The IEEE 802.16 WirelessMAN™ Standard: A New Foundation for Broadband Wireless Access

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Roger Marks

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Purpose:

To inform the Working Group concerning an address on IEEE 802.16 given by the Working Group Chair at the 2002 International Conference on Telecommunications (23-26 June 2002 in Beijing, China).

The IEEE 802.16 WirelessMAN™ Standard:
A New Foundation for
Broadband Wireless Access

IEEE
WirelessMAN™
802.16

http://WirelessMAN.org

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Chair, IEEE 802.16 Working Group

Appreciation

- To ICT 2002 for "Bridging East and West through Telecommunication"

- To the Beijing University of Posts and Telecommunications for hosting a wonderful ICT 2002

- To Prof. Liu Yuan An for inviting me to speak here about IEEE 802.16

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 (in progress)
                          Licensed
                          License-Exempt
  - MBWA: Mobile Broadband Wireless Access Study Group
- 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 want it

    - Data

    - Voice

    - Video distribution

    - Real-time videoconferencing

    - etc.

- High-capacity cable/fiber to every user is expensive

    - Construction costs do not follow Moore's Law

WirelessMAN: Wireless Metropolitan Area Network

Basestation

SOHO customer

Residential customer

Multi-tenant customers

Core network

Basestation

repeater

SME customer

Source: Nokia Networks
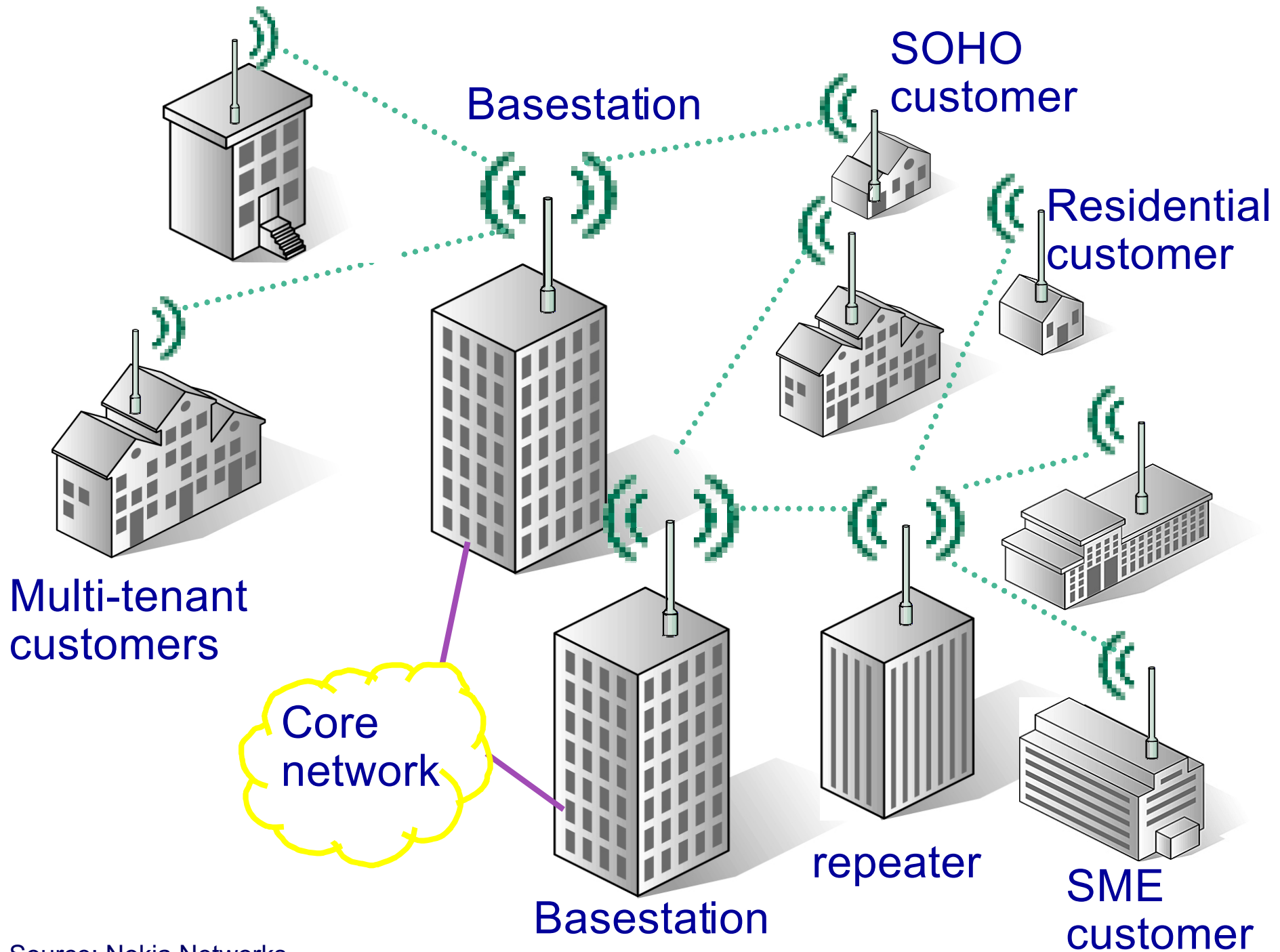
Properties of IEEE Standard 802.16

- Broad bandwidth: 25 and 28 MHz
  - Up to 134 Mbit/s 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 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?

Millimeter-Wave Bands for Wireless MAN

- Around 1 GHz spectrum in many countries

- Line-of-sight propagation

- Hub radius: a few kilometers

- In each 50 MHz, at each hub:

    – 3 Gbit/s

    – e.g. 64 customer sites at 45Mbit/sec each

    – up to 5000 sites/hub

- U.S. LMDS allocation includes 26 such 50 MHz blocks!

LMDS Band Allocation
(Local Multipoint Distribution Service)

28 & 31 GHz Band Plan

27.50	28.35	28.60	29.10	29.25	29.50	30.00	31.075	31.225

| LMDS* (850 MHz) | GSO/FSS* (250 MHz) | NGSO/FSS* (500 MHz) | MSS Feeder Links* & LMDS/ (150 MHz) | MSS Feeder Links & GSO/FSS* (250 MHz) | GSO/FSS* (500 MHz) | LMDS* non-itts (150 MHz) |

31.00 — 31.30

LMDS & NON-LTTS*
(75 MHz each)
Co-primary with incumbent
point-to-point licensees
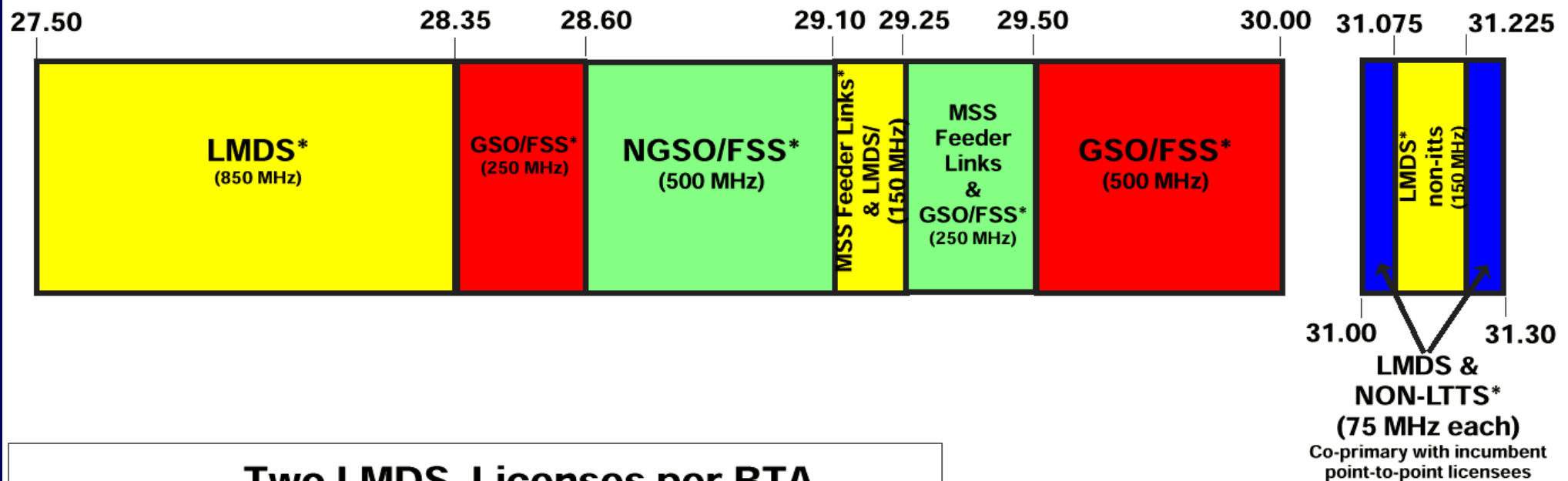
Two LMDS Licenses per BTA

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

Block B - 150 MHz: (blue)
31,000-31,075 MHz
31,225-31,300 MHz

Legend
"*" - Primary Service
FSS - Fixed Satellite Service
GSO - Geostationary Orbit
NON-LTTS - Non-Local Television Transmission Service
MSS - Mobile Satellite Service
NGSO - Non-Geostationary Orbit

Wireless Broadband Networks

Lucent Technologies
Bell Labs Innovations

Summary: WW Spectrum for BWA

Country	10 GHz ETSI	18-24 GHz	24 GHz DEMS	26 GHz ETSI	25-27 GHz	27.5-29.5 GHz	28 GHz Like US	31 GHz	38 GHz US	38 GHz ETSI	38 GHz Other
PMP Frequency Bands											
North America											
USA			X				X	X	X		
Canada			X		X		X		X		
Asia Pacific											
Australia							X	X			
Japan		X			XU						X
Korea					XU						
Malaysia	P										
New Zealand					X						
Philippines	X	X?			X		X				
Singapore						X?	X				
Taiwan				X							X
Thailand						X					
Central & South America											
Argentina	X		X		X		X	X	X		
Bolivia							X				
Brazil	P			P							
Chile					X		X				
Colombia					X		X				
Ecuador						X					
Mexico	X			X							
Paraguay						X					
Peru						X					
Venezuela						X					

CEPT Recommendation for Europe of 40.5-42.5 and 42.5-43.5 GHz not considered

Wireless Broadband Networks

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PMP Frequency Bands											
Europe, Middle East, Africa											
Czechoslovakia						X					
France						T					
Germany				X							
Hungary				X							
Ireland				X							
Israel				P?							
Netherlands				X							
Norway				X							
Poland						X					
Romania							X				
South Africa						X					
Spain				X			X	X			
United Kingdom	X										

