Emerging Global Standards in IEEE 802.16

Roger Marks, Jay Klein,

Brian Kiernan, Durga Satapathy

IEEE 802.16 Working Group on Broadband Wireless Access

http://WirelessMAN.org

Outline

IEEE 802.16 Process, Status, and Plans

- Roger Marks

Coexistence for 10-66 GHz

- Roger Marks

Air Interface for 10-66 GHz

- Jay Klein, Chair, 802.16 TG1 PHY

2-11 GHz Licensed Bands

- Brian Kiernan, Chair, 802.16 TG3

WirelessHUMAN™ Project (License-Exempt)

- Durga Satapathy; Chair, 802.16 TG4

Questions and Discussion

IEEE 802.16
Process, Status, and Plans

Roger Marks, NIST

Chair

IEEE 802.16 Working Group on Broadband Wireless Access

http://WirelessMAN.org

IEEE

- Institute of Electrical and Electronics Engineers, Inc.
- Non-profit technical professional society
- Transnational (global), with ~350,000 members

IEEE Standards Association

- Responsible for standards within IEEE
- Worldwide
- Accredited by ANSI; this means
  - Openness
  - Due Process
  - Consensus (not unanimity)
  - Balance (users/producers, etc.)
  - Right of Appeal

IEEE 802

- LAN/MAN Standards Committee
  - Local and Metropolitan Area Networks
- Weeklong sessions 3 times a year (~1000 people recently)
- Strong rules ensure openness and consensus during development

IEEE 802 Process Timeline

- **Study Group**
  - Develops plan to standardize
- **Find Consensus on initial draft**
  - May begin with Functional Requirements
  - Call for proposals
  - Merge and consolidate; some voting
- **Refine the draft until consensus reached**
  - Two-stage letter-ballot process
    (1) inside Working Group
    (2) in the outside world (“Sponsor Ballot”)
  - All encouraged to read and submit corrections
  - Track and resolve hundreds of comments

IEEE 802 Letter Ballot Response Choices

- Approve.
  - May attach non-binding comments.
- Do Not Approve.
  - Must attach specific comments on what must be done to the draft to change the vote to “Approve”.
- Abstain.

IEEE 802 Activities

- Wired
  - 802.3: Ethernet
  - 802.17: Packet Ring (new)
- Wireless
  - 802.11: Wireless LAN
    - Local Area Network
  - 802.15: Wireless PAN
    - Personal Area Network (e.g. Bluetooth™)
  - 802.16: WirelessMAN™
    - Metropolitan Area Networks

IEEE 802.16: History

- Fixed Broadband Wireless Access
- Weeklong sessions every two months
- Program development
  - August-November 1998
- IEEE Study Group stage
  - November 1998-March 1999
- Session #0: May 1999
- Session #12: March 12-16, 2001
  - Hilton Head, South Carolina, USA

IEEE 802.16 by the Numbers

- 124 Members
- 76 “Potential Members”
- 89 Official Observers
- >500 different individuals have attended a session
- 167 attendees at last session
- 2.8 Million file downloads last year
  - inc. > 20,000 copies of air interface document

Participation in IEEE 802.16

- Anyone may:
  - Attend and participate in meetings
  - Subscribe to mailing lists and read list archives
  - Post to mailing lists
  - Examine documents
    - subject to copyright issues
  - Contribute and comment on documents
  - Join the Sponsor Balloting Pool
    - Vote and comment on draft standards

Membership in IEEE 802.16

- Belongs to the individual
  - no formal company participation
- Earned through attendance
  - No membership fee, dues, etc.
- Provides voting rights
- Observer status
  - Participate in a single session
  - Provides access to all documents
    - Same access as members

Philosophy on Participation

- **People act in their own interests**.
  - Altruism not required.
  - The process channels individual interests for common gain.
    - Within anti-trust laws
- **You are welcome to participate**.
  - This will take work on your part.
- **You are welcome not to participate**.
  - You decide whether it is in your interest.

Resources

IEEE 802.16 Working Group on Broadband Wireless Access

info, documents, email lists, etc:

http://WirelessMAN.org

IEEE 802.16 Projects

- **Coexistence (within 10-66 GHz)**
  - **Task Group 2 [IEEE 802.16.2]**
    - Finalized Working Group Draft
- **Air Interface (PHYs with common MAC)**
  - **Task Group 1: 10-66 GHz [IEEE 802.16]**
    - MAC/PHY Draft in Working Group Letter Ballot
  - **Task Group 3: 2-11 GHz [IEEE 802.16a]**
    - Licensed bands only
    - Significant PHY consolidation started in Jan 2001
  - **Task Group 4: 5-6 GHz [IEEE 802.16b]**
    - License-exempt ("WirelessHUMAN™")
    - Chartered in December 2000; rapid development

802.16 Task Group 2 (TG2)

Developing IEEE 802.16.2:

Recommended Practice for Coexistence of Fixed Broadband Wireless Access Systems

Presenter:

Roger Marks,

NIST

TG2 Leaders

Chair

- Philip Whitehead, Radiant Networks

Vice Chair

- Rémi Chayer, Harris Corporation

Editor:

- Muya Wachira, Nortel Networks

802.16.2 Summary

- This Recommended Practice provides guidelines for minimizing interference in fixed broadband wireless access systems. Pertinent coexistence issues are addressed, and recommended engineering practices provide guidance for system design, deployment, coordination and frequency usage. This document covers frequencies of 10 - 66 GHz frequencies in general, but it is focused on 23.5 - 43.5 GHz. If followed by manufacturers and operators, it should allow a wide range of equipment to coexist in a shared environment with acceptable mutual interference.
- 11 Specific Recommendations

802.16.2 Philosophy

Resolving coexistence issues is an important factor for the fixed BWA industry. Recommendations are provided for consideration by operators, manufacturers and administrations to promote coexistence. Practical implementation within the scope of the current recommendations will assume that some portion of the frequency spectrum (at the edge of the authorized bandwidth) may not be able to be utilized. As well, there may be locations within the service area that cannot be used for deployment. Coexistence will rely heavily on the good-faith collaboration between spectrum holders for economical solutions to be implemented.

802.16.2 Scenarios

- **Co-channel**
  - operators are in either adjacent territories or territories within radio line of sight of each other and have the same spectrum allocation
- Adjacent Channel
  - licensed territories of two operators overlap and they are assigned adjacent spectrum allocations.

