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Technical Viability of EPOC Time Division Duplex (TDD) Mode

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Abstract

- There is interest, within the EPOC Study Group, in a Time Division Duplex (TDD) Mode for EPOC
  - The EPOC PHY would include both FDD and TDD Modes
  - The two modes would be part of the same PHY and would be selected via configuration of the coax portion
- However, it is important to show technical viability of a EPOC TDD Mode
- For a TDD Mode to be technically viable for EPOC it must be possible for it to be compatible with the Ethernet Full-Duplex MAC
- This presentation addresses the technical viability of a TDD EPOC Mode being compatible with the Ethernet Full-Duplex MAC

Outline

- Background on Time Division Duplex
- Background on Ethernet Full-Duplex MAC
- Viability of making a TDD Mode compatible with the Ethernet Full-Duplex MAC in the coax portion

Note: All references to TDD mode operations in the presentation are intended to apply to the coax portion of the system only (i.e. no changes to the fiber portion)

Background on TDD mode

- In a frequency division duplex (FDD) mode there are two frequency bands
  - One band is used for upstream
  - One band is used for downstream
- In a TDD mode there is one frequency band that is used for both upstream and downstream
- In TDD the upstream and downstream are duplexed in time
  - One time unit is allocated for upstream transmissions
  - A second time unit is allocated for downstream transmissions

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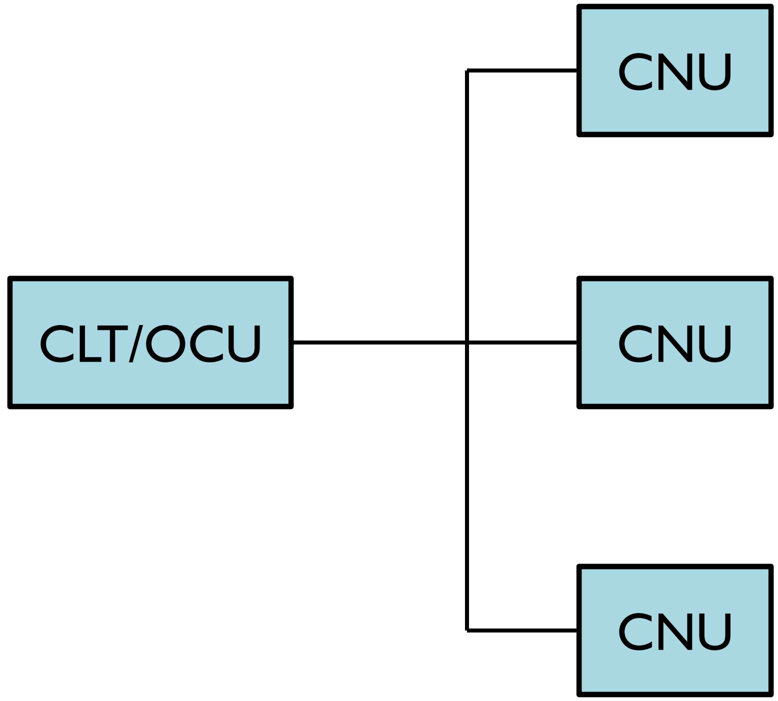
Network Illustration - Example



- In this illustration we use the terms CLT and CNU, which are the two end of the sole coax portion
  - OCU will have the same role of the CLT here in other example
  - Downstream from CLT to CNU, Upstream from CNUs to CLT
  - There is a propagation delay between the CLT and each CNU

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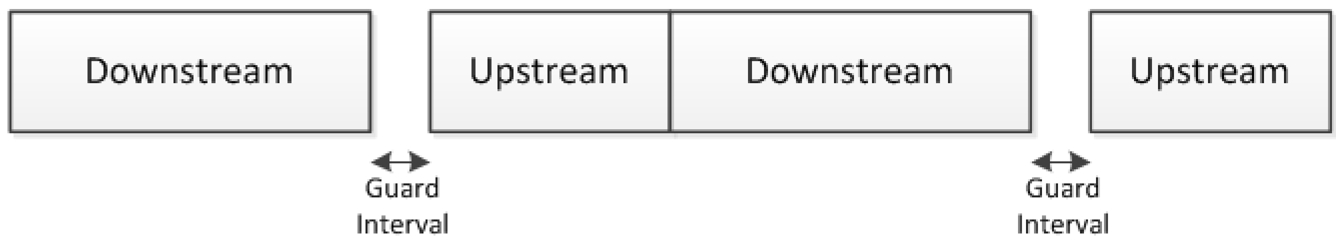
Time Duplex Illustration

- Timing measured at the CLT/OCU (coax line end)



- The Guard Interval is required due to propagation time on coax medium and switching time from transmit to receive – Cannot transmit and receive at the same time at CLT/OCU or at the CNUs
  - Guard interval ensures separate upstream/downstream time windows at the receivers
- Time allocated for downstream may be different than time allocated for upstream

