The IEEE 802.16 WirelessMAN Standard for Broadband Wireless Metropolitan Area Networks

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http://WirelessMAN.org

Broadband Wireless Access:
The Problem to Solve

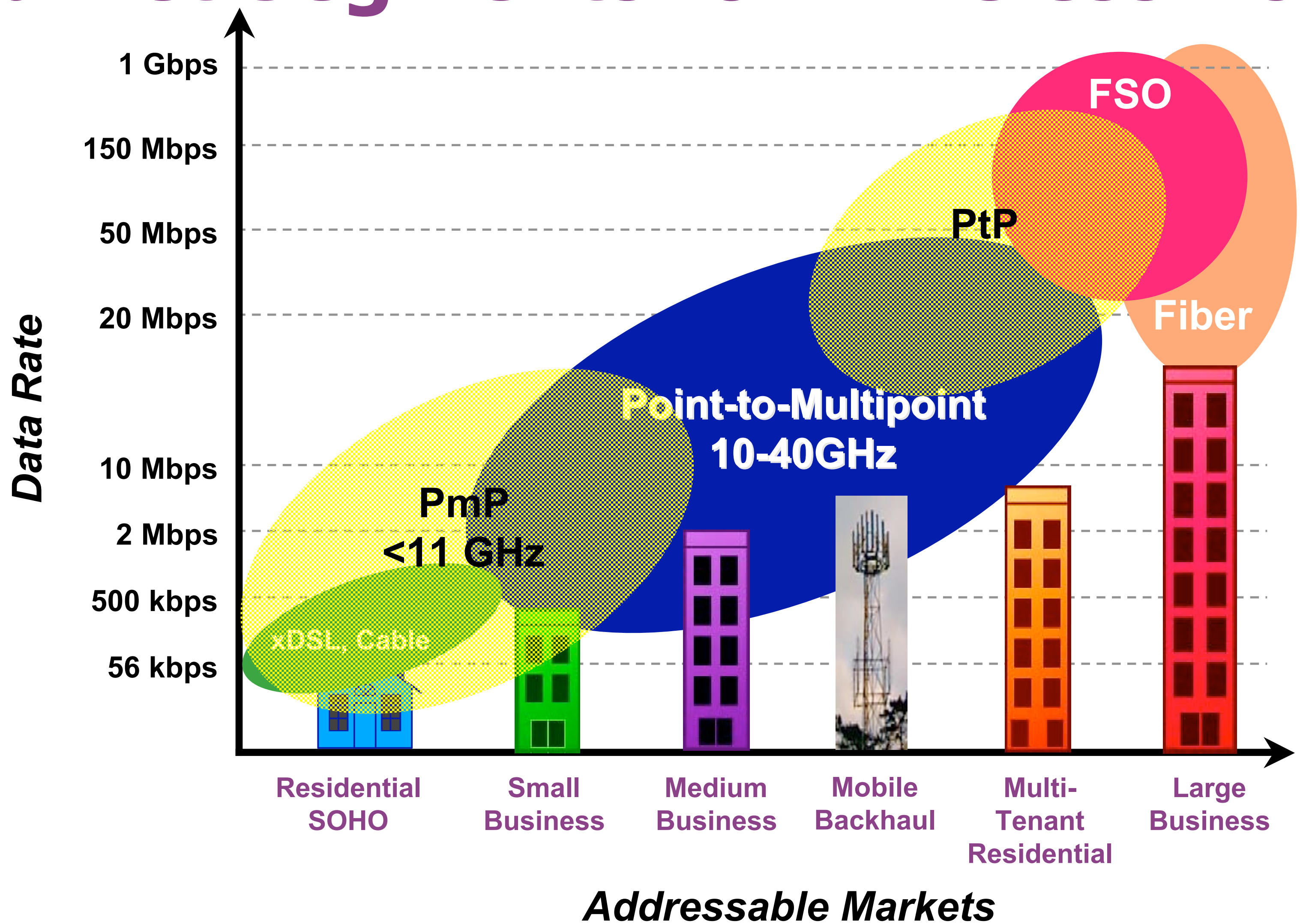
The World Wants Access

- 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
- 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

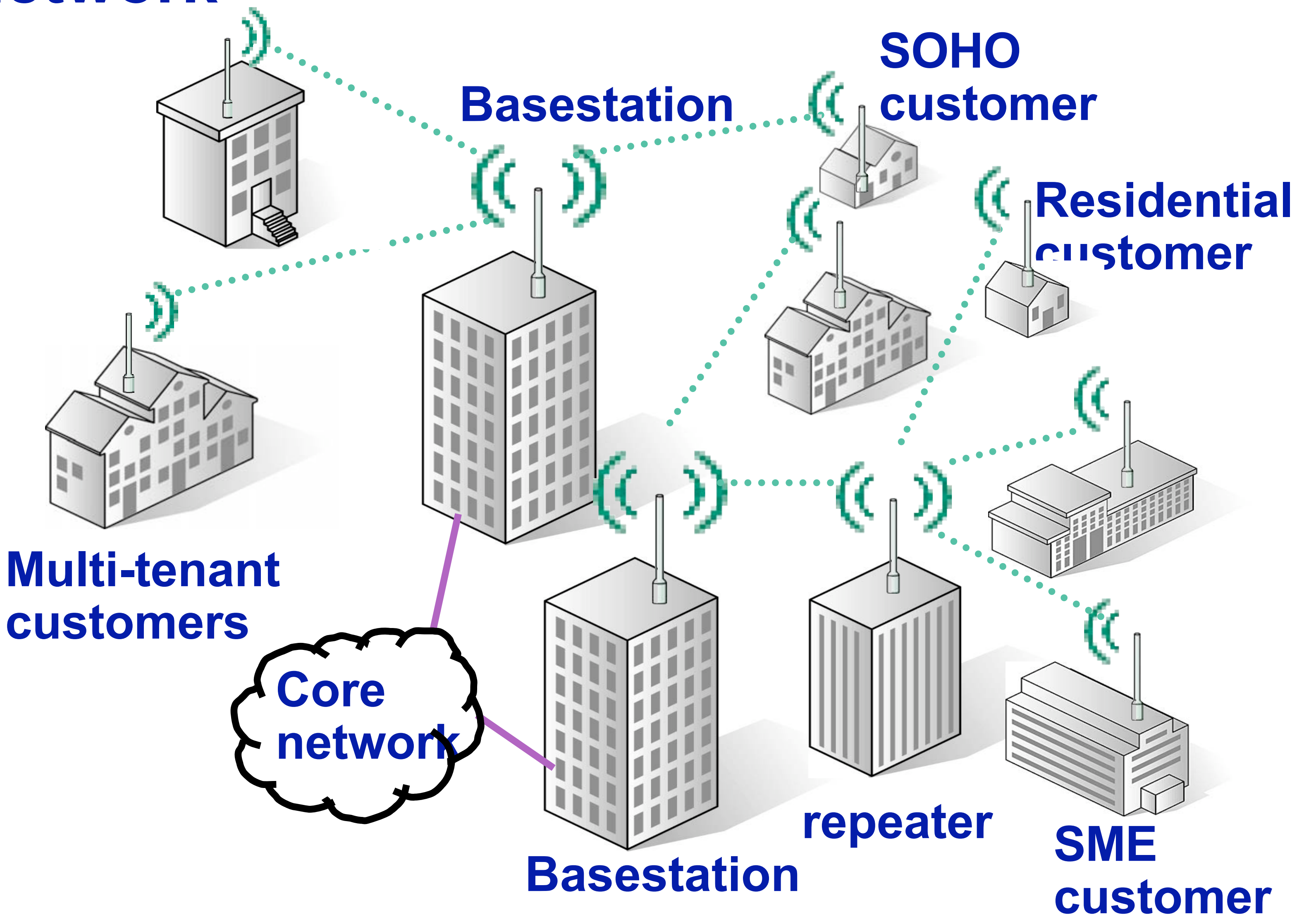
Market Segments for Wireless Access



Broadband Access to Buildings

- The “Last Mile” (or “first kilometer”)
  - 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



Physical Layer Last-Mile Options

- Copper – goes everywhere but does nothing
  - RBOCs own it – strategic dead end
  - Shannon's law – doesn't scale
  - OPEX – provisioning is difficult, costly, inflexible and slow
- Fiber – does everything but goes nowhere
  - Ultimate scalability – gigabits
  - CAPEX/OPEX – provisioning laterals is difficult, costly and slow
- PMP Broadband Wireless – does a lot and goes where you need it
  - Facilities based – spectrum is cheap and available
  - CAPEX low and declining - Moore's law
  - Moore's Law drives wireless CAPX down - Backhoes don't follow Moore's Law

The Solution

- Hybrid Fiber Wireless access infrastructure
  - Use existing fiber infrastructure within cities and extend the footprint with broadband wireless.
  - Fiber build out proves in at ~ $10,000 per building to justify “lighting the building”
  - LMDS Wireless build out justifies “lighting the customer”
  - MMDS Wireless build out proves in at substantially lower cost

Hybrid Fiber Wireless Architecture (HFW)

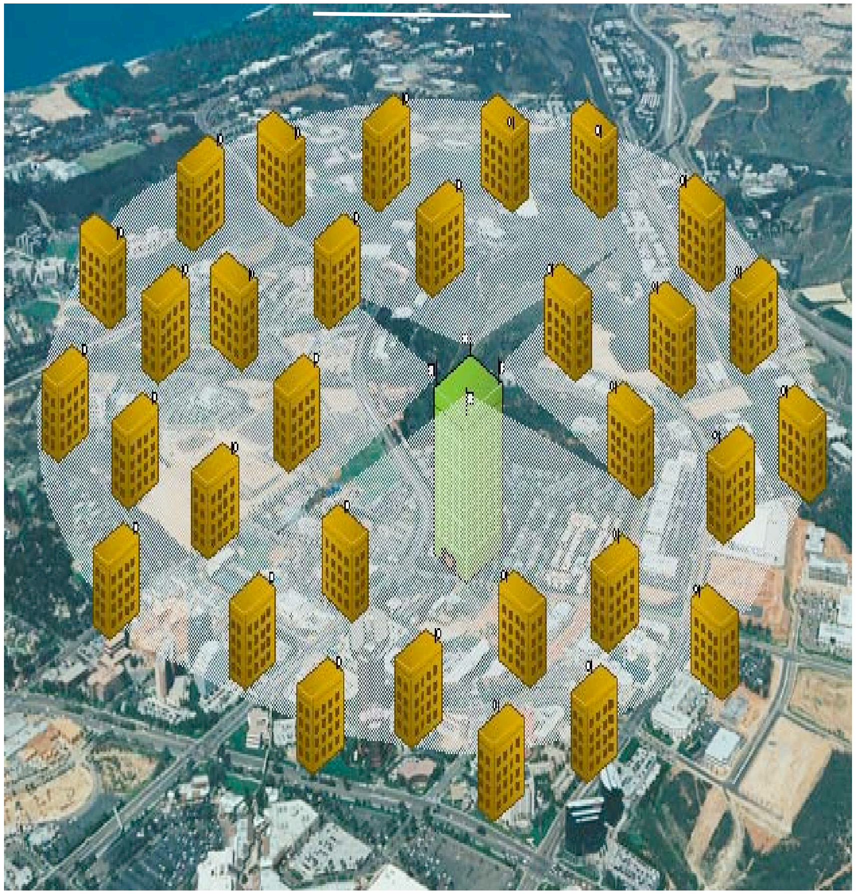
- Extends Fiber footprint 3 – 10+ Km

- Transforms 10% footprint to 90+% footprint without digging a single hole!

