

Can PON technologies accelerate 5G deployments?

Workshop

“Optical technologies in the 5G Era”

ONDM Conference 2018 (Dublin, 17.5.2018)

Thomas Pfeiffer, Nokia Bell Labs (Stuttgart)

with inputs from Pascal Dom, Sarvesh Bidkar, and Francois Fredricx

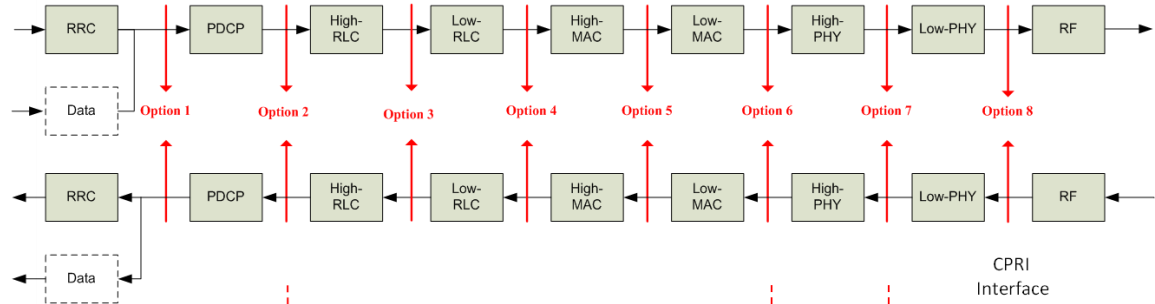
Considerations

- what are possible use cases where PON is beneficial for backhaul or fronthaul?
- can we leverage FTTx network deployments for fiber links in 5G?
- what are critical technical requirements and how can PONs meet them?
- is it only about cost, or are PONs in specific cases even more performant for x-haul than other transport technologies?
- ...

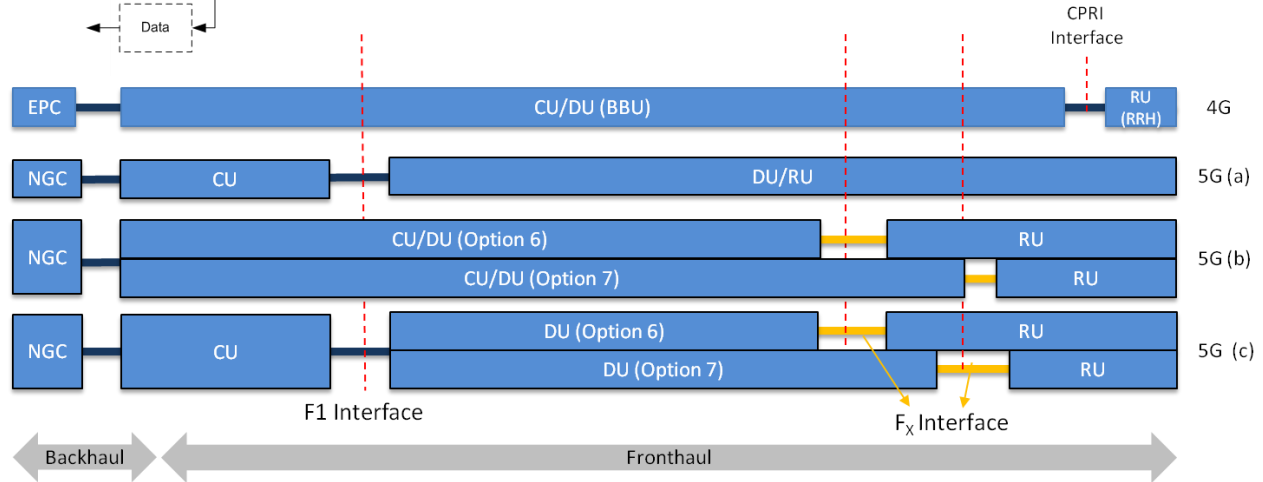
New functional split architectures of base stations

Reducing the general 3GPP model to few relevant split points

3GPP split architecture
(cf. TR 38.801)



reduced model
accounting for the
split points chosen
by 3GPP for x-haul
(cf. G.sup.5GP)



Bandwidth and latency requirements in NGFH architectures

3GPP Release 14, TR 38.801 V14.0.0 (2017-03)

Protocol Split option	Required DL bandwidth	Required UL bandwidth	Max. allowed one way latency [ms]
Option 1	4Gb/s	3Gb/s	1 – 10 ms
Option 2	4016Mb/s	3024 Mb/s	
Option 3	[lower than option 2 for UL/DL]		
Option 4	4000Mb/s	3000Mb/s	100 – few 100 μ s
Option 5	3000 Mb/s	4000Mb/s	
Option 6	4133Mb/s	5640 Mb/s	
Option 7a	10.1~22.2Gb/s	16.6~21.6Gb/s	
Option 7b	37.8~86.1Gb/s	53.8~86.1 Gb/s	
Option 7c	10.1~22.2Gb/s	53.8~86.1Gb/s	
Option 8	157.3Gb/s	157.3Gb/s	

