

Multiaccess in Ethernet Passive Optical Networks (EPON)

Marek Hajduczenia, PhD

Principal Engineer

Advanced Commercial Engineering

Charter Communications

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

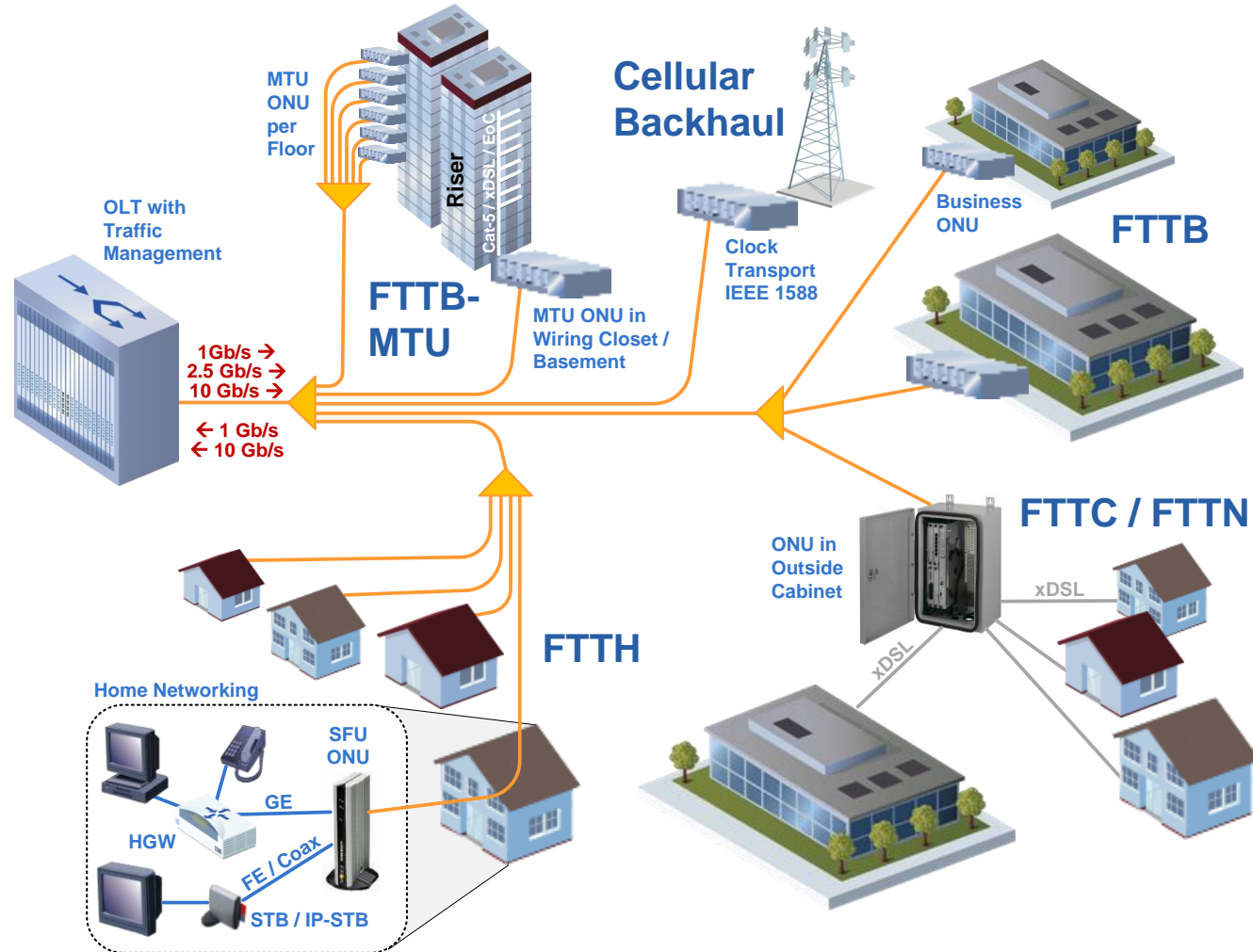
All configurations

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

All Data Rates

- 1 / 2.5 / 10 Gbps

**All on the same
outside plant
(ODN)!**

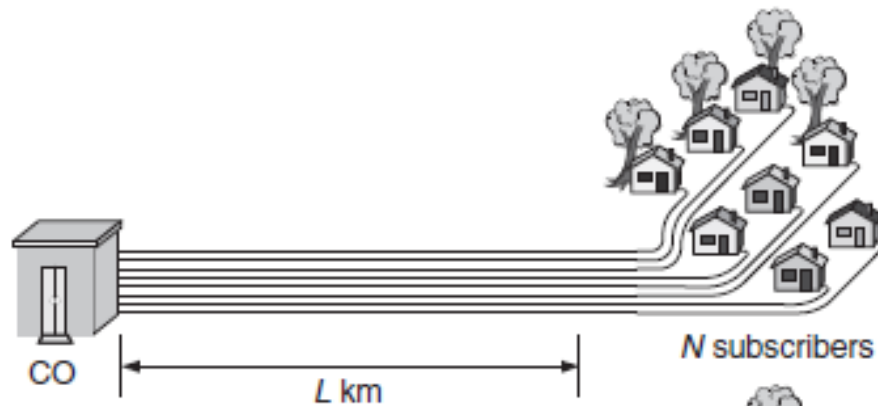


PON versus P2P