- Coexistence issues may arise simultaneously from both scenarios as well as from multiple operators having the same scenario.

802.16.2 Timeline

- Passed Working Group Letter Ballot

- 1 April 2001
  - Sponsor Ballot scheduled to finish
- 5 May 2001
  - Final draft due to IEEE Standards Board
- 14 June 2001
  - IEEE Standards Board has opportunity for final approval

802.16 Task Group 1 (TG1)

Developing IEEE 802.16:

Standard Air Interface for Fixed Broadband Wireless Access Systems

Presenter:

Jay Klein,

Ensemble Communications

TG1 Leaders

Chair and Editor

- Roger Marks, NIST

PHY Chair

- Jay Klein, Ensemble Communications

MAC Chair

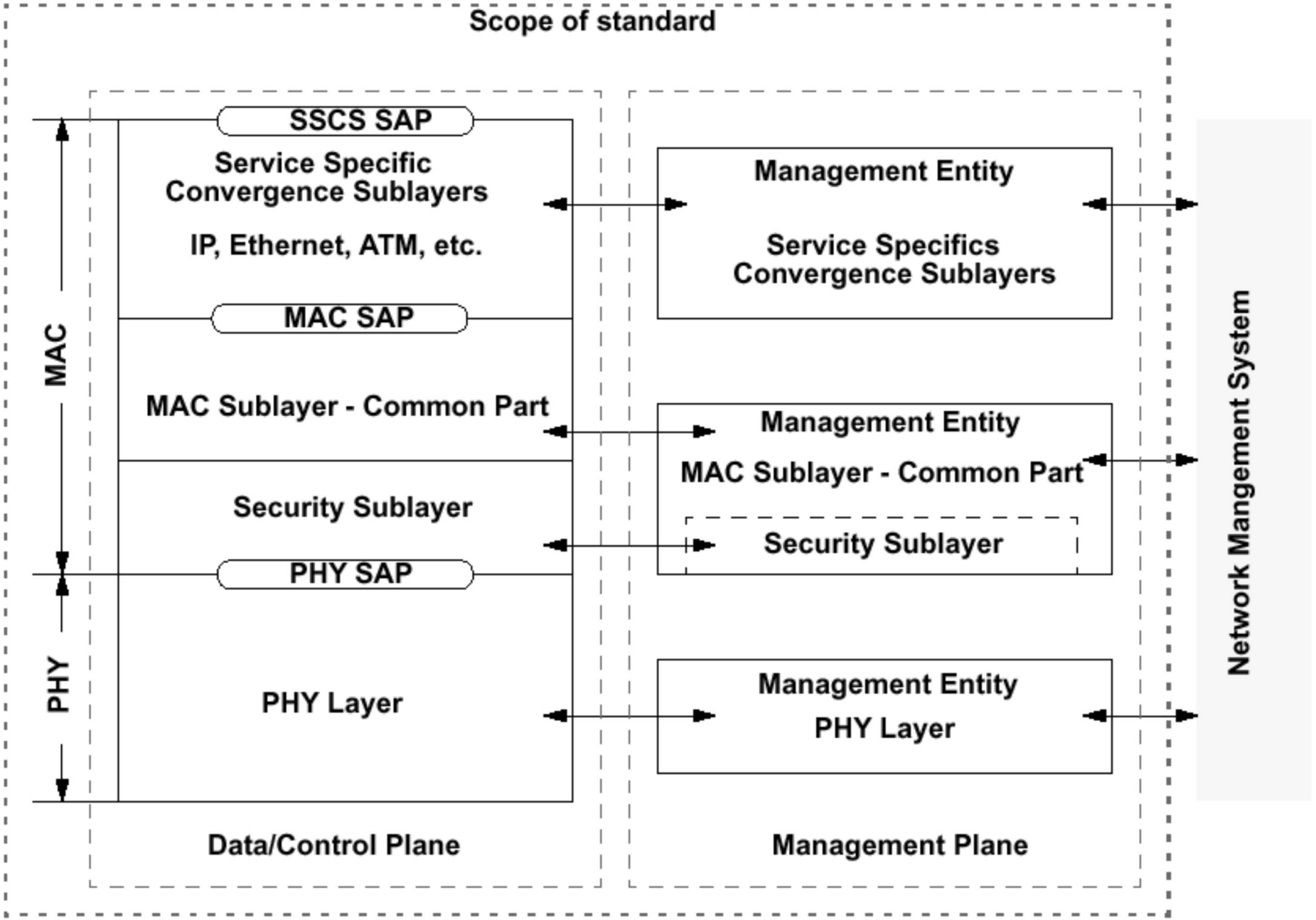
- Carl Eklund, Nokia Research Center

802.16 (TG1) Abstract

- This standard specifies the air interface, including the medium access control layer (MAC) and a physical layer (PHY), of fixed point-to-multipoint broadband wireless access systems providing multiple services. The medium access control layer is capable of supporting multiple physical layers optimized for the frequency bands of the application.The standard includes a particular physical layer implementation broadly applicable to systems operating between 10 and 66 GHz.

TG1 - Scope of Standard

- Air Interface Standard Development
  - **PHY** and **MAC**
  - Subscriber Station and Base Station
- Millimeter wave frequency range
  - LMDS focus
  - Applicable to 10-66 GHz
- Point to Multipoint (PMP) topology


Scope of standard
SSCS SAP
Service Specific
Convergence Sublayers
IP, Ethernet, ATM, etc.
MAC SAP
MAC Sublayer - Common Part
Security Sublayer
PHY SAP
PHY Layer
MAC
PHY
Data/Control Plane
Management Entity
Service Specifics
Convergence Sublayers
Management Entity
MAC Sublayer - Common Part
Security Sublayer
Management Entity
PHY Layer
Management Plane
Network Mangement System

Some PHY Considerations

- Line of Sight Communications
  - Due to operating frequency
  - Negligible multi-path ⇒ Large channels
- Broadband Channels
  - >10 MHz typical
  - High capacity – Downlink **AND** Uplink
- Multiple Access
  - Time division (TDMA)
  - High rate burst modems
- Duplex scheme agnostic
  - FDD or TDD

Some MAC Considerations

- Address the **Wireless** environment
- Different transport protocols
  - ATM, IP
- Broadband services
  - Very high bit rates, downlink and uplink
  - Different QoS requirements
- Likelihood of Terminal being shared
  - Combined with previous issue may heavily load Base Station
- Network Access
- Security

