Enhancements in the Aperto MAC

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Overview

- Transport Structure
  - Encapsulation
  - Request Grant Mechanism
- Link Robustness
  - ARQ
  - Link Layer Parameter Control
- Time Base Structure
  - Time Base
  - Flexible Scheduling
  - MAP Packet Issues

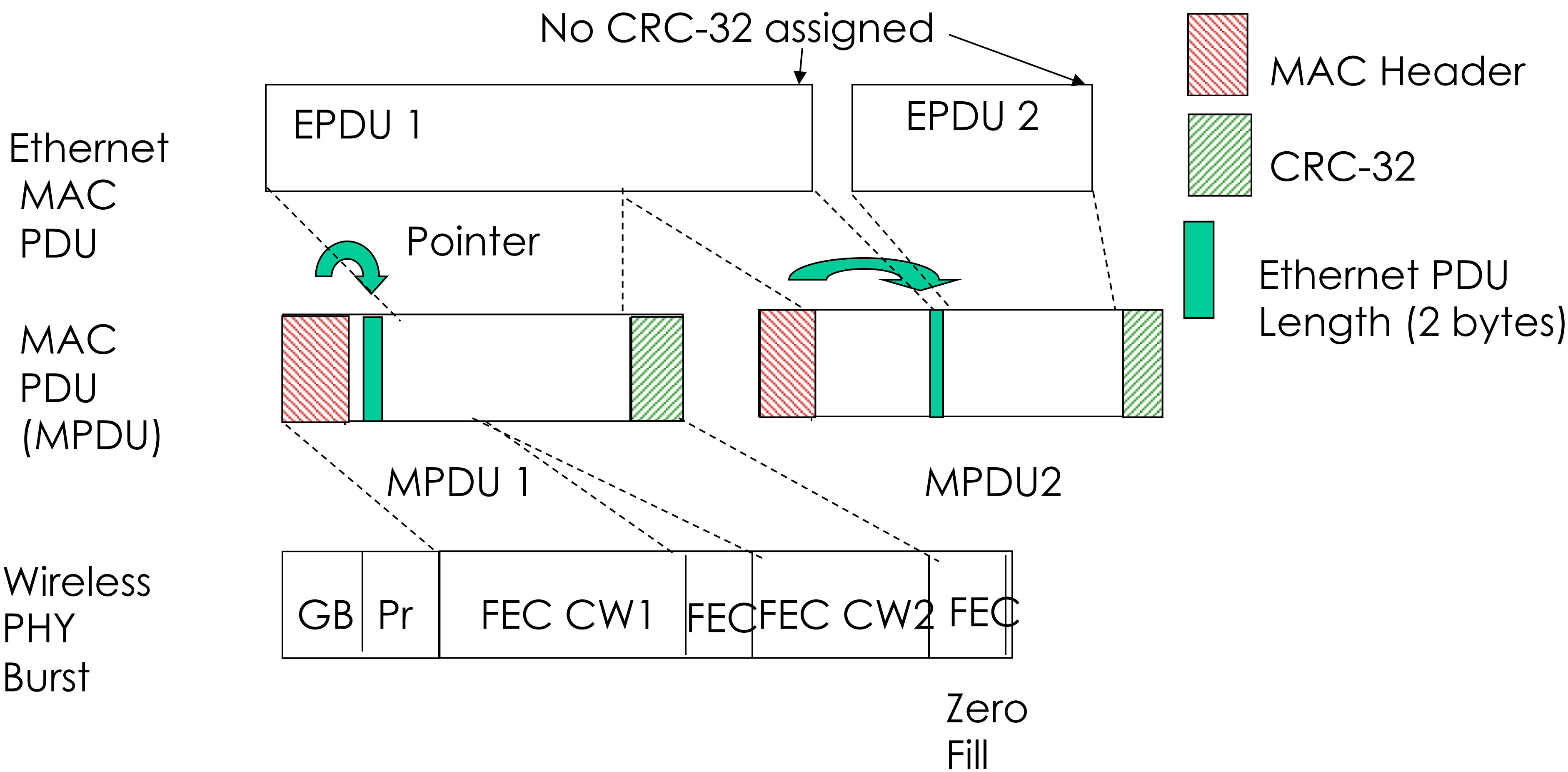
Transport Structure

Encapsulation – Concatenation + Fragmentation

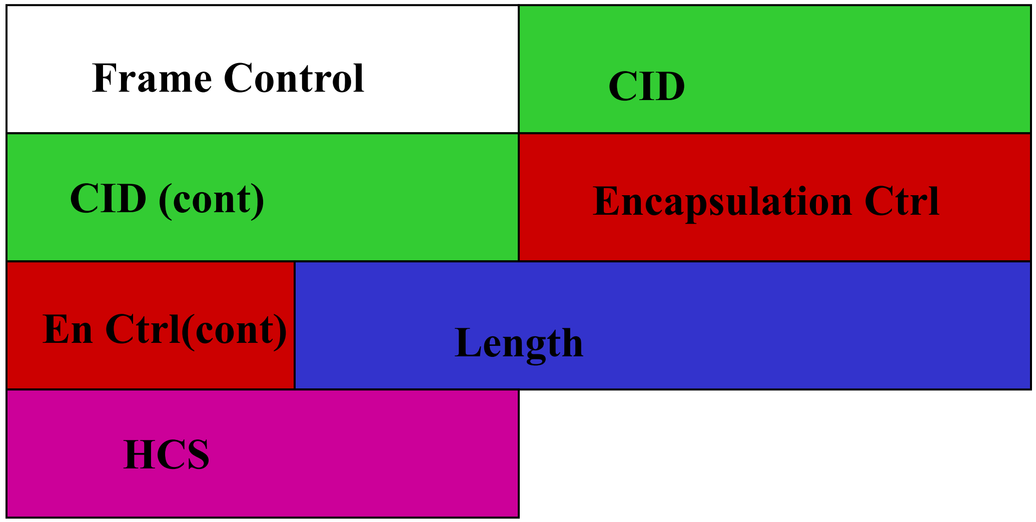
