ImmenStar

GPON Technology and iROS™ Development

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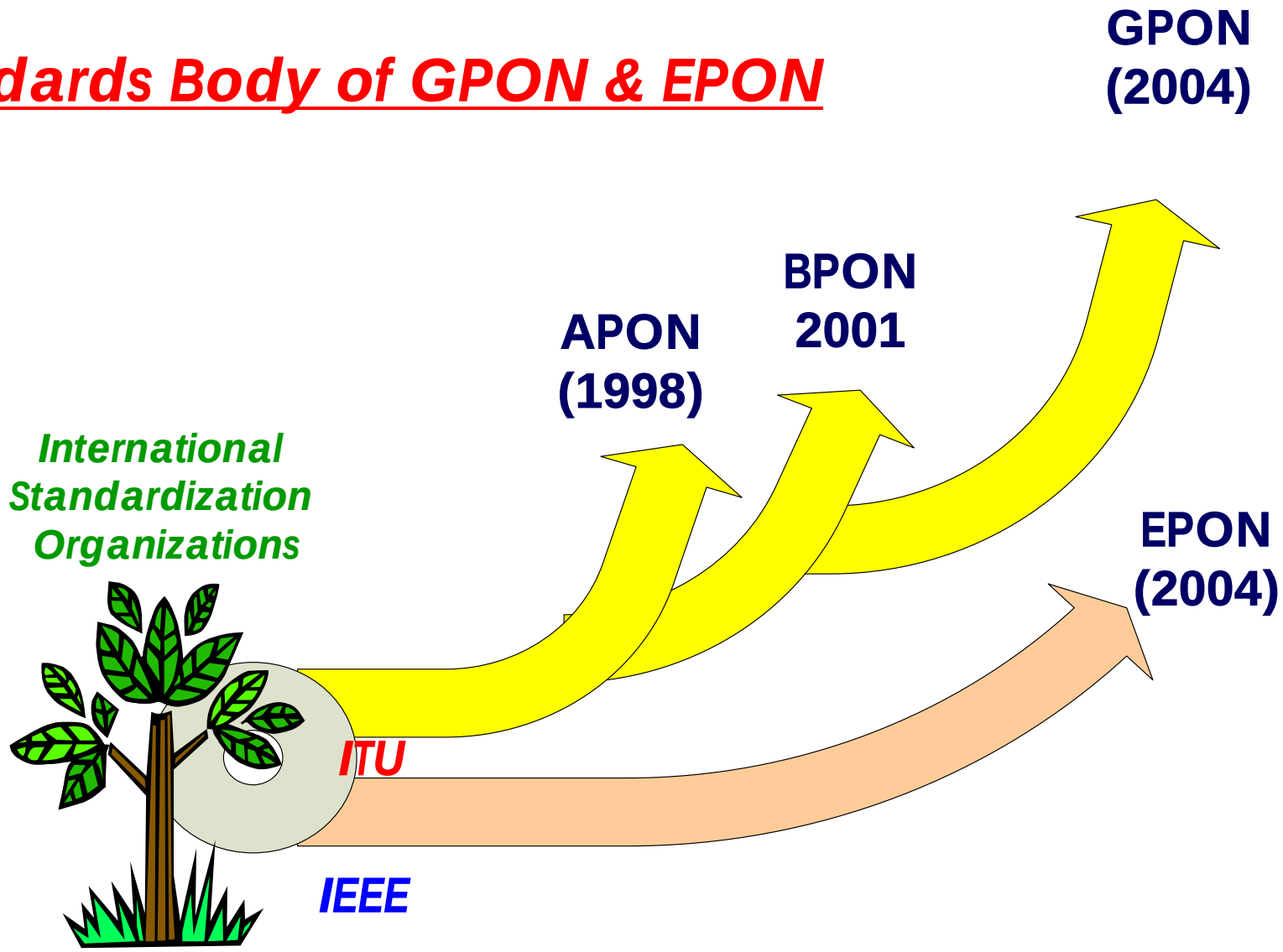
Agenda

- PON Technology and Standards Overview
- GPON Architecture
- GPON Framing and MAC Control
- ONT Management Control Interface (OMCI)
- Encryption
- iROS for GPON
- Summary

PON Technology and Standards Overview

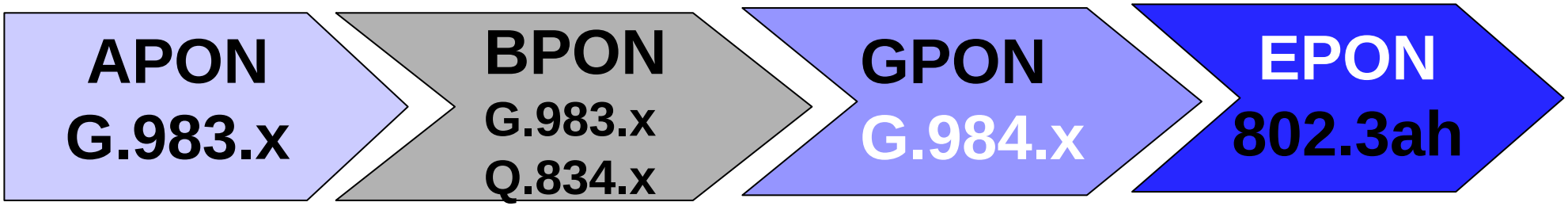
PON Standard Bodies

Standards Body of GPON & EPON



PON Standards Development

1996 → 2004



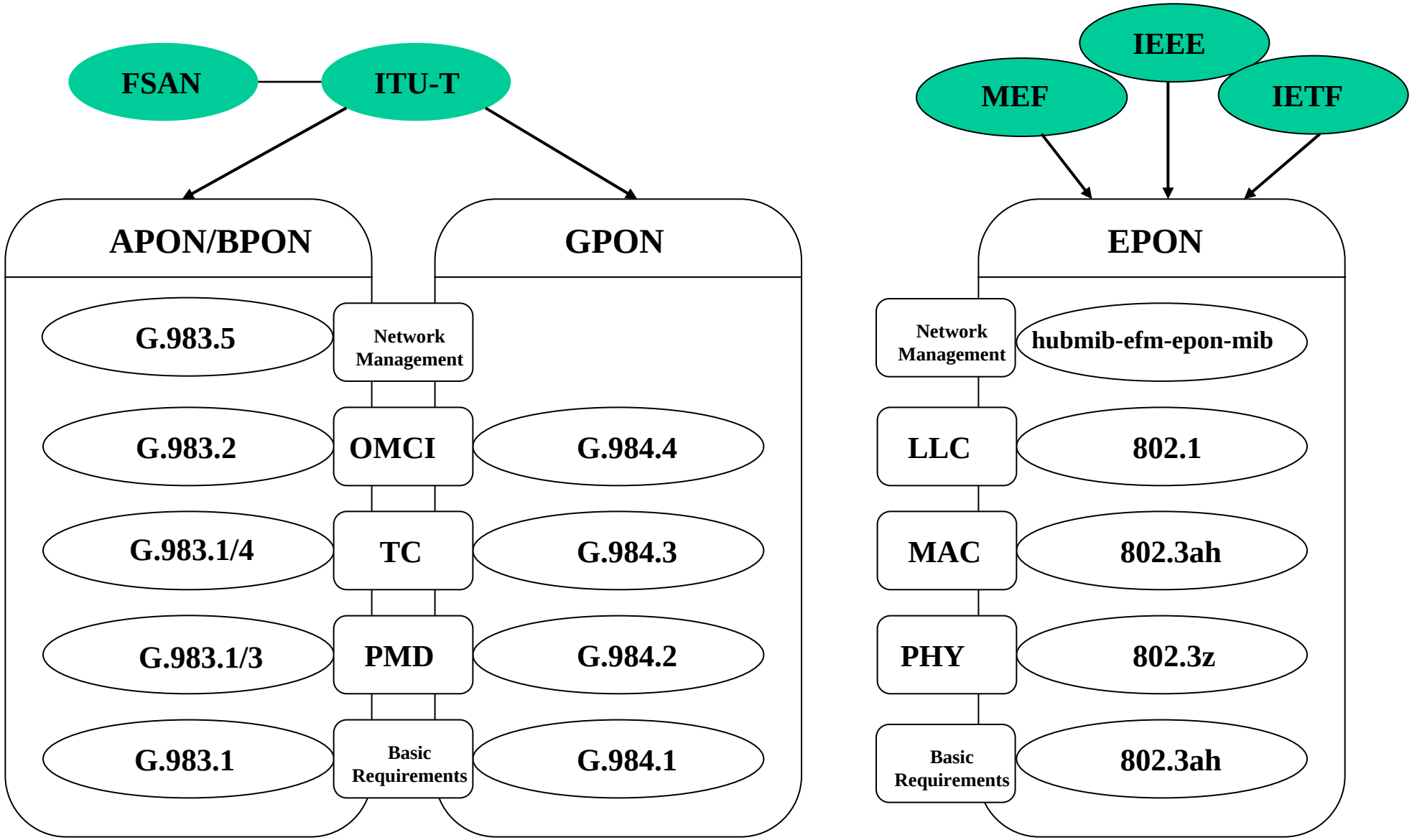
- Based on ATM
- Few system and chip vendors
- FSAN
- Only support of voice and data
- 155 Mbps
- 1998/10～2000/04, adopted by ITU-T
- G.983.1/2

- Based on ATM
- Few system and chip vendors
- FSAN
- Only support of voice and data
- DBA and protection introduced
- 622 Mbps
- 1998/10～2004/06, adopted by ITU-T
- G.983.1～10
- G.834.1～4

- Based on ATM、GFP
- Major system vendors and few chip vendors
- FSAN
- Support of voice, data and video
- OAM&P and protocol adaptation introduced
- 2.5 Gbps
- 2003/03～2004/06, adopted by ITU-T
- G.984.1～4

- Based on Ethernet standard
- Major system vendors and a few chip vendors
- Metro Ethernet Forum
- IP friendly for voice, data and video
- Seamless interconnection to CPE and Metro
- 1 Gbps
- 2000/12～2004/06, adopted by IEEE and known as 802.3ah

APON/BPON/GPON/EPON Standards



BPON/GPON ITU-T Recommendations

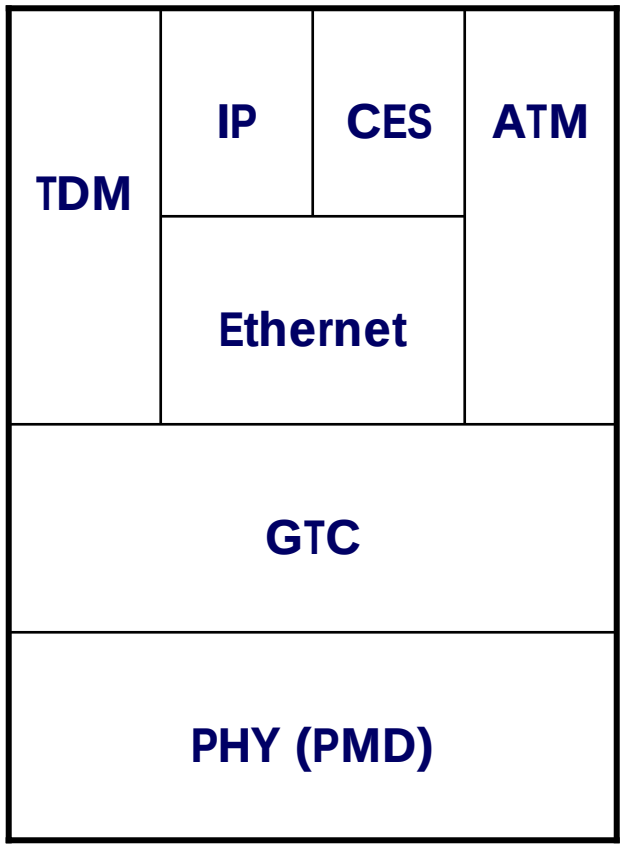
Number	Title	Date
G.983.1	Broadband optical access systems based on Passive Optical Networks (PON)	01/2005
G.983.2	ONT management and control interface (OMCI) for B-PON	07/2005
G.983.3	A broadband optical access system with increased service capability by wavelength allocation	03/2001
G.983.4	A broadband optical access system with increased service capability using dynamic bandwidth assignment	11/2001
G.983.5	A broadband optical access system with enhanced survivability	01/2002
G.984.1	**G-PON: General characteristics**	**03/2003**
G.984.2	**G-PON: Physical Media Dependent (PMD) layer specification**	**03/2003**
G.984.3	**G-PON: Transmission Convergence (TC) layer specification**	**02/2004**
G.984.4	**G-PON: ONT Management and Control Interface specification**	**06/2004**

GPON and EPON Comparison

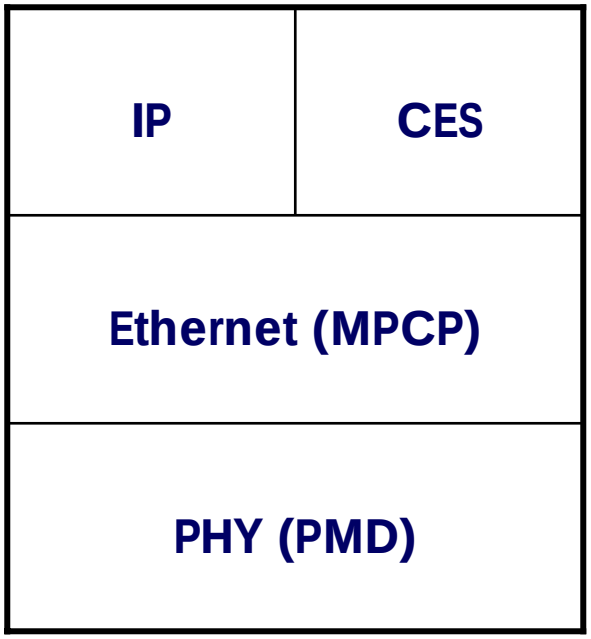
Item		FSAN / ITU-T G-PON	IEEE EPON
OAM	OAM	Mandatory and provided at three levels	Optional and supports FEI and loopback
	Security	AES in downstream direction	Generic and provided by 802.1AE
	Protection	1+1 or 1:N protection switching	Not defined
MAC Layer	Service	Full services (Ether, TDM, POTS)	Ethernet data
	Frame	GEM frame	Ethernet frame
PHY Layer	Distance	10 / 20 km (Logical: 60 km)	10 / 20 km
	Branches	64 (Logical: 128)	16 or over
	Bit rate	Up : 156M, 622M, 1.25Gbit/s Down : 1.25G, 2.5Gbit/s	1.25Gbit/s (Up and Down)
	Bandwidth	Same as above (NRZ coding)	1Gbit/s (8B10B coding)
	Opt. Loss	15 / 20 / 25dB	15 / 20dB
	Wave-length	Down : 1480-1500nm Up : 1260-1360nm (Available to video signals overlay)	Down : 1480-1500nm Up : 1260-1360nm (Available to video signals overlay)
	Upstream burst timing	Laser turn on/off: 13 ns (Max) AGC setting and CDR clock: 44 ns (Max)	Laser turn on / off : 512ns (Max) AGC setting and CDR lock : 400ns (Max)