Background Ethernet Full-Duplex MAC

- The Ethernet Full-Duplex MAC is specified in Annex 4A of the Ethernet standard [1]
- A brief synopsis is provided here

- From [1] – The full-duplex MAC provides the following functions
  - Data encapsulation (transmit and receive)
    - Framing (frame boundary delimitation, frame synchronization)
    - Addressing (handling of source and destination addresses)
    - Error detection (detection of physical medium transmission errors)
  - Media access management (Physical Layer congestion)

Full-Duplex Operation

- From the Standard
  - The Physical Layer Signaling (PLS) component of the Physical Layer provides an interface to the MAC sublayer for the serial transmission of bits onto the physical media
  - The *carrierSense* signal indicates that the transmit function must defer because of congestion at the Physical Layer (see 4A.2.3.2.1).
  - The *receiveDataValid* signal indicates the presence of incoming data to the receive function (see 4A.2.4.2).
- The *carrierSense* signal from the PHY to the MAC is a "virtual carrier sense" that indicates the medium is "busy" – Virtual CSMA signaling
- The *receiveDataValid* from the PHY to the MAC indicates that there is data for the MAC layer

Full-Duplex Transmission

- MAC receives data from its client (next higher layer)
- MAC builds Ethernet Frame
  - Prepends preamble and start frame delimiter
  - Pads payload to minimum duration as needed
  - Prepends source address (SA) and destination address (DA)
  - Adds type/length field
  - Adds frame check sequence (FCS) for error detection
- Frame transmission begins once the *carrierSense* signal is removed and after the interframe delay

Full-Duplex Reception

- The arrival of a Frame is detected by the PHY layer
- After PHY-layer synchronization the PHY turns on the *receiveDataValid* signal which is sent to the MAC
- The PHY layer decodes the data it receives and send decoded data to the MAC layer
- The MAC discards the preamble and the start frame delimiter
- The MAC decapulates the data and checks the DA to see if the data is intended for this station
- It checks the frame check sequence and sends the Ethernet Frame (minus preamble and start frame delimiter) to MAC client (next higher layer)

Technical Viability of TDD mode and Ethernet Full-Duplex MAC

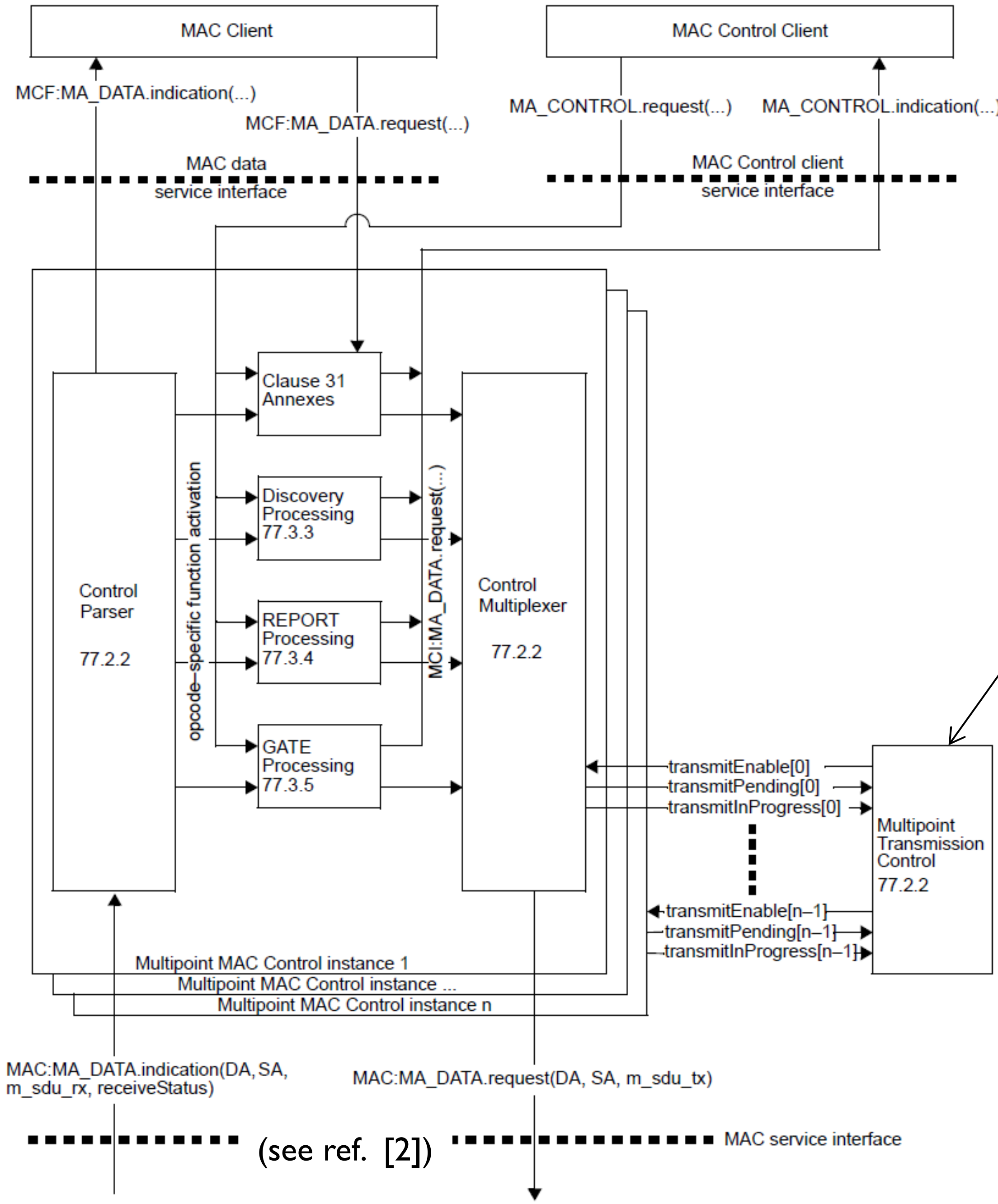
TDD mode of operations applied to the coax portion, between the CLT (or OCU) and the CNUs

