Multiaccess in Ethernet Passive Optical Networks (EPON)

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What is Passive Optical Network (PON)?

- Passive Optical Network (PON) implements a point-to-multipoint fiber-based access architecture
- Passive fiber splitters are used to split a single optical fiber to serve multiple end-points, without using dedicated fibers between the hub and customer.
- A PON consists of an optical line terminal (OLT) at the service provider's central office (hub) and a number of optical network units (ONUs) near end users.
- A PON reduces the amount of fiber and central office equipment required compared with point-to-point architectures.
- Downstream signals are broadcast to all customers sharing the given OLT port. Encryption prevents eavesdropping.
- Upstream signals are combined using a multiple access protocol, usually time division multiple access (TDMA).

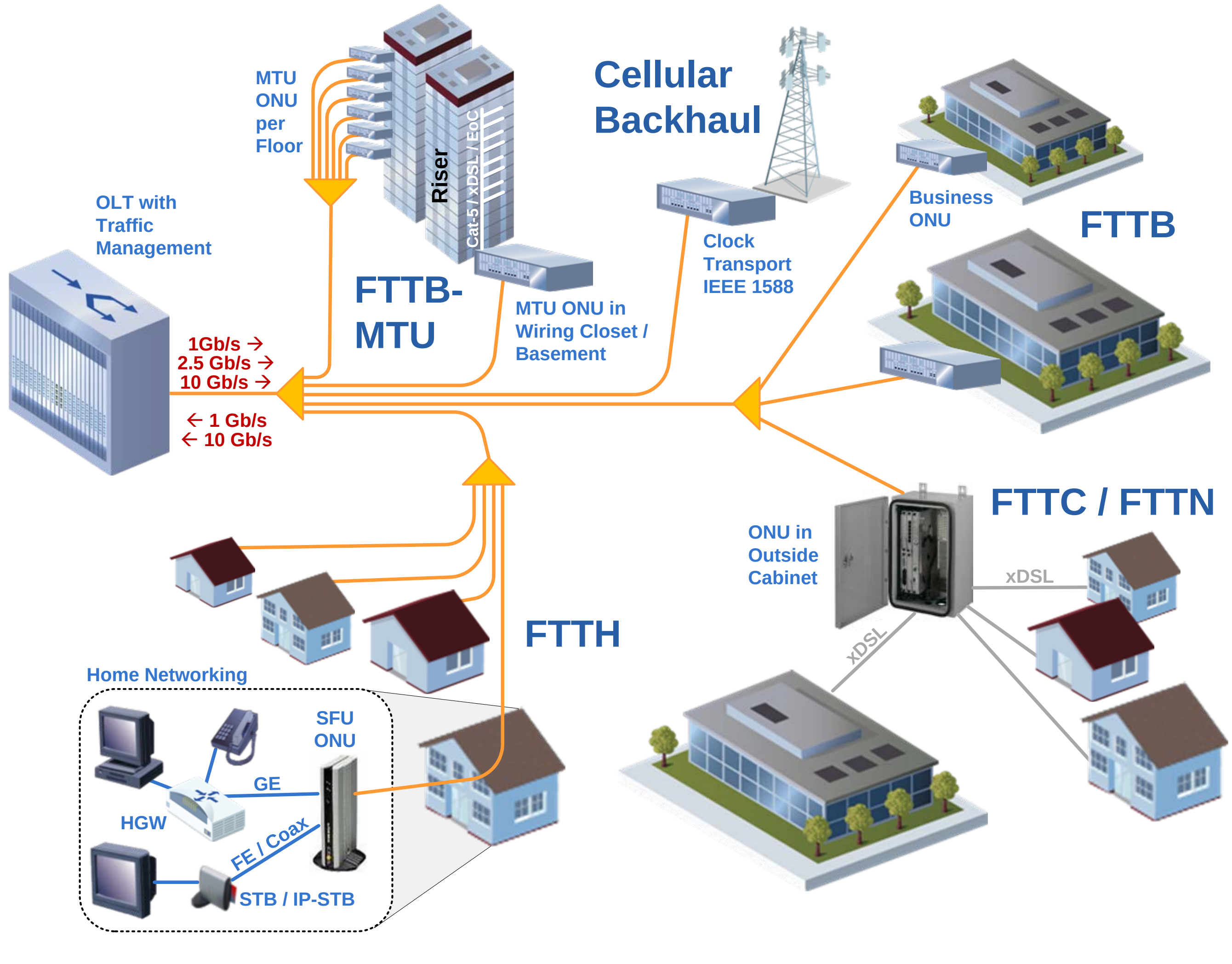
PON – Universal Access Architecture

All user types
- Residential
- Businesses
- Cellular backhaul

All configurations
- SFU
- MDU/MTU
- FTTH
- FTTC/FTTN

All Data Rates
- 1/ 2.5 / 10 Gbps

All on the same outside plant (ODN)!



