TTC-PON

An upgrade proposal for off-detector TTC

From TTC to PON
The TTC-PON Project
TTC-PON applied to experiments

OUTLINE

From TTC to PON

The TTC-PON Project

TTC-PON applied to experiments

OUTLINE

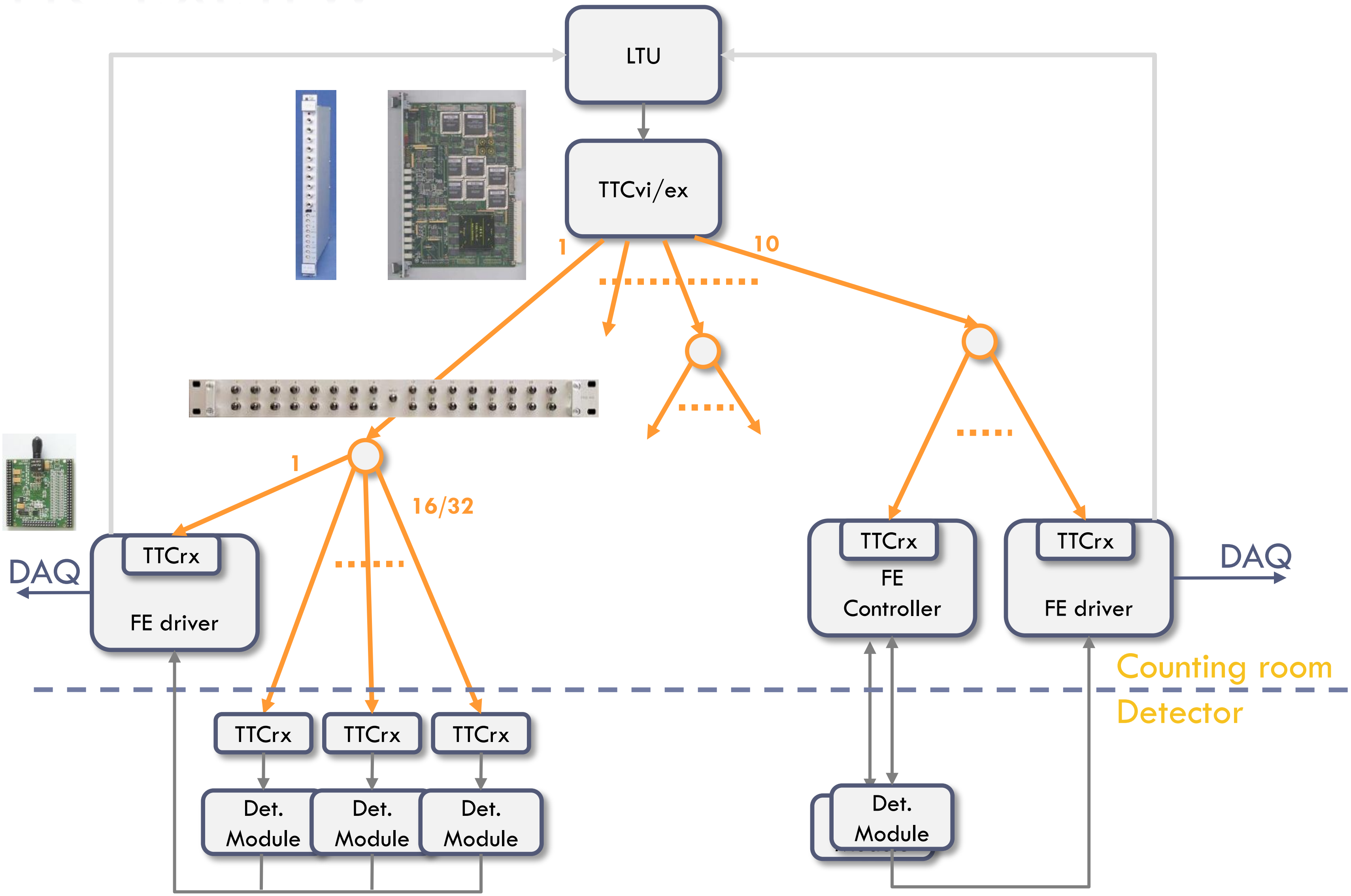
TTC SYSTEM

- Timing, Trigger and Control System
- Bringing:
  - LHC bunch clock (BC)
  - Trigger signals
  - Control data
  - Down to each part of the detector with low and fixed latency and low jitter LHC recovered clock (10ps rms)
- Common modules to all experiments
- Designed at the end of the 90's

TTC SYSTEM

- Encoding:
  - 2 channels
  - A: low & fixed latency dedicated to triggers
    - Not encoded. 1=trigger, 0=no trigger
  - B: everything else
    - Synchronous event and bunch counter resets
    - Trigger types
    - Commands
    - Forward Error Correction using Hamming code
  - Bi-Phase-Mark, Time Domain Multiplexed
    - 1 bunch clock (25ns) carries 1 bit of A channel and 1 bit of B channel
    - Transition=1, no transition=0
    - Line rate of 160 Mbps

TTC SYSTEM


LTU
TTCvi/ex
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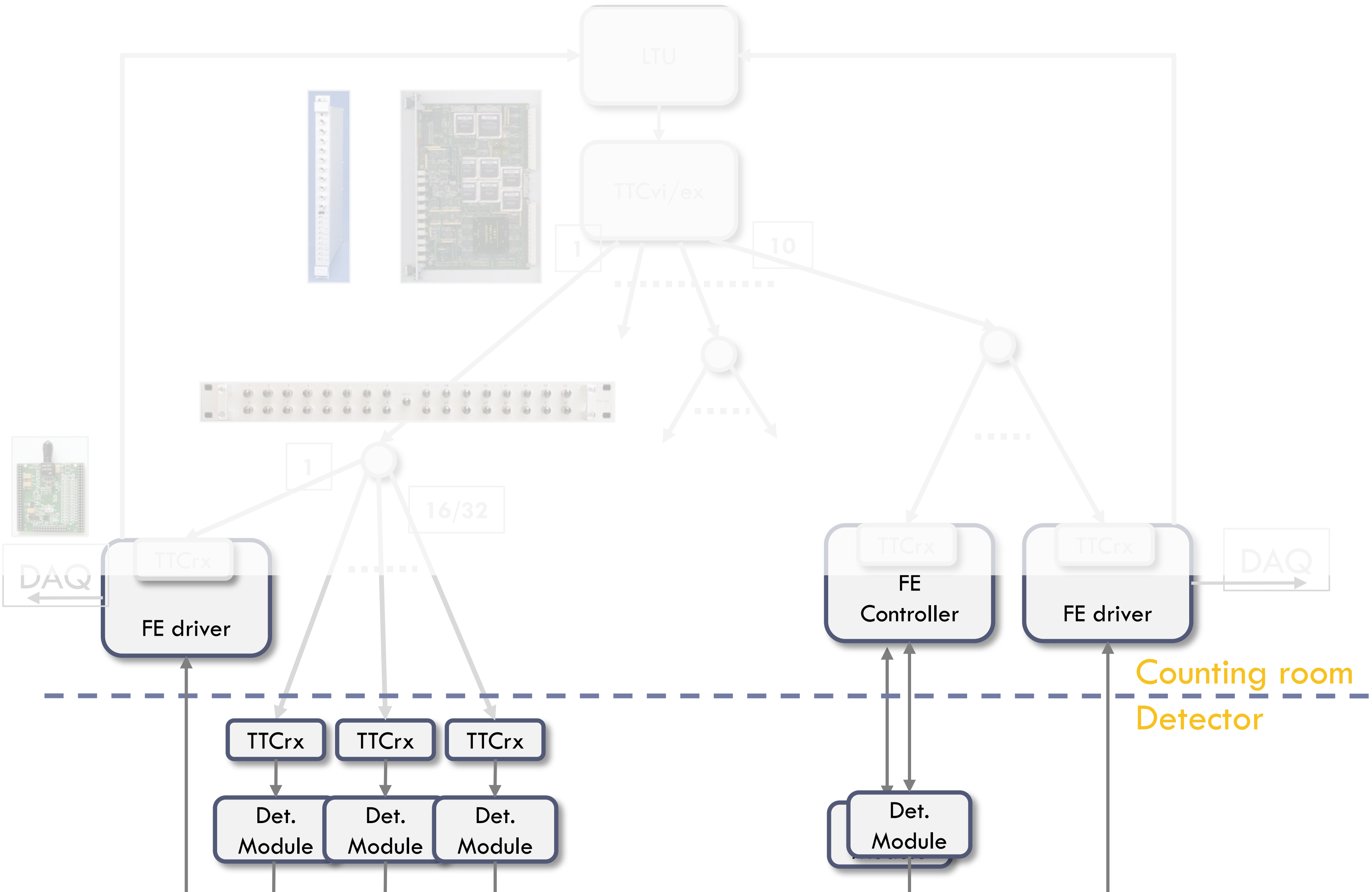
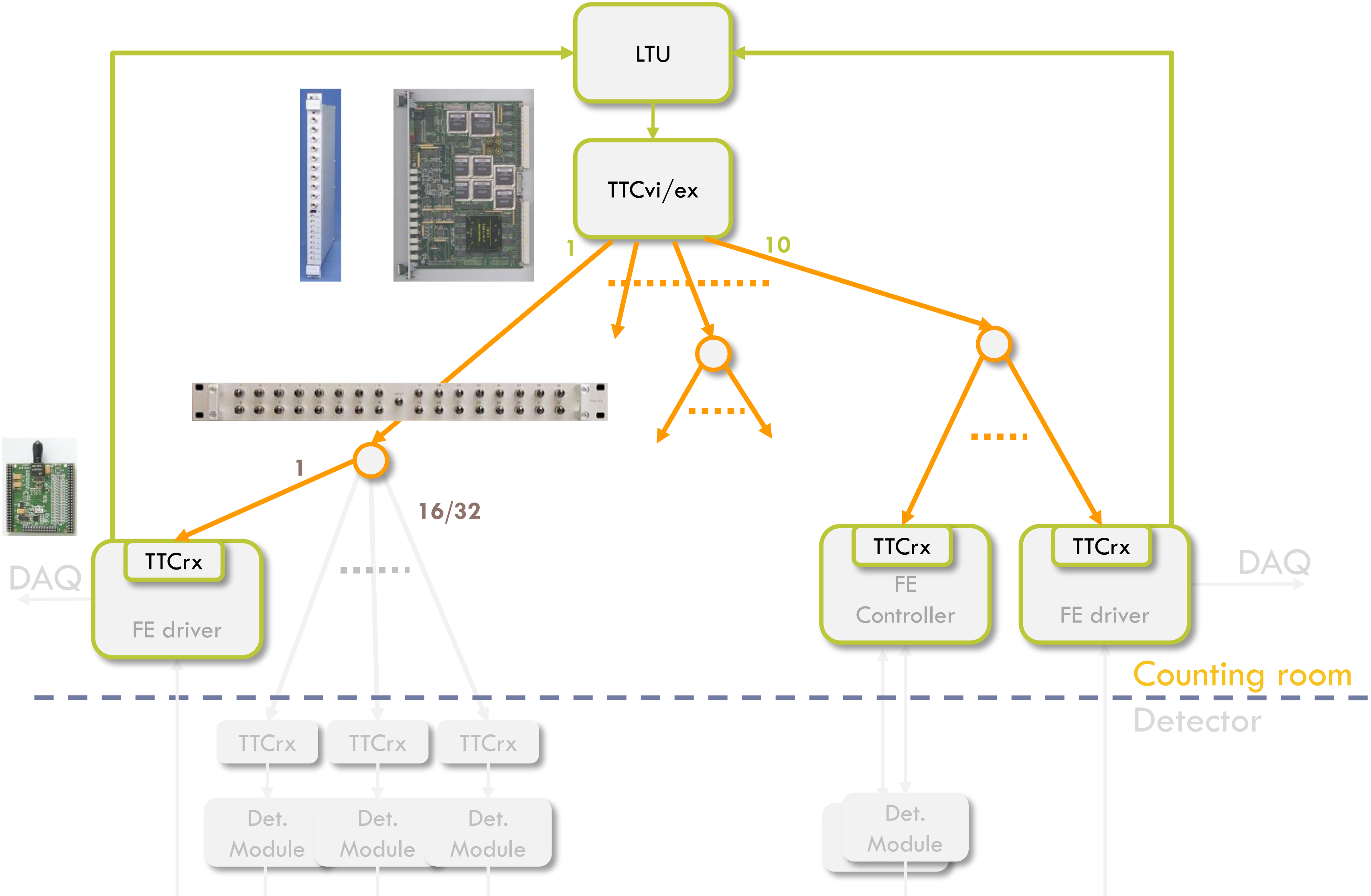
10
1
16/32
TTCrx
FE driver
DAQ
TTCrx
TTCrx
TTCrx
Det.
Module
Det.
Module
Det.
Module
TTCrx
FE
Controller
TTCrx
FE driver
DAQ
Counting room
Detector
Det.
Module

