Document Number:
IEEE 802.16.1mp-00/05

Title:

Proposed Amendments to MAC/PHY Layers to Include a Bandwidth-On-Demand MAC Sublayer

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Source:

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Session # 5 at Clarion Hotel in Richardson, Texas – January 10-14, 2000

Base Document:

IEEE 802.16.1mc-00/05 and IEEE 802.16.1pc-00/06

Purpose:

To propose adoption of the proposed amendments as an option to the base document for inclusion in 802.16.1 PHY standard.

Presentation Purpose

This presentation is made as a

friendly amendment to

other MAC & PHY proposals

submitted to 802.16.1

Presentation Outline

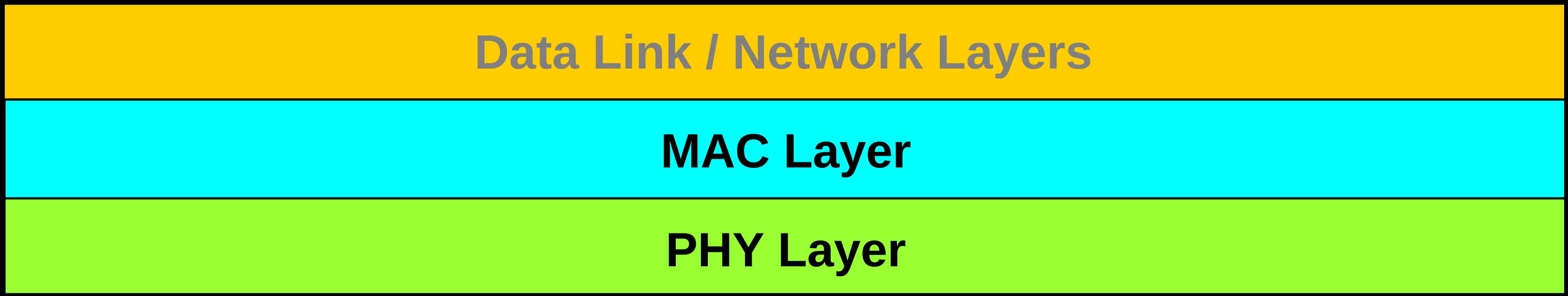
- **Broadband Wireless Access MAC/PHY Basics (Generic)**
- **Proposed Data Channel Assignment Approach**
- **Proposed Next Generation BWA**
  - **Early market benefits**
- **An unmet market need**
- **Proposed Program**
- **Discussion**

Some
Broadband Wireless Access
MAC/PHY Basics
(Generic)

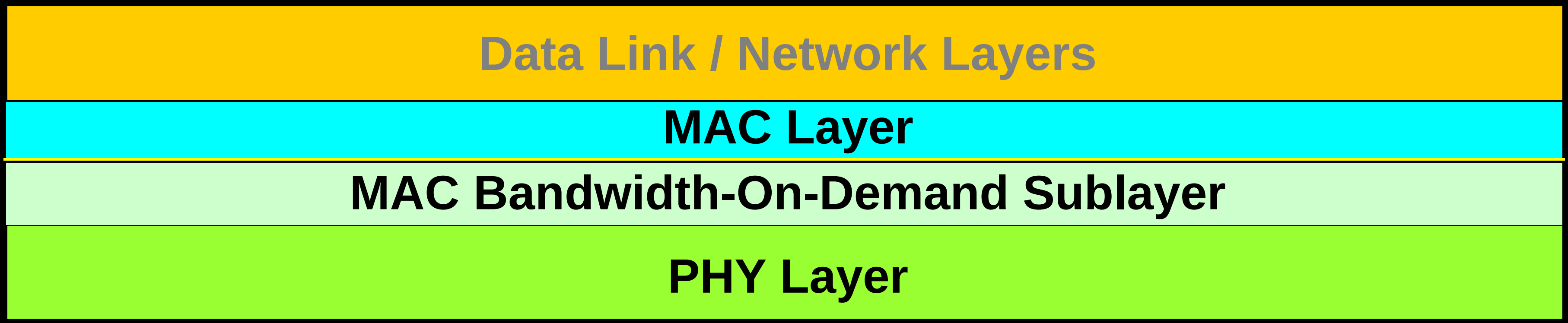
Topics Covered

- Reference Model
- Bandwidth-On-Demand Sublayer
- TDM/TDMA
- Common Signaling Channel
- Proposed Approach
- Factors Affecting Bandwidth Efficiency
  - PHY overhead vs delay
  - MAC overhead vs delay
  - Asynchronous traffic buffering

Conventional Reference Model



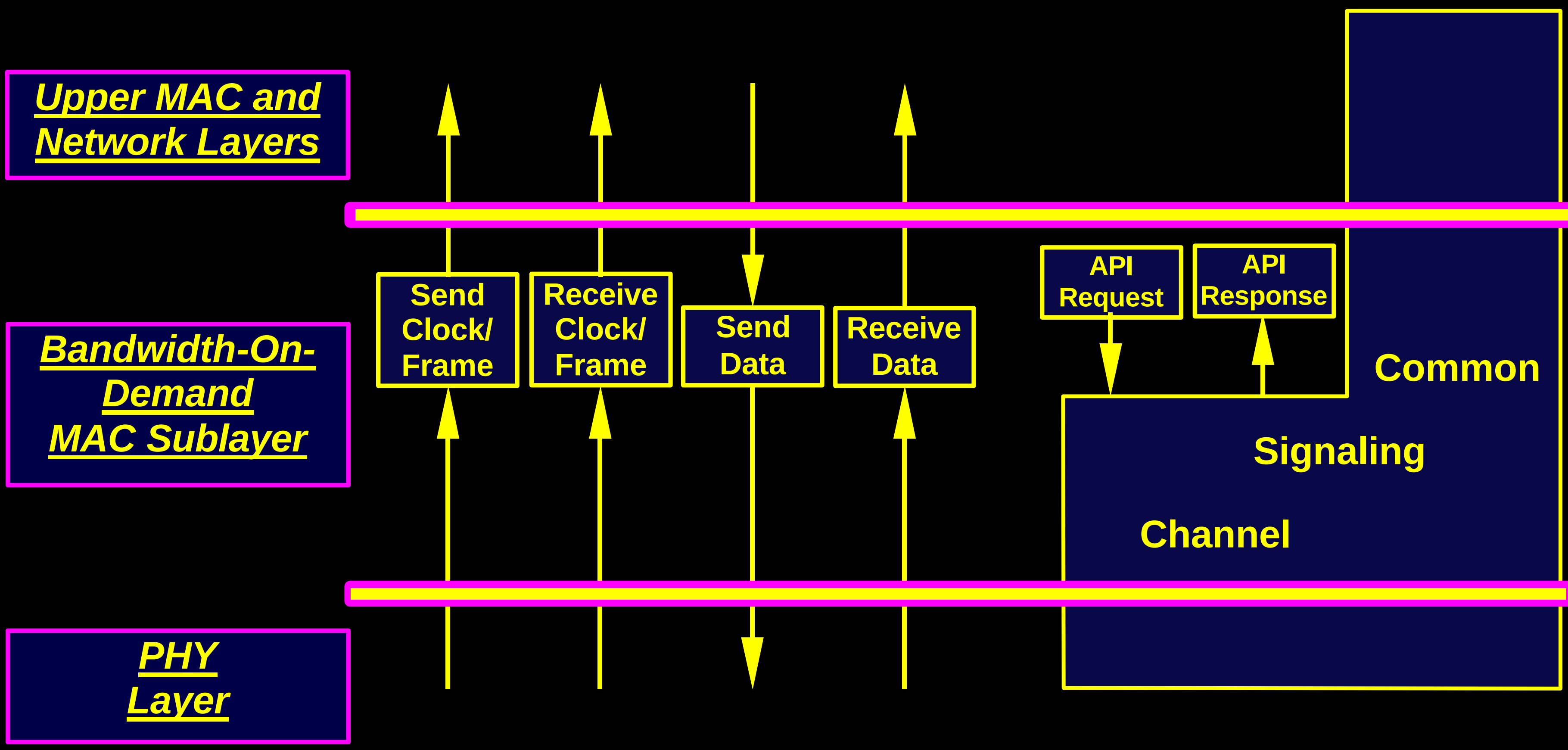
Proposed Reference Model



Role of the MAC Bandwidth-On-Demand Sublayer

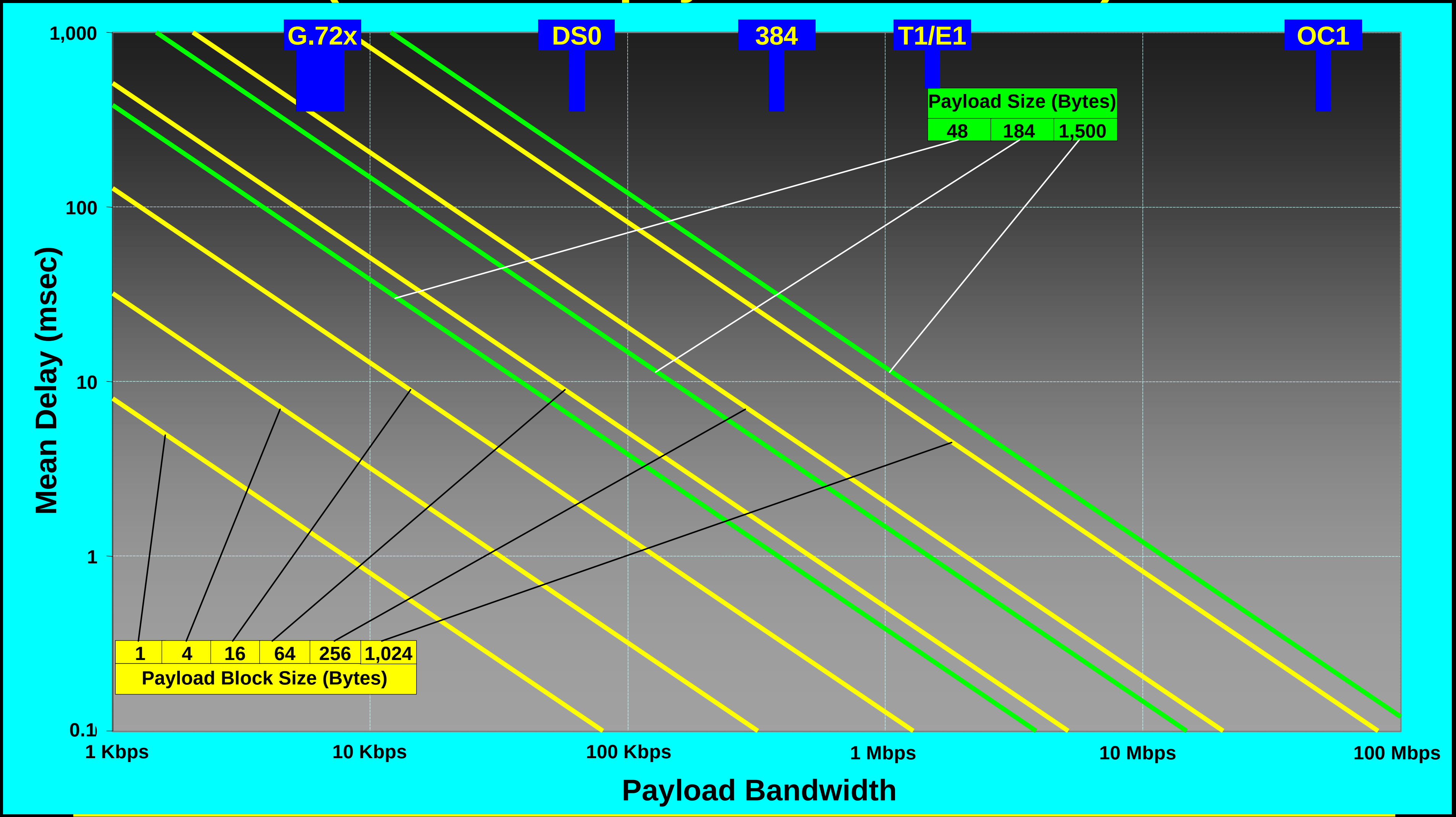
- To provide a simple standardized interconnection to <u>all</u> MAC and higher network layer protocols
- To interconnect with the PHY layer in a manner that
  - uses available bandwidth efficiently
  - minimizes delay, delay variation & jitter

Proposed MAC Sublayer / PHY Interface Schematic

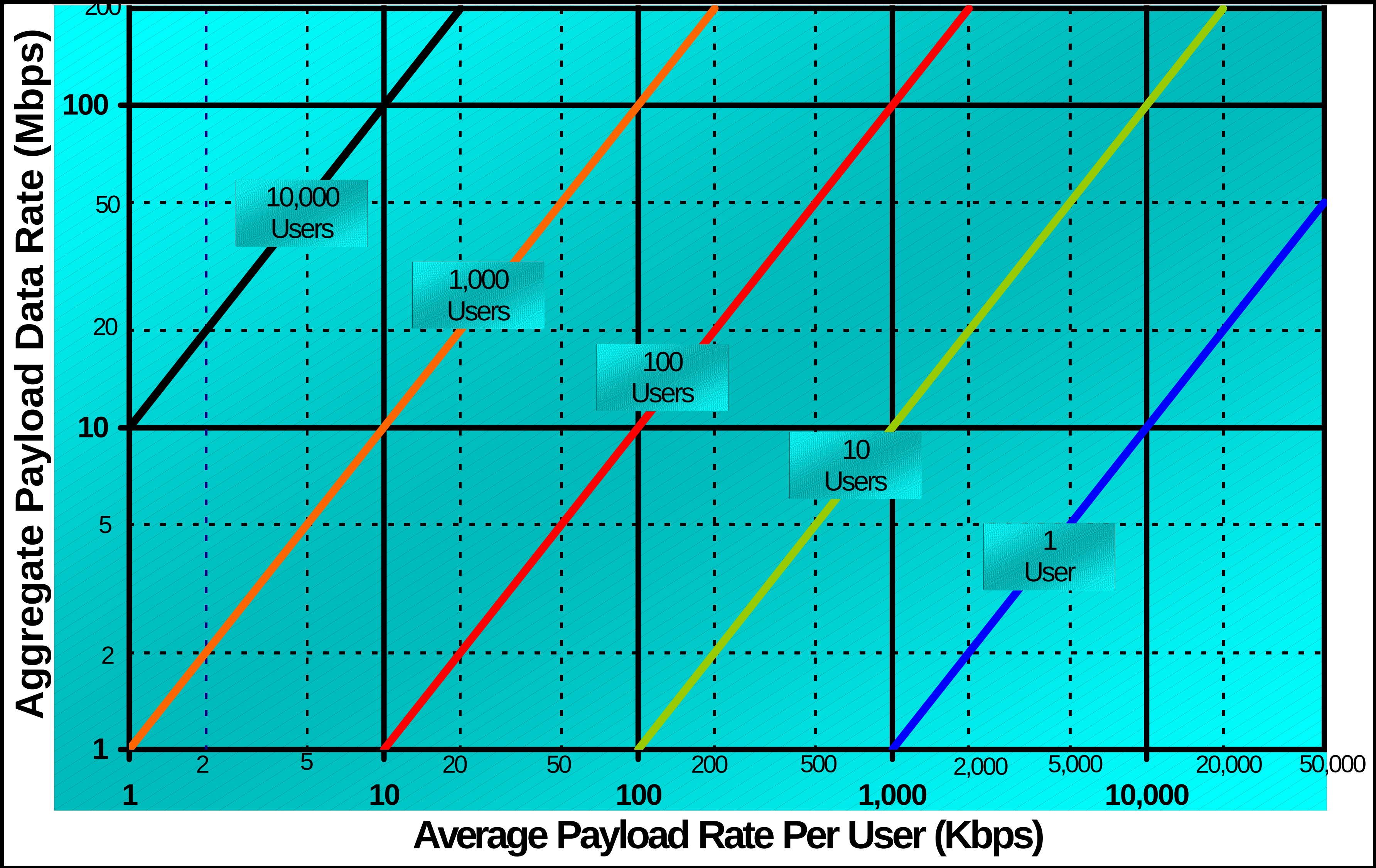


Delay vs Bandwidth

(for various payload block sizes)