- **Existing Protocols: Require that each MSDU be transported by a its own MPDU. This can lead to in-efficiencies for some common cases, such as upstream transport of TCP ACK packets.**

- **Aperto MAC:**
  - **Allow Concatenation of MSDUs into a single MPDU.**
  - **Allow Concatenation+Fragmentation simultaneously**
  - **Can be achieved by a simple pointer based scheme.**

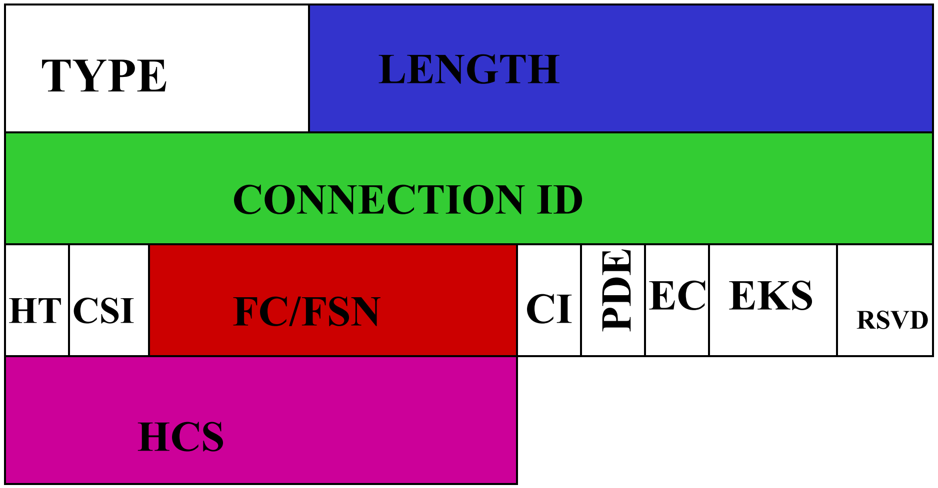
Aperto MAC Packet Encapsulation (cont)



