Project	**IEEE 802.16 Broadband Wireless Access Working Group**
Title	**MAC Proposal: Current Status**
Date Submitted	**2000-3-7**
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Re:	This is a MAC protocol presentation for "Phase II" of the 802.16 MAC protocol selection process. It is in response to the call for contributions as input to 802.16 Session #6.
Abstract	The proposal described herein describes a MAC protocol that: • Supports the transport of diverse traffic types simultaneously (TDM, variable- and fixed-length PDU) • Maximizes capacity of the air link • Provides a commercially viable network for system operators • Uses well-understood technology • Supports FDD (both full and half-duplex) and TDD • Is responsive to varying bandwidth demands The MAC protocol closely resembles cable modem MAC protocols (e.g., DOCSIS and 802.14) yet addresses issues important to BWA systems.
Purpose	The 802.16 Working Group should consider this MAC protocol proposal at Session #6.
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MAC PROPOSAL: CURRENT STATUS

March 7, 2000

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Proposal Status

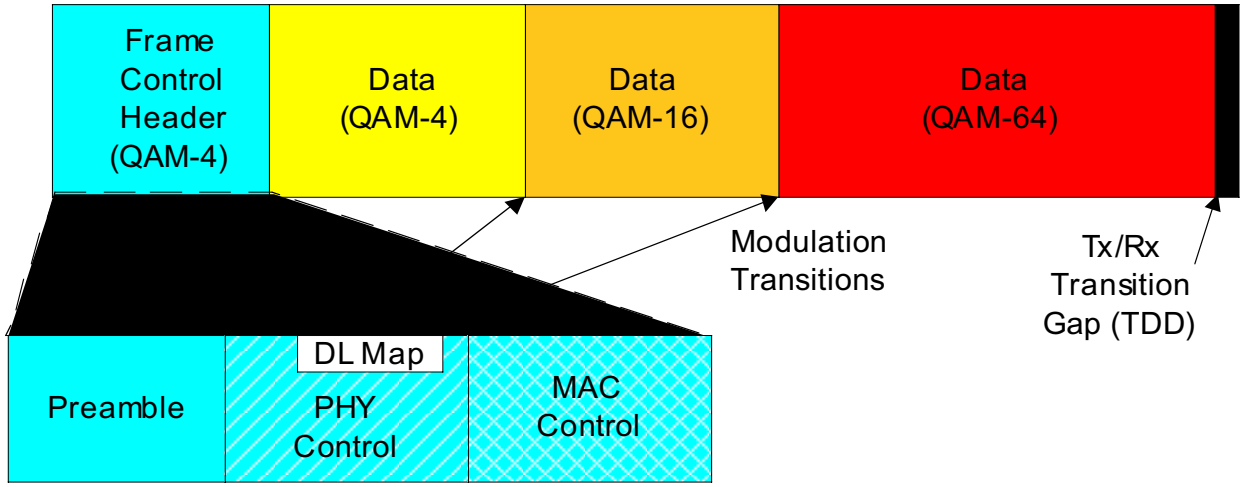
- What has evolved
- Discussions with D+ (we're E+)
- ETSI alignment issues

CQPSK (TFM) Modulation

- **Reduced cost option:**
  - Radio costs in millimeter-wave region are the dominant ones
  - Therefore look for savings in the radio
  - CQPSK is tolerant of RF amplifier nonlinearity, reduces costs
- If CQPSK is used, it is the only modulation used on the uplink
  - Highly robust, but there is concern over interference with adjacent frequency channels
- **High capacity option:**
  - Otherwise, adaptive choice of QAM-4, QAM-16, and QAM-64
  - Dependent on S/N at individual subscriber station
- **Downstream is adaptive QAM in all cases**

