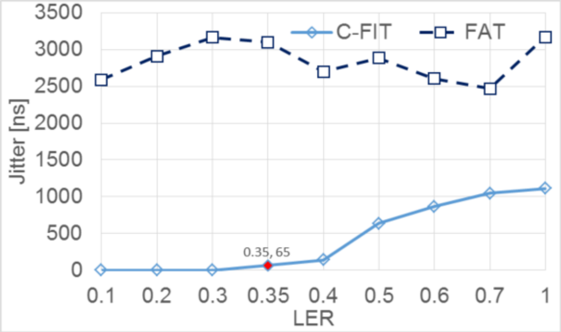
Joint resource allocation for combined fronthaul/midhaul/backhaul using Ethernet

Divya Chitimalla

Motivation for using shared resources in fronthaul/midhaul/backhaul

- Previous study conducted on Jitter tolerance using Ethernet showed that with around 35% utilization we can achieve tolerable 65ns jitter on Ethernet fronthaul
- What to do with rest 65% Ethernet?
- Can we use it to send backhaul/midhaul?



D. Chitimalla, K. Kondepu, L. Valcarenghi, M. Tornatore, and B. Mukherjee, "5G Fronthaul – Latency and Jitter Studies of CPRI over Ethernet ", Journal of Optical Communications (JOCN), submitted 2016.

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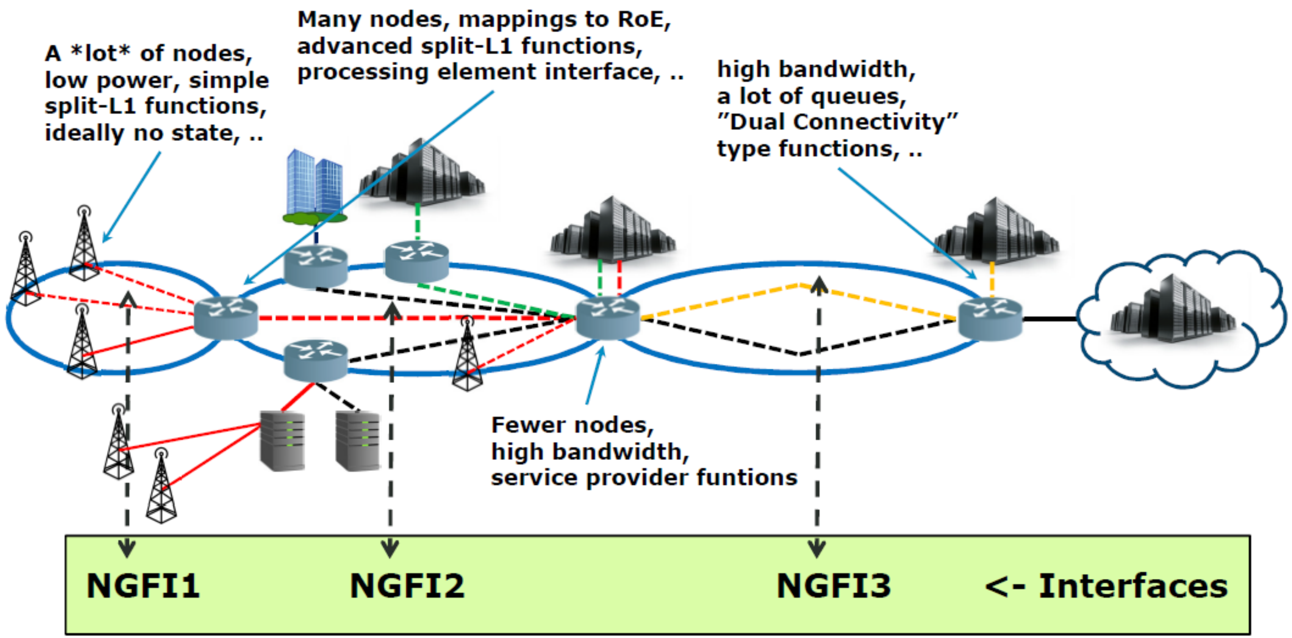
- Propose an architecture and functional splits to 4.5/5G RAN that:
- Allow E2E packet & Ethernet solutions.
- Allow converged fronthaul and backhaul network deployments.
- Scale up to 5G numbers keeping align with optics evolution.
- Aim at transport level interoperability
- Relaxed backhaul bandwidth requirements, support for low latency applications and radio/proximity optimized applications.
- Converged fronthaul and backhaul with unified E2E networking infrastructure and OAM.
- Fully virtualized coordinated RAN.
- Reduced buffering in vRAN nodes and centralized higher layer radio resource/mobility management

J. Korhonen, "Practical approach to converged FH/BH network architecture and functional partitioning", *IEEE 1914.1TF*, 2016. [Online] Available: http://sites.ieee.org/sagroups-1914/files/2016/08/tf1_1608_korhonen_practical_approach_2.pdf. Accessed: 31 Oct. 2016