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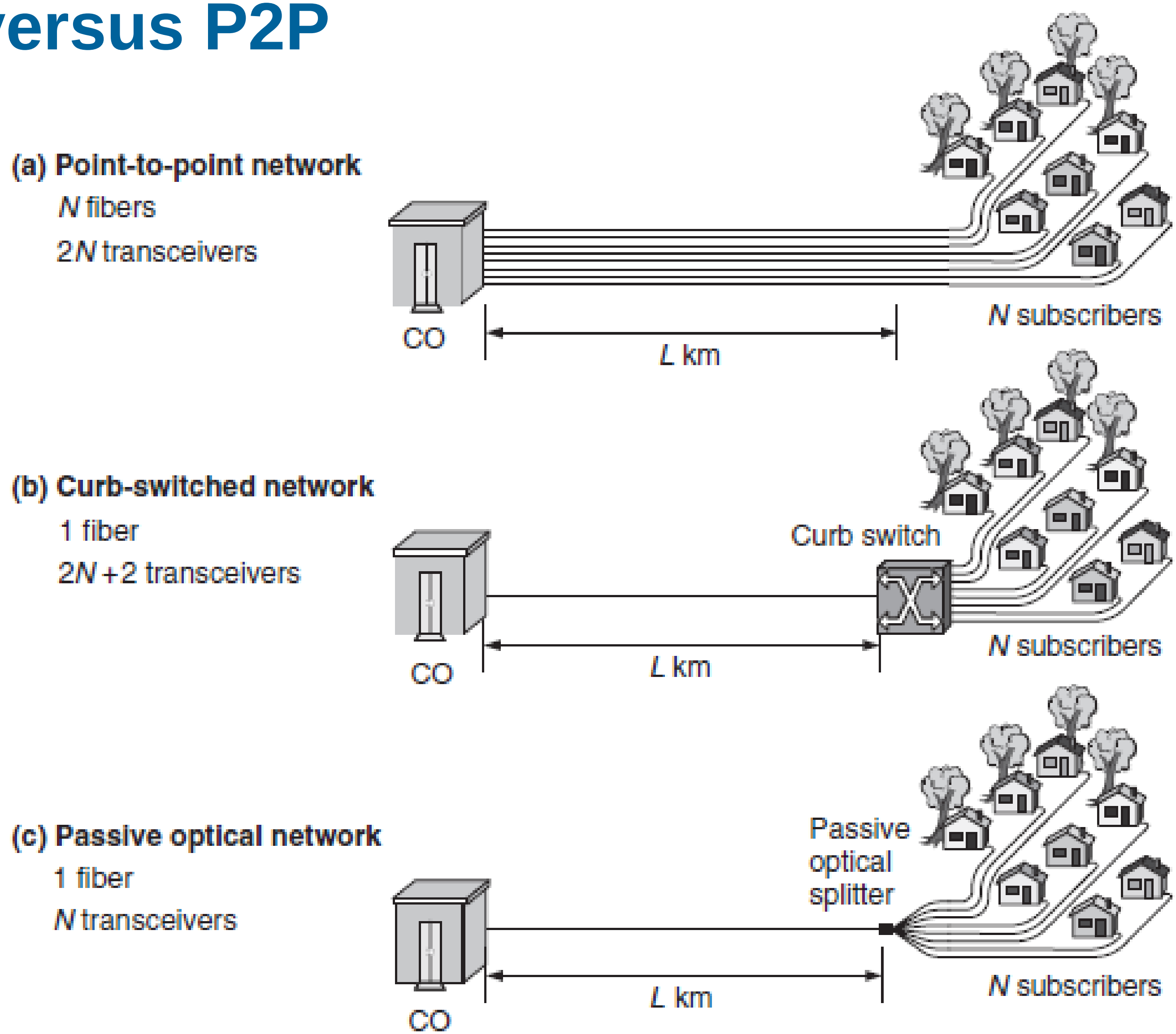
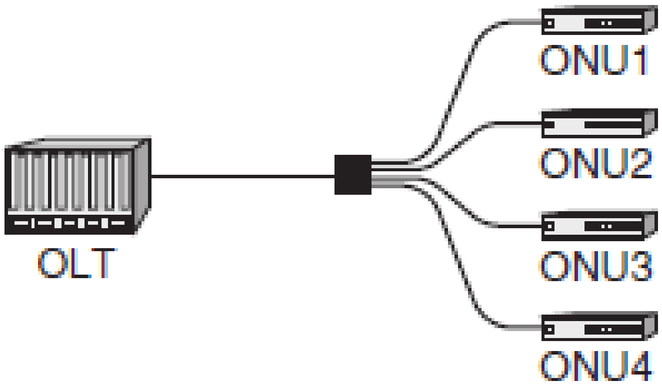
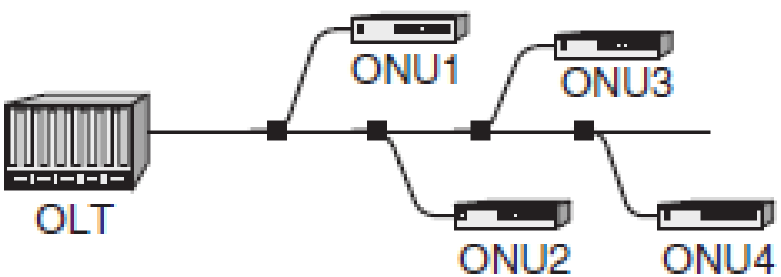
PON versus P2P



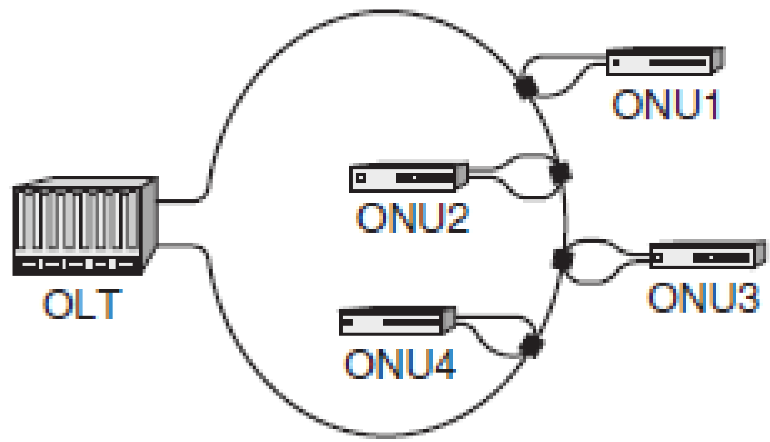
Different PON topologies



(a) Tree topology (using 1 × N splitter)