(a) Point-to-point network

N fibers

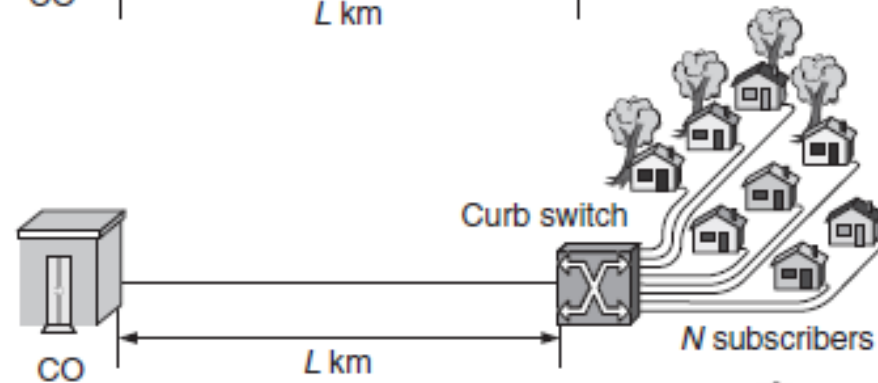
$2N$ transceivers



(b) Curb-switched network

1 fiber

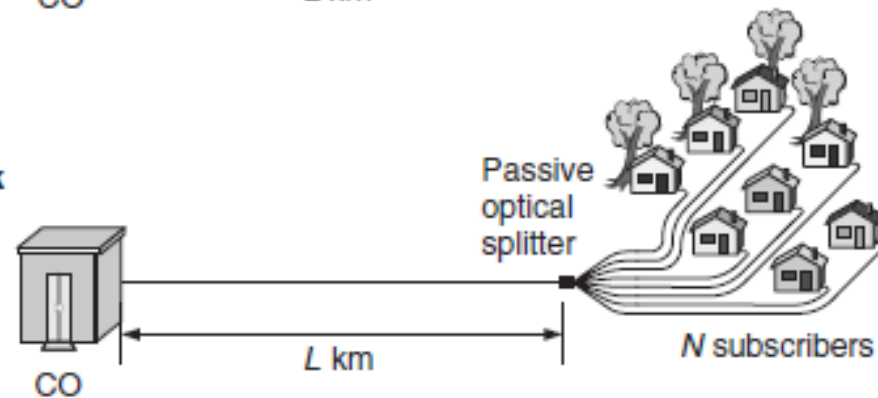
$2N + 2$ transceivers



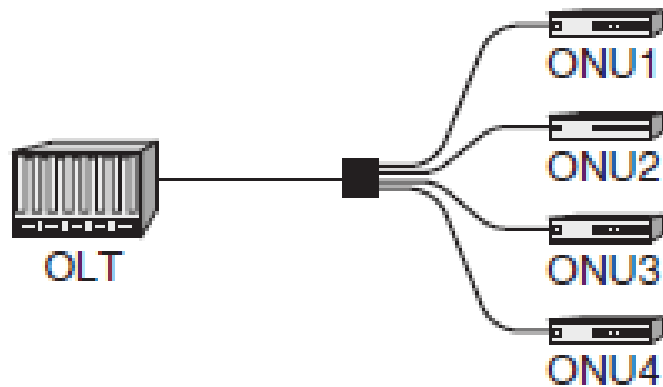
(c) Passive optical network

1 fiber

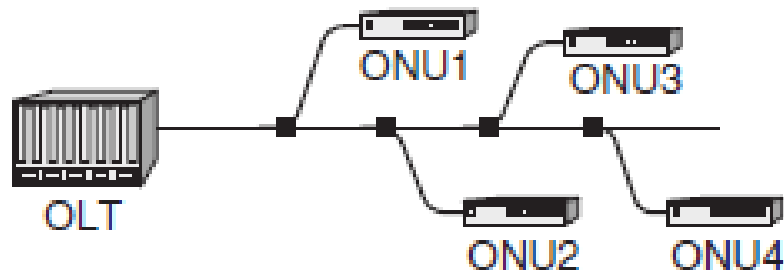
N transceivers



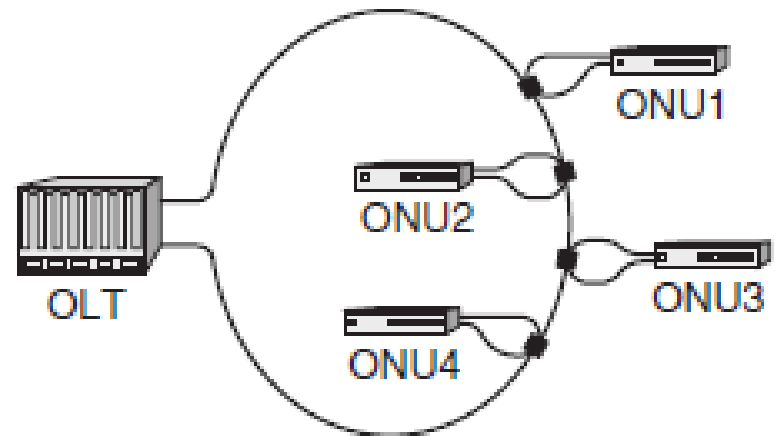
Different PON topologies



(a) Tree topology (using $1 \times N$ splitter)

