Joint ITU-T/IEEE Workshop on the Future of Ethernet Transport

Transport of Time over PONs

Frank Effenberger,

Director, FTTx ATD

Huawei Technologies

Introduction

- PON characteristics

- Time over G-PON

- Time over EPON

- Accuracy estimates

- Open items

  - Sync messaging

  - Multiple time domains

PON characteristics

- The medium is fine for timing
  - All PONs use bidirectional transmission on single mode fiber
  - Delay is nearly symmetrical and constant

- The MAC presents a problem
  - Downstream has only incidental queuing delays
  - Upstream has significant TDMA allocation delays
  - This results in asymmetry in both delay and jitter

- Attempting to operate a packet-based scheme "over-the-top" of PON is facing a big problem
  - The basic assumption of all packet schemes is symmetric delay
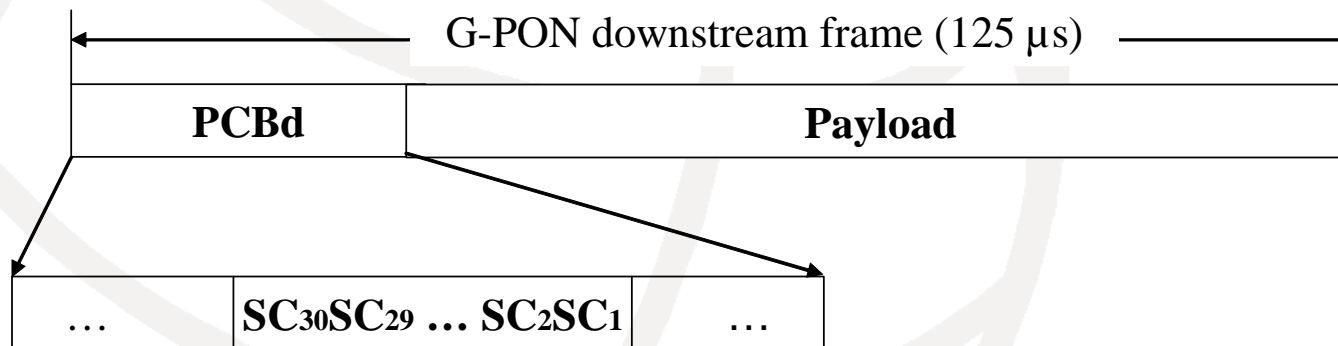
TDMA system holds the key

- All TDMA PON systems actually measure the PON time-of-flight
  - This is necessary to operate the TDMA system efficiently
  - The measurement is quite good (~10's of ns)

- The solution is to use the PON TDMA timing system to handle the PON link, and interface this to the packet-based solutions at either side
  - OLT gets the time from the network
  - OLT sends the time to the ONUs
  - ONUs can send the time downstream

GPON Time reference

- G-PON uses periodic framing, with a superframe counter
  - This structure repeats approximately every 37 hours, providing an easy timing reference
- During activation, the ONU's transmission delay is measured, and an equalization delay is sent to the ONU
  - This delay is updated continuously for delay variations
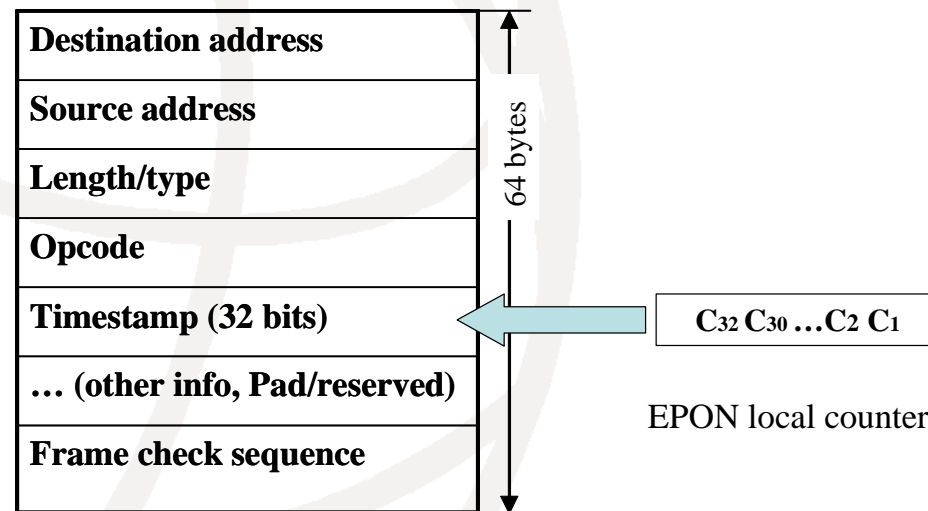- In this way, the ONU knows how far it is from the maximum PON distance

G-PON downstream frame (125 µs)	
PCBd	Payload

…	$SC_{30}SC_{29}$ … SC_2SC_1	…

PCBd: physical control block downstream

SC: superframe counter

ToD over G-PON

- OLT computes the ToD corresponding to a certain frame occurrence arriving at the maximum range
  - It sends this relationship to all the ONUs using the OMCI channel
- ONUs can then compute the time at their particular location

