



Transporting Mobile Traffic : a Demanding Use Case for Optics

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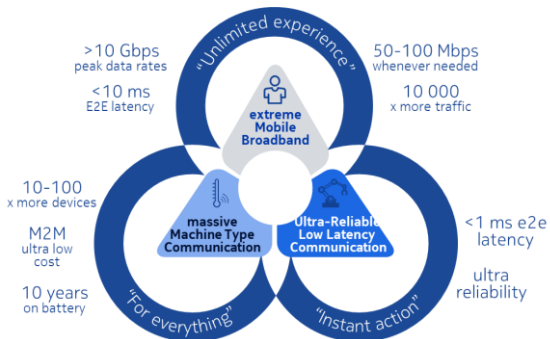
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Summary

- Context: 5G → 5G-Advanced → 6G
- Requirements on pluggable optics
 - Distance / Capacity / Latency / Power / Monitoring / **Synchronization**
- Technologies
- Conclusions

Mobile Generations: More! ... and Less!

5G



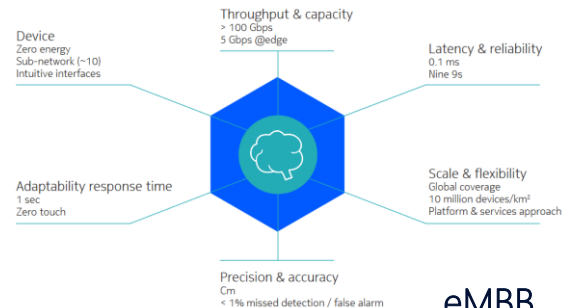
eMBB
URLLC
mMTC

5G-A



eMBB
URLLC
mMTC

6G

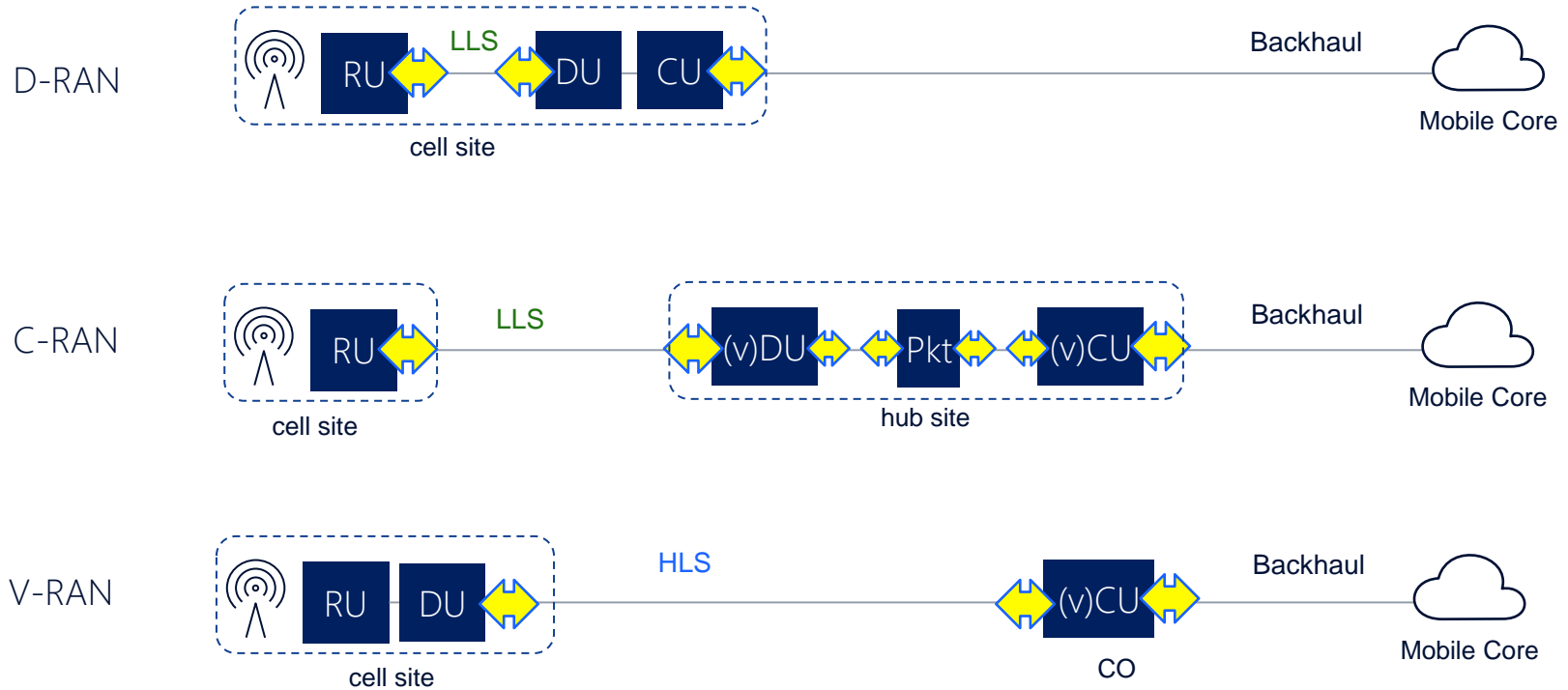


eMBB
URLLC
mMTC

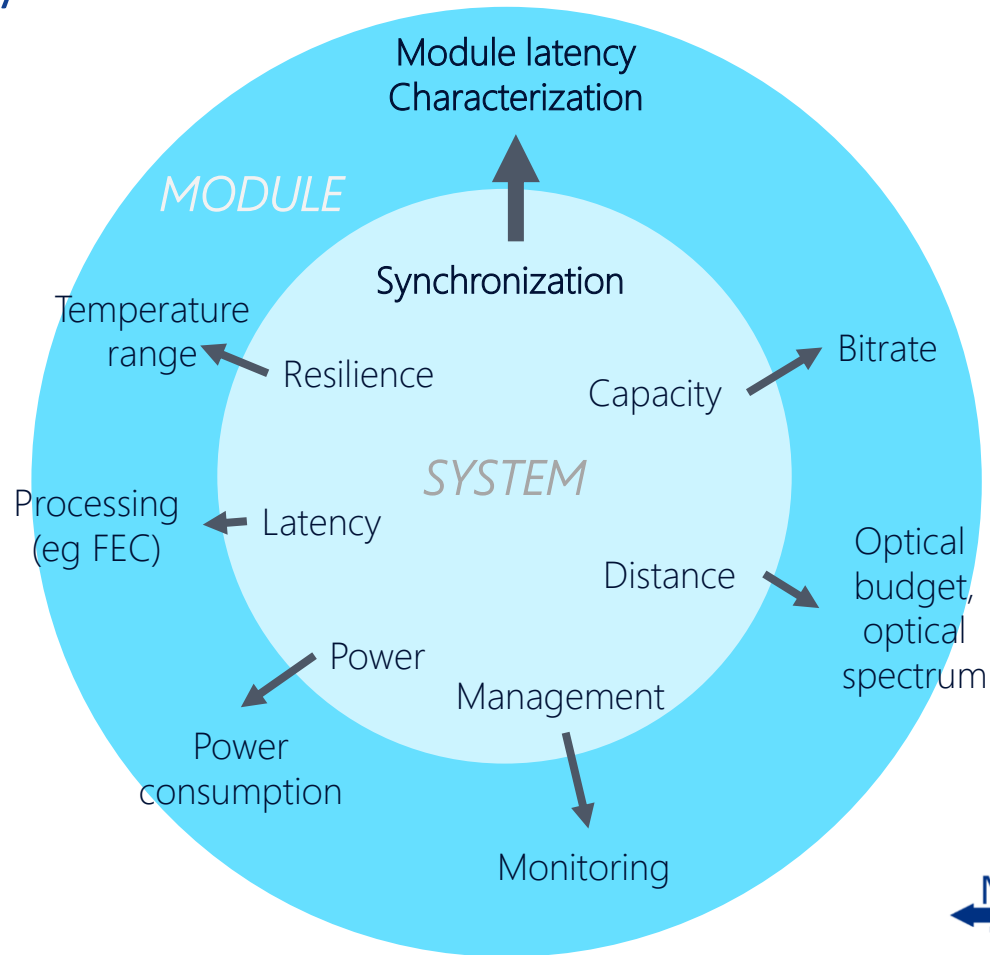
Mobile transport, use cases (MOPA blueprints)



