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)!
PON versus P2P

(a) **Point-to-point network**
- \( N \) fibers
- \( 2N \) transceivers
- \( N \) subscribers
- \( L \) km

(b) **Curb-switched network**
- 1 fiber
- \( 2N + 2 \) transceivers
- \( L \) km
- \( N \) subscribers
- Curb switch

(c) **Passive optical network**
- 1 fiber
- \( N \) transceivers
- \( L \) km
- \( N \) subscribers
- Passive optical splitter
Different PON topologies

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

(b) Bus topology (using $1 \times 2$ tap couplers)

(c) Ring topology (using $2 \times 2$ 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

Source: “Ethernet Passive Optical Networks” by G. Kramer
Discovery Process (1)

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

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

- 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

<table>
<thead>
<tr>
<th>Fields</th>
<th>Octets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Destination address (DA)</td>
<td>6</td>
</tr>
<tr>
<td>Source address (SA)</td>
<td>6</td>
</tr>
<tr>
<td>Length/type = 88–08&lt;sub&gt;16&lt;/sub&gt;</td>
<td>2</td>
</tr>
<tr>
<td>Opcode = 00–02&lt;sub&gt;16&lt;/sub&gt;</td>
<td>2</td>
</tr>
<tr>
<td>Timestamp</td>
<td>4</td>
</tr>
<tr>
<td>Number of grants/flags = 09&lt;sub&gt;16&lt;/sub&gt;</td>
<td>1</td>
</tr>
<tr>
<td>Grant start time</td>
<td>4</td>
</tr>
<tr>
<td>Grant length</td>
<td>2</td>
</tr>
<tr>
<td>Sync time</td>
<td>2</td>
</tr>
<tr>
<td>Pad = 0</td>
<td>31</td>
</tr>
<tr>
<td>Frame check sequence (FCS)</td>
<td>4</td>
</tr>
</tbody>
</table>

![Image showing GATE MPCPDU fields and their corresponding octets]

- 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.

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Source: “Ethernet Passive Optical Networks” by G. Kramer
REGISTER_REQ / REGISTER / REGISTER_ACK MPCPDUs

- 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)

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