Average Payload Rate Per User



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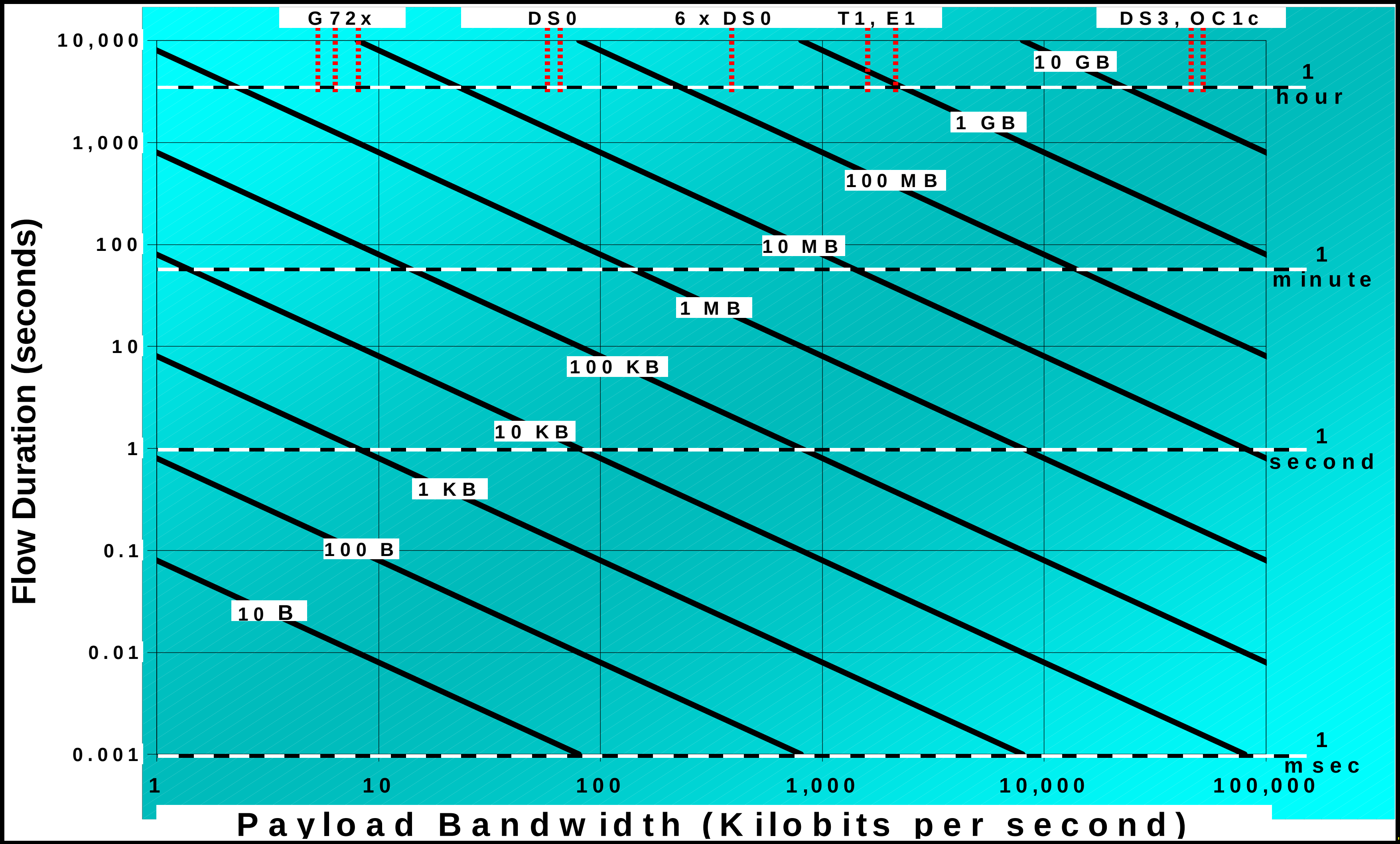
Note Attached

Bandwidth-On-Demand MAC/PHY Functionality

- Assign bandwidth to flows
- Flows may be single session or aggregations thereof
- Advantages include
  - Low transport delay & delay variation
    - Delay is inversely proportional to channel bandwidth
  - Low (and bounded) jitter
  - MAC & Network Protocol Independence
  - Simplicity

Dealing with Flows



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Note Attached

The Specific Approach

- **Define the PHY layer as a single TDM stream of fixed size "cell slots" — (*c* bits per cell slot)**
- **The size of TDM frames is based on GCD of all supported data rates**
- **TDM frame size can be a field programmable parameter assuring non-obsolescence**

The Specific Approach

- **Bandwidth is assignable in increments of one cell slot (*c* bits) per frame**
  - **i.e., channel bandwidth = *c* times number of assigned cell slots per frame times frame rate**
- **Define two ways by which individual cell slots are identified**
  - **A logical (Element Address) domain**
  - **A physical time division address (Ordinal Position Number) domain**

Examples

- For a cell slot size of 1 byte
  - Frame size of 8 msec allows bandwidth granularity of 1,000 bps
  - Frame size of 6 msec allows bandwidth granularity of 1,333.33 bps and can support TDM cells that support ATM for n*DS0's with minimum transport delay
  - Frame size of 24 msec supports both

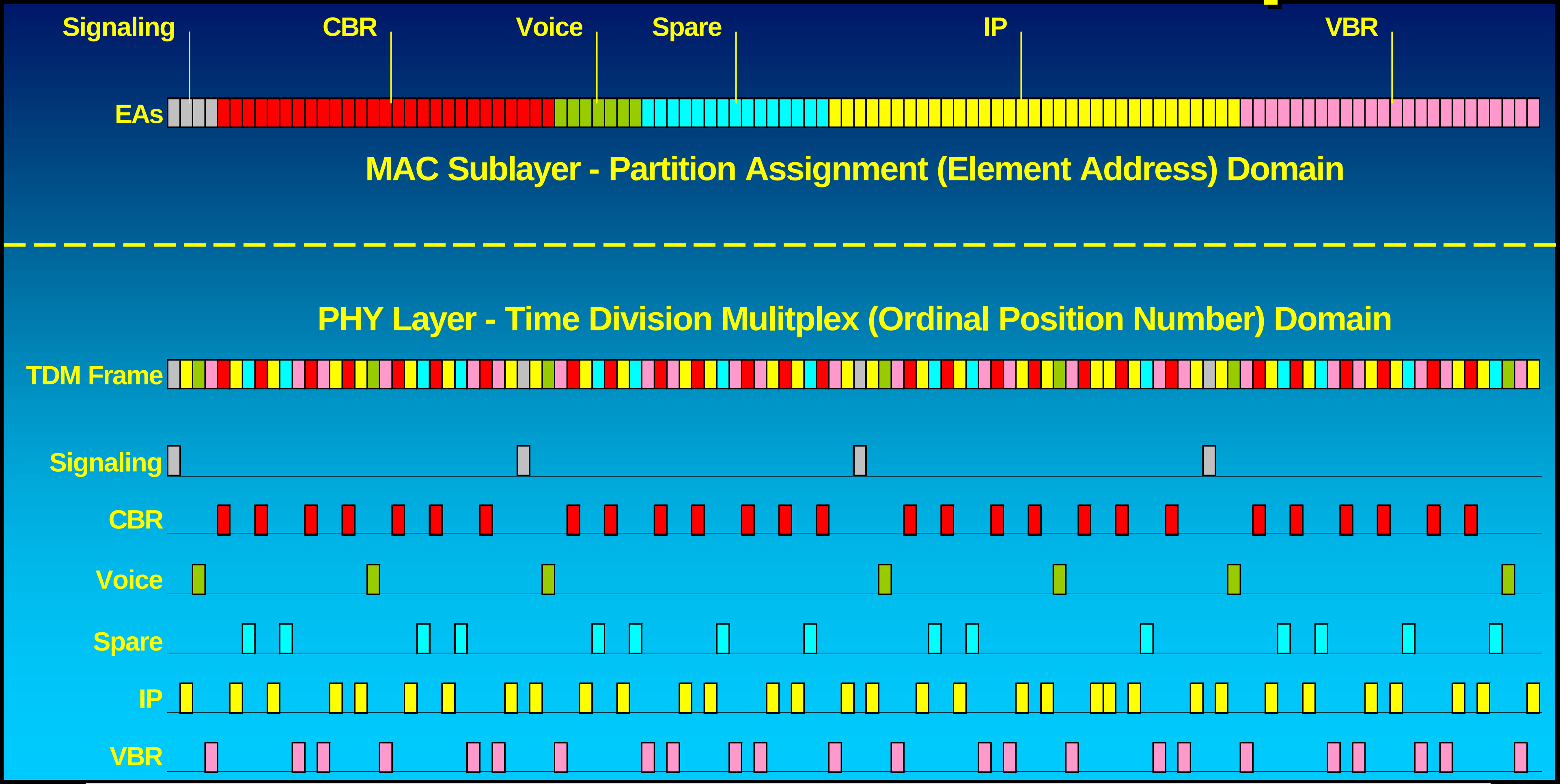
Function of the Domains

- The Element Address (Logical) domain
  – Contiguous Element Addresses can be used to assign cell slots to a channel
- The Ordinal Position Number (Time Division) domain
  – Cell slots for a channel are nearly uniformly spaced throughout a frame
- A simple-to-implement transform translates cell slot assignment addresses from one domain to the other

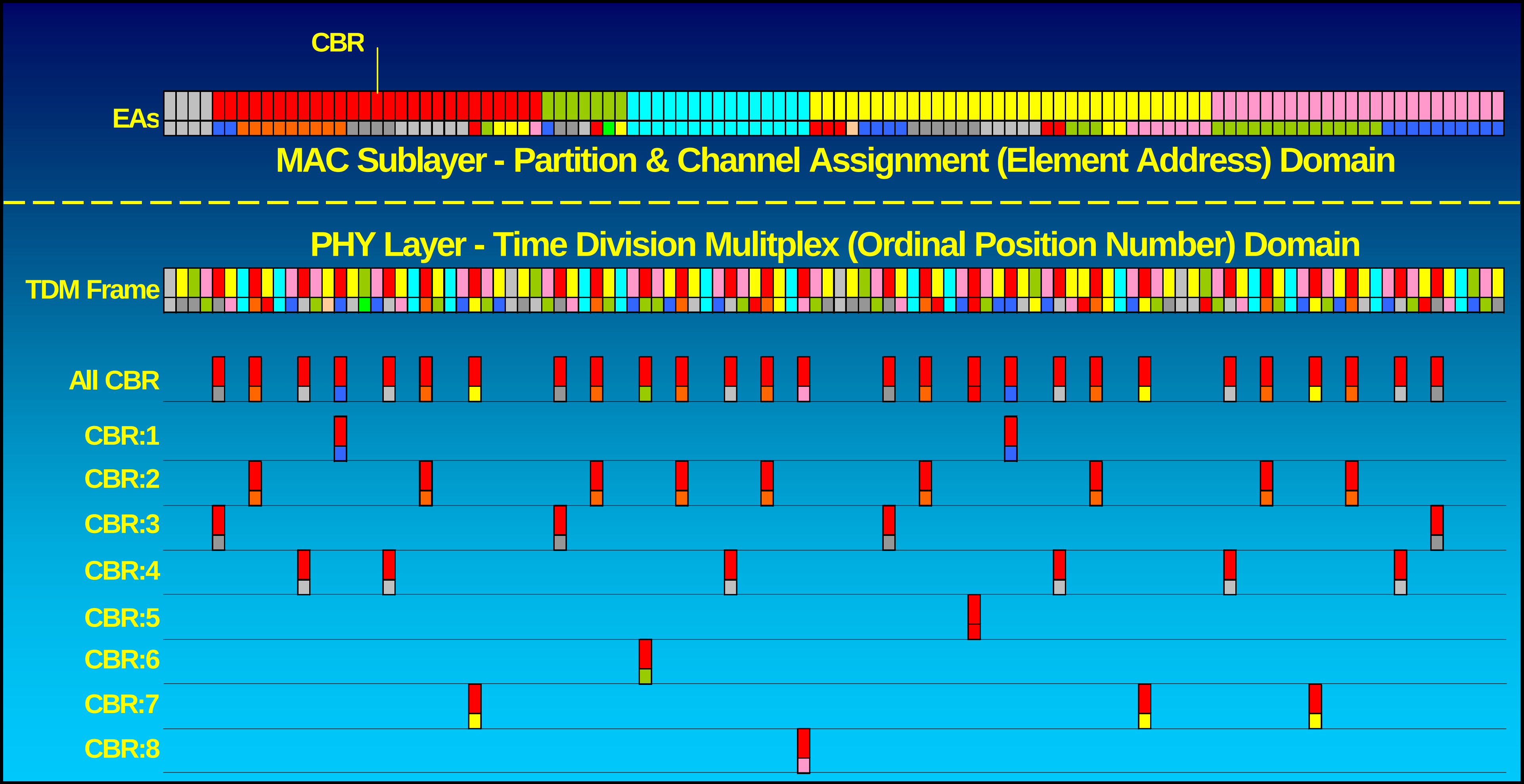
Element Address Domain

- Each Element Address denotes a single cell slot within a frame
- An entire frame can be divided into partitions of contiguous element addresses, each of which denotes a particular class of service
- Each partition can be subdivided into individual channels

Element Address / Ordinal Position Number Example



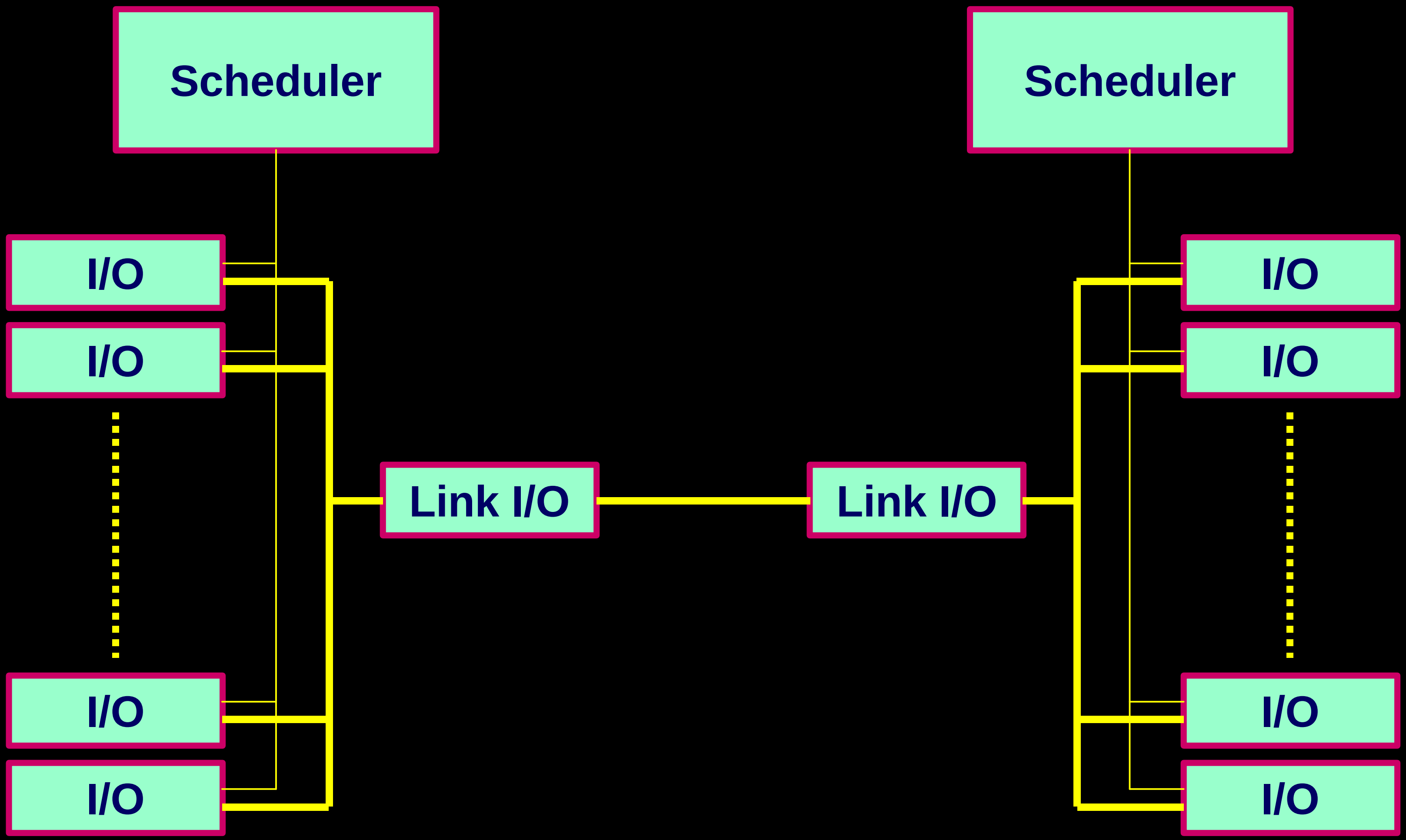
Channels Embedded in CBR Partition



Technique can be applied to FDD, TDD and H-TDD

In TDD and H-FDD, domains are partitioned in time as well as by Element Address

The Two-Unit Case With Synchronized Schedulers



Common Signaling Channel

Using a Common Signaling Channel

within a TDM environment

increases

bandwidth utilization efficiency

Common Signaling Channel

- A Base Station to Subscriber Station Common Signaling Channel is used for basic system control
- It need be of the order of 2% to 4% of total base station payload bandwidth
- Channel BER is engineered to be less than 10^{-11}