Protocol Stacks

GPON Protocol Stack



EPON Protocol Stack



EPON vs GPON

EPON

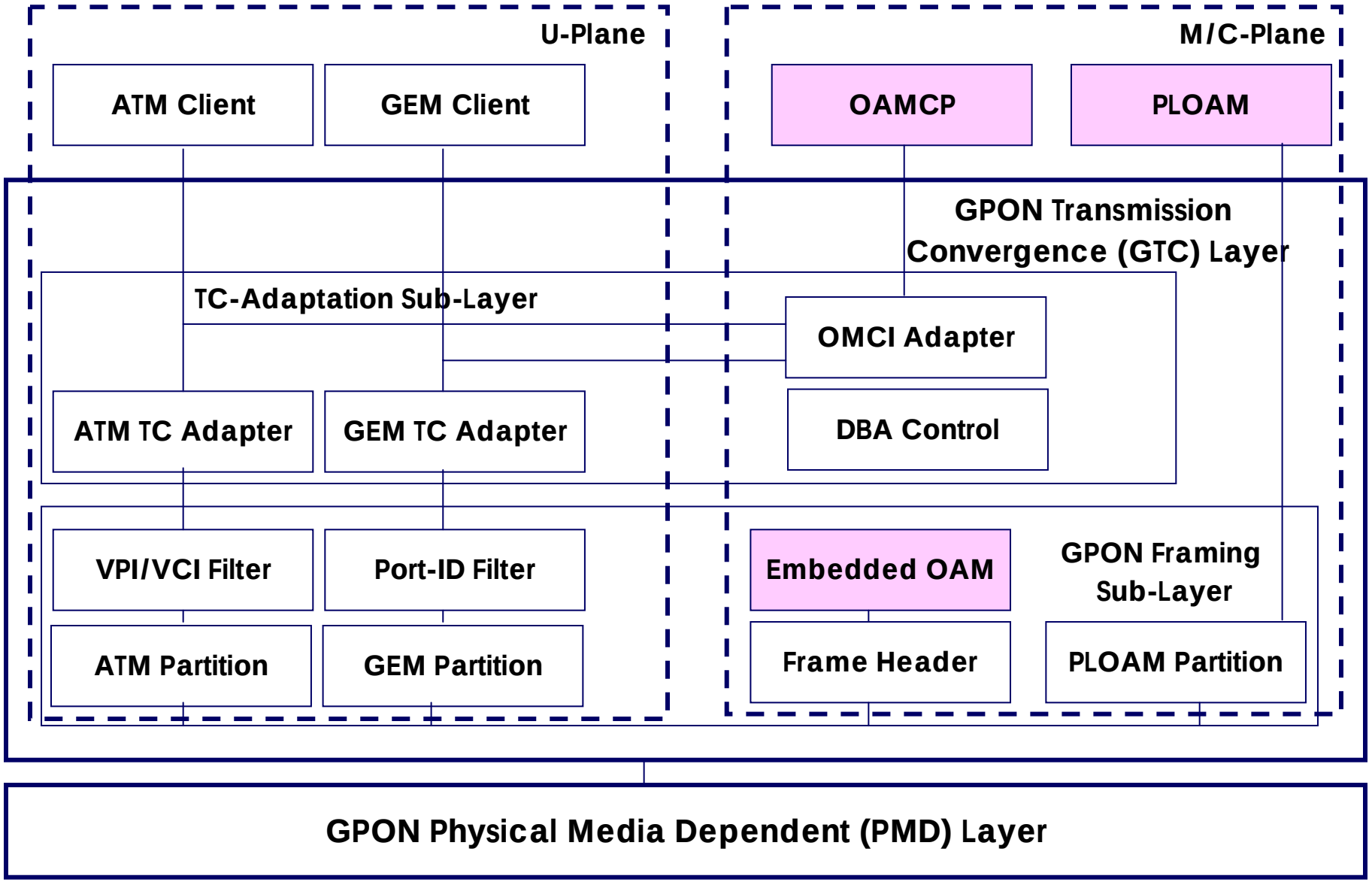
- IEEE 802.3 Protocols
- Variable length packets
- Up to 1,518 bytes / packet, segmentation not used.
- Variable 64 -1,500 bytes
- 18 bytes of overhead
- Broadcasts data downstream in Ethernet packets
- Transmits packets upstream in timeslots using TDM

GPON

- ITU-T Rec. G.984.x
- Variable length fragments/fixed length cells
- IP packets fragmented
- Typical 48 byte payload
- 5 bytes of overhead
- Broadcasts data downstream in fragments or cells
- Transmits burst upstream in timeslots using TDMA

GPON Architecture

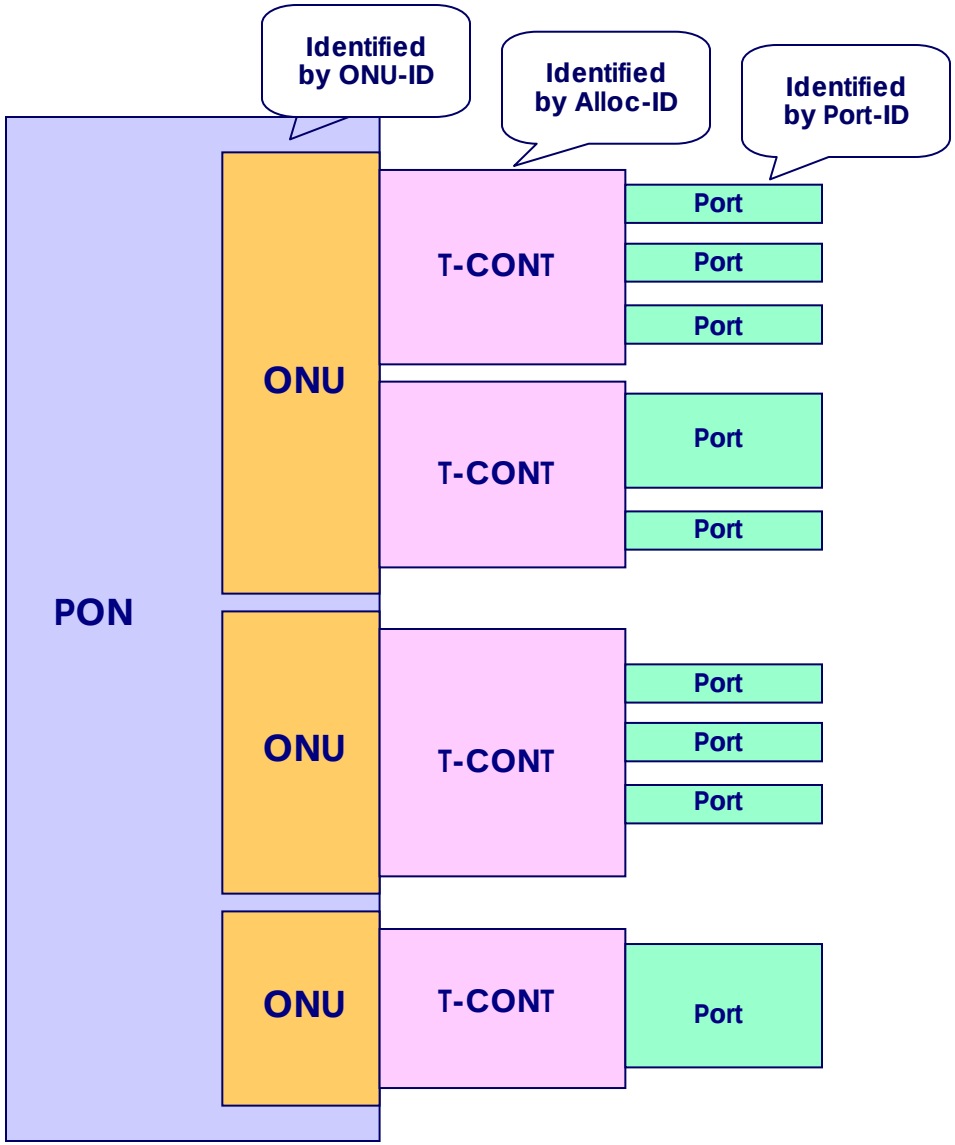
GPON Protocol Stack



Supported Asymmetric Rates

Downstream	Upstream
2.48832 Gbps	2.48832 Gbps
	1.24416 Gbps
	0.62208 Gbps
	0.15552 Gbps
1.24416 Gbps	1.24416 Gbps
	0.62208 Gbps
	0.15552 Gbps

GEM Multiplexing Service



- **Three identifiers**
  - ONU-ID (0 – 256)
  - Alloc-ID (0 – 4095)
  - Port-ID (0 – 4095)
- **Two QoS scheduling levels**
  - T-CONT (bandwidth management)
  - Port (queuing and scheduling)
- **T-CONT**
  - Basic upstream container
  - Associated with one ONU-ID
  - Five types of T-CONT defined
  - Each T-CONT has a traffic profile
  - Each ONU has default Alloc-ID equal to ONU-ID
  - Default Alloc-ID used for PLOAM and OMCI traffic or optionally user traffic
  - DBA report and grant based on it
- **Port**
  - Associated with traffic flows
  - Port-ID globally unique
  - Each Port-ID has traffic descriptors for policing and shaping
  - Scheduling between Port-ID to T-CONT mapping
  - Identify ONU in both US and DS

T-CONT Types

Type	Description
T-CONT 1	Unsolicited periodic grants of fixed payload allocations. Intended for the emulation of leased line services and CBR-like applications. Only static T-CONT not serviced by DBA
T-CONT 2	Intended for VBR traffic and applications with both delay and throughput requirements such as video and voice.
T-CONT 3	Intended for ABR traffic which is better than best effort traffic, with guaranteed minimum rate.
T-CONT 4	Intended for best effort UBR traffic and applications as such only serviced on request and bandwidth availability.
T-CONT 5	Intended to service two or more of other T-CONT types, and sometime referred to as colorless grants. Up to ONU to decide which queue to service.

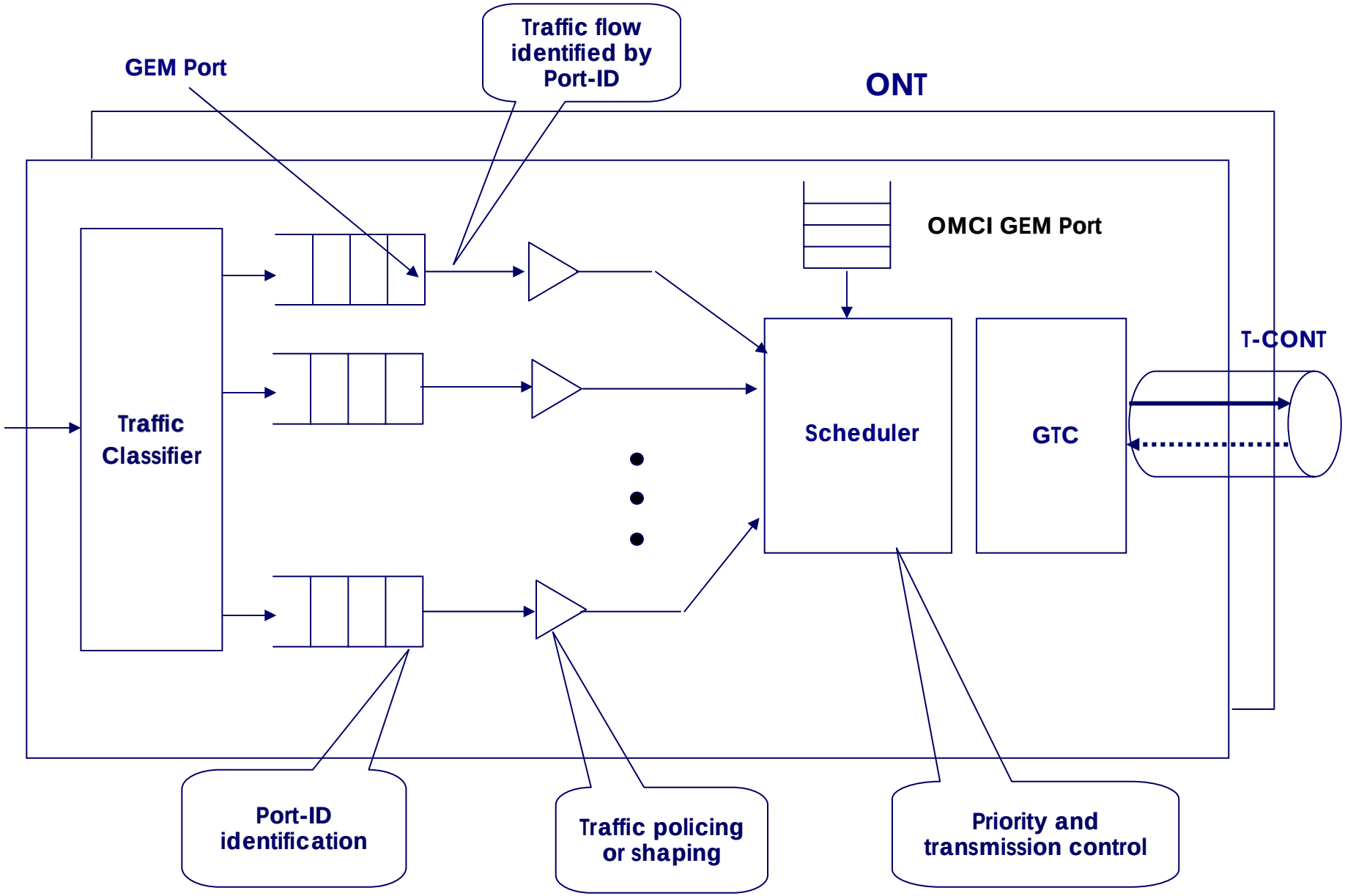
FSAN Class of Services (CoS)