EPON time reference

- EPON uses timestamps in MPCP packets
  - This running counter rolls over every 68 seconds, also an easy timing reference
- During activation, OLT measures ONU RTT, but only uses it internally to pre-delay grant times

EPON MPCP message
Destination address
Source address
Length/type
Opcode
Timestamp (32 bits)
… (other info, Pad/reserved)
Frame check sequence

64 bytes

$C_{32} C_{30} …C_2 C_1$

EPON local counter

EPON MPCP message

ToD over EPON

- EPON ONU's don't know their position, only the OLT knows
- The OLT has to pre-calculate what the ToD will be when a selected MPCP timestamp would arrive at a particular ONU
  - The OLT sends this to the ONU via the slow protocol channel
- The ONU then sets its own time according to the value received

Accuracy estimate

- There are several sources of error in the time transport over PON systems
  - Clock quantization error
  - TDMA drift error
  - Fiber asymmetry
- Clock quantization error is small
  - G-PON measures time in bits (~ ±1 ns)
  - EPON measures time in time quanta (~ ±8 ns)
- TDMA drift is larger
  - G-PON allows ±4 bits of drift (~ ±4ns)
  - EPON allows for ±12 TQ's of timing tolerance (~ ±96 ns)

Fiber Asymmetry

- Different wavelengths are used in each direction
- The index of refraction is slightly different
- The effect can be characterized by the dispersion of the fiber
- There are uncontrolled
  - Variations of the fiber
  - Variations of the wavelength
- Combined, these would produce an error of ±5 ns
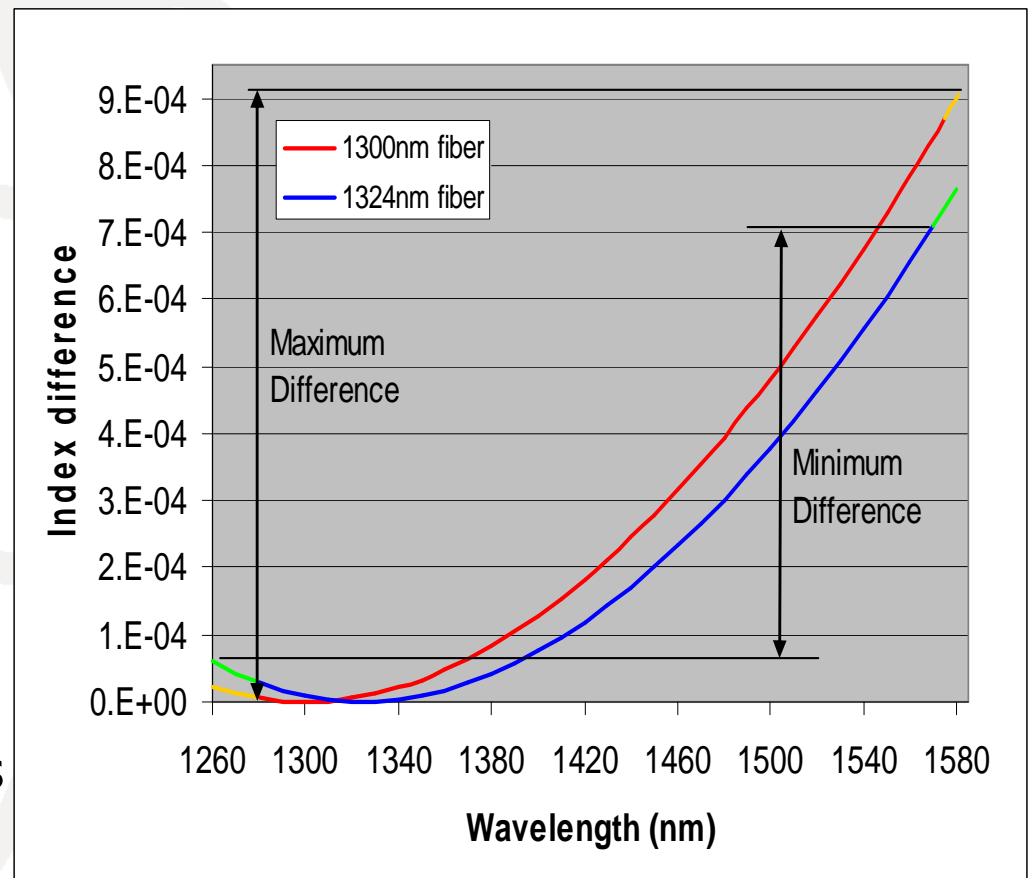
Open items

- ## Sync messaging
  - How can the ONU know how good the clock is?