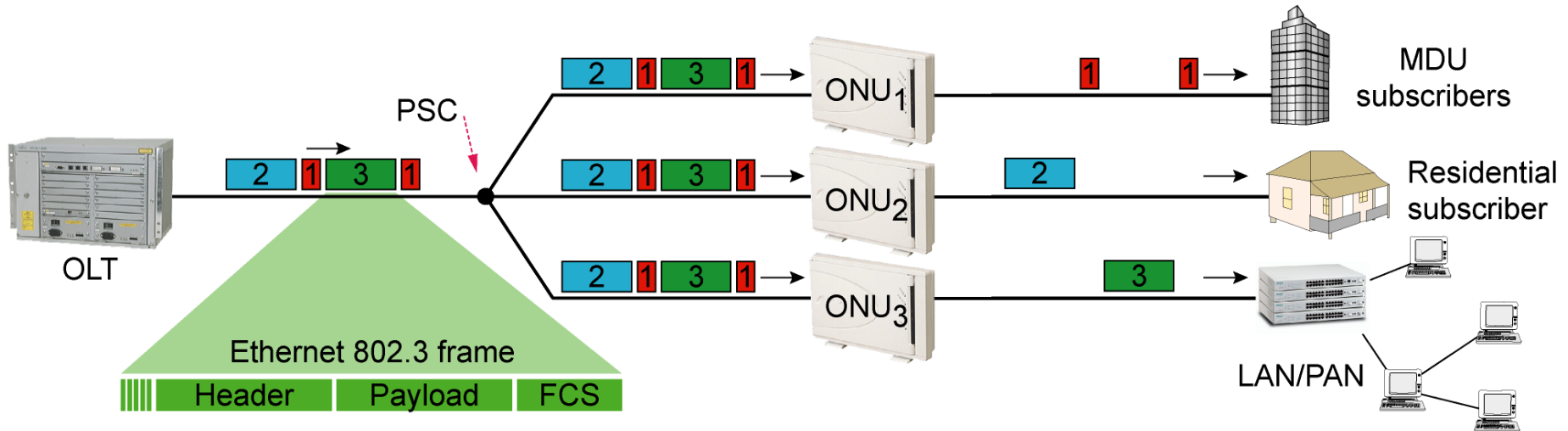


(b) Bus topology (using 1×2 tap couplers)



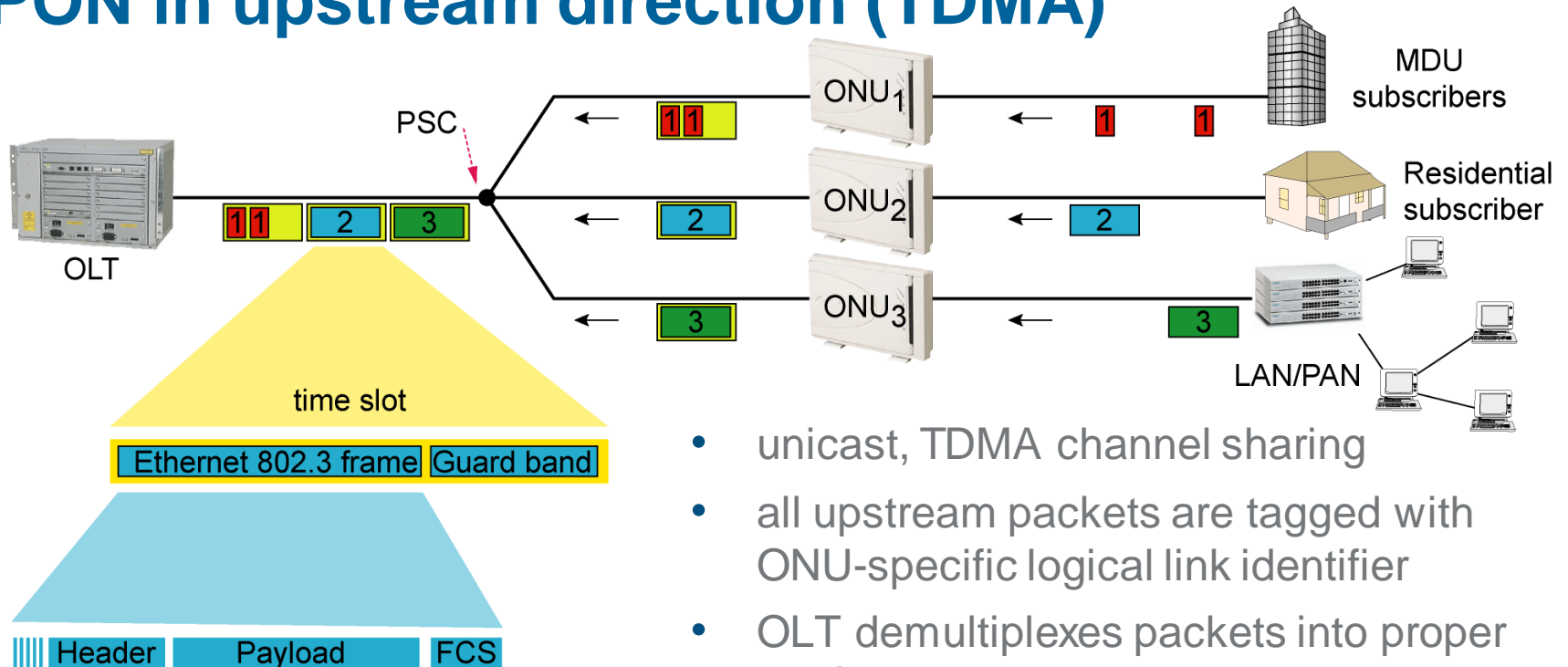
(c) Ring topology (using 2×2 tap couplers)

