Wireless Metropolitan Area Networks:

Global Standards and Global Deployment

http://WirelessMAN.org

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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

Global Standardization

2001 IEEE Conference on Standards and Innovation in Information Technology
Boulder, Colorado, USA, 3-5 October 2001
http://siit2001.org

GOVERNMENT ACTIVITY TO INCREASE BENEFITS FROM THE GLOBAL STANDARDS SYSTEM*

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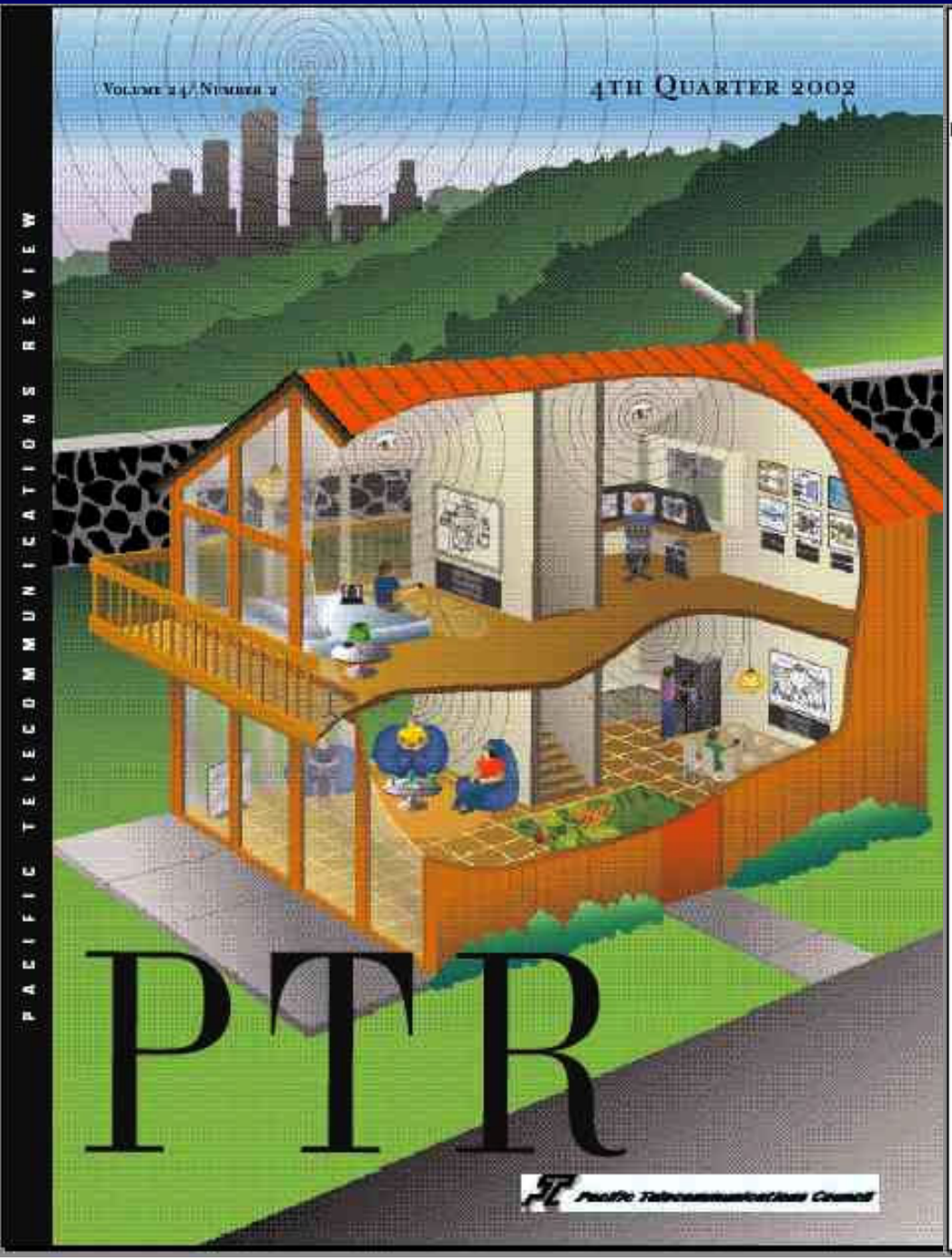
In this paper, we review the factors influencing the evolution of the global standards system. We then discuss some of the approaches that governments have taken or are exploring in order to modify the system for the benefit of domestic and worldwide economic development. We use as an example an effort of the U.S. National Institute of Standards and Technology to encourage voluntary consensus standards for interoperable broadband wireless access systems.

Globalization of the economy has in turn led to globalization of standardization. Governments play a strong role in shaping the global standards system. They have explored many approaches to optimize the system to meet their economic and social needs. Governmental activity sometimes conflicts with the interests of other governments or of local industry. In this paper, we investigate some of these issues.

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
  - 802.16 represented by Liaisons:
    - Jay Klein and Marianna Goldhammer
- 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

Countries of 802.16 Pre-Registrants Here

- CANADA (10)
- FINLAND (2)
- FRANCE (1)
- ISRAEL (5)
- JAPAN (2)
- KOREA ( )
- CHINA (1)
- RUSSIA (1)
- UK (4)
- USA (31)

BWA/802.16 Interest within China

"IEEE 802.16a Broadband Wireless Access (BWA) Standard Development and Internet Application": conference sponsored by the government of People's Republic of China 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"

- 240 people (100 from government; 80 from telecom operators)