Type	Definition
CoS-4	Low delay, Low jitter, Low PLR
CoS-3	Medium delay, Medium jitter, low PLR
CoS-2	Medium delay, Medium jitter, Medium PLR
CoS-1	High delay, High jitter, High PLR

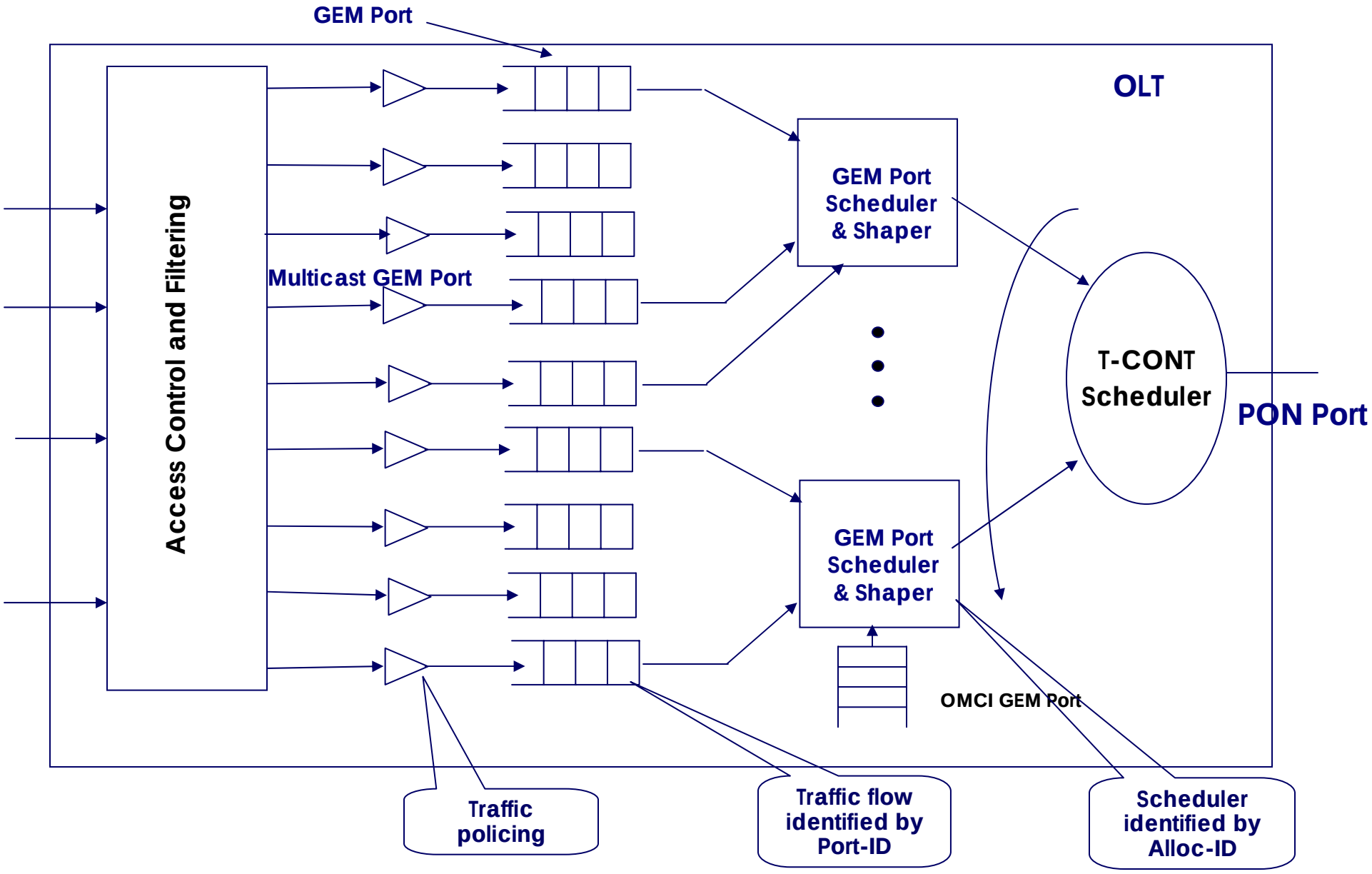
	Low	Medium	High
Delay	5ms	100ms	500ms
Jitter	2/5ms (DS/US)	15ms	40ms
PLR	10^{-6}	10^{-5}	10^{-4}

Note: QoS parameters are measured between UNI and SNI.
PLR – Packet Loss Ratio.

Upstream ONU QoS Model



Downstream OLT QoS Model

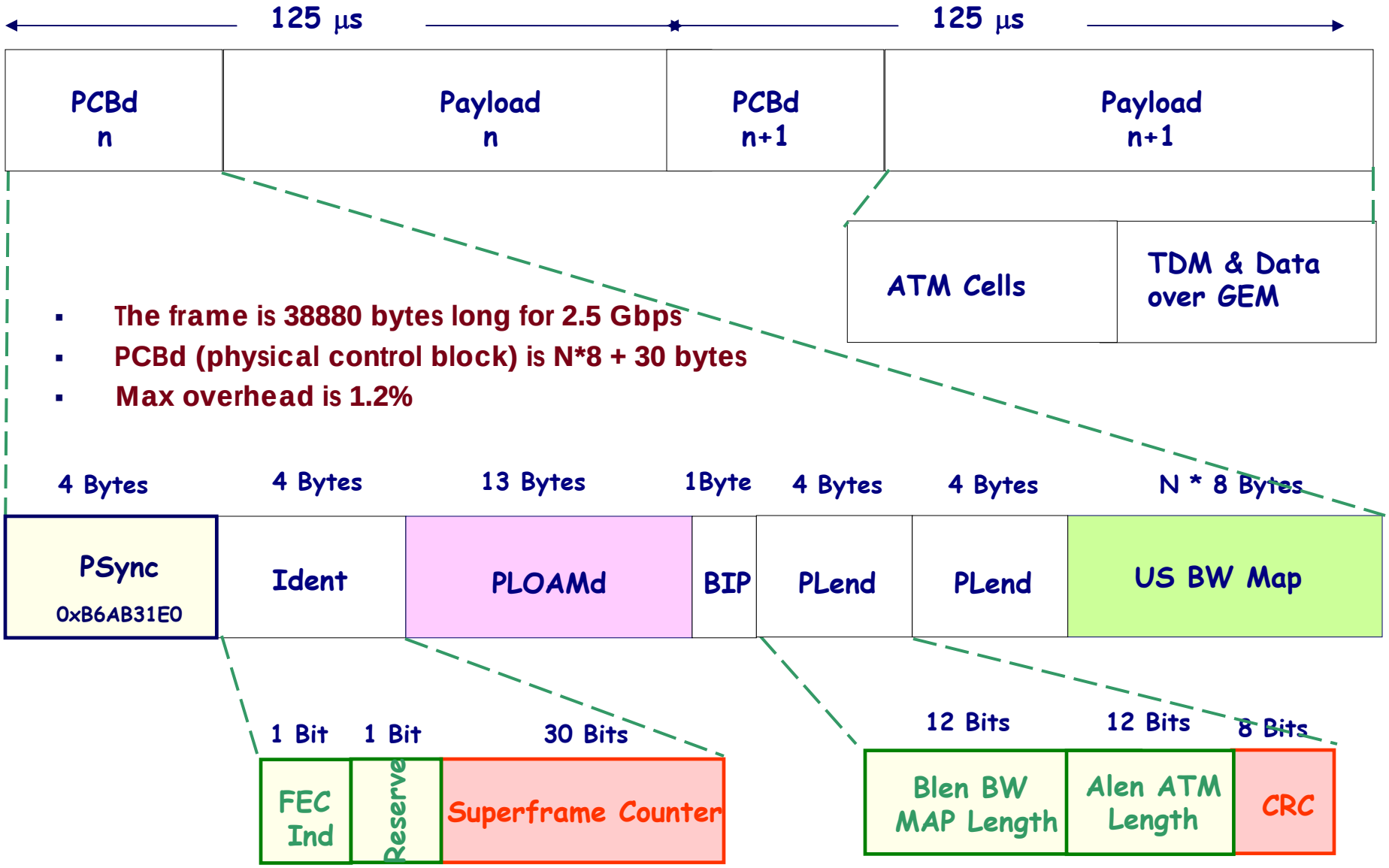


GPON Framing and MAC Control (GTC)

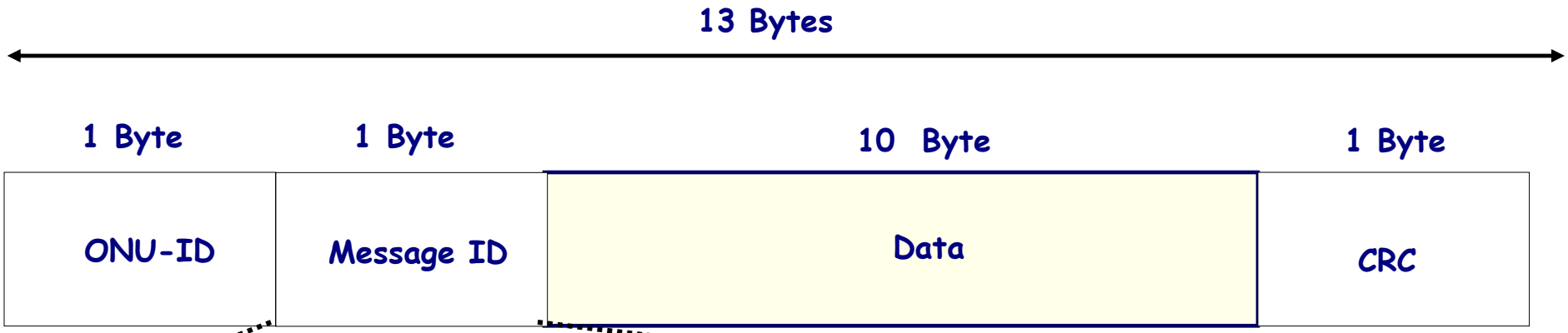
OLT and ONU Communication

- **Embedded OAM channels**
  - ✓ Several fields are defined in the downstream and upstream frames to convey real time information including BW Map, key switching, DBA and link BER.
- **PLOAM messages**
  - ✓ A dedicated 13-byte message is exchanged between OLT and ONTs to convey OAM functions.
- **OMCI (ONT Management Control Interface)**
  - ✓ Special OAM frames are transported over dedicated GEM channel using a specially assigned Port-ID.

Downstream GTC Frame



PLOAM Message Format



Downstream

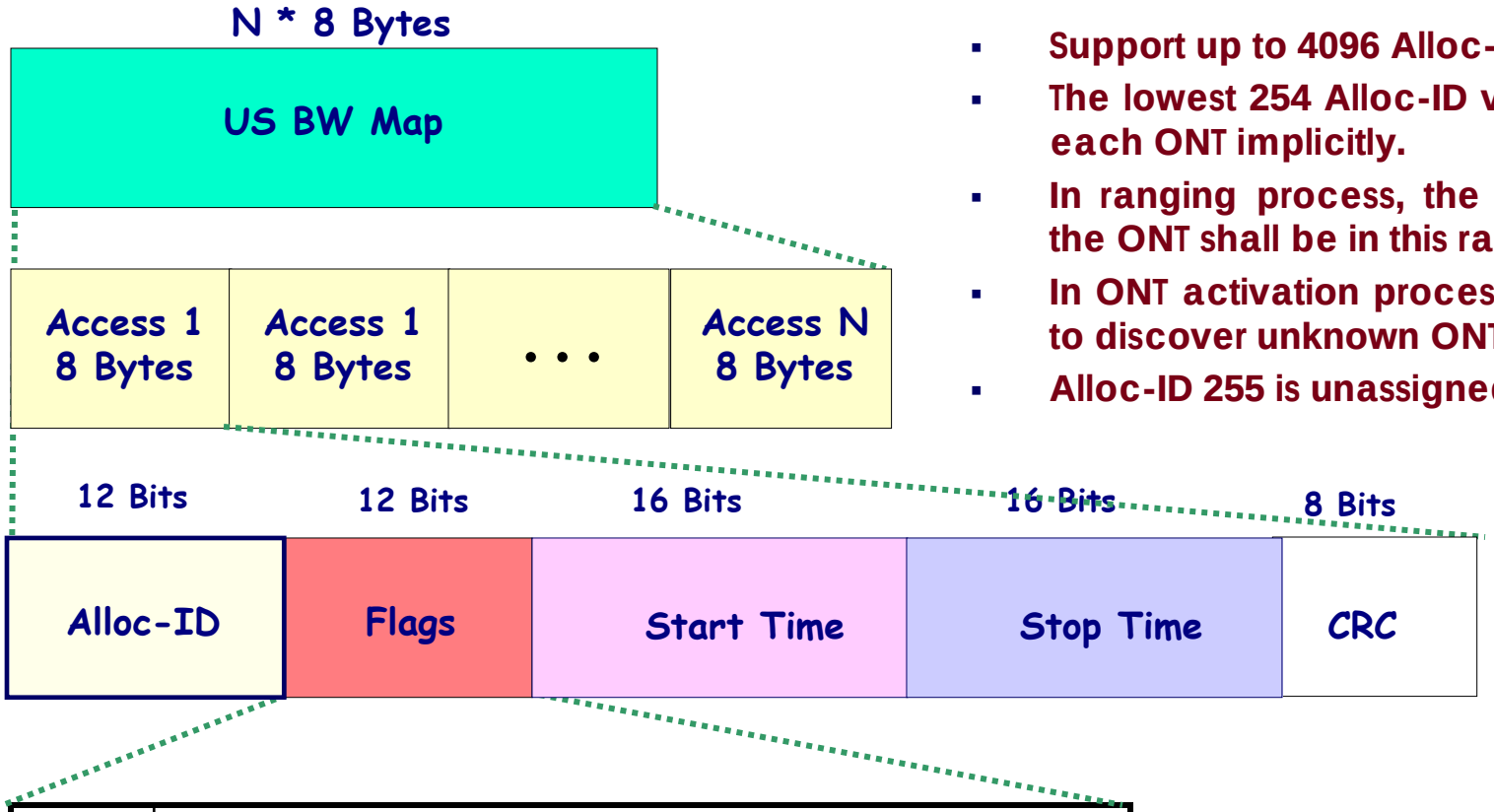
Message ID	Message Type
00000001	Downstream Overhead
00000010	Serial Number Mask
00000011	Assign ONU ID
00000100	Ranging Time
00000101	Deactivate ONU ID
00000110	Disable Serial Number
00000111	Configure VP/VC
00001000	Encrypted VPI/Port ID
00001001	Request Password
00001010	Assign Alloc ID
00001011	No Message