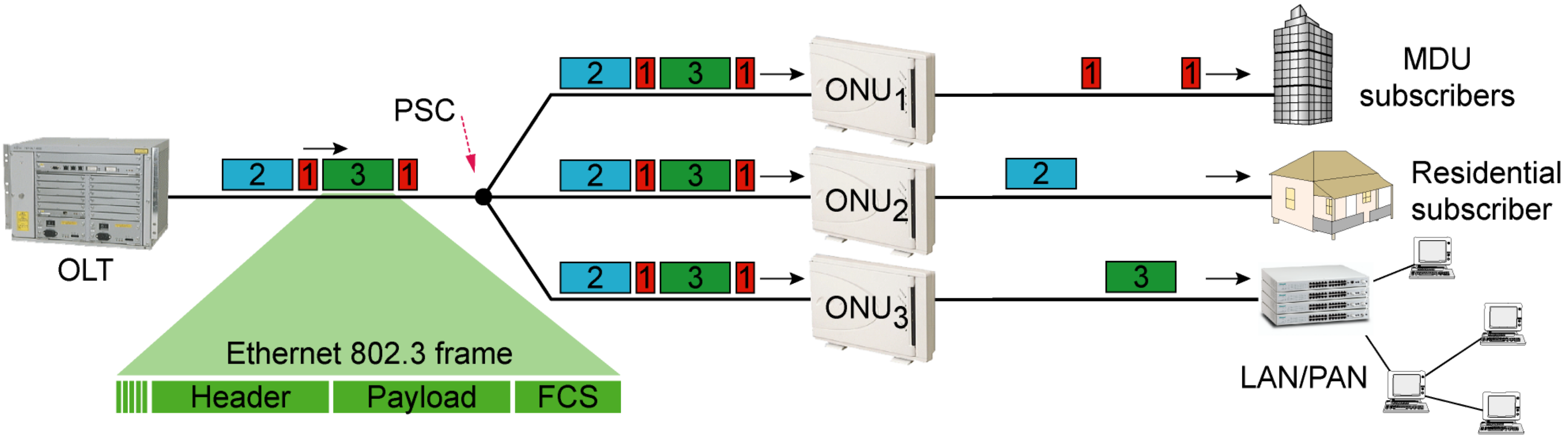


(b) Bus topology (using 1 × 2 tap couplers)



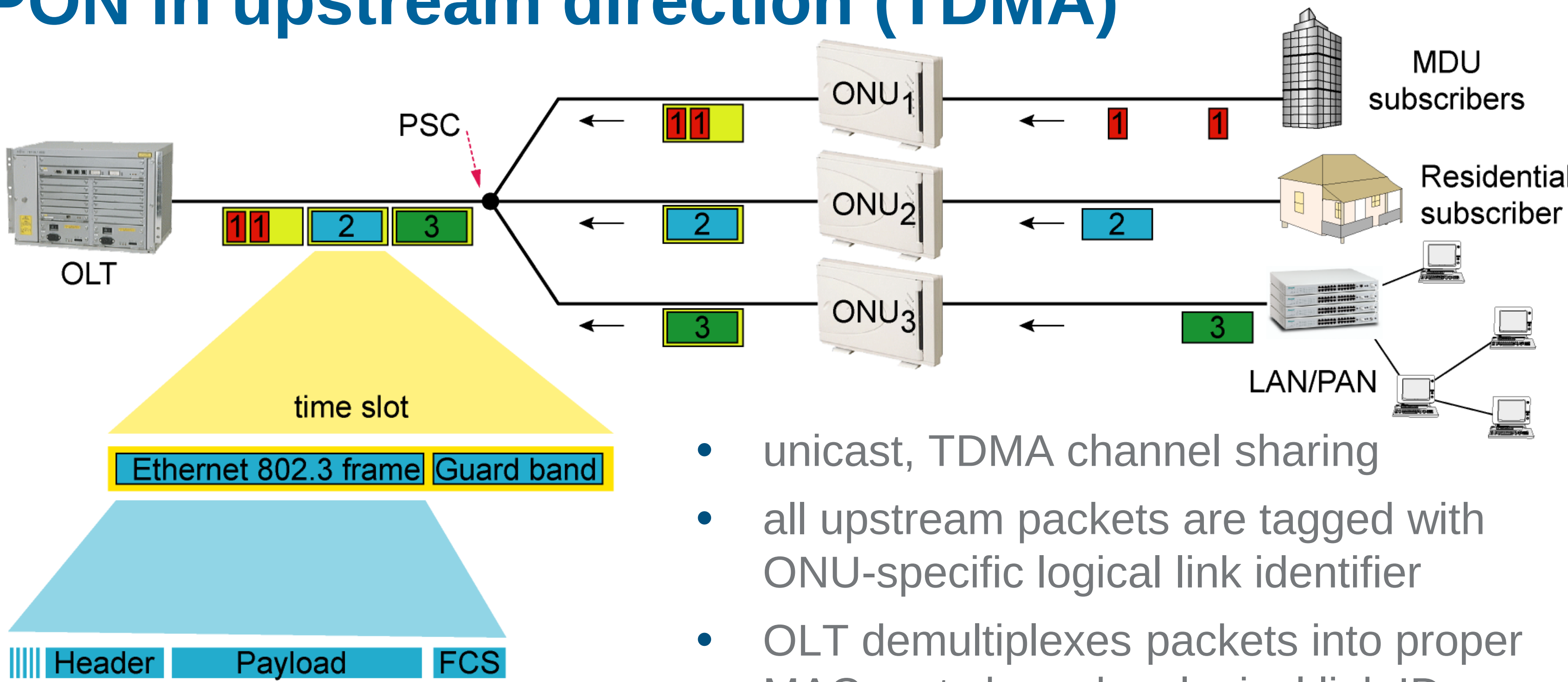
(c) Ring topology (using 2 × 2 tap couplers)