TDD, FDD Downstream Subframe Structure

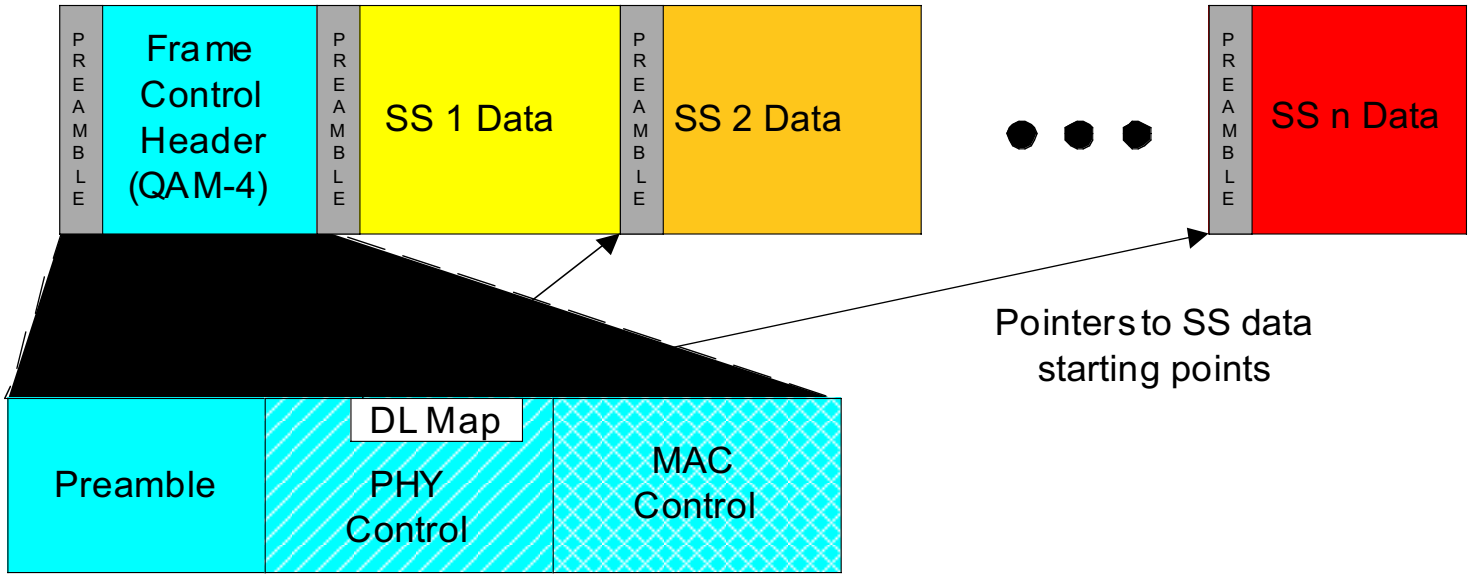
- **Multiple constellations simultaneously: QAM-4, -16, -64**
- **Nearby users can use QAM-64, distant ones use QAM-4; QAM-16 in between**
- **Downlink map is simple: just pointers to each modulation**