Latencies

„*non-realtime*“: msec, service related

„*realtime*“: μ sec, RAT related

Bandwidths

- Split Option 2:
few percent increase vs. backhaul
- Split Option 6, 7:
order of magnitude decrease vs CPRI

Model calculation for high capacity scenario using LTE models:
100 MHz bandwidth, 256-QAM, 8 MIMO layers, 32 antennas,
2*(7-16) bit per IQ sample
(will be updated when 5G parameters are available)

Which transport solution for which architecture ?

- Future NGFN networks will have to meet widely differing requirements, depending on
 - RAT details: number of antennas, wireless capacity/RF bandwidth, MIMO layers, ...
 - service types:
latency, sporadic/continuous traffic, aggregation on radio and fixed network segment, ...
 - chosen split point
- There will be a need for
 - big static pipes (cf. WDM-PON) for continuous traffic and for high aggregation in the radio segment
 - dynamic pipes (T(W)DM-PON) with statistical multiplexing for aggregating traffic from multiple sites
 - ultra-low latency on the RAT and on the services level (URLLC)
 - convergence with FTTx services on the same network

cost points (capex and opex) will be decisive ...

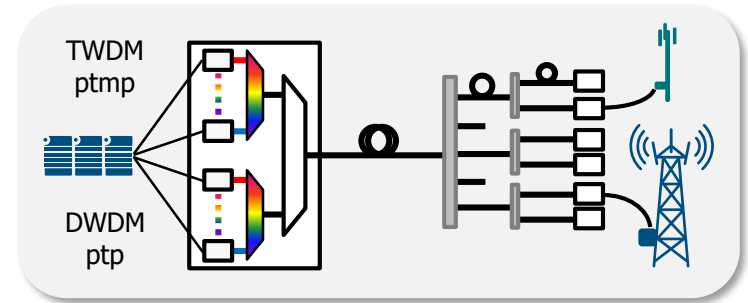
PON variants: state-of-the-art and future evolutions

Available today:

- XGS-PPON (G.9807), NG-PON2 (G.989.x), 10G-EPON (IEEE 802.3)

XGS-PON, NG-PON2: up to 10G per channel over 40 km

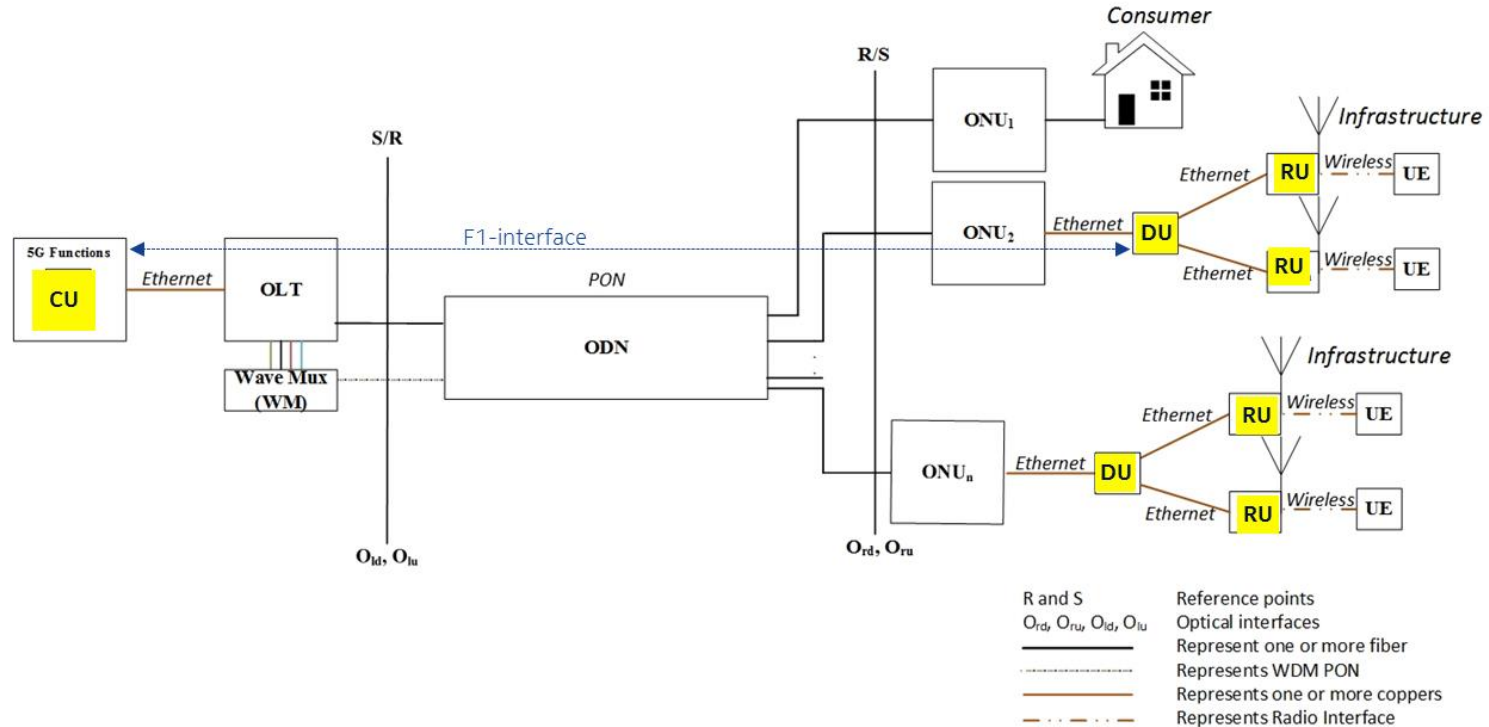
- ptmp: XGS-PON, TWDM-PON
up to 10G/10G, 4 or 8 ch
- ptp: DWDM-PON
any rate (up to about 11G spec'ed in
G.989.2, including native CPRI as client)