Origin of Current Draft

- 11/1999 - full PHY & MAC numerous proposals were considered
- 5/2000 - 2 merged proposals are the basis of current draft
  - "E+": Technology approach – New
    - Main Companies: Ensemble, Nokia, BreezeCOM, Siemens, Lucent, Ericsson, DMC, 3Com
  - "D+": Technology approach - DVB (PHY) and DOCSIS (MAC)
    - Main Companies: Motorola, Newbridge/Alcatel, Nortel, Vyyo, SpaceBridge, Crosspan
- Following the merger – unified industry effort to perfect draft
- Last 3 months invested in document restructuring allowing the 802.16 MAC serve multiple PHYs

TG1 - Core Concepts

- PHY
  - Burst Mode used for Downlink (Mode B) **&** Uplink
    - FDD and TDD
    - Uses Adaptive Burst Profiles (Adaptive Modulation)
  - DVB variant can be used for Downlink (Mode A)
    - FDD only
    - Continuous Waveform
- MAC
  - Protocol Agnostic Engine
    - Convergence Layers used to match network protocol
  - Some of DOCSIS framework adopted
    - For example: Initial Access, Privacy and Authentication

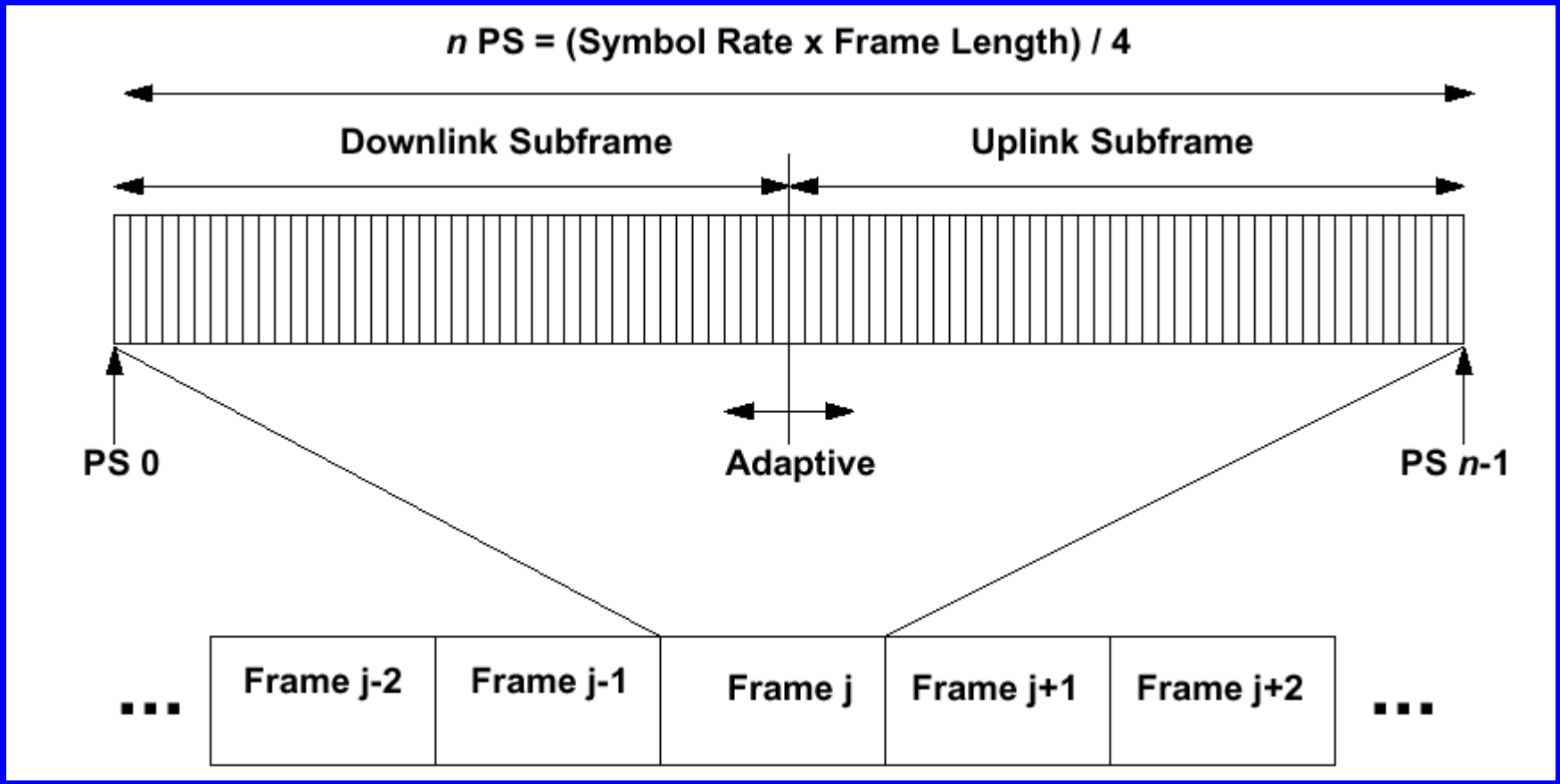
Adaptive Modulation

- Terminals are dynamically assigned to use a specific burst profile according to their link conditions
  - Burst profiles are combinations of Modulation and FEC
  - Trade-off capacity vs. robustness in ***real-time***
- Roughly X2 Capacity for the same cell area
- Only the downlink Control Channel must be *apriori* known
  - All other burst profiles could be configured “on the fly”
  - Terminal capabilities recognized at registration