Message ID	Message Type
00001100	POPUP
00001101	Request Key
00001110	Configure Port ID
00001111	Physical Equipment Error
00010000	Change Power Level
00010001	PON Section Trace (PST)
00010010	BER Interval
00010011	Key Switching Time
00010100	Extended Burst Length

Upstream

Message ID	Message Type
00000001	Serial Number ONU
00000010	Password
00000011	Dying Gasp
00000100	No Message
00000101	Encryption Key
00000110	Physical Equipment Error
00000111	PON Section Trace (PST)
00001000	Remote Error Indication (REI)
00001001	Acknowledgement

Upstream Bandwidth Map

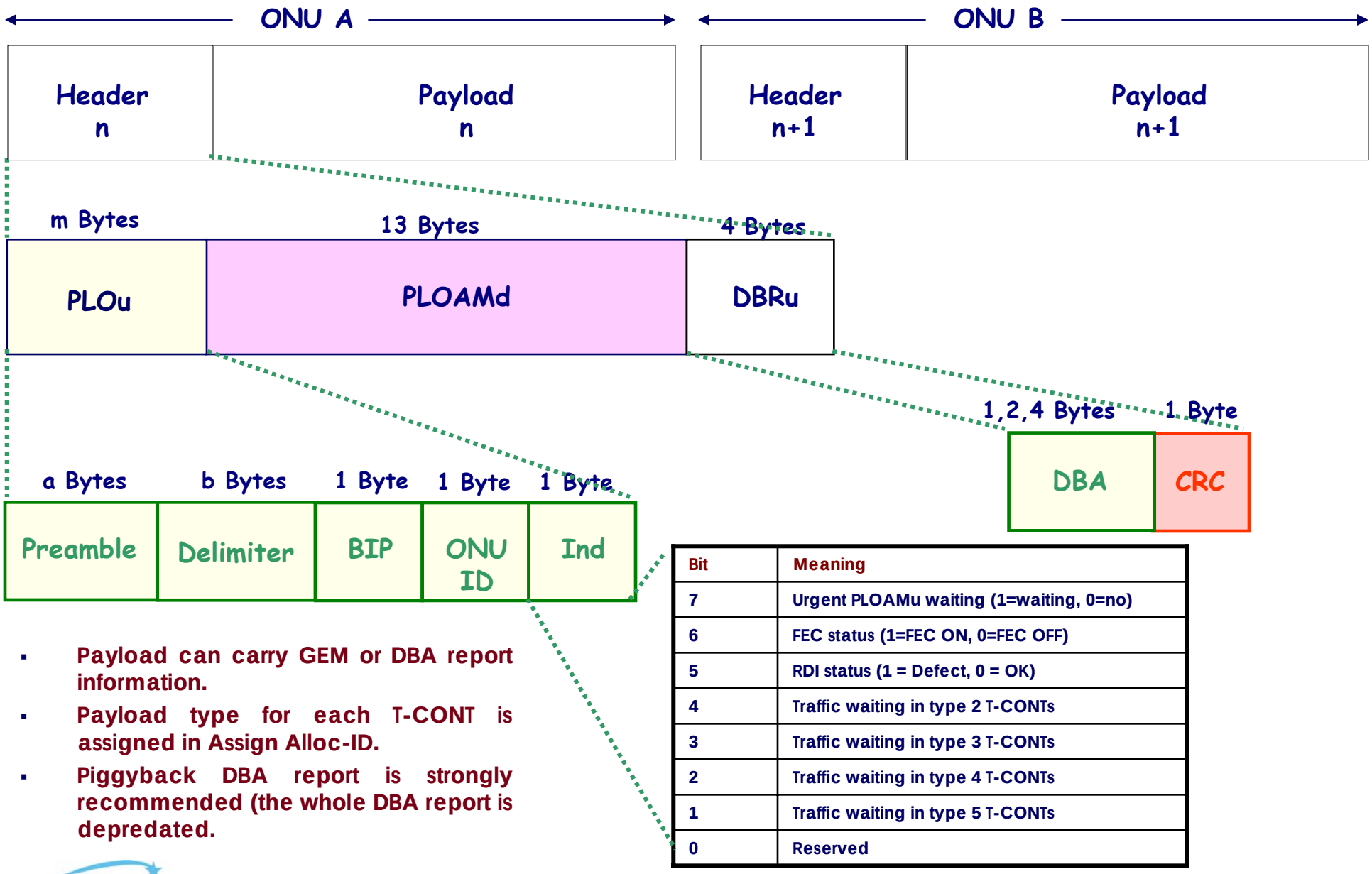


- Support up to 4096 Alloc-IDs.
- The lowest 254 Alloc-ID values are assigned to each ONT implicitly.
- In ranging process, the first Alloc-ID given to the ONT shall be in this range.
- In ONT activation process, Alloc-ID 254 is used to discover unknown ONTs
- Alloc-ID 255 is unassigned.

Bit	Meaning
11	Should always be set to 0 (PLSu feature is deprecated)
10	If set, send PLOAMu
9	If set, use FEC
8 & 7	Send DBRu, based on the following 00: Do not send DBRu (0 bytes) 01: Send the mode 0 (2 bytes) 10: Send the mode 1 (3 bytes) 11: Send the mode 2 (5 bytes)
0 - 6	Reserved

- Start Time, measured in Bytes, starts with zero at the beginning of the upstream frame.
- Stop Time also measured in Bytes
- DBA flags indicate DBA report modes.

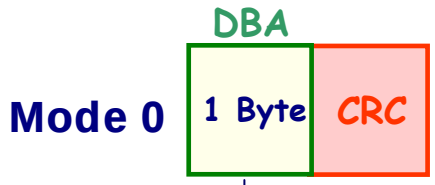
Upstream GTC Frame



Bit	Meaning
7	Urgent PLOAMu waiting (1=waiting, 0=no)
6	FEC status (1=FEC ON, 0=FEC OFF)
5	RDI status (1 = Defect, 0 = OK)
4	Traffic waiting in type 2 T-CONTs
3	Traffic waiting in type 3 T-CONTs
2	Traffic waiting in type 4 T-CONTs
1	Traffic waiting in type 5 T-CONTs
0	Reserved

- Payload can carry GEM or DBA report information.
- Payload type for each T-CONT is assigned in Assign Alloc-ID.
- Piggyback DBA report is strongly recommended (the whole DBA report is depredated.

Piggyback DBRu Report Modes

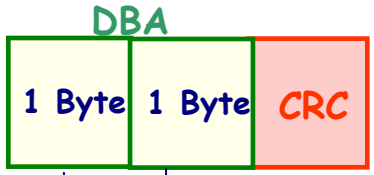


Mode 0

Suitable for the aggregate

Note: Buffer is measured in the number of GEM blocks

Total amount of data in the T-CONT buffer



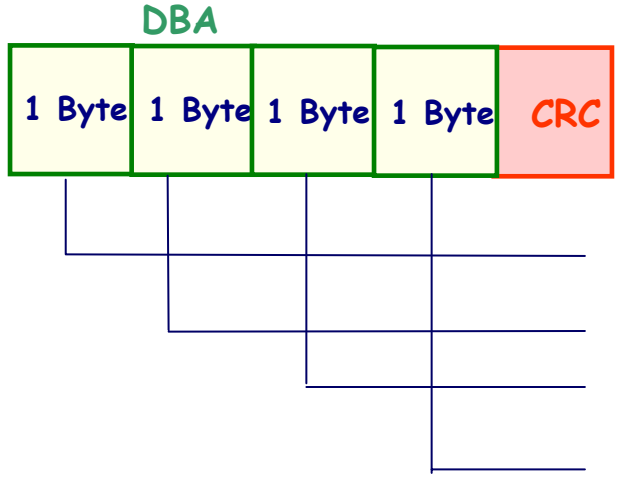
Mode 1

Suitable for T-CONT type 3 and 5

Total amount of data with PR tokens buffer

Total amount of data with SR tokens buffer

Mode 0 -> Mandatory
Mode 1 and 2 -> optional



Mode 2

Suitable for T-CONT type 5

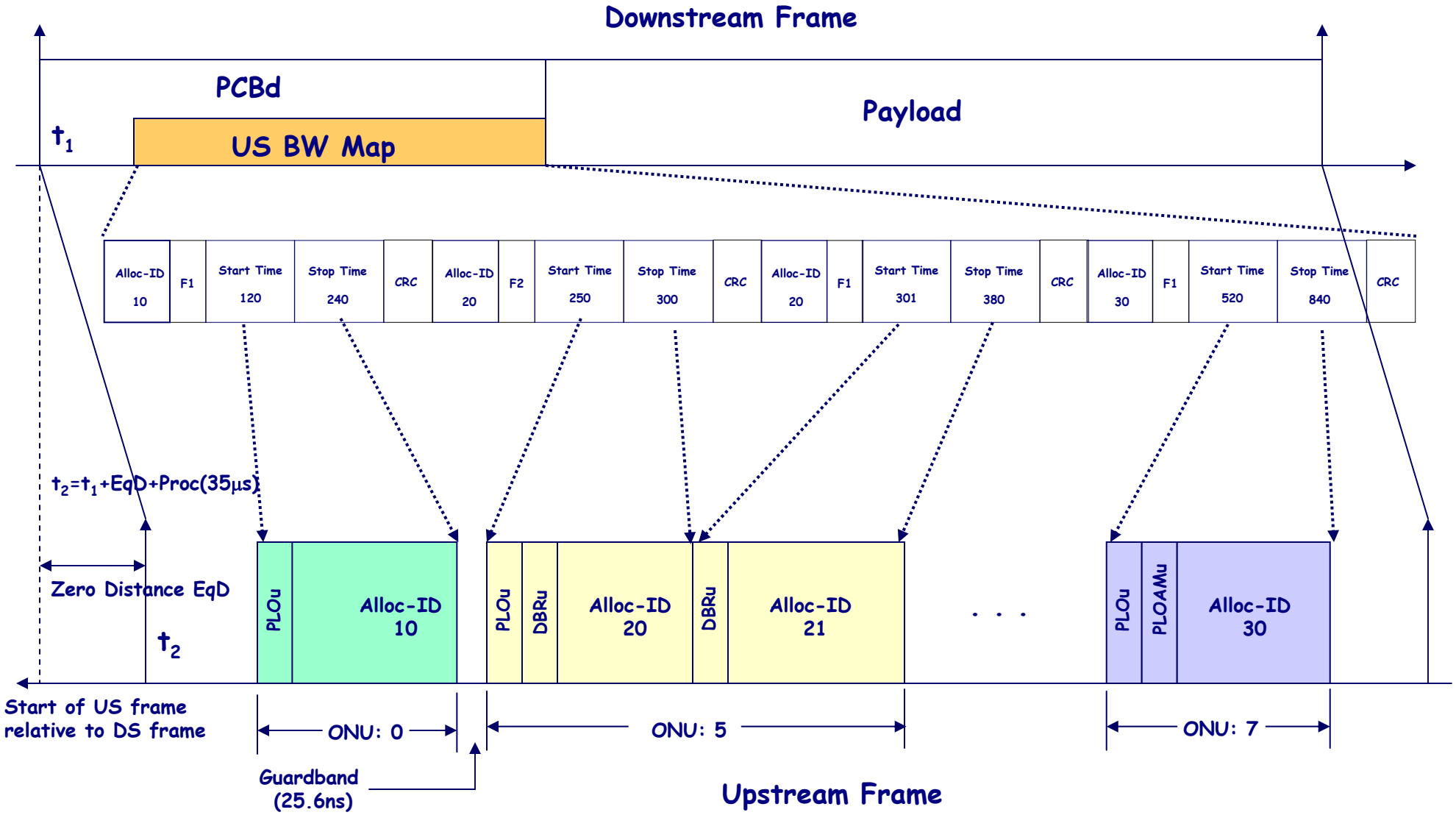
Total amount of data with T-CONT type 2 & PR tokens

Total amount of data with T-CONT type 3 & SR tokens

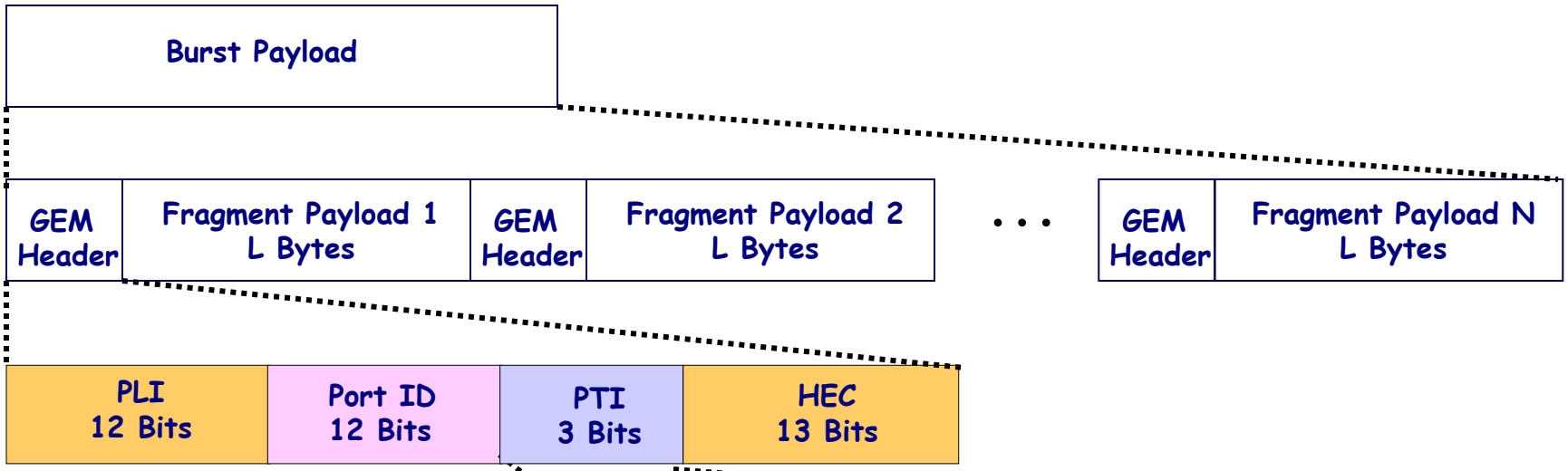
Total amount of data with T-CONT type 3 & PR tokens

