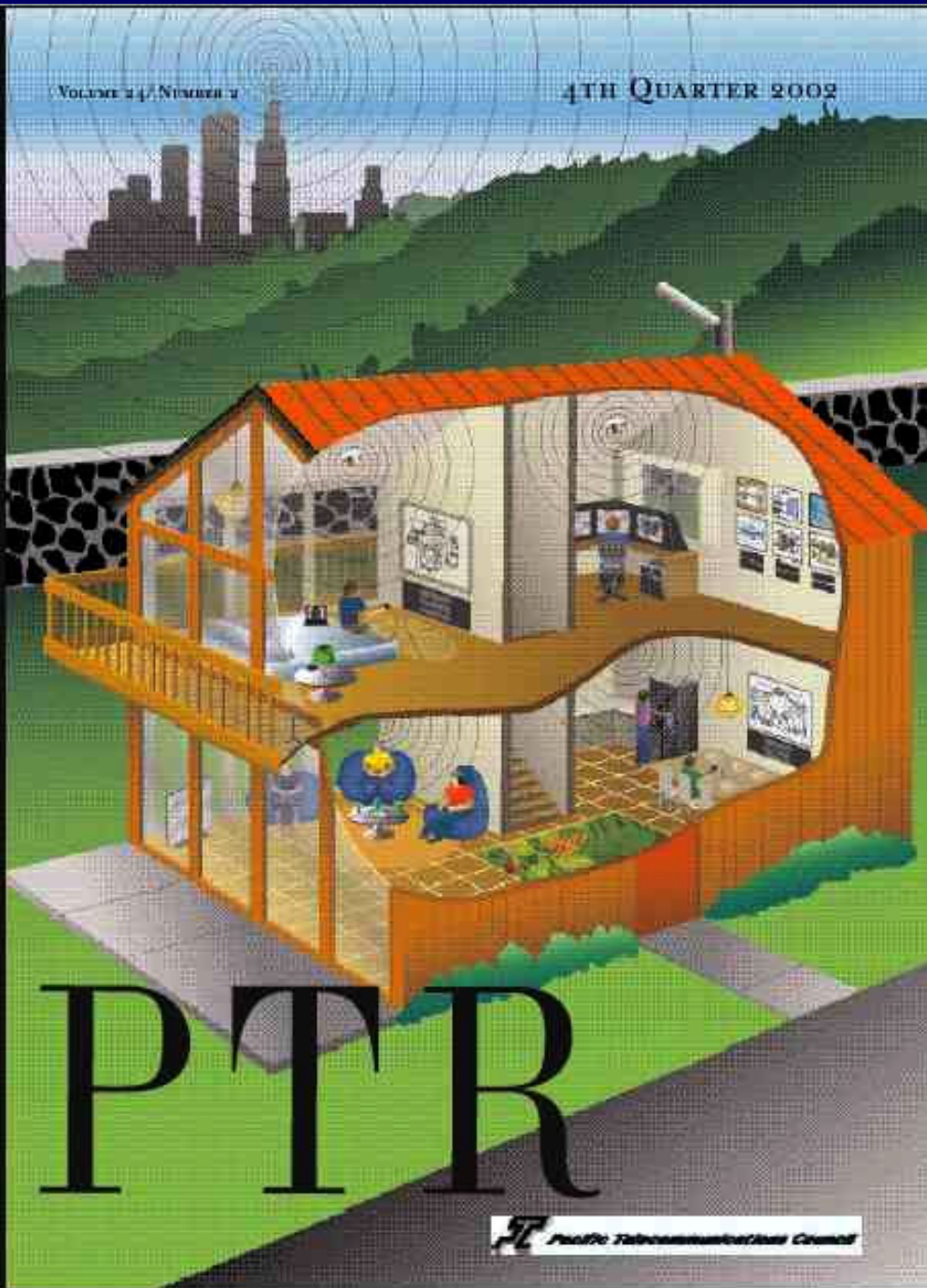
The World Wants Standards

- 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

13

PACIFIC TELECOMMUNICATIONS REVIEW



CONTENTS

5	PUBLISHER'S FOREWORD Hoyt Zia
7	GUEST EDITOR'S INTRODUCTION Richard C. Kirby
8	EDITOR'S INTRODUCTION Richard Nickelson
9	STATUS AND TREND OF INFORMATION SECURITY FOR THE NEXT GENERATION NETWORK Dong-Il Seo, Ph.D., Sung Won Sohn, Ph.D., Hyun Sook Jo, Ph.D. and Sang Ho Lee, Ph.D. <i>As the new all-digital global telecommunication network rapidly evolves, security becomes the major concern.</i>
19	EVOLVING ROLES AND TECHNOLOGIES OF SATELLITE COMMUNICATIONS Yasuhiko Ito, Takeshi Mizutani and Hideyuki Shikanoaga <i>Next generation satellite services are of critical importance to the industry, following the assertion that high quality services can be economically provided in rural areas and mobile environments only by satellite.</i>
30	ADVANCES IN WIRELESS NETWORKING STANDARDS Roger B. Marks, Ph.D. <i>The IEEE 802 family of wireless networking standards is arguably the most important current development for the future of telecommunications.</i>
38	STANDARDIZATION – 2003 AND BEYOND Houlin Zhao <i>ITU, the most important global body dealing with standardization, is being driven by the convergence of services and of networks to help shape the face of the next generation of networks.</i>
45	RADIOCOMMUNICATIONS – MOVING AHEAD TO SERVE MANKIND Robert Jones <i>The current rapid evolution of the network towards wireless connectivity places the important work of the ITU Radiocommunication Sector in the spotlight.</i>
50	BOOK REVIEW
51	A NEW WORLD IN THE MAKING - WITH OPPORTUNITIES FOR ALL Karl Heinz Rosenbrock, Dip. Ing. <i>Standards play a major role in the Next Generation Network, especially for wireless services, which have a long history of standardization by ETSI.</i>