TTC SYSTEM – CANDIDATE FOR VERSATILE LINK & GBT



TTC SYSTEM – CANDIDATE FOR PON



TTC SYSTEM LIMITATIONS

- Aging, components getting obsolete
- Limited trigger rate (11 consecutive triggers max)
- No protection against error transmission on triggers (no encoding on A channel)
- No bidirectionnality
  - No feedback on control
  - Required a separate network for Busy/Throttle system
- Limited bandwidth
  - Trigger types could not be synchronous to triggers
  - Commands
- Too LHC-specific (frequency range limited to [40.077-40.081] MHz)

TTC SYSTEM – UPGRADE REQUIREMENT

- Bi-directionality
- Increased bandwidth
- Common system
- Scalability
- Partitioning flexibility
- Better performances than TTC for clock recovery
- Low and fixed latency
- Backward compatibility with legacy TTC system

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N etwork

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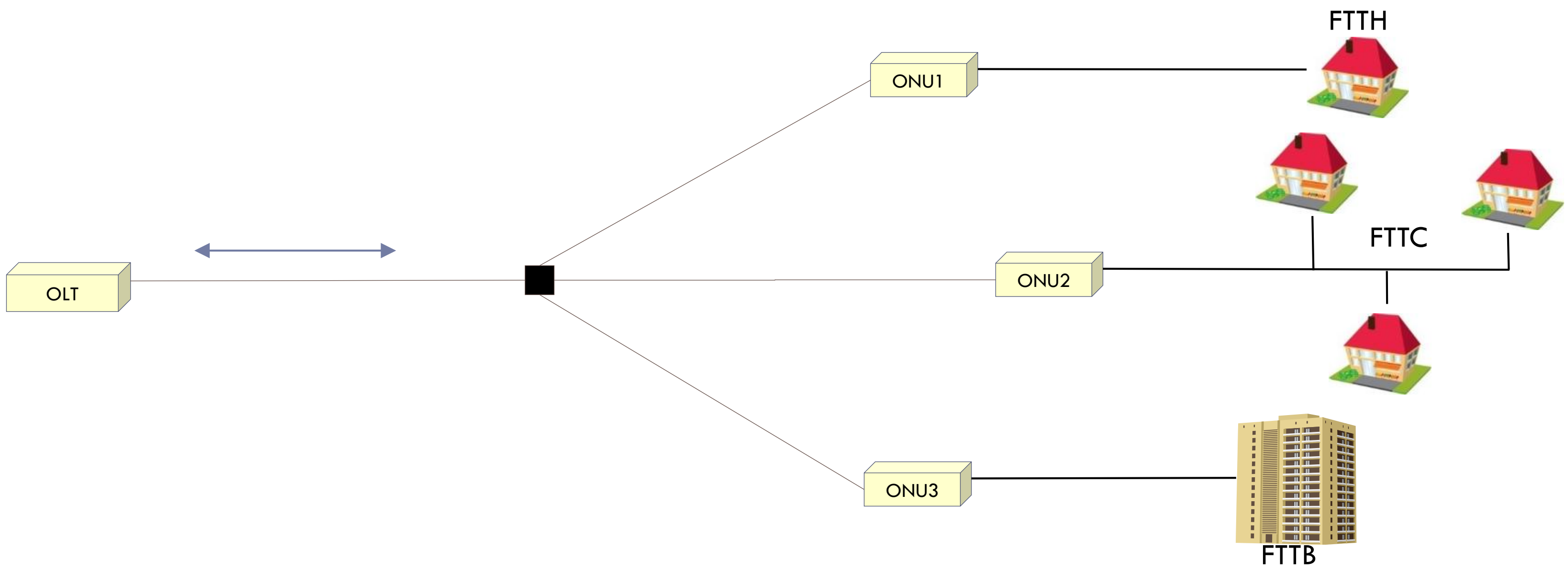
WHAT IS A PON?

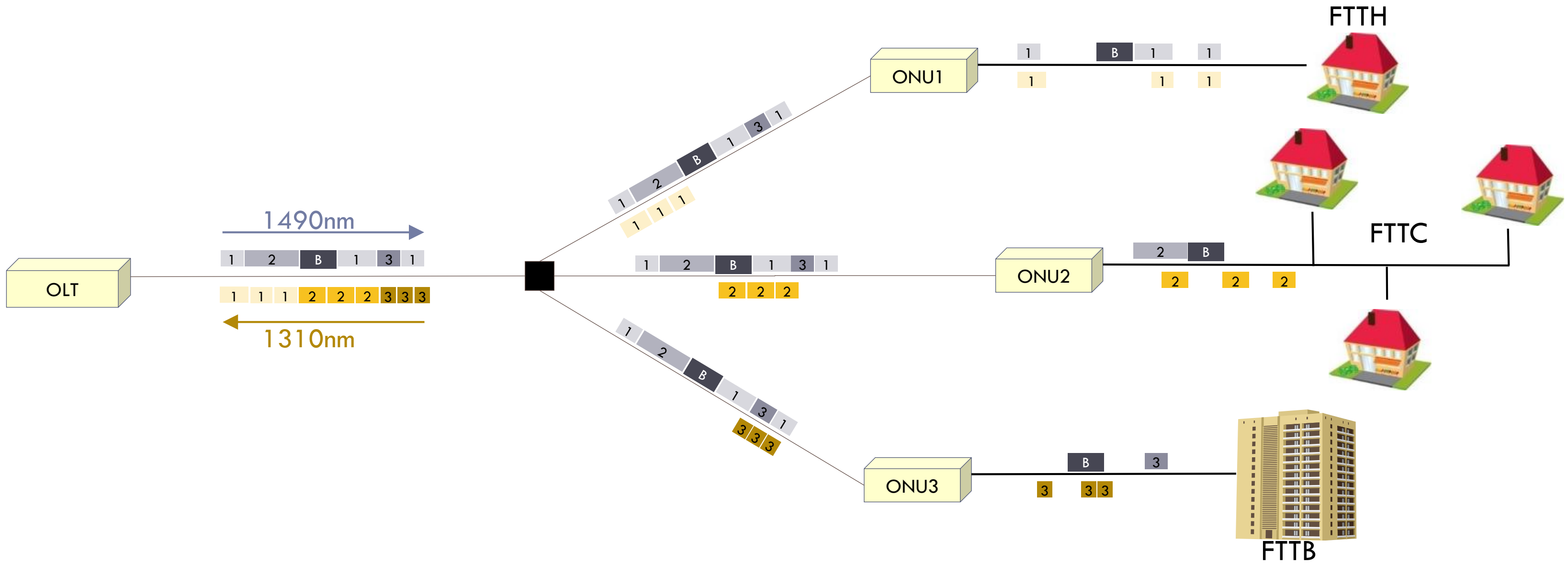
- Passive Optical Network
- Major topology of growing Access Network Market (FTTx)
- Point-to-MultiPoint (P2M)
- One single fibre in charge of both downstream and upstream transmissions (using wavelength multiplexing technique)



WHAT IS A PON?