CEPT Recommendation for Europe of 40.5-42.5 and 42.5-43.5 GHz not considered

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

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)

June 2002: trial 3.5 GHz wireless access service authorized in 5 cities (Nanjing, Xiamen, Qingdao, Wuhan and Chongqing)

802.16 and ETSI

- Over 50 liaison letters between 802.16 and ETSI

- ETSI HIPERACCESS
  - Above 11 GHz
  - ETSI began first, but IEEE finished first
  - 802.16 has encouraged harmonization
  - BRAN is discussing harmonization efforts

- ETSI HIPERMAN
  - Below 11 GHz
  - IEEE began first
  - Signs of healthy cooperation
  - Selected 802.16 MAC/802.16a OFDM PHY as baseline

IEEE 802.16 History

- Project Development: 1998-1999

- Meet every two months:
  - Session #1: July 1999
  - Session #19: May 2002

- Future Sessions
  - Session #20/July 2002: Vancouver, Canada
  - Session #21/Sep 2002: Cheju, Korea
  - Session #22/Nov 2002: Hawaii, USA

IEEE 802®
The LAN/MAN Standards Committee
[sponsor: IEEE Computer Society]

Wired:

– 802.3 (Ethernet) {10 Gbit/s approved in June 2002}

– 802.17 (Resilient Packet Ring)

Wireless:

– 802.11: Wireless LAN

- Local Area Networks

– 802.15: Wireless PAN

- Personal Area Networks {e.g., Bluetooth=IEEE 802.15.1}

– 802.16: WirelessMAN^{TM}

- Metropolitan Area Networks

– [co-sponsor: IEEE Microwave Theory and Techniques Society]

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

IEEE 802.16 by the Numbers

- 119 Members (peaked at 178)
- 39 "Potential Members"
- 33 Official Observers
- >750 different individuals have attended a session
- 2.8 Million file downloads in year 2000
- Members and Former Members from
  - 12 countries
  - 144 companies

Countries of 802.16 Members (current and former)

- CANADA (48)
- FINLAND (4)
- FRANCE (2)
- GERMANY (2)
- GREECE (2)
- ISRAEL (22)

- ITALY (1)
- JAPAN (2)
- KOREA (4)
- SPAIN (1)
- UK (11)
- USA (161)

Note: 2 participants from Beijing at Session #17

Companies of 802.16 Members (current & former)

- 3Com Corp.
- Advantech AMT Company
- Agilent Technologies
- Airspan Communications Ltd.
- Akelia Wireless
- Alcatel
- Alvarion Ltd.
- Analog Devices
- Aperto Networks
- ArrayComm, Inc.
- Astute Networks
- AT&T Wireless Services
- BAE Systems
- Barcombe Consulting
- BeamReach Networks, Inc.
- Bell Canada
- Belstar Systems Corp.
- BridgeWave Communications, Inc.
- Broadcom Corp.
- Broadstorm Telecommunications
- Caly Networks
- Canon R&D Center Americas, Inc.
- Carleton University
- Ceragon Networks
- CircuitPath Network Systems
- Clearwire Technologies
- CommAccess Technologies, Inc.
- Communications Consulting
- ComTier
- Concordia University
- Conexant Systems
- Coreon Inc.
- Correlant Communications
- Crosspan
- DENSO International America
- DMC Stratex Networks

- E. A. Robinson Consulting
- Ensemble Communications
- Enterasys Networks
- EPCOS AG
- Escape Communications
- ETRI
- Fujitsu Microelectronics
- Fujitsu Network Comms
- Gabriel Electronics
- Gennum Corporation
- Georgia Institute of Technol
- Global Communications Solns
- GTE Laboratories Incorporated
- Harris Corporation
- Hexagon System Engineering
- HighSpeed Communications
- Hitachi America R&D
- HRL Laboratories
- Hughes Network Systems
- IceFyre Semiconductor
- iCODING Technology Inc.
- IDRIS Communications
- Industry Canada
- Infineon Technologies AG
- InnoWave ECI
- Integrated Device Technology
- Integrity Communications
- Intel
- InterDigital Communications
- Intersil
- Iospan Wireless
- Juniper Networks
- Kostas Associates
- Legend Silicon Corp.
- Lockheed Martin
- Lucent

- Mabuhay Networks
- Malibu Networks
- Marconi
- Marvell Semiconductor
- Media Works
- Meriton Networks
- Mitsubishi Electric Corp.
- Mitsubishi Electronics America
- MostlyTek Ltd.
- Motorola
- National Rural Telephone
- Navini Networks
- nBand Communications
- NEC America, Inc.
- Netro Corporation
- Nextcomm, Inc.
- NIST
- Nokia Networks
- Nortel Networks
- Nottingham Trent University
- NTT
- Oak Wireless
- Omnitel Pronto Italia
- Paul Thompson Associates
- Provigent, Inc.
- Proxim Corporation
- Radia Communications, Inc.
- Radiant Networks PLC
- RADWIN Ltd.
- Rafael
- Rainbow Network Systems
- Raze Technologies
- Red Dot Wireless
- Redline Communications
- RF Solutions
- Ron Meyer Consulting

- Runcom Technologies Ltd.
- SACET
- Samsung
- Saraband Wireless, Inc.
- SP Wireless
- SpaceBridge Networks
- Speedcom Wireless
- Spike Broadband Systems
- Spike Technologies, Inc.
- SPL-ACT Wireless
- Sprint
- SR Telecom Inc.
- StarWave Consulting
- Telaxis
- Telcordia
- Telegen Ltd.
- Teligent, Inc.
- Texas Instruments
- Transcomm Inc.
- Trapeze Networks
- Triton Network Systems
- U S WEST
- University of Sheffield
- Vectrad Networks
- Vyyo Inc.
- WaveIP Ltd.
- Wavesat Telecom
- Wavion
- Wavtrace
- Westwave Comms
- Wi-LAN Inc.
- Widax Corp.
- WinStar
- Wireless Facilities, Inc.
- World Access Inc.
- Xilinx

IEEE 802.16 Projects

- Air Interface (PHYs with common MAC)
  - 802.16: 10-66 GHz
    - Completed in October 2001
    - Published in April 2002
    - Interoperability test documents in development
      - Profiles; PICS; Test Purposes; Abstract Test Suites
  - 802.16a: 2-11 GHz
    - Licensed and license-exempt bands only
    - Balloting since November 2001
    - Completion expected in October 2002
  - Mobile Broadband Wireless Access Study Group
- Coexistence
  - IEEE 802.16.2 (10-66 GHz)
    - Published in September 2001
  - P802.16.2a: amendment
    - with 2-11 GHz licensed
    - Completion expected in March 2003