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 standar
 - Propose and promote access profiles for IEEE 802.16 standard
 - Certify interoperability levels both in network and the cell
 - Achieve global acceptance
 - Promote use of broadband wireless access overall
- **Developing & submitting baseline test specs**

WiMAX Members

- **Airspan Networks**
 - **Alvarion Ltd.**
 - **Aperto Networks**
 - **Ensemble Communications**
 - **Fujitsu Microelectronics**
 - **Intel Corporation**
 - **Nokia**
 - **OFDM Forum**
 - **Proxim Corporation**
 - **Wi-LAN Inc.**
 - **Redline Communications**
 - **Wavesat Telecom Inc**
- Newer ones:**
- **Andrew Corp.**
 - **Atheros**
 - **Powerwave**
 - **Redline Comms Inc**
 - **RF Integration**
 - **SR Telecom**
 - **others**

News: *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

News: *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 in March 2003)

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

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**

802.16 Projects: 10-66 GHz

Air Interface

IEEE Standard

802.16

Publ: Apr 2002

- MAC
- 10-66 GHz PHY

802.16c (Profiles)

Publ: Jan 2003

Conformance

802.16/Conf01

(PICS)

Appr: June 2003

P802.16/Conf02

Passed WG LB;
to SB this week

P802.16/Conf03

Draft this week

P802.16/Conf04

PAR: future

Coexistence

IEEE Standard

802.16.2

Publ: Sep 2001

802.16 Projects: 2-11 GHz

Air Interface

802.16a

- 2-11 GHz PHY

Publ: April 2003

P802.16d (Profiles)

- PAR: Dec 2002
- WG Ballot open:
April 2003
- Changing to Revision

P802.16e

- Mobile Extension
- PAR: Dec 2002
- WG Ballot:
Sept or Nov 2003?

Conformance

Coexistence

802.16.2a

- 2-11 GHz
- RevCom:
June 2003
- Not approved by
IEEE-SA SB
- Changing to
Revision

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

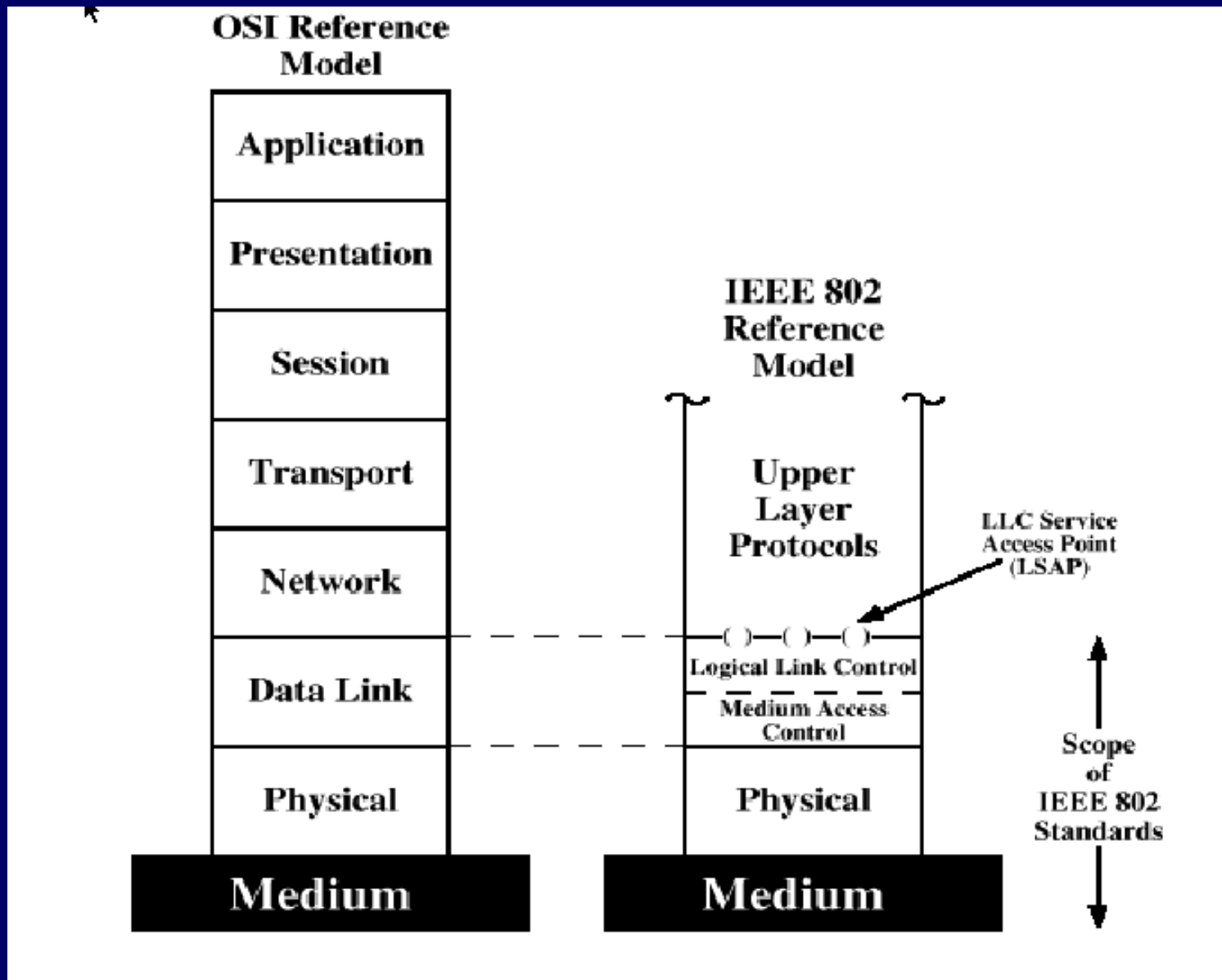
Abstract: This standard specifies the air interface of fixed (stationary) point-to-multipoint broadband wireless access systems providing multiple services. The medium access control layer is capable of supporting multiple physical layer specifications optimized for the frequency bands of application. 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