Total amount of data with T-CONT type 4 & PR tokens

Media Control Example



GEM Payload Framing



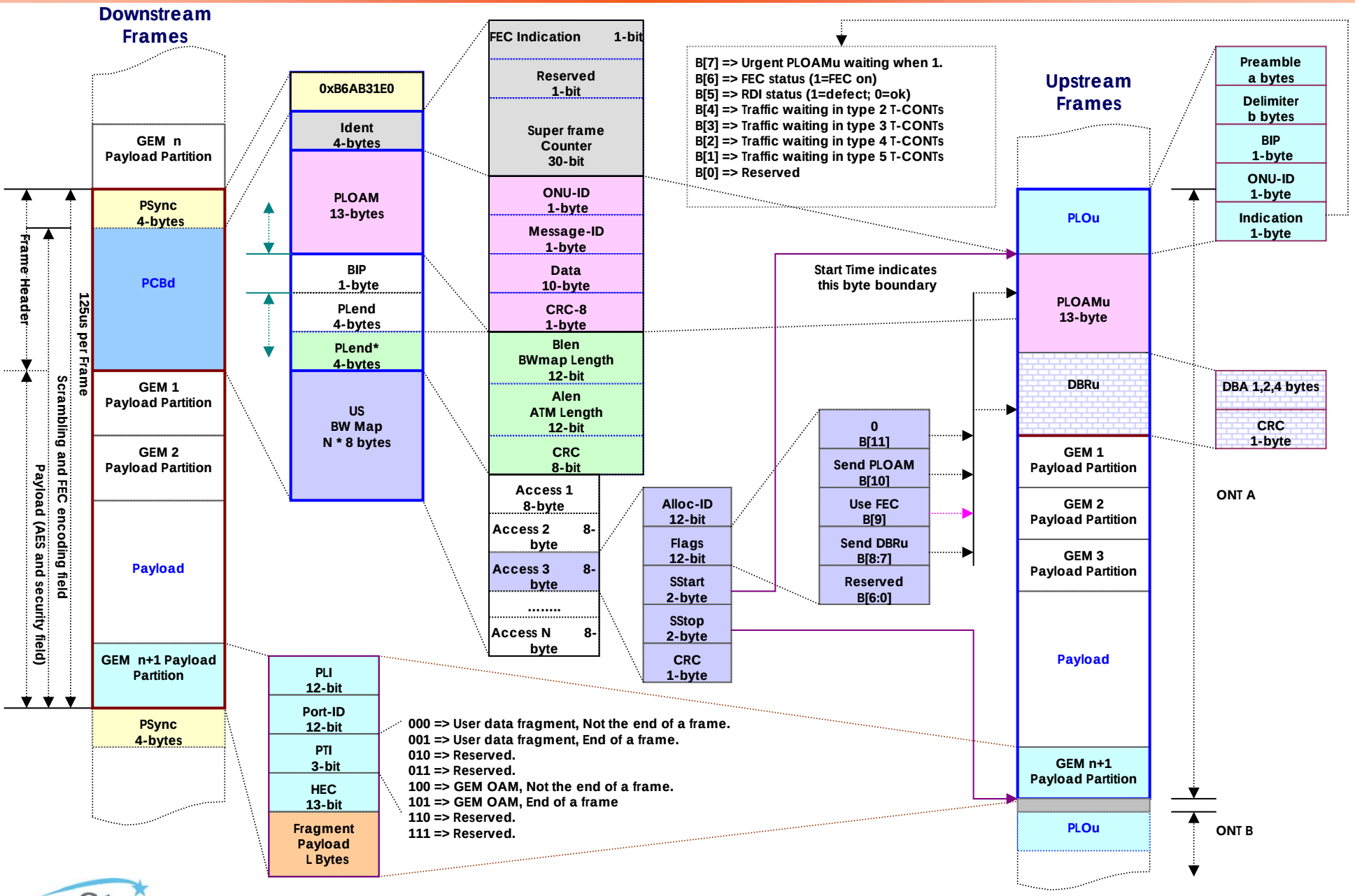
- Used for both downstream and upstream
- Hunting algorithm is used for frame delineation
- Payload length indicator indicates L bytes
- Idle frame defined to be all zeros in the GEM header
- Port-ID is used for ONU identification and multiplexing
- Port-ID is associated with one ONU for unicast traffic
- Port-ID can be associated with more than one ONU for multicast traffic

PTI	Meaning
000	User data fragment, Not the end of a frame
001	User data fragment, End of a frame
010	Reserved
011	Reserved
100	GEM OAM, Not the end of a frame
101	GEM OAM, End of a frame
110	Reserved
111	Reserved

Fragmentation and Reassembly

- **ONT**
  - ✓ Required to have at least two GEM re-assembly buffers.
  - ✓ Used to support time-urgent fragments.
  - ✓ Should not interleave more than two user data frames unless it determines the OLT has additional capability.
- **OLT**
  - ✓ Required to have at least two GEM re-assembly buffers per Alloc-ID.
  - ✓ Should not interleave more than two user data frames to any single ONU unless it determines the ONU has additional capability.

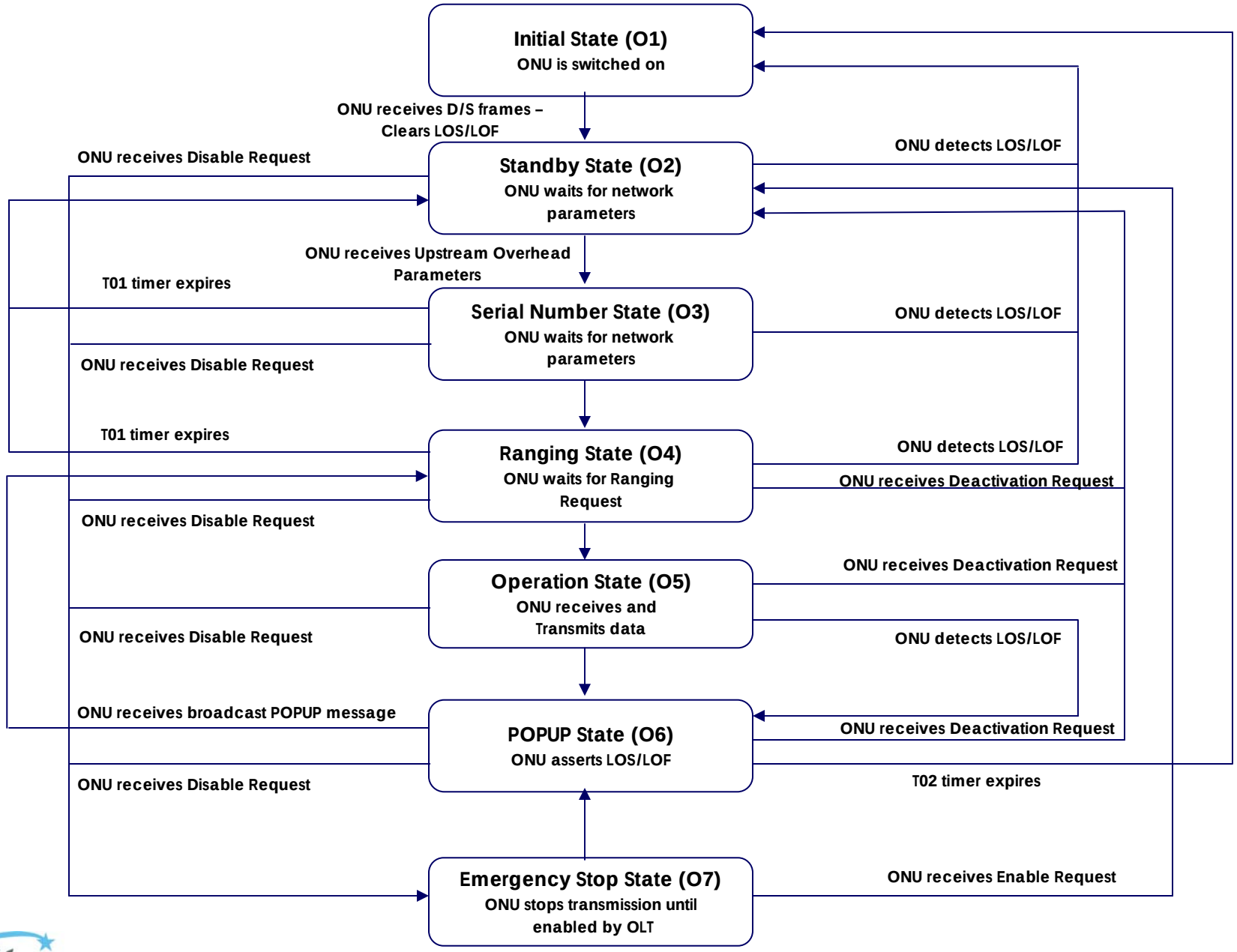
GPON Frame Map



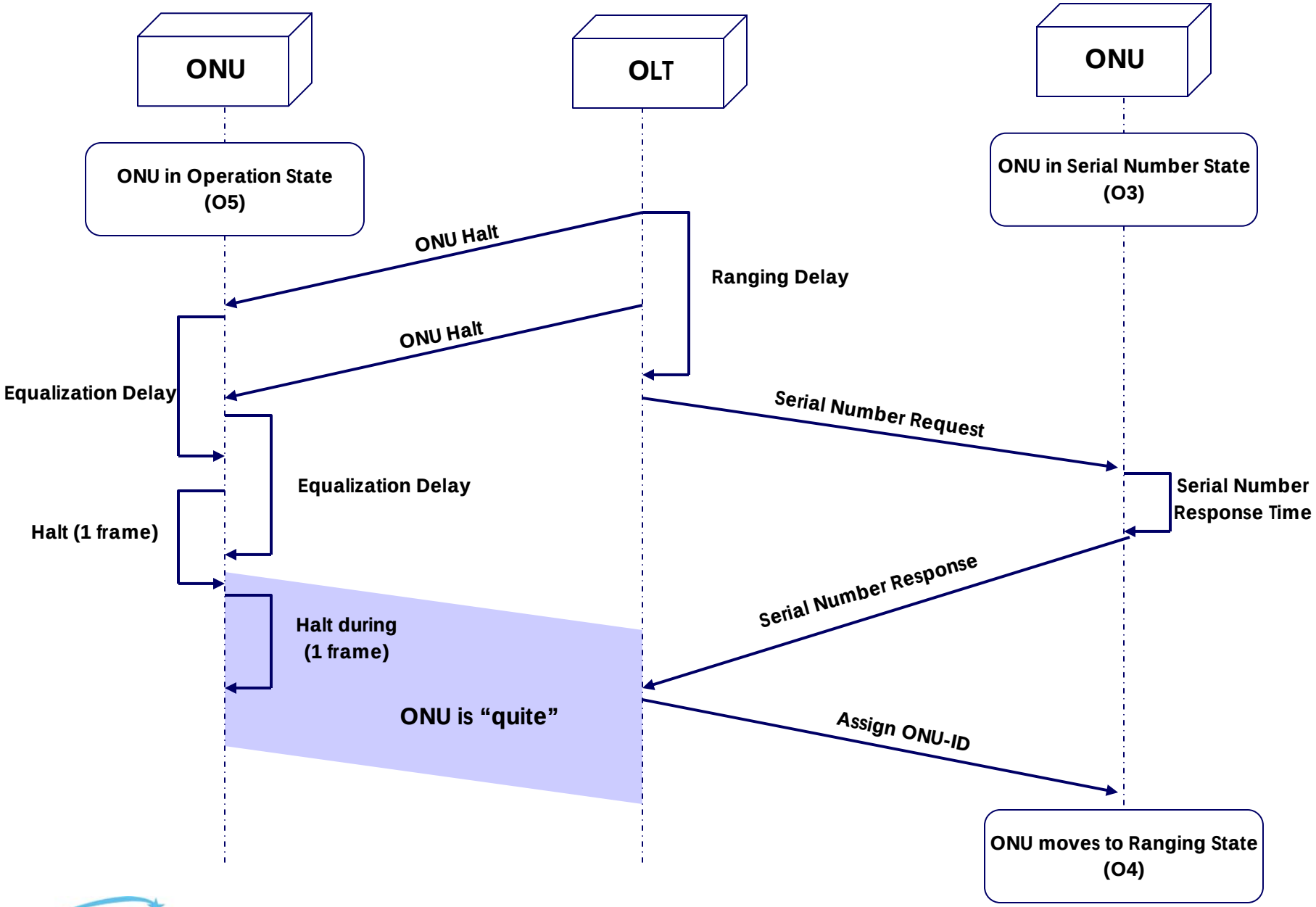
ONT Activation Procedure

- **Serial number acquisition process**
  - ✓ Discovers a new ONU by a unique Serial Number
  - ✓ Assign the new ONU a unique ONU-ID
- **Ranging process**
  - ✓ Measures and calculate the equalization delay of a newly discovered ONU
- **Two modes of activation**
  - ✓ Manual control – enabled by OpS system when a new ONU has been added to the PON system.
  - ✓ Automatic – OLT periodically initiates the process, and the frequency of polling is programmable.