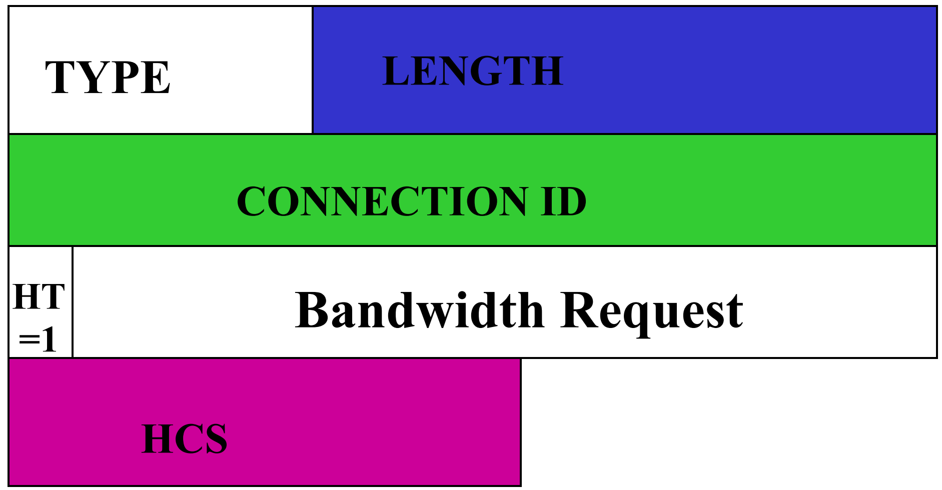
Impact on Headers



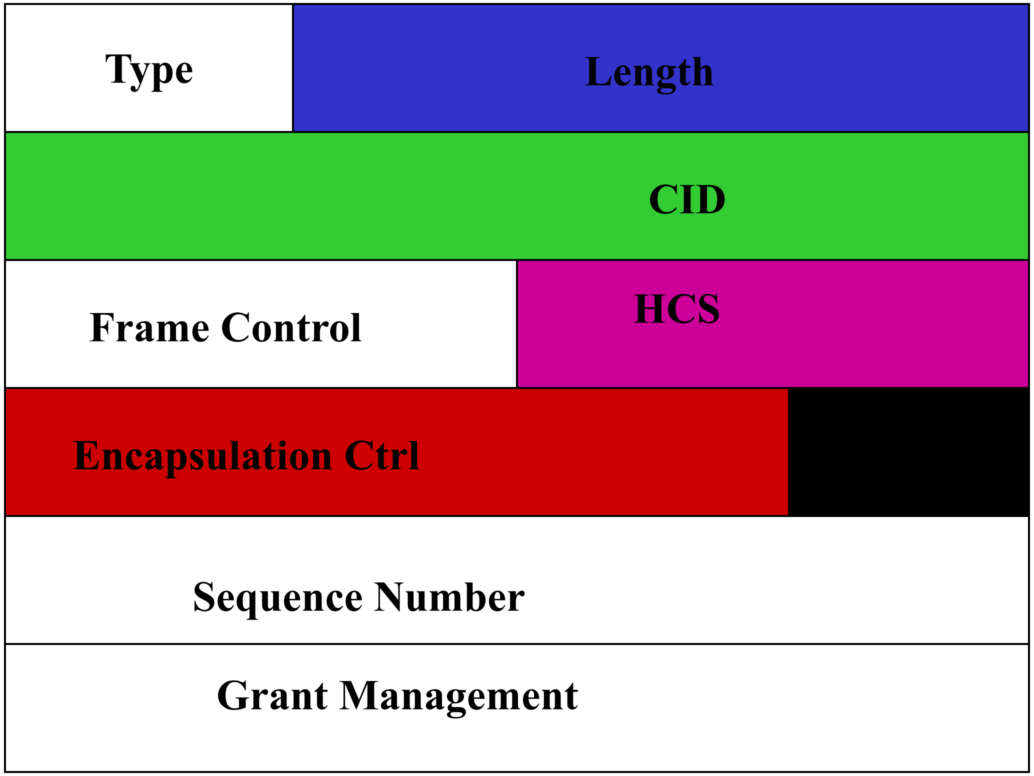
Impact on Headers



Impact on Headers



Headers


Type
Length
CID
Frame Control
HCS
Encapsulation Ctrl
Sequence Number
Grant Management

The Aperto Request Grant Mechanism

- **Current MAC Protocols: The current request mechanism does not allow a CPE to request more than 256 bytes of data, in the piggyback mode.**
- **System Impact: This forces the CPE to transmit a separate REQuest packet, every time it wants to make a request that exceeds 256 bytes.**
- **Solution:**
  - **Increase the size of the piggyback REQuest field to 2 bytes**
  - **The encapsulation scheme meshes very well with the Request/Grant scheme**

ARQ

ARQ

- **Current MAC Protocols: The ARQ protocol, for both upstream and downstream directions, is not completely specified.**