PON in downstream direction (P2MP)



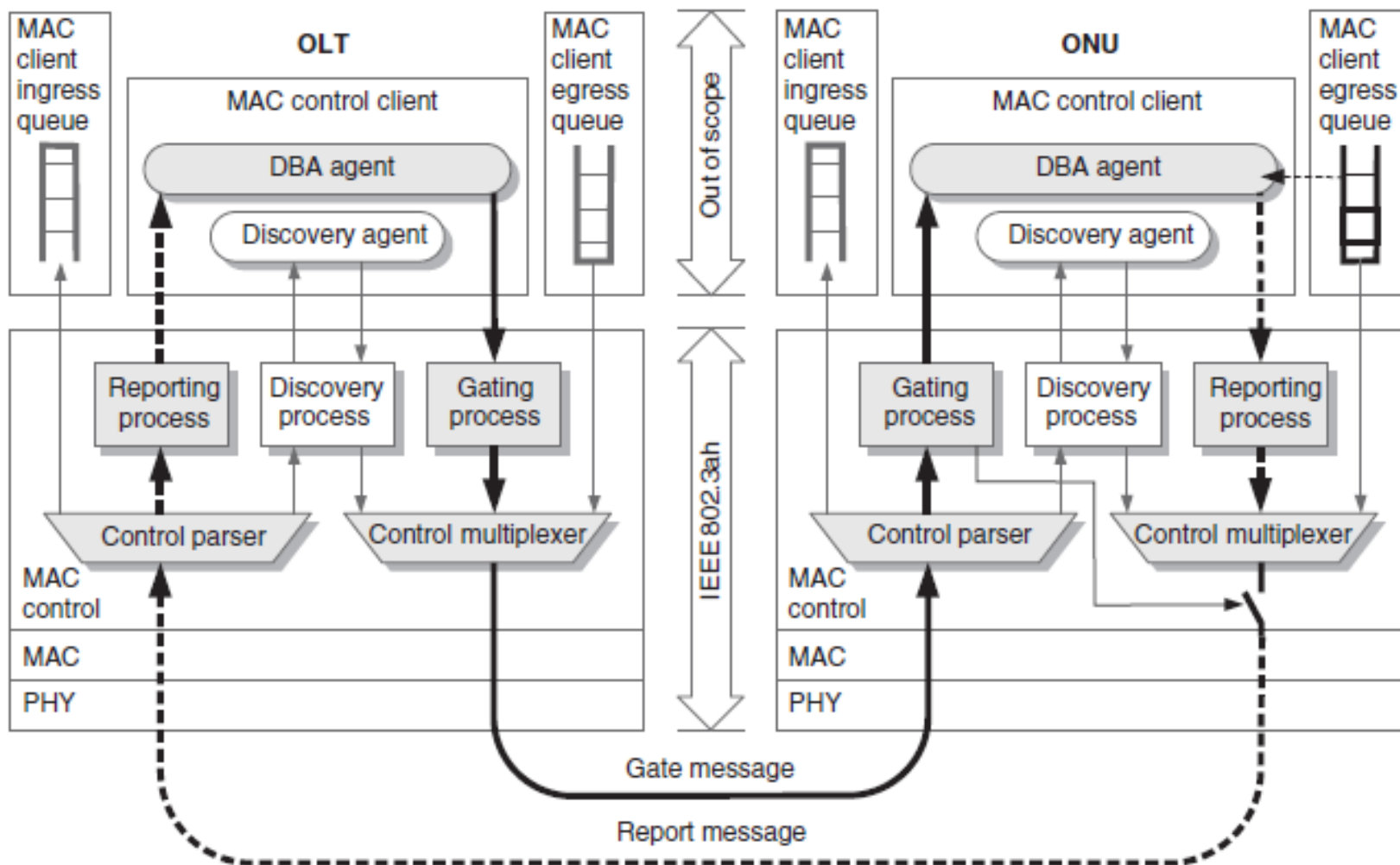
- broadcast, Point To Multipoint (P2MP) system on passive fiber tree
- all downstream packets are tagged with logical layer identifiers
- ONUs filter downstream data packets based on logical layer identifiers
- analog video supported via extended optional overlay (uni/bidirectional)
- data privacy via 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)