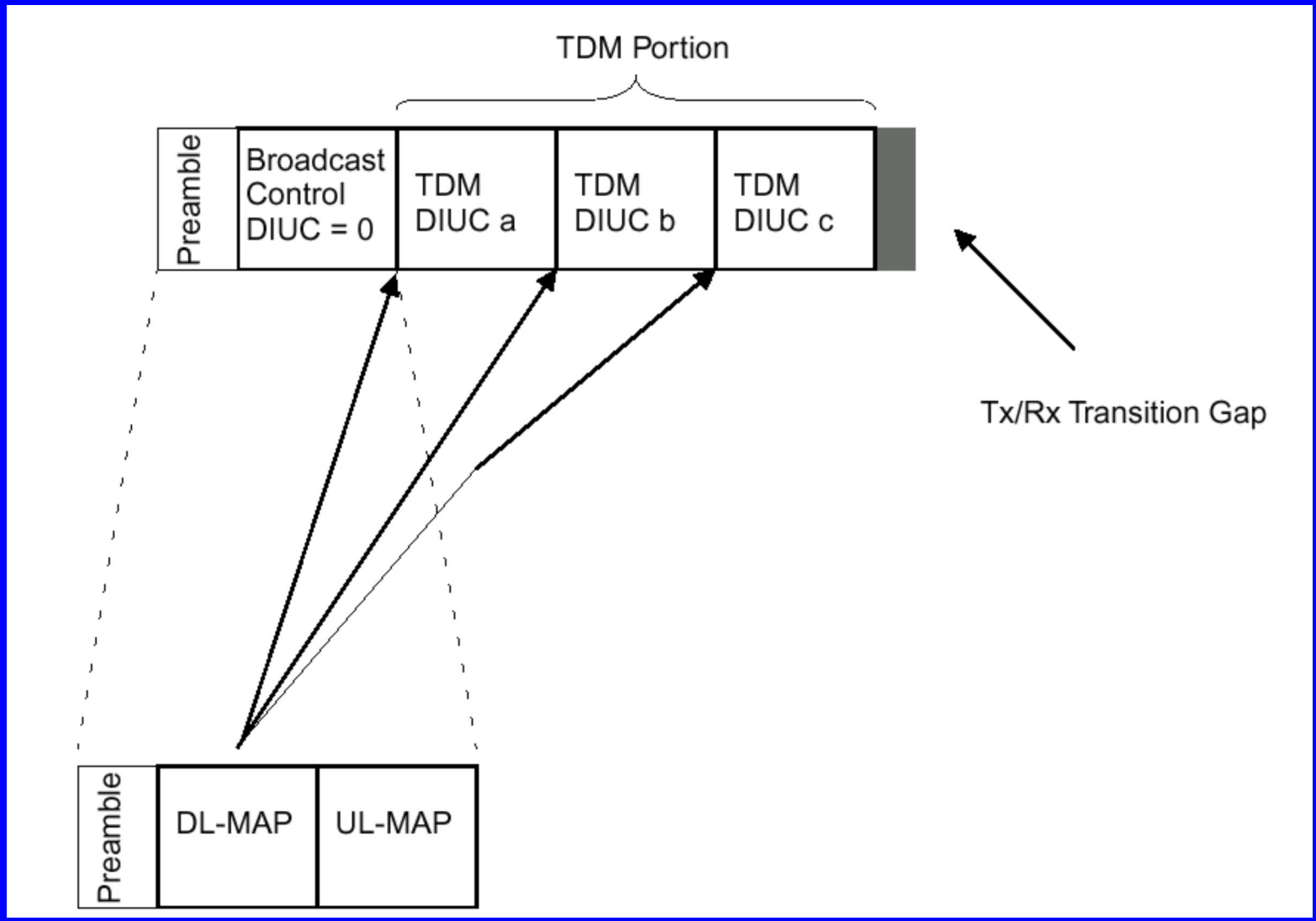
Duplex Scheme Support

- Burst technology allows Terminal cost reduction for TDD and FDD
- FDD
  - Downlink & Uplink on separated RF channels
  - Half-duplex terminal supported by burst technology & MAC
- TDD
  - Downlink & Uplink time share the same RF channel
- Terminals on downlink are associated with a specific TDM burst
- Terminals on uplink are allotted a variable length time slot for their transmissions