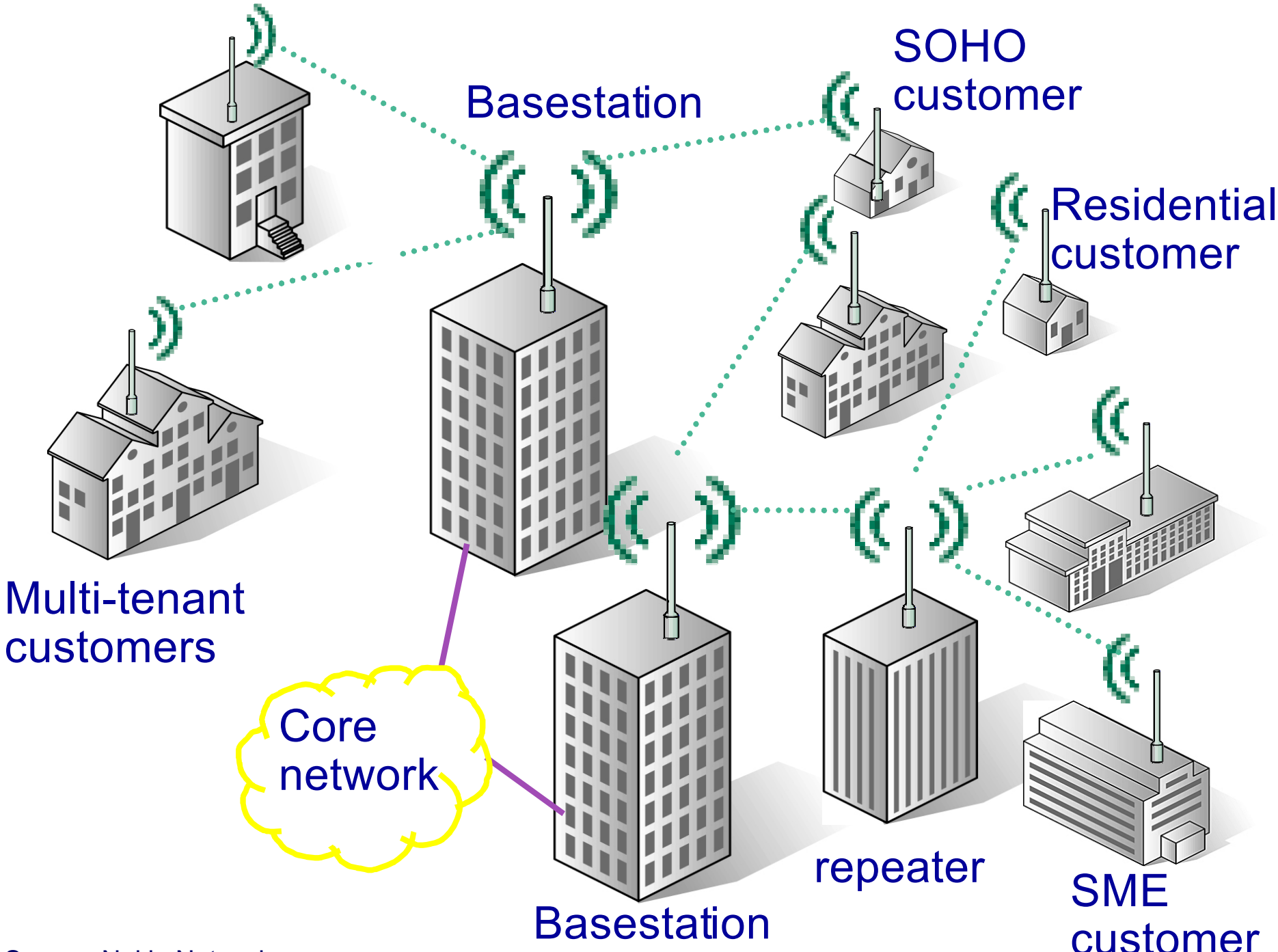
BWA/802.16 Interest within China (2)

June 2002

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

WirelessMAN™: Wireless Metropolitan Area Network



Source: Nokia Networks

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 effficient 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
- Future Sessions
  - Session #24/Mar 2003: Dallas, TX, USA (with 802)
  - Session #25/May 2003: Singapore (with 802.11, etc)
  - Session #26/July 2003: San Francisco (with 802)

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

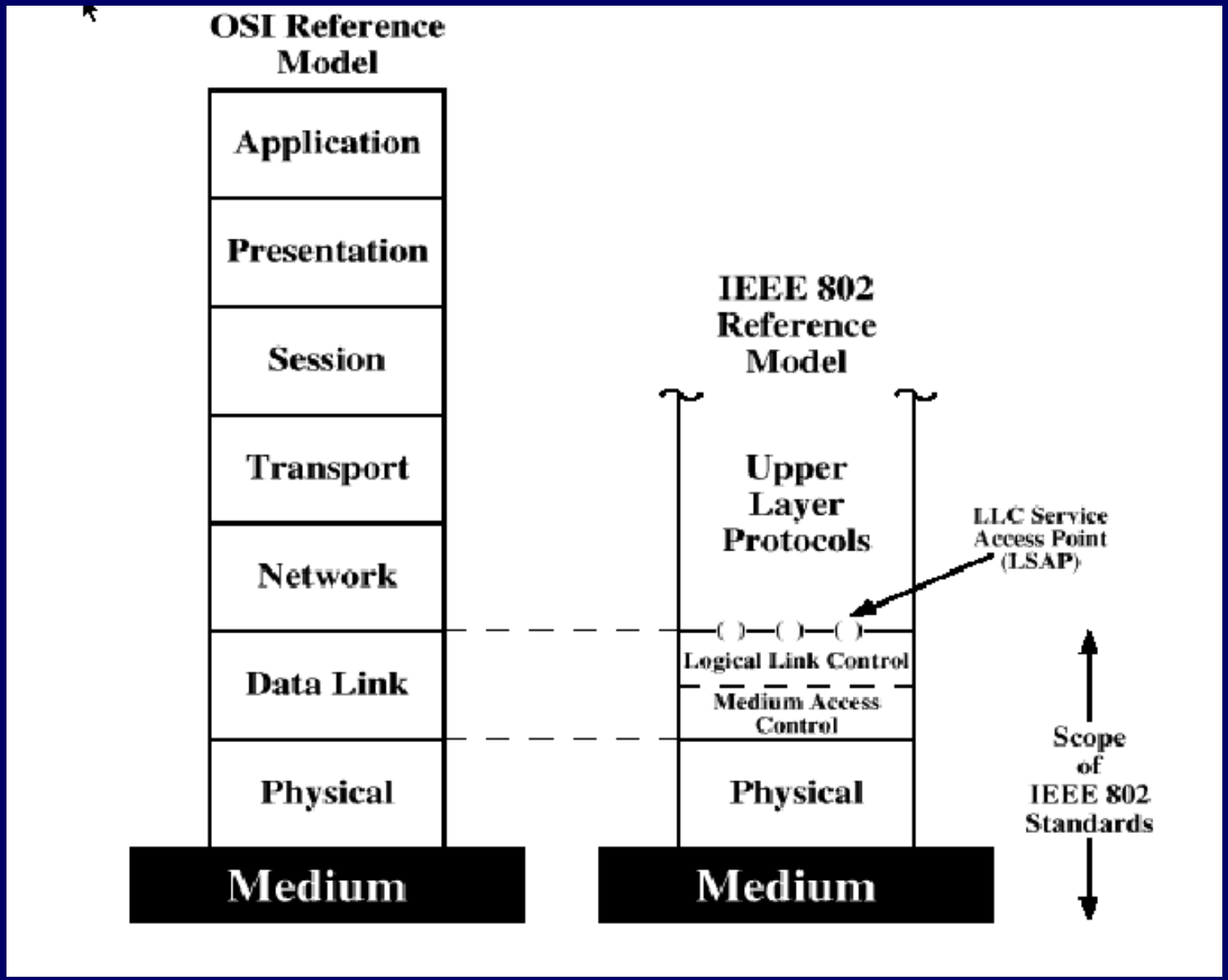
- Call for Contributions
  - Specific topics for discussion at next meeting
- Receive and post written contributions
- Discuss and debate at meeting
- Create draft by 75% vote
- Working Group Ballot
- IEEE "Sponsor Ballot"
- Ballot Responses:
  - "Approve" (can include comments)
  - "Disapprove": indicate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