Common Signaling Channel

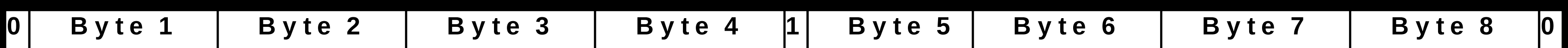
- **Subscriber Station to Base Station Common Signaling Channel is shared among all Subscriber Stations under Base Station control, i.e., access to the upstream Common Signaling Channel is controlled by Base Station assignments**

Proposed Common Signaling Channel Message Format

- **Goals:**
  - to assure robust system operation (synchronization and error control)
  - to minimize required control messaging bandwidth
  - to provide flexibility for meeting future needs without major modification

Possible Message Format

FC = Message Framing Control Bit
Set to 0 if following bits are start of message
Set to 1 if following bits are message continuation



2-Frame Message (5-8 bytes)

2 bits	14 bits	8 bits	8 bits
Type	SSID	Bandwidth	Start

Basic Bandwidth Control Message

Type Field
- 00 – Bandwidth Control Message (downstream)
- 01 – Bandwidth Control Message (upstream)
- 10 – General Message (downstream)
- 11 – General Message (upstream)

SSID – Sublayer Service ID
Bandwidth – Number of increments for partition identified by SSID
Start – Channel start Element Address (in partition bandwidth increments) after partition boundary

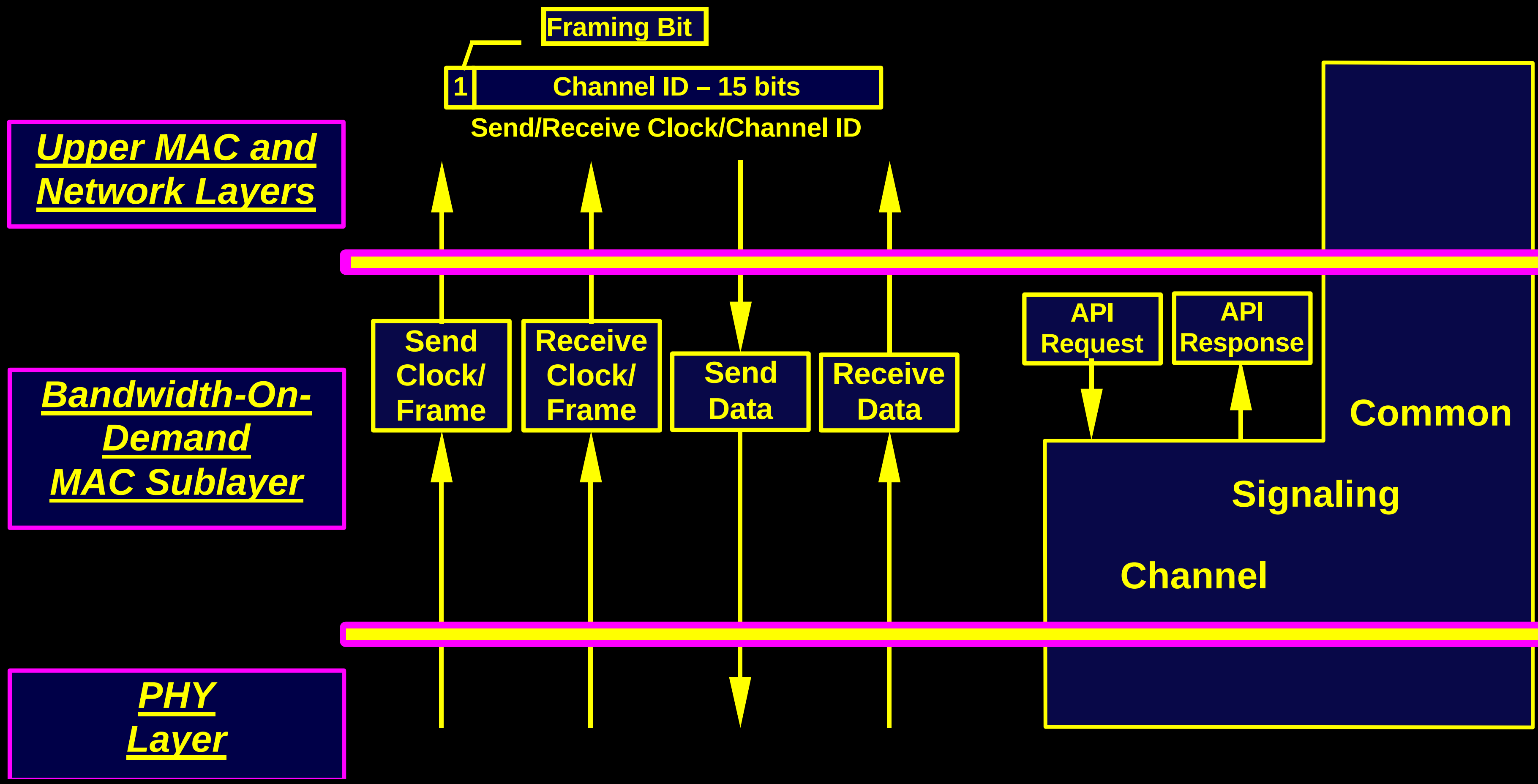
Rationale for Format

- Most messages will be bandwidth allocation messages
- For CSC bandwidth = 3% total, one bit per 33 bits = 0.09% of total
  - Note: The amount of bandwidth devoted to Common Signaling Channel is an integer multiple of 33 bytes per frame. For example, for an 8 msec frame, it would be an integer multiple of 33,000 bps.

Suggested Downstream Error Detection Approach

- Send a 32-bit CRC at fixed periods (e.g., once each millisecond)
- Advantages:
  - More robust error control than 16-bit CRCs per message
  - More bandwidth efficient than 16-bit CRCs per message
  - For ~ 1 Mbps Common Signaling Channel, this error control method uses only 32 Kbps. For an aggregate 50 Mbps payload bandwidth, this amounts to only 0.06% of bandwidth

MAC Sublayer / PHY Interface Schematic



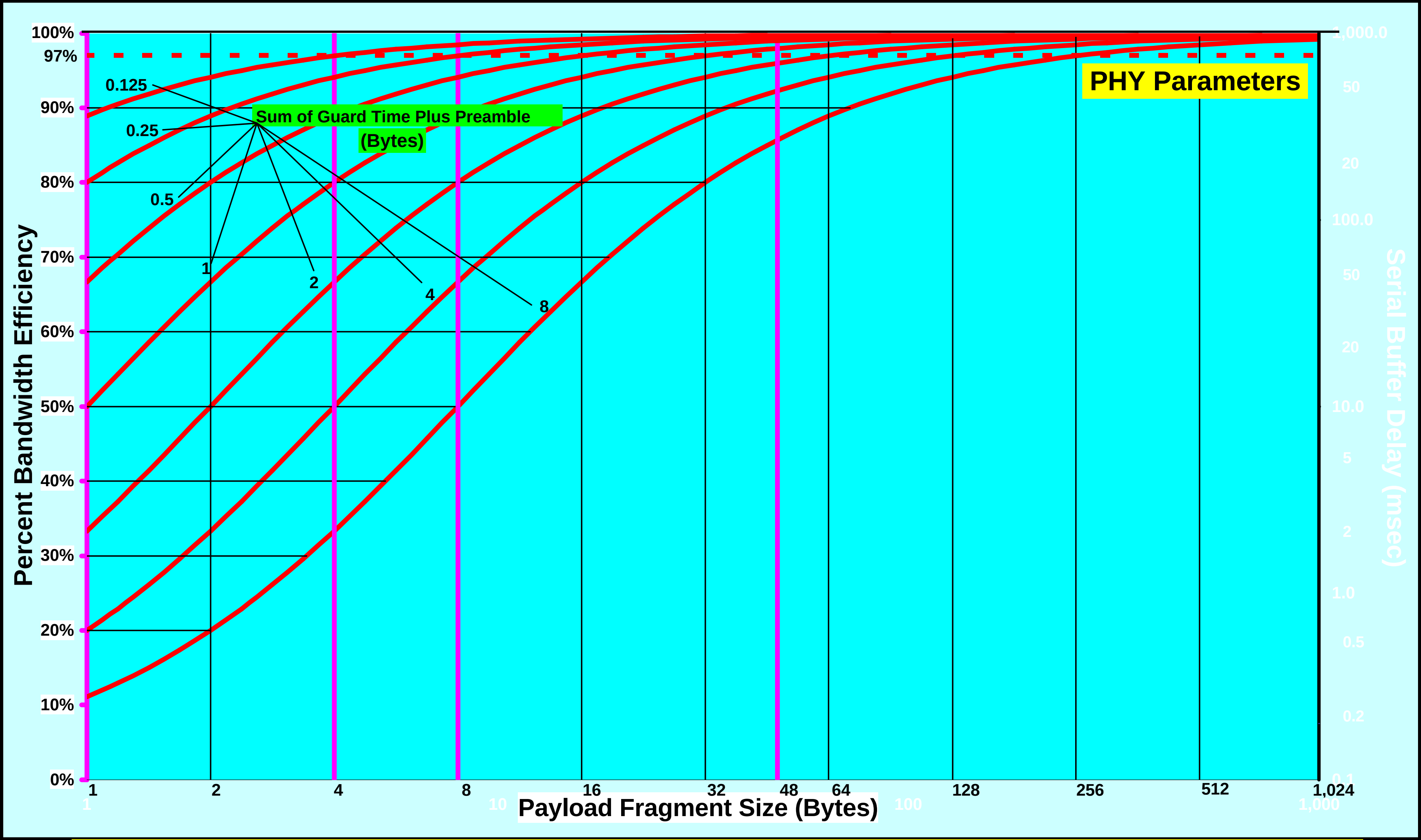
Role of the PHY Layer

To transfer primitive data elements sent across the MAC/PHY interface from one end of a physical connection to another

Primitive Data Elements: How big?

- The size of primitive data elements is a critical parameter affecting BWA system performance
- Few physical constraints exist downstream for PHY
- Practical modem constraints exist upstream for PHY

Primitive Data Elements: How Big?



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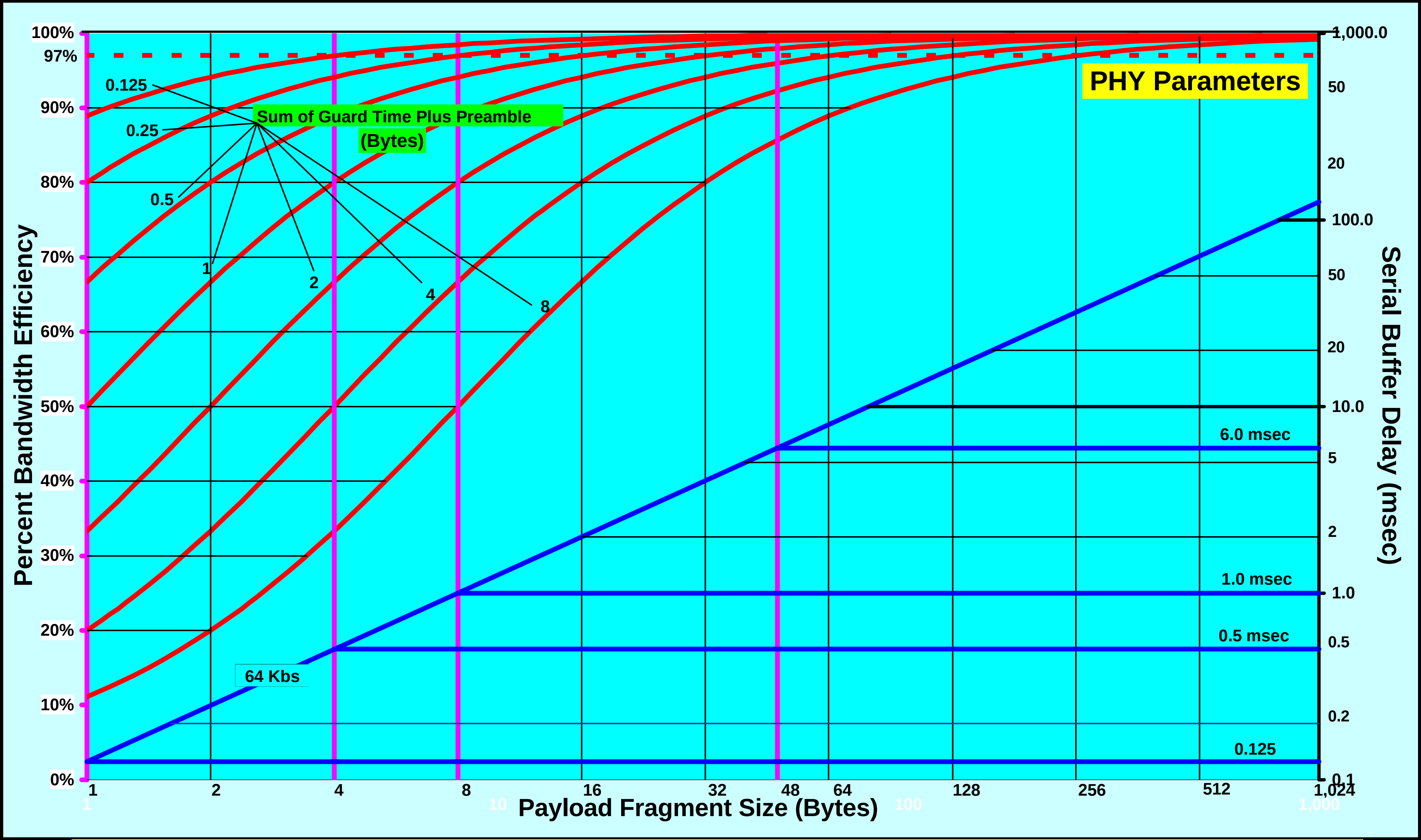

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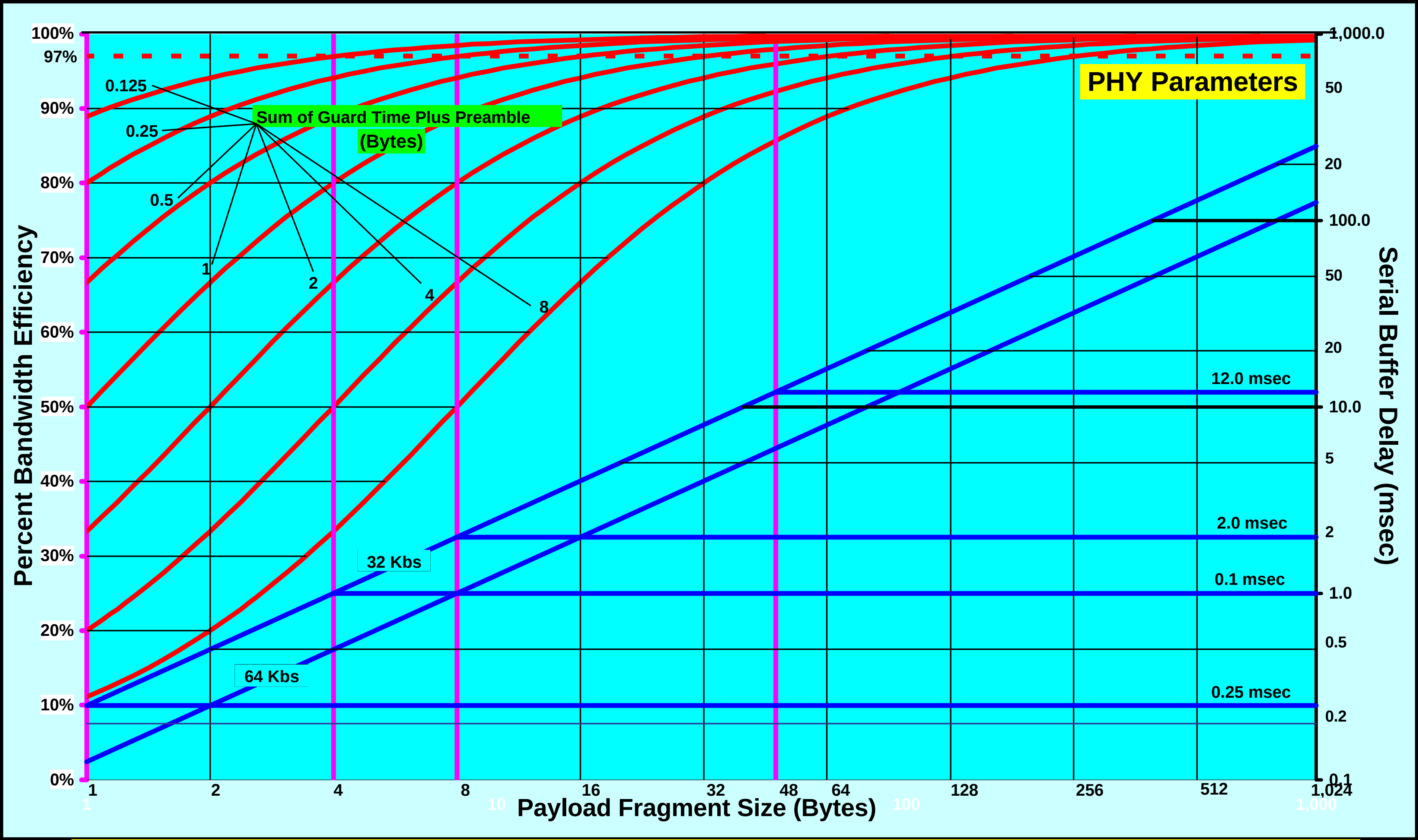