IEEE Standard 802.16:
The WirelessMAN-SC™ Air Interface
Published: 8 April 2002

# 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

Reference Model
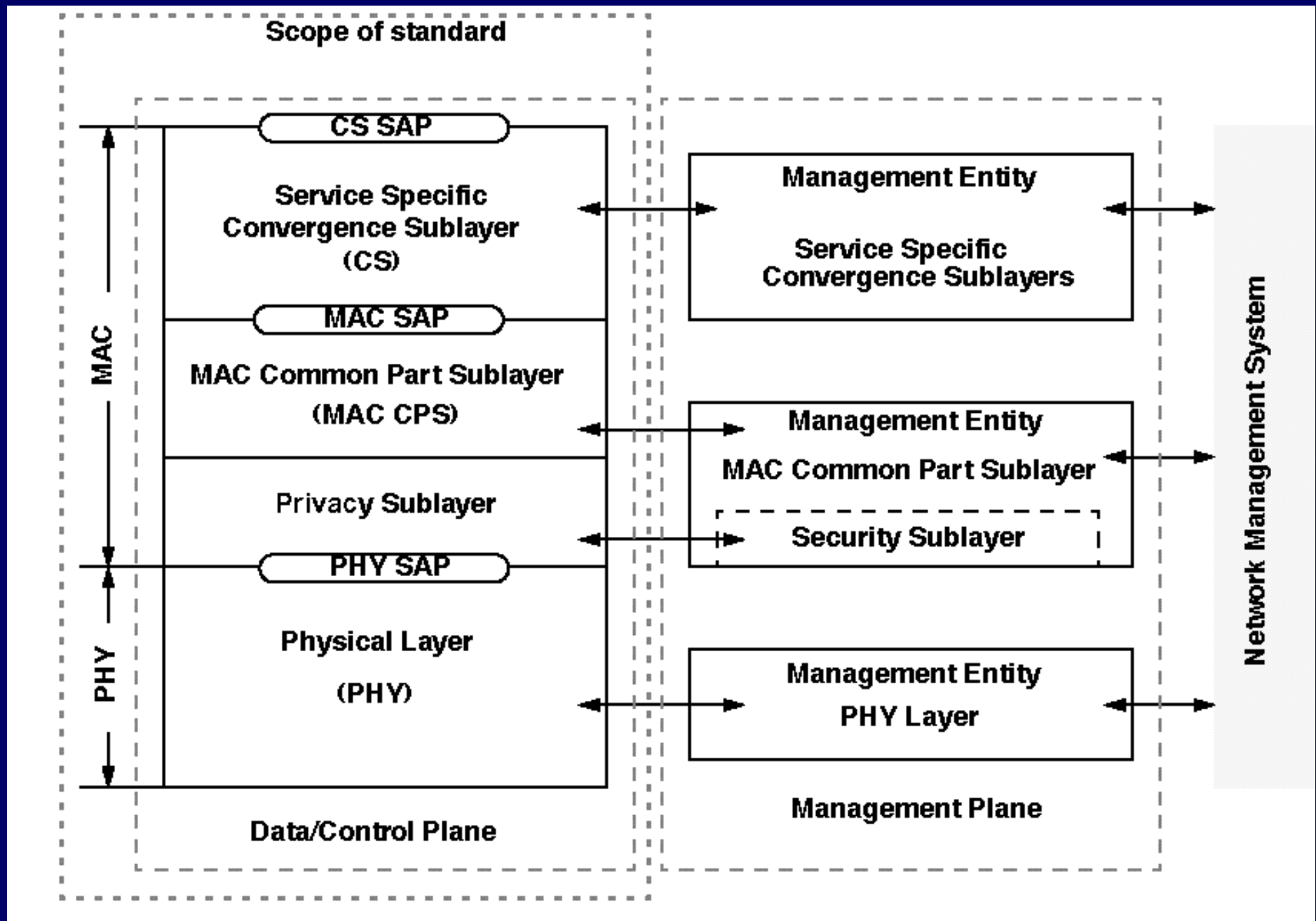
Adaptive PHY
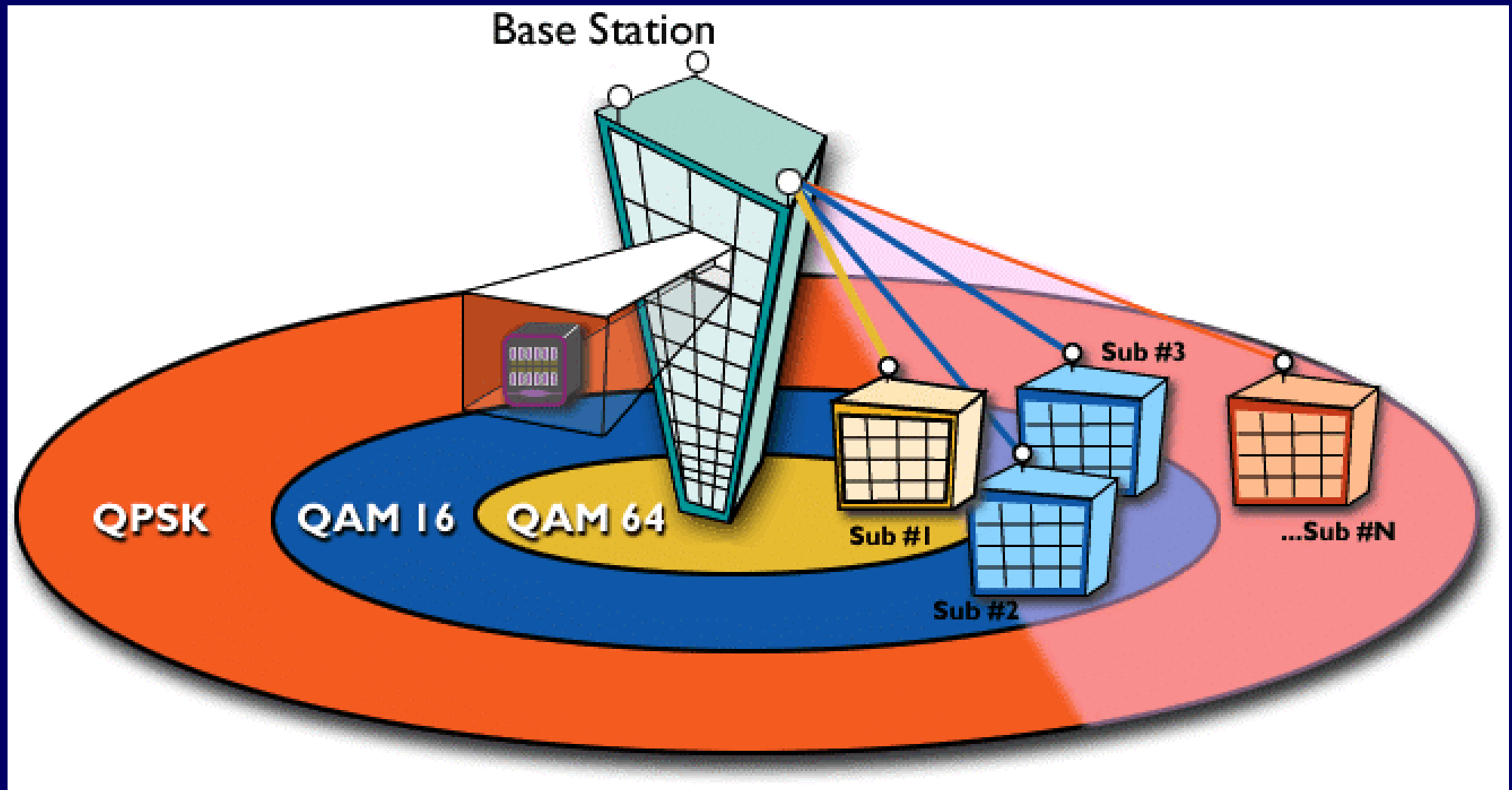
(burst-by-burst adaptivity not shown)

Definitions

- BS
  - Base Station
- SS
  - Subscriber Station
- Downlink (DL)
  - BS to SS
- Uplink (UL)
  - SS to BS

Modulation

- Single Carrier QAM, Gray coded
  - QPSK
  - 16QAM
    - Mandatory for Downlink, Optional for Uplink
  - 64QAM
    - Optional for both Downlink & Uplink

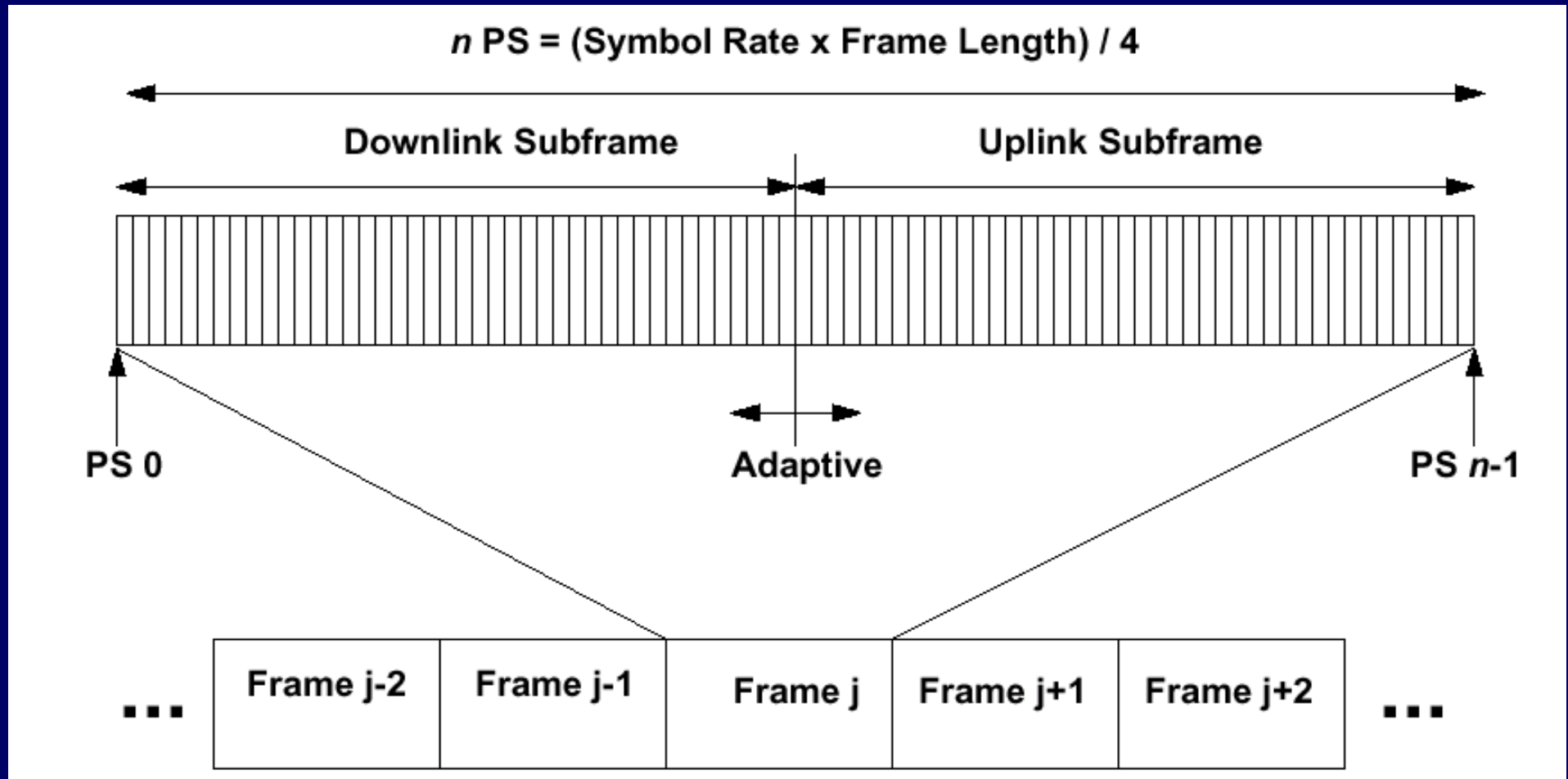- Preambles based on 16 symbol CAZAC sequences

FEC

- Reed Solomon
  - RS GF(256), t = 0…16
- For most critical communications, RS is concatenated with a BCC
  - No interleaving, suitable for burst
  - BCC is a rate 2/3 block code based on a tail-bite termination of the $(7,5)_8$ Convolutional Code for every 16 data bits
- Shortening allowed
- Turbo Product Codes (TPC) are optional

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)