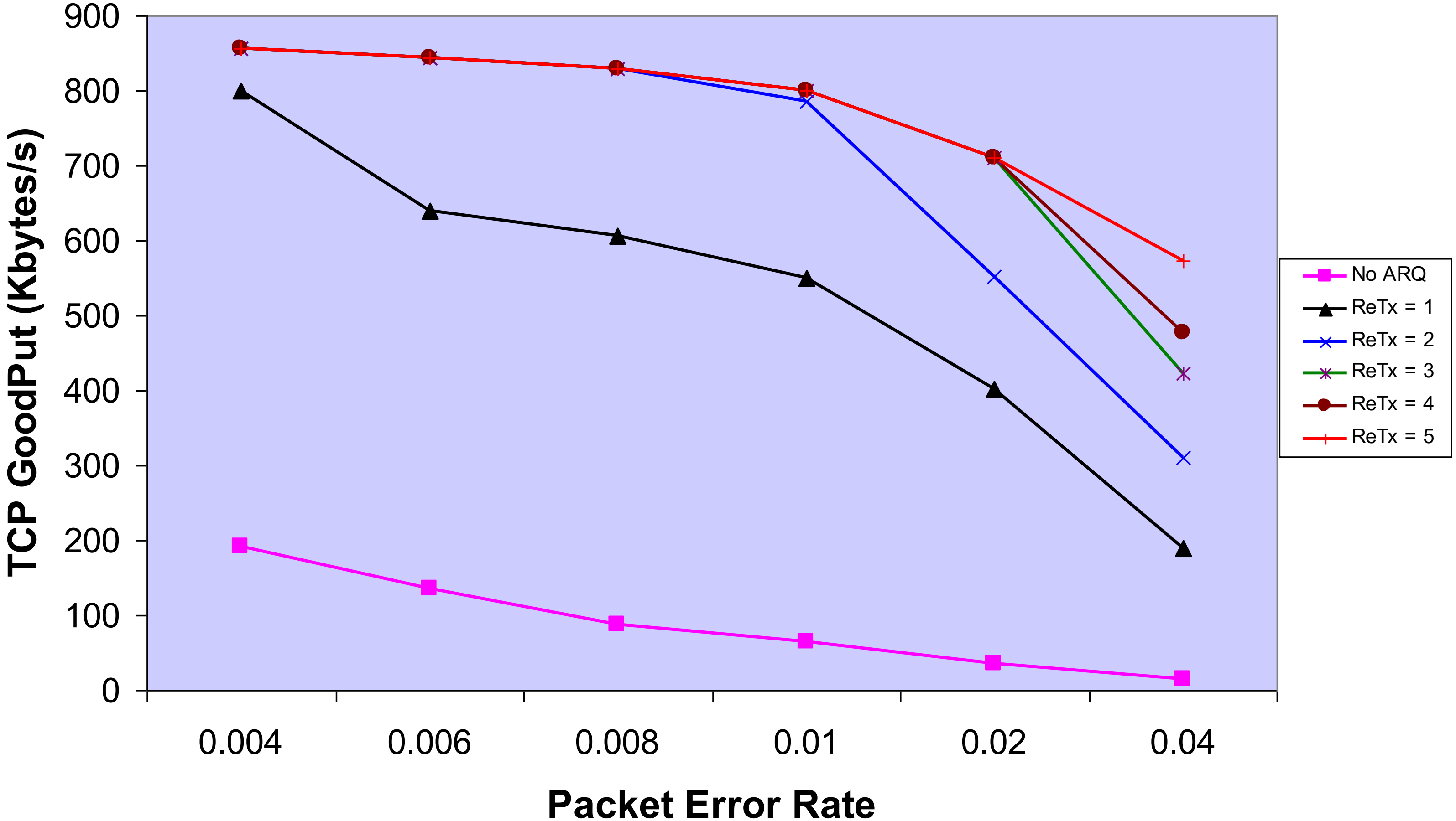
- **System Impact: ARQ is extremely important to achieve good performance in the presence of wireless related channel impairments.**

- **Solution: Specification of a complete ARQ solution, for both upstream and downstream directions**

ARQ Requirements

- Ease of implementation
- ARQ in both upstream and downstream directions
- Ability to scale up to hundreds of connections
- Ability to support different levels of ARQ
- The unit of re-transmission should be the MPDU, not the MSDU
  - Enables the scheduler to decrease the MPDU size in bit error rate environments
- Should not consume an excessive amount of upstream BW due to ACK packets.