tomorrow:

- IEEE, ITU: (1 ... 4) x 25G
- research: tens of wavelengths, high power budgets (optically amplified), long reach (up to 100 km)
(various EU projects, such as PIEMAN, SARDANA, DISCUS)

A) Obvious use case for PON: transport at F1 interface between CU and DU



A) Sample calculation of capacities for air interface and F1 transport

Air interface quiet time
peak data rate for 5G

(Assumptions:
- up to 100 MHz:
sub-6GHz, 256QAM; FDD with
possibly different UL and DL BW
- above 100 MHz:
> 6GHz (256QAM; TDD with
aggregated UL + DL bandwidths)

<i>MIMO</i>	Air Peak data rate (Mbps)						
16	718	1436	2872	7180	19008	38016	76032
8	359	718	1436	3590	9504	19008	38016
4	180	359	718	1795	4752	9504	19008
2	90	180	359	898	2376	4752	9504
1	45	90	180	449	1188	2376	4752
	10	20	40	100	200	400	800
<i>RF Bandwidth (MHz)</i>							

Aggregate F1 data rate;
white, green, yellow cells
indicate compliance with
GPON, 10G PON, 25G PON

<i>MIMO</i>	aggregated F1 interface data rate from a single DU, serving 10 RUs (Mbps)						
16	1465	2930	5860	14649	38780	77560	155120
8	732	1465	2930	7324	19390	38780	77560
4	366	732	1465	3662	9695	19390	38780
2	183	366	732	1831	4848	9695	19390
1	92	183	366	916	2424	4848	9695
	10	20	40	100	200	400	800
<i>RF Bandwidth (in MHz)</i>							

B) Fx-fronthaul (Options 6/7) of small cells in ultra-dense radio networks

conventional Fx-FH C-RAN



C-RAN with local Fx-FH for small cells

distance from CO is limited
by Fx-fronthaul latency (sub-msec)

distance from CO can be as much as allowed
by F1-fronthaul latency (msec)

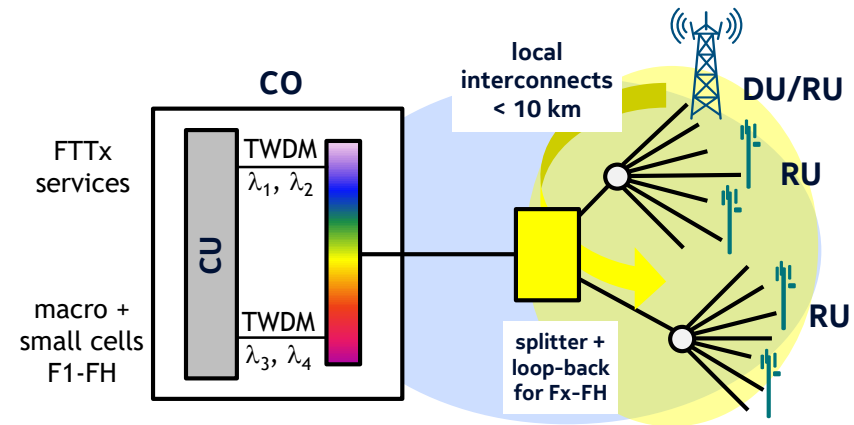
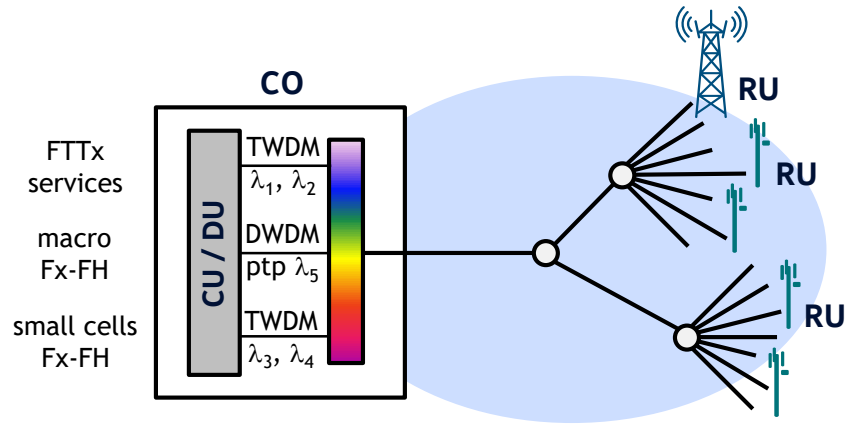
←----- < 10 km ----->