PON in downstream direction (P2MP)



- broadcast, Point To Multipoint (P2MP) system on passive fiber tree
- all downstream packets are tagged with logical layer identifiers
- ONUs filter downstream data packets based on logical layer identifiers
- analog video supported via extended optional overlay (uni/bidirectional)
- data privacy via encryption, origin authentication via 802.1X mechanisms
- 1G/10G coexist on the same fiber interface
- distance limited by power budget (typ. ~20km) / number of supported ONUs

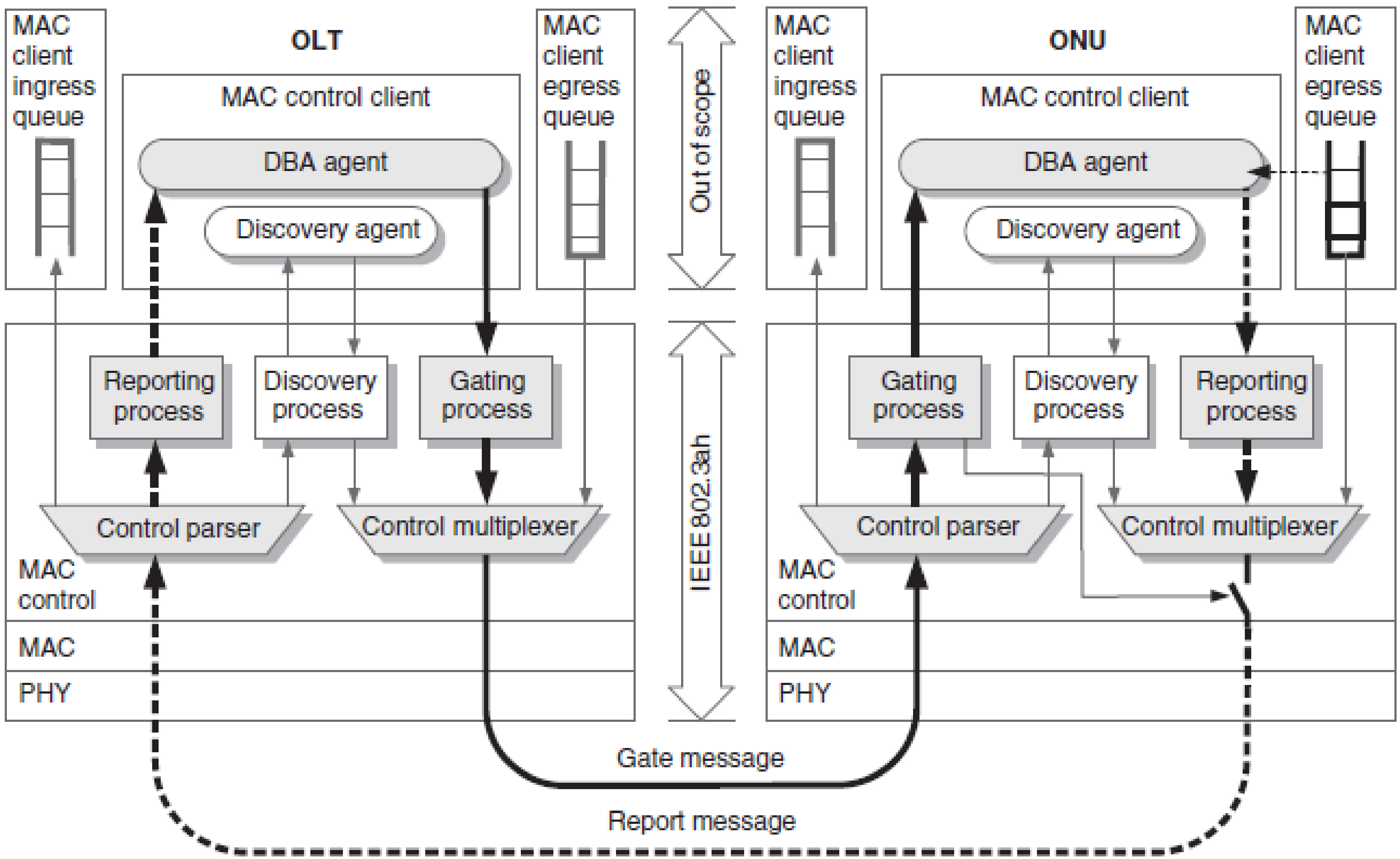
PON in upstream direction (TDMA)



- unicast, TDMA channel sharing
- all upstream packets are tagged with ONU-specific logical link identifier
- OLT demultiplexes packets into proper MAC ports based on logical link ID

- transmissions from individual connected customers are scheduled by OLT in a non-overlapping manner observing SLA rules
- different service types (best-effort, guaranteed bandwidth, etc.) can be supported on the same OLT port
- encryption is typically disabled in upstream

Dynamic Bandwidth Allocation process (1)