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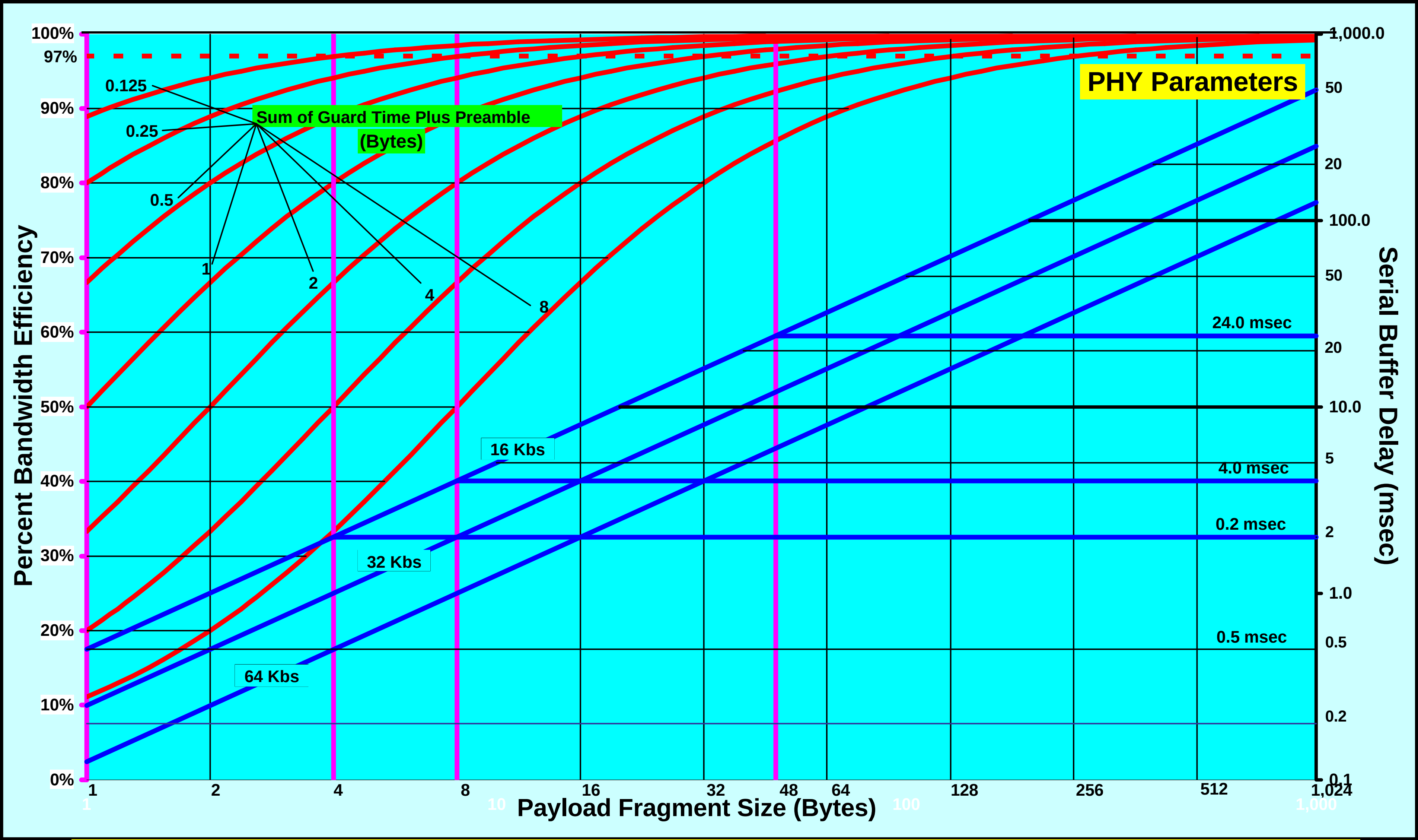

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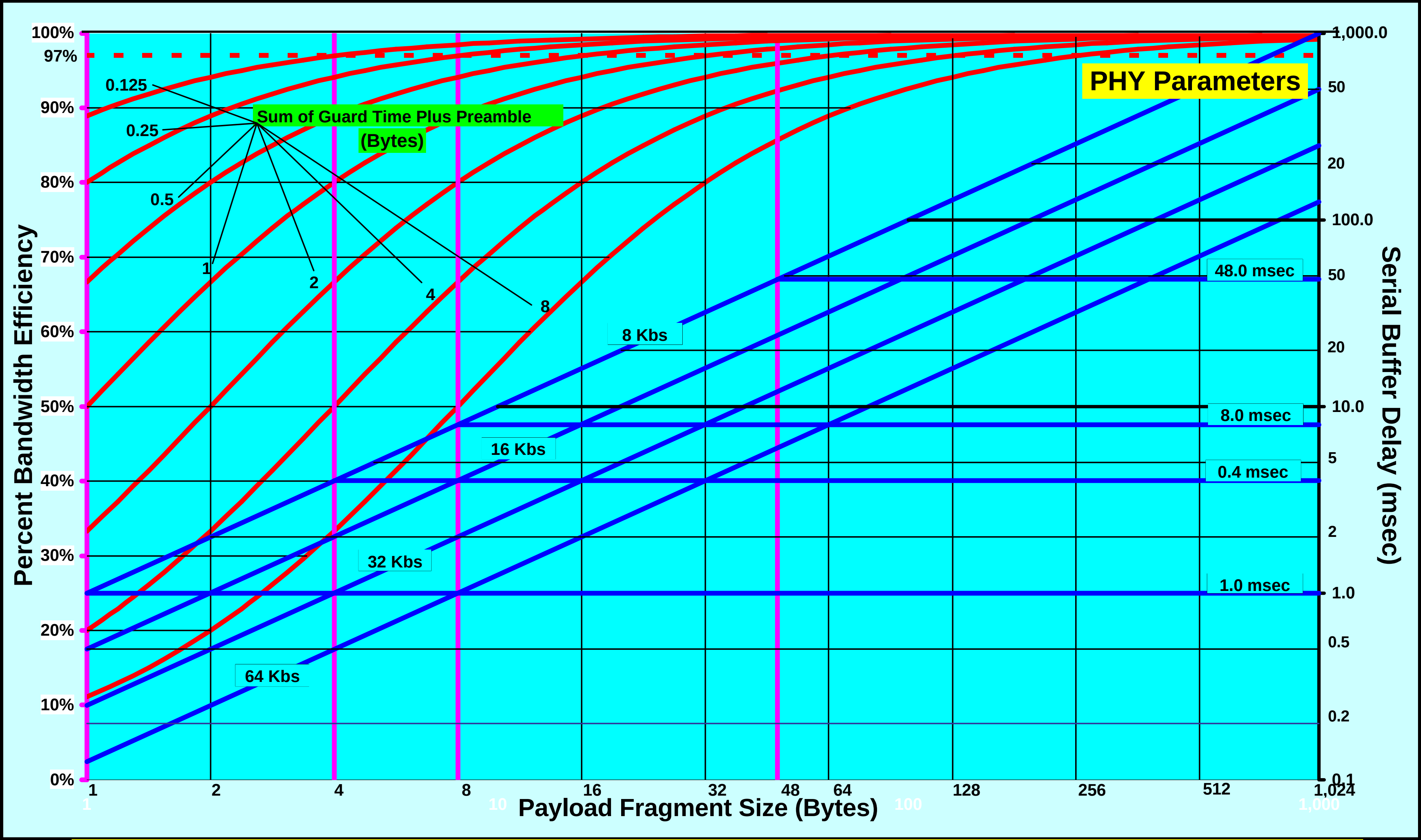

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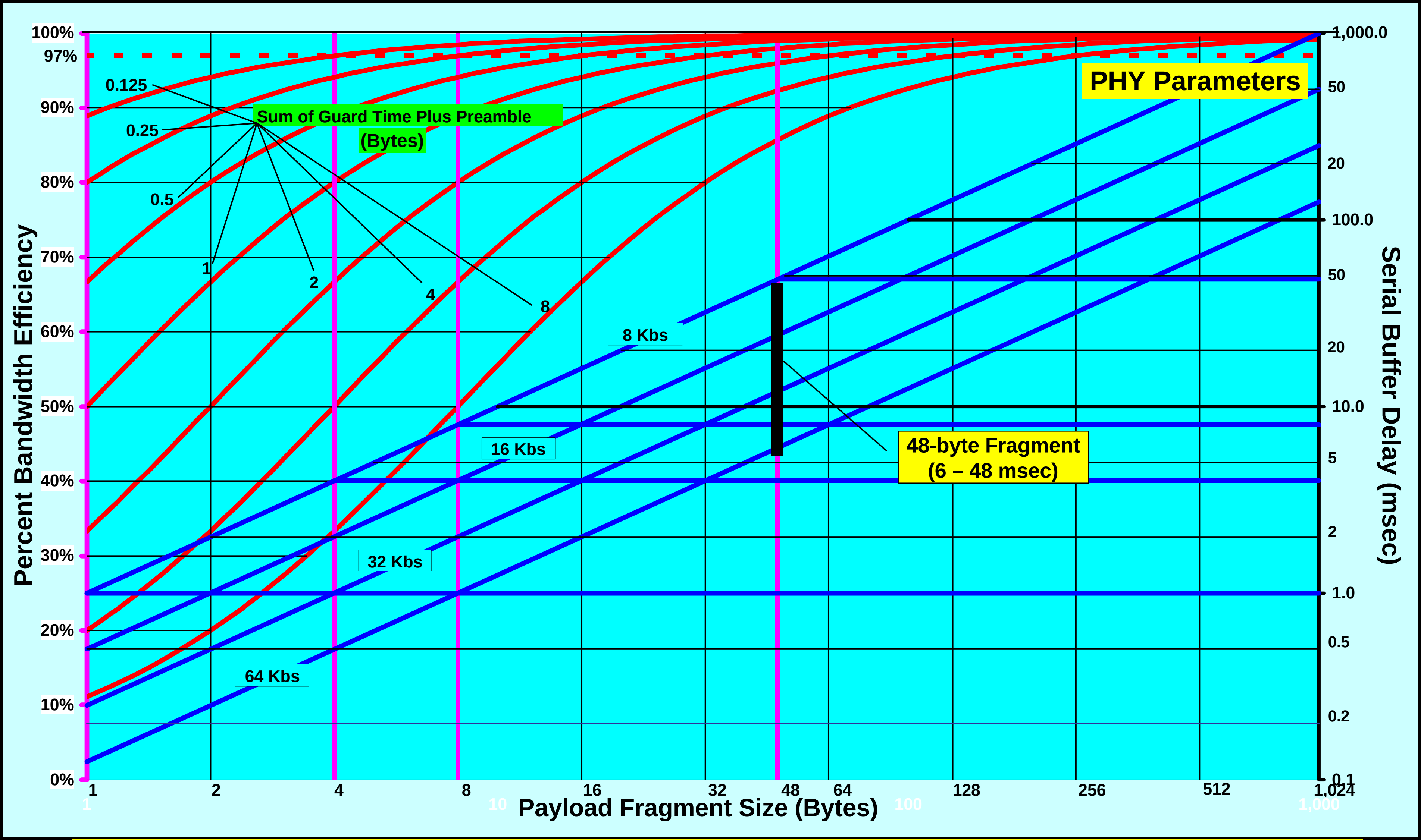

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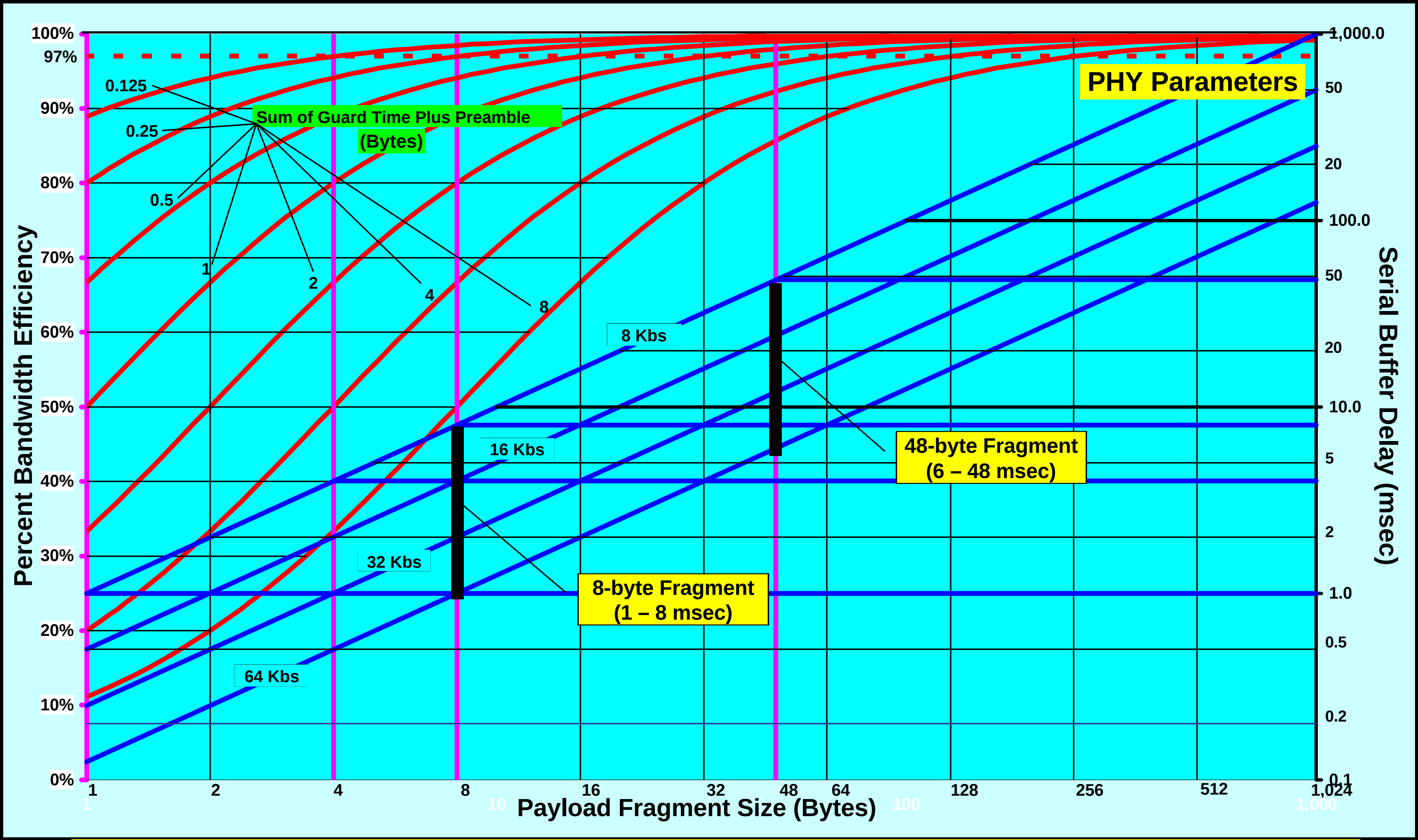