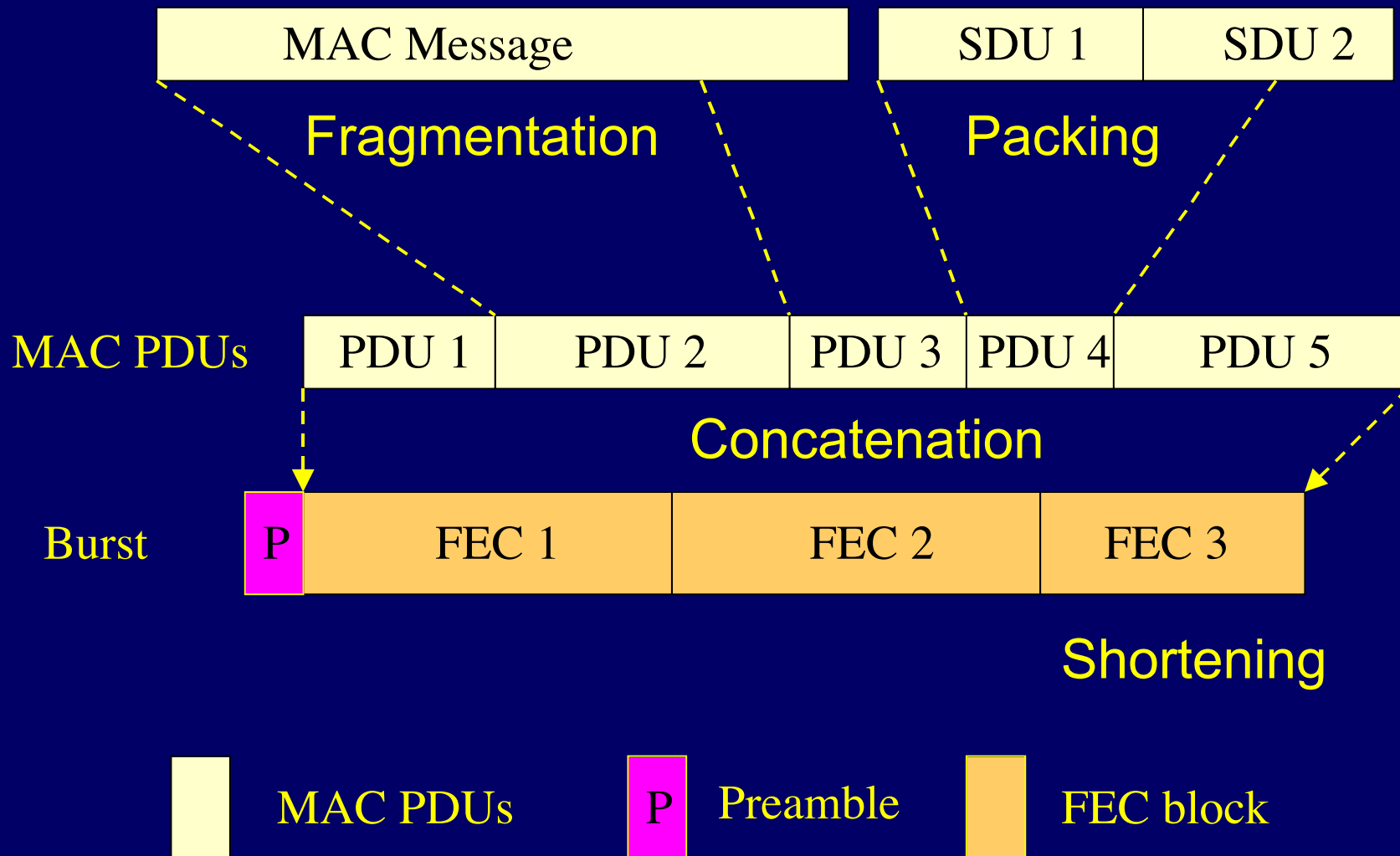
Scope of 802 Standards



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



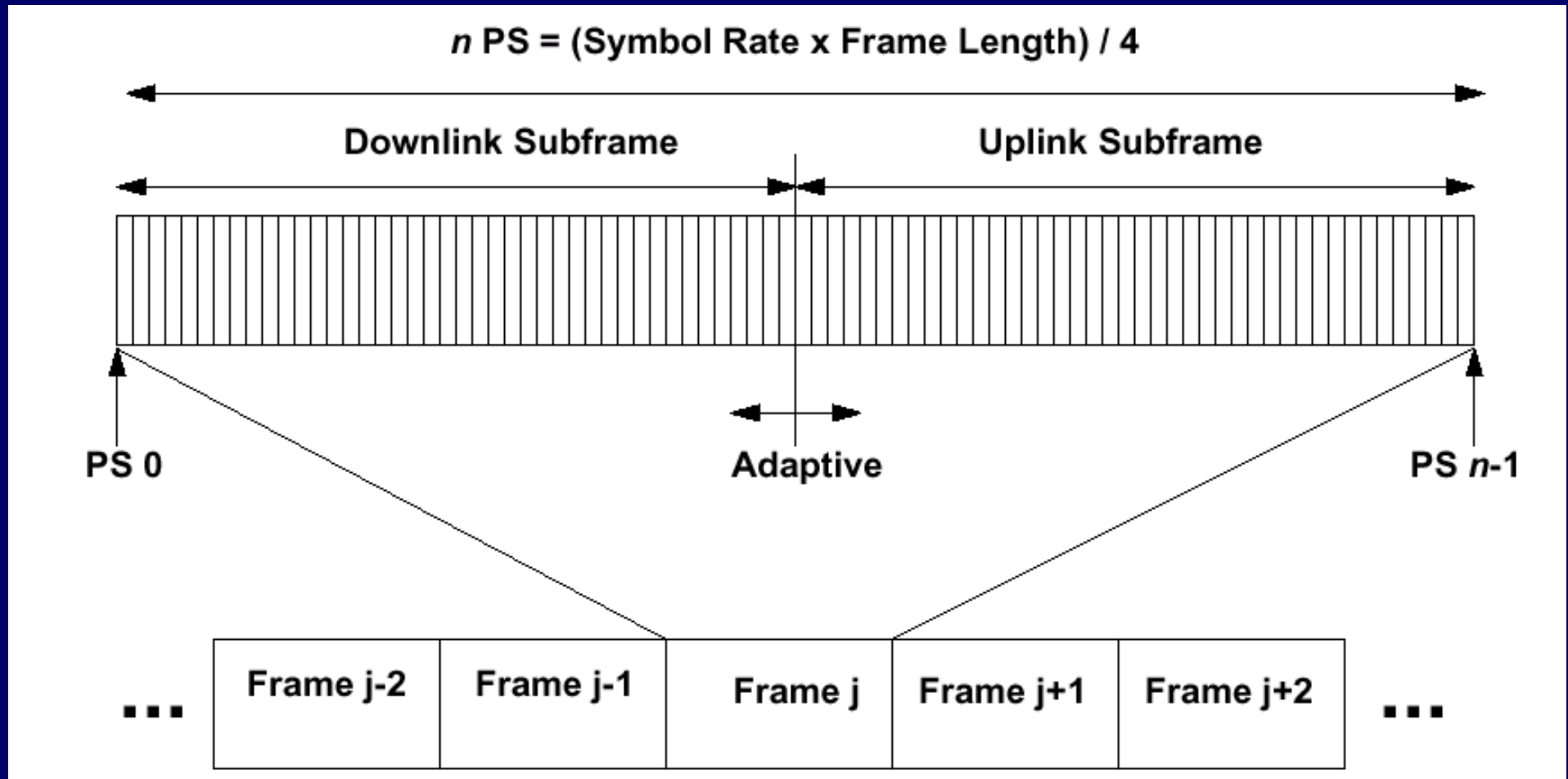
Multiple Access and Duplexing