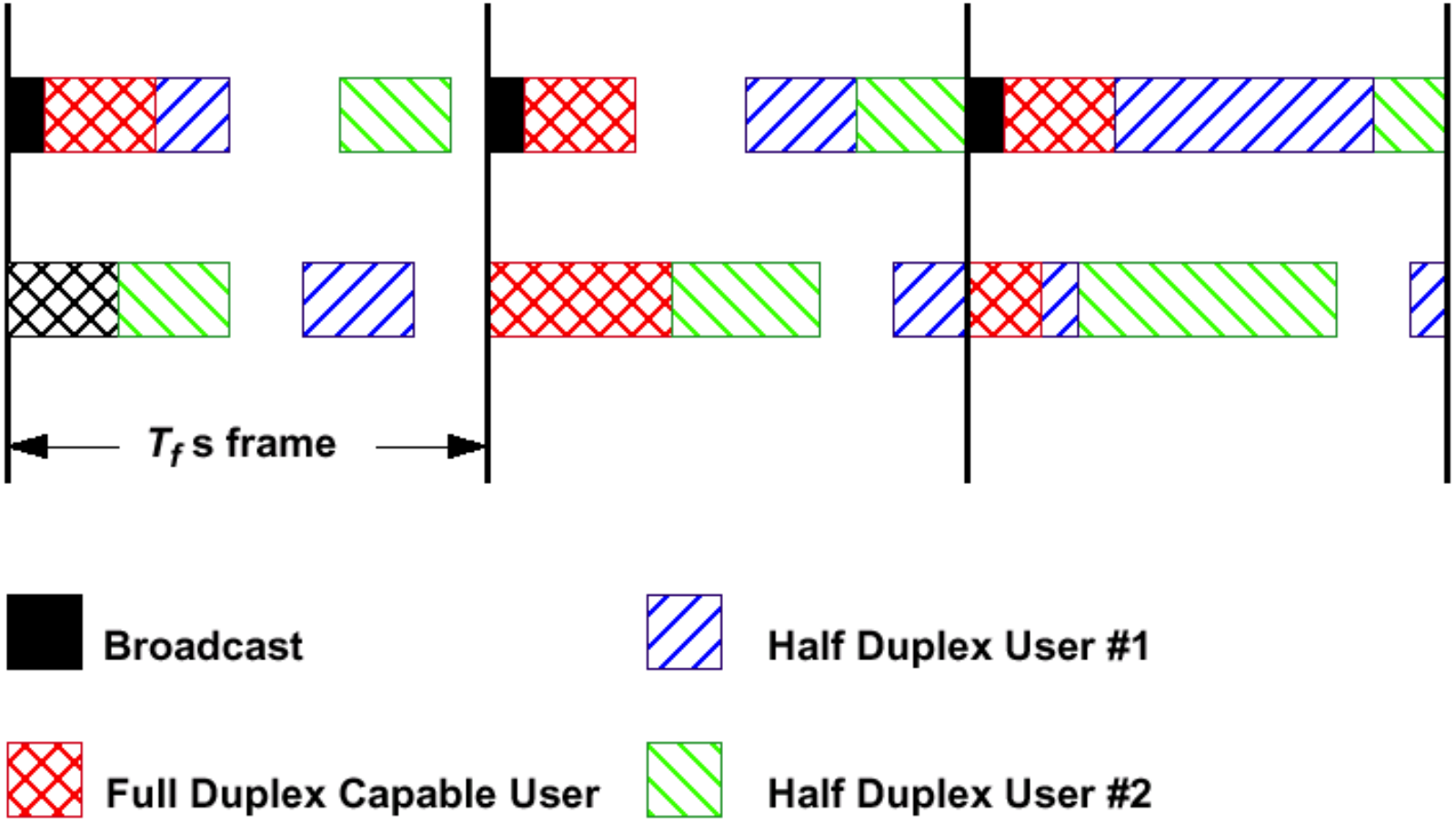
TDD Case


n PS = (Symbol Rate x Frame Length) / 4
Downlink Subframe
Uplink Subframe
PS 0
Adaptive
PS *n*-1
...
Frame j-2
Frame j-1
Frame j
Frame j+1
Frame j+2
...

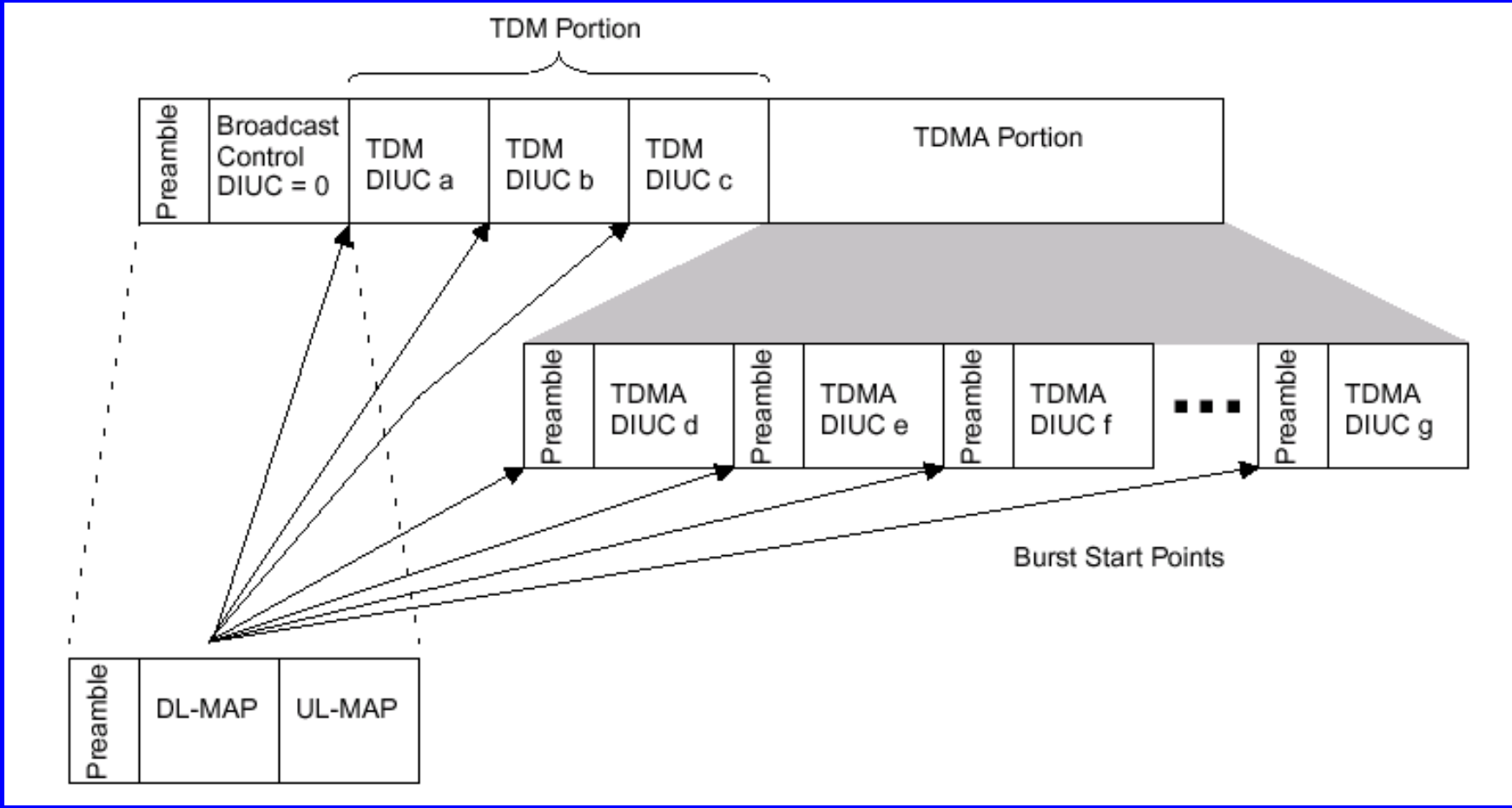
Adaptive Modulation with TDD



FDD (Burst) Case



Adaptive Modulation with FDD (Burst)



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
  - Corner points (QPSK like)
- Scrambler based on a 15 bit PN generator

FEC

- Reed Solomon
  - RS GF(256), t=0…16
- For robust communications the RS code 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 $(7,5)_8$ Conv. Code for every 16 data bits
- Shortening allowed
- Turbo Product Codes (TPC) are optional
- For a DVB based downlink the regular RS+CC (with interleaving) is used

Framing Structure

- Frame length is either 0.5 mSec, 1 mSec or 2 mSec
  - As baud rate increases smaller frames are used
- Allocation process is done in terms of PSs
  - PS = Physical Slots
  - A PS is defined for TG1 PHY as 4 Modulation Symbols
  - Depending on modulation, a PS contains 1, 2, or 3 bytes
- Frameless operation supported as well

Baud Rates & Channel Size

- Flexible plan - allows equipment manufactures to choose according to spectrum requirements
  - 10 to 32 Mbaud
  - Roll-off factors 0.15, 0.25 or 0.35
- Recommended baud rates in the standard are suitable for ***worldwide*** deployments
  - Examples: 40 MHz (32 Mbaud [0.5 msec frame]), 28 MHz (22.4 MBaud [1 msec frame])
  - In framed operation, baud rate is tied to the frame length