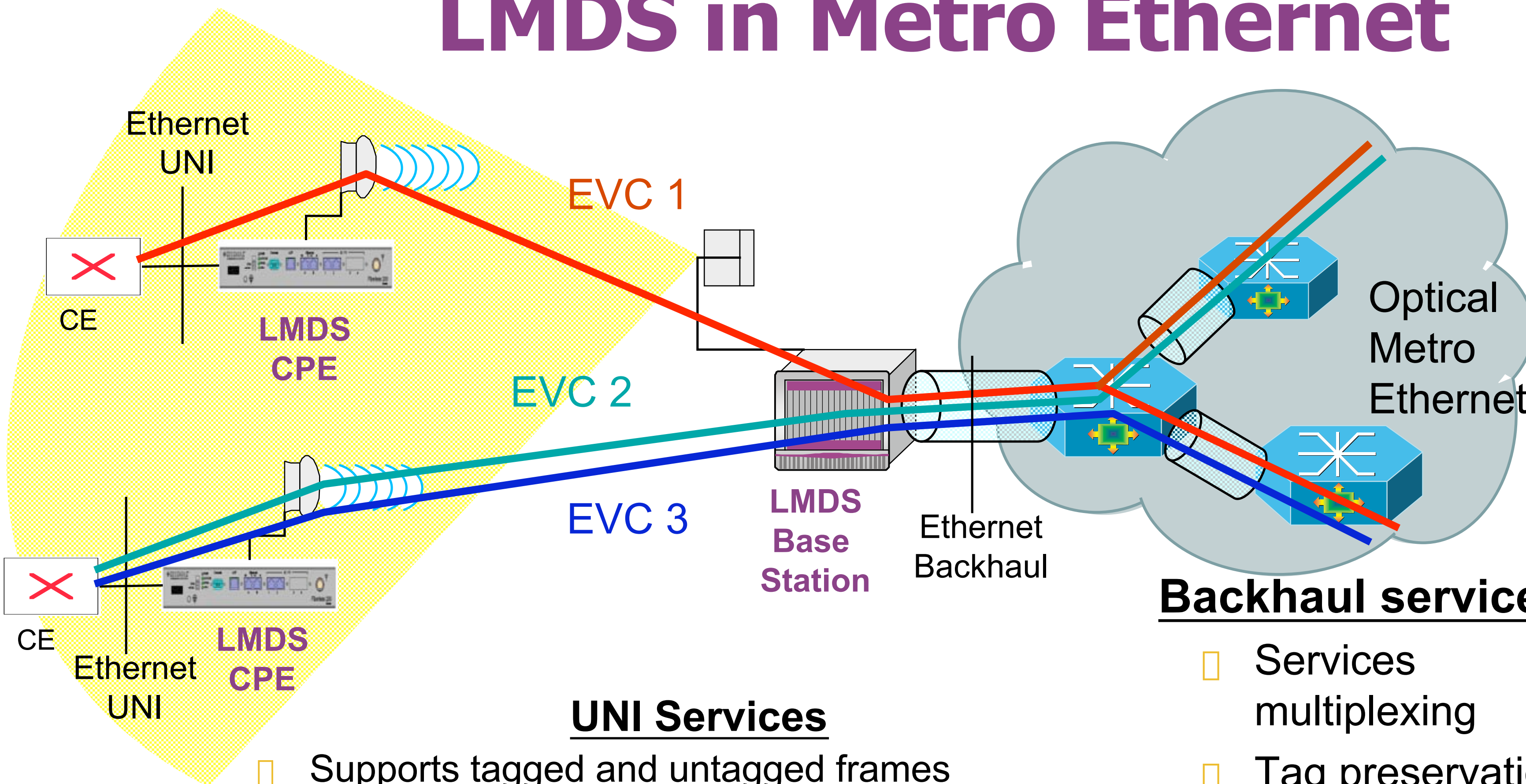
- No outside plant construction

- Full carrier class service offering

- Business model proves in at 1/10th the revenue of fiber



LMDS in Metro Ethernet



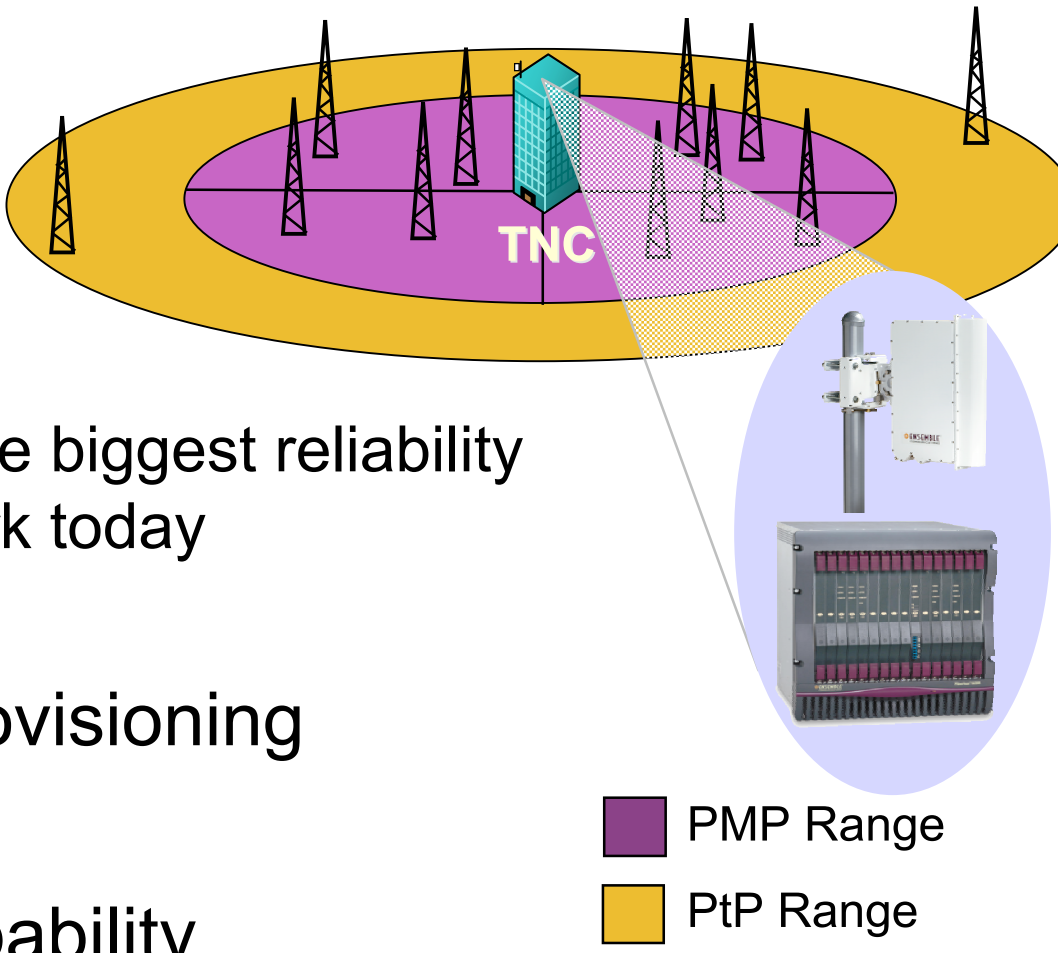
Backhaul services

- Services multiplexing
- Tag preservation
- *Hard* QoS (4 classes of service)

UNI Services

- Supports tagged and untagged frames
- Service multiplexing on the same UNI
- Classification (VLAN id, P-bits or DiffServ/TOS)
- Metering using PIC, CIR and MBS
- *Hard* QoS (4 classes of service)

Wireless tower and hot spot backhaul



- Highly Scalable
- Highly reliable
  - Copper T1's are the biggest reliability issue in the network today
- Simple & quick Provisioning
- Low cost nxT1 capability

Why not just use 802.11?