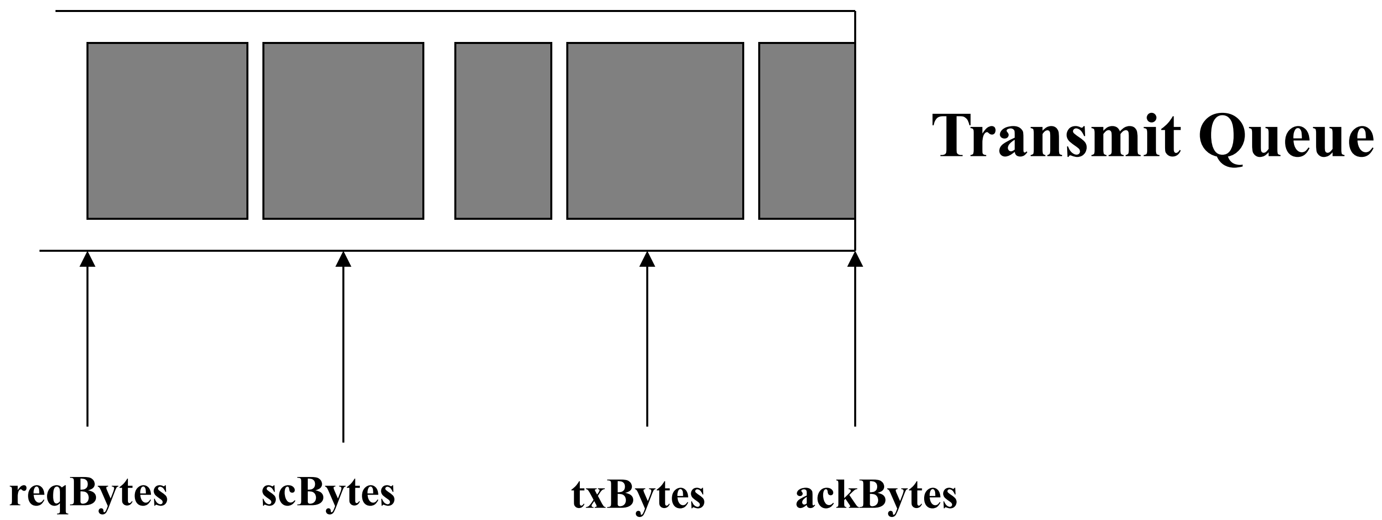
ARQ Dramatically improves Performance

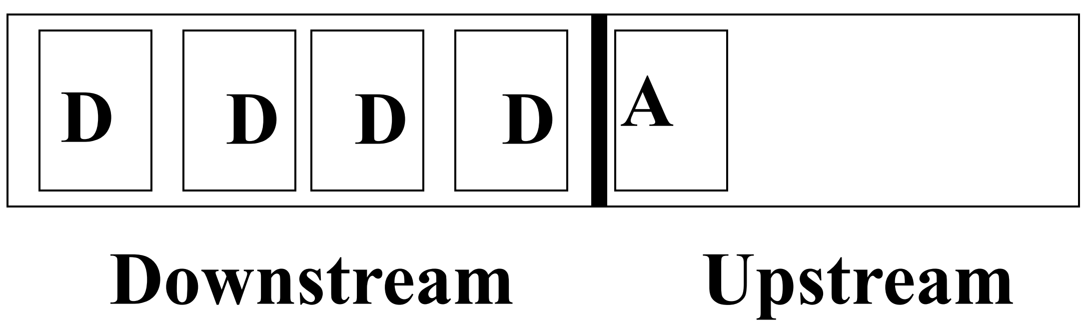


Aperto Solution

A byte based ARQ scheme that fits seamlessly with the byte base REQ/Grant mechanism, and the byte based encapsulation scheme

ARQ Proposal





ARQ Proposal (cont)

- **How much can the proposed protocol be improved with Selective Repeat?**
- **Not by much, because:**
  - **The efficiency of the GBN protocol is proportional to N, which is the number of packets transmitted before the ACK for the first packet comes back. If the ACK is sent back in every frame, then N is small.**
- **Issues with Selective Repeat:**
  - **Buffering at the Receiver can be a problem when there are hundreds of connections**
  - **Need to ACK or NACK every packet – BW consumption by ACK packets can be a problem**
  - **Recovery from errors, such as lost MAPs or lost ACKs**
  - **Greater complexity of receiver logic**