Optical
Pluggable
Module



Requirements: System → Module

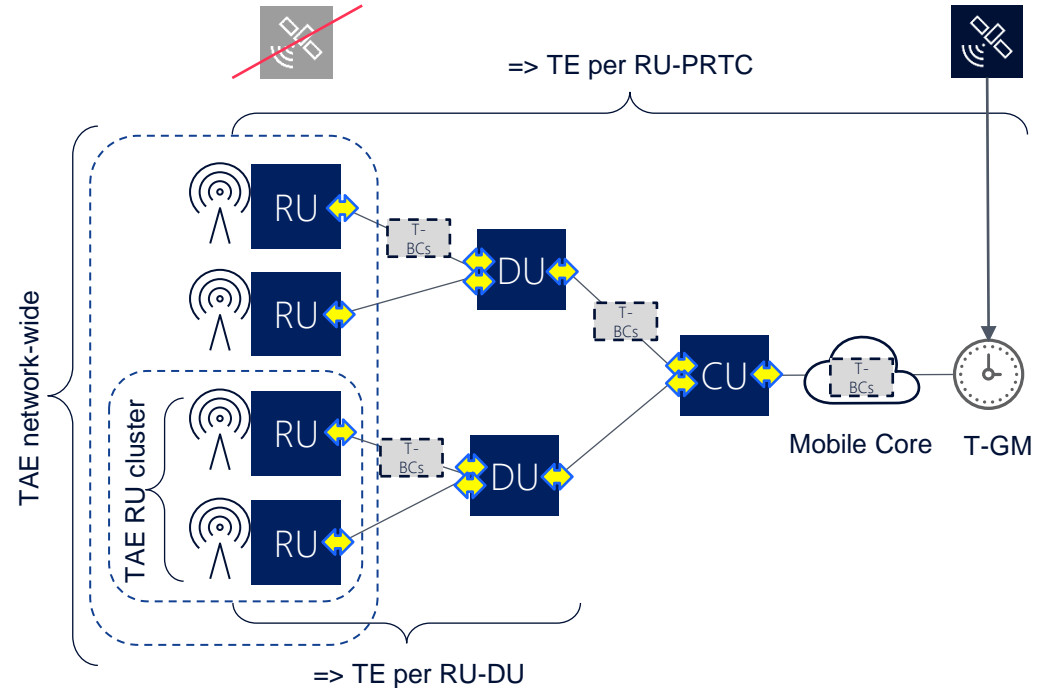


Needs for “tight” synchronization

- Distribution of sync via network (PTP)
- Network-wide sync of all RUs (air interfaces)
 - TAE between any 2 RUs => TE between any RU and PRTC
- mMIMO across cluster of RUs (fronthaul)
 - TAE between any 2 RUs in cluster => TE between any RU and common clock reference
 - Different Categories of accuracy
- Localisation accuracy
 - Very accurate => only for local PtP links



- Classification of intermediate nodes (T-BC)
 - Max cTE and dTE and total TE per Class A / B / C / D node

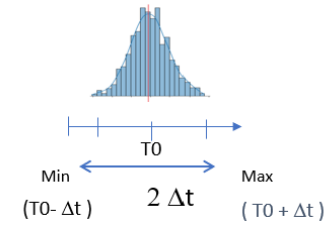


Tight Sync – Importance of module latency

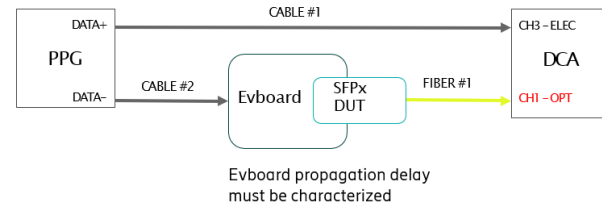
- Synchronization distribution via PTP assumes symmetrical latency in both directions. Known asymmetries can be compensated for.
- Mobile fronthaul poses highly demanding requirements in terms of end-end synchronization accuracy between T-GM and RUs
- Contribution of the pluggables to latency (a)symmetry and hence to cTE can no longer be neglected
- MOPA goal is twofold;
 1. Allow pluggables to be characterized for their typical Tx and Rx latencies so that these can be compensated by PTP
=> **How can they be measured, which info to store in module (EEPROM)**
 2. Allow pluggables to be classified in terms of inaccuracies on their Tx and Rx latencies so that their consumption of the end-end cTE budget can be estimated.
=> **Definition of classes, which info to store in module (EEPROM)**

Module Rx and Tx latencies : Static (typical) and quasi-static (variations) values

- Each module has Rx and Tx latency value
 - a Typical value R_0, T_0
 - + Variations $\Delta R_{max}, \Delta T_{max}$ (when power-cycle, voltage, ...)
- Values to be determined during DVT
 - per type of module and per operating mode (eg speed)
- Measurement requires characterization of test set-up
 - Cables, fibers, Oscilloscopes, ...
- Values to be stored in the module's EEPROM
 - R_0, T_0 : per electrical lane, per operating mode
 - $\Delta R_{max}, \Delta T_{max}$: max over all lanes, per operating mode



T_0 = mean propagation delay at BOL
 $\Delta t = 3\sigma$



Measure the propagation delay across Evboard + DUT Tx + Fiber #1
 Calculate the DUT Tx propagation delay

$$D_{DUT-TX} = D_{Measured} - D_{Evboard} - D_{F1}$$

Module quasi-static values => cTE => Classification

- Starting from T-BC Class (A,B,C) for cTE requirements, defining % spare for optical module (.2, .10, .20)