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 voting group

Distribution of IEEE 802® Standards

Scope of 802 Standards



IEEE 802.16 (Wireless MAN)

- Wireless Metropolitan Area Networks
- Broadband Wireless Access
  - Primarily "fixed" (non-moving)
  - Evolving to support mobile users

IEEE 802.16 by the Numbers

- 82 Members (peaked at 178)
- ~850 different individuals have attended a session
  - From 22 countries (Australia, Canada, China, Finland, France, Germany, Greece, Israel, Italy, Japan, Korea, Netherlands, Norway, Pakistan, Russia, Singapore, Spain, Sweden, Taiwan, UK, USA)
- 2.8 Million file downloads in year 2000

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): being published today
    - 1802.16.1 (PICS): in WG ballot; completion expect in April
    - 1802.16.2: (Test Suite Structure & Purposes)
      - Initiated on 11 Dec; WiMAX submitted proposal two days ago
- 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
    - Approval expected this month (January 2003)
  - Followup interoperability projects
    - P802.16d: first meeting today (≥10 submitted documents)
  - Followup air interface project: *mobility*
    - P802.16e: first meeting today (≥9 submitted documents)
- Coexistence
  - IEEE Standard 802.16.2a (Recommended Practice)
    - In IEEE ballot
    - Completion expected in March 2003

IEEE Standard 802.16: The WirelessMAN-SC™ Air Interface

Published: 8 April 2002 (349 pages)

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

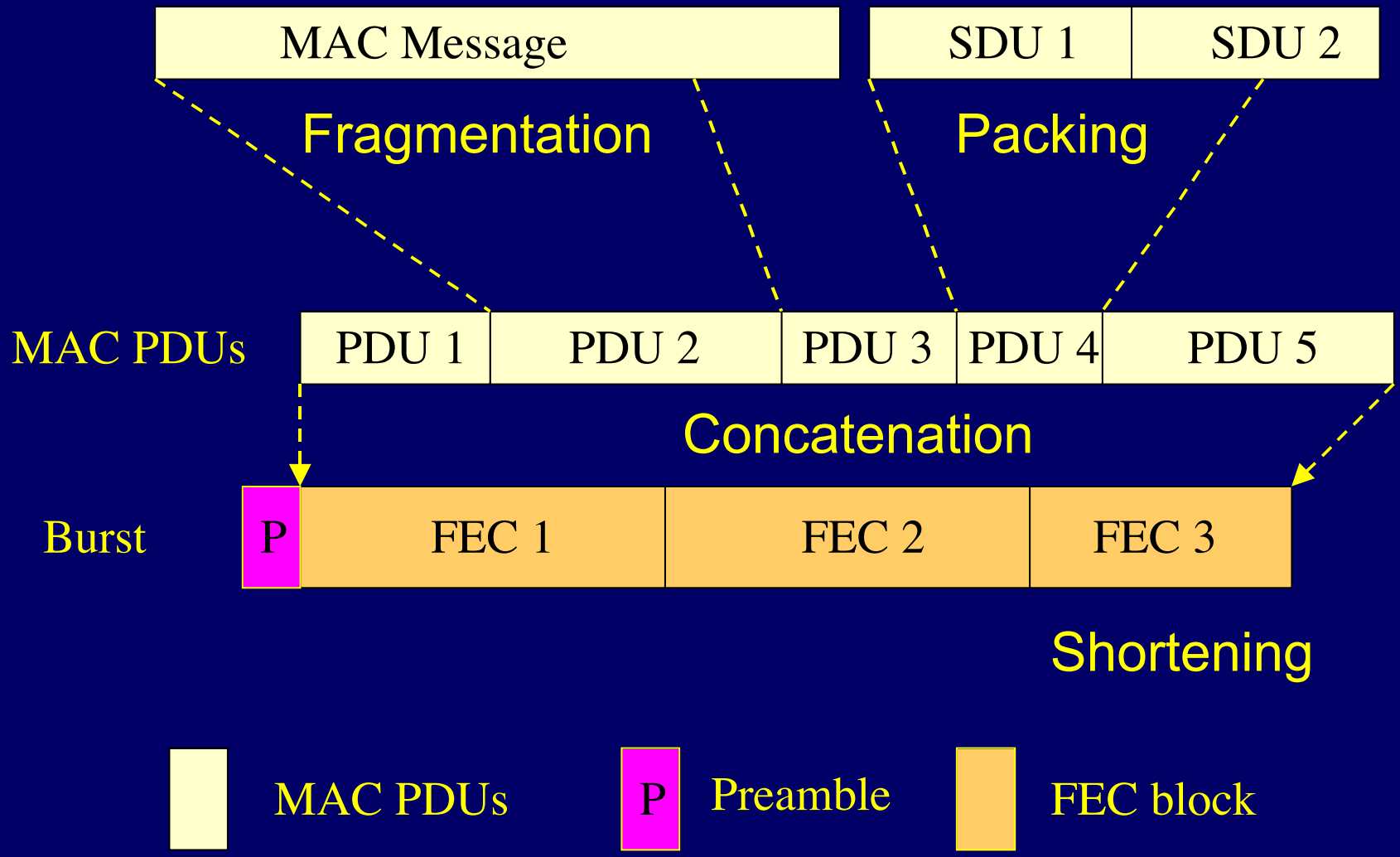
- Compared to a Wireless LAN:
  - Multimedia QoS, not only contention-based
  - Many more users
  - Much higher data rates
  - Much longer distances