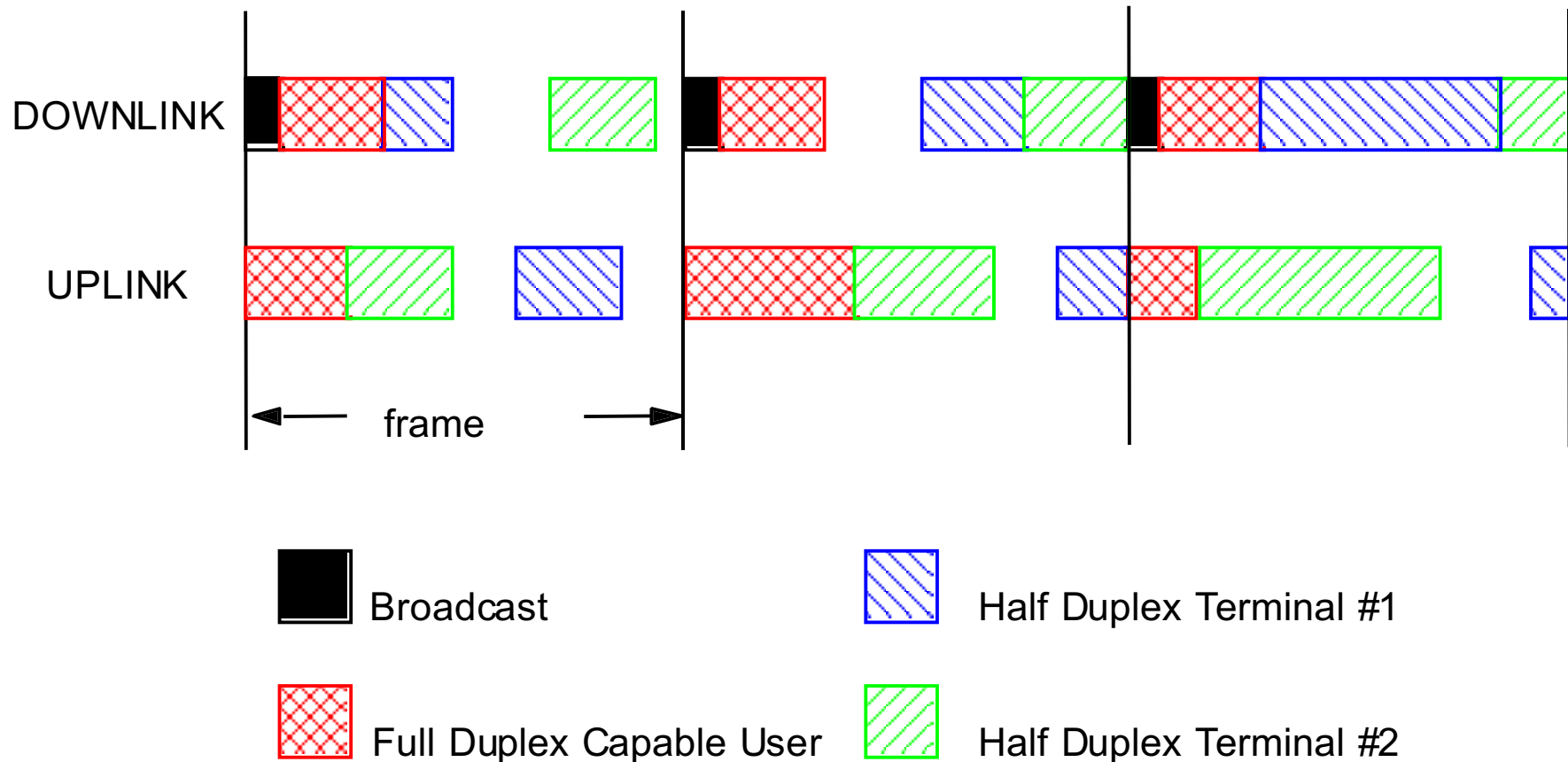# TDD Frame (10-66 GHz)

Frame duration: 1 ms

Physical Slot (PS) = 4 symbols

Burst FDD Framing

DOWNLINK

UPLINK

frame

Broadcast

Half Duplex Terminal #1

Full Duplex Capable User

Half Duplex Terminal #2

Allows scheduling flexibility

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
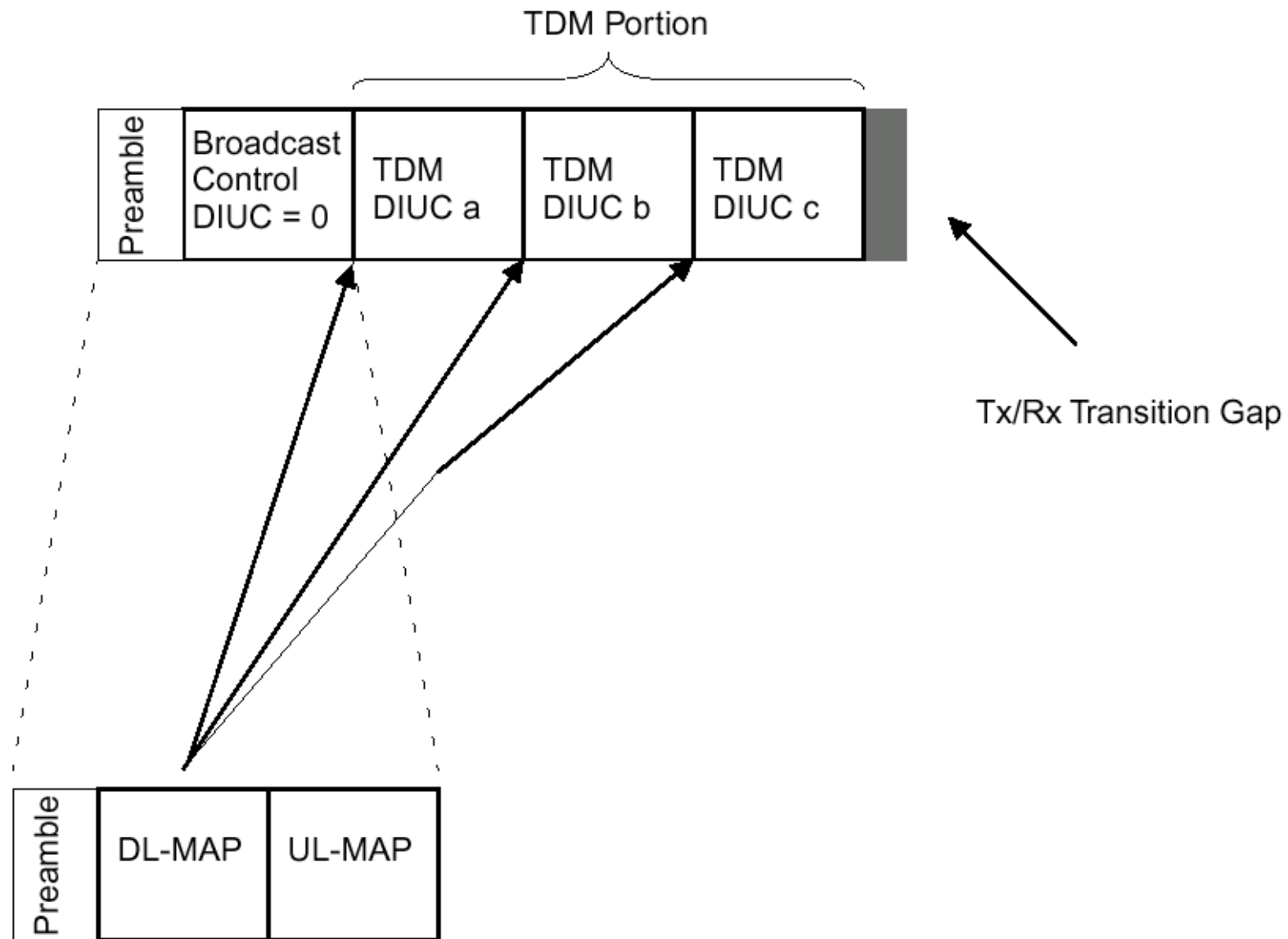

DIUC: Downlink Interval Usage Code

Burst Profile Change (MAC Level)
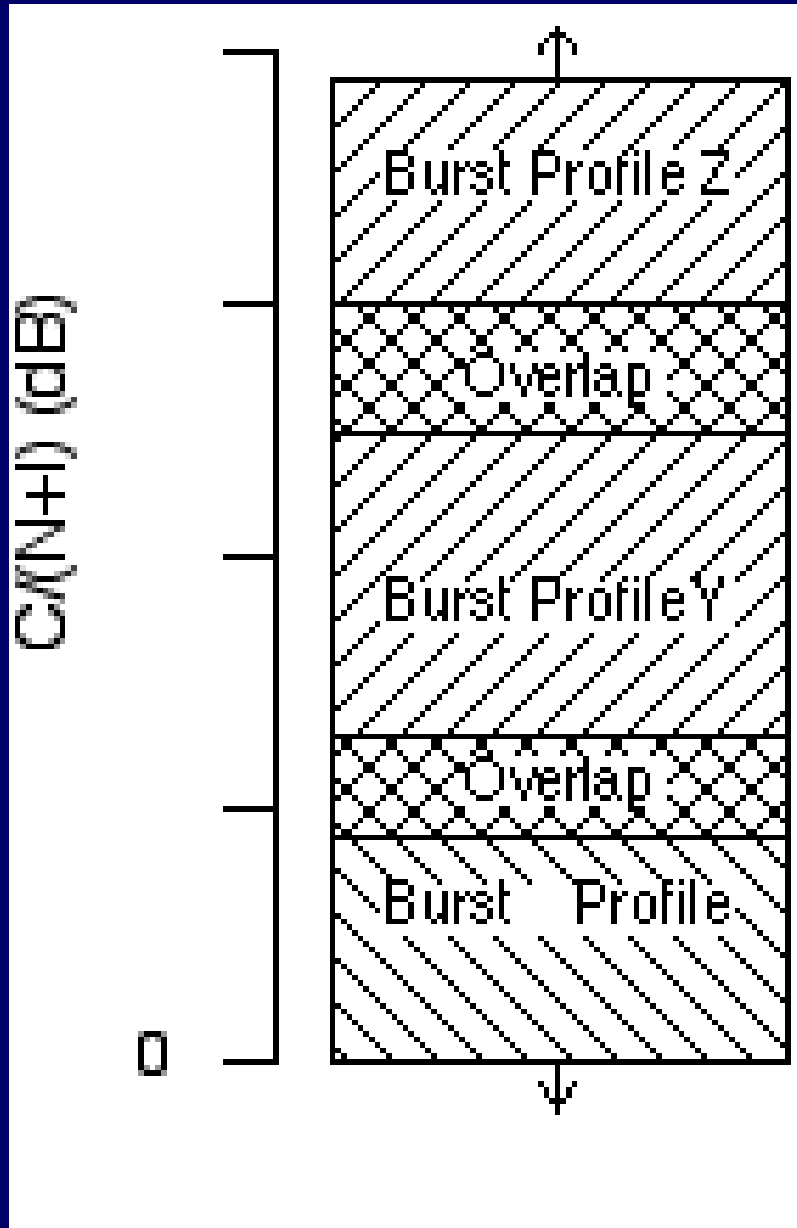
- Each burst profile has mandatory exit threshold and minimum entry threshold
- C/(N+I) too low: SS must request fall back to more robust DIUC once at mandatory exit threshold
- SS allowed to request a less robust DIUC once above the minimum C/(N+I) entry level
- Requests to change DIUC done with MAC messages