34

- 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)

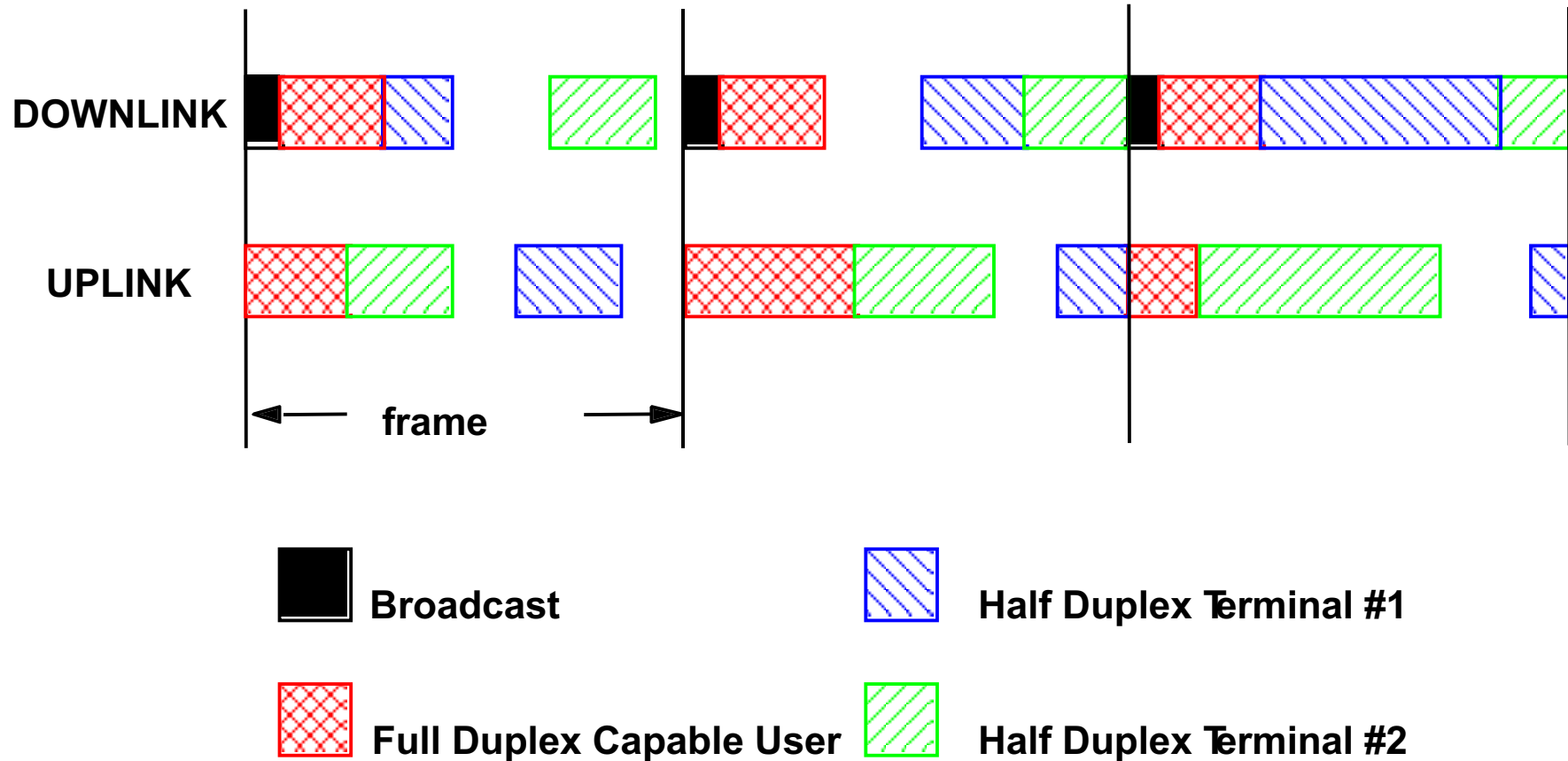
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Frame duration: 1 ms