←----- >> 20 km ----->

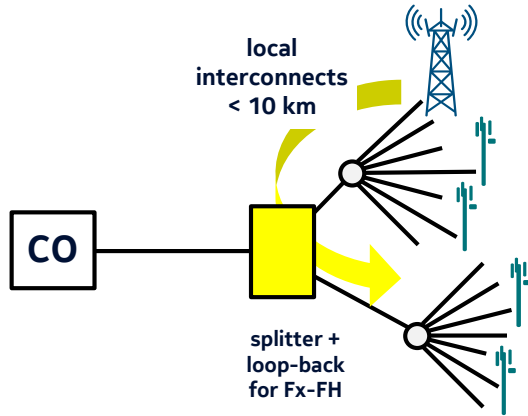
fronthaul from CO to macro + small cells

F1-fronthaul from CO to macro cell

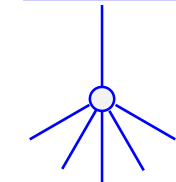
Fx-fronthaul from macro to small cells



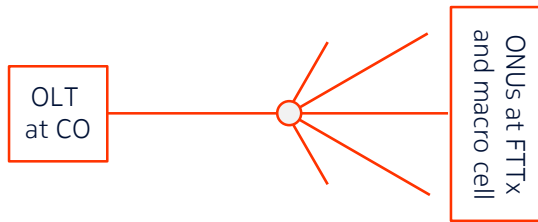
B) Local C-RAN: two independent PONs on the same ODN



short range PON
for Fx-FH on
separate wavelength



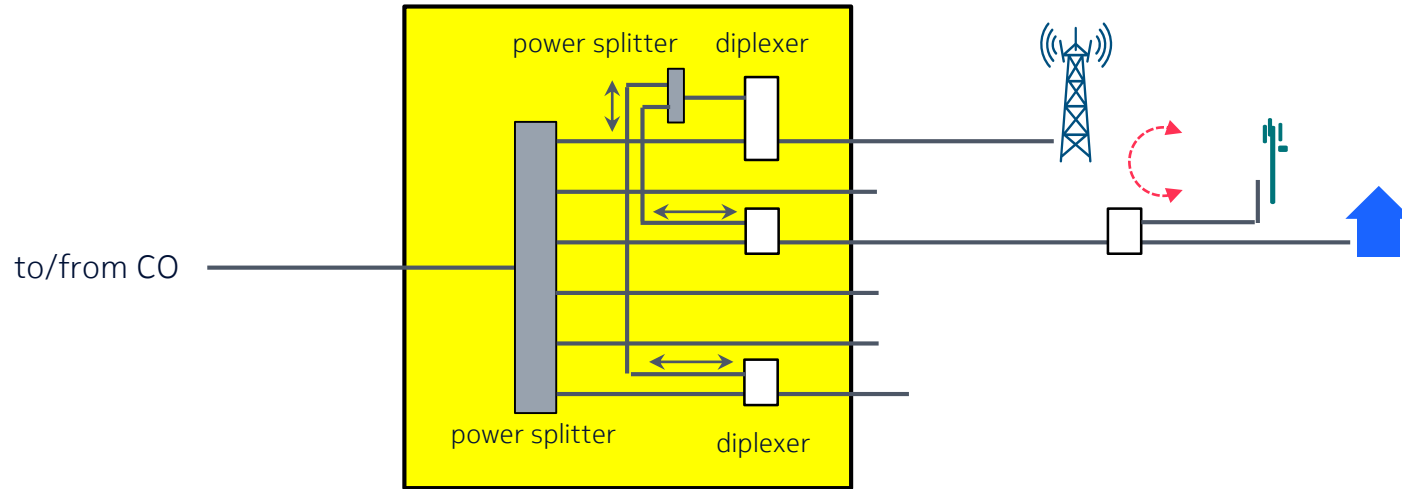
blue ODN
reuses
drop section
of red ODN



long range PON
for FTTx and F1-FH

what's inside the
central splitter + loop-back box?