H-FDD/TDMA Downstream Subframe Structure

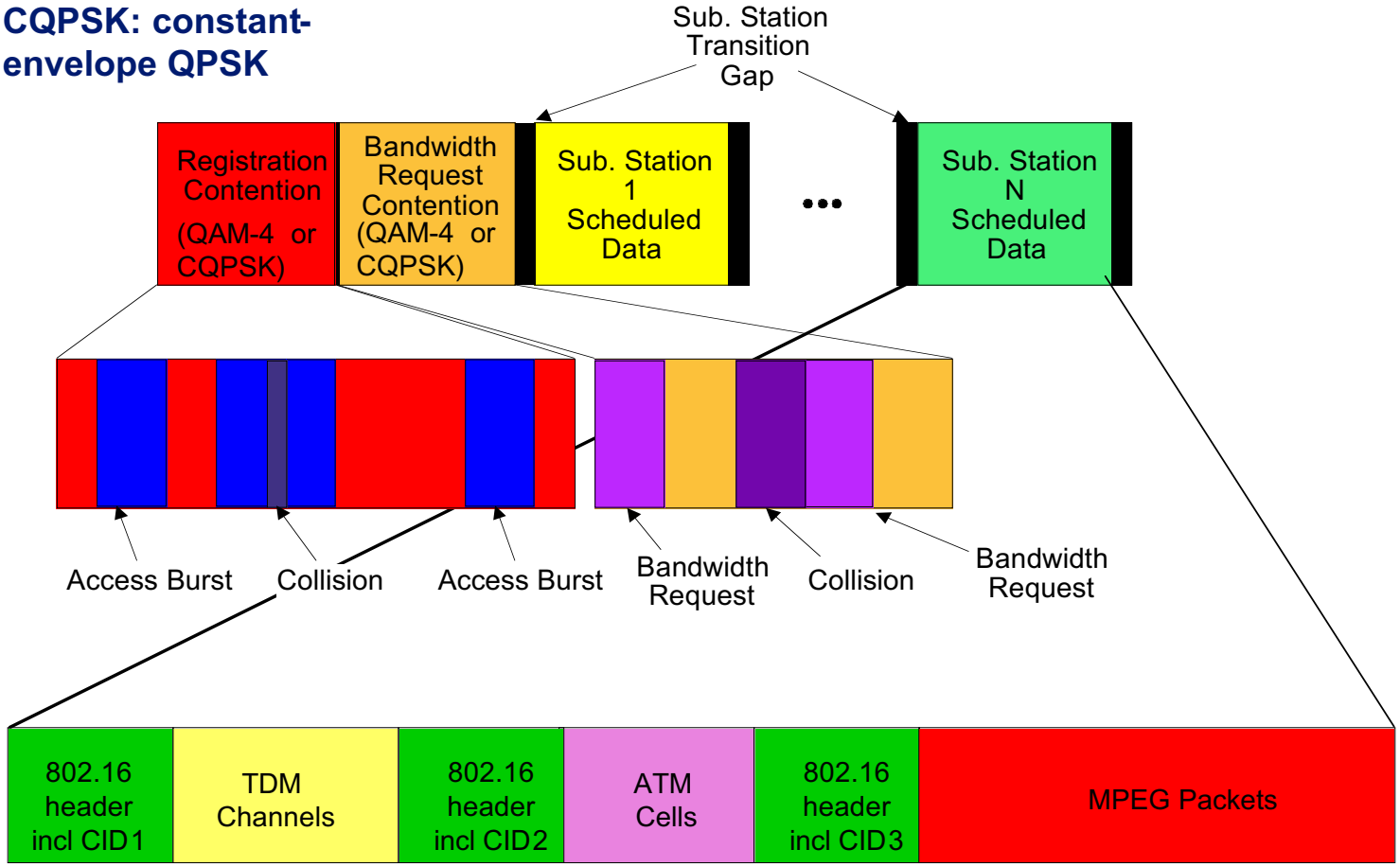
Subscriber station gets data based on time specified in map