Example of 1G-(E)PON

- Downstream: 1490nm @ 1.25 Gbps
- Upstream: 1310nm @ 1.25 Gbps



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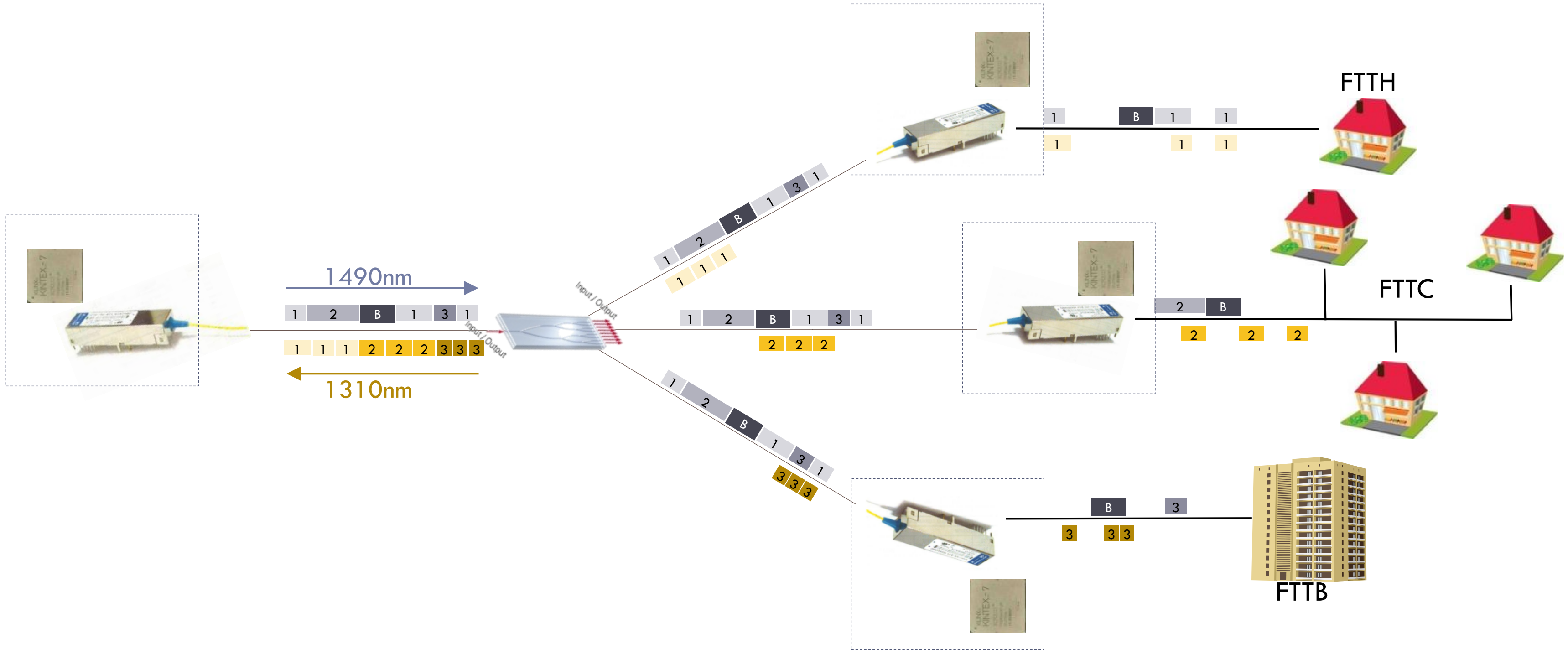

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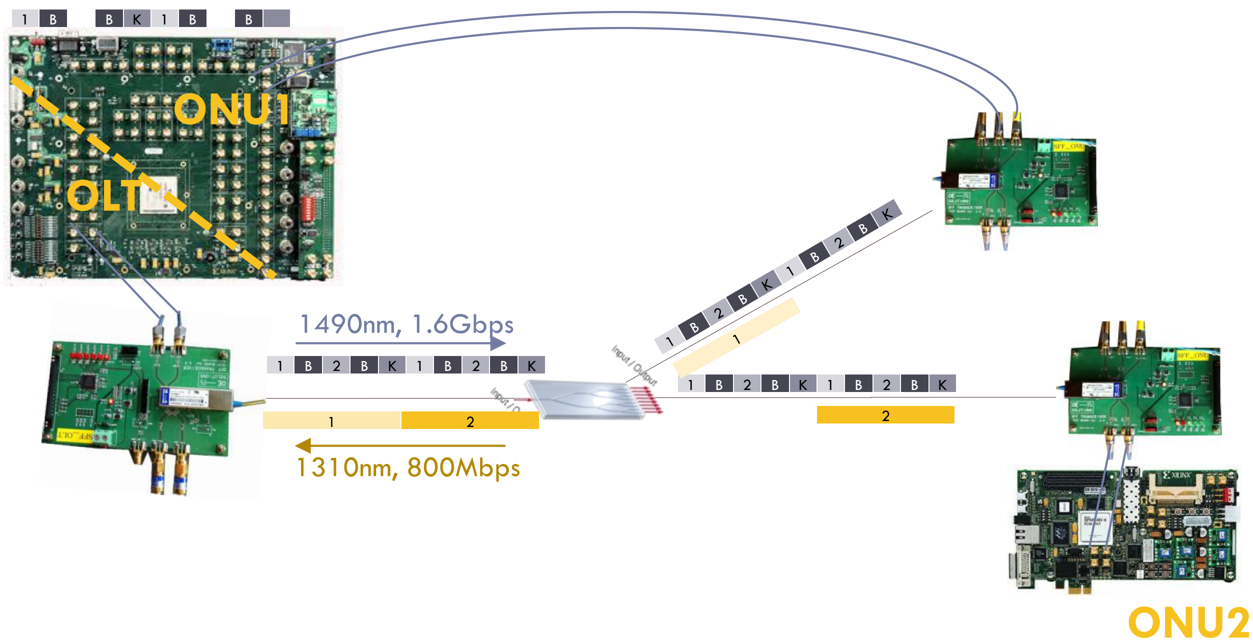
TTC-PON PROOF OF CONCEPT [2010]



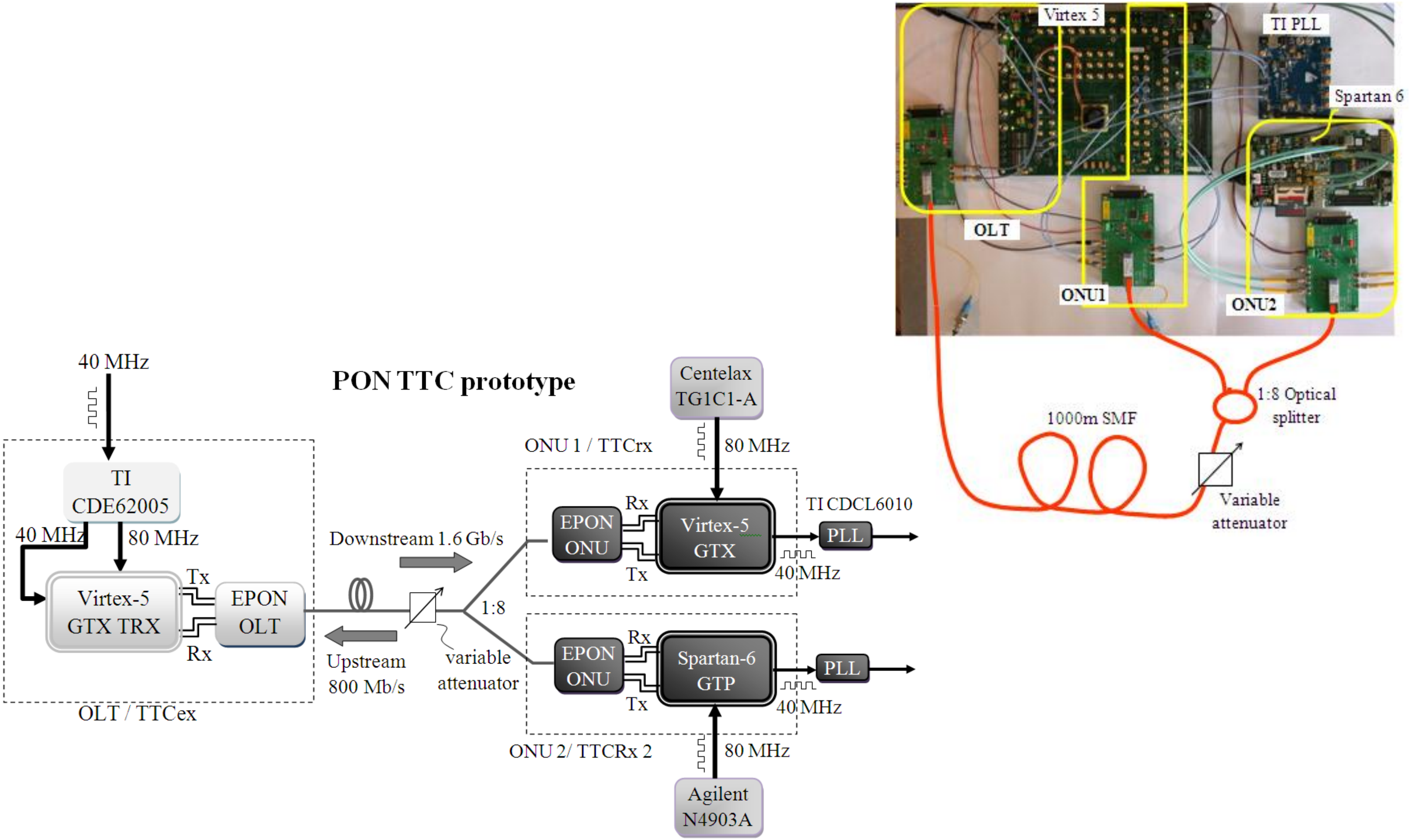
Study conducted by I. Papakonstantinou (Aceole Fellow, now at UCL), Csaba Soos (CERN/PH/ESE) and the Opto Team of PH/ESE/BE.