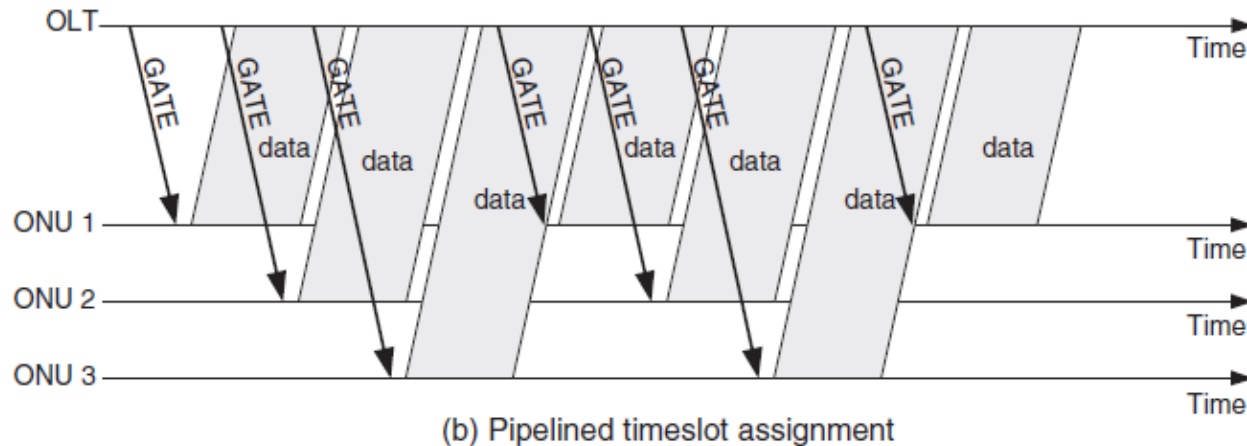
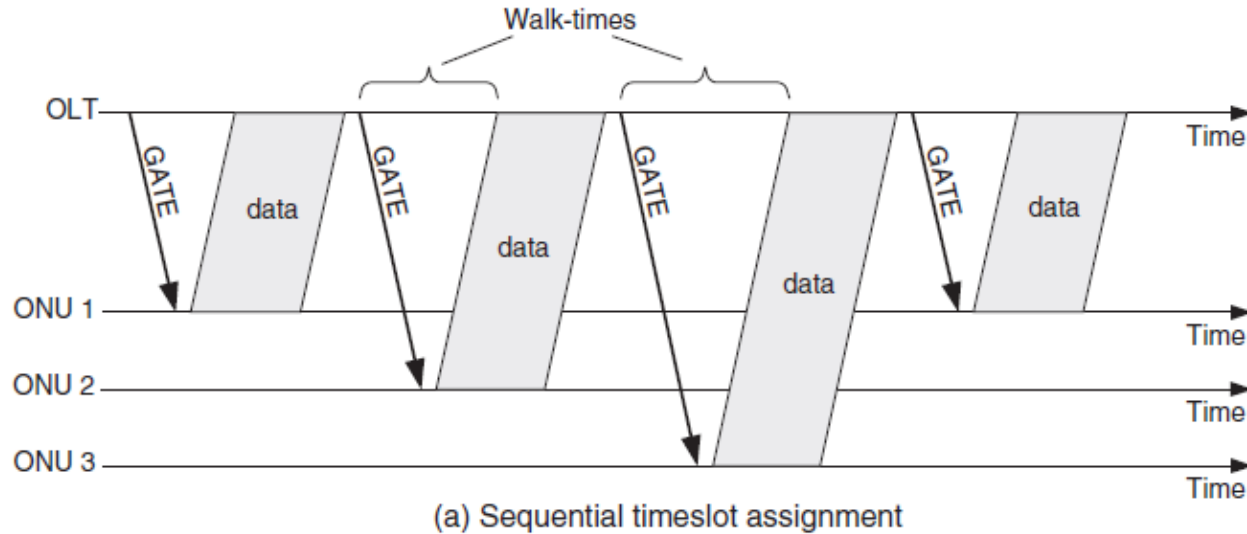