Map entries are per subscriber station, not per connection



Upstream Subframe

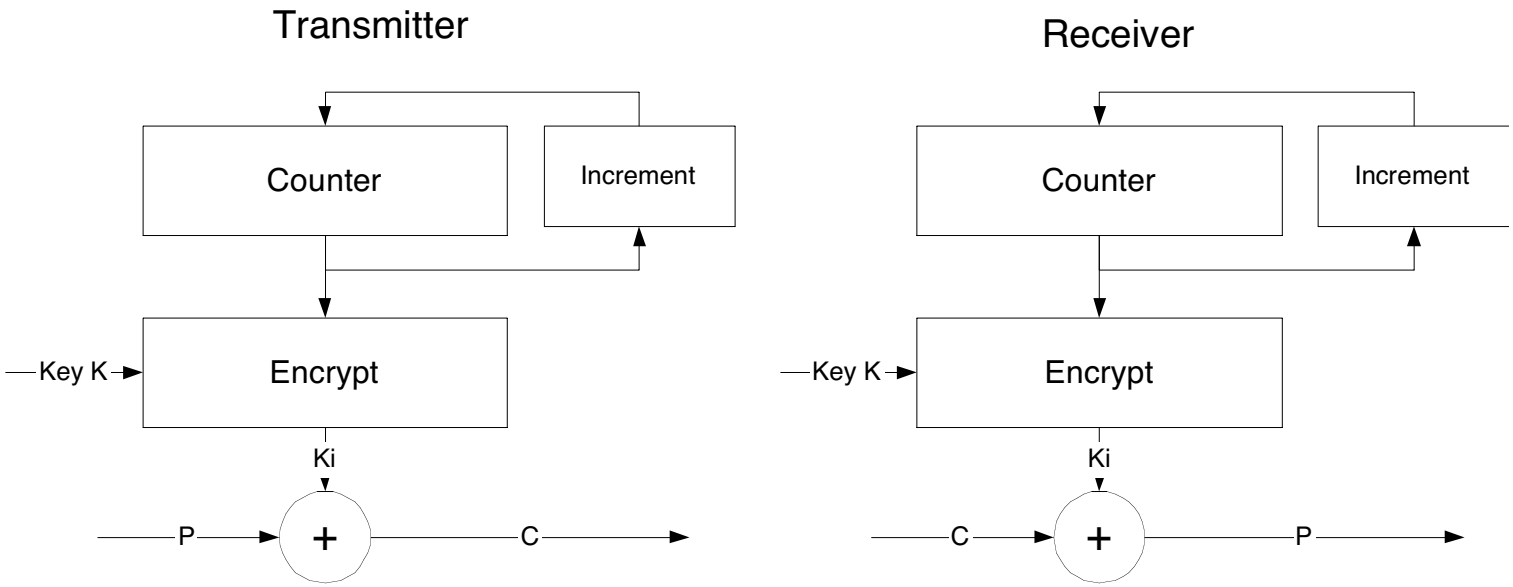
CQPSK: constant-envelope QPSK



Data from multiple connection IDs

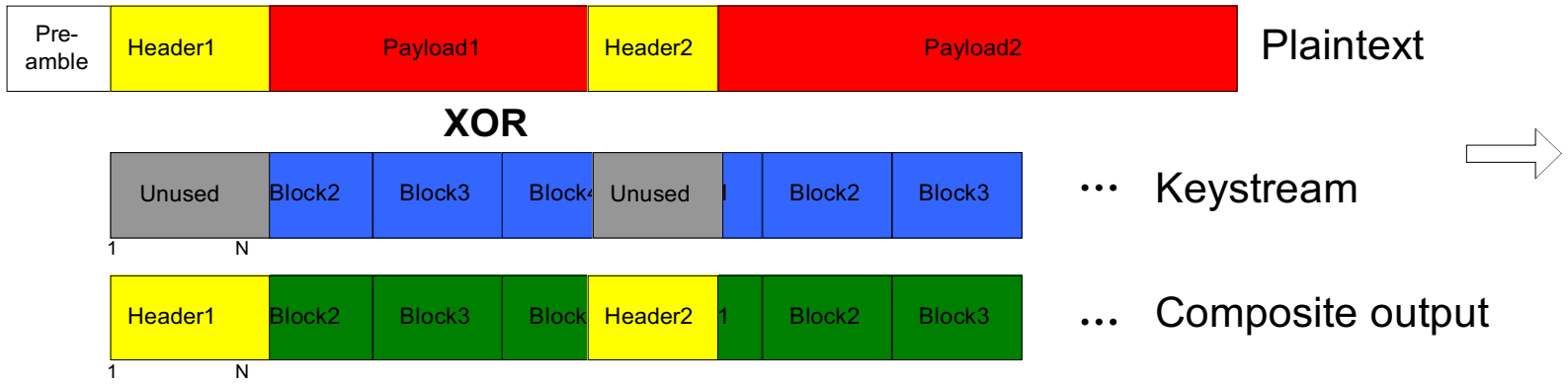
Encryption

- Need to avoid error multiplication
- One transmission bit error in ciphertext --> one bit error in cleartext
- Solution: use DES/TDES in OFB/counter mode
- Generate keystream from initial key and frame number/position in frame