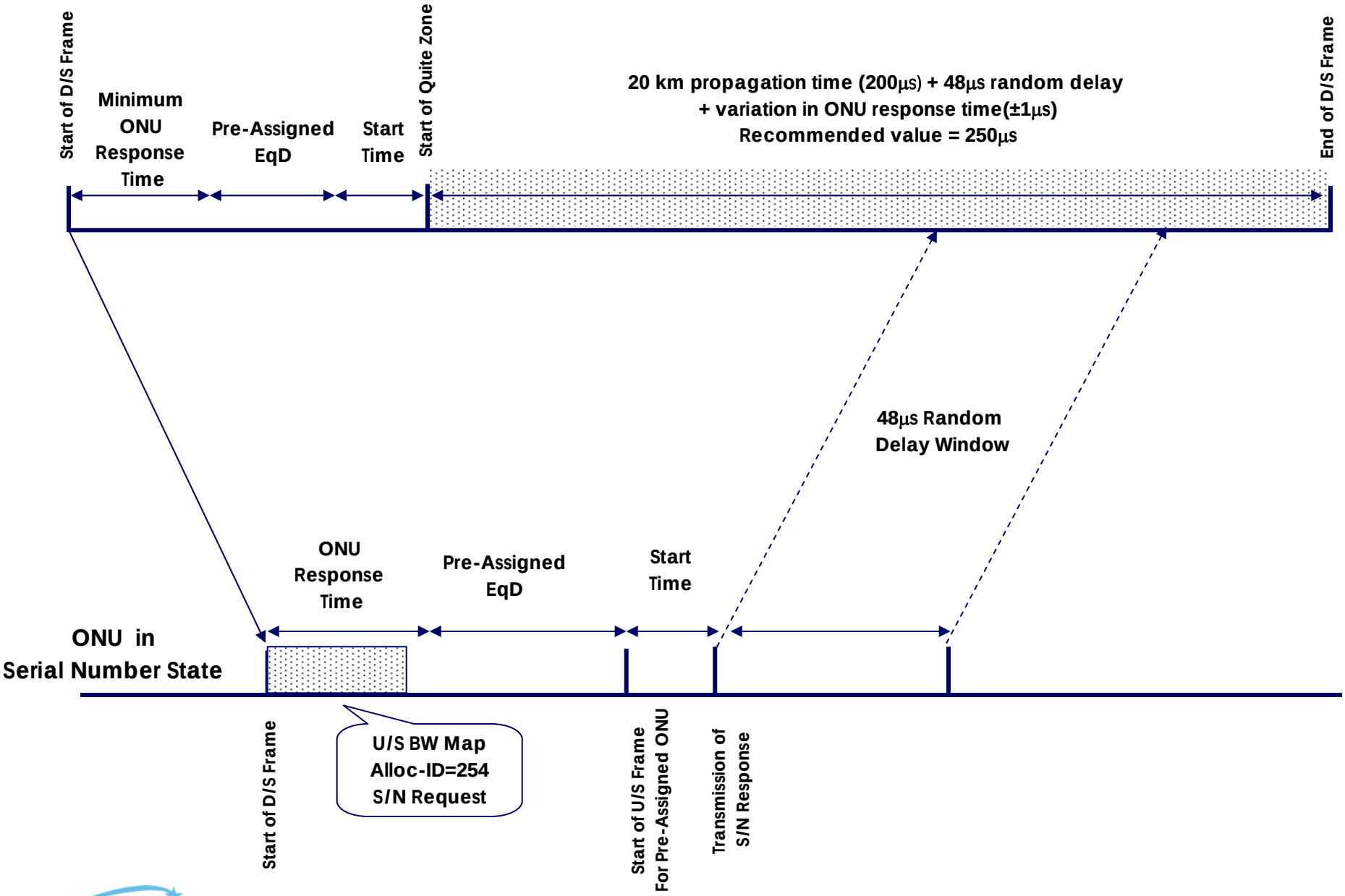
ONU State Machine



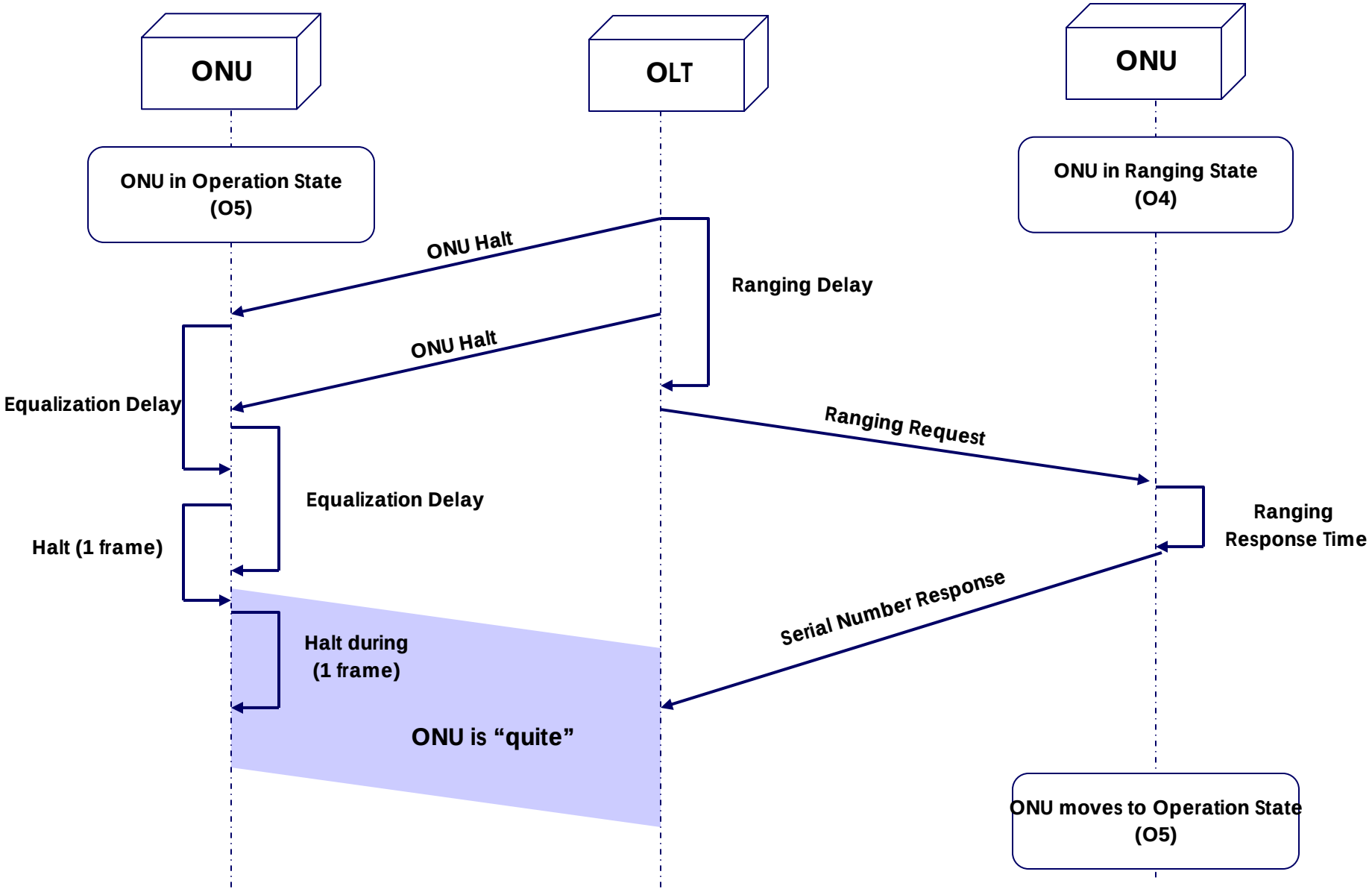
Serial Number Acquisition Process



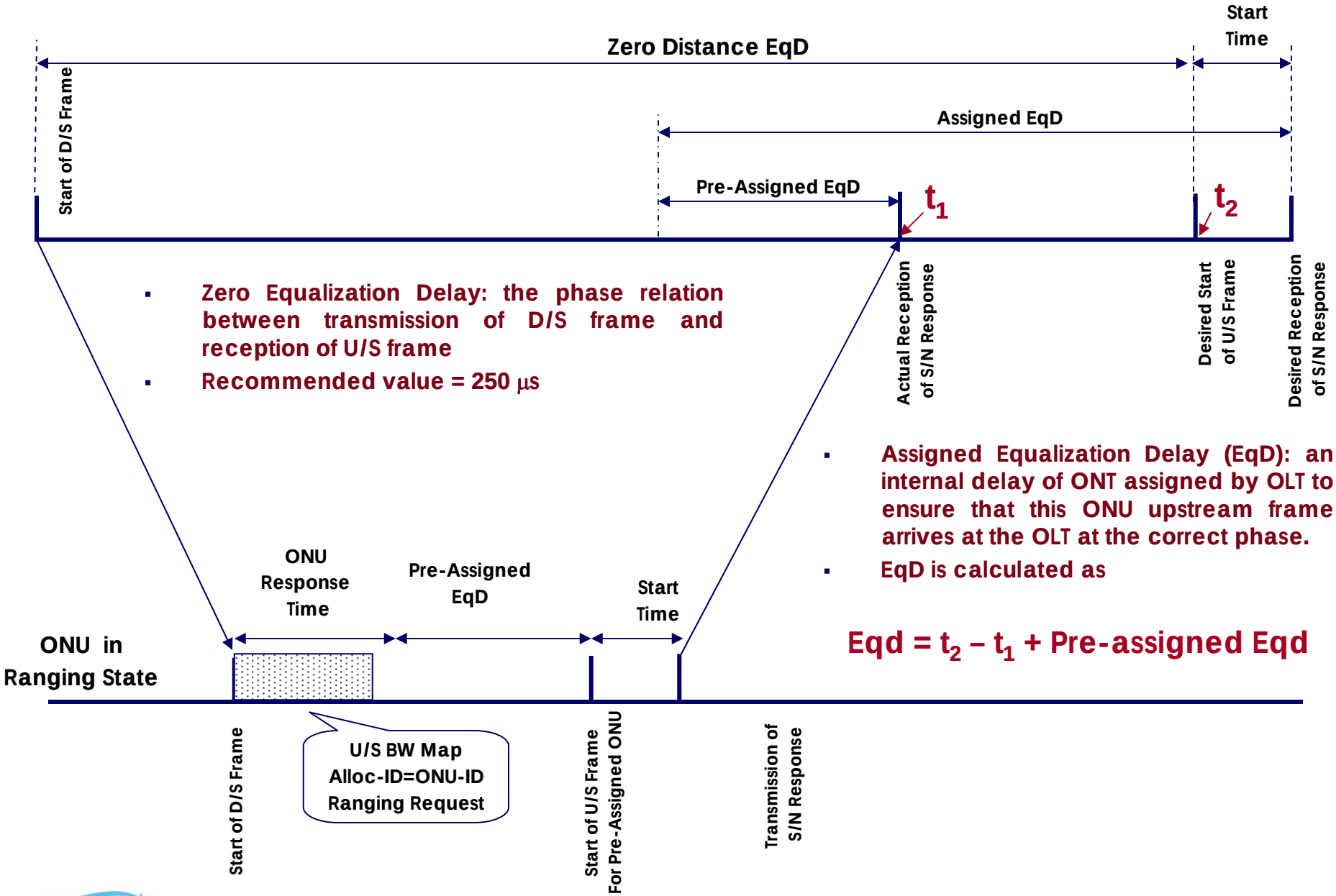
Quite Zone for SN Acquisition



Ranging Process



Quite Zone during Ranging

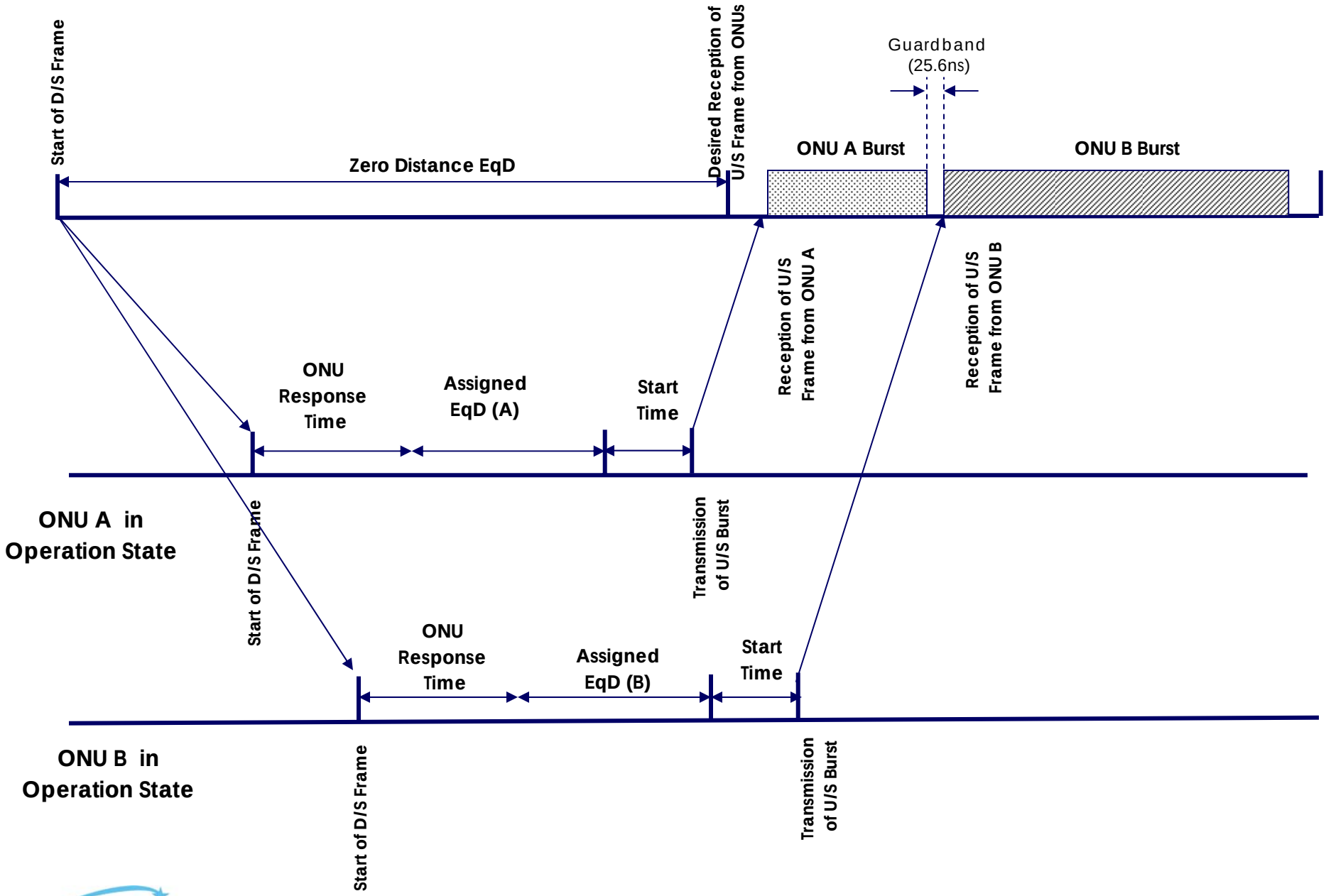


- Zero Equalization Delay: the phase relation between transmission of D/S frame and reception of U/S frame
- Recommended value = 250 μs