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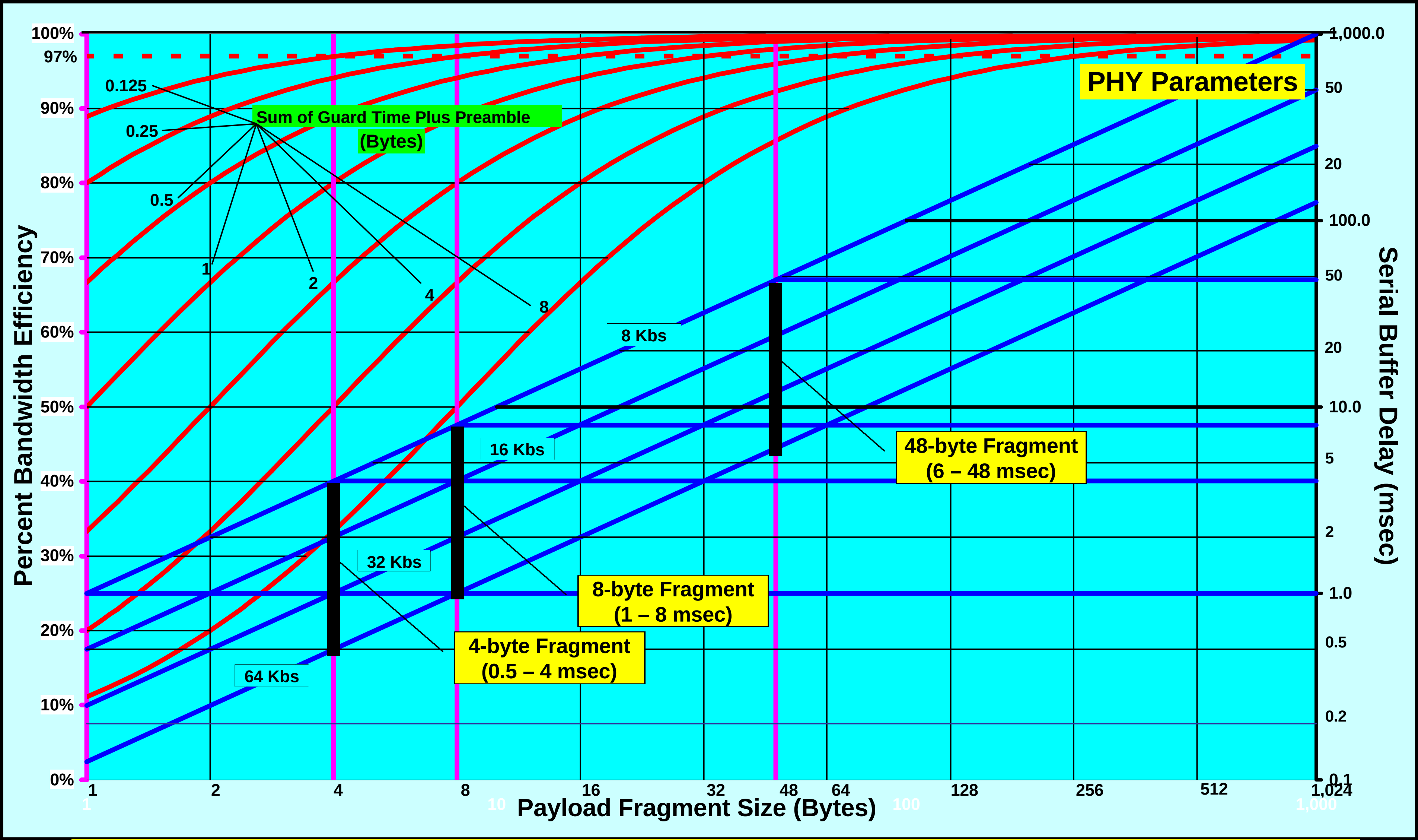

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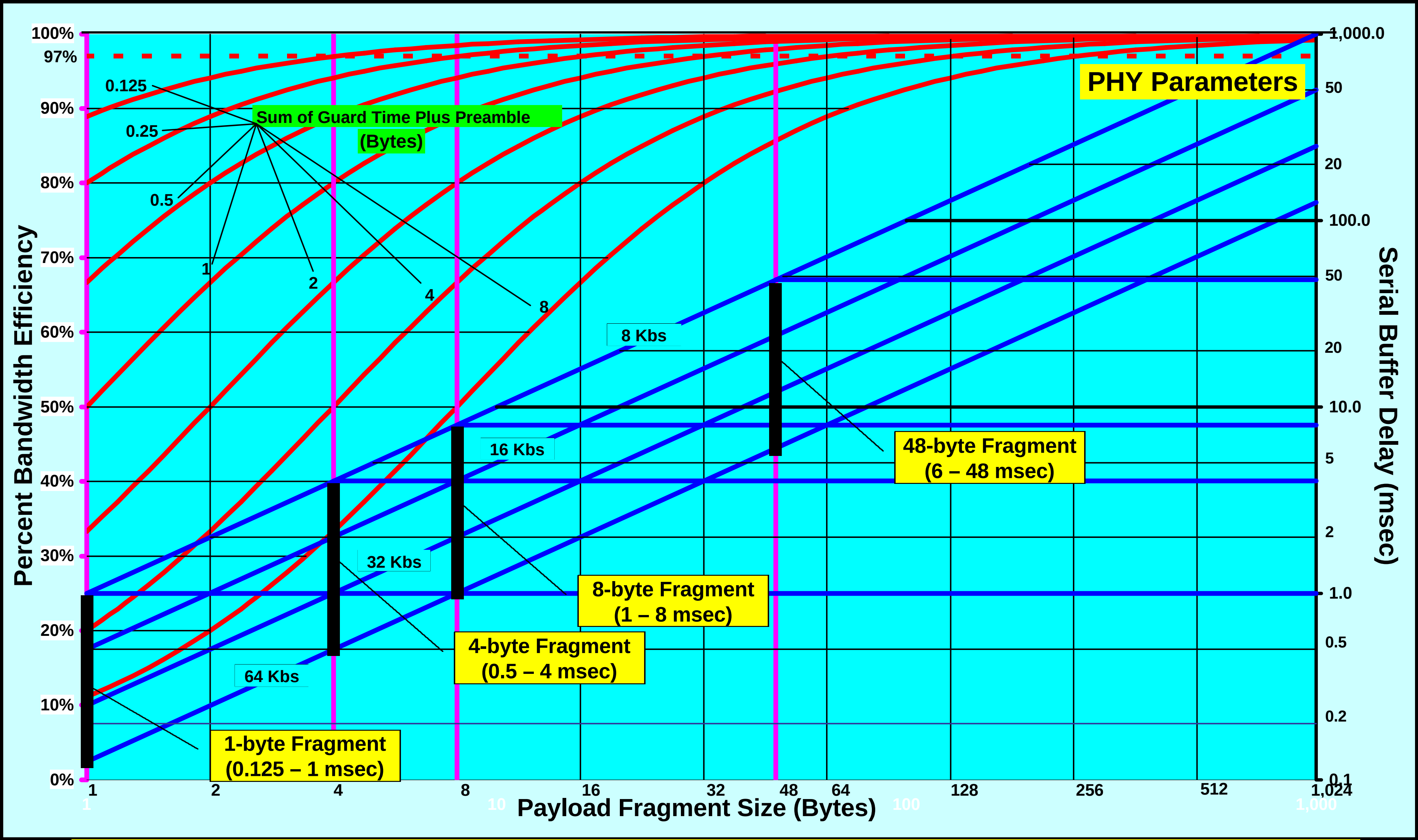

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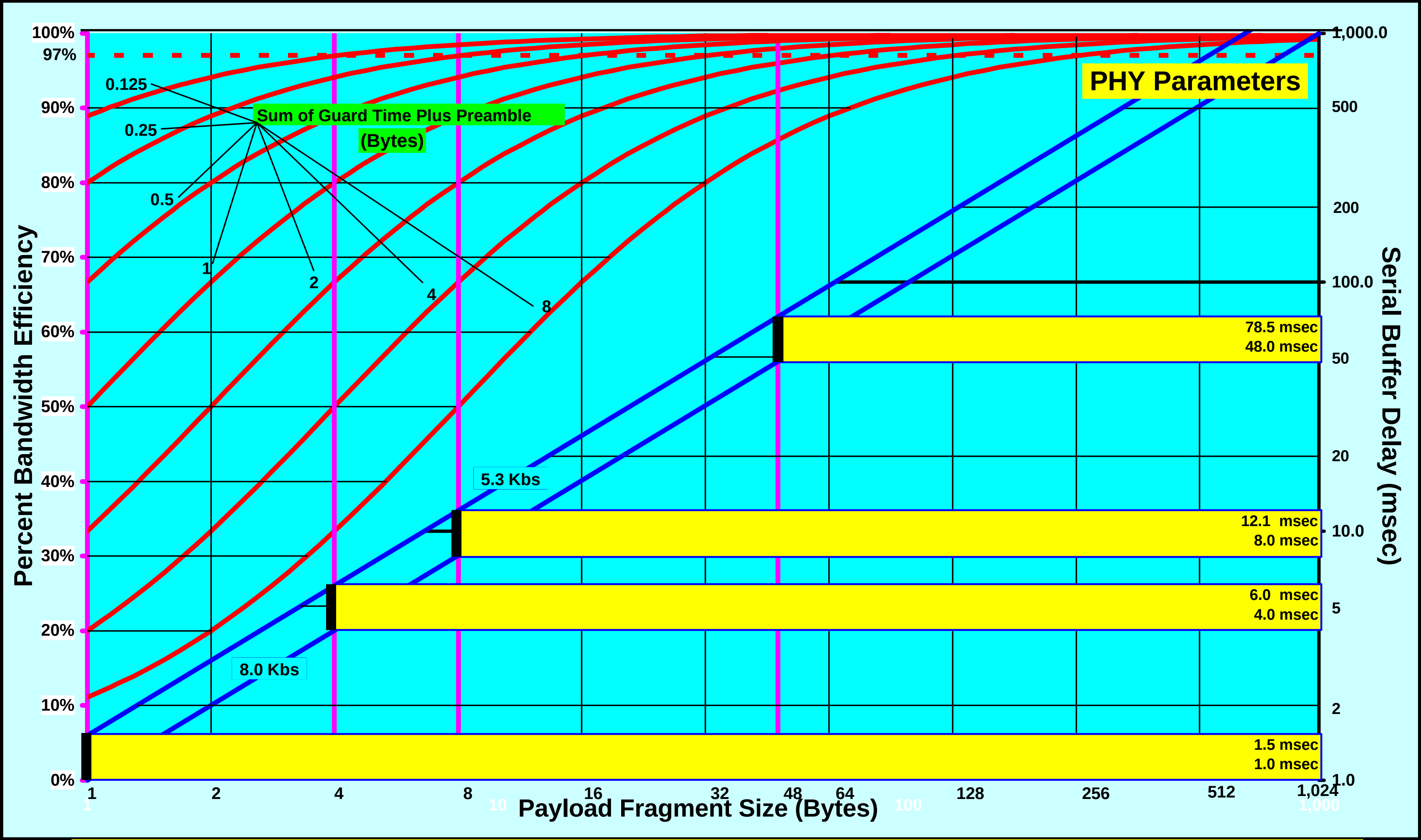


PHY Layer Primitive Data Element Size Constraints

- **Small primitive data element size is necessary for**
  - **low latency voice support**
  - **minimizing bandwidth required for maintaining Subscriber Station synchronization and transmitter power control**

PHY Layer Primitive Data Element Size Constraints

- **No substantial primitive data element size constraints downstream — size can be one byte**
- **Upstream primitive data element size constrained by a tradeoff between minimum burst size and required guard time plus burst preamble**

Role of the MAC

To multiplex data flows

to and from

a diverse set of

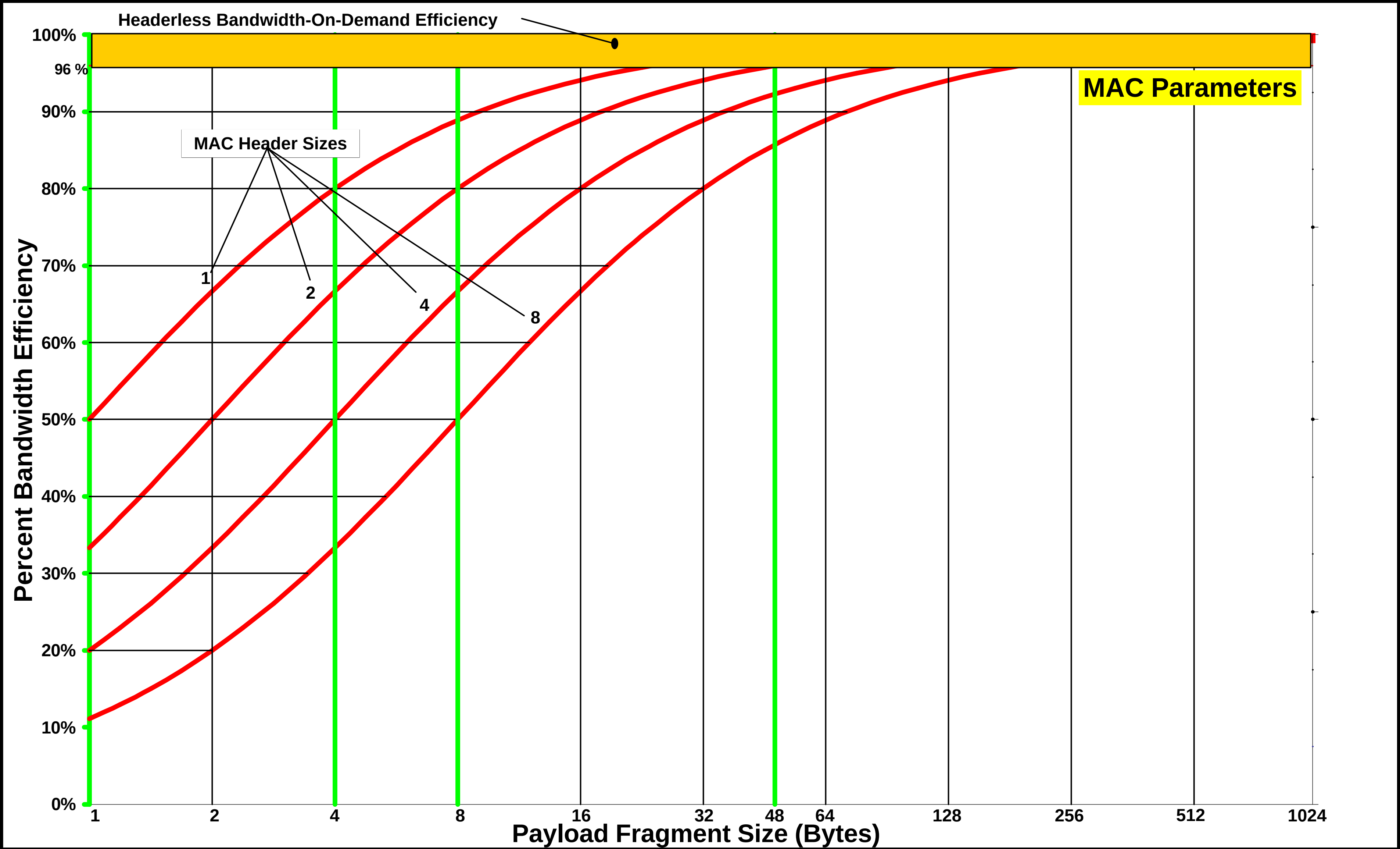
sources and sinks

and connect them to the PHY Layer

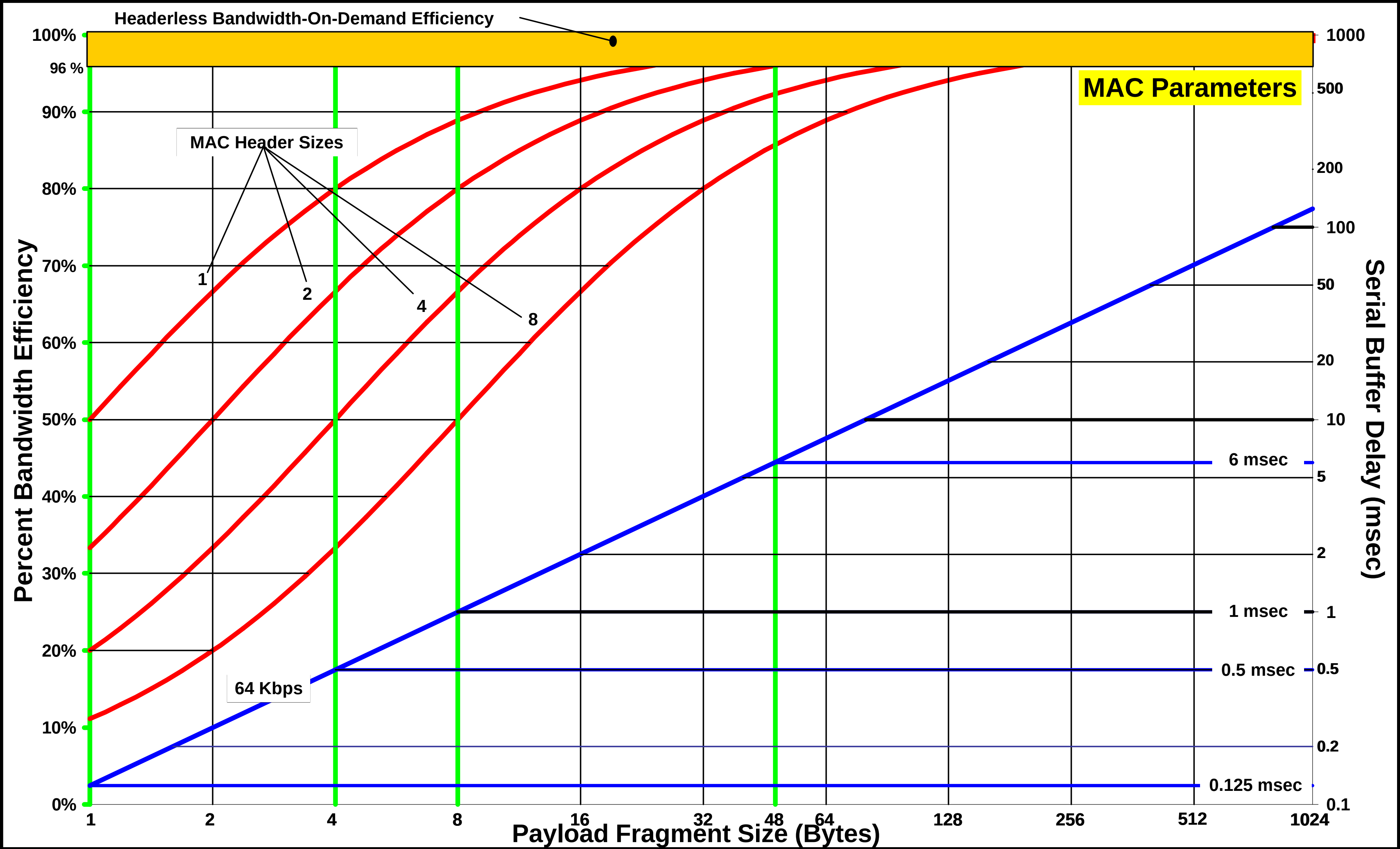
Primitive Data Elements: How big?