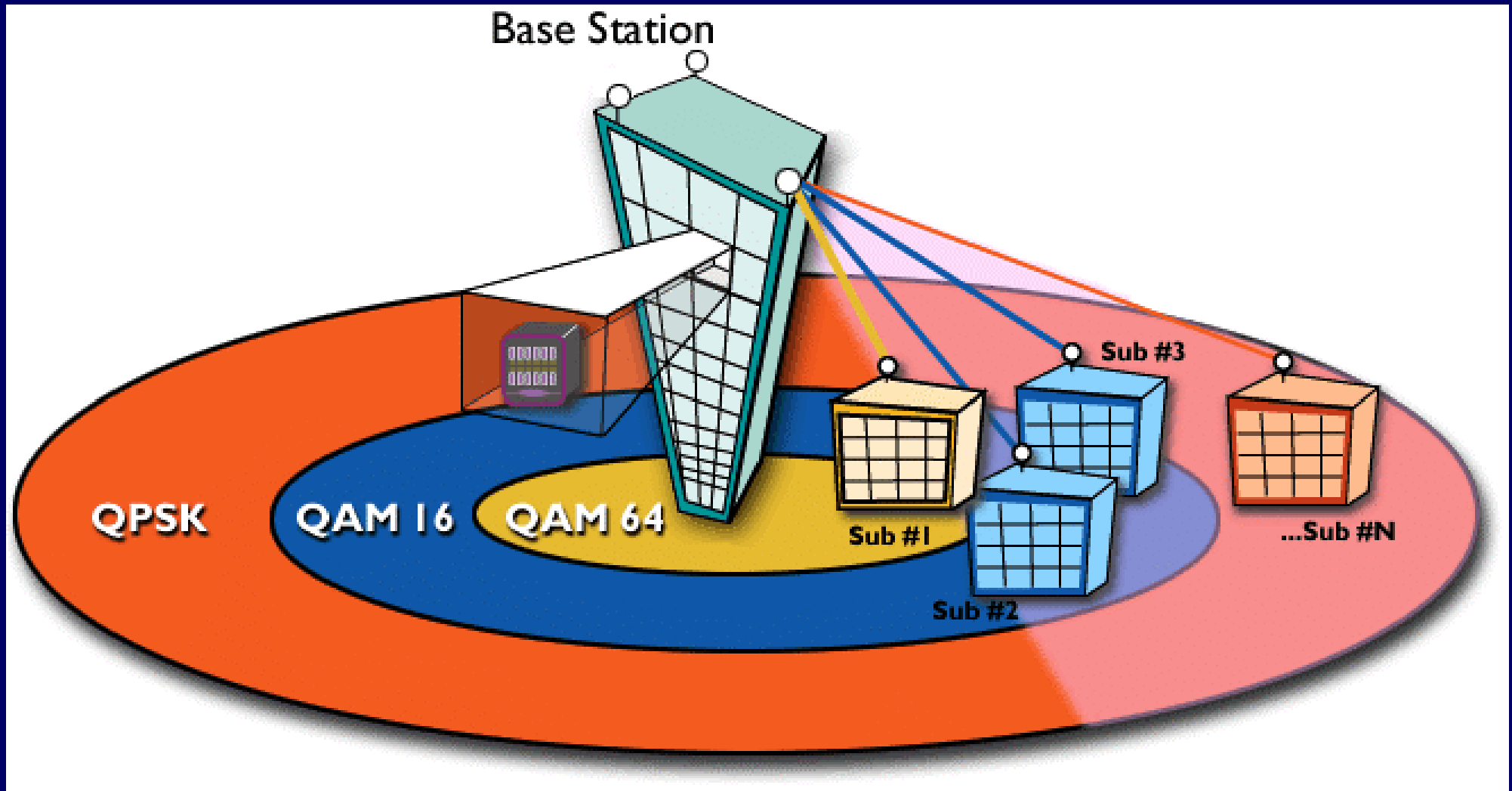
Physical Slot (PS) = 4 symbols

Burst FDD Framing



Allows scheduling flexibility

Adaptive PHY

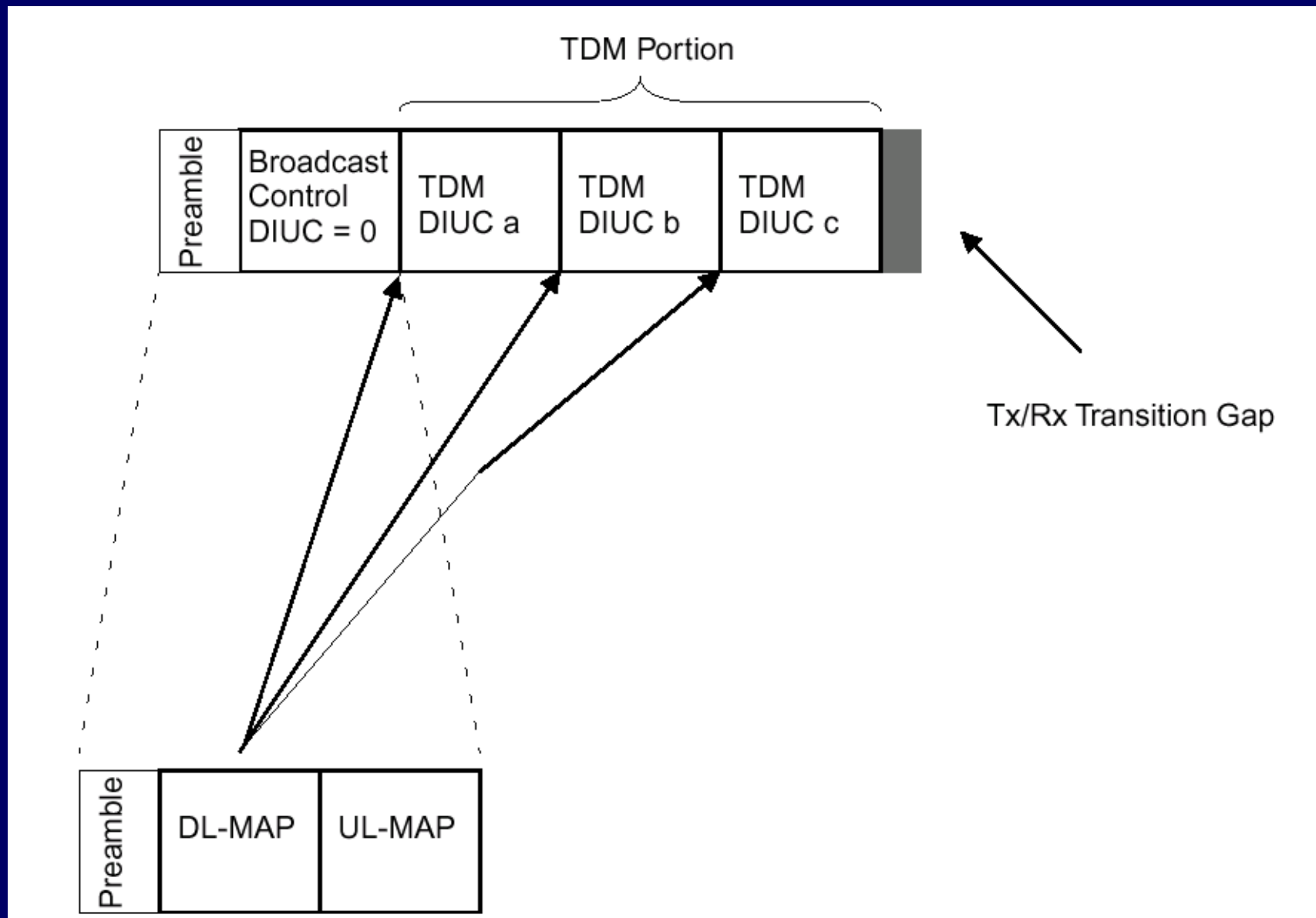


(burst-by-burst adaptivity not shown)