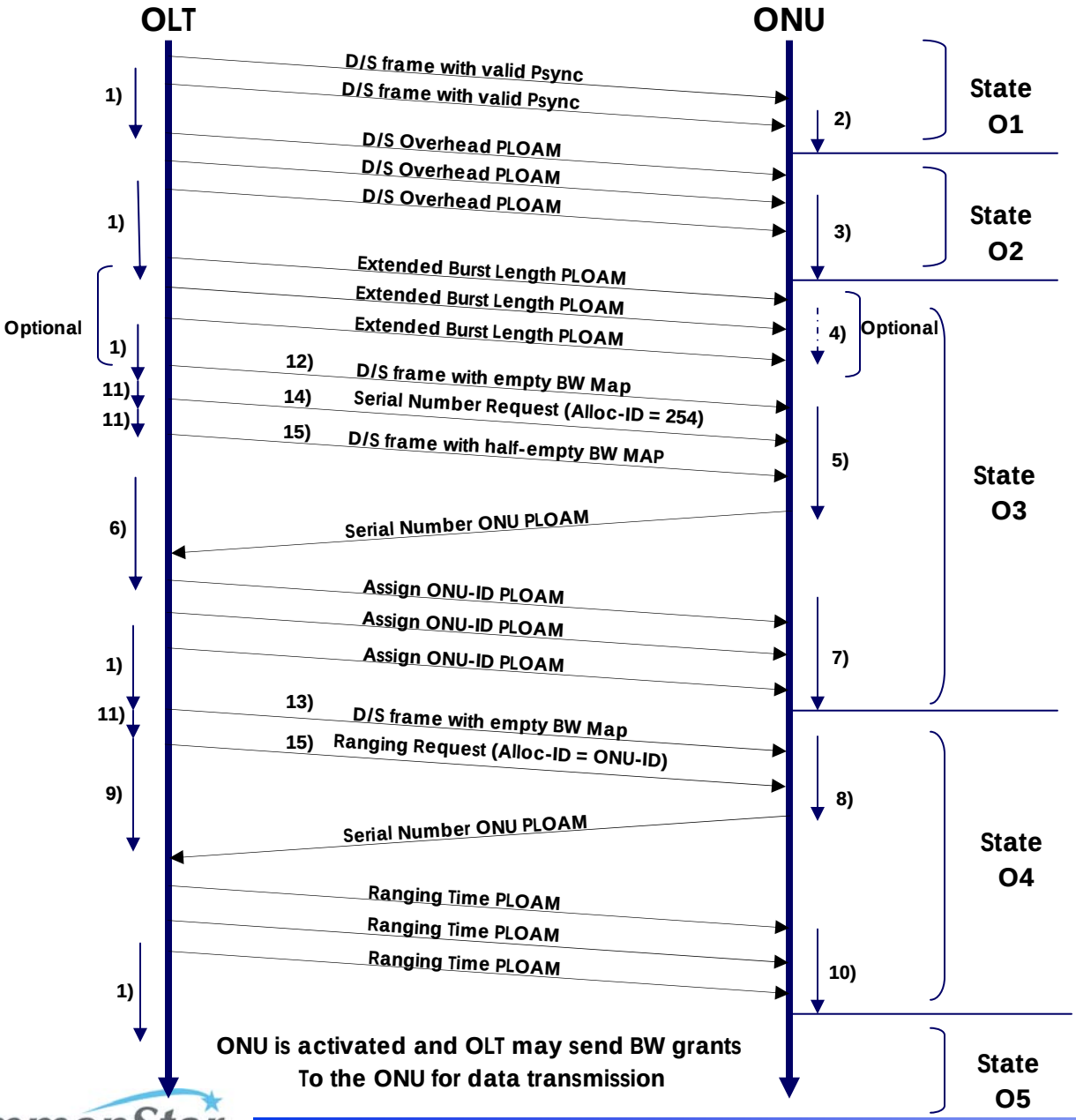
- Assigned Equalization Delay (EqD): an internal delay of ONT assigned by OLT to ensure that this ONU upstream frame arrives at the OLT at the correct phase.
- EqD is calculated as

$$Eqd = t_2 - t_1 + \text{Pre-assigned Eqd}$$

Operation State Timing



Activation Process Flow



1) OLT waits at least 750μs for the ONU to process the messages
2) ONU clears LOS/LOF
3) ONU constructs the preamble and delimiter, and sets pre-assigned EqD (=0)
4) ONU constructs extended preamble
5) ONU randomizes a response time and constructs SN PLOAM
6) OLT analyzes incoming PLOAM and assigns ONU-ID for SN
7) ONU stores assigned ONU-ID
8) ONU prepares response PLOAM
9) OLT measures time until response is received and calculates ONU assigned EqD
10) ONU updates its assigned EqD
11) Transmissions are in consecutive frames
12) "Quite Zone" for activation, suspending active ONUs
13) "Quite Zone" for ranging, suspending active ONUs
14) Serial Number request (Alloc-ID = "254", PLOAM Flag = "1")
15) The first Start Time in this frame shall be equal to PLOu + 75μs

ONT Activation Summary

- The activation process is performed by exchange of upstream and downstream flags and PLOAM messages
  - ✓ Can be enabled manually or automatically
- The ONU receives the PON operating parameters via Upstream Overhead
  - ✓ Preamble, delimiter, optical power level, pre-assigned EqD
- OLT initiates Serial Number acquisition process
  - ✓ Assigns ONU-ID to a newly discovered ONU
- OLT initiates Ranging process
  - ✓ Calculates EqD to a newly discovered ONU
  - ✓ Communicates Assigned EqD to the ONU
- ONU adjusts the start of its U/S frame clock based on EqD

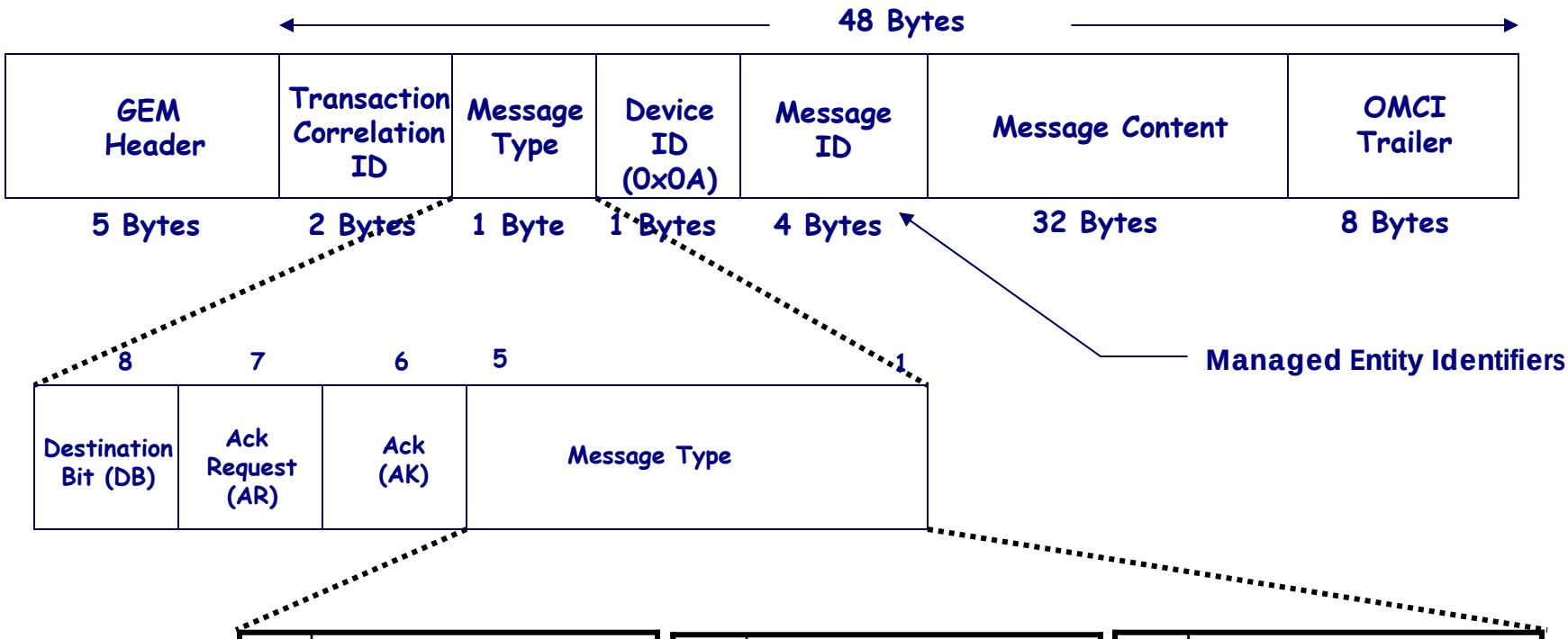
Multicast

Downstream Multicast

- Single GEM port is assigned for this purpose
  - ✓ The multicast GEM port is only meaning full in the downstream.
  - ✓ Each PON port will have a separate multicast Port-ID.
- Multicast is not encrypted
  - ✓ It will require a separate key exchange protocol.
- IGMP snooping signaling is not transported on multicast GEM port
  - ✓ Treated as normal unicast traffic.
- P2P communication is not defined
  - ✓ Will require P2P emulation layer over downstream single-copy-broadcast channel.

ONT Management and Control Interface (OMCI)

OMC Protocol (OMCP)

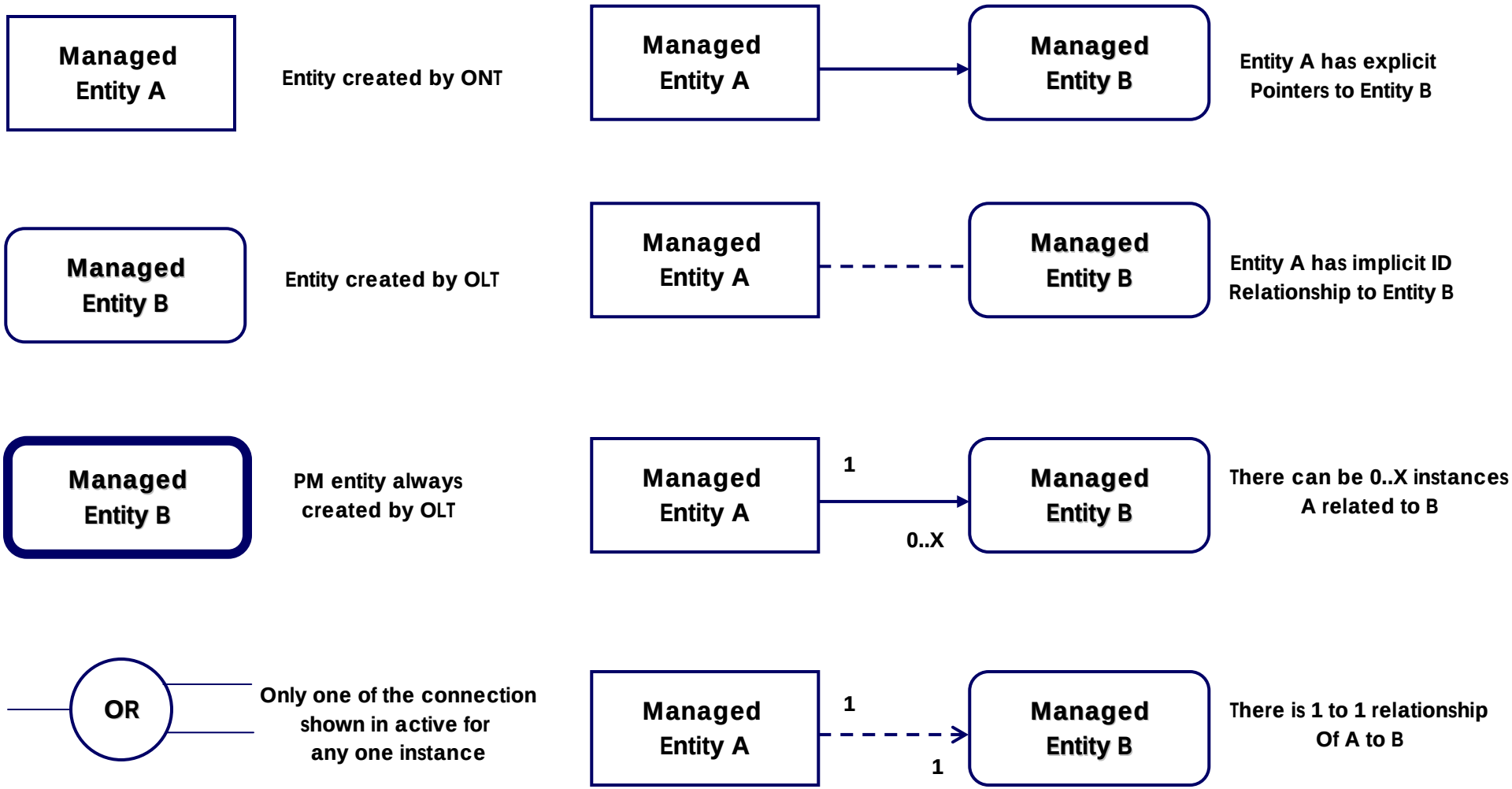


MT	Type
4	Create
5	Create complete connection
6	Delete
7	Delete complete connection
8	Set
9	Get
10	Get complete connection
11	Get all alarms
12	Get all alarms next

MT	Type
13	MIB upload
14	MIB upload next
15	MIB set
16	Alarm
17	Attribute value change
18	Test
19	Start software download
20	Download section
21	End software download

MT	Type
22	Activate software
23	Commit software
24	Synchronize time
25	Reboot
26	Get next
27	Test result
28	Get current data