And documented :

•*Passive Optical Networks in Particle Physics Experiments*, Ioannis Papakonstantinou, 24th November 2009, PH-ESE Seminar

•*A Fully Bidirectional Optical Network with Latency Monitoring Capability for the Distribution of Timing-Trigger and Control Signals in High-Energy Physics Experiments,* Ioannis Papakonstantinou et al., IEEE TNS, Aug. 2011.

TTC-PON PROOF OF CONCEPT [2010]

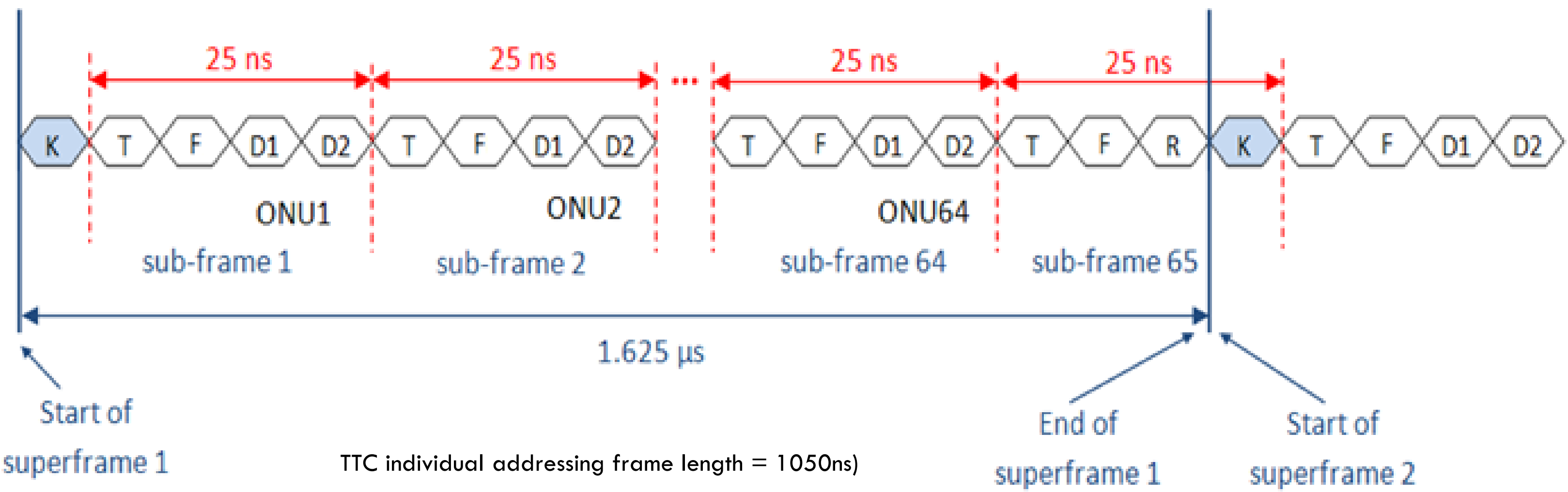


TTC-PON PROOF OF CONCEPT [2010]

- Raw rate 1.6Gbit/s
- Arbitrary protocol for 64 ONUs
- Synchronous transmission of super-frames with a period of 1625ns = 65*25ns at 1.6Gbit/s
- 8b/10b encoding (1Field = 1 symbol)
- 590.8 Mb/s broadcast only
- 9.23 Mb/s per ONU

Downstream Protocol

Field	Operation
<K>	Frame alignment and synchronization
<T>	L1A trigger accept decision, real time transmission
<F>	Auxiliary, to be defined in the future (could be used for upstream channel arbitration to reduce buffering capacity)
<D1>, <D2>	Broadcasted/individually addressing commands (depending on first bit of D1)
<R>	Upstream channel arbitration (address of the next ONU allowed to transmit upstream)

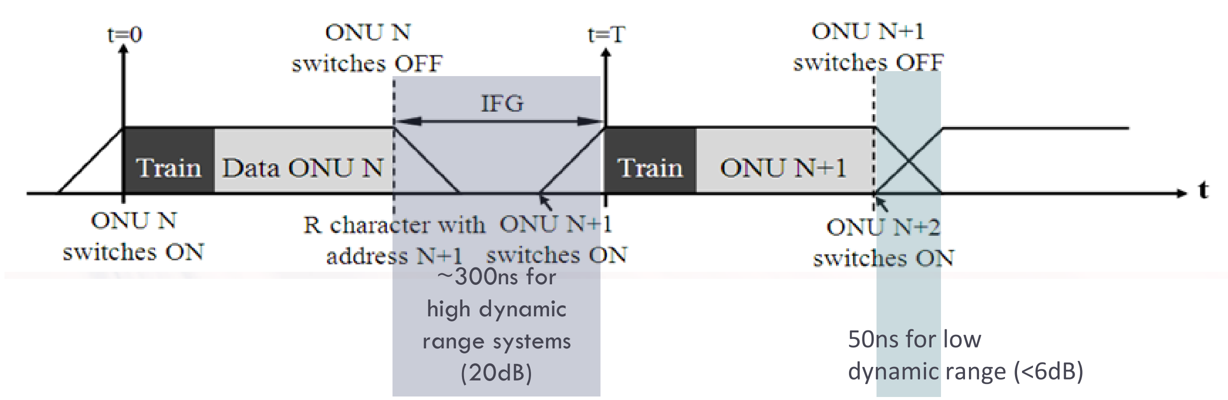


TTC individual addressing frame length = 1050ns)

TTC-PON PROOF OF CONCEPT [2010]

Upstream Protocol

- **Channel arbitration** at the OLT (based on a simple round-robin scheme)
- Slave (ONU) N1 receives an R/F character with its address and switches its laser ON
- OLT deserializer works in burst mode
- **Inter Frame Gaps** between successive emissions allows OLT receiver to adapt between bursts (dynamic threshold)
- Long sequence of idle bytes for CDR & frame alignment
- 4 bytes of payload
- Total BW 800Mb/s
- Latency not fixed but bonded



TTC-PON PROOF OF CONCEPT [2010]

Compared Performance wrt TTC legacy

	Properties	1G-PON Proof-of-concept	TTC legacy
↑↓	Clock Rate Distance Splitting Ratio Encoding	40 MHz 100 m - 1000 m Flexible, Up to 64 NRZ 8b/10b	40 MHz 100 m -1000m Flexible, up to 32 BPM
↓	Bit Rate Wavelength	1.6 Gb/s 1490 nm	160 Mbps 1310 nm
	TRIGGERS Trigger Rate Trigger Type Latency Encoding	 40 MHz, unconstrained Synchronous, 8 to 32 bits Fixed and Deterministic, 9BX 8b/10b	 40MHz, but max 11 consecutive Asynchronous Fixed and Deterministic, 4BX None
	DATA Error Detection Error Correction Broadcast Payload Individual Payload Recovered Clock Jitter	 1 bit (8b/10b) - 590Mbps 9.2Mbps guaranteed per ONU if 64 ONUs 25ps rms out of the FPGA (no extra PLL)	 2 bits 1 bit (Hamming) 20Mbps 7.6Mbps to be shared between Rx 25ps rms out of the TTCrx (no QPLL)
↑	Bit Rate Wavelength Latency Payload BW Allocation	800 Mb/s 1310 nm Bonded, split ratio related. 1:8 => 2us,1:64 => 14 us Split ratio related. 1:8 => 18 Mb/s, 1:64 => 2.2Mb/s TDMA, Fixed, Round Robin	X

TTC-PON PROOF OF CONCEPT [2010]