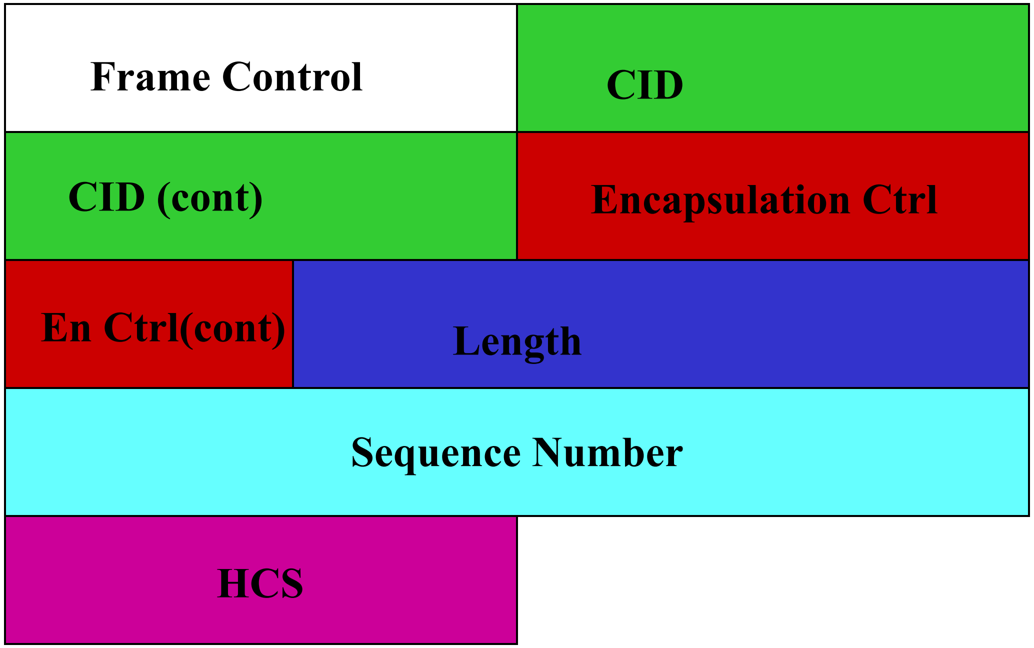
Hybrid GBN + SR Mode of Operation

- Such a mode is also used by the TCP protocol to keep ARQ complexity under control
- The receiver buffers out of order packets, but returns only the sequence number of the first in order packet that it is expecting
- The transmitter does not re-transmit all packets after the lost one, but only the one explicitly requested by the receiver NACK
- This mode keeps the link overhead due to ACKs under control

Link Layer Parameter Control

- Issue: Current Protocols allow dynamic control of only two link parameters – Modulation and FEC.
- System Impact: Restricts the ability for the BS to dynamically control a larger set of link parameters. For example, Dynamic Power Control
- Solution: Add a field in the Downstream and Upstream MAP Ies that can be used to specify a larger set of link parameters, which can be subject to dynamic control.

Header Formats



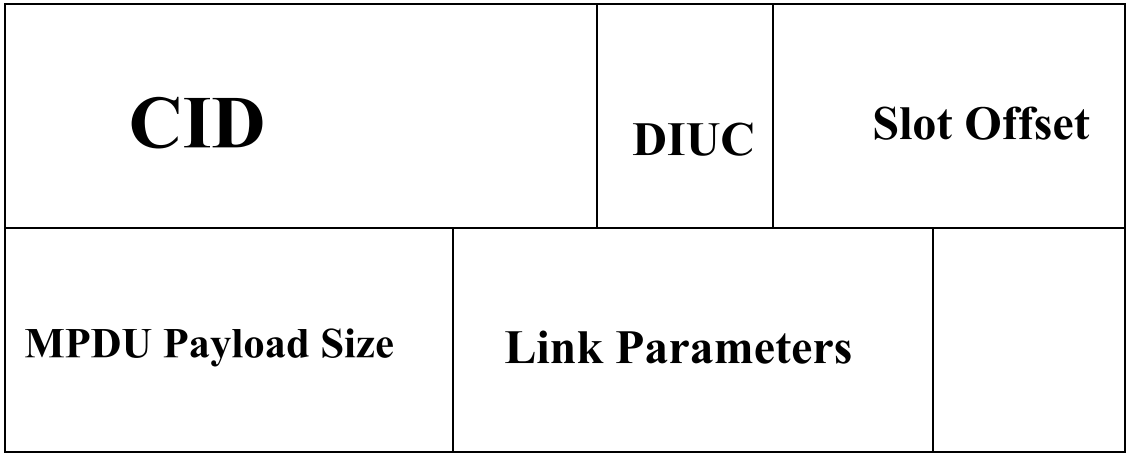
Link Layer Parameter Control

There are 2 ways to control transmit parameters:

- **MAP based control**
  - **The MAP has information about PHY parameters in the burst**
- **Preamble based control**
  - **The PHY parameter information is pre-pended in front of the burst**

- **Advantages of MAP based control:**
  - **Preamble based control allows the BS and SS to individually decide the link parameters (OK for 802.11). However in the upstream, this is a problem, since the size of the burst is a function of the link parameters, and only the BS has control over the size of the burst.**
  - **MAP based control is more relevant in a centrally controlled system such as 802.16. The BS runs algorithms to optimize link parameters, and then controls the transmissions from every PHY using the MAP message.**

MAP Format



Time Base Structure

Time Base Issues

- Issue 1: A single OFDM symbol can carry a large amount of data. The TG1 specification states that the base unit of time is 4 symbols, which forces the smallest transmission unit to contain a large amount of data.
  - System Impact: Coarse transmission granularity leads to waste of bandwidth.

- Issue 2: The additional time resolution in the current TG1 specification is a function of the symbol duration. For example, if the symbol time is 50 us, then the time resolution is 3.125 us.
  - System Impact: A coarse level of time resolution will impede distance ranging, which needs a time resolution around 100 ns.

Time Base Issues (cont)

Solution:

- The base unit of time is defined independently of the symbol rate, and is set to 1 us.
- The additional time resolution is also independent of the symbol rate, and is specified to be 1/64th of the base unit, I.e., 15 ns.
- For arbitrary symbol rates, the main constraint in the definition of a mini-slot, is that the number of symbols per mini-slot be an integer. For example given a symbol rate of
  - R Symbols/tick,
  - M ticks/mini-slot,
  - N, the number of symbols per mini-slot,

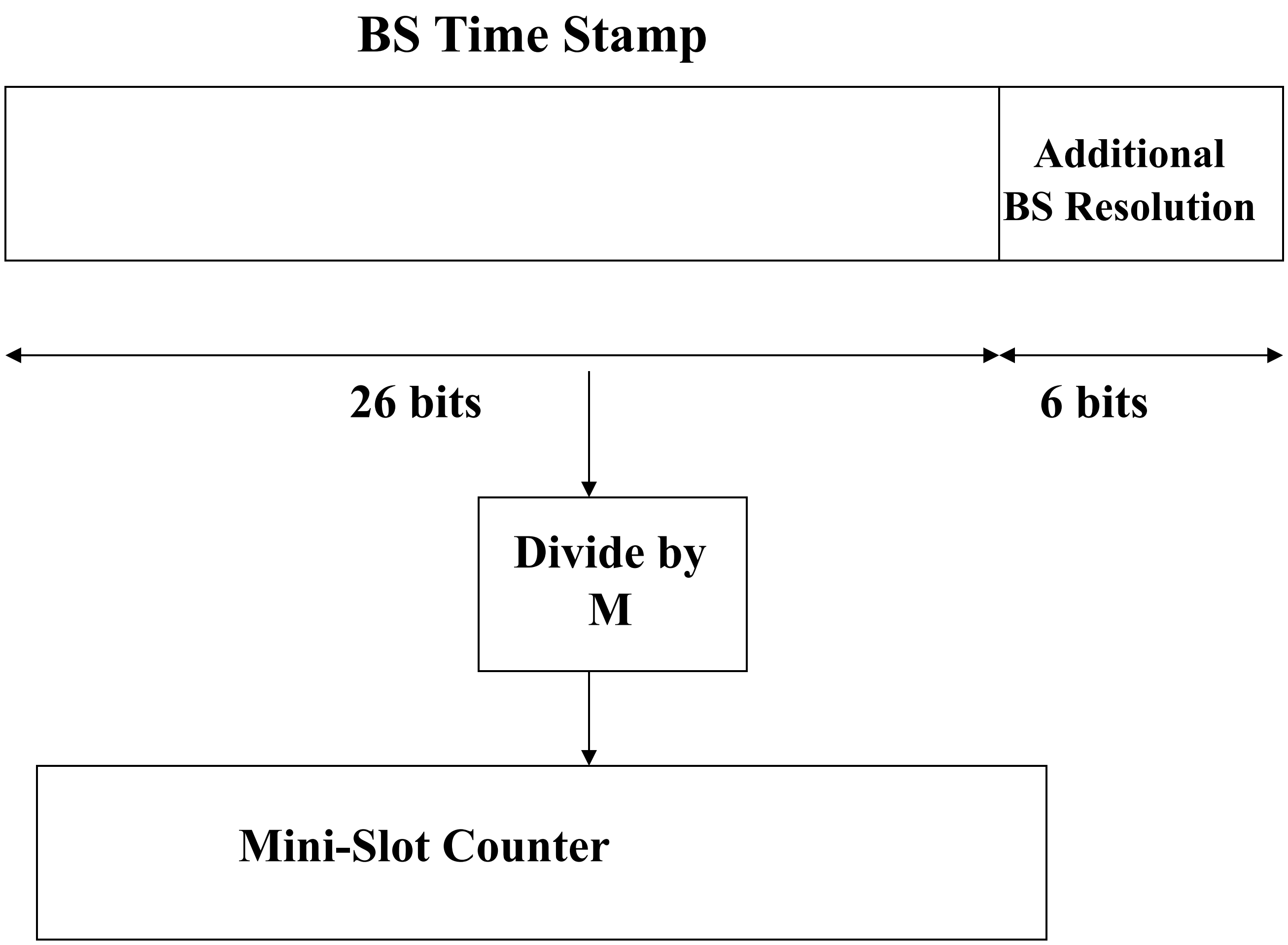
then N = MR. In this situation, M should be chosen such that N is an integer. In order to accommodate a wide range of symbol rates, it is important not to constrain M to be a power of 2.