Headers Remain Clear

- Headers are not encrypted
- Skip over portions of keystream corresponding to headers
- Blocks missing due to transmission errors do not cause loss of synchronization



ARQ

- An option in two ways:
  - A system may opt for it or not: fully conforming if not implemented
  - If it does, then ARQ is still optional per connection
- No impact on non-ARQ services
- Very useful for handling infrequent problems: weather, interference
- Some services can benefit, others can't
  - Data can benefit: not delay-sensitive
  - Voice over IP can benefit: compression has delays anyway
  - STM can't: delay budget is very small
  - Video probably can't: data volumes are large; MPEG sometimes can cover for missing data
- Ongoing discussions of improvements
  - Less overhead, greater simplicity
  - Detailed discussion in May

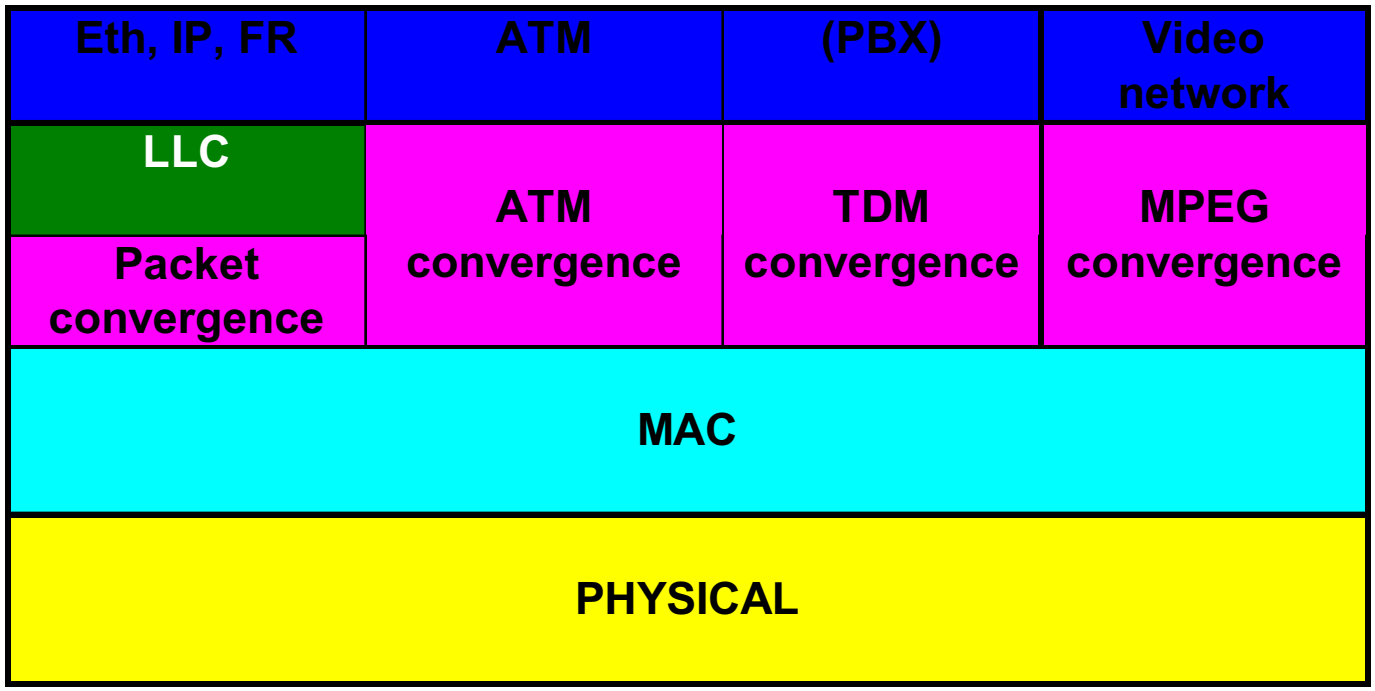
ETSI Alignment