Compared Performance wrt TTC legacy

	Properties	1G-PON Proof-of-concept	TTC legacy
↑↓	Clock Rate	40 MHz	40 MHz
	Distance	100 m - 1000 m	100 m -1000m
	Splitting Ratio	Flexible, Up to 64	Flexible, up to 32
	Encoding	NRZ 8b/10b	BPM
↓	Bit Rate	1.6 Gb/s	160 Mbps
	Wavelength	1490 nm	1310 nm
	TRIGGERS		
	Trigger Rate	40 MHz, unconstrained	40MHz, but max 11 consecutive
	Trigger Type	Synchronous, 8 to 32 bits	Asynchronous
	Latency	Fixed and Deterministic, 9BX	Fixed and Deterministic, 4BX
	Encoding	8b/10b	None
	DATA		
	Error Detection	1 bit (8b/10b)	2 bits
	Error Correction	-	1 bit (Hamming)
	Broadcast Payload	590Mbps	20Mbps
	Individual Payload	9.2Mbps guaranteed per ONU if 64 ONUs	7.6Mbps to be shared between Rx
	Recovered Clock Jitter	25ps rms out of the FPGA (no extra PLL)	25ps rms out of the TTCrx (no QPLL)
↑	Bit Rate	800 Mb/s	X
	Wavelength	1310 nm	
	Latency	Bonded, split ratio related. 1:8 => 2us,1:64 => 14 us	
	Payload	Split ratio related. 1:8 => 18 Mb/s, 1:64 => 2.2Mb/s	
	BW Allocation	TDMA, Fixed, Round Robin	

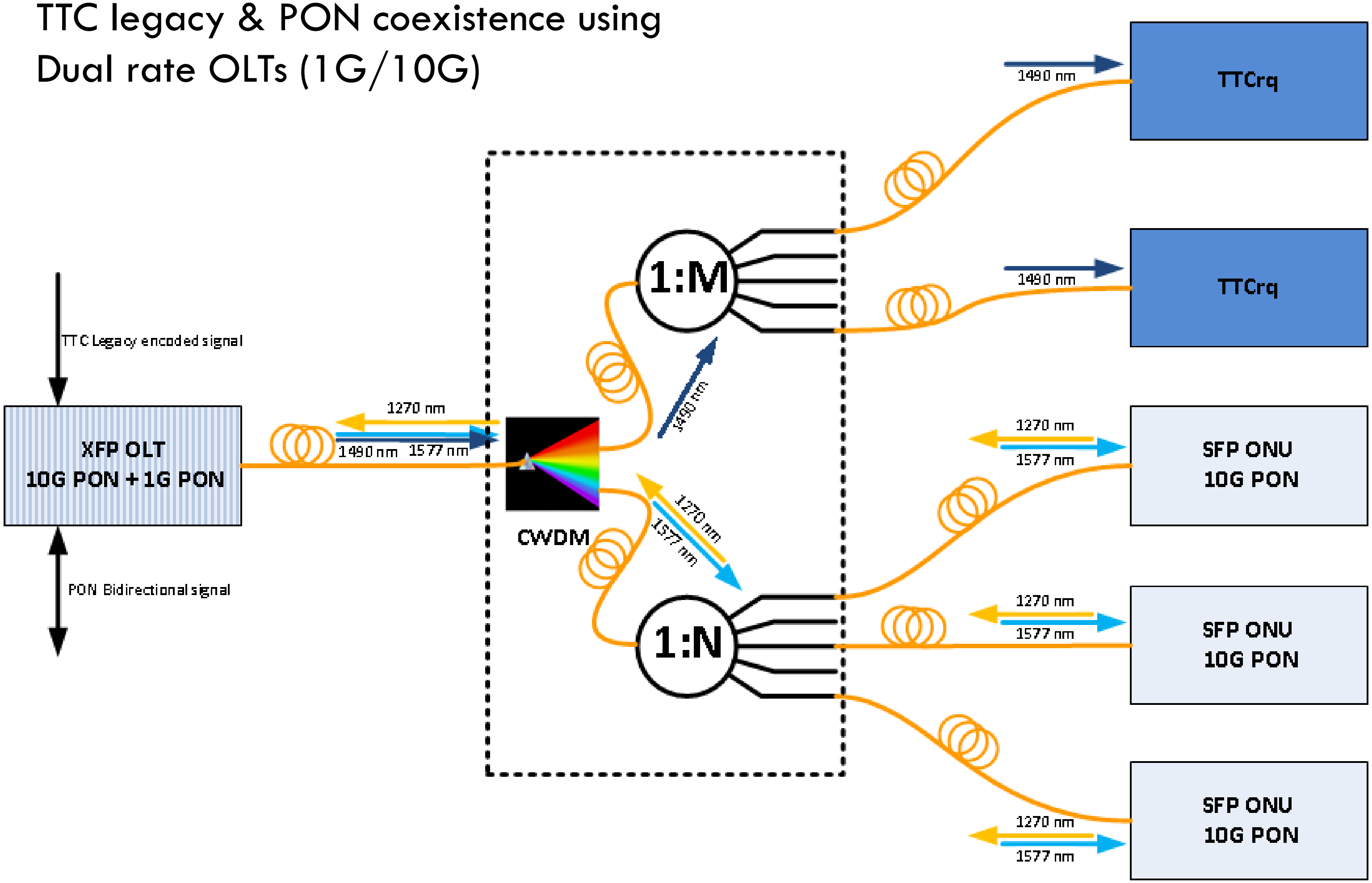
Preliminary results based on the simple proof of concept

TTC-PON PROJECT – LAUNCHED!

- First prototype very promising
- Still space for improvement on downstream trigger latency and upstream busy transmission
- Many ideas to optimize this early proof-of-concept
  - busy latency optimization: improving protocol upstream
  - TTClegacy & PON coexistence: using 10G-1G PON overlay products
  - Trigger latency: improve the serdes logic
  - Other multiplexing techniques (Wavelength multiplexing (WDM), Orthogonal Codes (CDMA)) to be investigated in partnership with UCL University College London
- A Doctoral student started in October on this project

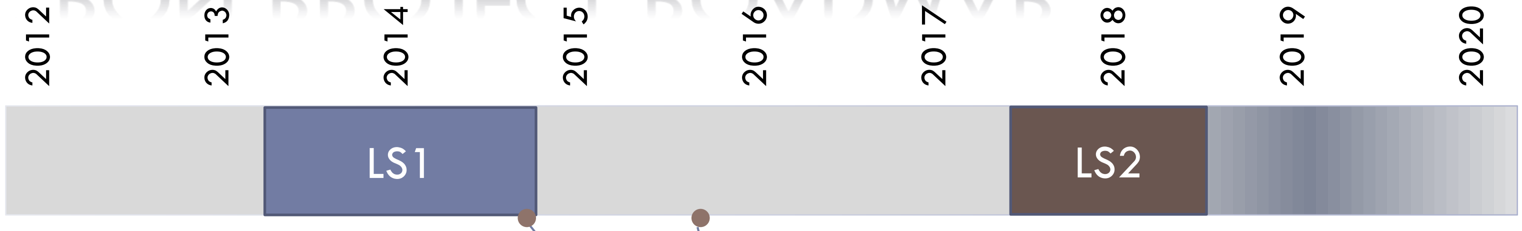
TTC LEGACY & PON COEXISTENCE IDEA

TTC legacy & PON coexistence using
Dual rate OLTs (1G/10G)



Courtesy of D. M. Kolotouros

TTC-PON PROJECT ROADMAP



- TDMA investigations (using evaluation kits)
- Specification with experiments

Propose solutions to experiments@ TWEPP15

Present TDMA-based prototype @ TWEPP14

Prototyping, qualification and commissionning of a demonstrator within CMS TTC upgrade (FMC based)

Investigation on other multiplexing schemes with UCL (CDMA, WDM)