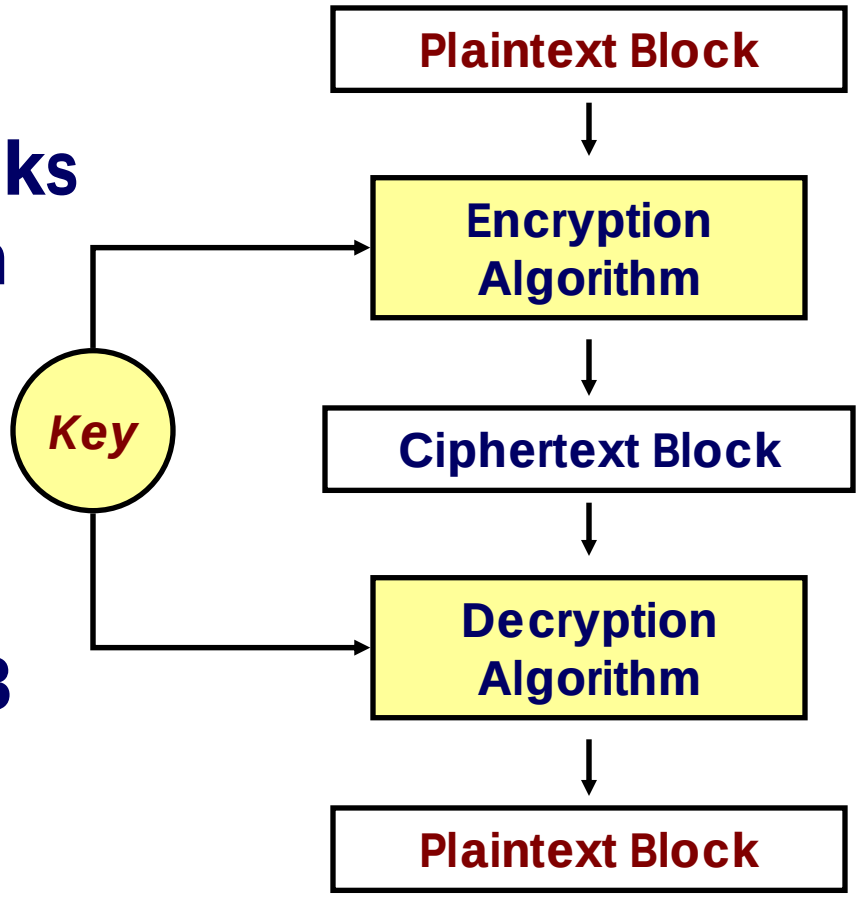
Legend for Managed Entity Relation



Encryption

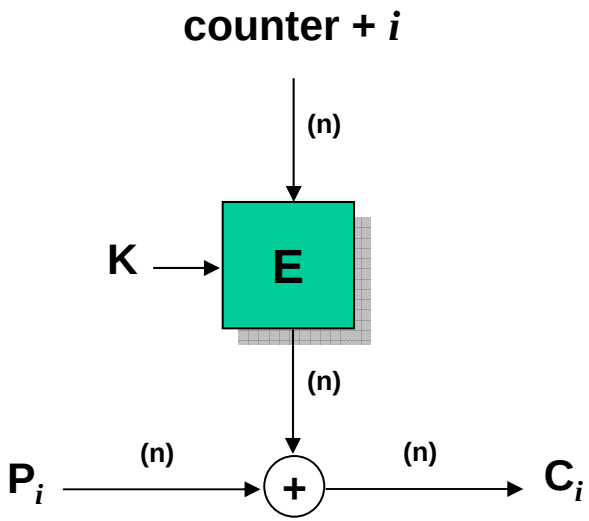
Block Ciphers

- Encrypt a block of input to a block of output
- Typically, the two blocks are of the same length
- Most symmetric key systems block size is 64
- In AES block size is 128
- Different modes for encrypting plaintext longer than a block

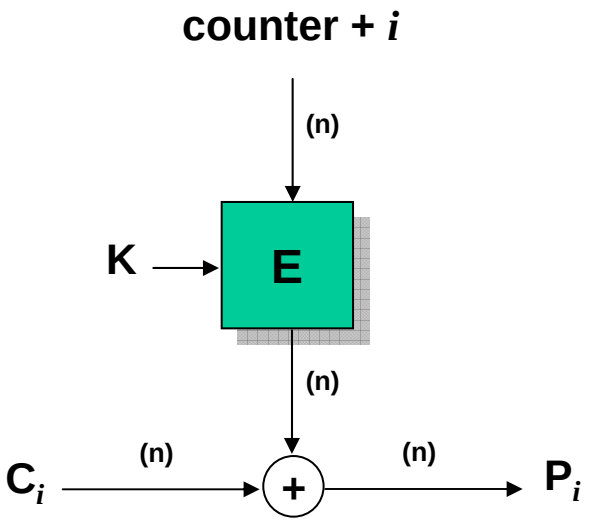


AES Counter Mode (CTR)

Encryption



Decryption



- Efficiency (parallelizable)
- Random access (the i-th block can be decrypted independently of the others)
- Preprocessing (the values to be XORed with the plaintext can be pre-computed)
- Security (at least as secure as the other modes)
- Simplicity (does not need the decryption algorithm)

AES CTR Mode Properties

- **Major properties**
  - ✓ Both encryption and decryption use the same function (or the decryption algorithm not used)
  - ✓ Easily to be implemented (~20K gates).
  - ✓ Parallel implementation possible.
  - ✓ Each block operates independently.
  - ✓ Implicitly synchronization assumed.
- **Uniqueness**
  - ✓ A unique counter block for each plaintext block that is ever encrypted under a given key, across all messages.
  - ✓ Often requires dynamic key exchange.

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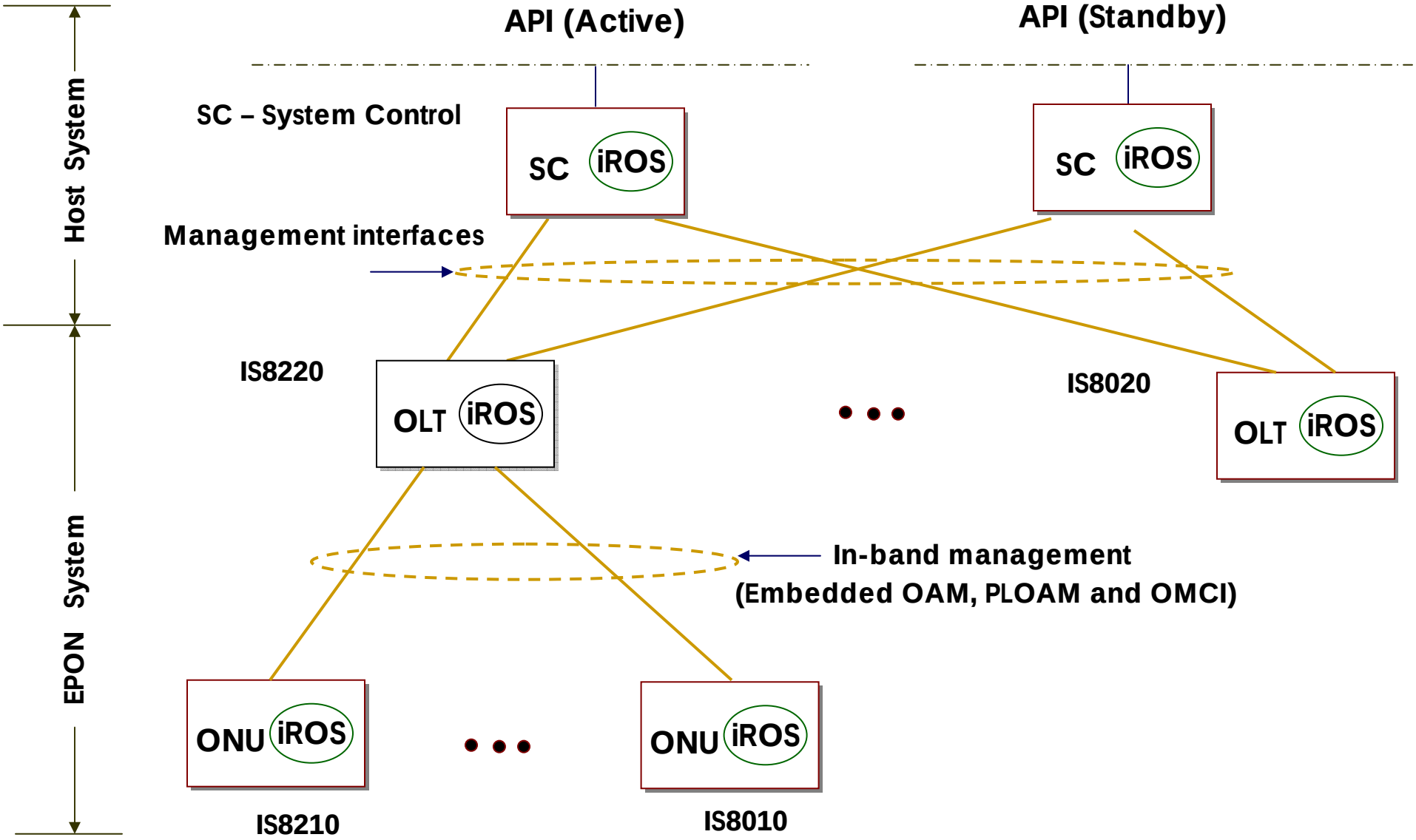
GPON Properties and AES Design

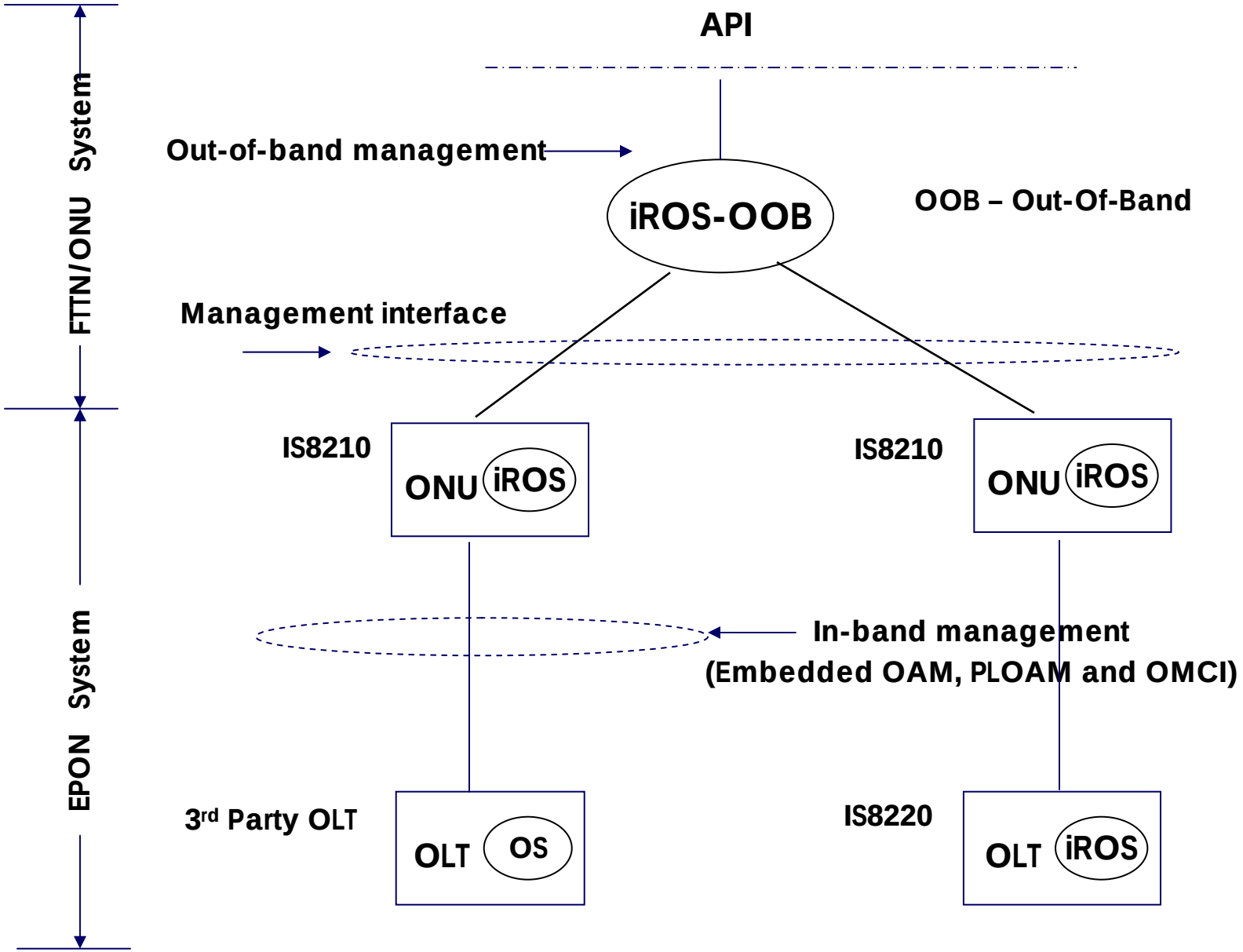
- GPON has specific properties to be utilized for security purpose.
  - ✓ GPON system is clock synchronized.
  - ✓ Super frame counter (30-bit in PCBd) is be used as an incrementing function for generating counters for AES CTR mode.
- Only downstream unicast traffic is encrypted.
- Only GEM payload is encrypted.
- Encryption instance is based on Port-ID.

iROS for GPON

iROS System Architecture



iROS OOB Architecture



Major Subsystems

- **System registration and configuration**
  - ✓ Dynamic OLT registration and deregistration
  - ✓ Support for OLT hot swap capability
  - ✓ OLT reset
  - ✓ ONU activation/deactivation (manual or automatic)
  - ✓ Managed entities create/set/get
- **System maintenance, monitoring, and testing**
  - ✓ Remote ONU firmware update
  - ✓ OLT firmware update
  - ✓ Statistics collection
  - ✓ Alarm and event reporting (Dying Gasp, and REI)
  - ✓ ONU loopback test
  - ✓ OLT loopback test
  - ✓ Layer 2 ping to OLT

Major Subsystems (Cont'd)

Address and bridging management

- ✓ Filtering database configuration (add/delete/get)
- ✓ VLAN configuration
- ✓ Link aggregation configuration
- ✓ Frame transmission and reception

Traffic management

- ✓ Two configurable QoS modes: 802.1p and DSCP
- ✓ Support of two level scheduling and queuing: T-CONT and Port-ID
- ✓ Both hardware and software based DBA algorithms
- ✓ Multiple DBA operation modes (NSR, SR Mode 0, 1, 2)
- ✓ Traffic profile configuration per T-CONT per PON
- ✓ Traffic classification at ONU
- ✓ Upstream traffic policing configuration
- ✓ Downstream traffic policing and shaping configuration
- ✓ Buffer management configuration
- ✓ IGMP snooping

Major Subsystems (Cont'd)

- **Security management**
  - ✓ **ONU password validation**
  - ✓ **802.1x authentication method**
  - ✓ **AES key exchange**

Thank You