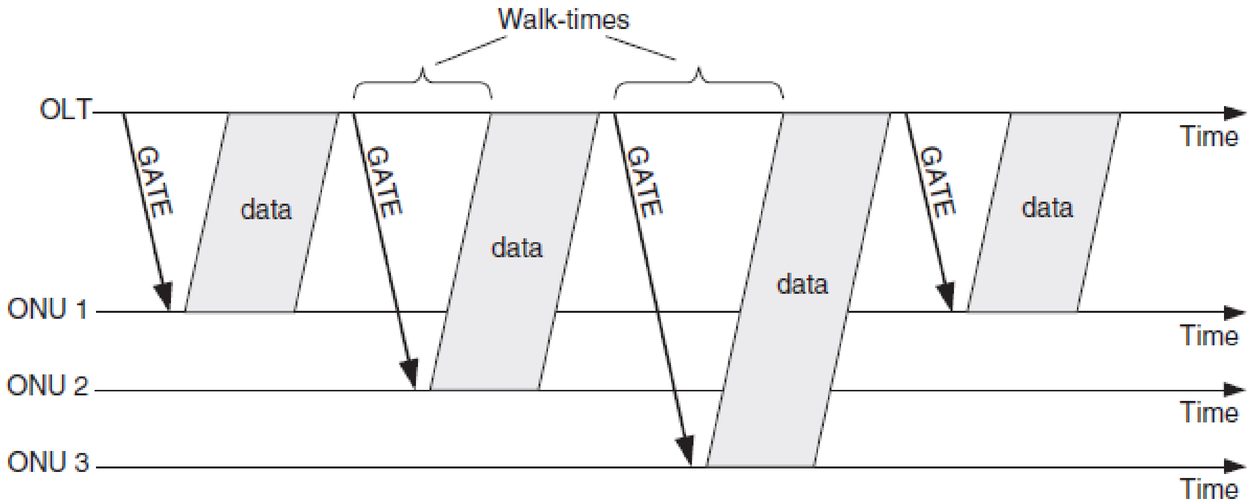


Source: "Ethernet Passive Optical Networks" by G. Kramer

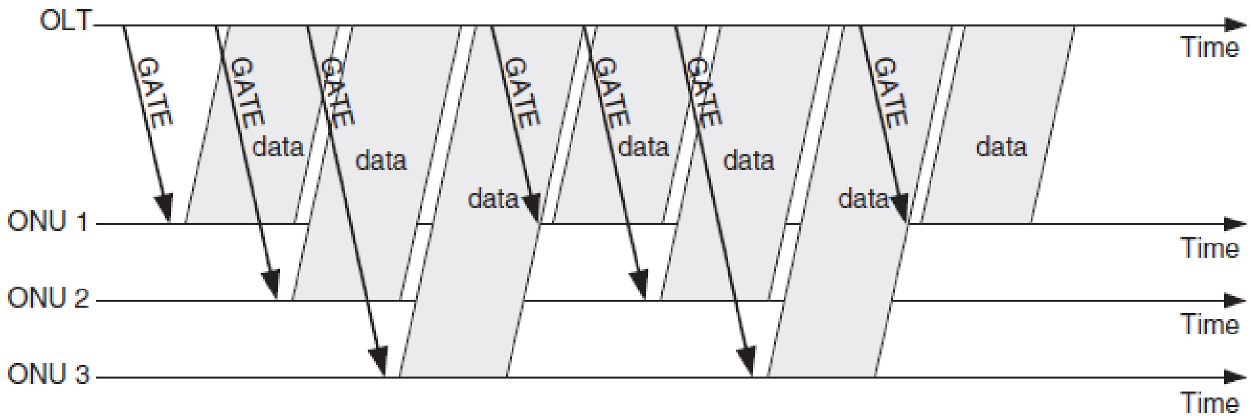
Dynamic Bandwidth Allocation process (2)

- ONU reports current bandwidth demand for its queues to DBA controller in OLT via **REPORT** MPCPDU
- OLT DBA controller ***may*** take ONU bandwidth demand into account when periodically granting bandwidth via **GATE** MPDPDU
  - Bandwidth amount, periodicity, priority, etc. depend on DBA implementation, configured services, etc. and are implementation specific
- Discovery process periodically opens quiet (no data transmission allowed) Discovery Windows in upstream
  - unregistered stations present themselves to OLT and get registered
- Ranging and RTT (Round Trip Time) variations are compensated real-time via timestamps in MPCPDUs
  - Each MPCPDU is timestamped relative to central OLT clock

Dynamic Bandwidth Allocation process (3)