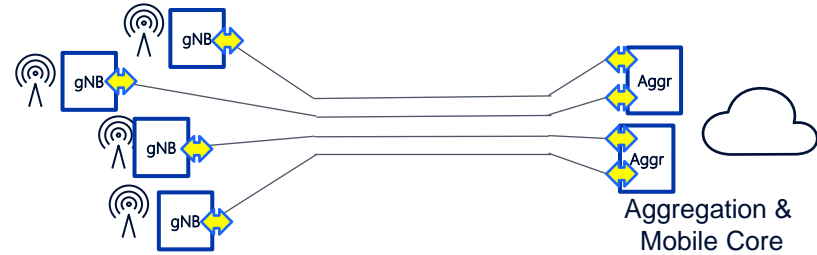
	Class A.10	Class A.20	Class B.10	Class B.20	Class C.2	Class C.10
<i>Max constant time error budget allocated to one pluggable</i>	<i>+/- 5ns</i>	<i>+/-10ns</i>	<i>+/- 2ns</i>	<i>+/- 4ns</i>	<i>+/- 0.2ns</i>	<i>+/- 1ns</i>
	<i>$\Delta T_{max} = +/- 5ns$</i>	<i>$\Delta T_{max} = +/- 10ns$</i>	<i>$\Delta T_{max} = +/- 2ns$</i>	<i>$\Delta T_{max} = +/- 5ns$</i>	<i>$\Delta T_{max} = +/- 0.2ns$</i>	<i>$\Delta T_{max} = +/- 1ns$</i>
	<i>$\Delta r_{max} = +/- 5ns$</i>	<i>$\Delta r_{max} = +/- 10ns$</i>	<i>$\Delta r_{max} = +/- 2ns$</i>	<i>$\Delta r_{max} = +/- 5ns$</i>	<i>$\Delta r_{max} = +/- 0.2ns$</i>	<i>$\Delta r_{max} = +/- 1ns$</i>

Table APB.2: Proposed optical pluggable classes.

Technologies of interest – PtP & Point-to-Multipoint systems (eg TDM PON)

Dedicated point-point optical links

- Accessibility to dark fiber depends on fiber-“richness” of a region and accessibility to (duct) flexibility points

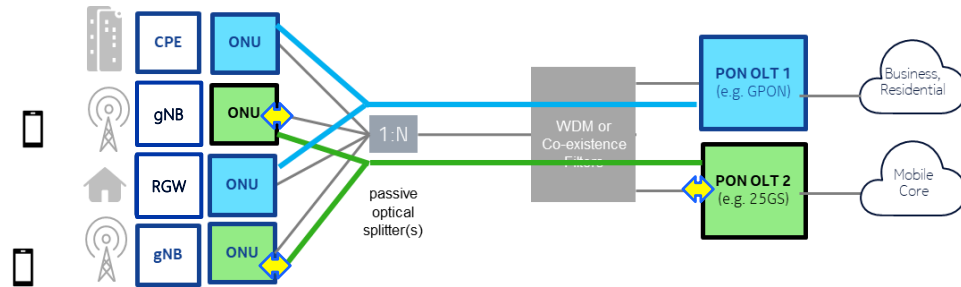


Fiber infrastructure sharing

- Greatly reduces Total Cost of Ownership (TCO) for the Mobile Network Operator
- WDM, Packet aggregation, Point-to-Multipoint
- TCO study by Comsof on example of PON ODN: (white paper “5G Fiber convergence: How to optimize network designs?”)

After analyzing a variety of scenarios (from dense urban to rural), we found that if an FTTH-5G network is anticipated while planning for an FTTH network, the range of cost savings for the 5G fronthaul due to convergence can reach between 65% and 96%.

TDM PON example: 5G in overlay with (existing) Residential PON



Summary – wish list for optical pluggables

- Mobile transport puts **severe** requirements on optical transport



- Replacable (**pluggable**) and **outdoor-grade**
- Rate and distance: **multiple types of optics** beneficial for cost/power (see MOPA blueprints)
- Capable of allowing **tight synchronization**
- **Bidis** are preferred (to re-use installed single fibers)
- Monitoring capabilities **at pluggable level** (w/o need for host)
- Transceivers; any technology that works, but **cost** and **power dissipation** will influence choices
- **PtP connections (grey/WDM/packet)** and **PON systems** are part of the solution space for mobile transport
 - Leveraging installed fiber infrastructure has TCO benefits



Thank you

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