Prototyping, pre-production

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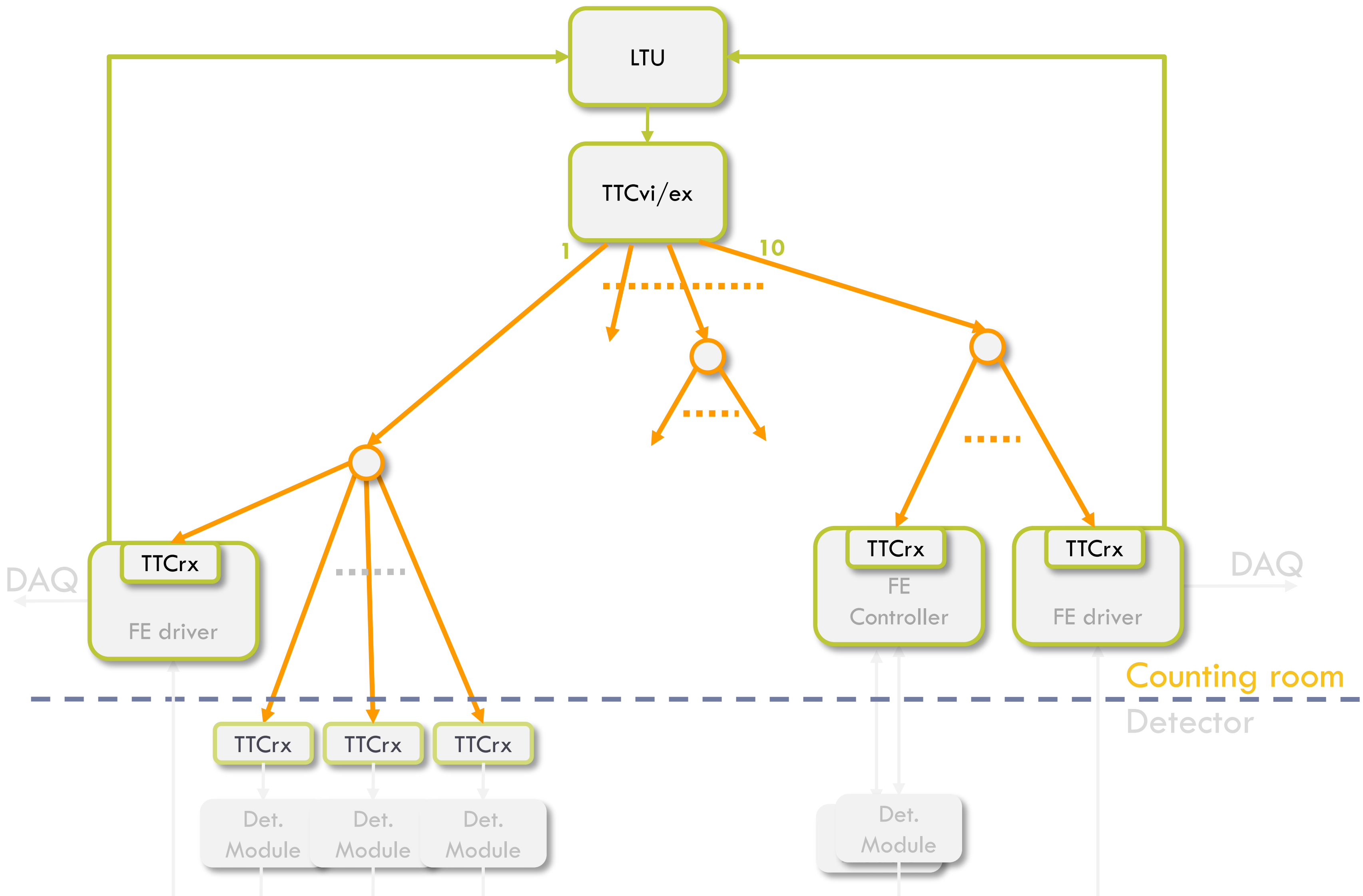
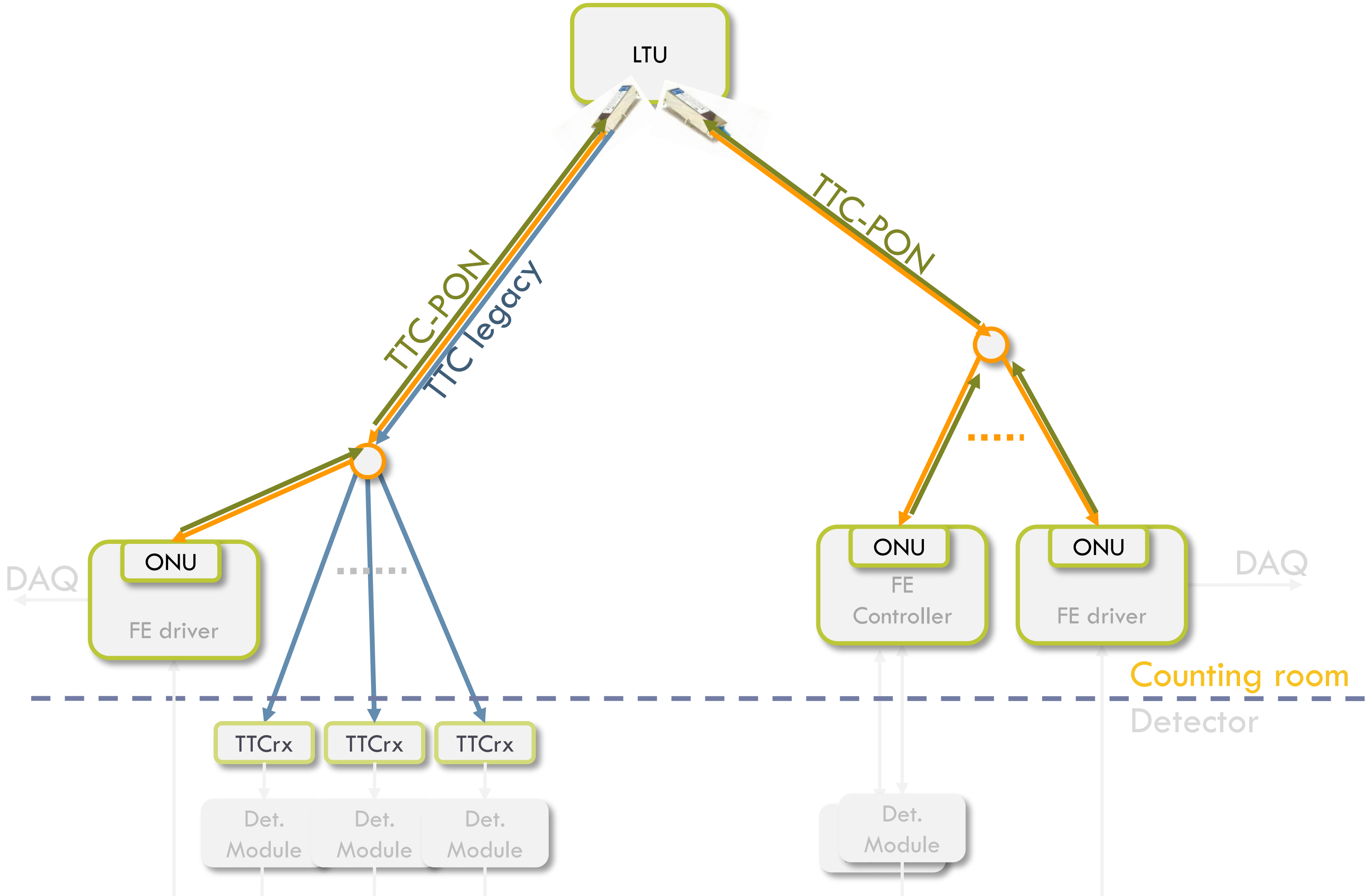
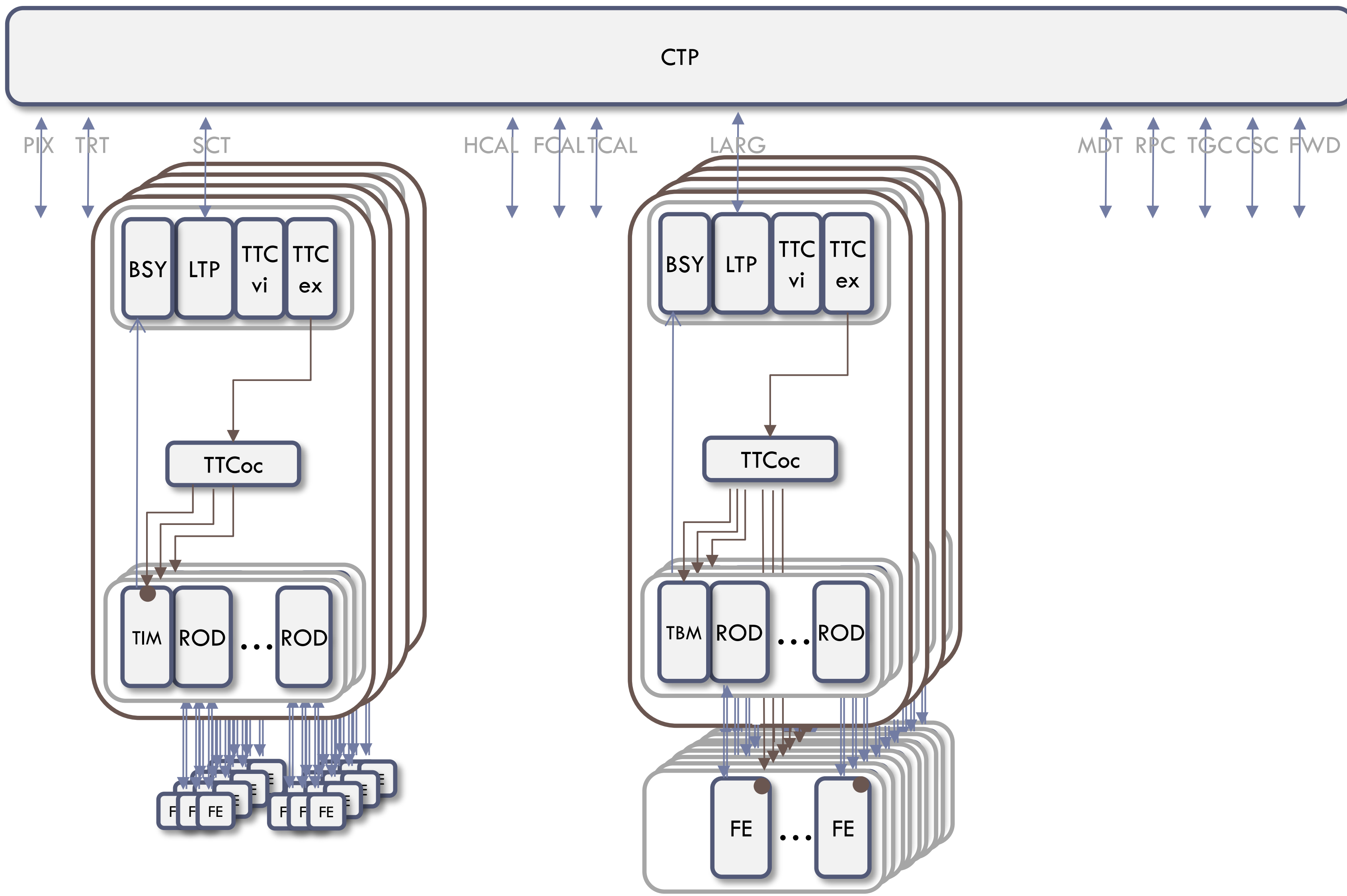
FROM [GENERIC] TTC