Adaptive Burst Profiles

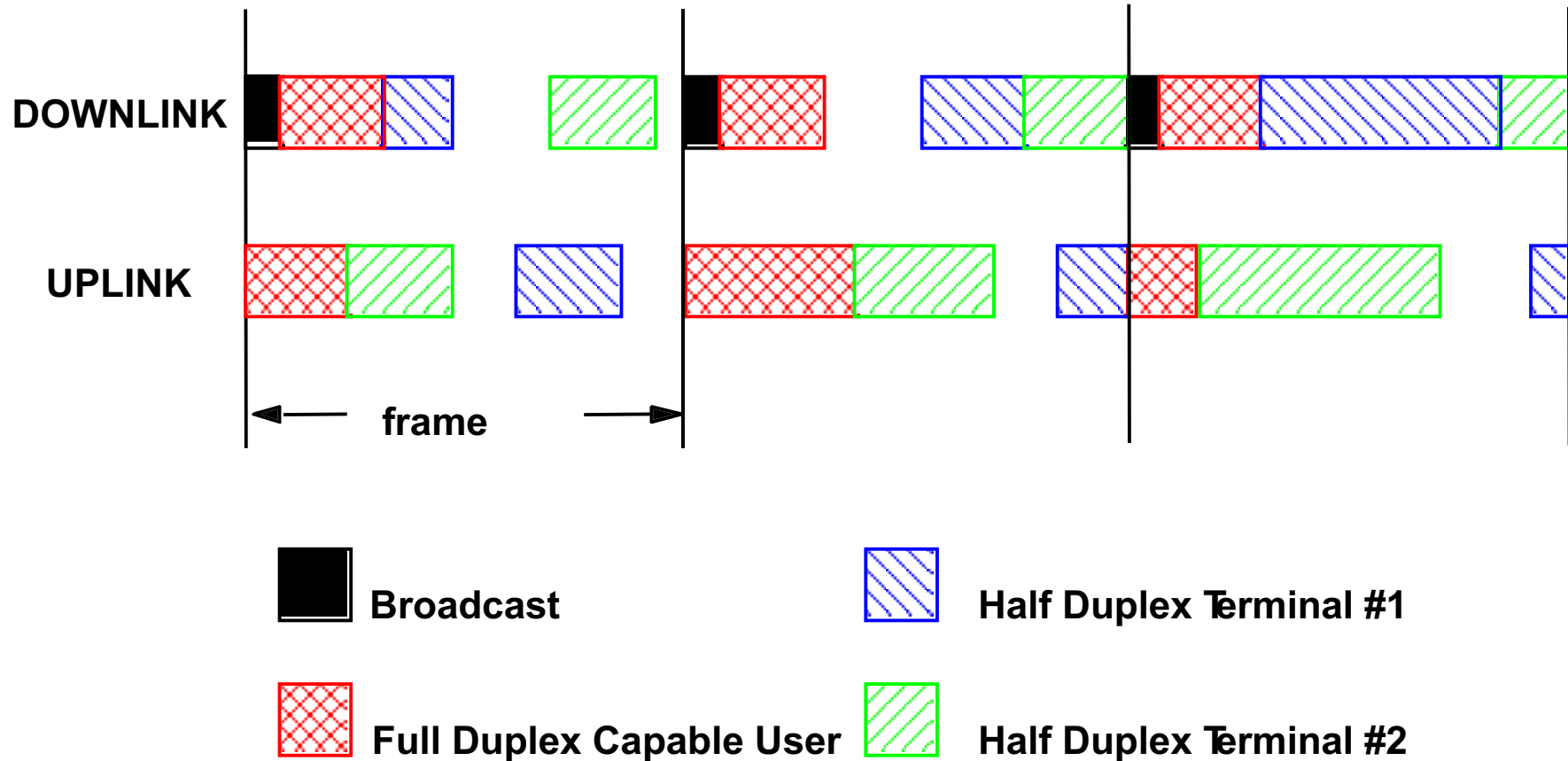
- **Burst profile**
 - Modulation and FEC
- **Dynamically assigned according to link conditions**
 - Burst by burst, per subscriber station
 - Trade-off capacity vs. robustness in *real time*
- **Roughly doubled capacity for the same cell area**