B) Splitter with additional loop-back for local Fx-FH in WDM overlay

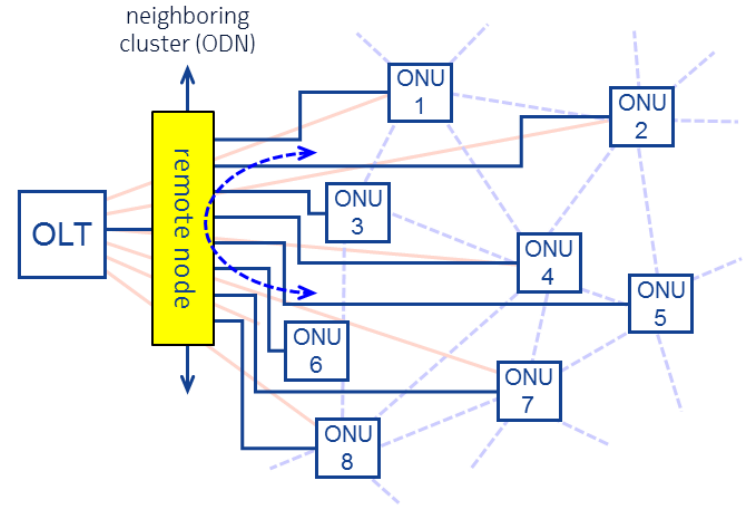
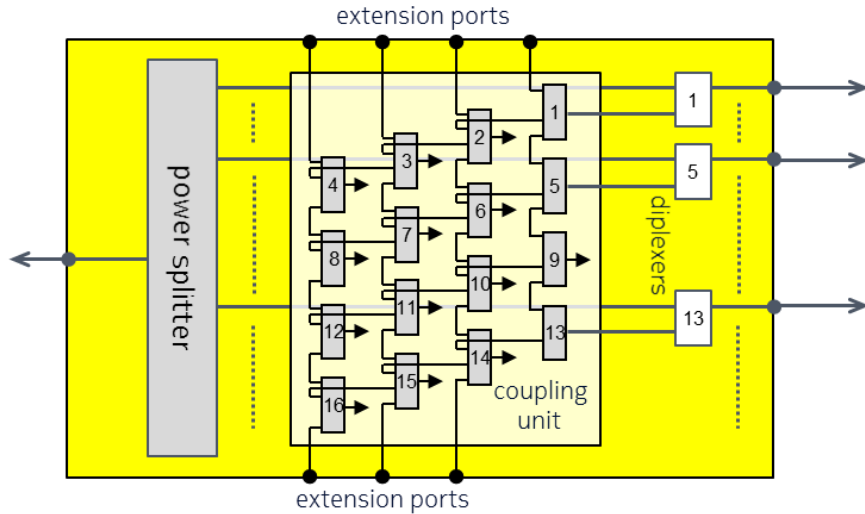


Splitting loss for single stage architecture:

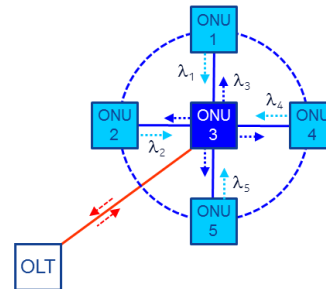
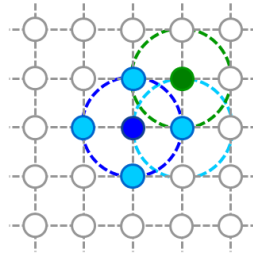
local PON $\sim 1/N_1$ ($< 1/N$)
long distance PON $\sim 1/N$
($N+N_1$ nodes being served on $1/N$ ODN)

- needs N_1+2 additional elements
- port selection for small cells is not flexible