- The size of primitive data elements is a critical parameter affecting Broadband Wireless Access system performance
- MAC multiplexing methodology is key
- Current Packet/Cell based multiplexing does not efficiently support low speed voice channels or power monitoring and control

Bandwidth Efficiency versus Payload Fragment Size for MAC Header Sizes of 1, 2, 4 & 8 Bytes



Bandwidth Efficiency and Buffer Delay for 64 Kbps Channel



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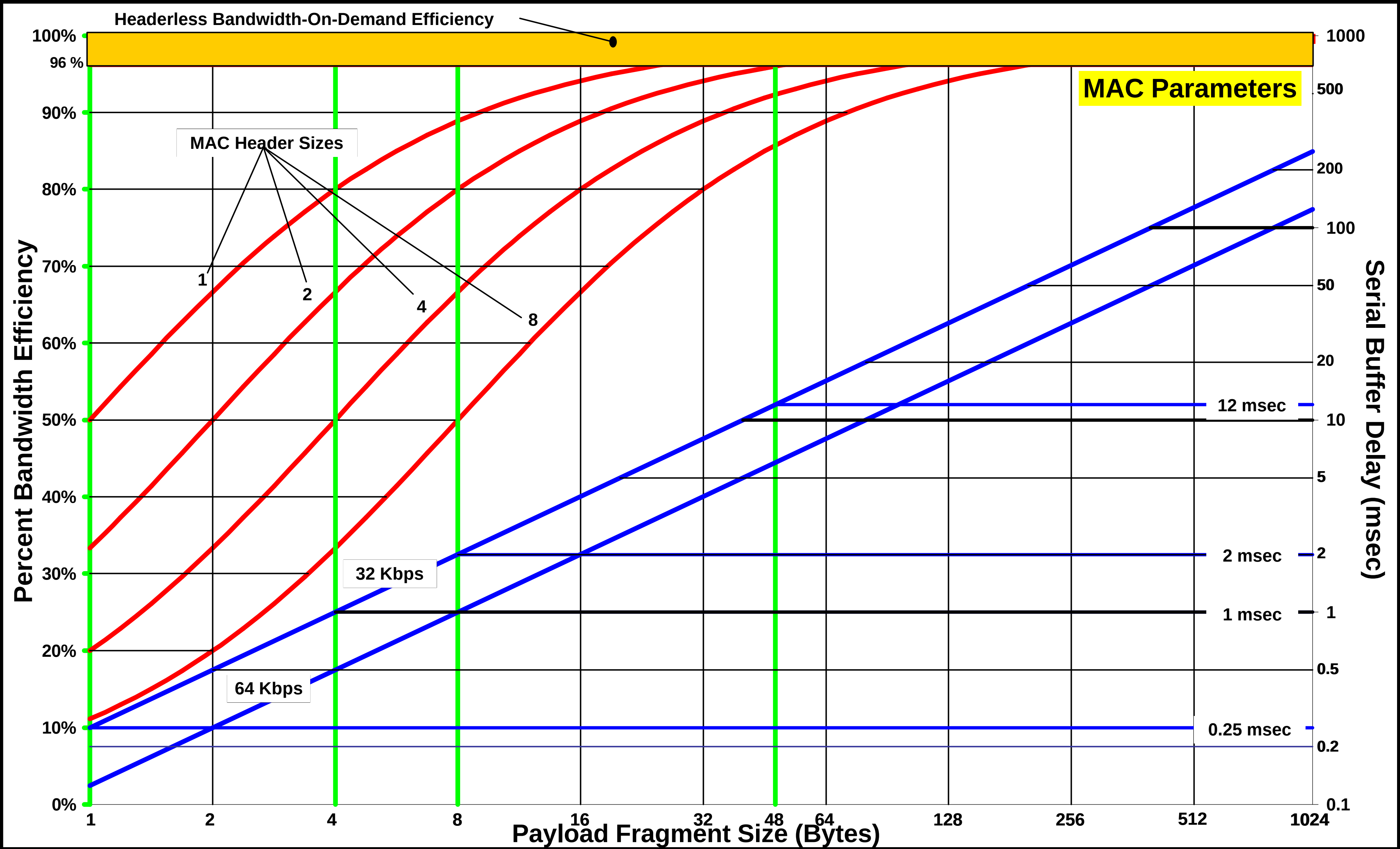
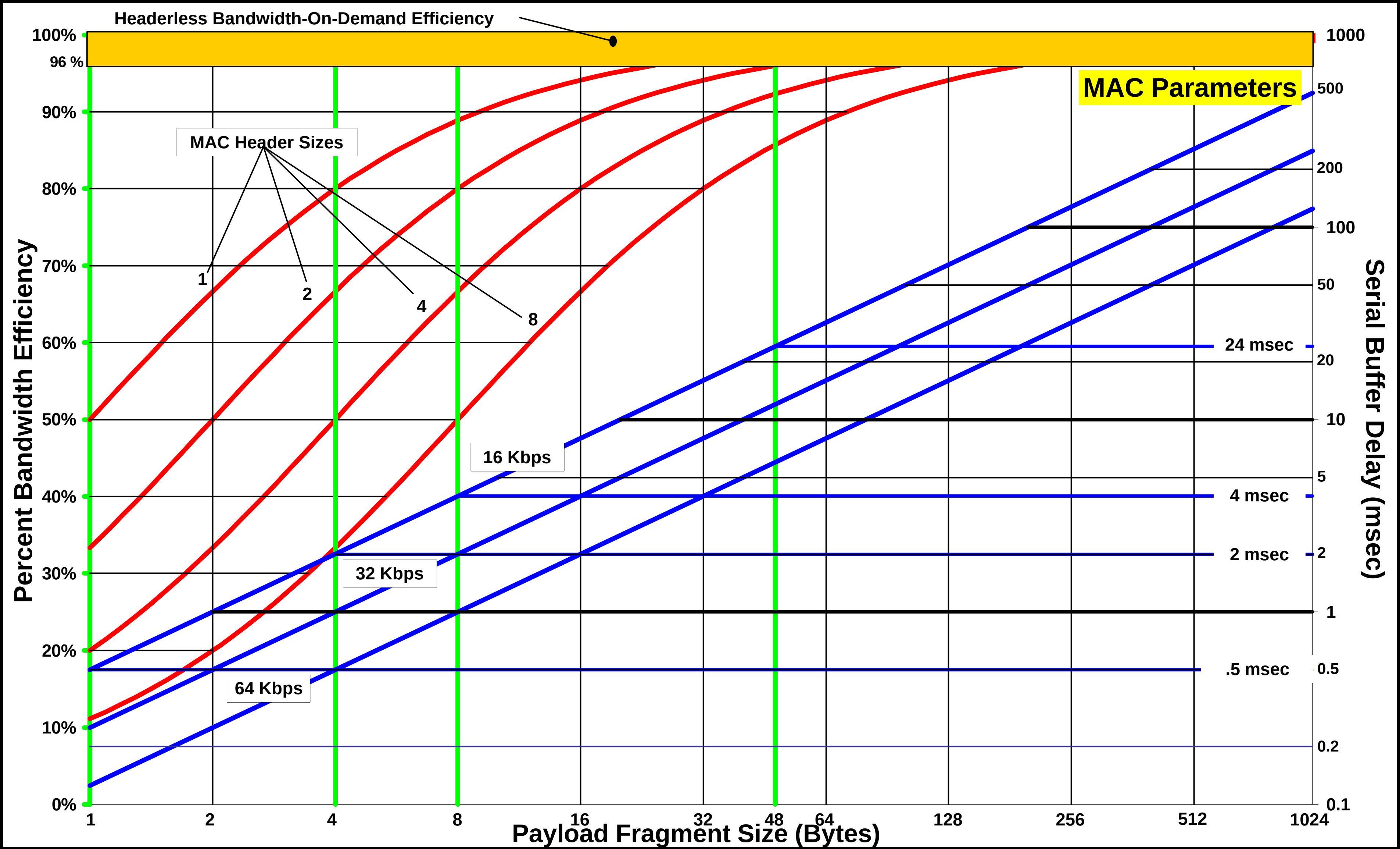
Bandwidth Efficiency and Buffer Delay for 32 & 64 Kbps Channels



Bandwidth Efficiency and Buffer Delay for 16, 32 & 64 Kbps Channels



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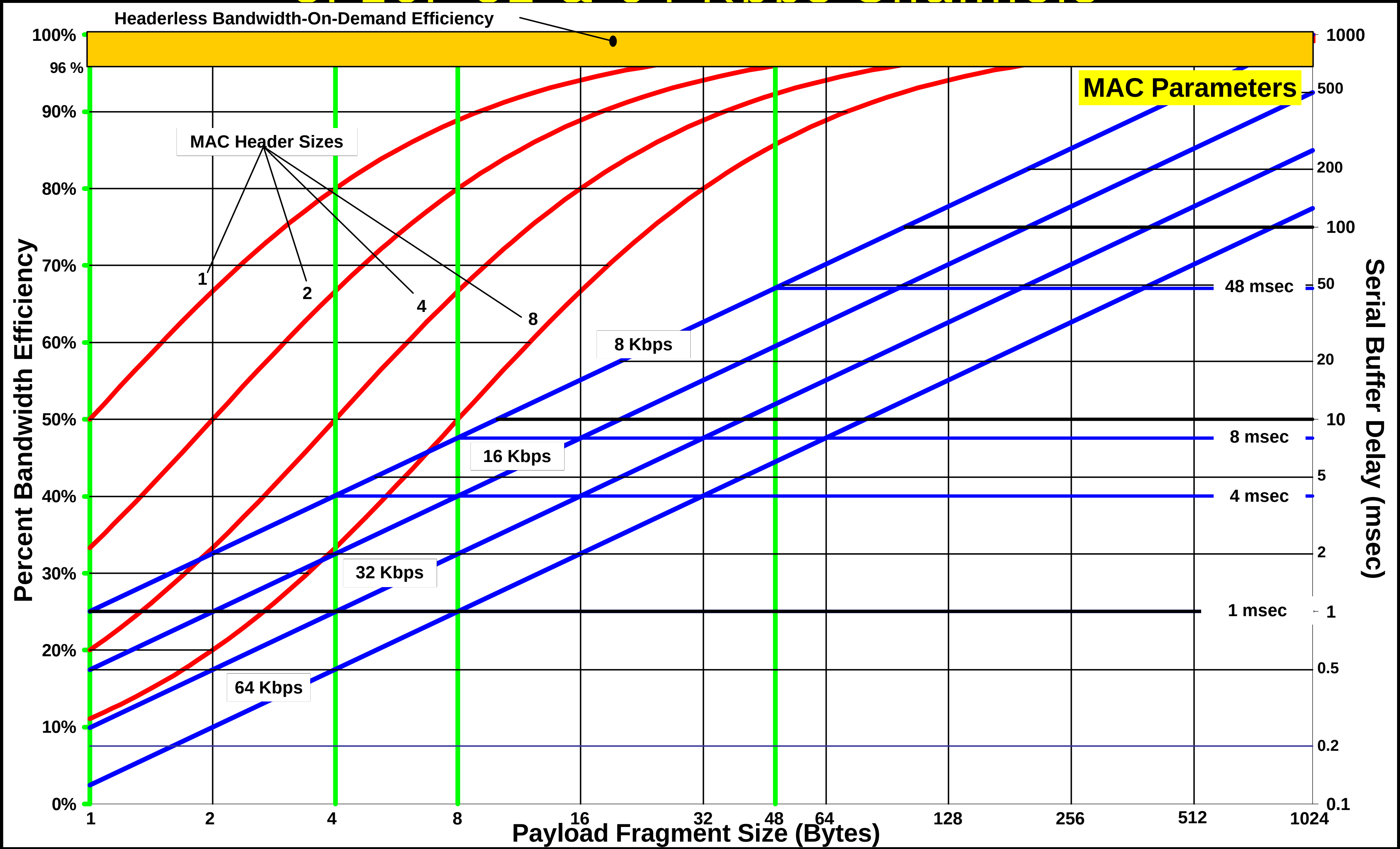
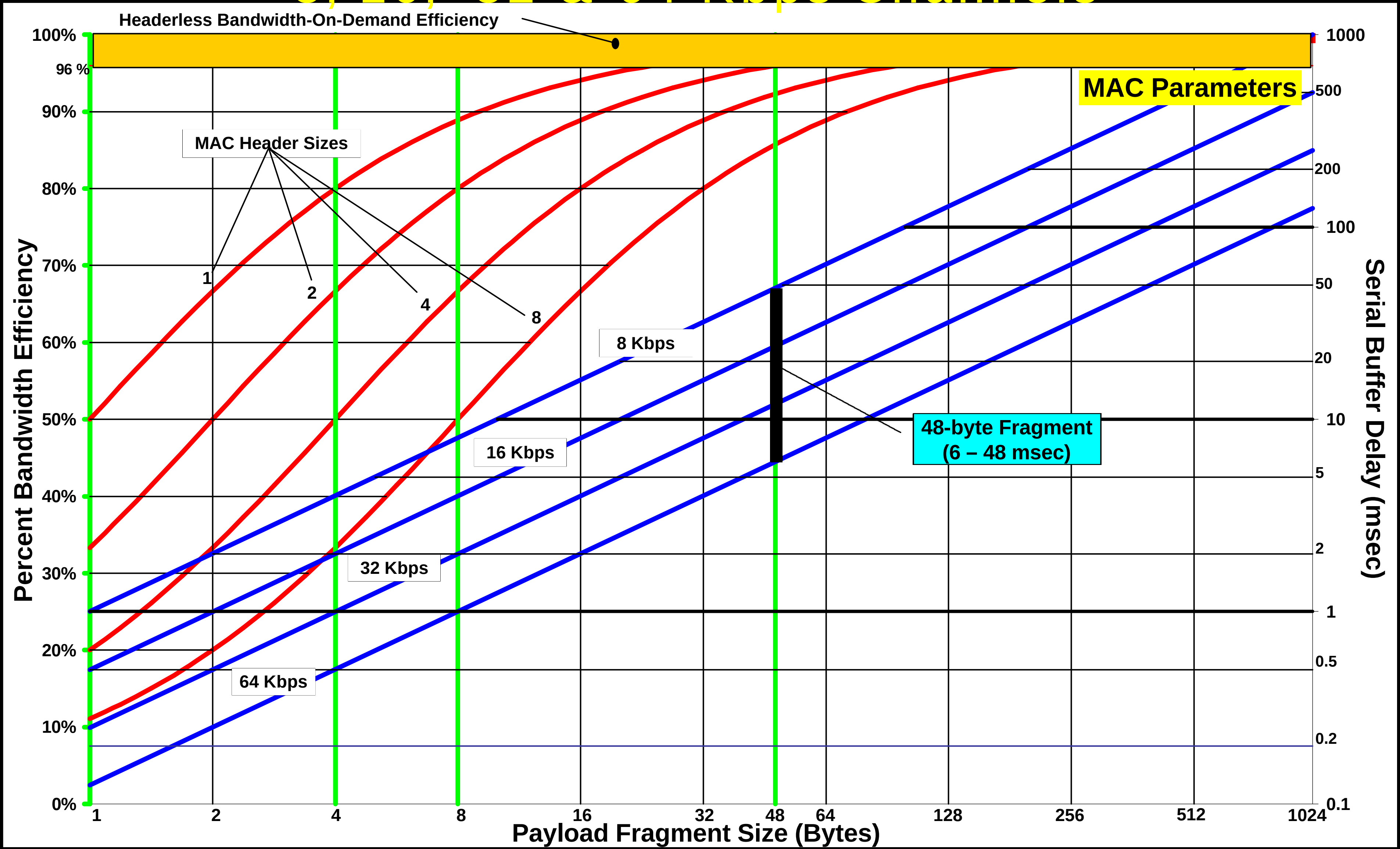
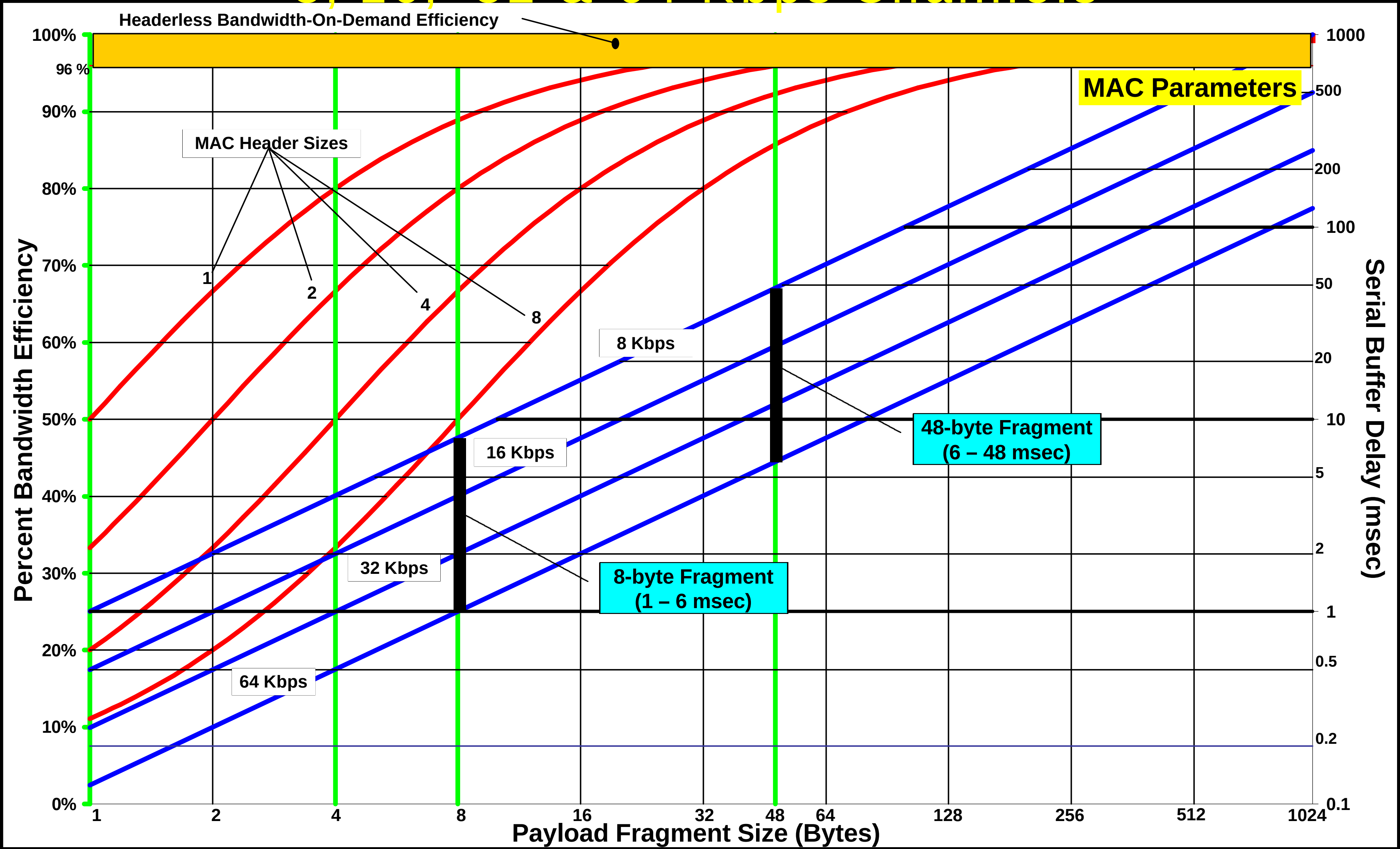
Bandwidth Efficiency and Buffer Delay for 8, 16, 32 & 64 Kbps Channels