- Benefits of convergence with ETSI are substantial
  - Worldwide markets
  - Better economies of scale
- Most IEEE 802 standards have a worldwide constituency
  - IEEE 802 now accredited as ITU reference
- Example of what not to do: digital video standards
  - Need for separate annexes in J.83, etc.
- Most significant MAC difference now: ETSI has only fixed-length data units.

Layer Structure

- MAC operates on common format, driven by BW and QoS requests
- Convergence layers handle specific issues for various data types

  Data formatting, compression
- Video does not bypass the MAC



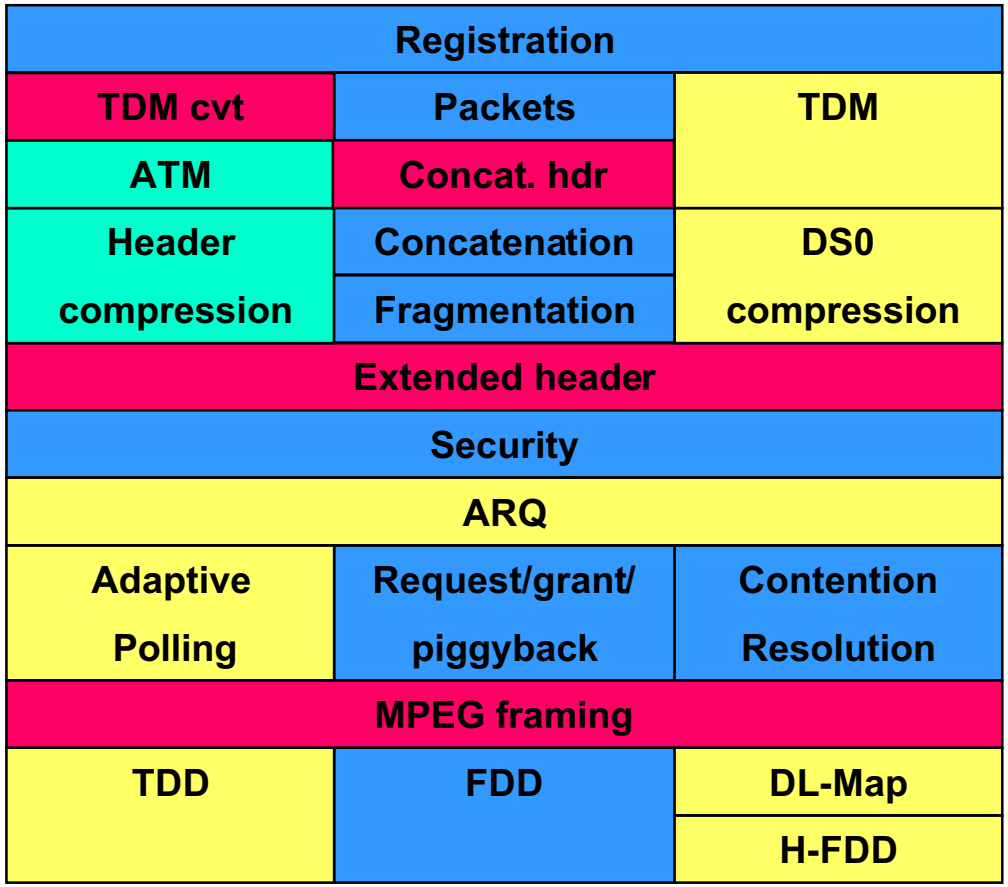
Addressing BWA Needs

This proposal and DOCSIS are similar

This proposal and DOCSIS add-ons are similar

This proposal only

DOCSIS or add-ons only



Major Differences vs. D+ Proposal

- We support multiple duplexing options
  - No single one is optimal for all situations