B) For more complex interconnects, with overlapping local clusters for CoMP

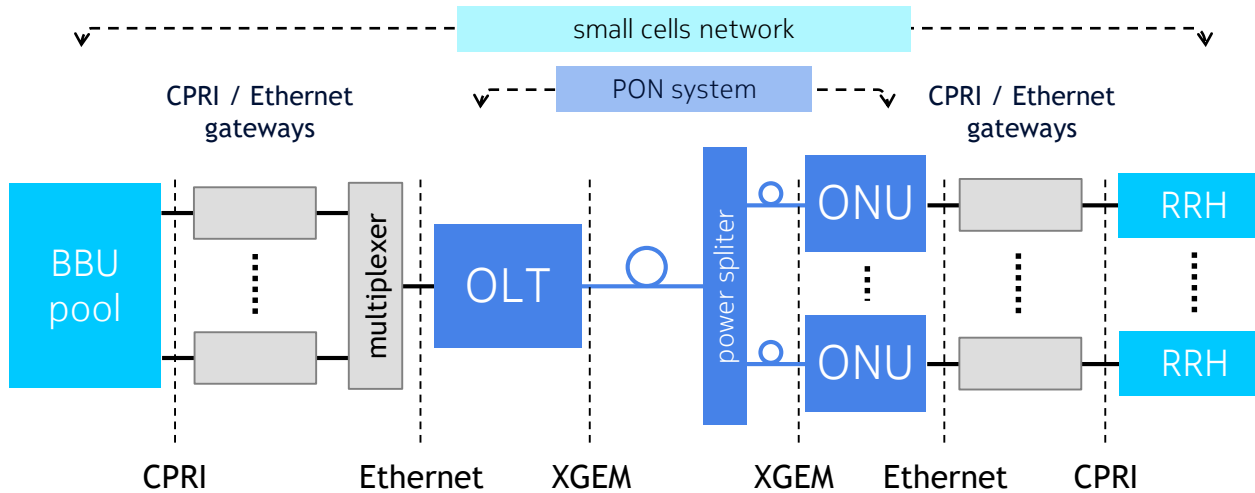


coupling unit establishes a square grid topology for the attached ONUs



- elementary cell:
- each ONU broadcasts data to 4 local neighbours
 - and is attached to the core node via common power splitter

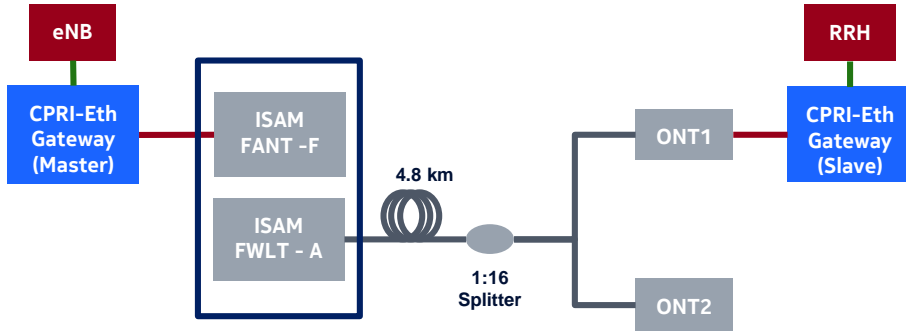
C) Minimizing (CPRI) fronthaul latencies over TDM-PON



Lowest latencies achievable by fixed bandwidth assignment on the TDM-PON network

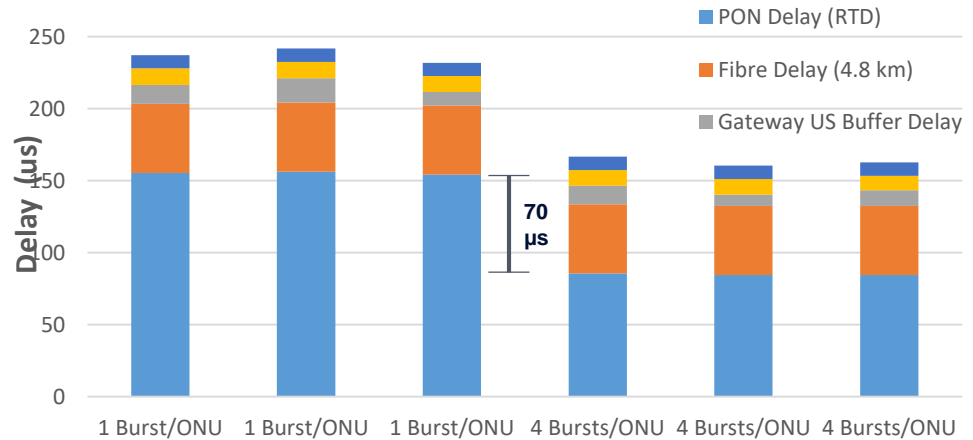
- option a): native CPRI-over-Ethernet:
 - chopping and encapsulating the CPRI stream as is
- option b): Radio-over-Ethernet (not shown)
 - IQ data and C&M data are encapsulated into Ethernet without CPRI framing