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

efficiently carry both IP and ATM

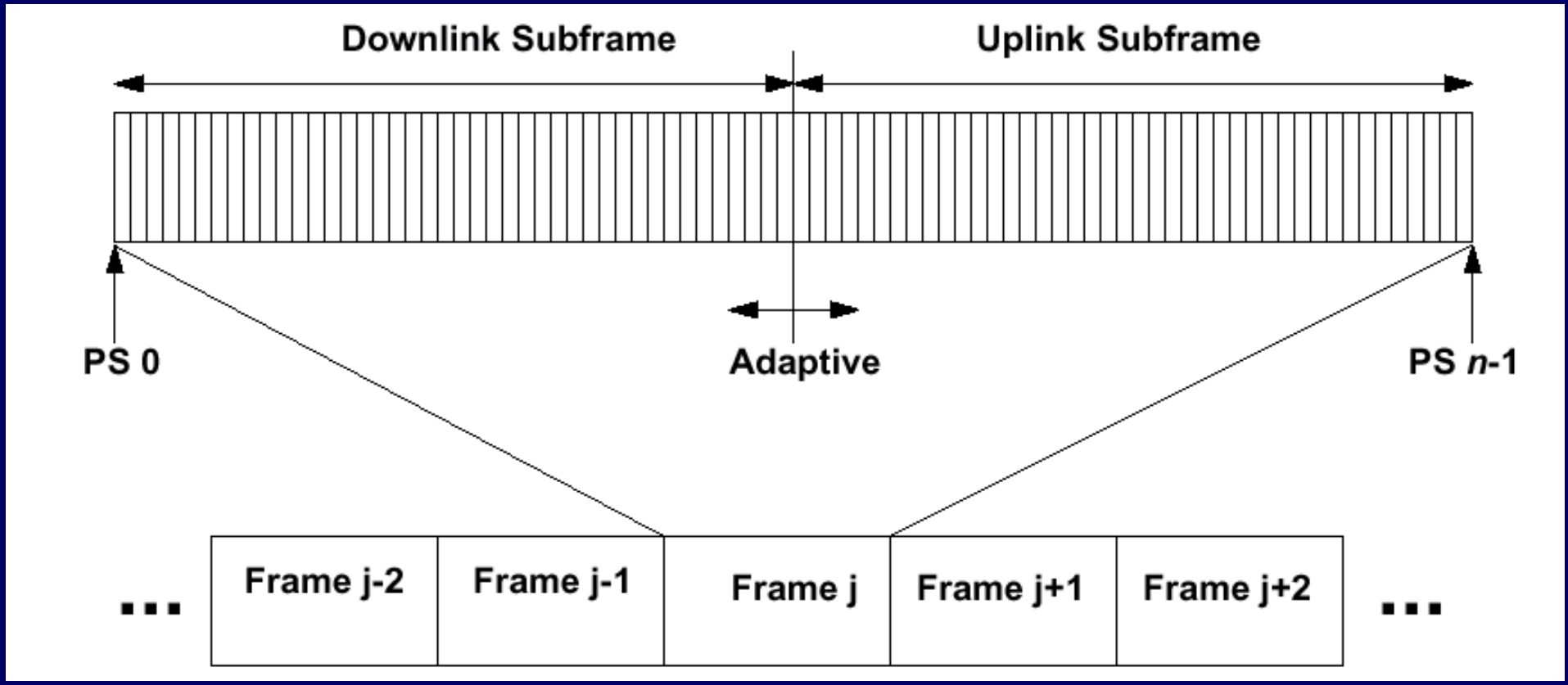


Multiple Access and Duplexing

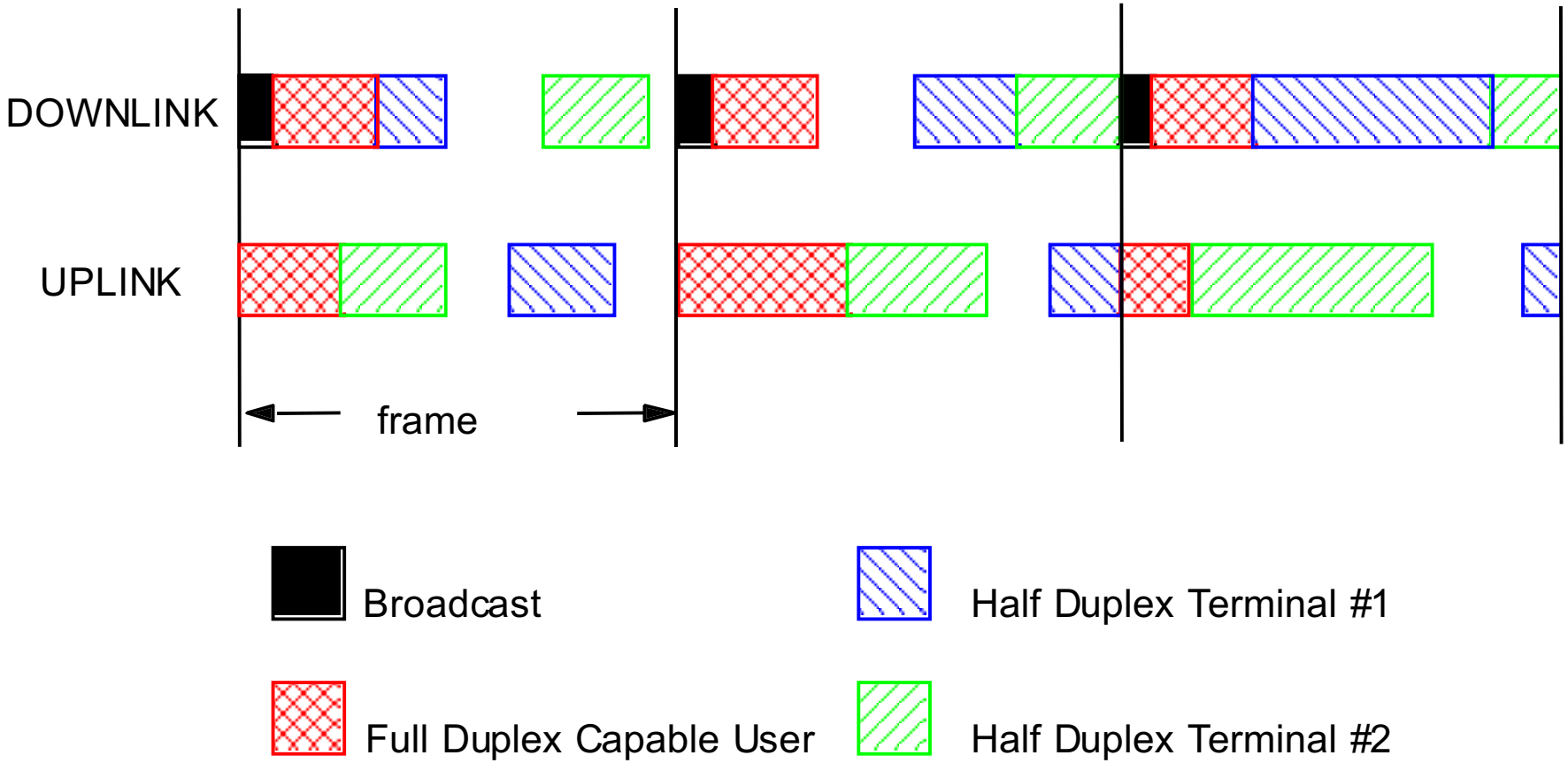
- On DL, SS addressed in TDM stream
- On UL, SS is allotted a variable length TDMA slot