802.16 MAC – A True BWA Solution

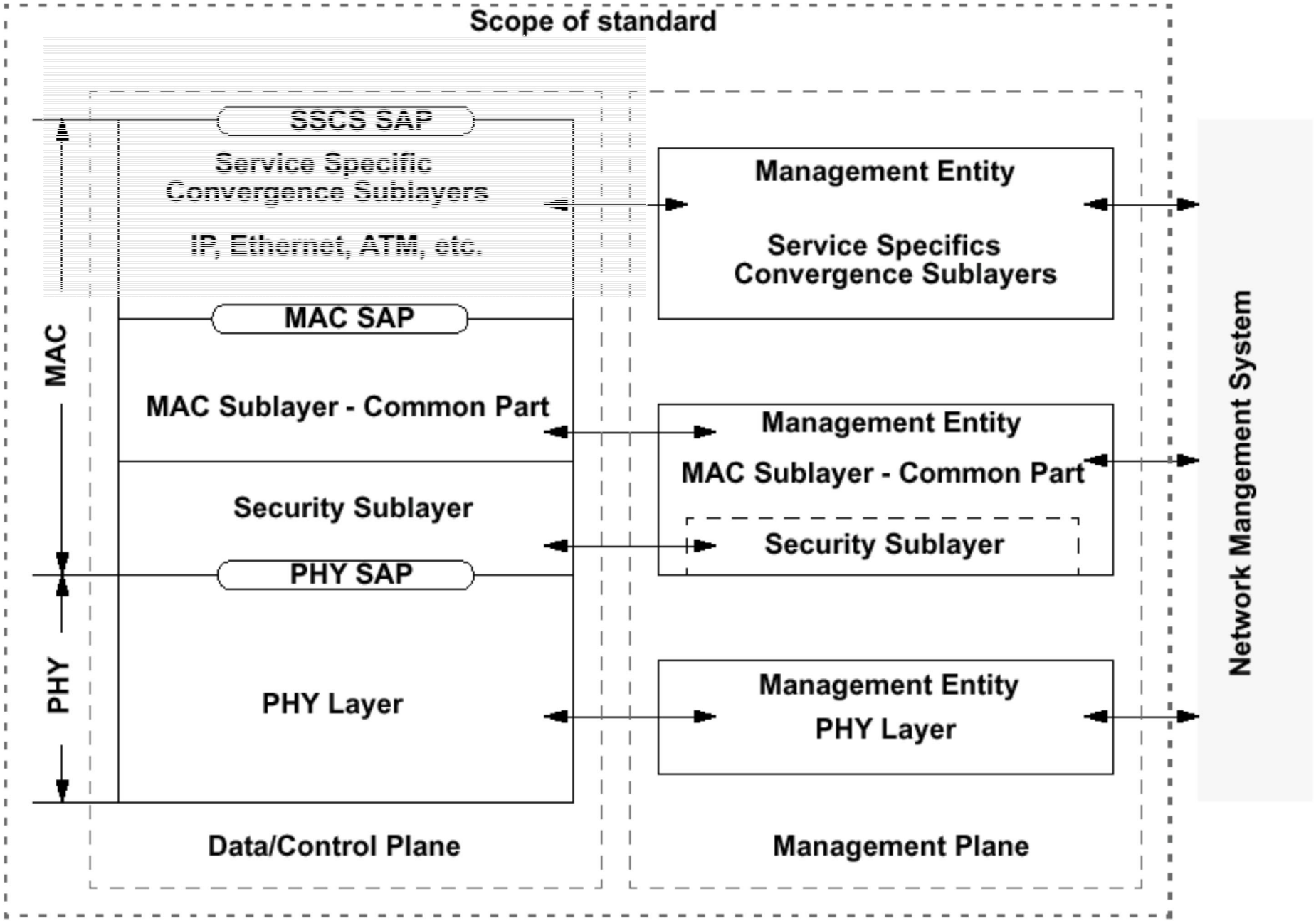
- Supports difficult user environments
  - High bandwidth, hundreds of users per channel
  - Continuous and burst traffic
- “Transport Agnostic” structure
  - ATM, IP
- Balances between stability of contention-less and efficiency of contention-based operation
- Flexible QoS offerings
  - CBR, rt-VBR, nrt-VBR, MGR, BE
  - Granularity within classes
- Supports wireless PHYs (i.e., adaptive modulation)

What was re-used from DOCSIS?

- Management
  - Dynamic service “editing” protocol (Add/Change/Delete)
  - Management message payload format
- Security
  - Authentication, Privacy & Encryption
- Polling categories
- Initial Access
  - Slightly modified allowing terminal capability negotiation
- The MAC protocol engine which is Ethernet based was completely removed

802.16 MAC: GPC & GPT

- GPC – Grant Per Connection
  - Base station grants bandwidth to a connection
  - Mostly suitable for a single user per terminal
- GPT – Grant Per Terminal
  - Base station grants bandwidth to the terminal
  - The terminal is allowed to re-distribute bandwidth among its connections, maintaining QoS and SLA
  - Suitable for the typical case of multi-connections per terminal; off-loading base station


Scope of standard
SSCS SAP
Service Specific
Convergence Sublayers
IP, Ethernet, ATM, etc.
MAC SAP
MAC Sublayer - Common Part
Security Sublayer
PHY SAP
PHY Layer
MAC
PHY
Data/Control Plane
Management Entity
Service Specifics
Convergence Sublayers
Management Entity
MAC Sublayer - Common Part
Security Sublayer
Management Entity
PHY Layer
Management Plane
Network Mangement System

ATM Convergence Sublayer

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

Packet Convergence Sublayer

- Initial support for Ethernet, IPv4, and IPv6 based services
- Payload header suppression (generic plus IP specific)
- Full QoS support
- Future support for PPP, MPLS, etc.