802.11 is fulfilling a need for data applications

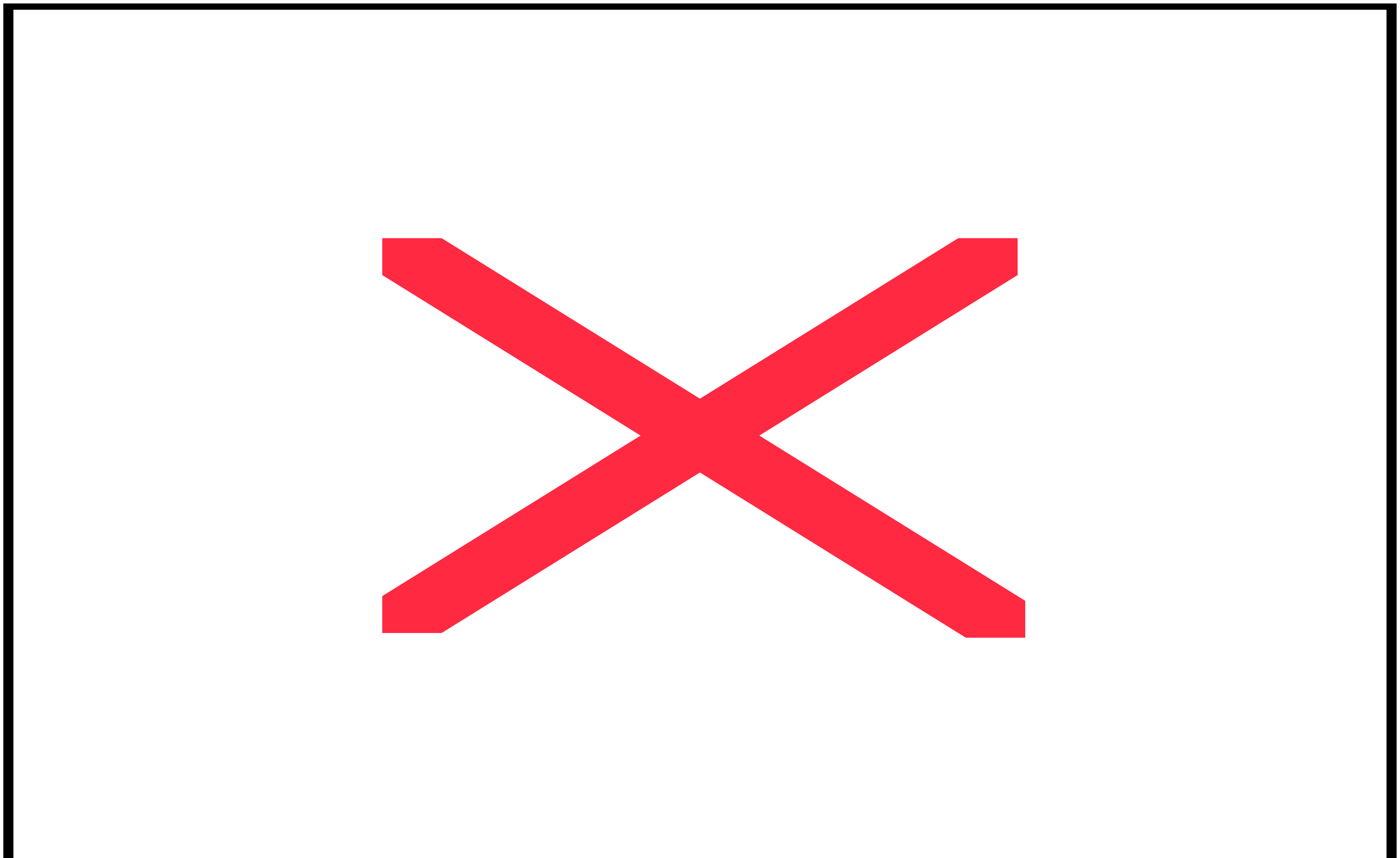
- Where is 802.11 going?
- What applications will it serve?
- Could 802.11 reliably carry multimedia?
- Could 802.11e provide sufficient QoS? 802.11n?
- When will 802.11, the way we know it, break? (QoS, Capacity)

802.16 is the next key disruption

Why 802.16 for Multimedia Wireless Networks?

- 802.16 provides ***True*** QoS
- Allows more efficient use of available spectrum than 802.11
- Better security, authentication, and protection against theft of service
- Possibility to use both licensed and unlicensed frequencies

802.16 Provides TRUE QoS

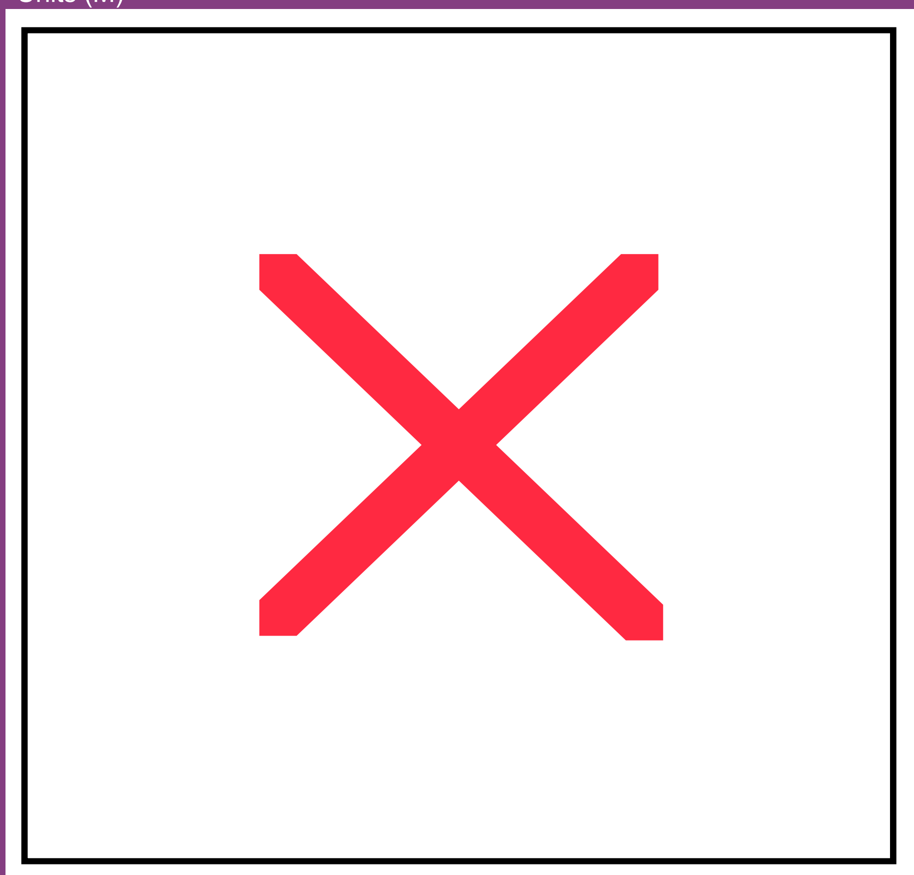


A Mass Market, standards based IEEE 802.16 MMDS SS will:

- Provide an alternative to T1 for small businesses
- Connect homes that are out of DSL/Cable coverage area
- Provide new means to deploy broadband where there is no infrastructure
- Guarantee interoperability
- Attract semiconductor manufacturers
- Achieve cost comparable to a DSL/Cable modem
- Could be subsidized by service providers
- Could offer higher speeds compared to DSL/Cable

Market projections (From Intel WCA Presentation)

Units (M)



Assumptions
- **802.16a MAN standard is adopted**
- **< $350 subscriber station**
- **LAN (Hot Spot) subscribers not included**

A connection can be
- a Hot Spot or Hot Zone serving hundreds or thousands of users
- a business serving all its employees
- a home, some with a wired or wireless network

Source: Intex Management Services research for Intel 12/02. Based upon April ‘02 report, “The WW Market for Broadband Wireless Access, 2002.”

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 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

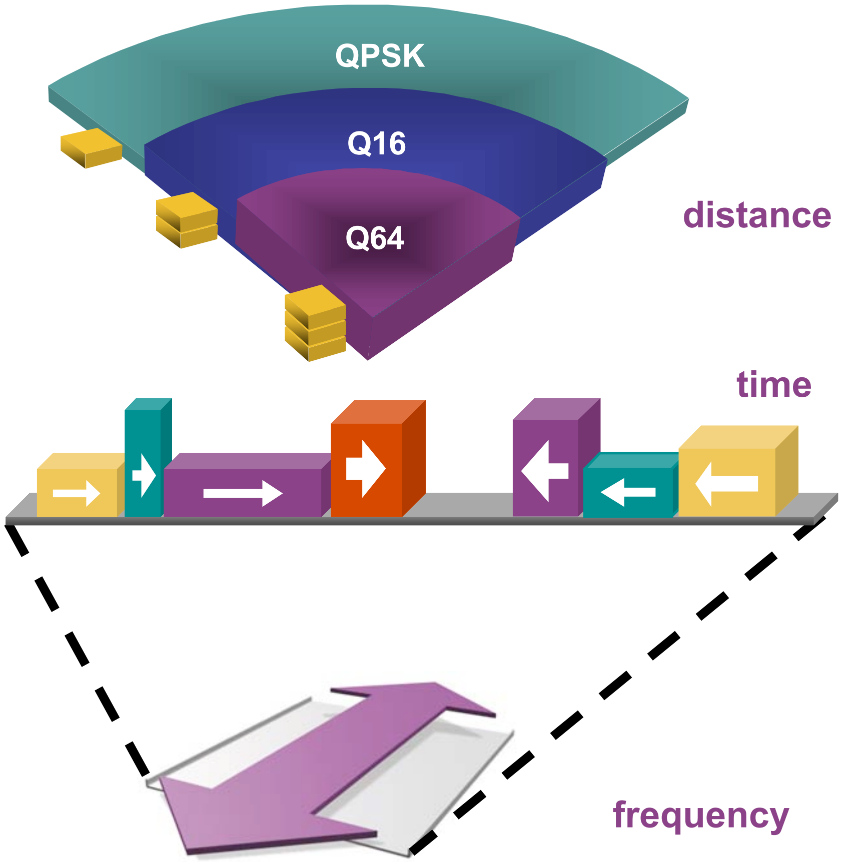
- Broad bandwidth
  - Up to 134 Mbps (>100 Mbps throughput) in 28 MHz channel (in 10-66 GHz air interface)
- Supports multiple services simultaneously with full QoS
  - Efficiently transport IPv4, IPv6, ATM, Ethernet, etc.
- Bandwidth on demand (frame by frame)
- MAC designed for efficient used of spectrum
- Comprehensive, modern, and extensible security
- Supports multiple frequency allocations from 2-66 GHz
  - ODFM and OFDMA for non-line-of-sight applications

Properties of IEEE Standard 802.16

- 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.