C) CPRI latency analysis of demo system using commercial TDM-PON



PON Upstream Burst Configuration		Master Gateway upstream buffer delay (μs)	PON round-trip delay w/o fiber (μs)	Measured CPRI Round-Trip Delay (μs)
1 burst per ONU	Measurement 1	13,02083333	155,341378	237,1669962
	Measurement 2	16,92708333	156,1193612	241,688469
	Measurement 3	9,440104167	154,1520198	231,8435235
4 bursts per ONU	Measurement 1	12,92317708	85,43718082	166,4164449
	Measurement 2	7,877604167	84,41343183	160,9330605
	Measurement 3	10,80729167	84,4341799	162,4512044

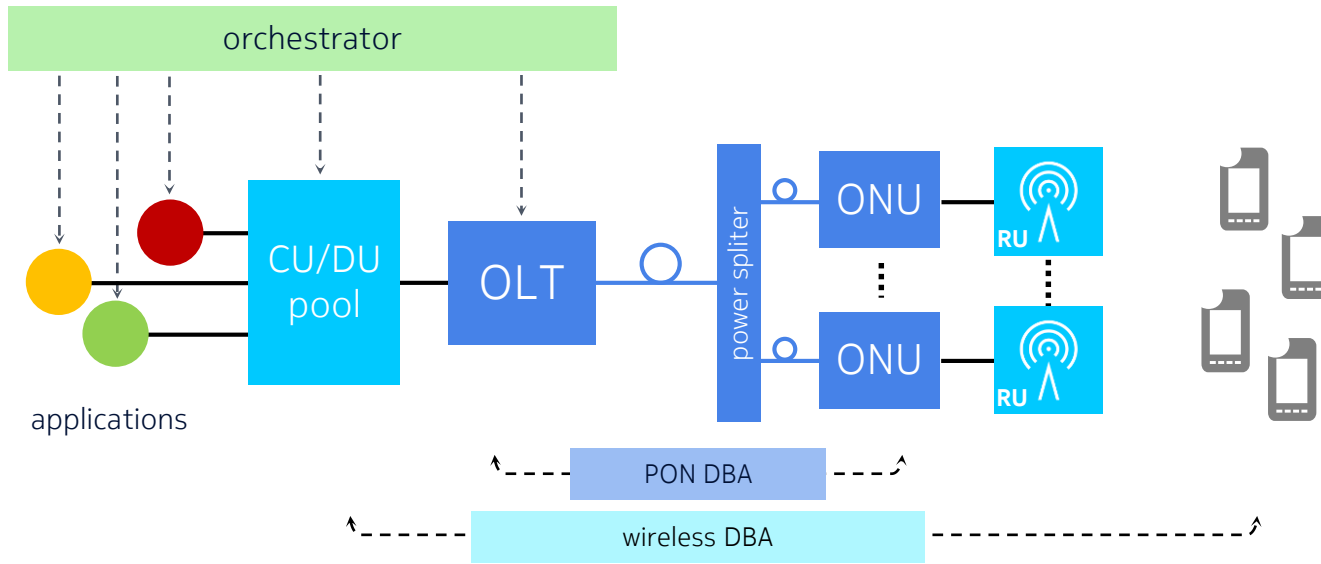
- gateway buffer latency is $\approx 10\text{s } \mu\text{s}$
- 2 x gateway processing delay $\approx 10 \mu\text{s}$
- estimated PON round trip delay is $\approx 85 \mu\text{s}$ with 4 bursts per ONU per $125 \mu\text{s}$ PON frame
- fiber round trip delay $\approx 48 \mu\text{s}$