FDD Downlink Subframe
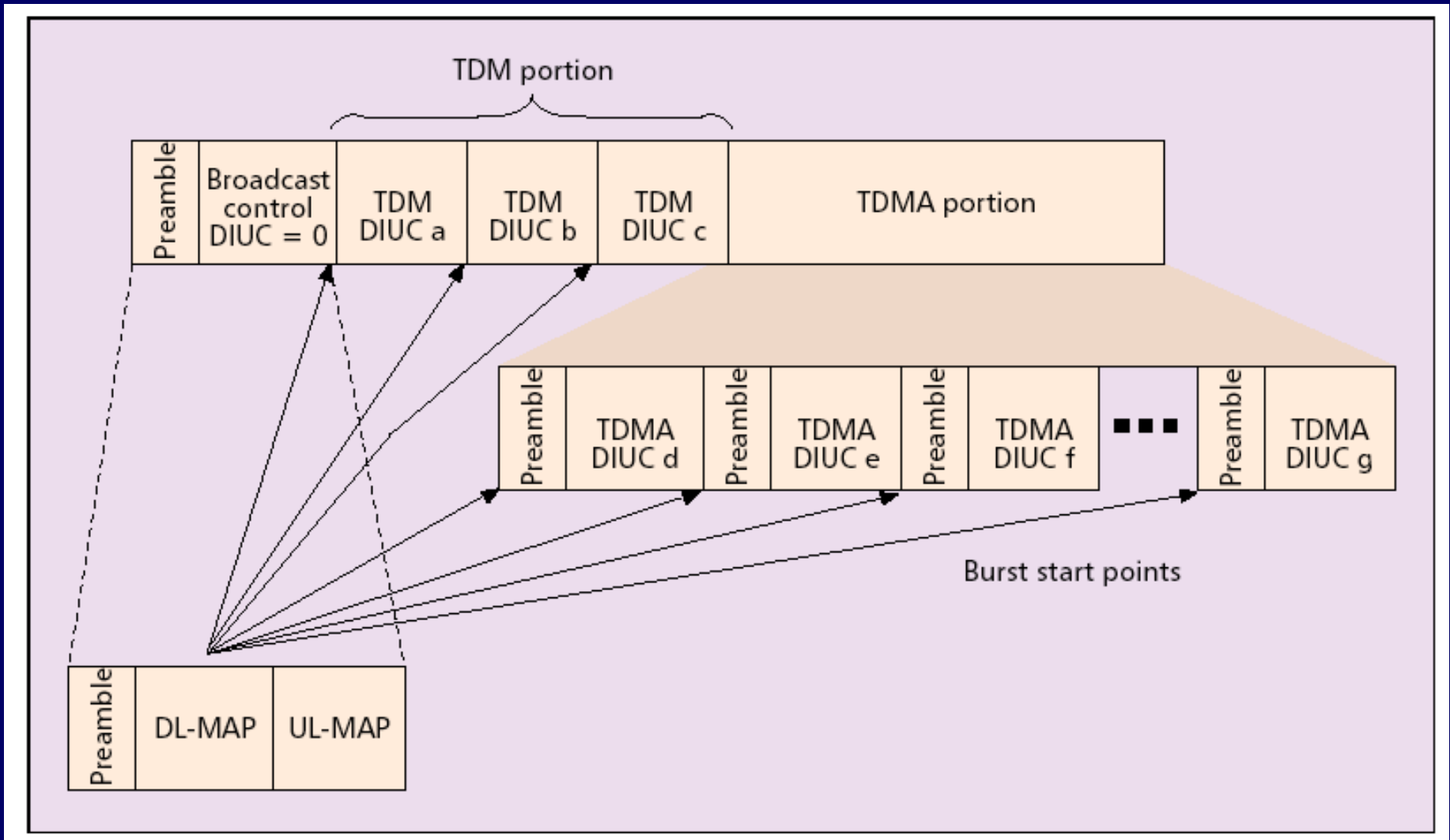
TDMA portion: transmits data to some half-duplex SSs (the ones scheduled to transmit earlier in the frame than they receive)
- Need preamble to re-sync (carrier phase)

FDD Uplink Subframe: Minimum Advance
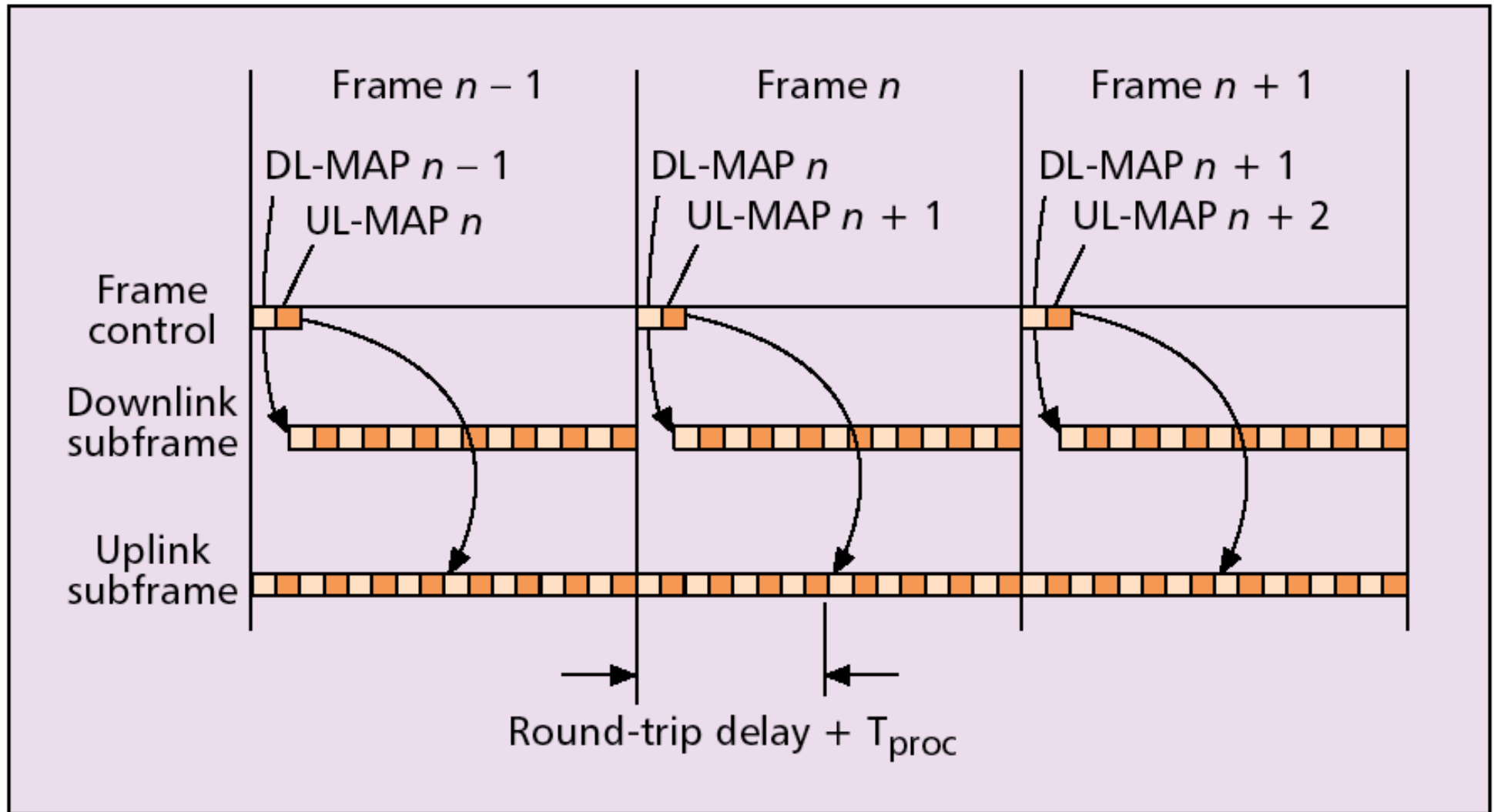
Typical Uplink Subframe (TDD or FDD)
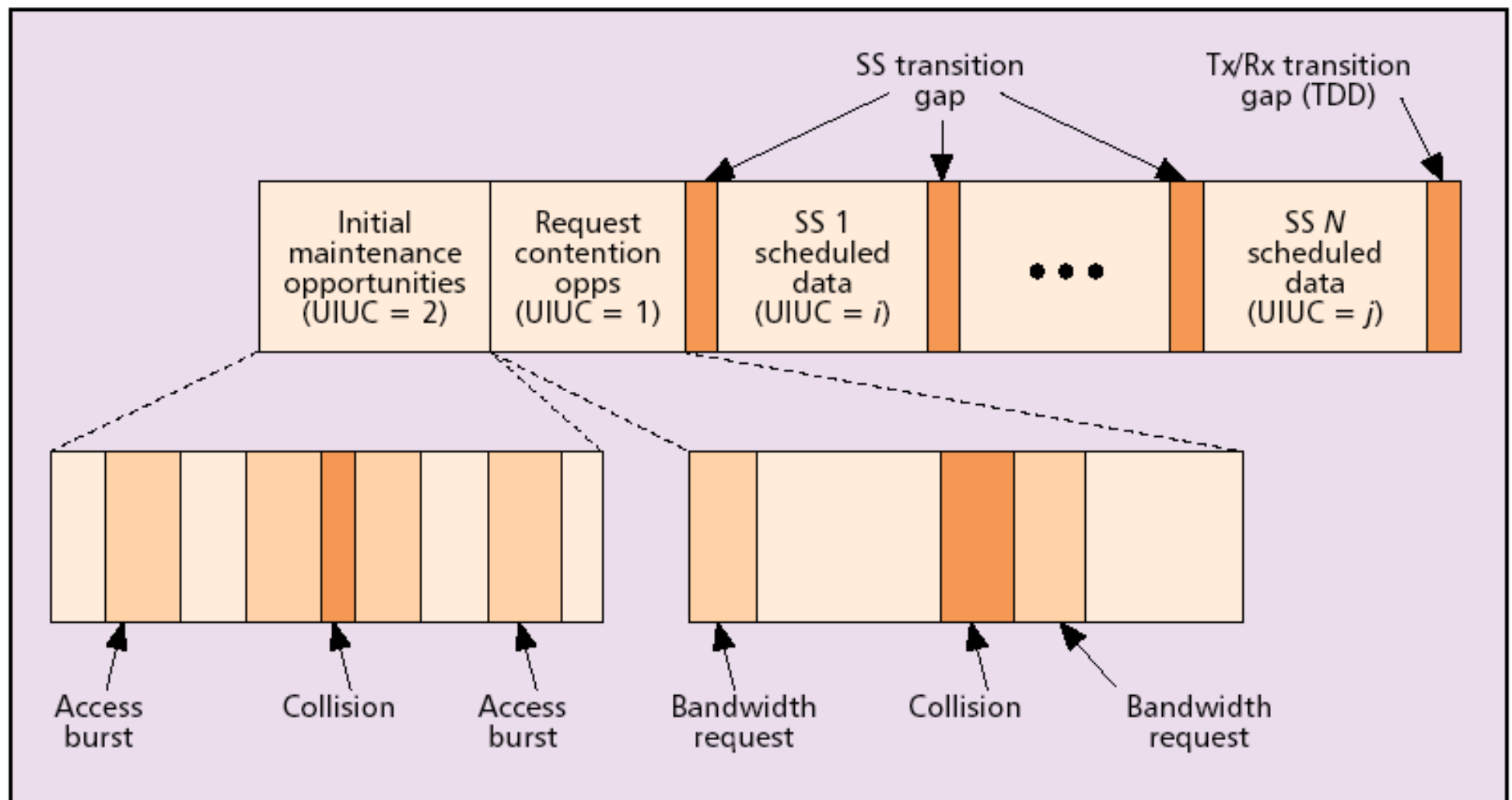
Baud Rates & Channel Size (10-66 GHz)