TO [GENERIC] TTC-PON



EXAMPLE: WHAT PON COULD BRING TO ATLAS



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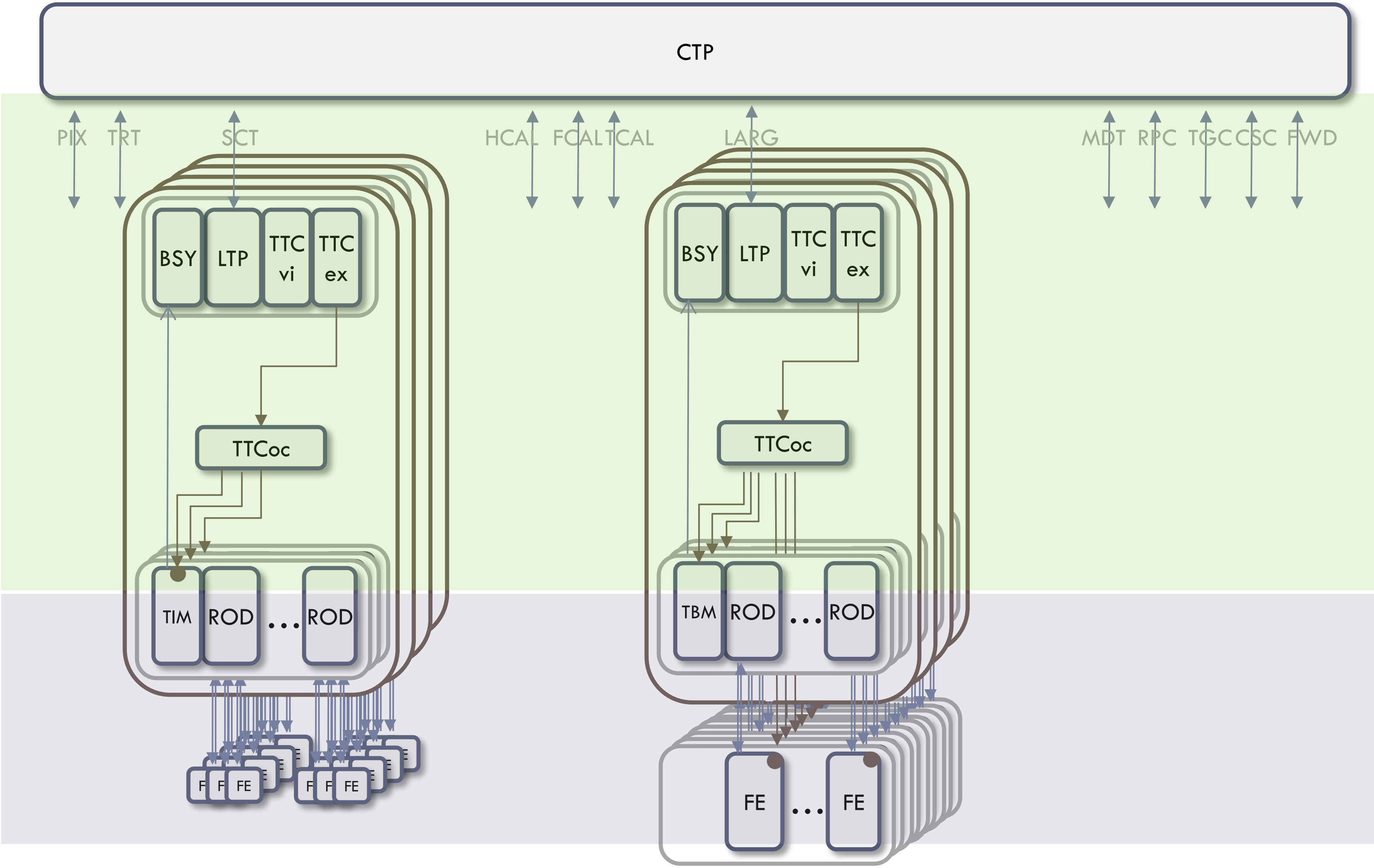

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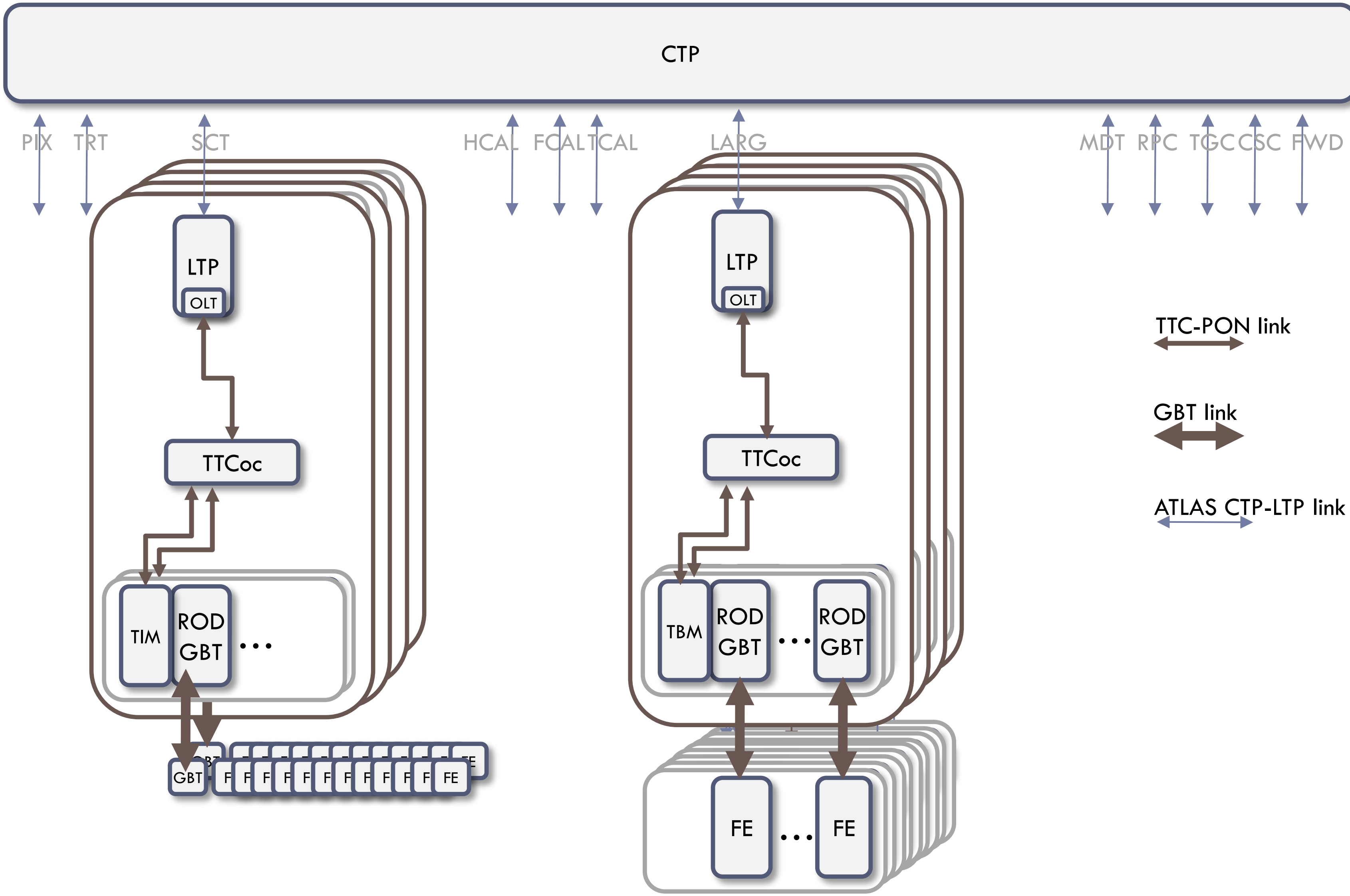