- ## Multiple time domains
  - If we want, can we provide multiple clocks over the common PON link?
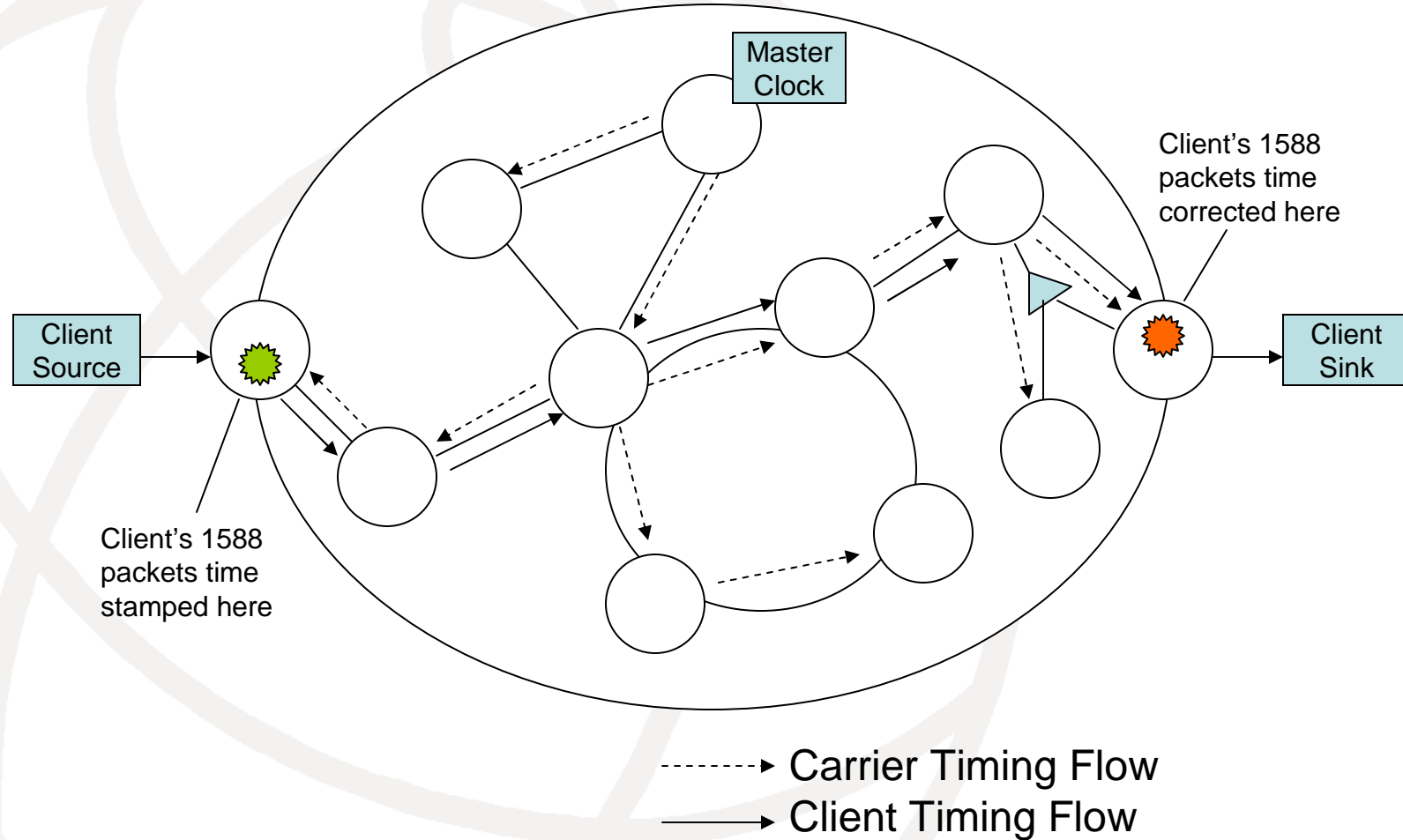
Sync messaging

- Various synchronous timing systems have a method to indicate the clock quality
  - SSM in SDH
  - Announce messages in P1588
- How to pass this information across the PON?
  - Directly (in-band) using packet formats
  - Via a specialized PON channel (e.g., OMCI)
- The OLT would be involved either way
  - To receive the sync info from the network, and multicast it to all the ONUs it serves
- The ONU could remain transparent in the in-band method

Multiple time domains

- It is yet to be established if multiple time domains in a carrier network is a real requirement
  - If you have a true ToD, why would customers insist upon their own? (Are they from Mars?)
  - If you are a carrier, do you really want to support yet another unbundling requirement?

- Hypothetically, if there is such a requirement, how can we support it using the PON schemes presented?
  - P1588 has the transparent clock correction scheme, and this might be used to advantage

End-to-end transparent clock

Master Clock

Client Source

Client's 1588 packets time stamped here

Client's 1588 packets time corrected here

Client Sink

- - - - → Carrier Timing Flow

———→ Client Timing Flow

Conclusions

- Precision time over PONs is ready
  - G.984.3 Am 2 for G-PON
  - G.987.3 for XG-PON
  - P802.1AS for EPON and 10GEPON

- Solution has good precision
  - Errors < ±100 ns
  - Well below the 1 µs network requirement

- Solution is extendable
  - Sync messaging and multiple domains have solutions right at hand

Thank you!