(a) Sequential timeslot assignment



(b) Pipelined timeslot assignment

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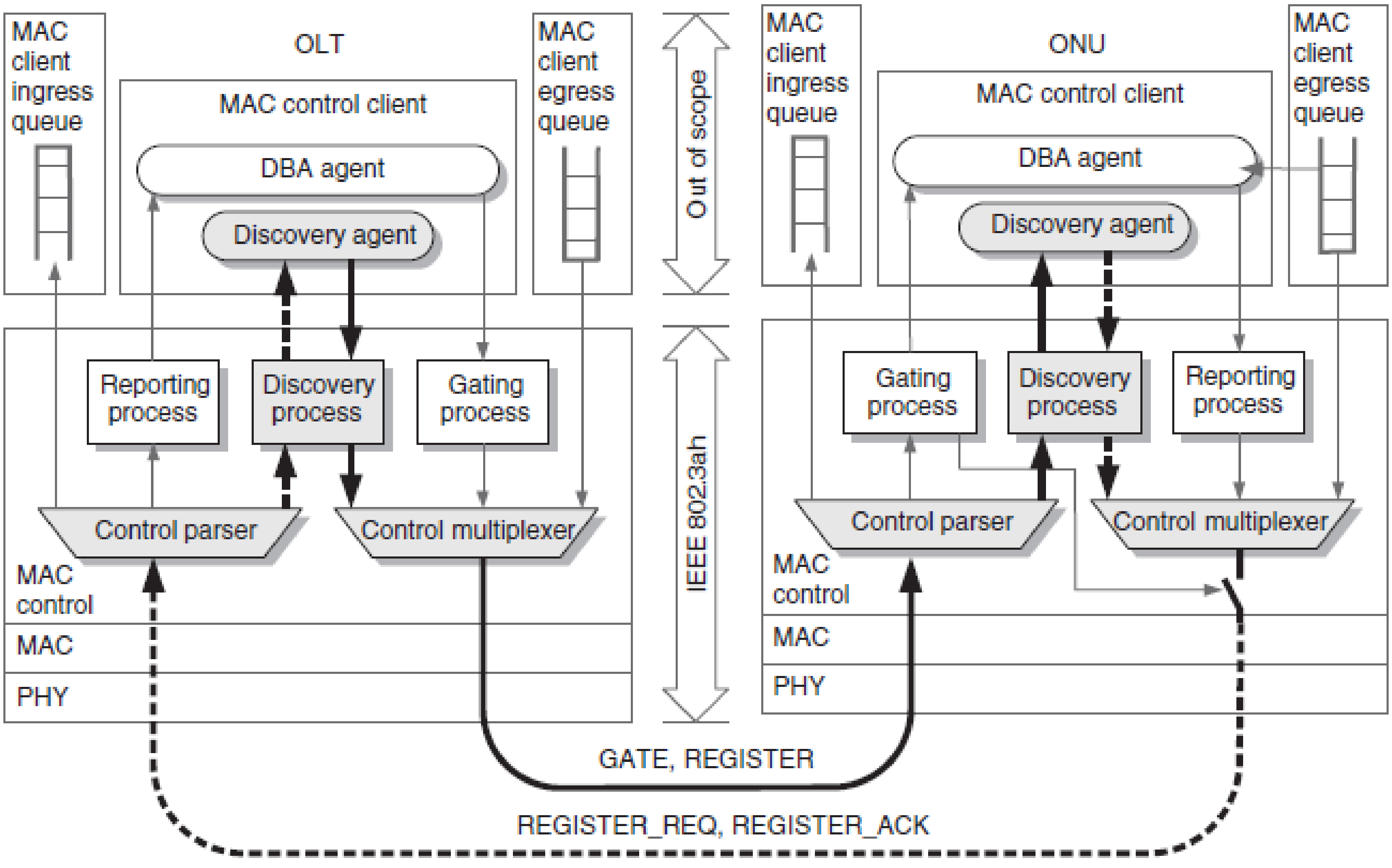
- Pipielined bandwidth allocation used to maximize upstream channel utilization
- Each ONU-OLT distance is different and measured independently

Discovery Process (1)



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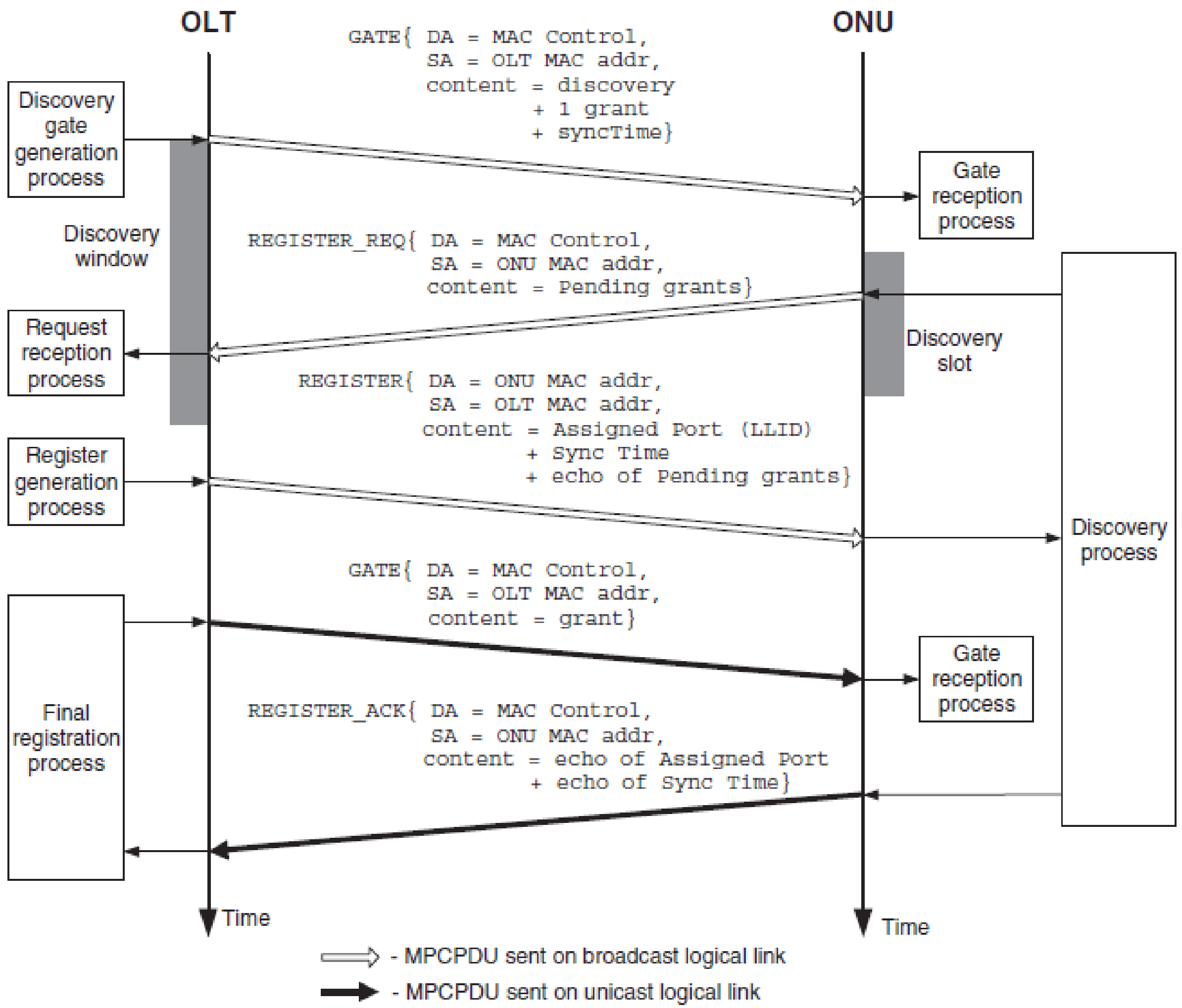
Discovery Process (2) time diagram