Packing

- Pack multiple higher layer data units into a single MAC PDU.
- Available for fixed (ATM) and variable length SDUs
- Saves up to 10% of system bandwidth

Applicability for TG3 & TG4

- TG3 & TG4 are addressing a similar problem
  - Different frequency bands
    - TG3: 2-11 GHz licensed
    - TG4: 5-6 GHz license-exempt
  - Different user level
- The WG has invested time for the following:
  - Draft was restructured to allow easy MAC interfacing with other PHYs
  - TG3/TG4 provided useful input which led to some modifications, for example:
    - ARQ
    - Header flexibility
    - Larger frame lengths

802.16 (TG1) Timeline

- 13 March
  - Working Group Letter Ballot closes
- March-April
  - Comment resolution
- May-June
  - Sponsor Ballot
- 3 August 2001
  - Final draft due to IEEE Standards Board
- 13 September 2001
  - IEEE Standards Board has opportunity for final approval

Final Notes

- The 802.16 TG1 Air Interface is a powerful standard addressing true BWA market needs
- The outcome is due to successful cooperation between BWA industry leaders
- The 802.16 MAC is powerful enough to cover any BWA technology variant in any spectrum in any market

802.16 Task Group 3 (TG3)

Developing Amendment IEEE 802.16a:

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

Presenter:

Brian G. Kiernan,

InterDigital Communications Corp.

TG3 Leaders

Chair

- Brian G. Kiernan, InterDigital Communications Corp.

Vice Chair

- Carl Bushue, Sprint

Secretary

- Dean Chang, Aperto Networks

IEEE 802.16a
Licensed Bands from 2-11GHz

- Scope –
  - Specification of physical and media access control layers of the air interface for broadband wireless access systems (data rates of DS1/E1 or greater) … in licensed bands designated for public network access … between 2 and 11 GHz
- Oriented toward residential, SOHO, telecommuter, and SME markets

IEEE 802.16a
Licensed Bands from 2-11 GHz

- Working Group Study Group created Dec 1999
- First SG meeting held January 2000
  - 101 people, 72 companies
- Second meeting created documents needed for a new IEEE 802.16 Task Group 3
- IEEE approves project in March 2000

IEEE 802.16a
Licensed Bands from 2-11 GHz

- First official meeting - May 2000
  - 90 people, 76 companies
- Functional Requirements Established
  - 802.16.3-00/02r4
- PHY proposals currently under evaluation – both OFDM and Single Carrier
- Enhanced version of 802.16 MAC

IEEE 802.16a
Licensed Bands from 2-11 GHz

- Some Fundamental Requirements
  - Packet based Point – to Multipoint transport
  - Multi – Cell Deployment
  - Voice, Data and Video Services
  - Directly Competitive with DSL and Cable
  - Service Specific QoS Support
  - Dual Mode FDD/TDD
  - Security

IEEE 802.16a
Licensed Bands from 2-11 GHz

- First Call for PHY Proposals – Oct 2000
  - 20 Proposals received
  - 15 Return Invitees
- Second Call for PHY Proposals – Jan 2001
  - 14 Proposals received
  - 6 Return Invitees
- Convergence and Consolidation in Process

IEEE 802.16a
Licensed Bands from 2-11 GHz

- MAC is an extension of 802.16 MAC
- Incorporates enhancements such as:
  - ARQ Mechanisms
  - Type Fields
  - Extended Header
- Strong push for TG3/TG4 compatibility
- Work Ongoing – Contributions Solicited

IEEE 802.16a
Licensed Bands from 2-11 GHz

- **Plans and Expectations**
  - March 2001 – PHY selection, MAC enhancements settled – initial draft text
  - May 2001 – Enhancements and Improvements – Consolidated addenda text
  - July 2001 – Initial Draft standard – initiate WG Letter Ballot

802.16 Task Group 4 (TG4)

Developing IEEE Amendment 802.16b:

Media Access Control Modifications and Additional Physical Layer for License-Exempt Frequencies

Wireless High-Speed Unlicensed Metropolitan Area Network ("WirelessHUMAN™")

Presenter:

Durga P. Satapathy, Chief Scientist,

Sprint, Converged Network Design

TG4 Leaders

Chair

- Durga P. Satapathy, Sprint

Vice Chair

- Sanjay Moghe, RF Solutions

Secretary

- Ken Peirce, Malibu Networks

Coexistence Liaison

- David Chauncey, Clearwire Technologies

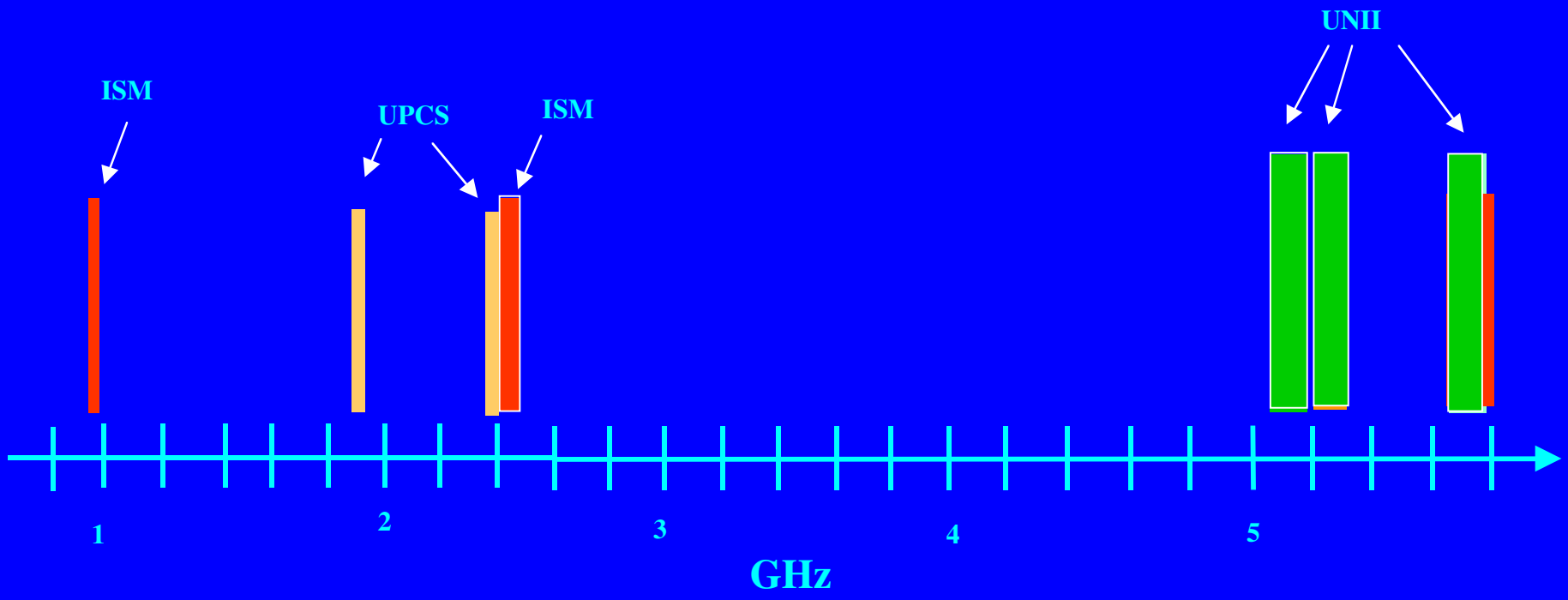
Outline

- Introduction to Unlicensed Spectrum
- Benefits and Challenges
- Standards for License Exempt Spectrum
- The IEEE WirelessHUMAN™ Standard