IMPACT OF THIRD-GENERATION PMP TECHNOLOGIES

3rd Gen. Technology in 802.16



Adaptive Modulation

variable modulation maximizes both air-link capacity and coverage

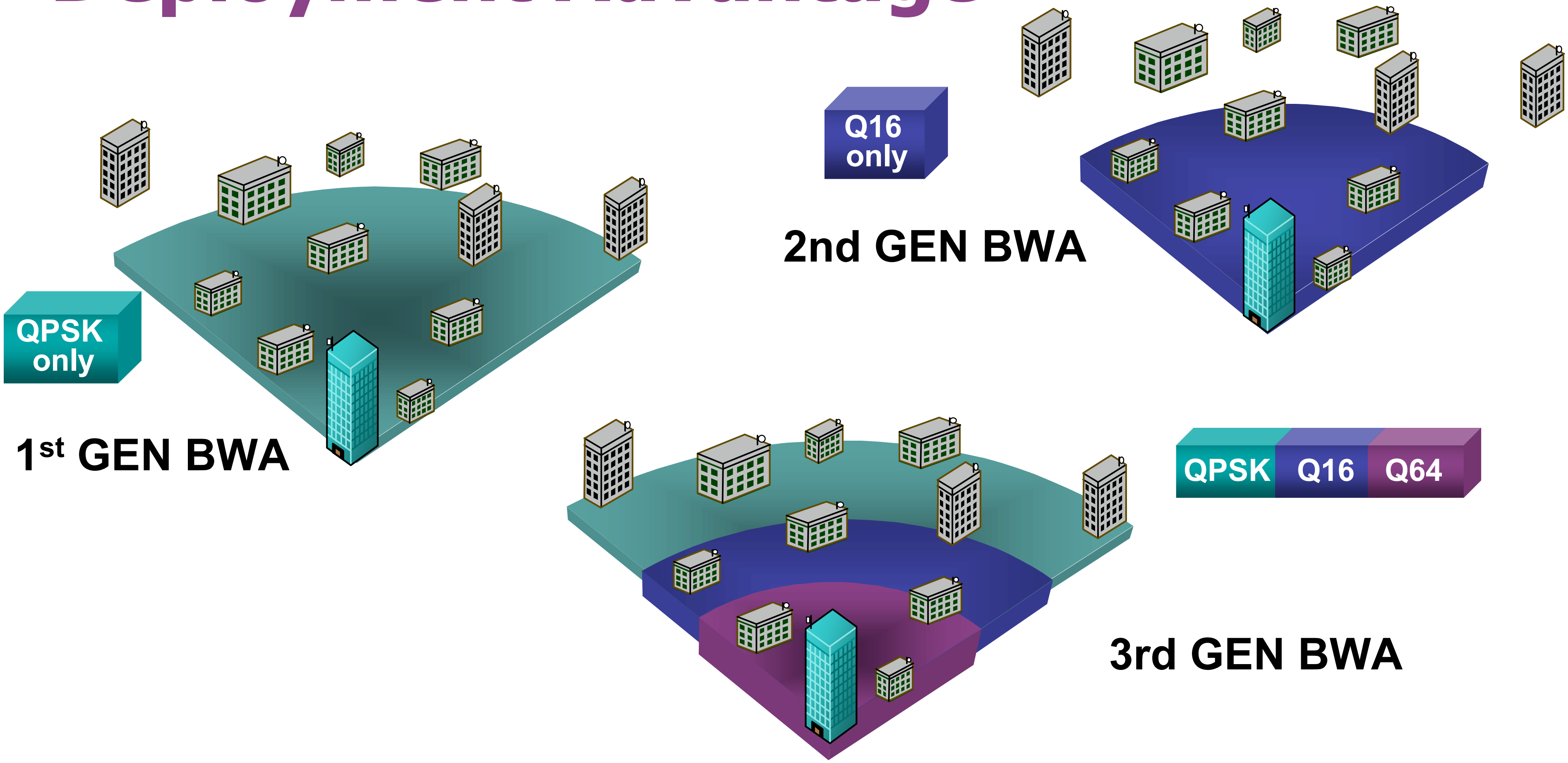
Adaptive TDMA

True bandwidth on demand and variable packet sizes provide differentiated, bursty services to multiple users

Adaptive TDD

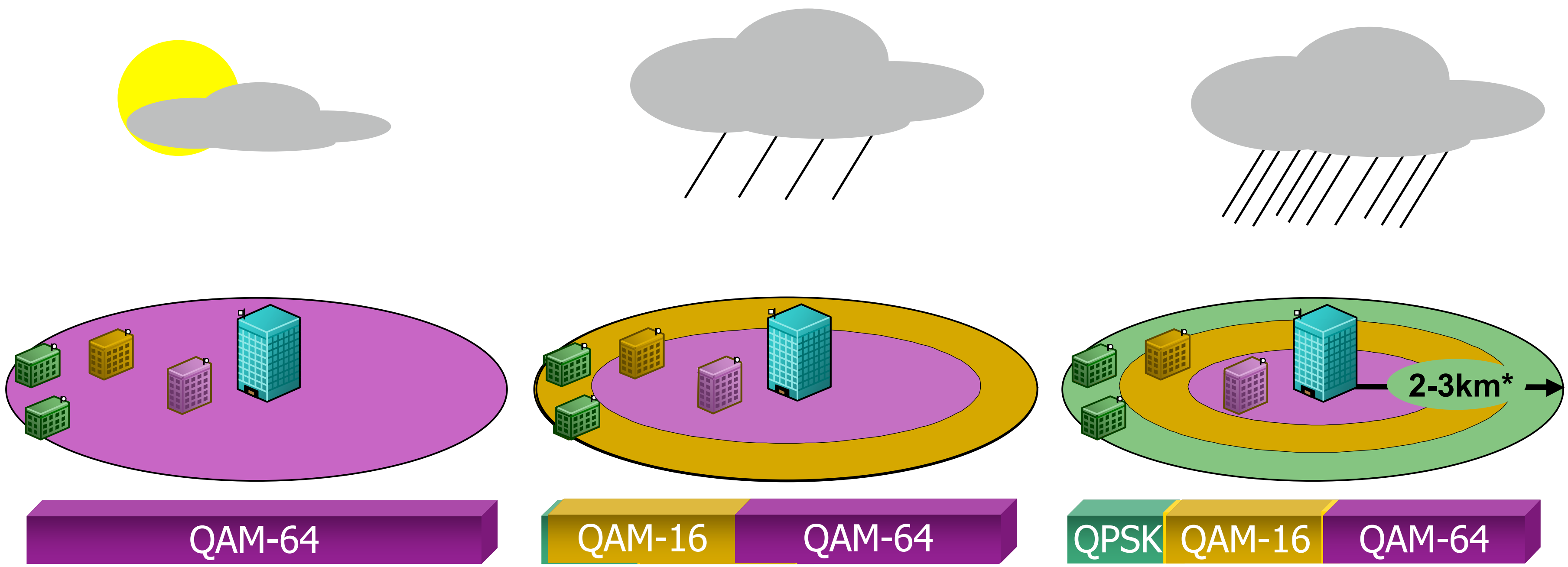
variable asymmetry in a single broadband channel best matches bandwidth to demand

Deployment Advantage



More than 2x Capacity & 2x Coverage with Adaptive Modulation

Coverage/Capacity Advantage of Adaptive PHY

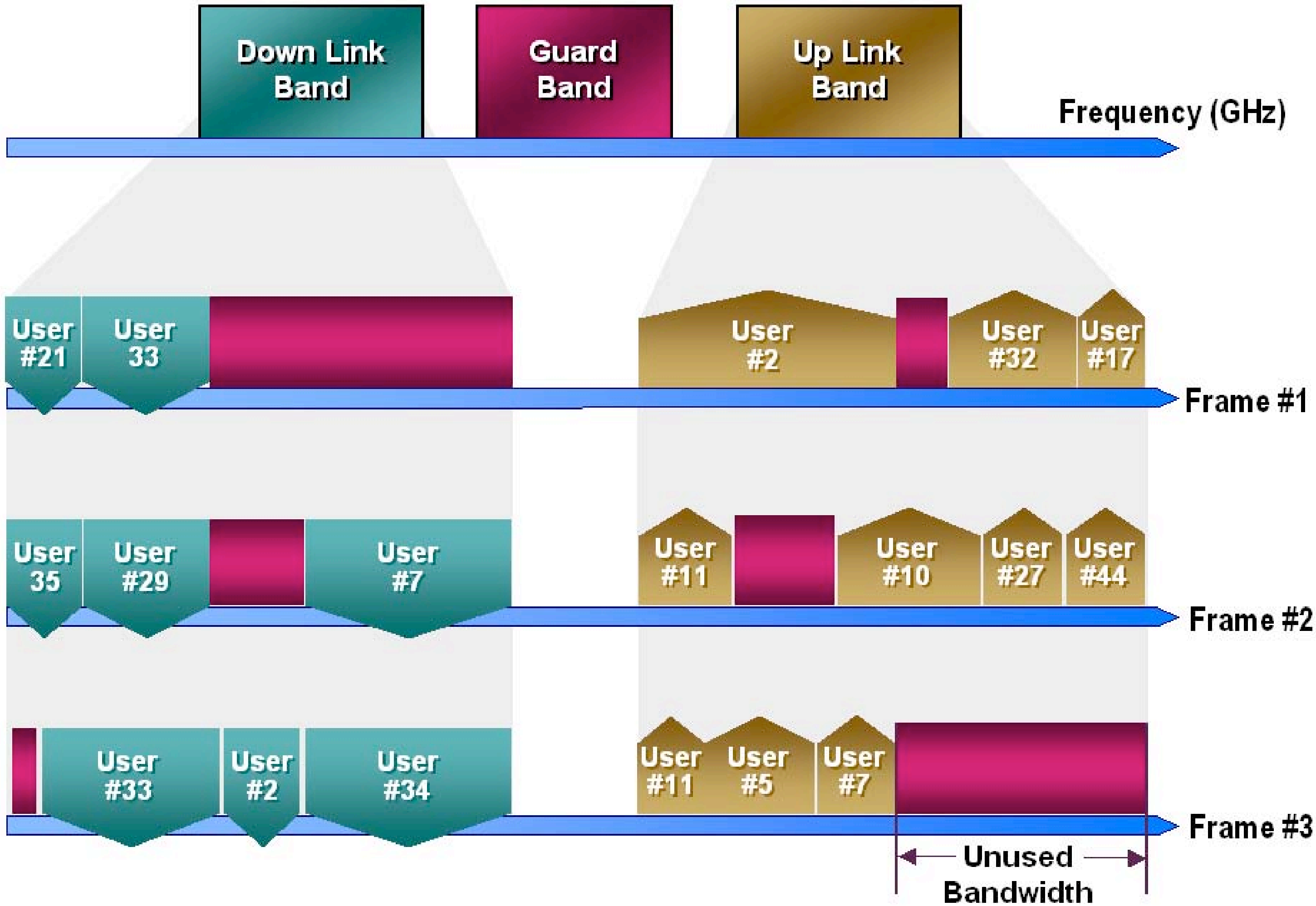


100% of Channel Capacity	85% of Channel Capacity	70% Channel Capacity
99.95%*	99.993%	99.999%,
~ 364 days 19.5 hrs/yr	~ 4 hrs/yr	~ 20 min/yr