- 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

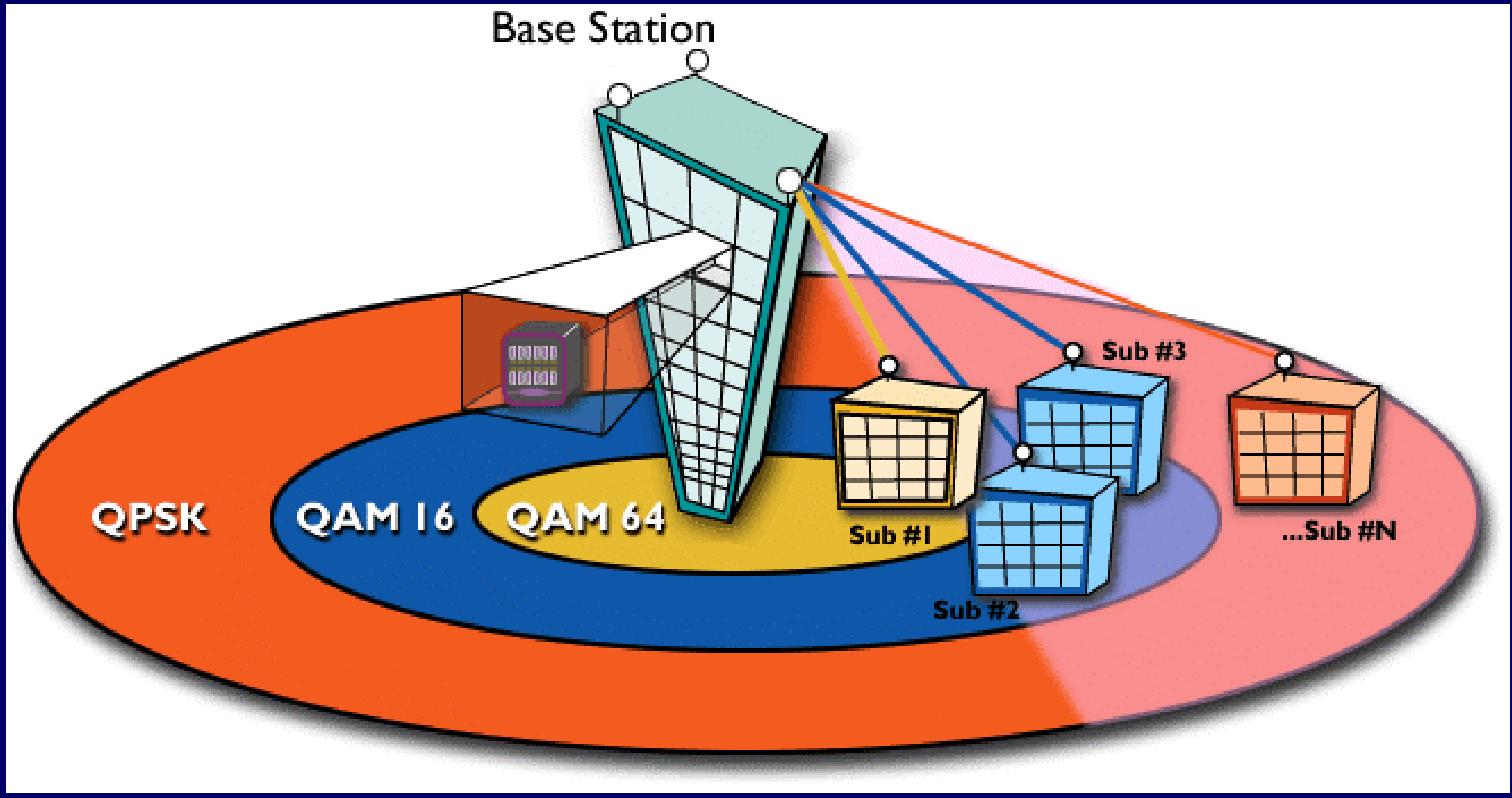

Downlink Subframe
Uplink Subframe
PS 0
Adaptive
PS n-1
...
Frame j-2
Frame j-1
Frame j
Frame j+1
Frame j+2
...

Burst FDD Framing



Allows scheduling flexibility

Adaptive PHY



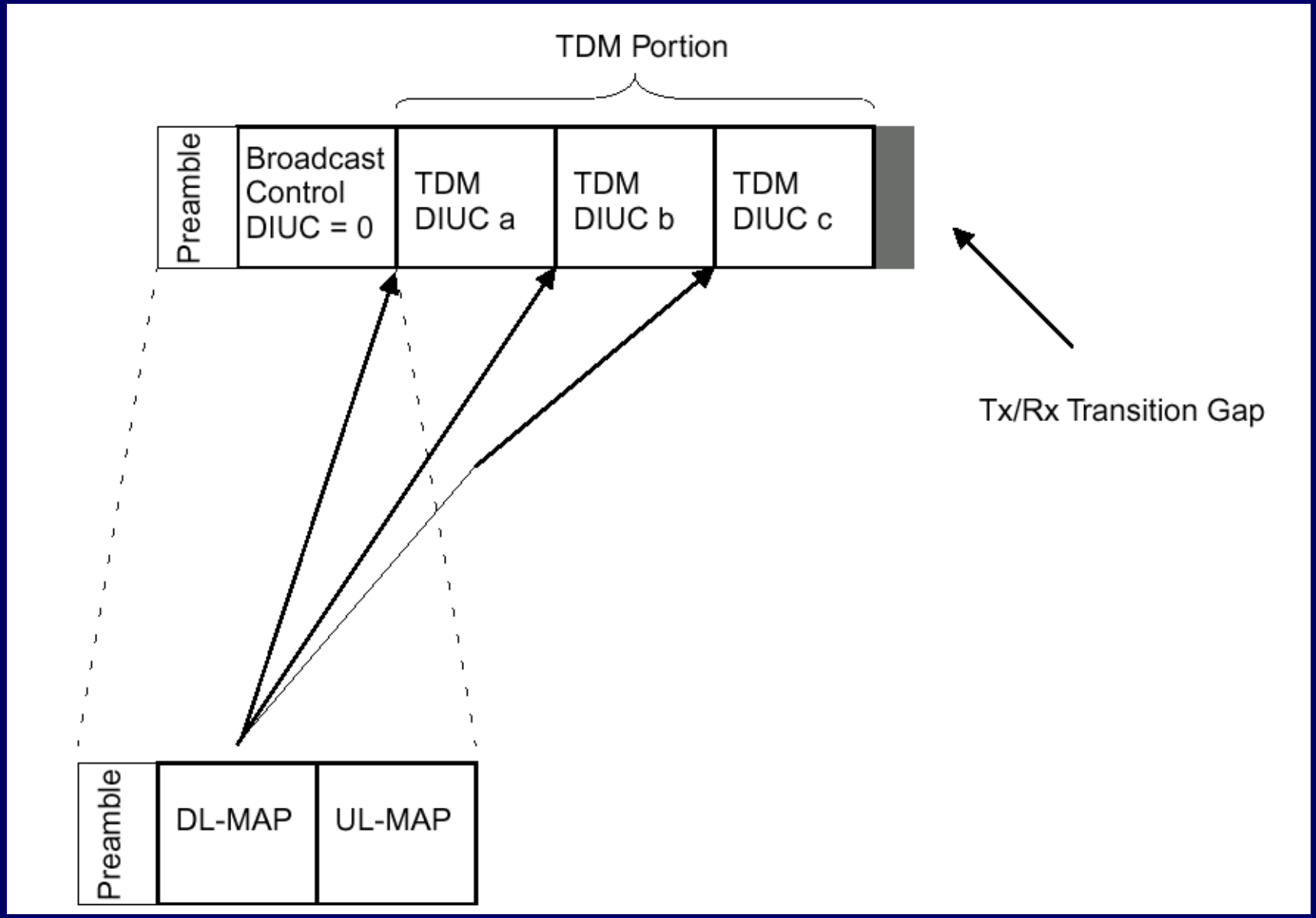
(burst-by-burst adaptivity not shown)