Source: "Ethernet Passive Optical Networks" by G. Kramer

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

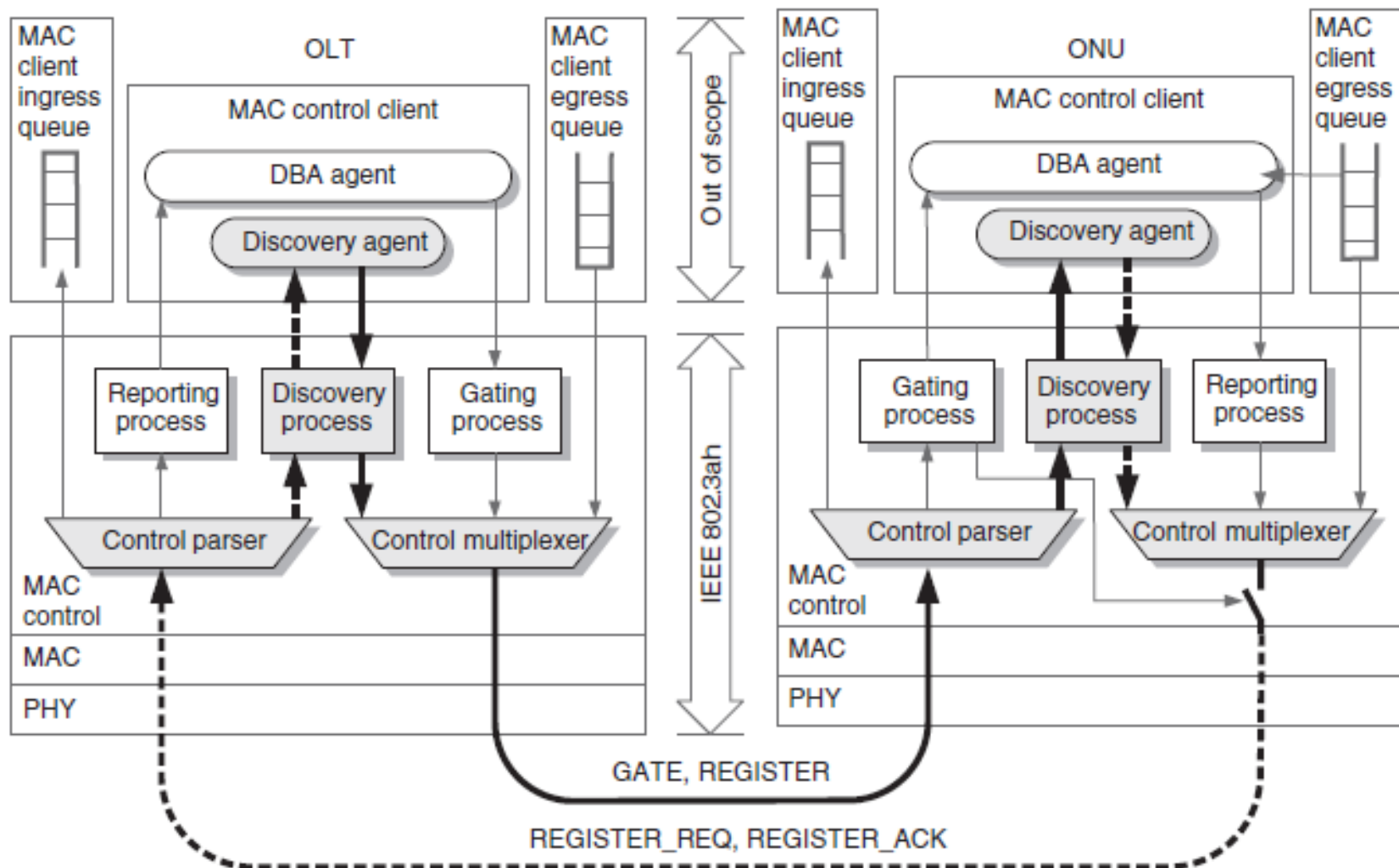
Dynamic Bandwidth Allocation process (3)