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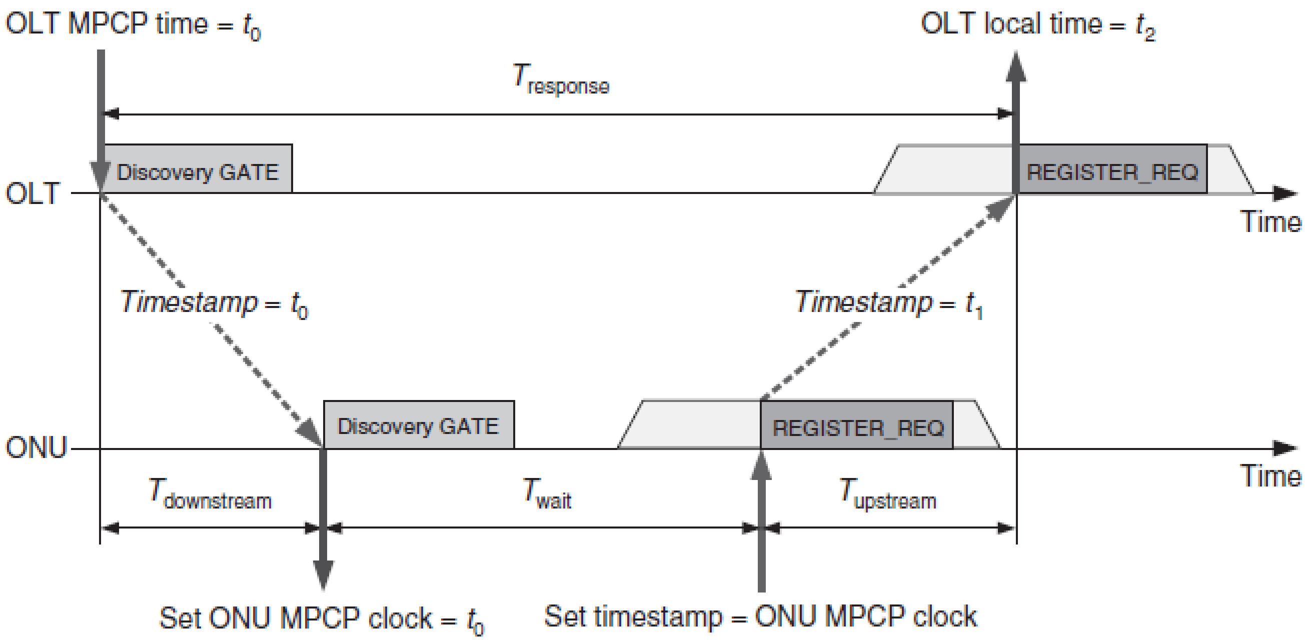
RTT Measurement



- All distance measurements performed in time domain, relative to OLT (central station) reference point
- RTT for the given ONU is measured constantly every time a pair of MPCPDU is exchanged
  - all MPCPDUs are timestamped, ONU local clock is always synchronized to OLT

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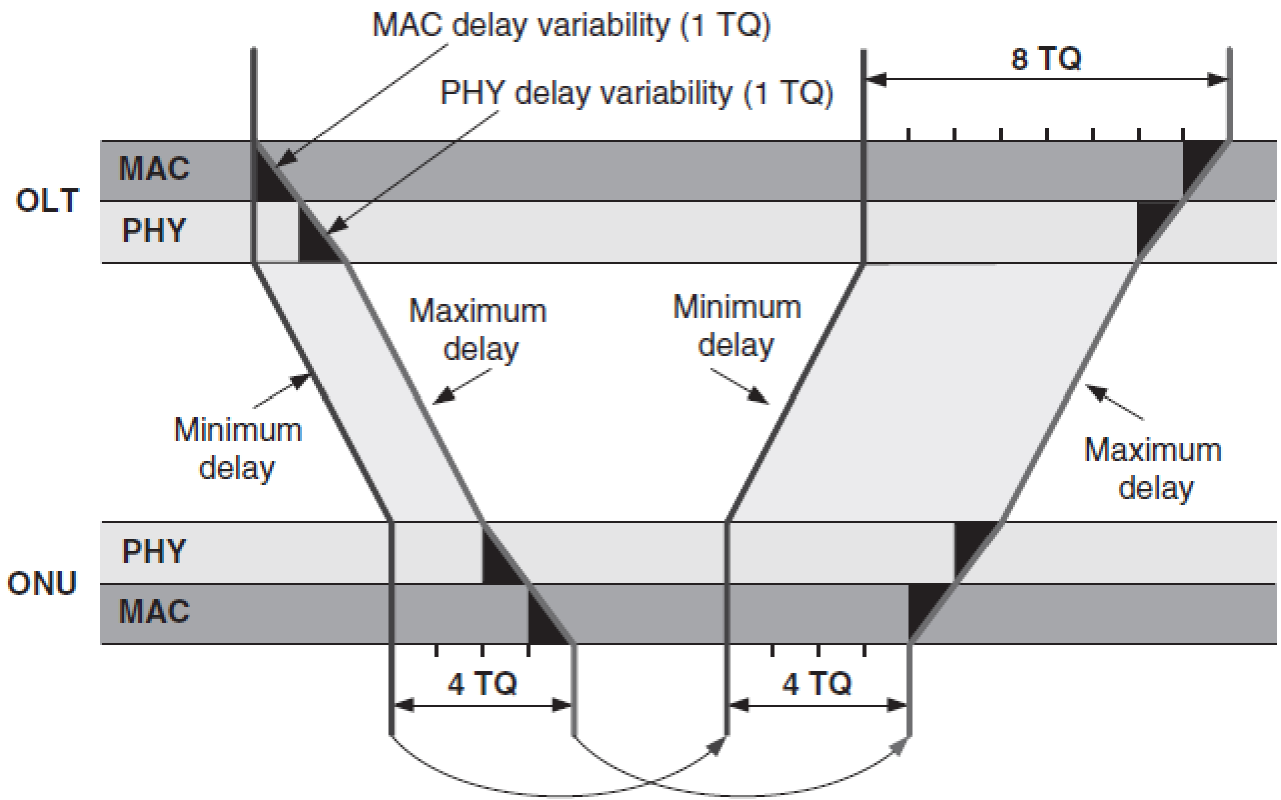
MAC and PHY delay variabilities