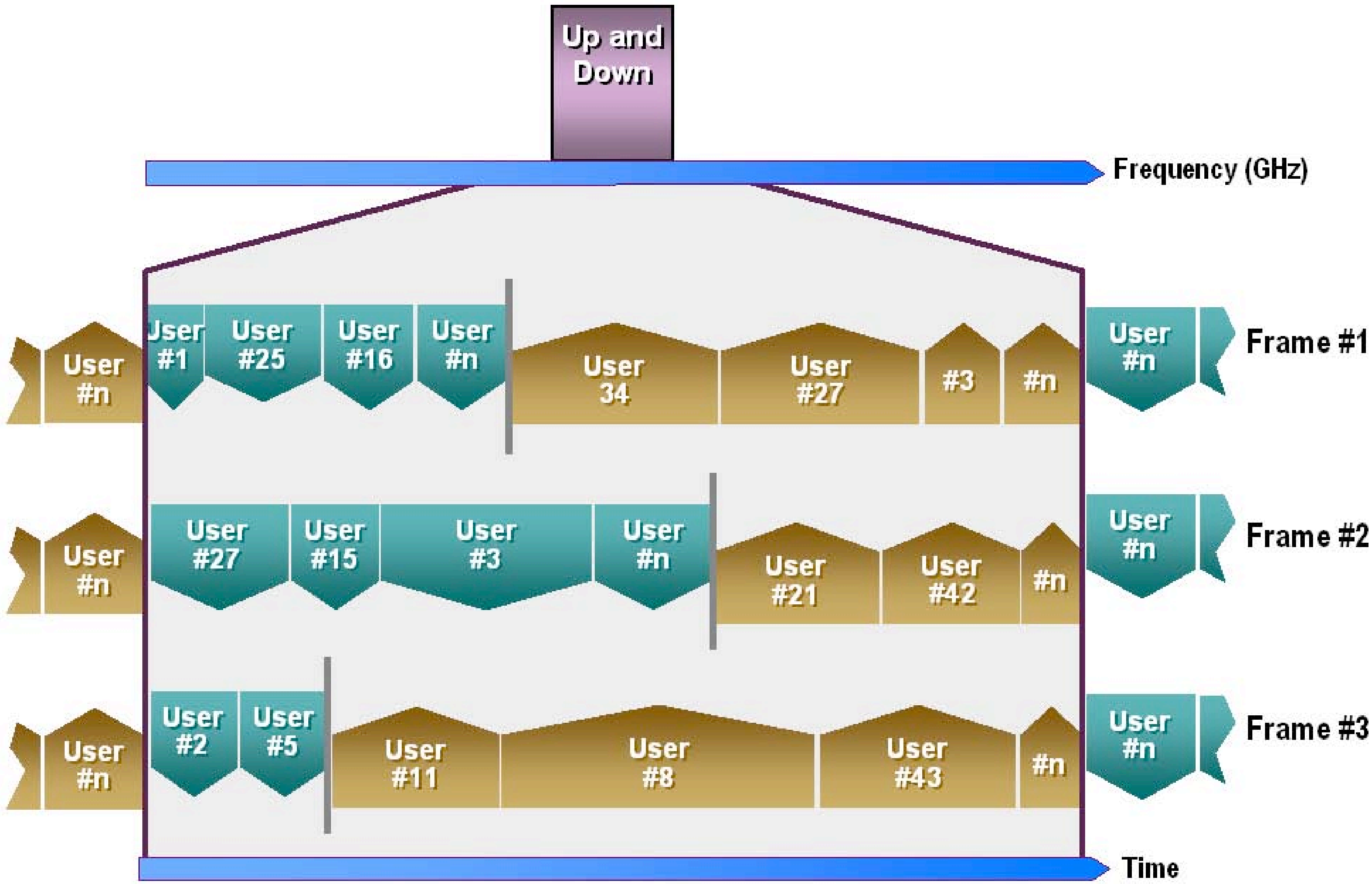
Modulation changes dynamically to match propagation path conditions

** Typical for .01% rain rate 40-50 mm/hr at 28GHz (egg. Chicago. SFO is about 35mm/hr)*

Dedicated, Fixed Symmetry with FDD

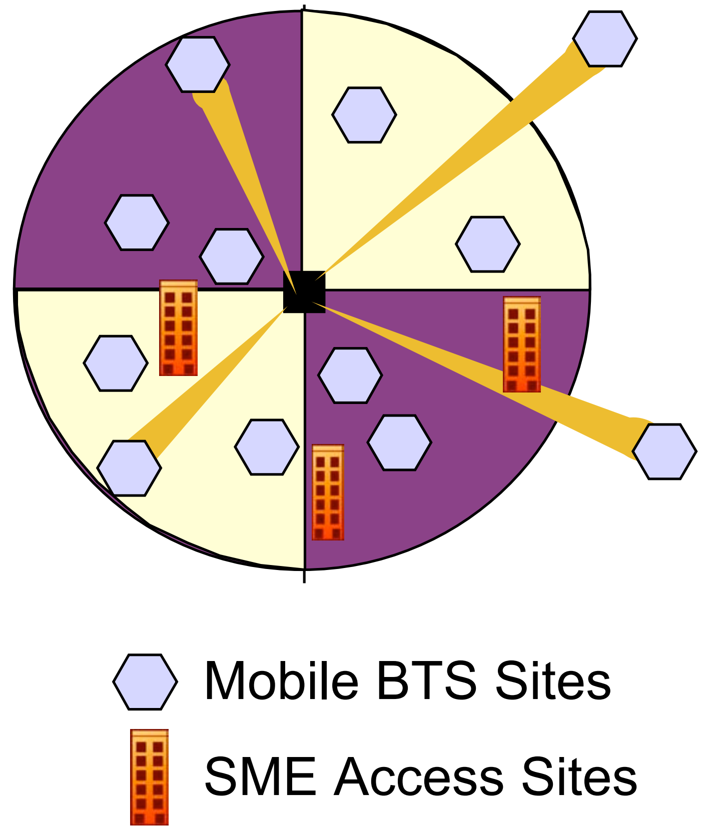


Spectral Efficiency with Adaptive TDD

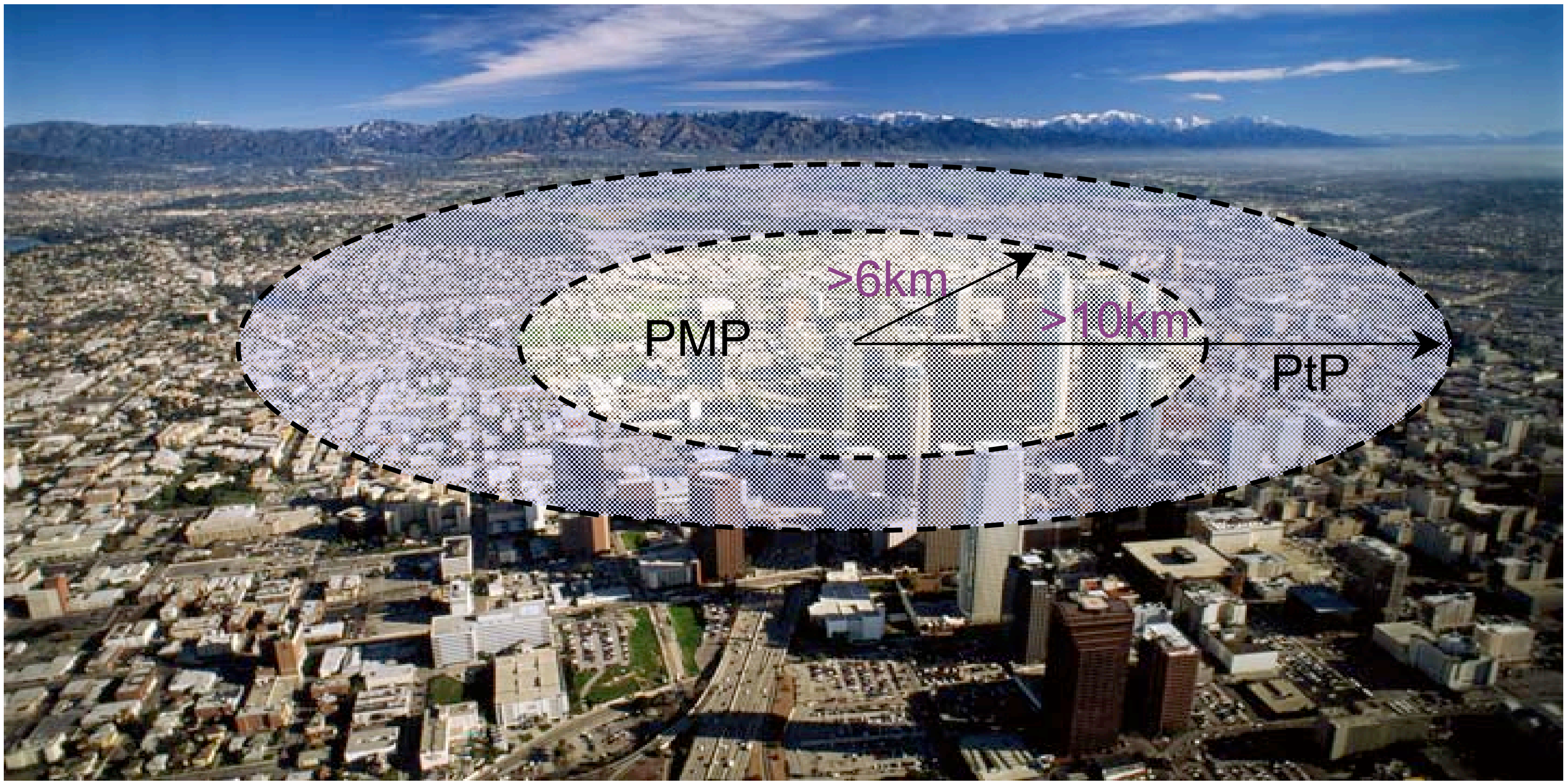


802.16 Supports PMP and PtP Links

- High system gain for maximum coverage and availability
- Capacity for access as well as mobile backhaul
- Use PtP links for extended range (~50%)



Coverage of Downtown L.A.