- **Burst profile for downlink broadcast channel is well-known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

TDD Downlink Subframe



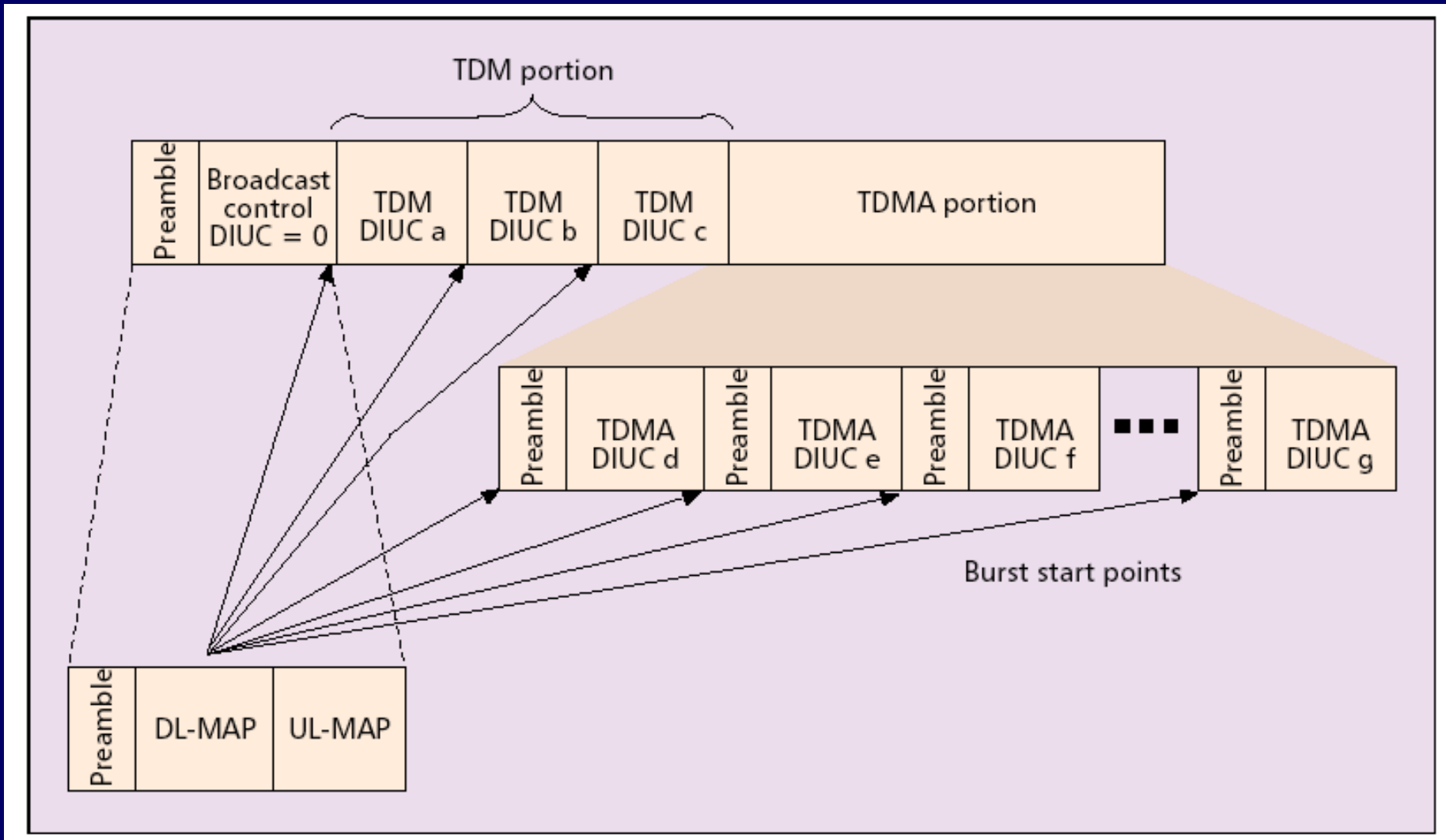
DIUC: Downlink Interval Usage Code

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)