- No changes to OLT and optical transmission to OCU/ONU

Operations with Ethernet Full-Duplex MAC - example:

- Introduce a TDD Timer at the CLT/OCU
  - The TDD Timer provides indicators for the Downstream Time Window and the Upstream Time Window on coax
- Coax downstream transmission
  - The TDD Timer can be used to control when downstream transmission is allowed on coax and when it is not allowed
- Coax downstream reception
  - TDD timing information is provided from the CLT/OCU to the CNU and can be used by the PHY entity in the CNU to handle with non-continuous downstream reception on coax

Coax Downstream Transmission - details



(see ref. [2])

Coax Resource Allocation and *TDD Duplex Control* functionalities can be integrated within the augmented Multipoint Transmission Control for downstream in the coax portion, at CLT/OCU

Technical Feasibility of TDD Mode and Ethernet Full-Duplex MAC

- Coax Upstream transmission / reception
  - The TDD Timer is available to the dynamic bandwidth allocation (DBA) entity, which controls transmission of *gate* messages for scheduling upstream transmissions
  - The DBA entity sends the *gate* messages to the CNUs during the downstream time window
  - The DBA entity selects the *startTime* and *length* within the *gate* message so that the upstream transmission falls fully within the upstream time window
- No change with respect to the current system operation as upstream transmission/reception is already bursty.

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Conclusions

- Provided background material on TDD Mode and Ethernet Full-Duplex MAC
- Demonstrated technical viability of a TDD Mode compatibility with the Ethernet Full-Duplex MAC
  - Introduce a TDD Timer for TDD mode operation
  - TDD Timer used to control downstream and upstream transmissions via MPCP/DBA
  - TDD Timing is provided to CNU to secure non-continuous downstream reception

References

[1] "Simplified full duplex media access control," IEEE 802.3 Ethernet Standard, Annex 4A

[2] IEEE 802.3av-2009, "Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications, Amendment 1: Physical Layer Specification and Management Parameters for 10Gb/s Passive Optical Networks".

Annex – Considerations on transmission in high frequencies or low frequencies

Coax PHY Design Drivers

Possible mapping between carrier frequency, duplexing method and coax media type:

	Upstream	Downstream
Active / Passive plant - FDD	Low band (<85MHz)	High band (>750MHz)
Active / Passive plant – FDD	High band (>750MHz)	High band (>750MHz)
Passive plant - TDD	High band (>750MHz)	High band (>750MHz)

Coax Channel Model

- Attenuation due to RF signal propagation in the coax cable
- Multi-path propagation (Micro-reflections)
- Interference due to:
  - Blockers (DOCSIS, CATV, EoC)
  - Ingress noise (2G/3G, FM radio)
- Burst noise
- All these features need to be clearly specified <u>for the carrier frequency of interest</u>
  - High frequency
  - Low frequency

Coax PHY Design Drivers

- Overall cable attenuation: higher at higher frequencies
  - Transmit power depends on carrier frequency
- Cable attenuation: more freq. dependent at lower frequencies
  - Adaptive modulation can cope with it
- Micro-reflections: more severe at lower frequencies
  - Design for the worst case or adapt to each case (e.g., flexible CP duration for OFDM)
- Burst noise / Ingress noise : same measures for high and low frequencies (only specific frequencies appear to be heavily affected)

➢ An adaptive PHY will be able to cope with different carrier frequencies