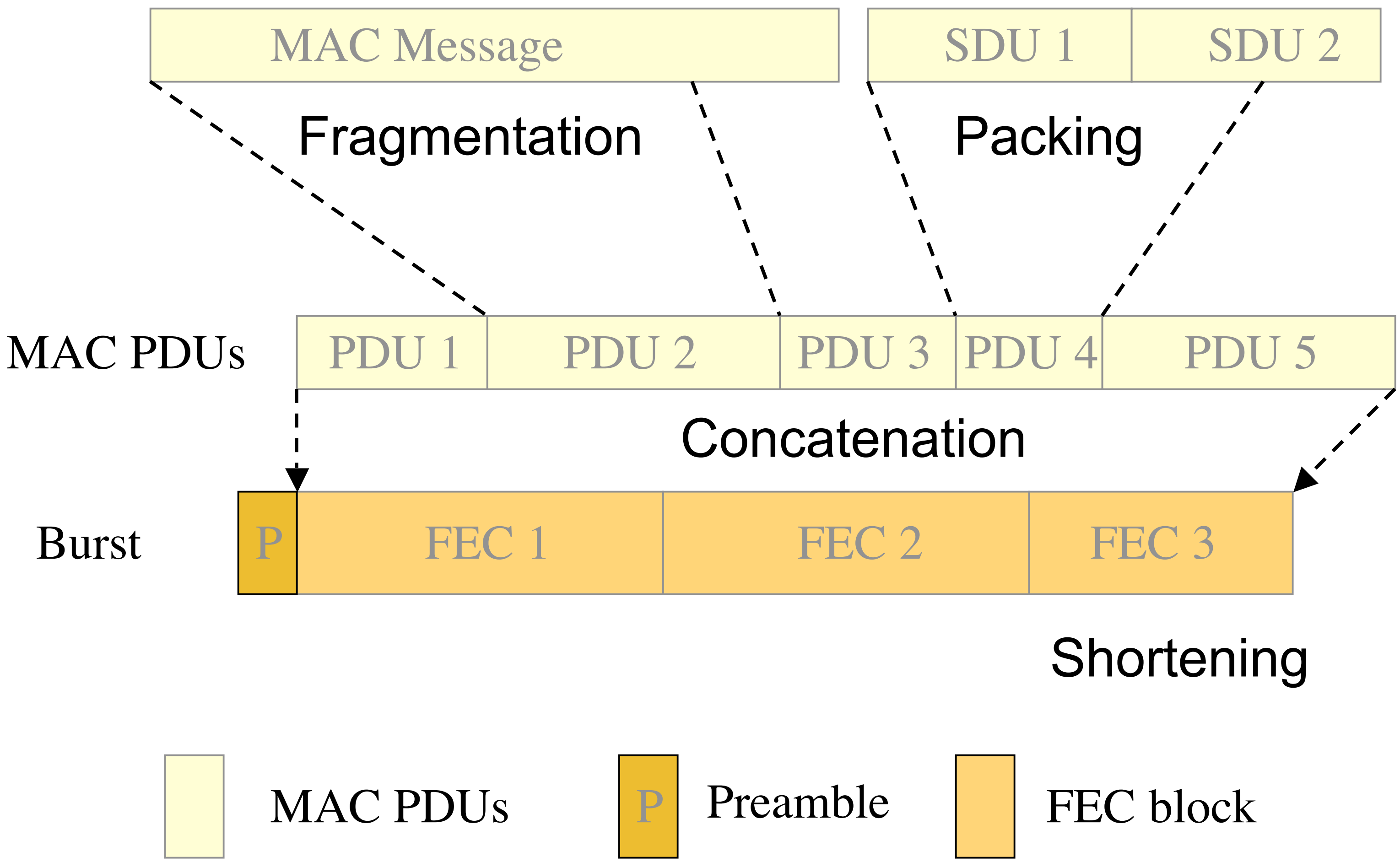
Sufficient range to cover entire downtown area

IEEE 802.16
MAC Details

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

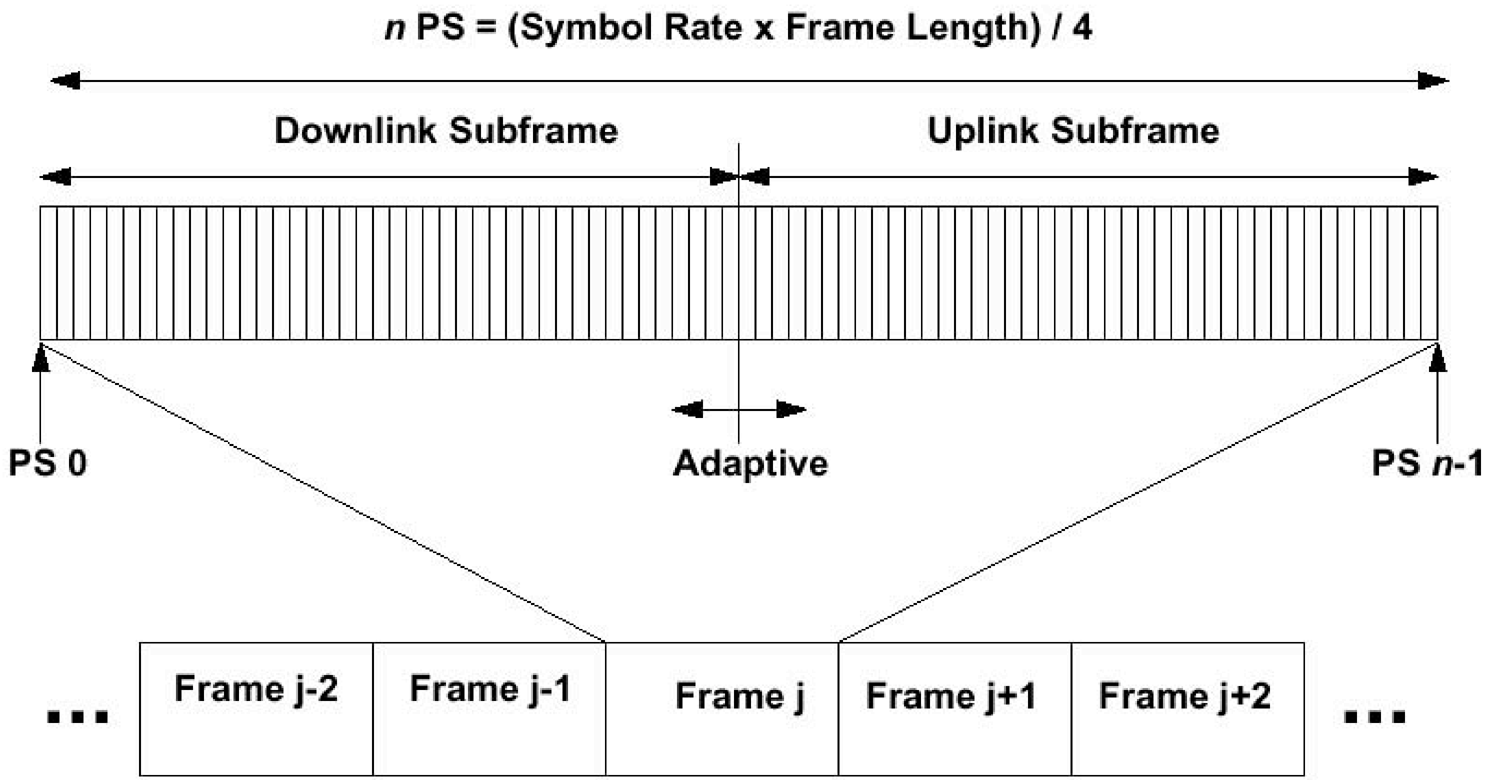


Multiple Access and Duplexing

- 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)