Bandwidth Efficiency and Buffer Delay for 8, 16, 32 & 64 Kbps Channels



Bandwidth Efficiency and Buffer Delay for 8, 16, 32 & 64 Kbps Channels



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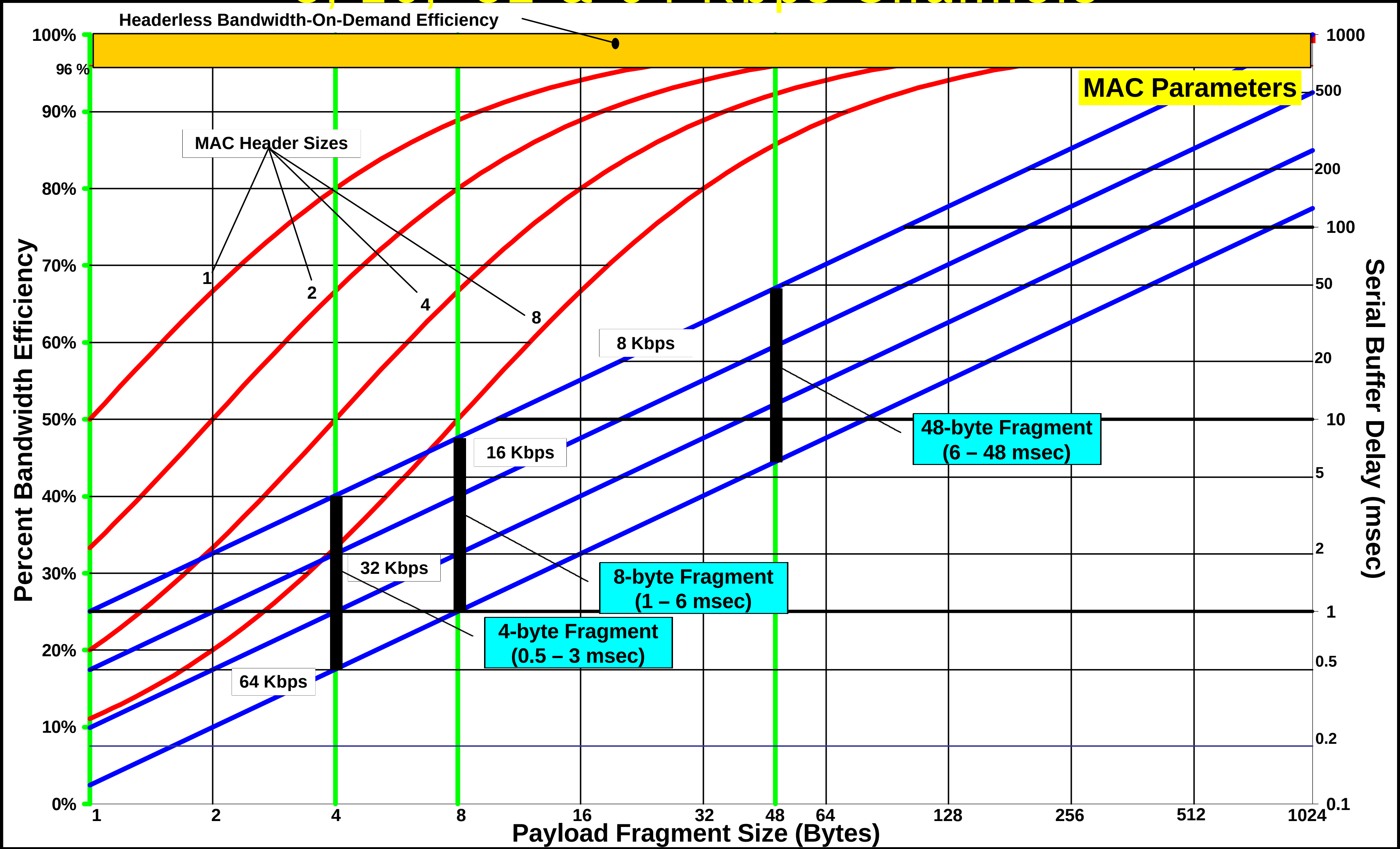
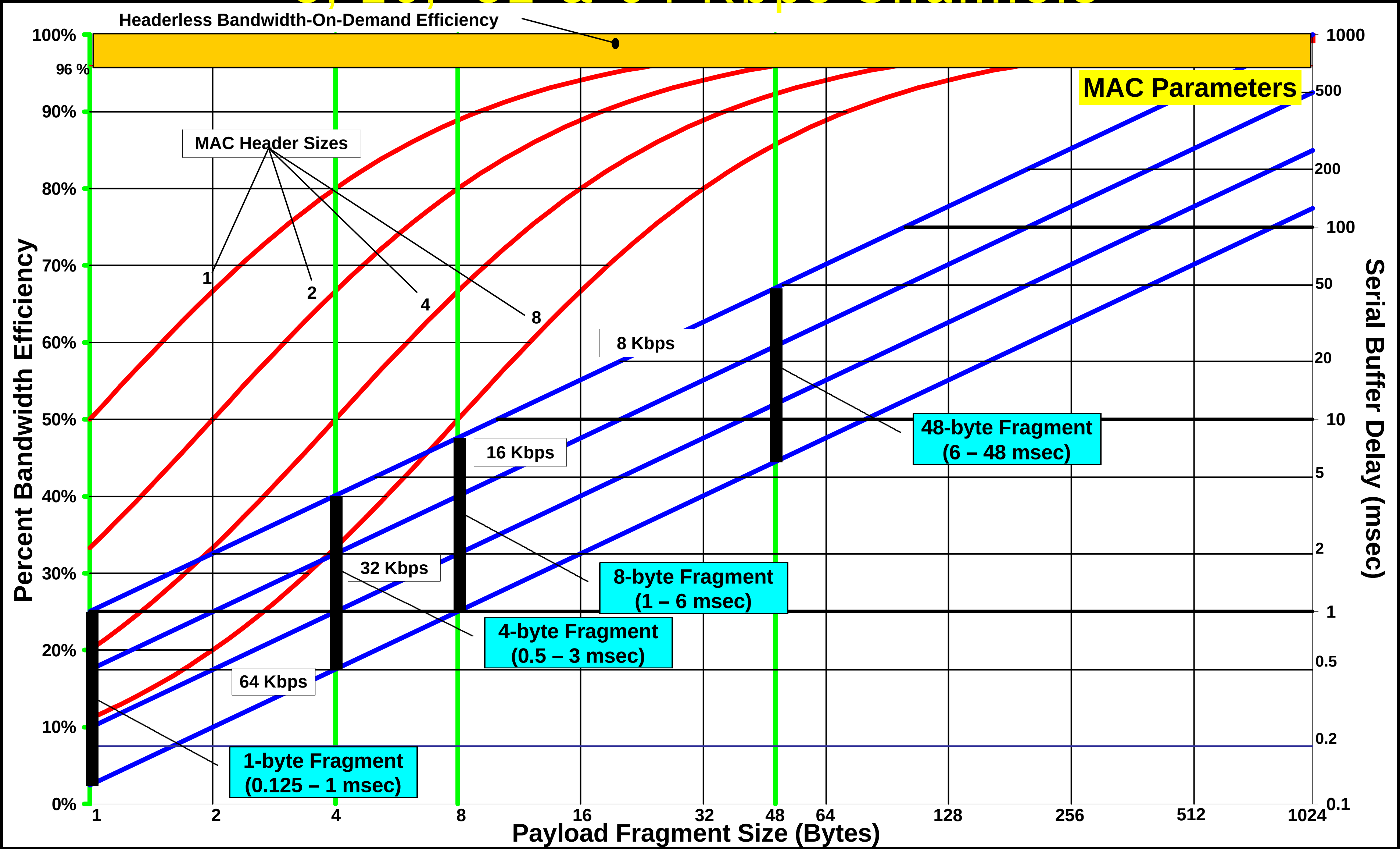
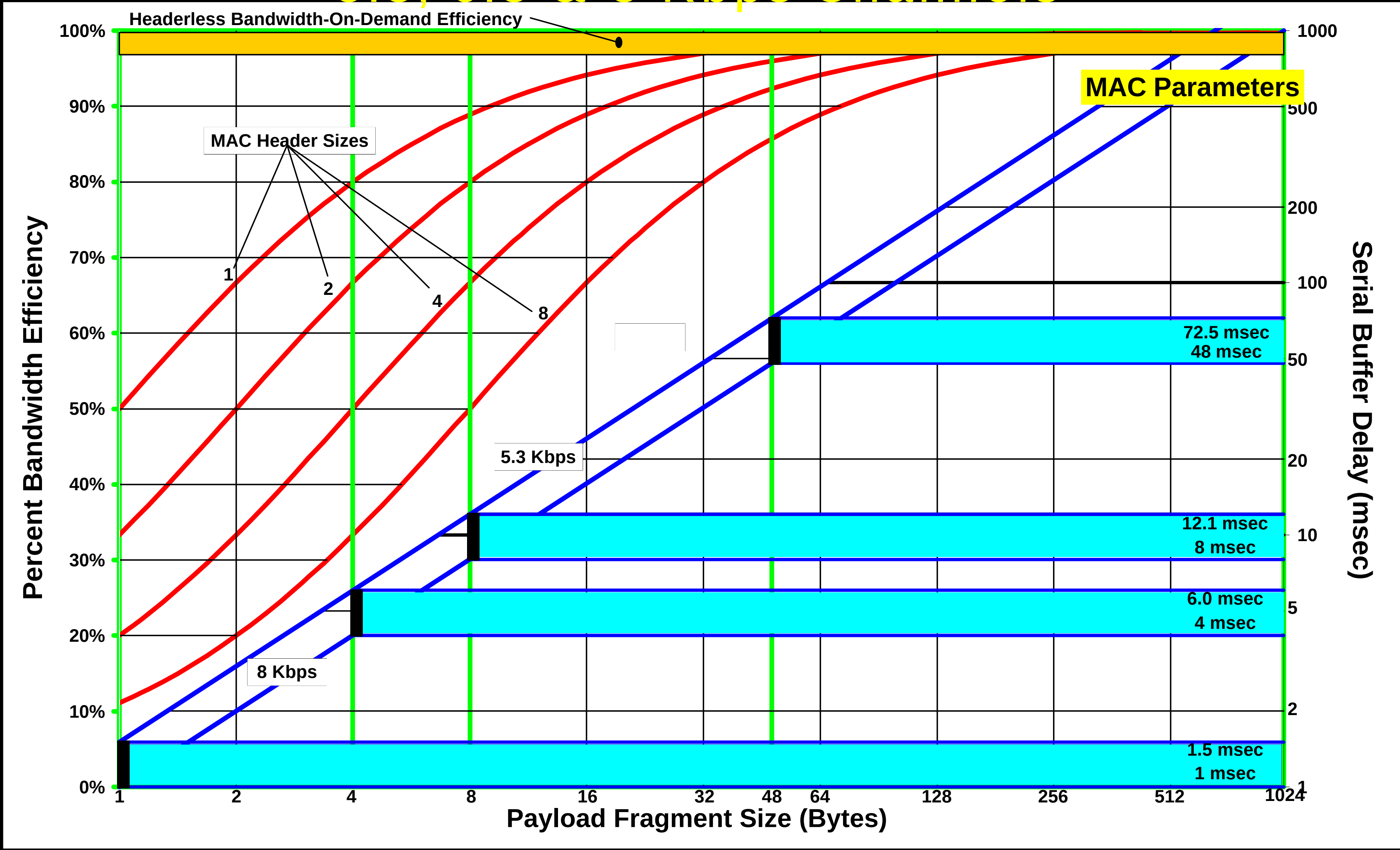


Bandwidth Efficiency and Buffer Delay for 8, 16, 32 & 64 Kbps Channels



Bandwidth Efficiency and Buffer Delay for 5.3, 6.3 & 8 Kbps Channels



MAC Layer Size Constraints

- A major constraint on data element size is a tradeoff between MAC header size and payload size
- Efficiency is adversely affected by the need for control packets that delineate bandwidth-control maps

Factors Affecting Bandwidth Efficiency

- PHY guard time and preamble overhead
- MAC header and control packet overhead
- Efficiency of asynchronous queues

Asynchronous Queuing

- Random queues without effective flow control produce unacceptable delays or packet/cell discard
- Source flow control (bandwidth management) is the most effective way of assuring QoS and efficient use of bandwidth
- A Bandwidth-On-Demand MAC Sublayer is a simple, efficient, generic flow control mechanism

Best-of-Breed Approach

- **Use *short* fixed length "cell slots" that are assigned to channels using Element Address to Ordinal Position Number domain transformation**
- **Use Common Signaling Channel to control bandwidth assignments and for system management**

What's the Problem

- The approach works great for downstream traffic — cell slots can be one byte long
- BUT … there is no short burst modem that exists with small guard time and preamble requirements
- Also …

The Dilemma

- Current Broadband Wireless Access customers are not clamoring for low speed channel support
- However, Broadband Wireless Access customer needs will likely change in the near future (probably at Internet speed)