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***

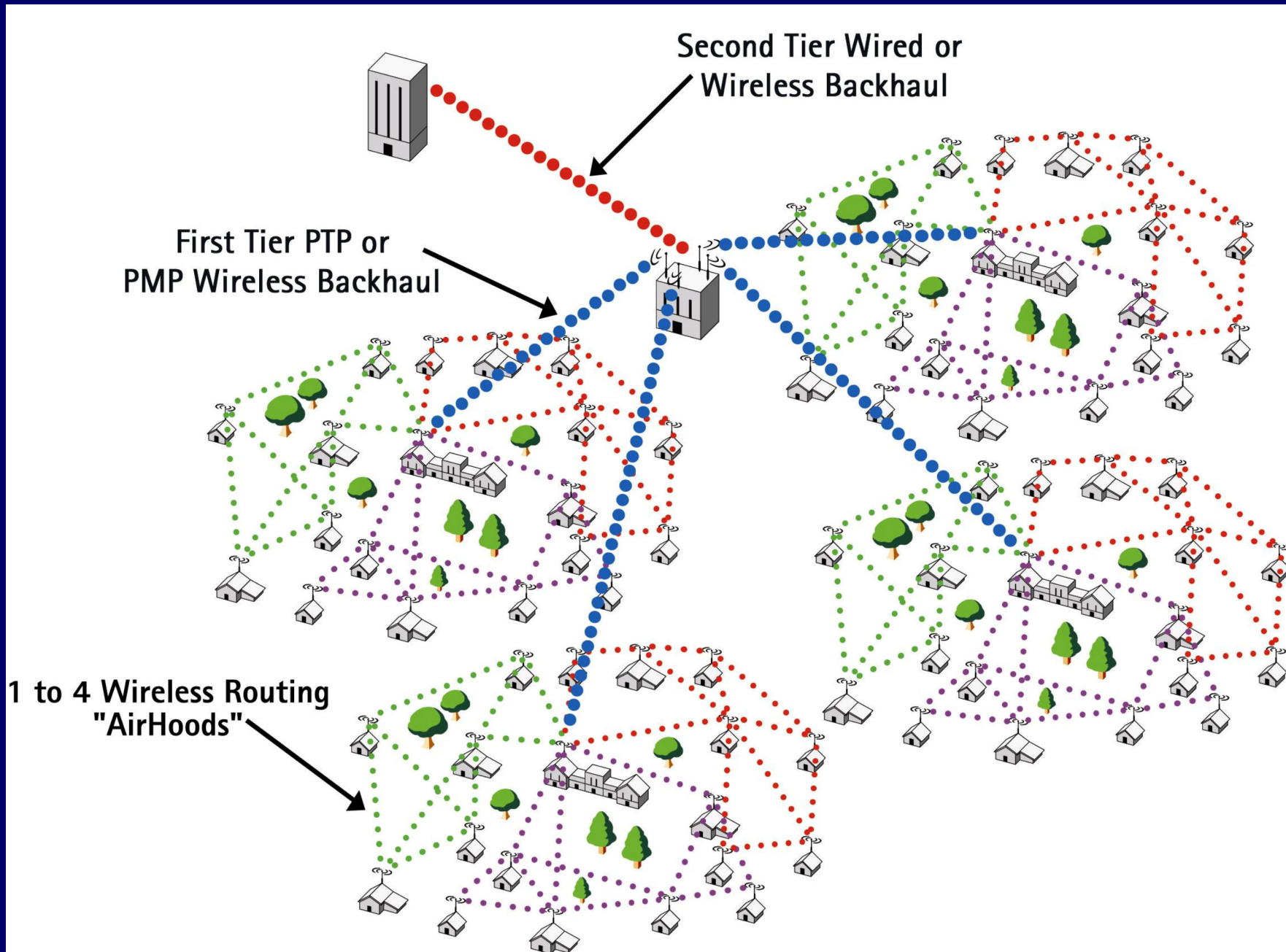
802.16a PHY Alternatives: Different Applications, Bandplans, and Regulatory Environments

- **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



What's Next ?

- **Compliance documentation**
- **Mobility: 802.16e**
- **Possible extensions:**
 - **mesh enhancements**
 - **Millimeter-wave PHY**
 - **Special point-to-point mode**
- **New 802 Handoff Study Group**

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.**
- **Compliance & 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 is free
- IEEE Std 802.16.2 is free

IEEE Standard 802.16: Tutorial

IEEE Communications Magazine, June 2002

(available on 802.16 web site)

TOPICS IN BROADBAND ACCESS

IEEE Standard 802.16: A Technical Overview of the WirelessMAN™ Air Interface for Broadband Wireless Access

Carl Eklund, Nokia Research Center

Roger B. Marks, National Institute of Standards and Technology

Kenneth L. Stanwood and Stanley Wang, Ensemble Communications Inc.

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>