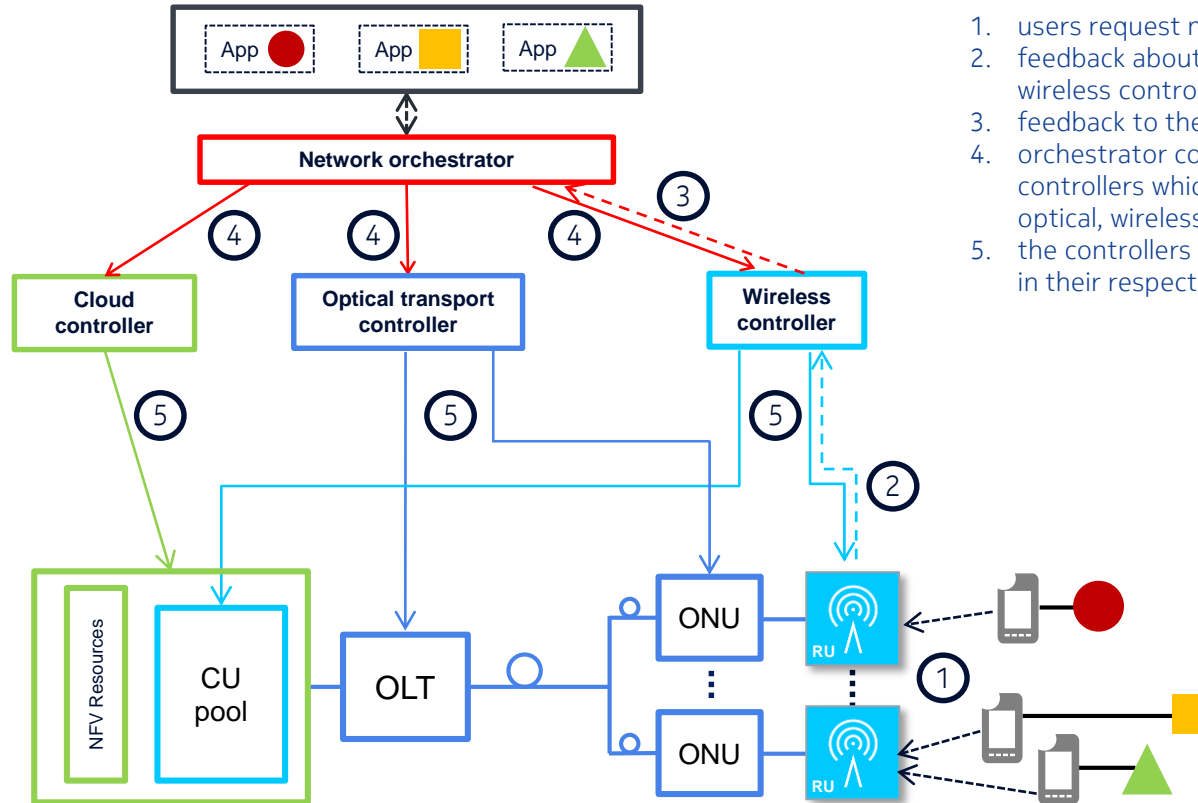
C) Minimizing (eCPRI) Next Generation Fronthaul latencies on TDM-PON

NGFH splits allow for taking advantage of statistical multiplexing gains

- dynamic coordination of wireless and PON capacities according to scheduled traffic : Co-DBA
- SDN type coordination of capacities across applications, radio and PON by a common orchestrator



C) end-to-end coordinated dynamic bandwidth assignment



1. users request new bandwidth
2. feedback about the new requirement to the wireless controller
3. feedback to the network orchestrator
4. orchestrator communicates to the controllers which resources to assign in the optical, wireless and cloud domain
5. the controllers assign the required resources in their respective domain

Summary

Specific use cases considered, particularly with focus on small cells

Bandwidth considerations:

- statistical multiplexing at F1 and Fx interface → TDM-PON

- high aggregate bandwidth on either interface → WDM-PON

Latency and jitter optimization for

- local CRAN in distant areas

- local interconnections for CoMP

- Cooperative DBA (Co-DBA)

- SDN-type orchestration across application – wireless – PON

5G is driving PON technologies towards 25G and beyond,
along with optimized architectures and control plane

NOKIA

Copyright and confidentiality

The contents of this document are proprietary and confidential property of Nokia. This document is provided subject to confidentiality obligations of the applicable agreement(s).

This document is intended for use of Nokia's customers and collaborators only for the purpose for which this document is submitted by Nokia. No part of this document may be reproduced or made available to the public or to any third party in any form or means without the prior written permission of Nokia. This document is to be used by properly trained professional personnel. Any use of the contents in this document is limited strictly to the use(s) specifically created in the applicable agreement(s) under which the document is submitted. The user of this document may voluntarily provide suggestions, comments or other feedback to Nokia in respect of the contents of this document ("Feedback").

Such Feedback may be used in Nokia products and related specifications or other documentation. Accordingly, if the user of this document gives Nokia Feedback on the contents of this document, Nokia may freely use, disclose, reproduce, license, distribute and otherwise commercialize the feedback in any Nokia product, technology, service, specification or other documentation.

Nokia operates a policy of ongoing development. Nokia reserves the right to make changes and improvements to any of the products and/or services described in this document or withdraw this document at any time without prior notice.

The contents of this document are provided "as is". Except as required by applicable law, no warranties of any kind, either express or implied, including, but not limited to, the implied

warranties of merchantability and fitness for a particular purpose, are made in relation to the accuracy, reliability or contents of this document. NOKIA SHALL NOT BE RESPONSIBLE IN ANY EVENT FOR ERRORS IN THIS DOCUMENT or for any loss of data or income or any special, incidental, consequential, indirect or direct damages howsoever caused, that might arise from the use of this document or any contents of this document.

This document and the product(s) it describes are protected by copyright according to the applicable laws.

Nokia is a registered trademark of Nokia Corporation. Other product and company names mentioned herein may be trademarks or trade names of their respective owners.