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

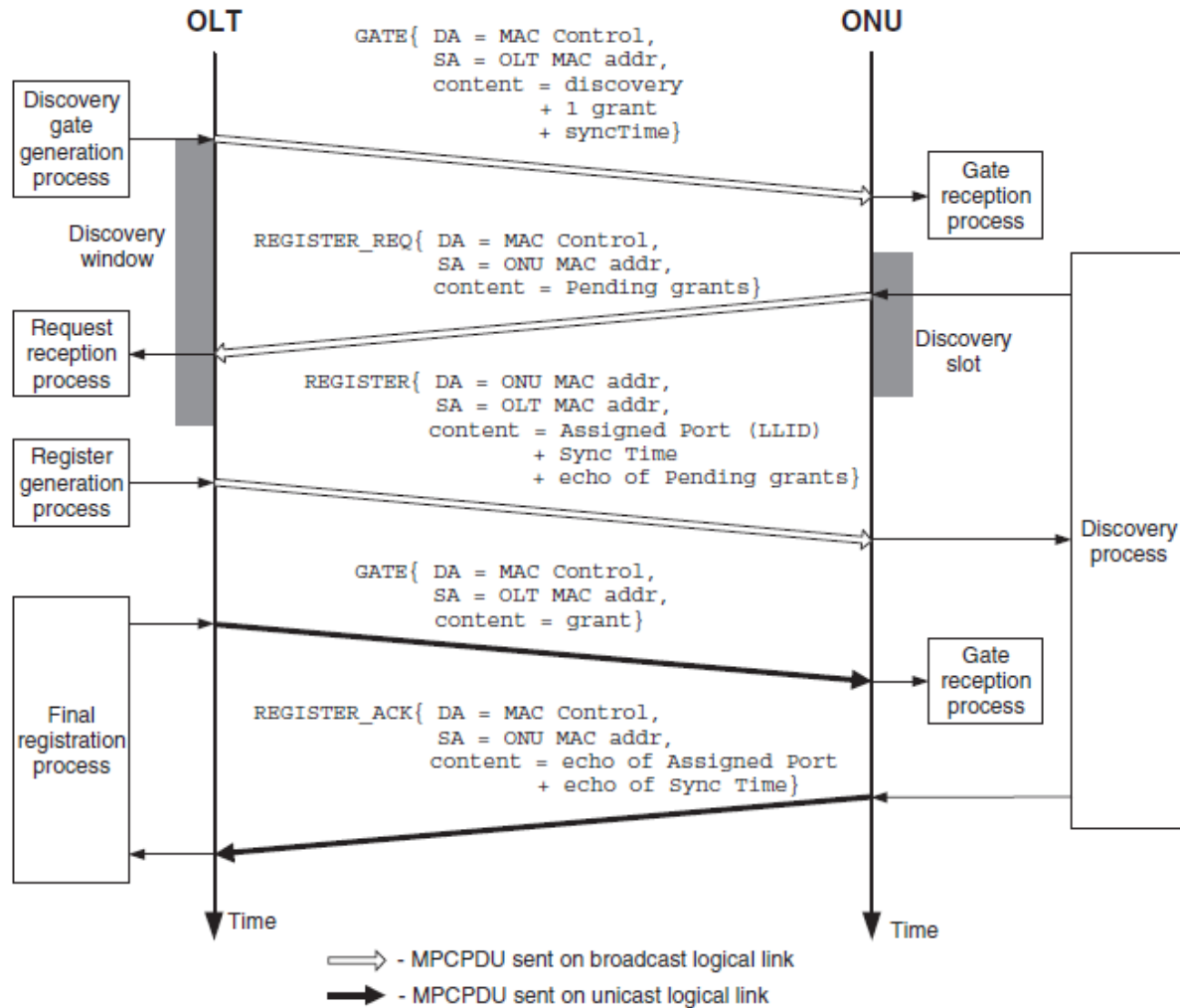
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Discovery Process (1)



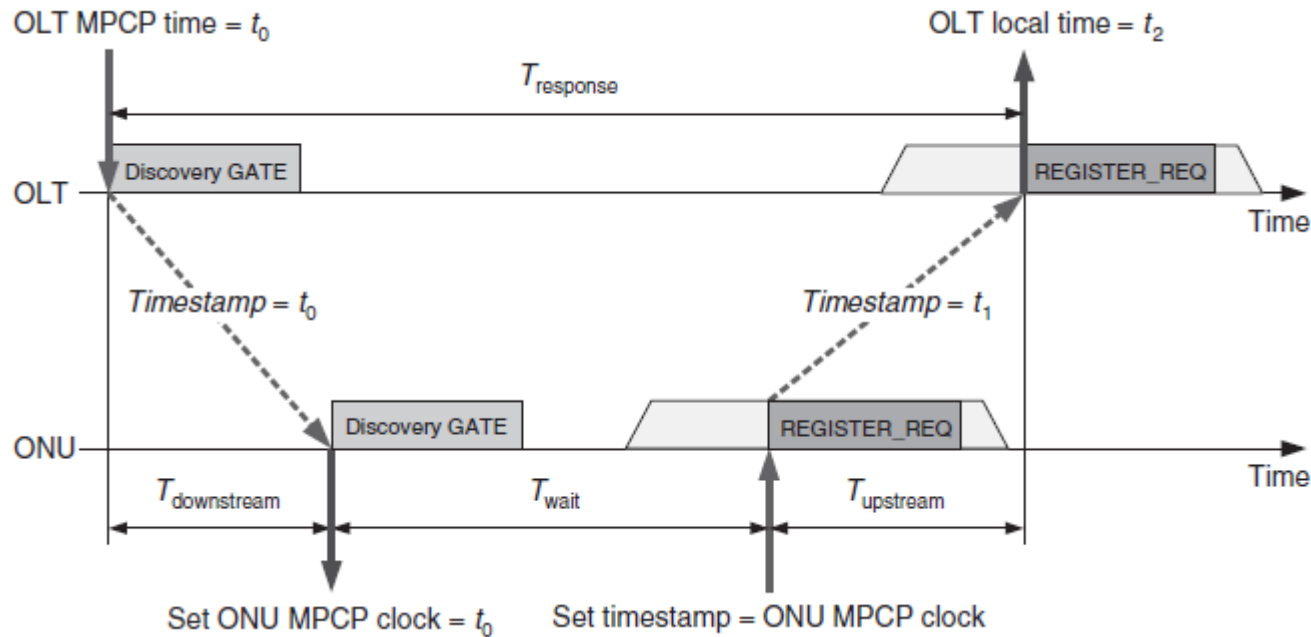
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Discovery Process (2) time diagram