- Flexible plan - allows equipment manufactures to choose according to spectrum requirements

Channel Width (MHz)	Symbol Rate (Msym/s)	QPSK Bit Rate (Mbit/s)	16-QAM Bit Rate (Mbit/s)	64-QAM Bit Rate (Mbit/s)
20	16	32	64	96
25	20	40	80	120
28	22.4	44.8	89.6	134.4

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

Definitions

- Service Data Unit (SDU)
  - Data units exchanged between adjacent layers
- Protocol Data Unit (PDU)
  - Data units exchanged between peer entities
- Connection and Connection ID
  - a unidirectional mapping between MAC peers over the airlink (uniquely identified by a CID)
- Service Flow and Service Flow ID
  - a unidirectional flow of MAC PDUs on a connection that provides a particular QoS (uniquely identified by a SFID)

ATM Convergence Sublayer

- Support for:
  - VP (Virtual Path) switched connections
  - VC (Virtual Channel) switched connections
- Support for end-to-end signaling of dynamically created connections:
  - SVCs
  - soft PVCs
- ATM header suppression
- Full QoS support

Packet Convergence Sublayer

- Initial support for Ethernet, IPv4, and IPv6
- Payload header suppression
  - generic plus IP-specific
- Full QoS support
- Possible future support for:
  - PPP
  - MPLS
  - etc.

Generic MAC Header

HT = 0 (1)	EC (1)	Type (6)	Rsv (1)	CI (1)	EKS (2)	Rsv (1)	LEN msb (3)
LEN lsb (8)			CID msb (8)				
CID lsb (8)			HCS (8)				
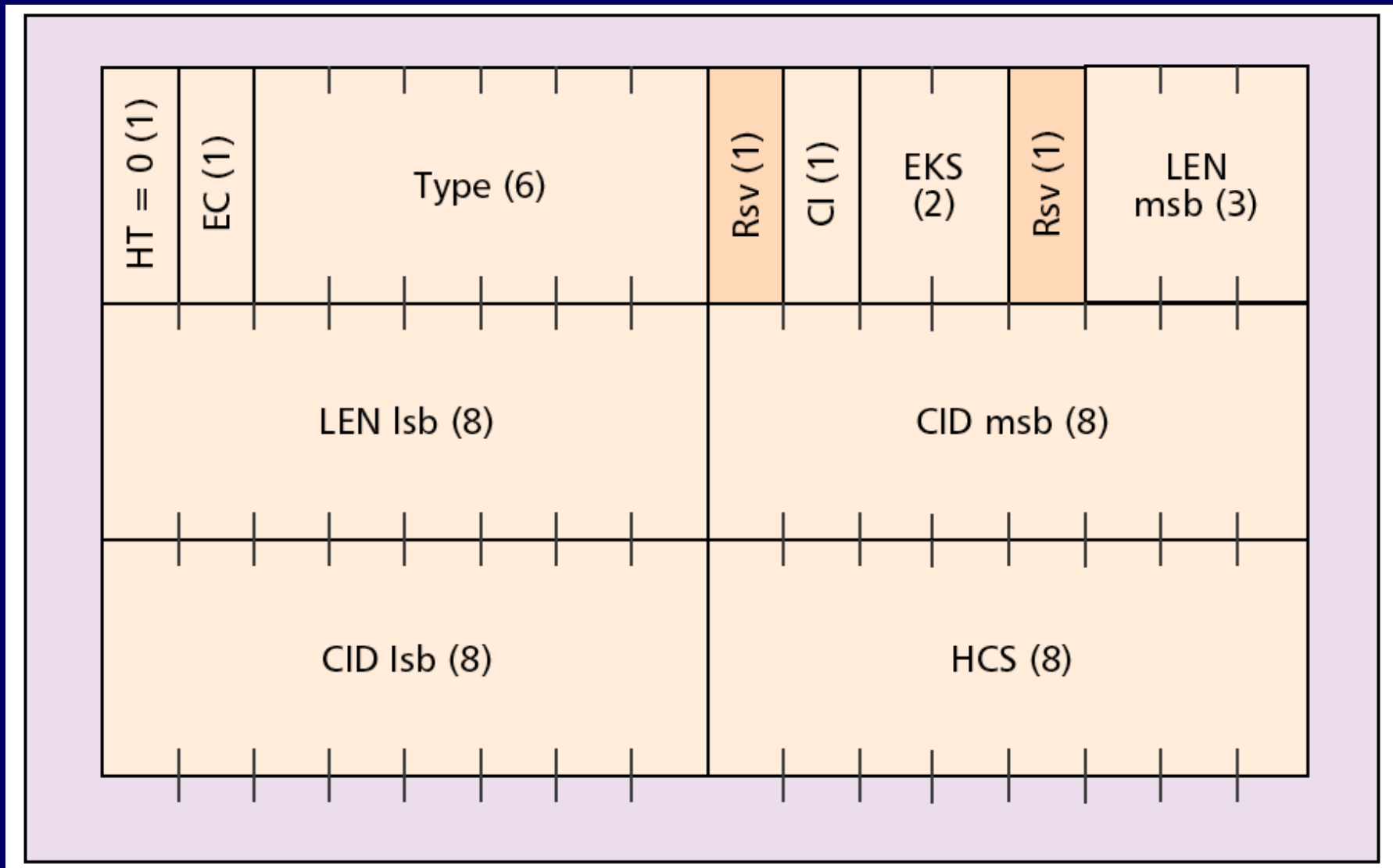
LEN: PDU length, in bytes (2048 max)

HT: Header Type

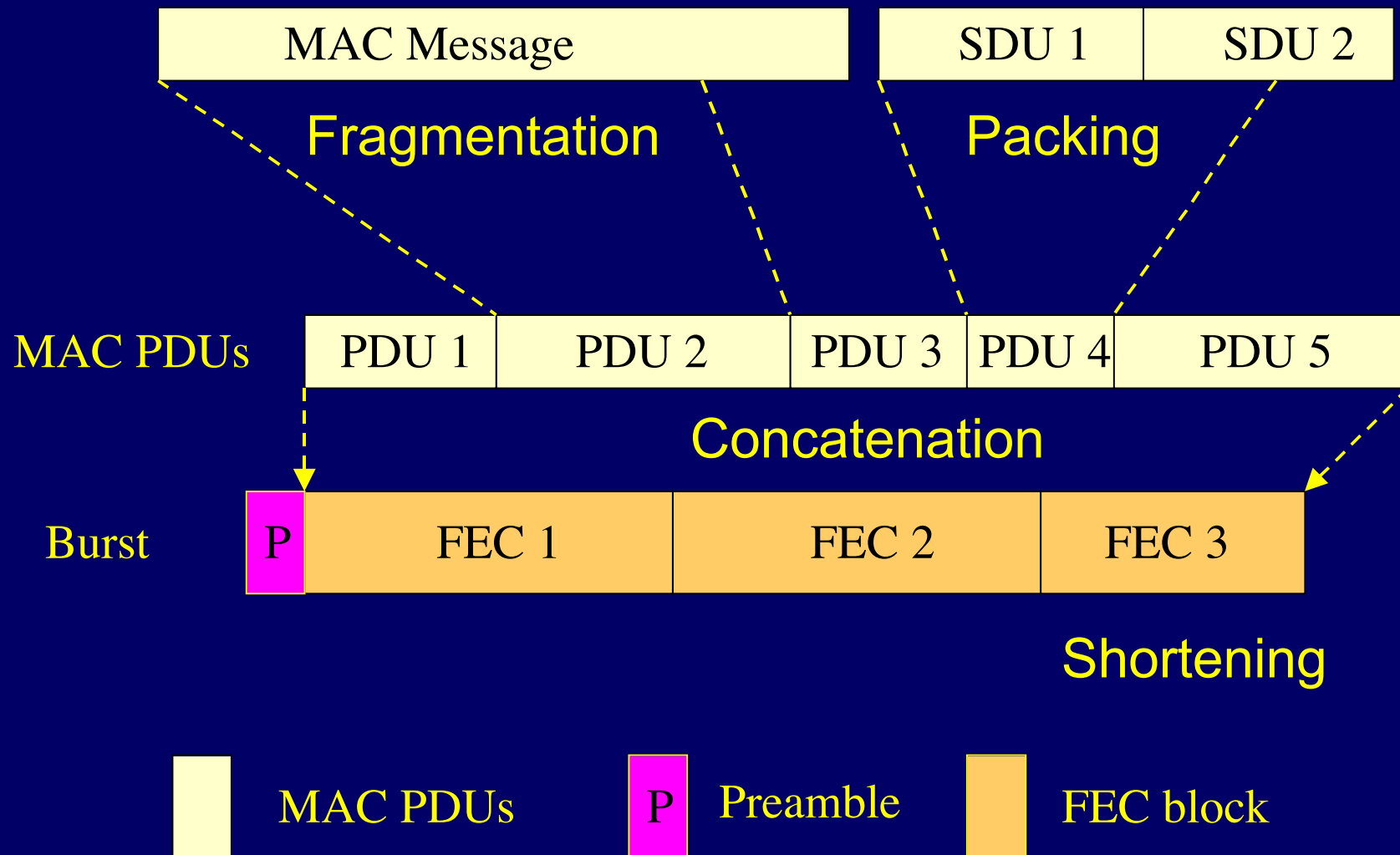Type: subheaders, etc.