Proposed Next Generation Broadband Wireless Access System Approach

Standard based on a Bandwidth-on-Demand MAC Sublayer

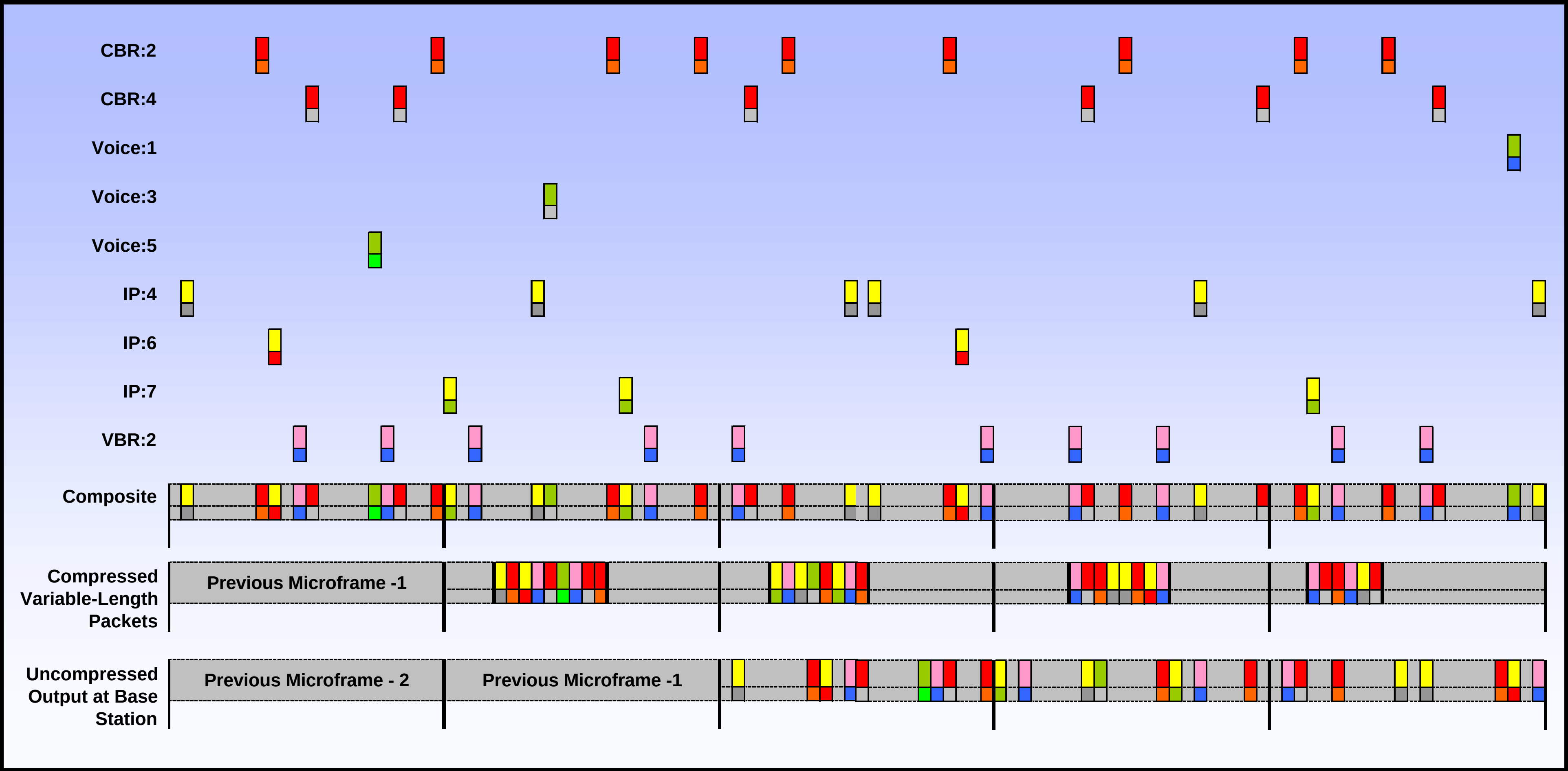
Proposed First Approach

- Use current burst size modems to aggregate upstream traffic using fixed length microframes (that are of the order of 1 msec long or less)
- The multiplexing functionality for a Subscriber Station is the same as for the Base Station (except for control)

Proposed First Approach

- Within each microframe period, aggregate traffic from each Subscriber Station into variable length packets
- Since there are a fixed number of cell slots in a frame, the variable length packets always fit within the time allotted

Single Upstream Aggregated Traffic Example



Benefits

- **Provides efficient use of bandwidth for (multiple) low speed channels as well as high speed channels**
- **Provides an infrastructure that can quickly move to voice-centric low-aggregate bandwidth markets when next generation modems are available**

Proposed Reference Model

<table>
<tr><th colspan="3">Proposed First Applications</th><th colspan="3">Future Applications Examples</th></tr>
<tr><td>STM Convergence</td><td>ATM Convergence</td><td>802.16 MAC Convergence</td><td>IP 802 Convergence</td><td>Frame Relay Convergence</td><td>MPEG Video Convergence</td></tr>
<tr><td colspan="6">Bandwidth-On-Demand MAC Sublayer</td></tr>
<tr><td colspan="6">PHY Layer</td></tr>
</table>

The Unmet Market Need

Support for low speed channels

Market Facts

- **Wireless telephones are becoming the access method of choice for all voice communication**
- **Internet access is being integrated into wireless telephones**
- **Estimated wireless telephones in use**
    - **(estimates provided by UMTS)**
  - **1 billion by 2005 (77 million data)**
  - **1.8 billion by 2010 (?? data)**

What Are Major Cell-phone Vendors Doing?

- Adding LAN wireless capability within Cellular Telephones for premises Voice/Internet access
- Voice traffic will be supported by
  - Cellular wireless sites for mobile users, BUT …
  - LAN wireless (802.11 / Bluetooth) for premises access

The Emerging Voice Market

- Cellular telephones (including wireless LAN capability) will drive the market
- The largest growth markets are projected to be Asia and South America … BUT …

The Emerging Voice Market

- **In these markets wireline to premises connections are insufficient to support projected growth and are costly to install**
- **Cellular telephone base stations are expensive and provide limited data bandwidth**

<u>Fixed wireless has a singular opportunity to fill the void for both business & residence</u>

A Potential Logic Trap

- **Premise:**

Since data traffic will predominate within communication networks, it is not important to worry about network efficiency for voice traffic

Backbone vs. Fixed Wireless Distribution Networks

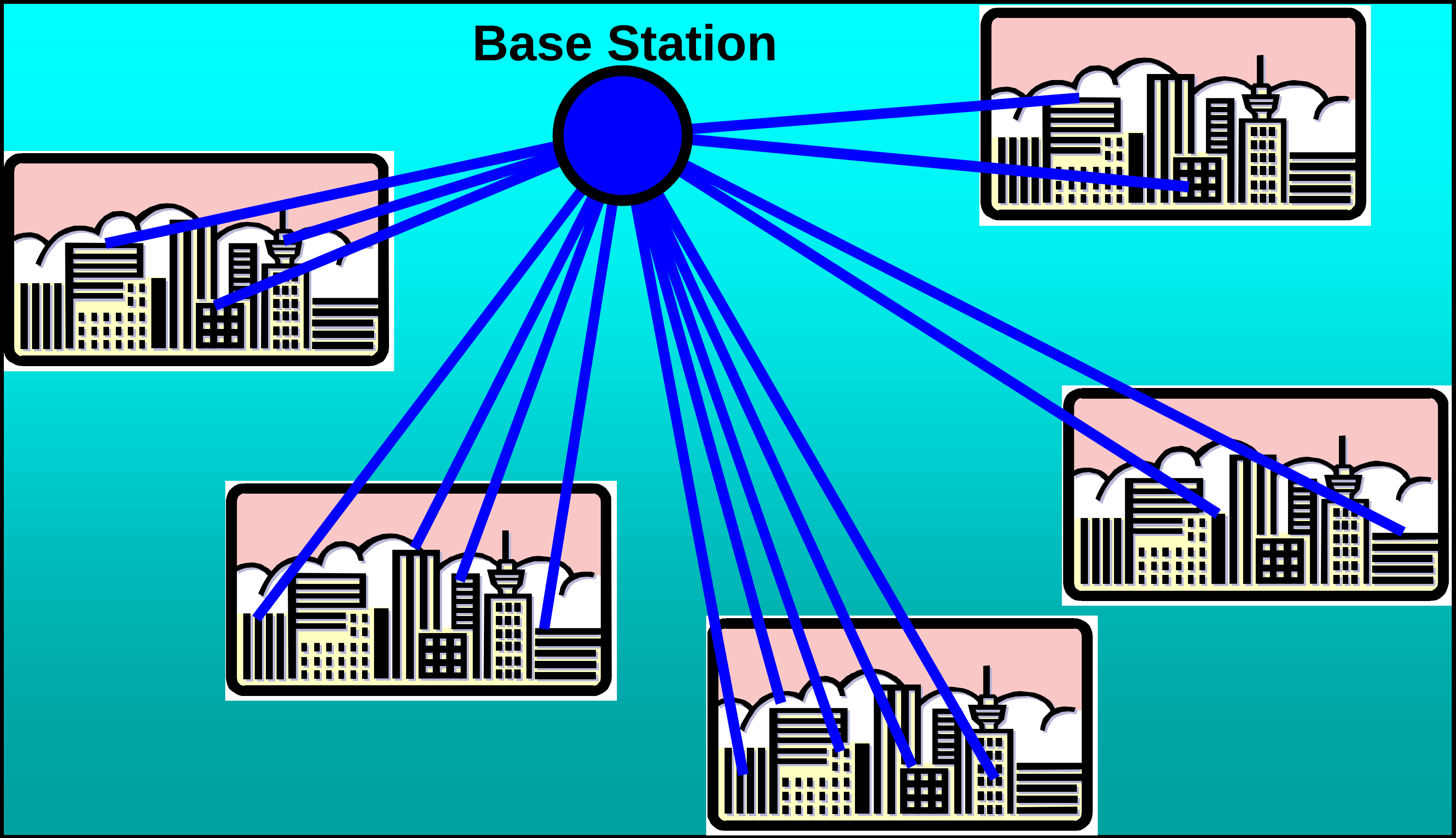
- **The premise is probably OK for backbone networks that aggregate traffic from many sources**
- **The premise <u>may</u> be true for some distribution network markets**
- **It is clearly <u>*not*</u> true for many others where voice will predominate for the foreseeable future.**

To assure its long-term success, the 802.16 standard must address both:

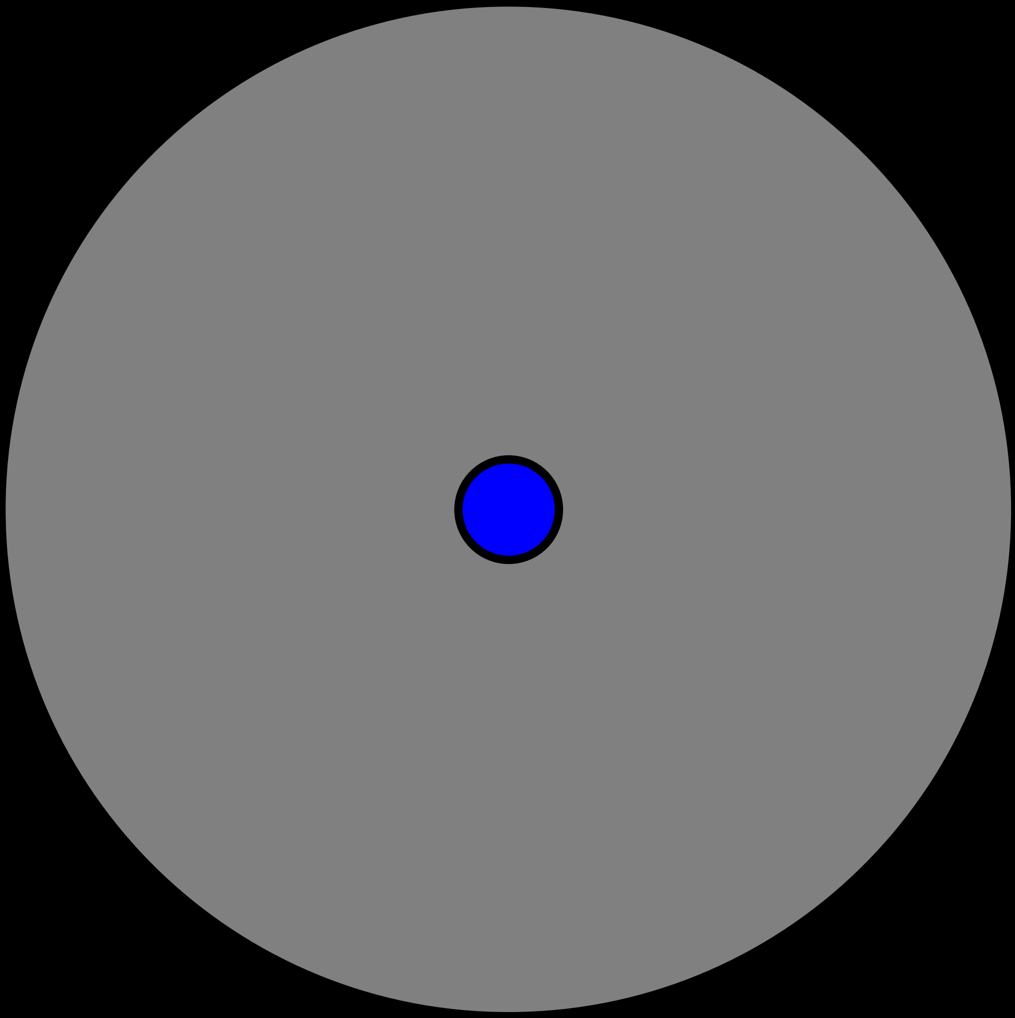
Broadband-dominated markets

Voice-dominated markets

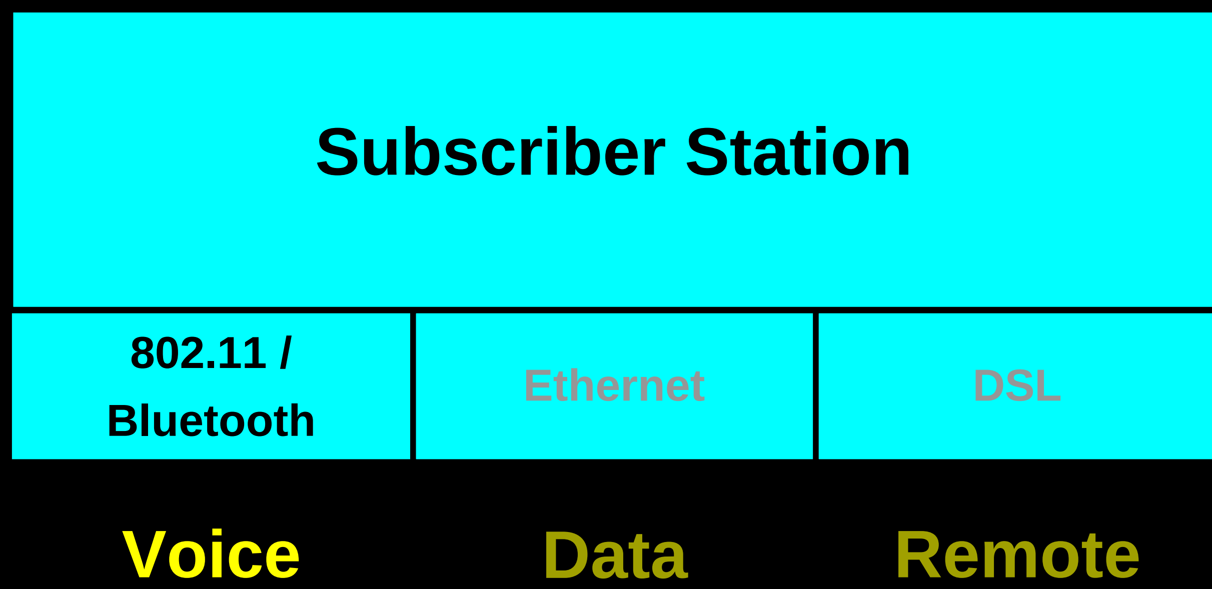
Broadband Dominated Market



Voice Dominated Market



Local Subscriber Station Access



The Good News

Only Fixed Wireless can satisfy fast-growing voice dominated markets

- **Cellular telephone base stations are not enough**
- **Wireline infrastructure to support projected growth does not exist**
- **Wireline infrastructure will be expensive (or impractical) to install**

Summary

- **A Bandwidth-on-Demand Sublayer is important to the future of Broadband Wireless Systems**
- **An untapped market exists that can become a major application for Broadband Wireless**

Proposed Program

- Form an (ad hoc) task group to formulate plan to develop an efficient short-burst modem
- Develop draft PHY standard based on Bandwidth-On-Demand MAC Sublayer for
  - Aggregated upstream traffic with variable-length burst modems
  - Non-aggregated traffic with short-burst modems

Additional Information

Two other (annotated) PowerPoint presentations are available that further describe the proposed approach. To receive these presentations or other descriptive material, please contact:

Ray Sanders at rws@CircuitPath.com