Mn: mandatory req.
Rn: recommended

- More flexibility to adapt to changing weather and usage patterns (M23)
  - ARQ option as backup for marginal situations
- We support all data types directly: packet, ATM, STM (M11-M16)
  - No complex ATM to handle T1/E1 (M34)
  - Channel compression available for T1 and E1
- Designed for BWA, not recycled from another application
  - No penalty for MPEG residue
- More efficient header design: no need for extended headers for concatenation, fragmentation, or encryption.
- MAC can easily serve multi-user building (R1)
  - Allocation of BW to subscriber station, not each connection

Semi-Distributed Bandwidth Allocation

- Allocation occurs on frame basis
  - Deterministic delay: frame is fixed in size
- Bandwidth request is per connection
  - Preserve QoS
- Requests can represent multiple packets
- Bandwidth allocation is given to subscriber station
  - Saves bandwidth: map is smaller
- Subscriber station can reallocate its assigned bandwidth
  - Higher QoS data may have come in since it made its requests
- Self-correcting: request reflects current status of queues at SS

Meeting Evaluation Requirements

- **This proposal either fulfills mandatory requirements or does not preclude items which are part of mandatory requirements.**

(1) Meets System Requirements:

Meets all system requirements

Native mode support for IP, ATM and STM -- no need for ATM to support STM

Support of different QoS constraints

- **Narrowband voice**
- **NxDS0 trunking**
- **DS1/E1**

Designed for BWA: commercial services, not single-family dwelling

(2) Mean Access Delays & Variance

Variety of allocation request mechanisms serve latency-sensitive services

Polling, piggy-backing, contention, poll-me bit

Meeting Requirements, Continued

(3) Payload & BW efficiency

Minimum overheads: no legacy header structure, e.g. MPEG
Address translation to connection ID minimizes pointer sizes
No need for high overhead of extended headers

(4) Simplicity of implementation

Division of labor: base station allocates bandwidth to subscriber station
Subscriber station can sub-allocate based on most recent information
No problems with implementation using existing processors
ASIC for real-time lower-layer functions, microprocessor for higher functions

(5) Scalability

Designed for channels with over 100 Mbps of traffic per upstream channel
Can easily handle any realistic traffic scenario.

(6) Service Support Flexibility

Optimized for the business environment
MAC supports various services: IP, ATM and STM.
Can support any new service as it is independent of its higher layer choice
(not optimized specifically only for Residential IP or only for ATM)

Meeting Requirements, Continued

(7) Robustness

- **Can easily recover from burst error scenarios**
  - **If a user data has an error, the MAC can re-synchronize on the next PDU immediately without losing the whole burst.**
- **Optional ARQ in addition**

(8) Security

- **Proposed security system provides strong encryption without error propagation**

(9) Maturity

- **Optimized for BWA, not some other existing technology**
- **Features in the MAC are based on experience with systems such as cable modems**
- **A related millimeter-wave system is currently in field trials**

(10) Sign-on Process

- **Fully automatic**
- **User parameters are tracked and changed on the fly (i.e., modulation, RF carrier)**

Meeting Requirements, Continued

(11) Adequacy of management functions

All required parameters are managed in ways that adapt to changes in conditions

(12) Convergence with existing technologies

Able to support packet (e.g.,Ethernet, IP), ATM, and legacy STM networks

QoS is fully supported; this will be increasingly important in the future

(13) Ability to work with PHY variations

The MAC works with all duplex schemes: TDD, FDD, HFDD

Supports multiple modulations simultaneously, changes them when needed to improve optimization

Conclusion

- Best approach is to design for BWA needs
- Convergence sublayer philosophy provides future flexibility and upgrade path
- Duplexing flexibility is important
- Support for per-subscriber adaptive modulation is important
  - Upgrade path for future PHY enhancements