CID: Connection ID

EC: Encryption Control

HCS: Header Check Sequence

EKS: Encryption Key Sequence

CI: CRC Indicator

MAC PDU Transmission

Packing Fixed-Length SDUs into a MAC PDU
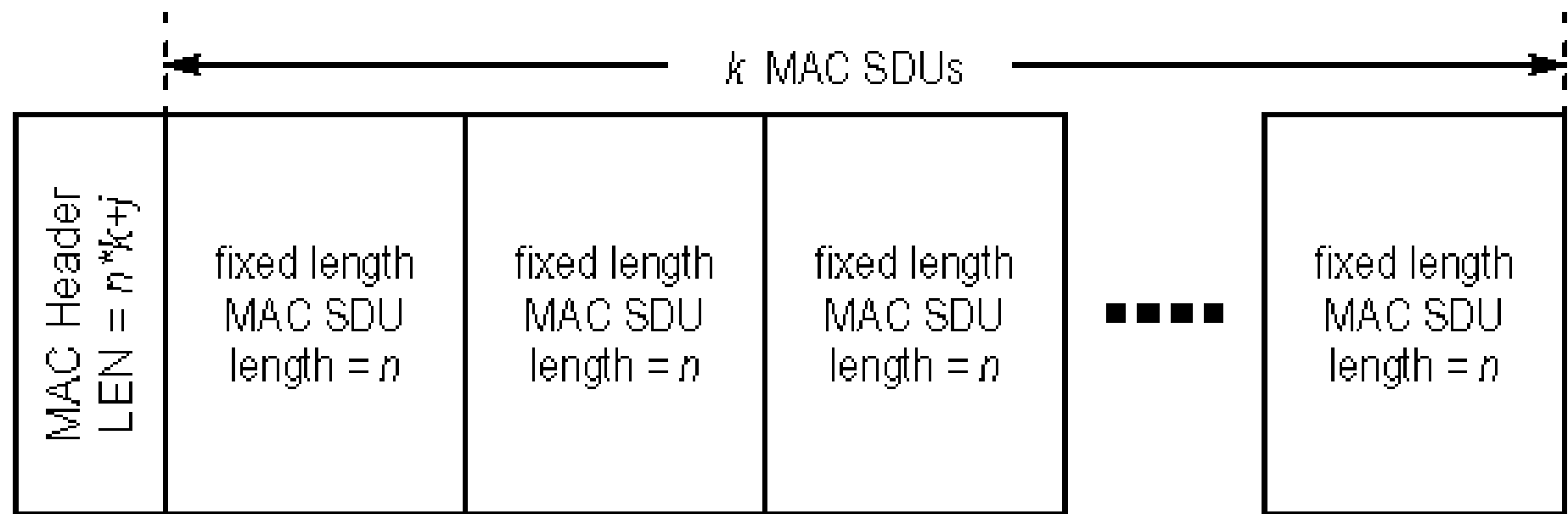
Packing Variable-Length SDUs into a MAC PDU
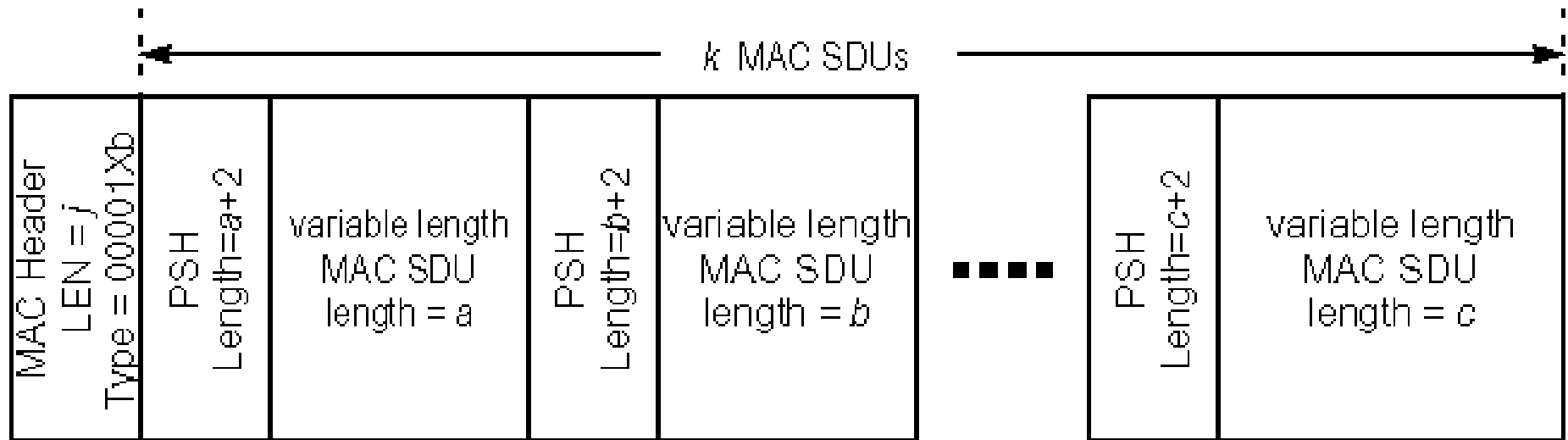
Packing with Fragmentation
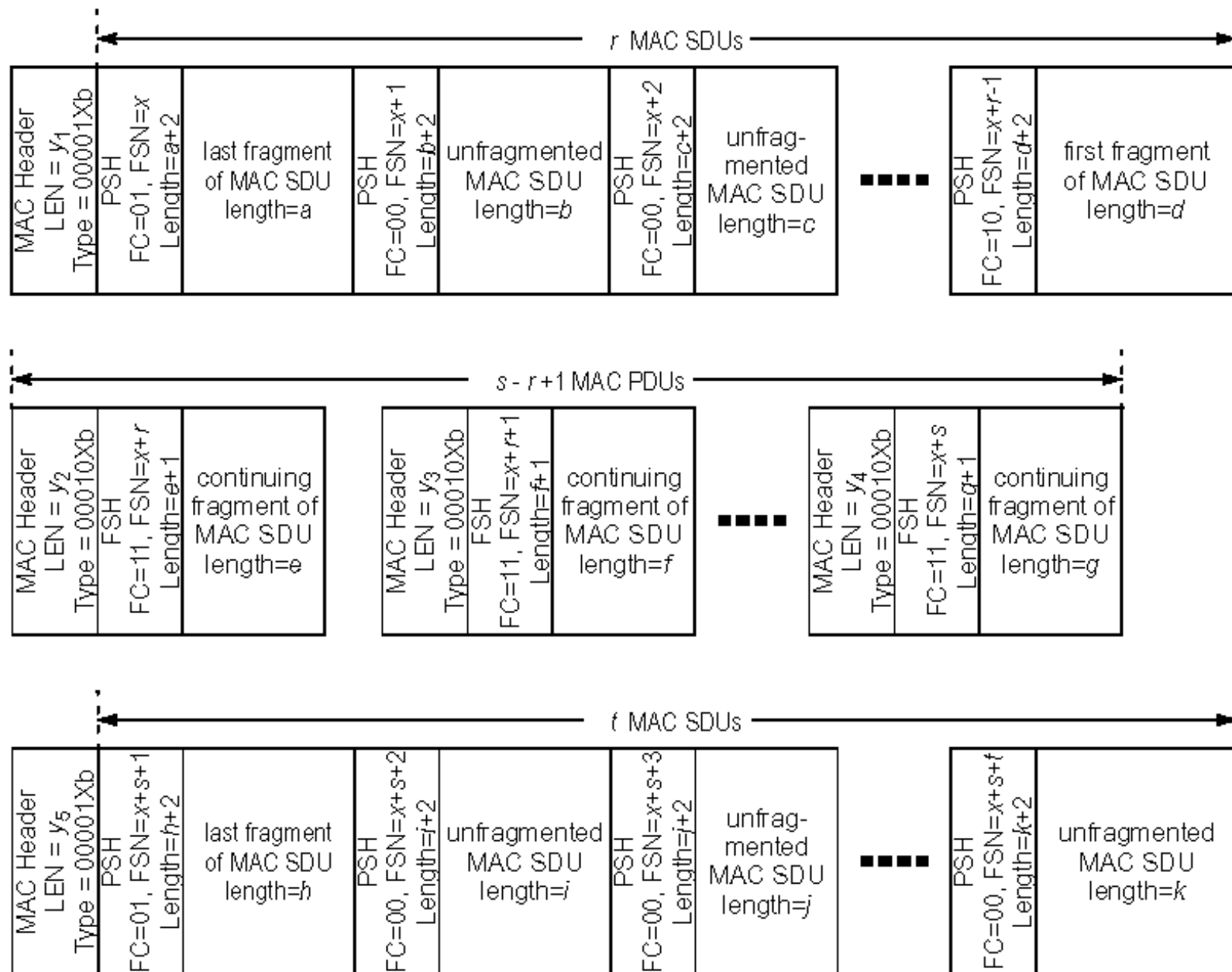
Classes of Uplink Service

Characteristic of the Service Flow

- Unsolicited Grant Services (UGS)
  - for constant bit-rate (CBR) or CBR-like service flows (SFs) such as T1/E1
- Real-time Polling Services (rtPS)
  - for rt-VBR-like SFs such as MPEG video
- Non-real-time Polling Services (nrtPS)
  - for nrt SFs with better than best effort service such as bandwidth-intensive file transfer
- Best Effort (BE)
  - for best-effort traffic

Uplink Services - UGS

- No explicit bandwidth requests issued by SS
- Prohibited from using any contention requests
- No unicast request opportunity provided
- May include a Grant Management (GM) sub-header containing
  - Slip indicator: indicates that there is an backlog in the buffer due to clock skew or loss of maps
  - Poll-me bit: indicates that the terminal needs to be polled (allows for not polling terminals with UGS-only services).