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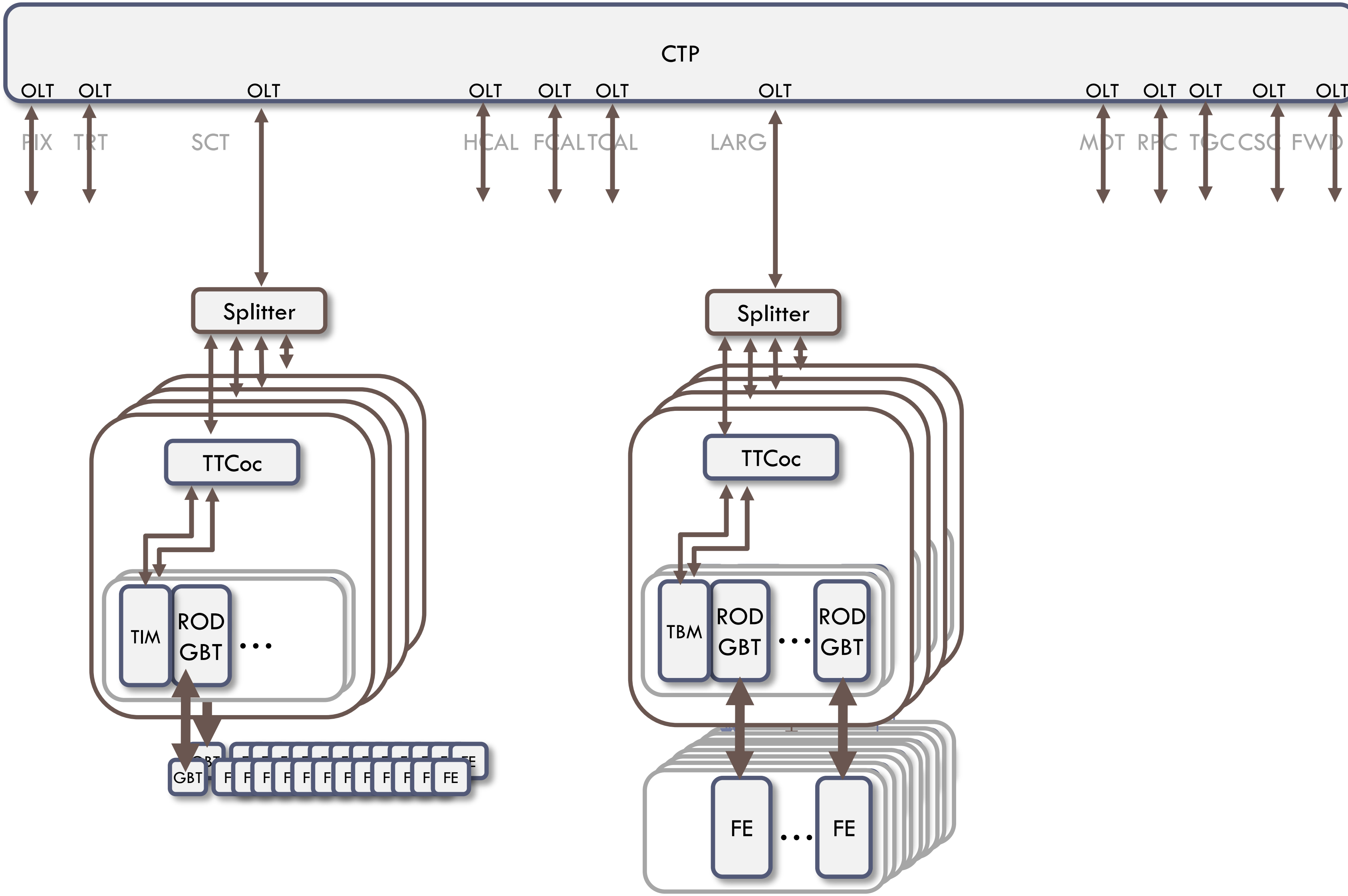
TRT
SCT
HCAL
FCAL
TCAL
LARG
MDT
RPC
TGC
CSC
FWD
LTP
OLT
TTCoc
TIM
ROD
GBT
TBM
FE
TTC-PON link
GBT link
ATLAS CTP-LTP link

OR THIS …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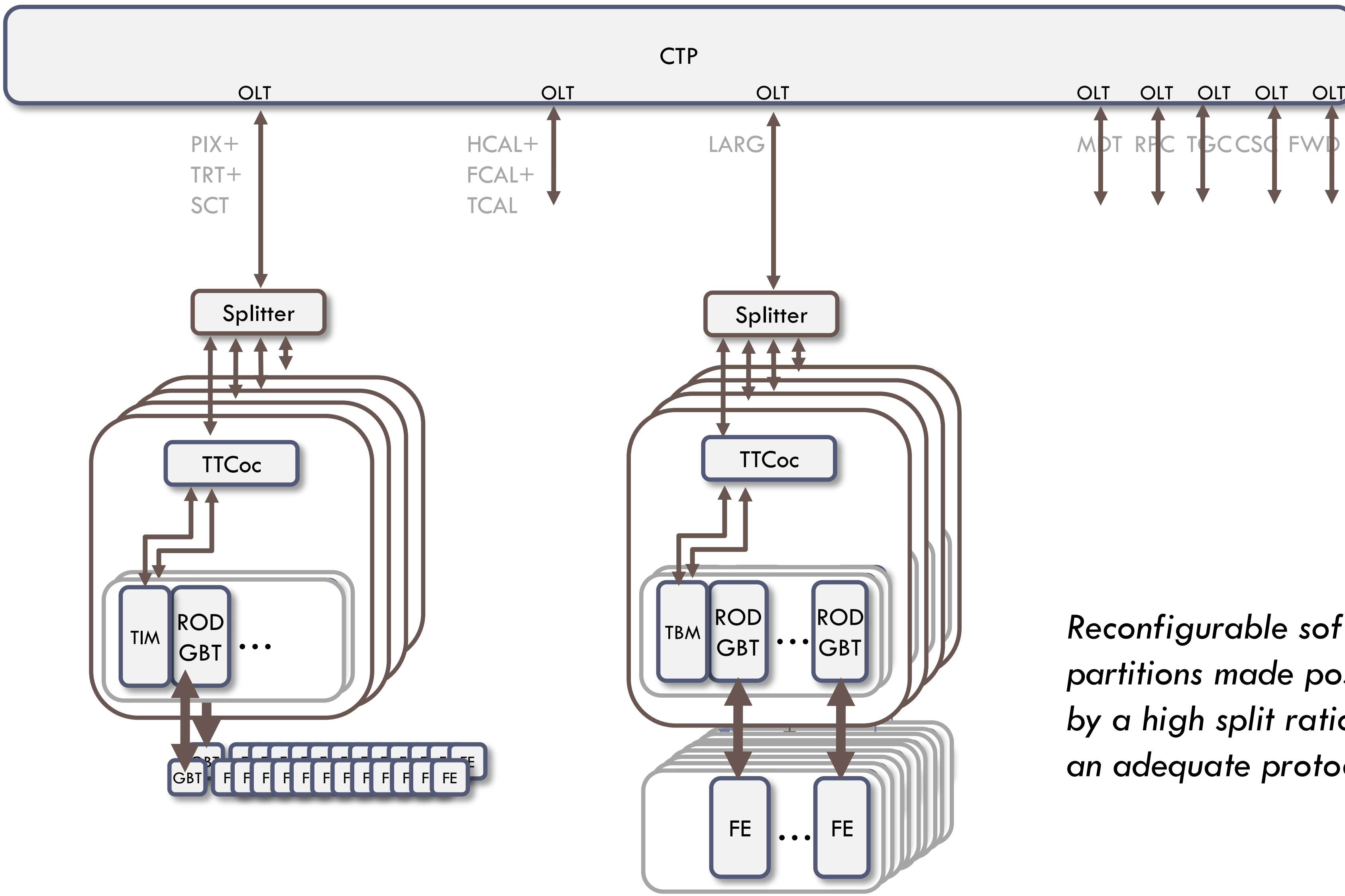
OR EVEN THIS …



Reconfigurable soft partitions made possible by a high split ratio and an adequate protocol

CONCLUSION

TO CONCLUDE …

- The TTC [off detector] needs an upgrade
- TTC-PON will propose solutions for LS2
  - We are currently investigating several topologies
- PON is an ideal candidate
  - Matches very well our needs
  - Opens doors for software partitionning
  - Garanties available COTS for a very long timescale

THIS THE MOMENT TO SHARE YOUR NEEDS

- Please contact sophie.baron@cern.ch if
  - You want more information
  - You would like to know how TTC-PON could fit in your system
  - You want to give us feedback on requirements, limitations, constraints for the TTC-PON project
- and visit our project web site:

http://cern.ch/TTC-PON

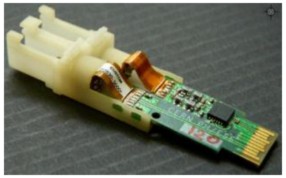
THANK YOU

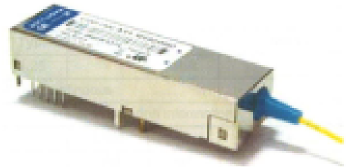
SPARE SLIDES

PON AND RADIATIONS

Typical SFP (2 fibers):
- TID < 1 krad = works fine
- TID ~10 krad = micro controller fails (for all types of commercial SFPs, test made by Versatile Link community this year)

ONU SFP @ 100krad:
- Impossible to use commercial components
- Need of a custom design with for example:
  - A rad-tol FPGA for the control (especially burst mode)
  - A versatile transceiver module (designed by ESE/BE)
  - A 2:1 splitter to match IN and OUT fibers into 1 single fibre





OLT XFP @ xxx rad (Trigger zone)
- Need to be qualified

TTC-PON 2010 Demonstrator Performance

Current TTC and PON-TTC Downstream latency characteristics

PON-TTC	Latency	Current TTC	Latency
GTX Tx	75 ns	TTCex	25 ns
EPON OLT Tx	2.11 ns		
EPON ONU Rx	2.16 ns	TTCrx	65-85 ns
GTX-GTP Rx	137.5 ns		
Total	**216.8ns**	Total	**90-110 ns**
Optical Fiber	5ns/m	Optical Fiber	5ns/m

PON-TTC Jitter characteristics

Point of Measurement	RMS C2C Jitter (ps)
Ref 40MHz	3.17
Recovered 40 MHz, ONU1 Filtered 40 MHz, ONU1	36.72 **3.6**
Recovered 40 MHz, ONU2 Filtered 40 MHz, ONU2	53.12 **3.8**

Min Upstream Frame Duration Breakdown Analysis

Field	1G-EPON (Current)	10G-EPON	2GPON	10GPON
Overlapping IFG (ns)	50	50	16	16
Training (ns)	125	12.5	62.5	12.5
4B Payload (ns)	40	4	20	4
Total per frame (ns)	**215**	**66.5**	**98.5**	**32.5**
No. of bunch-cycles between transmissions	9	3	4	2

TTC-PON PROOF OF CONCEPT (2010)