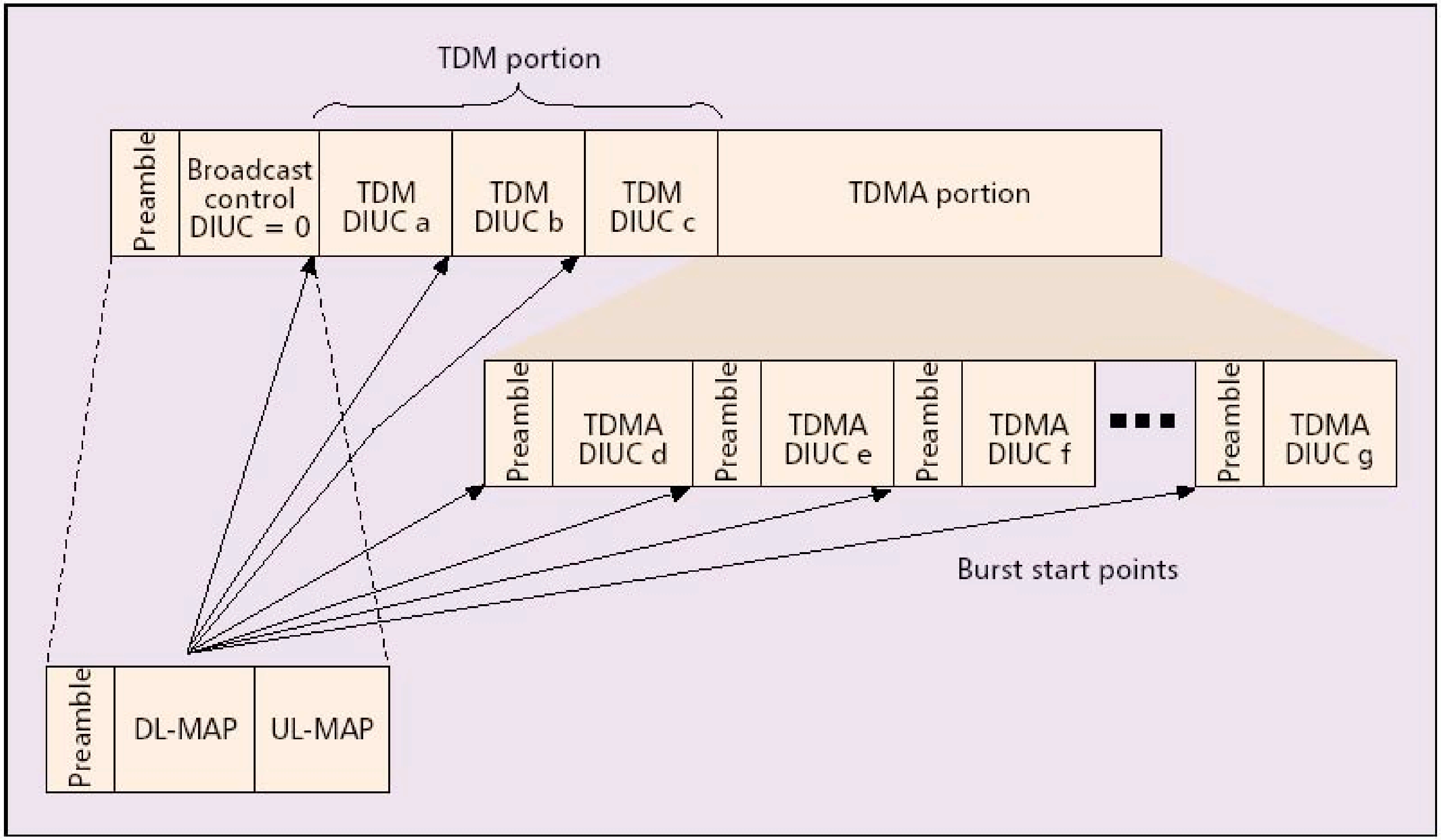
Frame duration: 1 ms

Physical Slot (PS) = 4 symbols

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

Downlink Subframe



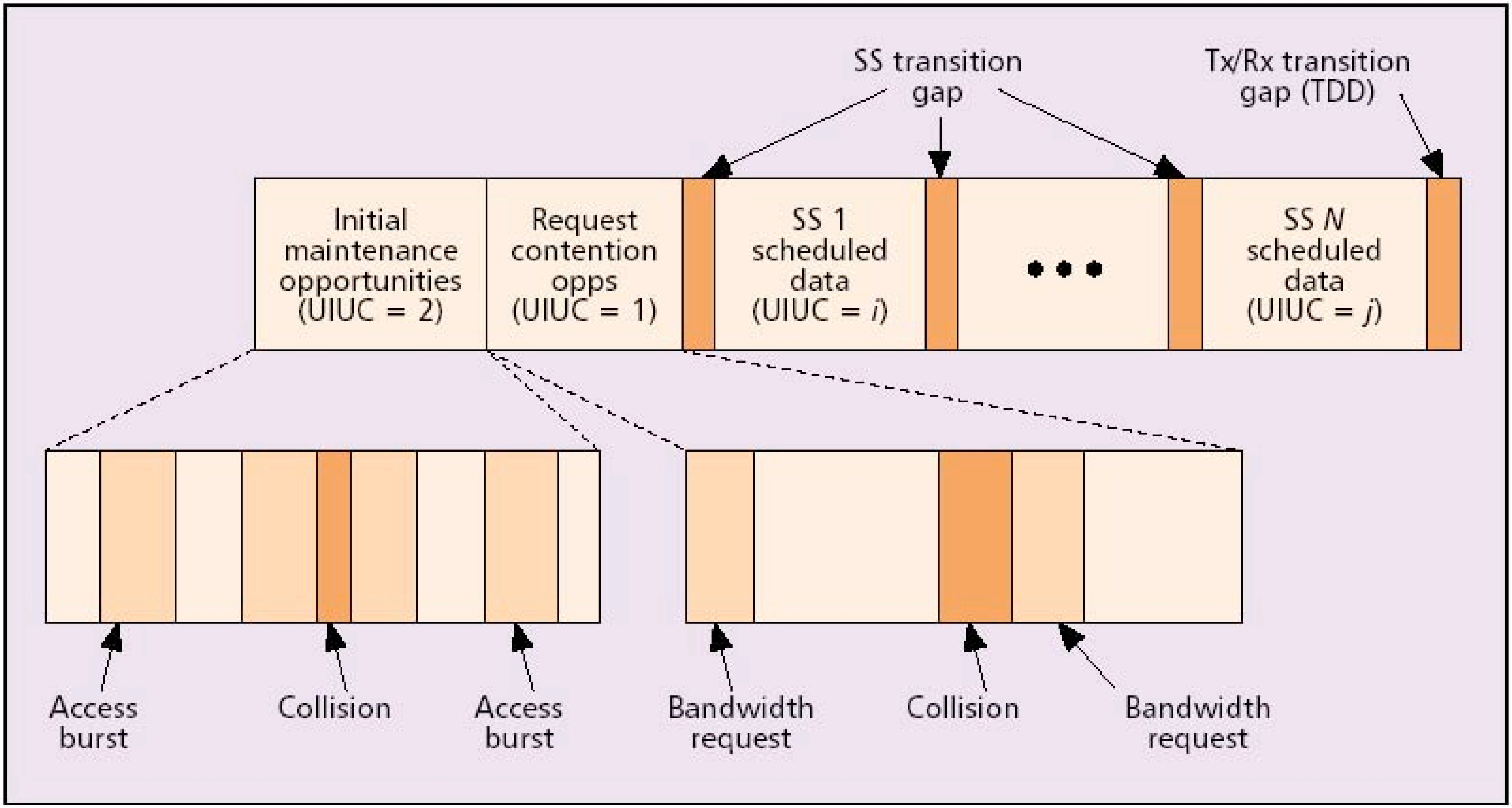
TDMA portion: transmits data to some half-duplex SSs (the ones scheduled to transmit earlier in the frame than they receive)

- Need preamble to re-sync (carrier phase)

Request/Grant Scheme

- Self Correcting
  - No acknowledgement
  - All errors are handled in the same way
- Many ways to request bandwidth
  - Unicast Polling
  - Multicast and Broadcast Polling
  - “Bandwidth Stealing”
  - Poll-me bit
  - Piggybacked Request

Typical Uplink Subframe



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.

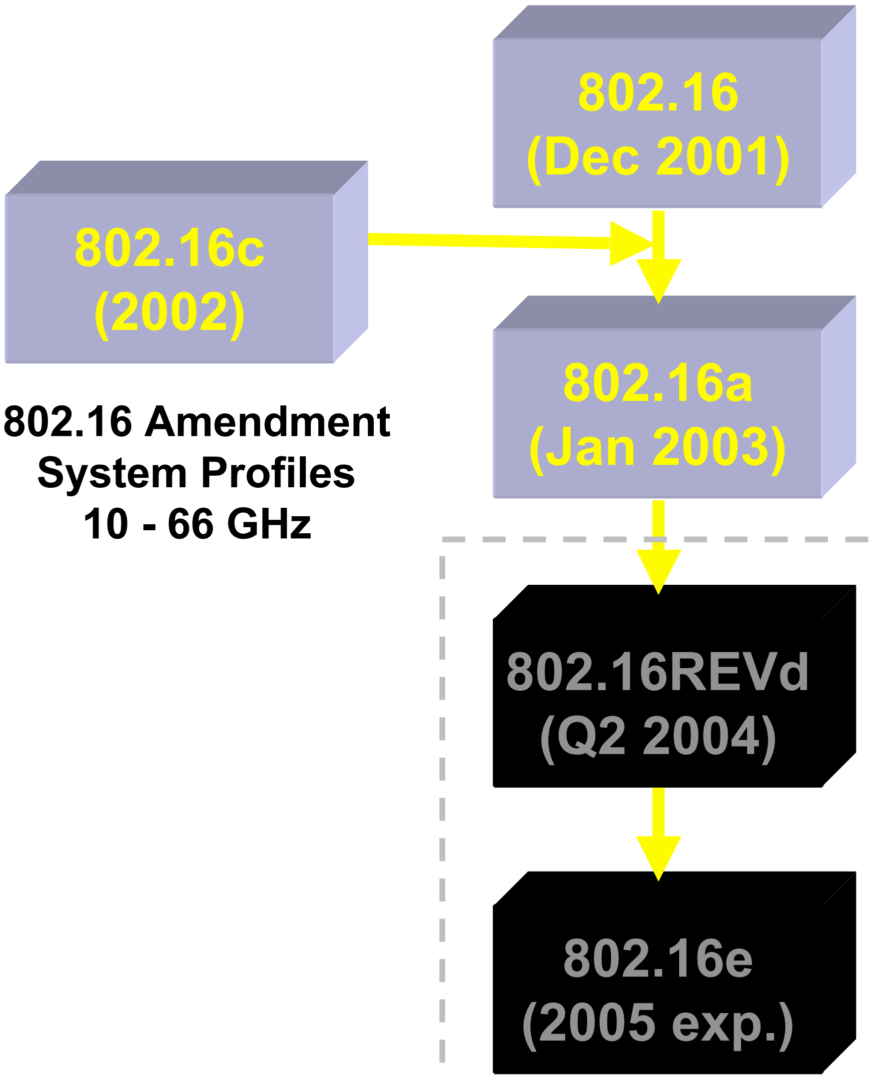
IEEE 802.16 Working Group

IEEE 802.16 Leadership

- Chair: Roger Marks
- Vice Chair: Ken Stanwood
- Secretary: Dean Chang

- TGC Chair: Ken Stanwood
- TGd Chair: Gordon Antonello
- TGe Chair: Brian Kiernan

802.16 Standards Genealogy



802.16 (Dec 2001)
- Original fixed wireless broadband air Interface for 10 – 66 GHz
- Line-of-sight only, Point-to-Multi-Point applications

802.16a (Jan 2003)
- Extension for 2-11 GHz
- Targeted for non line of sight, Point-to-Multi-Point applications like “last mile” broadband access

802.16REVd (Q2 2004)
- 802.16 Revision PAR for 802.16 & 802.16a/c to add System Profiles and Errata for 2-11 GHz in support of 802.16e requirements