Uplink Services - rtPS

- Intended for rt-VBR-like service flows such as MPEG video
- Prohibited from using any contention requests
- Terminals polled frequently enough to meet the delay requirements of the SFs
- Bandwidth requested with BW request messages (a special MAC PDU header)
- May use Grant Management sub-header
  - new request can be piggybacked with each transmitted PDU

Uplink Service - nrtPS

- Intended for non-real-time service flows with better than best effort service
  - e.g. bandwidth-intensive file transfer
- Works like rt-polling except that polls are issued less frequently
- Allowed to use contention requests
- May use Grant Management sub-header
  - new request can be piggybacked with each transmitted PDU

Uplink Service - BE

- Generic data
  - e.g. HTTP, SMTP, etc.
- No QoS guarantees
- Allowed to use contention requests
- May use Grant Management sub-header
  - new request can be piggybacked with each transmitted PDU

Request/Grant Scheme

- ## Self Correcting
  - No acknowledgement
  - All errors are handled in the same way, i.e., periodical aggregate requests
- ## Bandwidth Requests are always per Connection
- ## Grants are either per Connection (GPC) or per Subscriber Station (GPSS)
  - Grants (given as durations) are carried in the UL-MAP messages

GPSS vs. GPC

- Bandwidth Grant per Subscriber Station (GPSS)
  - Base station grants bandwidth to the subscriber station
  - Subscriber station may re-distribute bandwidth among its connections, maintaining QoS and service-level agreements
  - Suitable for many connections per terminal; off-loading base station's work
  - Allows more sophisticated reaction to QoS needs
  - Low overhead but requires intelligent subscriber station
  - Mandatory for P802.16 10-66 GHz PHY
- Bandwidth Grant per Connection (GPC)
  - Base station grants bandwidth to a connection
  - Mostly suitable for few users per subscriber station
  - Higher overhead, but allows simpler subscriber station

Maintaining QoS in GPSS

- Semi-distributed approach
- BS sees the requests for each connection; based on this, grants bandwidth (BW) to the SSs (maintaining QoS and fairness)
- SS scheduler maintains QoS among its connections and is responsible to share the BW among the connections (maintaining QoS and fairness)
- Algorithm in BS and SS can be very different; SS may use BW in a way unforeseen by the BS

Privacy and Encryption

- Secures over-the-air transmissions
- Protocol descends from BPI+ (from DOCSIS)
- Designed to allow new/multiple encryption algorithms
- Authentication
  - X.509 certificates with RSA
  - Strong authentication of SSs (prevents theft of service)
  - Prevents cloning
- Data encryption
  - Currently 56-bit DES in CBC (cypher block chaining) mode
  - Initialization Vector (IV) based on frame number
- Message authentication
  - Most important MAC management messages authenticated with one-way hashing (HMAC with SHA-1)

Security Associations

- A set of privacy information
  - shared by a BS and one or more of its client SSs in order to support secured communications
    - Note: multicast SAs allowed
  - includes Traffic Encryption Keys (TEKs) and CBC IVs

- Security Association Establishment
  - Primary SA established during initial registration
  - other SAs may be provisioned or dynamically created within the BS

SS Authorization

- Authentication and Authorization
  - SS manufacturer's X.509 certificate binds the SS's public key to its other identifying information
  - Trust relation assumed between equipment manufacturer and network operator
  - Possibility to accommodate "root authority" if required

- Authorization Key Update Protocol
  - The SS is responsible for maintaining valid keys
  - Two active AKs with overlapping lifetimes at all times
  - Reauthorization process done periodically
  - AK lifetime (7 days) & grace time timer (1 hr)

Traffic Encryption Key Management

- Authoriztion Key (AK) established with RSA
- Key Encryption Key (symmetric) derived from AK
- Traffic Encryption Keys (TEK) exhanged with symmetric algorithm negotiated at SA establishment (currently only 3-DES supported)
- Two sets of overlapping keying material maintained
- No explicit key acknowledgements
- Key synchronization maintained by 2-bit key sequence number in the MAC PDU header

Data Encryption

- DES in CBC mode with IV derived from the frame number
- Hooks defined for other stronger algorithms, e.g. AES
- Two simultaneous keys with overlapping and offset lifetimes allow for uninterrupted service
- Key sequence number carried in MAC header
- Only MAC PDU payload (including sub-headers) is encrypted
- Management messages are unencrypted

Amendment Project
IEEE P802.16a

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

IEEE P802.16a Status

- In ballot since November 2001
  - currently balloting Draft 4
  - expect completion of final draft in October 2002

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

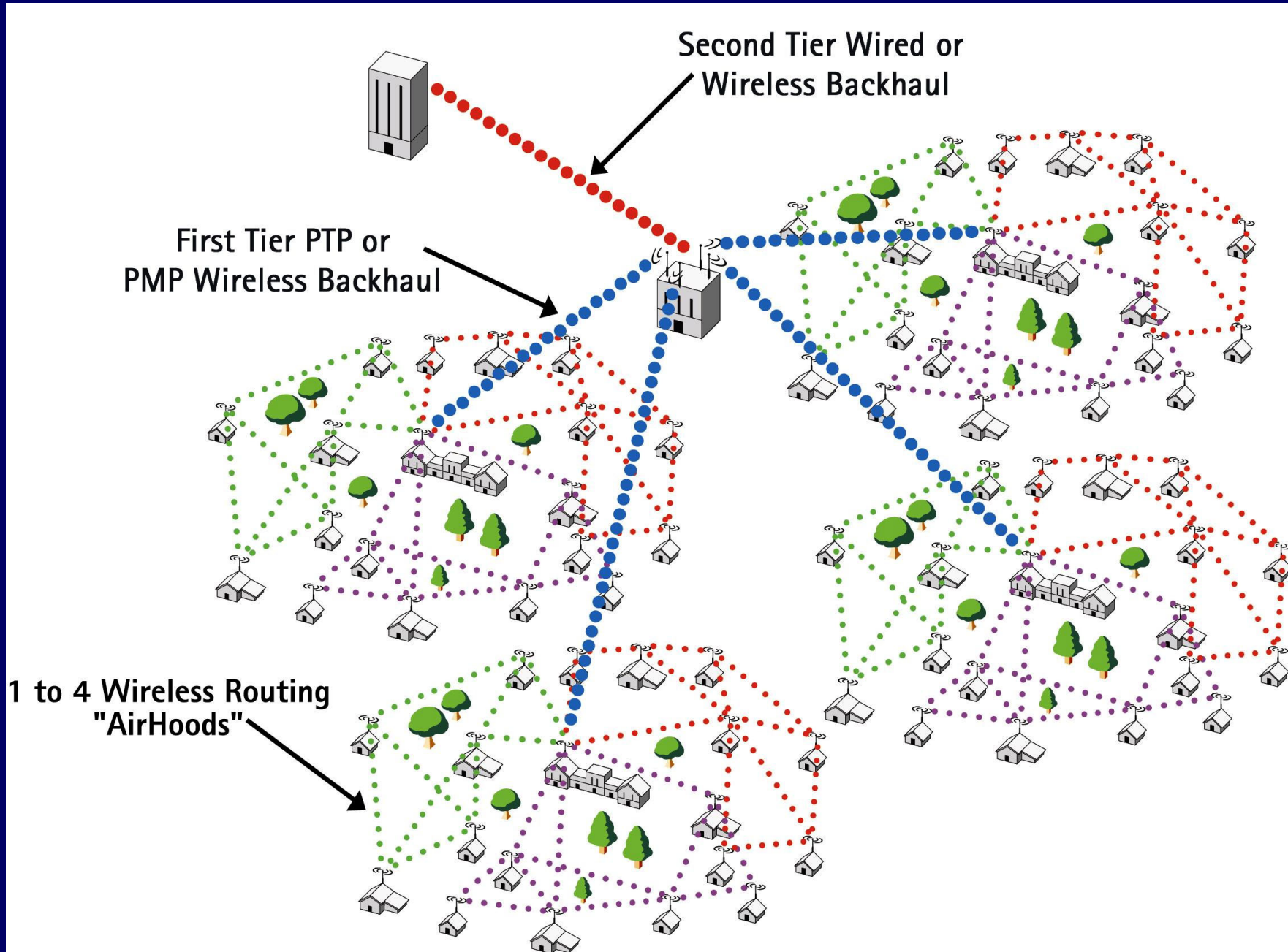- OFDM (WirelessMAN-OFDM Air Interface)
  - 256-point FFT with TDMA (TDD/FDD)
- OFDMA (WirelessMAN-OFDMA Air Interface)
  - 2048-point FFT with OFDMA (TDD/FDD)
- Single-Carrier (WirelessMAN-SCa Air Interface)
  - TDMA (TDD/FDD)
  - BPSK, QPSK, 4-QAM, 16-QAM, 64-QAM, 256-QAM
  - Most vendors will use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

Key 802.16a MAC Features

- OFDM/OFDMA Support
- ARQ
- Dynamic Frequency Selection (DFS)
  - license-exempt
- Advanced Antenna System (AAS) support
- Mesh Mode
  - Optional topology for license-exempt operation only (TDD only)
  - Subscriber-to-Subscriber communications
  - Complex topology and messaging, but:
    - addresses license-exempt interference
    - scales well

Mesh-based WirelessMAN

Second Tier Wired or Wireless Backhaul

First Tier PTP or PMP Wireless Backhaul

1 to 4 Wireless Routing "AirHoods"

Mobile Broadband Wireless Access

- Working Group 802.16 formed Mobile Broadband Wireless Access Study Group in March 2002
- Seems to be going in two directions:
  - Enhance IEEE Std 802.16 to provide nomadic operation, portability, and limited mobility
  - Consider a new, separate project for mobile BWA at vehicular speeds

What's Next ?

- Complete 2-11 GHz work
- Enhance 10-66 GHz spec
  - Interoperability test protocols
    - 802.16c (profiles) is in ballot
    - PICS and test protocols coming soon
- New enhancements
  - Mobility, repeaters, etc.
- Build a basis for 4G wireless

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

- IEEE P802.16c (Detailed System Profiles)
  - in ballot; tobe complete in September 2002
  - 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 (initiating effort; final in early 2003)
  - Test Suite Structure & Test Purposes (to follow)

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 above 11 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

802.16 Summary

- The IEEE 802.16 WirelessMAN Air Interface, addresses worldwide needs
- The outcome is due to successful cooperation between industry worldwide.
- The 802.16 MAC is flexible and powerful enough to support PHY variants in any spectrum allocation.
- The 802.16 Air Interface provides great opportunities for vendor differentiation, at both the base station and subscriber station, without compromising interoperability.
- Expansion to 2-11 GHz will soon be complete.
- Interoperability tests are coming.
- Mobility is the next major enhancement.

Conclusion

IEEE 802.16 standards are:

- open in development and application
- addressed at worldwide markets
- engineered as optimized technical solutions
- moving toward interoperability assurance
- being enhanced for expanded opportunities

I thank you for your interest in IEEE 802.16 and welcome your participation in the development or use of IEEE 802.16 standards.

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

- You are welcome to download and read these standards!

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.

IEEE 802.16 Resources

IEEE 802.16 Working Group on Broadband Wireless Access

info, documents, tutorials, email lists, etc:

http://WirelessMAN.org