Examples

In order to show that the time base is applicable to single carrier and OFDM symbol rates, consider the following examples:

- Single Carrier System - Given a symbol rate of 4.8 Msymbols/s (on a 6MHz channel), if the mini-slot duration is chosen to be 10 ticks (i.e., M = 10), then there are 48 symbols/mini-slot. Given 16QAM modulation this corresponds to a granularity of 24 bytes/mini-slot
- OFDM System - Given an OFDM symbol time of 50 us, the mini-slot duration is also chosen to be 50 ticks (i.e., M = 50). In this case there is only a single symbol per mini-slot

Time Base (cont)



Flexible Scheduling

- Issue: For TDD and HD-FDD modes, current protocols do not maintain a running mini-slot count. This count is reset at the start of every frame. There is no periodic timestamp broadcast from the BSC to the CPEs.

- System Impact:
  - The scheduler is restricted to describing the current frame in the MAP, which restricts its flexibility.
  - The ACK Time in the MAP is restricted to be in the previous frame, which imposes some restrictive real time requirements on the scheduler.

- Solution: Introduce periodic time stamp broadcast from the BSC to the CPEs. Maintain a running mini-slot count.

MAP Packet Format

- Issue: The downstream MAP les use PS numbering to locate bursts, while the upstream MAP uses mini-slot numbering. The Connection Ids are not specified for the downstream bursts, in contrast to the upstream bursts.

- System Impact: The SS is forced to receive and demodulate each and every downstream burst. This complicates the optimal choice of PHY parameters, since in order to receive every burst, the PHY parameters have to be ordered in increasing order of robustness.

- Solution: Replace PS numbering in DL-MAP by mini-slot numbering. Specify the Connection ID for every downstream burst.

TG1 Enhancements

- MAC Header Format
  - Alternative format for the GM field
- Concatenation/Fragmentation Scheme
  - Concatenation + Fragmentation simultaneously
  - Predictable overhead estimation
  - Low Overhead
  - Efficient recovery from errors
  - Flexibility in delimiter field (for ACK/NACK inclusion)
- ARQ
  - Separate Upstream ACKs
  - Downstream ACKs in MAP
  - Options for GBN and SR in signaling
  - Option to piggyback on MPDU
  - Cumulative ACKs supported
  - Robustness against error conditions
- MAP Packet Related issues
  - Relevance of MAP messages
  - Additional IE types
- Timing
  - Time Stamp definition
  - Mini Slot Count issues
- Parallel Polling