Source: Ensemble Communications

Adaptive Burst Profiles

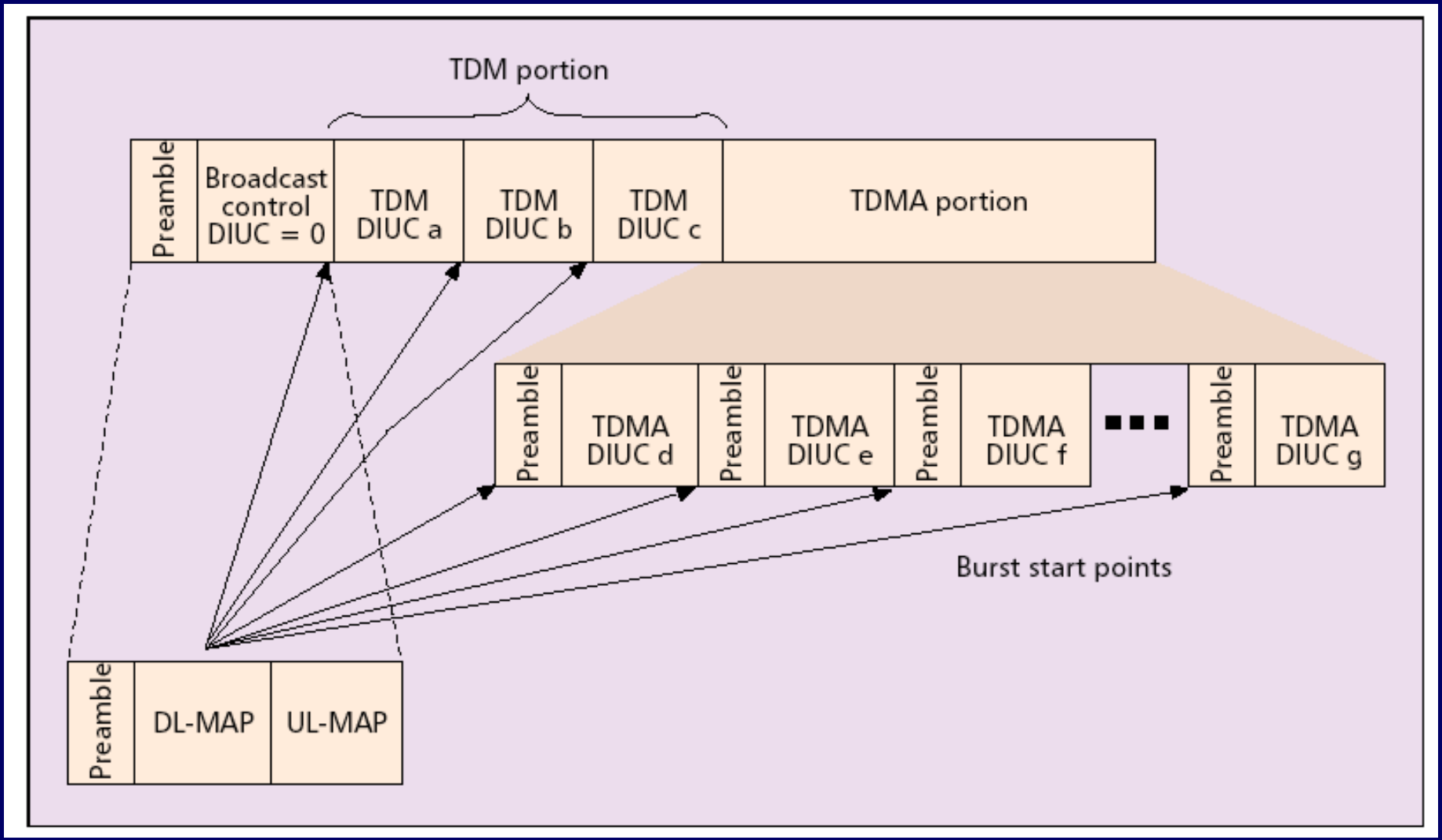
- Burst profile
  - Modulation and FEC
- Dynamically assigned according to link conditions
  - Burst by burst, per subscriber station
  - Trade-off capacity vs. robustness in *real time*
- Roughly doubled capacity for the same cell area
- Burst profile for downlink broadcast channel is well-known and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