What is Unlicensed Spectrum?

- Unlicensed spectrum is spectrum where a device may transmit without requiring a license from a regulatory body, such as the FCC in the United States.
- Unlicensed transmissions are still subject to rules and constraints, such as power limits.

Unlicensed Spectrum View



ISM: Industry, Science & Medicine

UPCS: Unlicensed Personal Communications Services

UNII: Unlicensed National Information Infrastructure

Bands and Applications

Unlicensed Bands	Spectrum	Typical Applications
40 MHz	Narrowband	Garage Door Openers
ISM: Industry Science and Medicine 902-928 MHz, 2.4-2.4835 GHz & 5.725-5.85 GHz)	234.5 MHz	Cordless Phones, Wireless LANs (WLAN) and Wireless PBXs (WPBX)
UPCS: Unlicensed PCS Asynchronous:1910-1920, 2390-2400 MHz Isochronous: 1920-1930 MHz	 20 MHz 10 MHz	 WLAN WPBX
UNII: Unlicensed National Information Infrastructure UNII (5.15-5.25 GHz) UNII (5.25-5.35 GHz) UNII (5.725-5.825 GHz)	 100 MHz 100 MHz 100 MHz	 Indoor applications WLAN,WPBX Short outdoor links, campus applications Long outdoor links, Point-To-Point links
Millimeter Wave (59-64 GHz)	5 GHz	Home networking applications

Regulatory Approaches

- All unlicensed bands impose power limits
- ISM bands require spread spectrum modulation
- UPCS: Isochronous and asynchronous band, each with *Spectrum Etiquette* (rules regulating access and usage, e.g. Listen Before Talk (LBT))
- NII bands & Mmwave bands: Minimal regulations e.g. power spectral density limits and emission limits

Benefits of Unlicensed Spectrum

- Free
- Nationwide Footprint
- Immediate Deployment
- Mature Industry
- Mobility
- Spectrum sharing
- Experimentation and innovation

Interference Mitigation Methods

- Typical Techniques
  - Spread Spectrum
  - Frequency Hopping
- Spectrum Etiquettes
- Diversity
  - Multi-band
  - Spatial diversity
- Smart Antennae
- Standards enforcement
- Use in concert with licensed spectrum

Standards for Unlicensed Spectrum

- IEEE 802.11
- IEEE 802.15
- ETSI BRAN HIPERLAN
- PACS UA/UB
- IEEE 802.16 WirelessHUMAN™

IEEE WirelessHUMAN™ Standard

- The IEEE 802.16 WirelessHUMAN Study Group was approved at the March IEEE 802 Plenary meeting
- The charter was to investigate the feasibility of providing High-speed Unlicensed MAN access (focus on UNII bands)
- Significant interest from both academia and industry (manufacturers and service providers)
- First meeting held at IEEE 802.16 in May 2000 with over 30 participants

Key Issues

- What are the existing regulations in the various unlicensed bands, and what unlicensed bands may be appropriate for WirelessHUMAN systems?
- What mechanisms for interference avoidance/suppression, resource sharing, and ensuring adequate performance exist in unlicensed bands?
- What are the unique system design issues/requirements of WirelessHUMAN systems from a MAC/PHY layer perspective? What elements can we utilize from existing work?

System Characteristics

- Metropolitan Area Network
  - Need for Point-To-Multipoint Systems
  - Typically cellular; sectorized with frequency reuse
  - Connectivity to wired infrastructure/ core networks
- Services: voice, video & data
- Fixed/Nomadic Wireless Service Provider Application
- Operation in presence of other unlicensed devices
- QoS support (in-system & external interference)

WirelessHUMAN™ Scope

- The WirelessHUMAN standard will utilize or modify applicable elements from the following:

  MAC: 802.16

  PHY: 802.11a ; HIPERLAN/2

- The standard enables access to data, video, and voice services with quality of service in unlicensed bands designated for public network access. It will focus on the 5-6 GHz range and may be applied to unlicensed bands between 2 and 11 GHz.

IEEE WirelessHUMAN™ Standard

- WirelessHUMAN™ Task Group was approved on December 7, 2000
- The Task group reviewed 20 contributions on MAC/PHY modifications at the Jan 2001 meeting.
- Reaching consensus on several issues, the Group selected best elements from the above contributions at its February Interim meeting held last week.

WirelessHUMAN™ Timeline

- Call For Proposals for WirelessHUMAN PHY/MAC: Nov 2000)
  - PHY: Modifications of 802.11a / HIPERLAN/2
  - MAC: Modifications of 802.16
- Review proposals : Jan 2001
- Select candidate proposals at Interim meeting: Feb 2001
- Decision on specific modifications: March 2001
- First Draft Standard: May 2001
- Comment Resolutions: July 2001
- Second Draft Standard: Sep 2001
- Finalize WirelessHUMAN Standard: Nov 2001

Open call for participation

- Join the WirelessHUMAN™ Group and be a part of the standards making process!
- See **http://WirelessMAN.org/tg4**
- WirelessHUMAN™ Leadership Team:
  - Chair: Dr. Durga P. Satapathy, Sprint
  - Vice Chair: Sanjay Moghe, RF Solutions
  - Secretary: Ken Peirce, Malibu Networks
  - Coexistence Liaison: David C. Chauncey, Clearwire Technologies Inc.

Contact Information

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IEEE WirelessHUMAN™
http://WirelessMAN.org/tg4 or
http://WirelessHUMAN.org