- Caused by operation of state diagrams in individual layers, presence of queues, etc.

Source: "Ethernet Passive Optical Networks" by G. Kramer

REPORT MPCPDU

Fields	Octets
Destination address (DA)	6
Source address (SA)	6
Length/Type = $88\text{–}08_{16}$	2
Opcode = $00\text{–}03_{16}$	2
Timestamp	4
Number of queue sets	1
Report bitmap	[1]
Queue #1 report	[2]
Queue #2 report	[2]
Queue #3 report	[2]
Queue #4 report	[2]
Queue #5 report	[2]
Queue #6 report	[2]
Queue #7 report	[2]
Queue #8 report	[2]
Pad = 0	0–39
Frame check sequence (FCS)	4

Report bitmap through Queue #8 report: Repeated *n* times as indicated by *Number of queue sets*

- Used by ONU to report at least one bandwidth demand for at least one Queue Set
- Exact structure depends on number of Queue Sets, number of queues per Queue Set, etc.
- Timestamped for RTT measurement

Source: “Ethernet Passive Optical Networks” by G. Kramer

GATE MPCPDU

Fields	Octets
Destination address (DA)	6
Source address (SA)	6
Length/type = $88–08_{16}$	2
Opcode = **$00–02_{16}$**	2
Timestamp	4
Number of grants/flags = **09_{16}**	1
Grant start time	4
Grant length	2
Sync time	2
Pad = 0	31
Frame check sequence (FCS)	4

(a)

Fields	Octets
Destination address (DA)	6
Source address (SA)	6
Length/type = $88–08_{16}$	2
Opcode = **$00–02_{16}$**	2
Timestamp	4
Number of grants/flags	1
Grant #1 start time	[4]
Grant #1 length	[2]
Grant #2 start time	[4]
Grant #2 length	[2]
Grant #3 start time	[4]
Grant #3 length	[2]
Grant #4 start time	[4]
Grant #4 length	[2]
Pad = 0	15/39
Frame check sequence (FCS)	4

(b)

- Used by OLT to grant up to 4 bandwidth slots to specific ONU (b) or open an Discovery Window in upstream direction (a) for a specific period of time

Source: “Ethernet Passive Optical Networks” by G. Kramer

REGISTER_REQ / REGISTER / REGISTER_ACK MPCPDUs

Fields	Octets
Destination address (DA)	6
Source address (SA)	6
Length/type = $88\text{–}08_{16}$	2
Opcode = $00\text{–}04_{16}$	2
Timestamp	4
Flags	1
Pending grants	1
Pad = 0	38
Frame check sequence (FCS)	4

REGISTER_REQ MPCPDU

Fields	Octets
Destination address (DA)	6
Source address (SA)	6
Length/type = $88\text{–}08_{16}$	2
Opcode = $00\text{–}05_{16}$	2
Timestamp	4
Assigned port	2
Flags	1
Sync time	2
Echoed pending grants	1
Pad = 0	34
Frame check sequence (FCS)	4

REGISTER MPCPDU

Fields	Octets
Destination address (DA)	6
Source address (SA)	6
Length/type = $88\text{–}08_{16}$	2
Opcode = $00\text{–}06_{16}$	2
Timestamp	4
Flags	1
Echoed assigned port	2
Echoed sync time	2
Pad = 0	35
Frame check sequence (FCS)	4

REGISTER_ACK MPCPDU

- Exchanged between ONU and OLT to indicate ONU attempt o register at the OLT (REGISTER_REQ MPCPDU), OLT’s permission to register (REGISTER MPCPDU) and completion of the registration process (REGISTER_ACK MPCPDU)

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More reading …

- MultiPoint Control Protocol (MPCP) is defined in Clause 64 for 1G-EPON and Clause 77 for 10G-EPON
    - There are slight changes in structure of MPCPDUs, basic operating principle remains the same
- Extended and more flexible version of MPCP will be also used in the future NG-EPON (IEEE P802.3ca)
- Adaptations to this protocol were defined in Clause 103 for EPoC (IEEE P802.3bn)