TDD Downlink Subframe



DIUC: Downlink Interval Usage Code

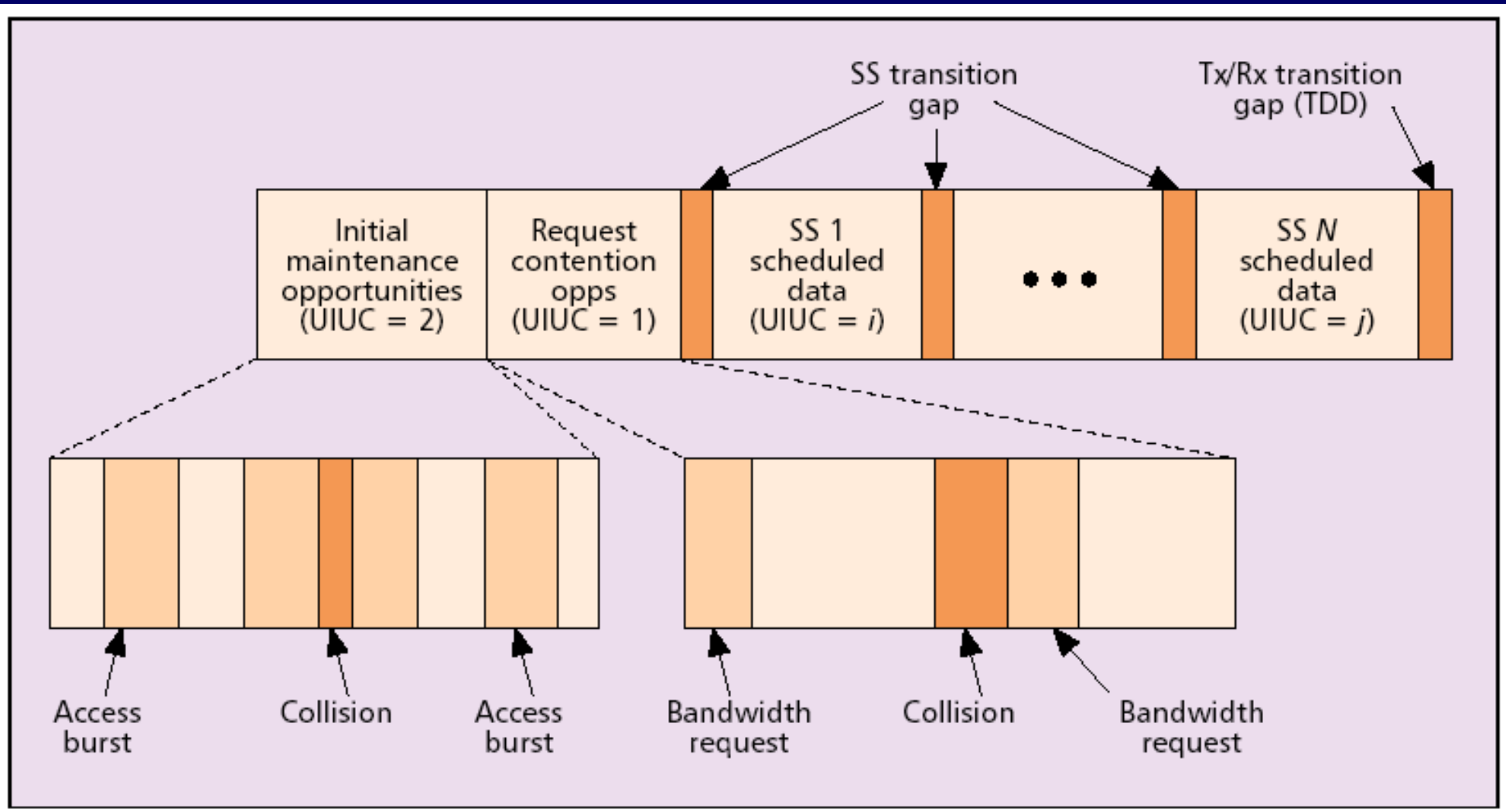
FDD Downlink Subframe



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)



Amendment Project
IEEE P802.16a

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

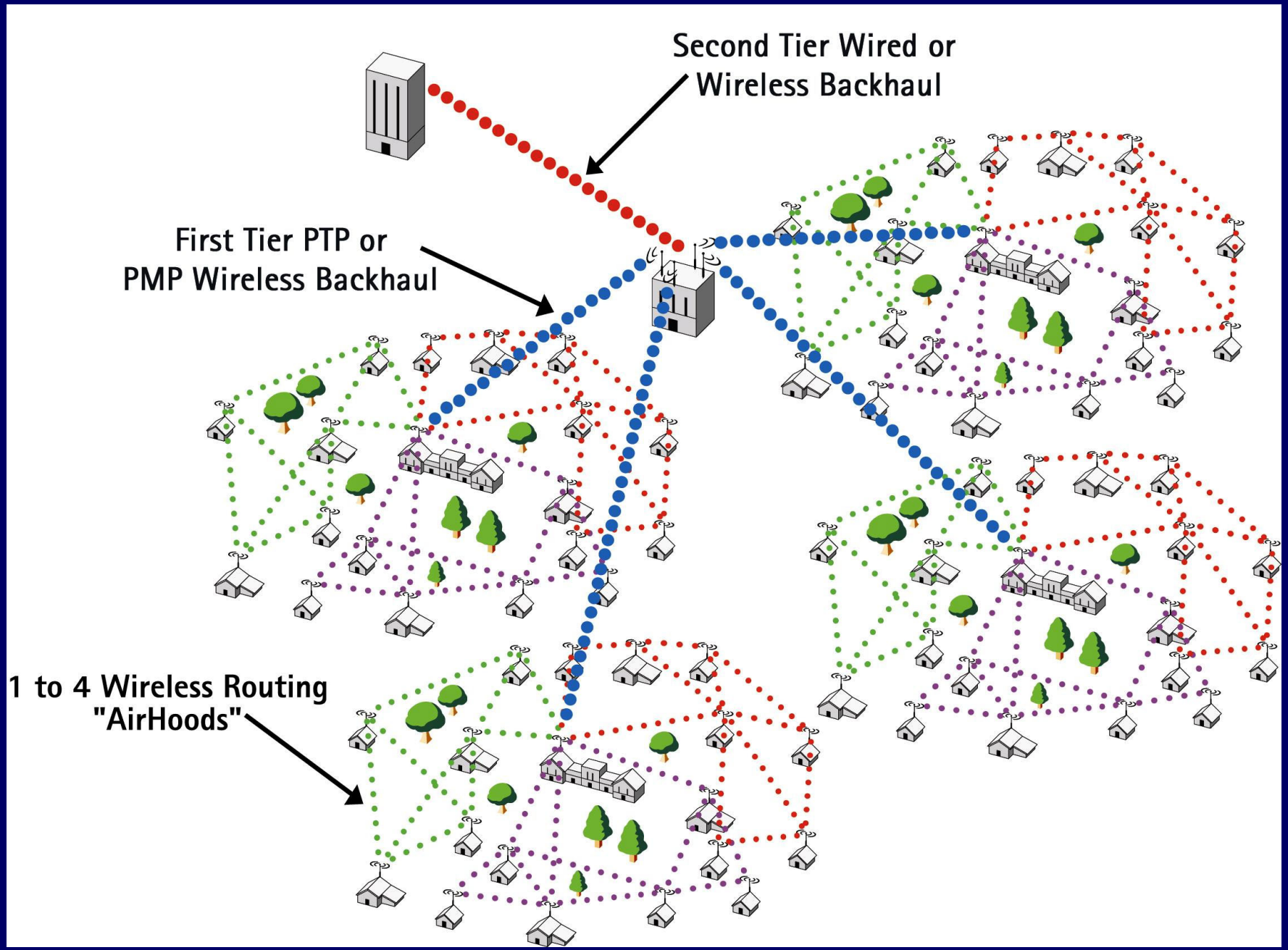
802.16a PHY Alternatives: Different Applications, Bandplans, and Regulatory Environments