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

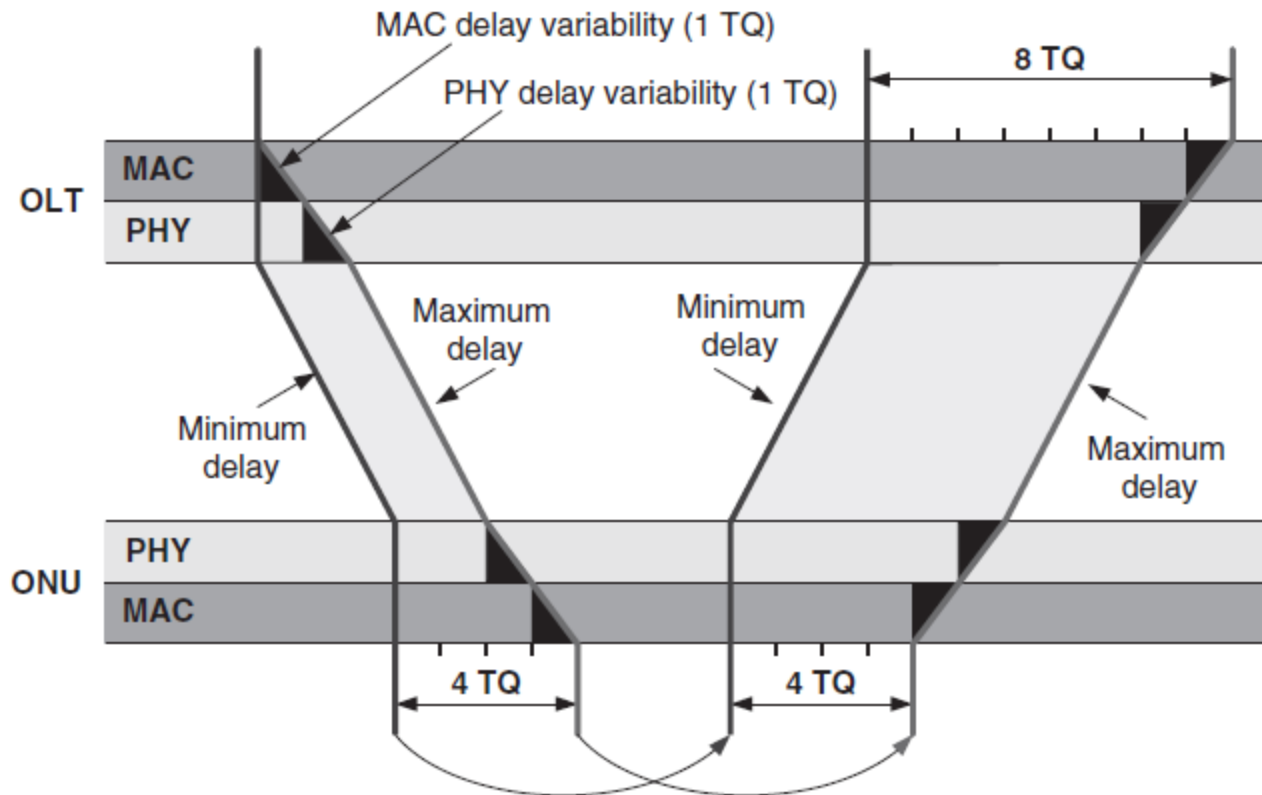
RTT Measurement



- 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

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

MAC and PHY delay variabilities



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

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REPORT MPCPDU

	Fields	Octets
	Destination address (DA)	6
	Source address (SA)	6
	Length/Type = 88-08 ₁₆	2
	Opcode = 00-03 ₁₆	2
	Timestamp	4
	Number of queue sets	1
Repeated <i>n</i> times as indicated by <i>Number of queue sets</i>	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

- 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

REGISTER_REQ / REGISTER / REGISTER_ACK MPCPDUs

Fields	Octets	Fields	Octets	Fields	Octets
Destination address (DA)	6	Destination address (DA)	6	Destination address (DA)	6
Source address (SA)	6	Source address (SA)	6	Source address (SA)	6
Length/type = 88-08 ₁₆	2	Length/type = 88-08 ₁₆	2	Length/type = 88-08 ₁₆	2
Opcode = 00-04 ₁₆	2	Opcode = 00-05 ₁₆	2	Opcode = 00-06 ₁₆	2
Timestamp	4	Timestamp	4	Timestamp	4
Flags	1	Assigned port	2	Flags	1
Pending grants	1	Flags	1	Echoed assigned port	2
Pad = 0	38	Sync time	2	Echoed sync time	2
Frame check sequence (FCS)	4	Echoed pending grants	1	Pad = 0	35
		Pad = 0	34	Frame check sequence (FCS)	4
		Frame check sequence (FCS)	4		

REGISTER_REQ MPCPDU

REGISTER MPCPDU

REGISTER_ACK MPCPDU

- Exchanged between ONU and OLT to indicate ONU attempt to 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)