802.16e (2005 exp.)
- Amendment for Mobile wireless broadband up to vehicular speeds in licensed bands from 2-6 GHz
- Enables roaming for portable clients (laptops) within & between service areas

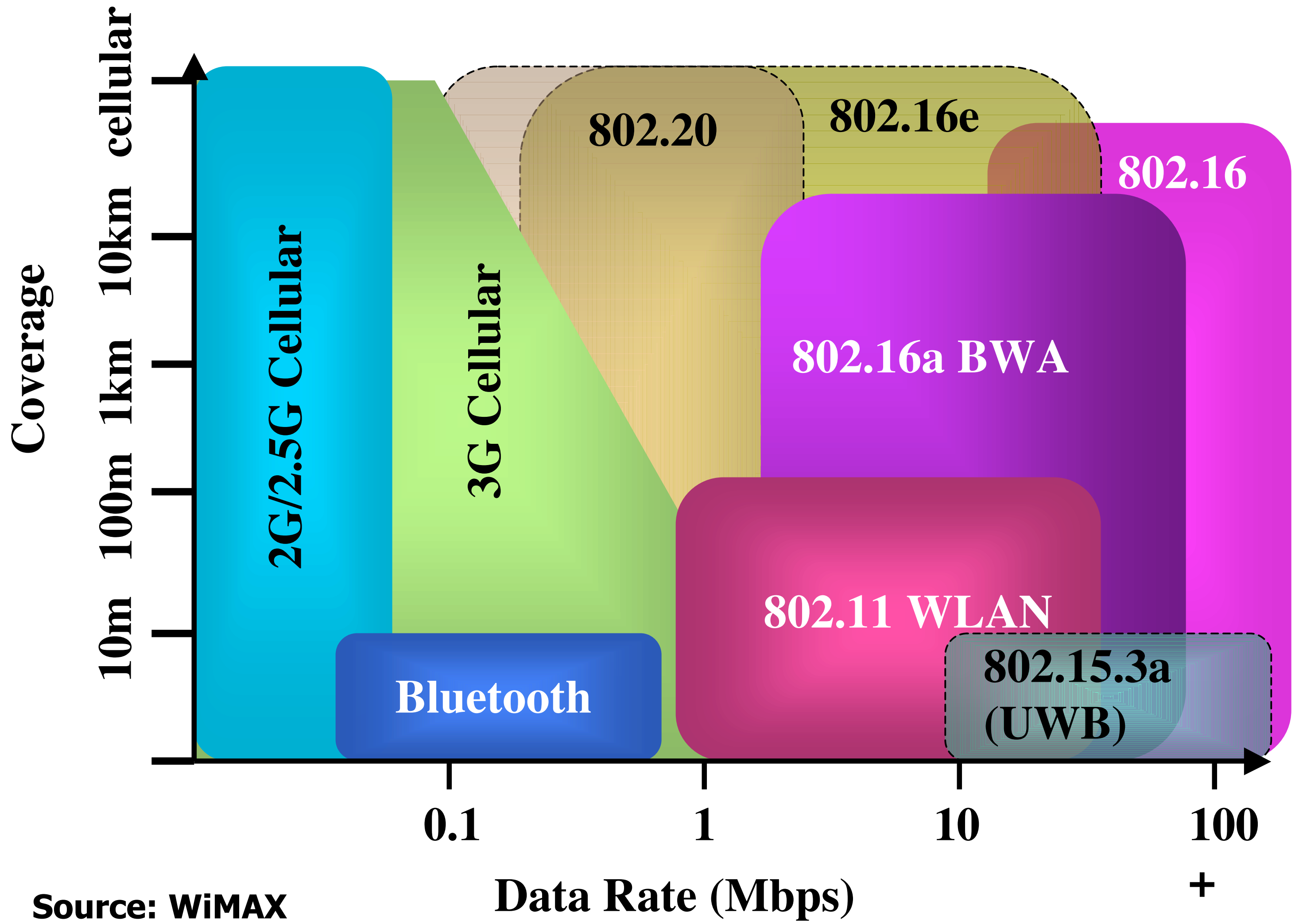
802.16a PHY Alternatives: Different Applications, Bandplans, and Regulatory Environments

- 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

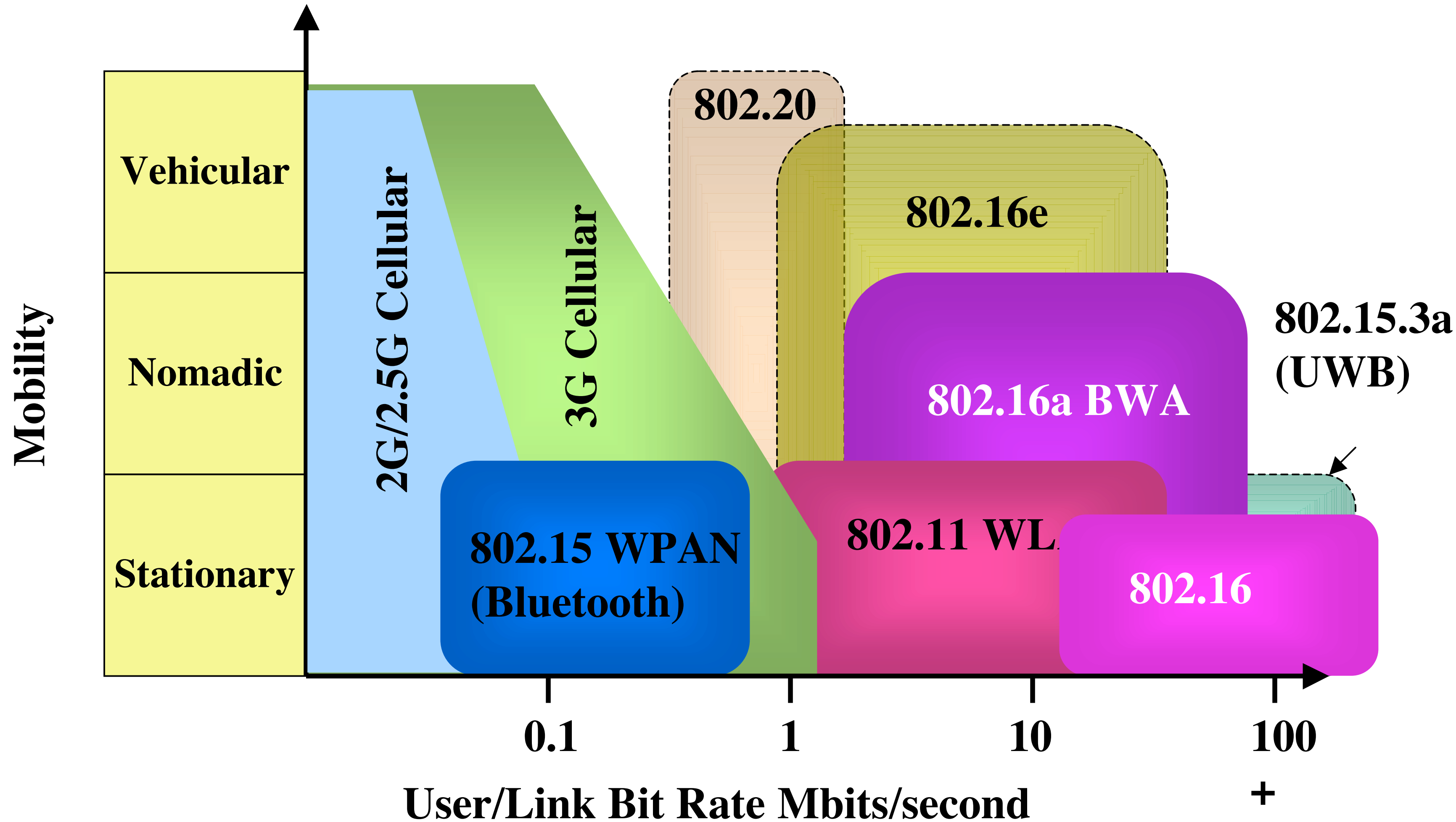
- OFDM/OFDMA Support
- ARQ
- Dynamic Frequency Selection (DFS)
  - license-exempt
- Adaptive Antenna System (AAS) support
- Mesh Mode
  - Optional topology
  - Subscriber-to-Subscriber communications

Wireless Standards



Source: WiMAX

Wireless Standards



Source: WiMAX

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
  - PHY Harmonized in Nov 2003
- ETSI HIPERMAN
  - Below 11 GHz
  - IEEE began first
  - Healthy cooperation
  - Harmonized with 802.16a OFDM

802.16 and ITU

- ITU-T January 2004:
  - 802.16 approved as draft recommendation for wireless extension of cable operator footprint.
- ITU-R November 2004:
  - liaison statement
  - Return statement from 802.16
  - Working towards ITU BWA recommendation

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)
- meetings in:
  - Finland
  - Korea
  - China
- Coordinated European efforts in ETSI

wimax

WiMAX Purpose

- To promote a common broadband wireless standard
- To develop reduced scope “profiles” to ease development
- To fill the gaps in the IEEE process relative to the ETSI process
- To create a broadband wireless access conformance and interoperability certification process
- To act as a certification body

Filling the Gaps - System profiles

- Allow scope reduction while maintaining interoperability
- Targeted towards common market opportunities
- The most common system implementations

Filling the Gaps – Test Specifications

- “ETSI-style” ISO/IEC 9646 compliant test specifications
  - PICS proforma
  - Test Suite Structure and Test Purposes (TSS&TP)
  - Radio Conformance Test (RCT) Specification
  - Abstract Test Suite (ATS)

WiMAX History

- First meeting April 2001 in Antibe, France
- Founding companies:
  - Ensemble
  - Nokia
  - Harris
  - CrossSpan
- Initially concentrated on 10-66 GHz
- Huge expansion started in Jan 2003
  - Intel PR engine

WiMAX Evolution

- 10-66 GHz work winding down
  - Profiles in 802.16c
  - PICS Proforma Approved
  - TSS&TP Approved
  - RCT in sponsor ballot
  - Still need Abstract Test Suite
- Technical work now concentrating on 2-11 GHz
  - Profiles in 802.16-REVd
  - PICS Proforma being submitted to IEEE 802.16
- Progressing towards certification process

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 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

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Roger B. Marks, National Institute of Standards and Technology
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