- 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
- Advanced Antenna System (AAS) support
- Mesh Mode
  - Optional topology
  - Subscriber-to-Subscriber communications
  - Complex topology and messaging, but:
    - addresses license-exempt interference
    - scales well

Mesh-based WirelessMAN



Source: Nokia Networks

Mobility Enhancement: 802.16e

March-November 2002:

- 802.16 Study Group on Mobility

11 December 2002:

- IEEE-SA approved new project 802.16e
- Amendment to 802.16/a/c/d
- "Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands"
  - "enhancements ... to support subscriber stations moving at vehicular speeds… Operation is limited to licensed bands suitable for mobility between 2 and 6 GHz. Fixed 802.16a subscriber capabilities shall not be compromised."

Universal Handoff

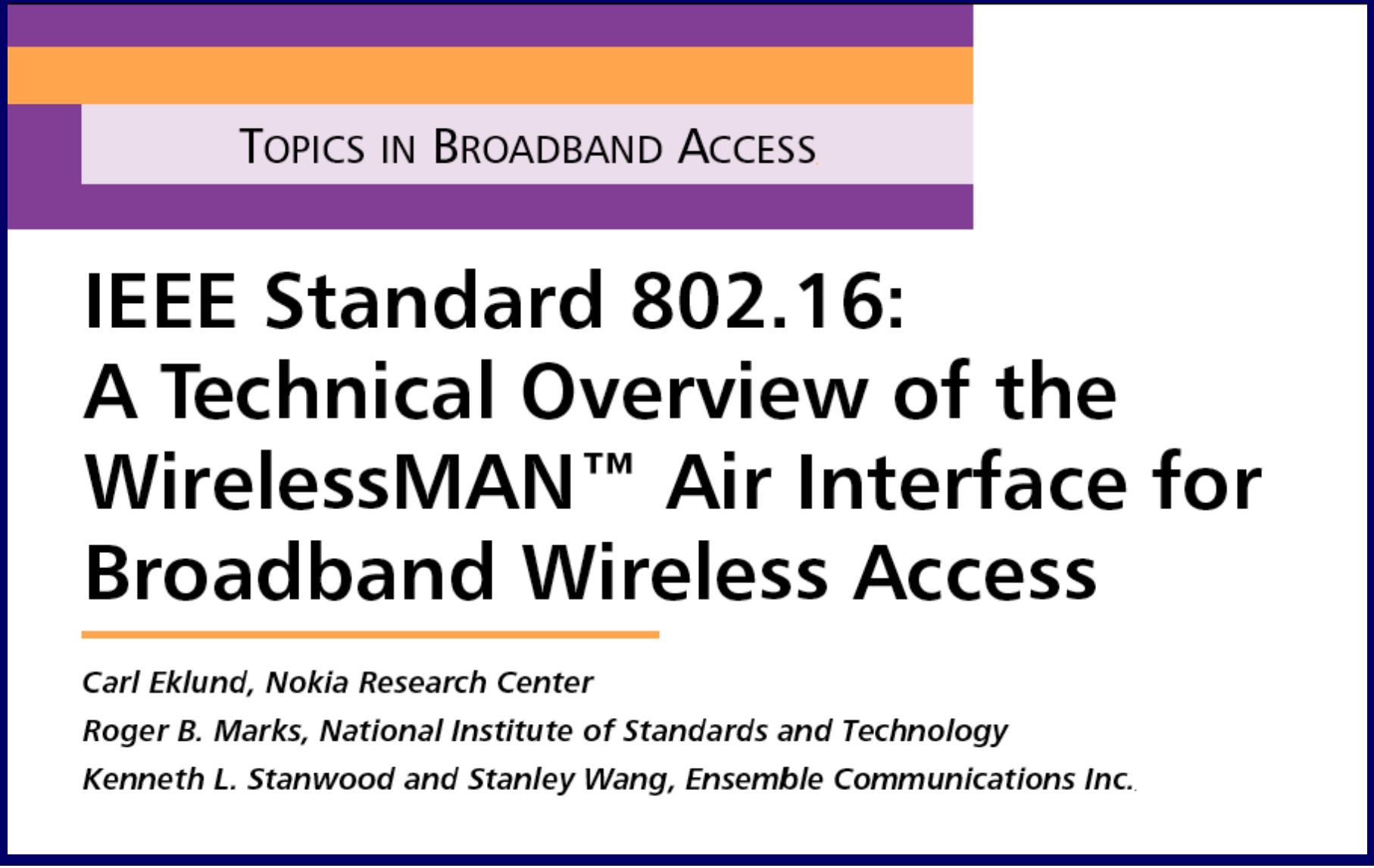
November 2002 IEEE 802 Tutorial

- "Handoff Mechanisms and their Role in IEEE 802 Wireless Standards"
- Organizers: Brian Kiernan and Roger Marks
  - 250 attendees
  - Explored the possibility of developing a standard to support mechanisms to hand off among all 802 wireless networks.
    - And then to non-802 networks
- May develop into new project

IEEE Standard 802.16: Tutorial Paper

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.

Some Key IEEE 802.16 Participants

- IEEE 802.16 (base standard)
  - MAC Chair: Carl Eklund; PHY Chair: Jay Klein
- 802.16c, 1802.16.1, 1802.16.2
  - Task Group Chair: Ken Stanwood; Editor: Carl Eklund
- 802.16a
  - Task Group Chair: Brian Kiernan; Editor: Nico van Waes
- 802.16d
  - Task Group Chair: Gordon Antonello; Editor: Nico van Waes
- 802.16e
  - Task Group Chair: Brian Kiernan; Vice Chair: Shawn Taylor
- 802.16.2
  - Task Group Chair: Phil Whitehead
- 802.16.2a
  - Task Group Chair: Phil Whitehead; Editor: Reza Arefi
- WG and 802.16a/e Secretary/Publicity Chair: Dean Chang

IEEE 802.16 Resources

IEEE 802.16 Working Group on Broadband Wireless Access

info, documents, tutorials, email lists, etc:

http://WirelessMAN.org

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