Converged fronthaul/midhaul/backhaul



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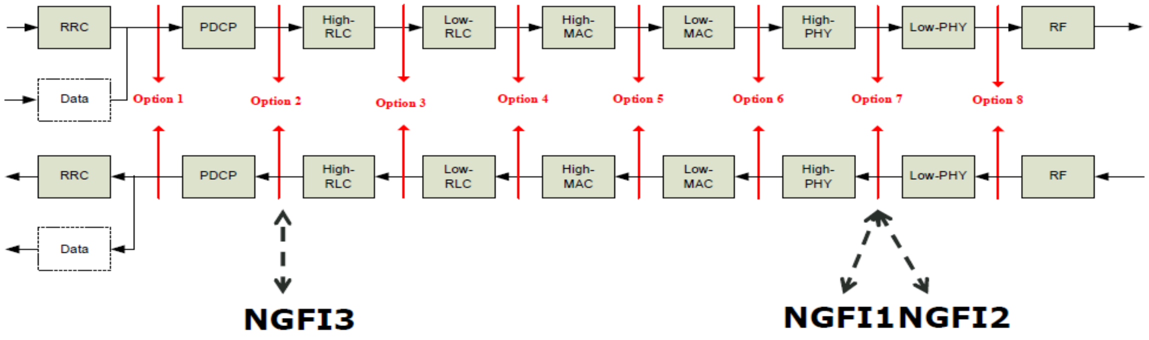

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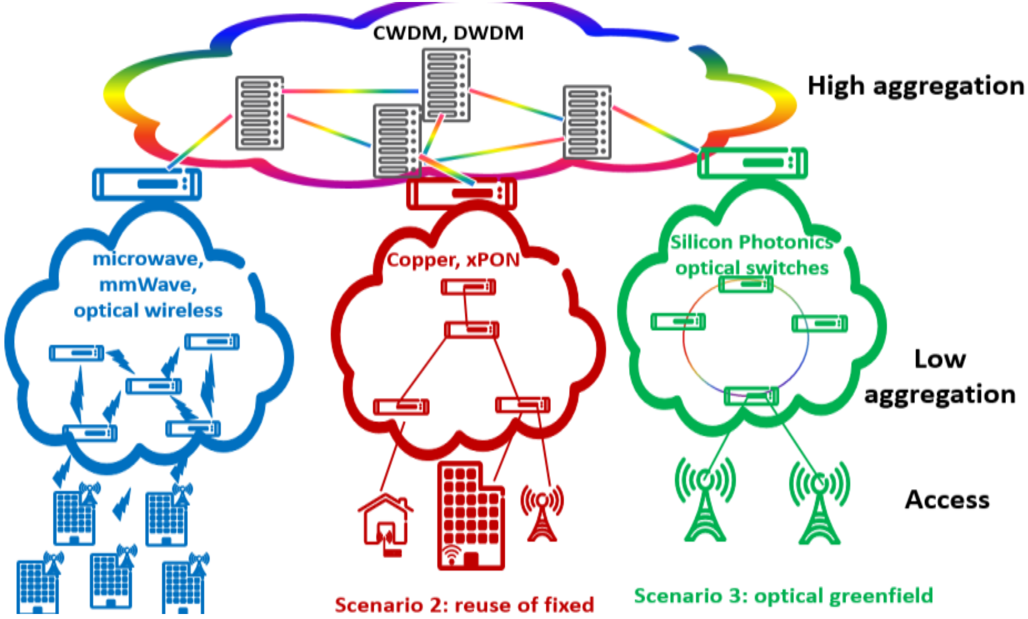
Towards a unified fronthaul-backhaul data plane for 5G: The 5G-Crosshaul project approach

- Flexible unified data plane integrating fronthaul and backhaul in 5G systems
- Primary packet-switching supported by auxiliary circuit-switching for extreme low latency scenarios
- 5G-Crosshaul
    - Packetized common transport layer for multiplexing and switching legacy (e.g. CPRI) or new fronthaul and backhaul traffic over same medium
    - SDN/NFV-based control infrastructure (i.e. XCI, 5GCrosshaul Control Infrastructure) with transport network as a service for network applications such as multi-tenancy, mobile edge computing, energy optimizers, smart traffic engineering
- Multiplexing backhaul and fronthaul - highly advantageous due common infrastructure and control for multiple purposes and decrease of total cost of ownership
- 3 multiplexing strategies (at physical layer, time division multiplex (TDM) and packet based) are discussed

Fabio Cavaliere (Ericsson Research) et. al., "Towards a unified fronthaul-backhaul data plane for 5G The 5G-Crosshaul project approach", Computer Standards & Interfaces, Nov. 2016



- Illustrates two transport aggregation stages considered in 5G-Crosshaul network
- High aggregation stage considers metro and core transport network
- Low aggregation refers to transport network that is closer to edge, and so, to RAN equipment (e.g., small cells, RRUs)

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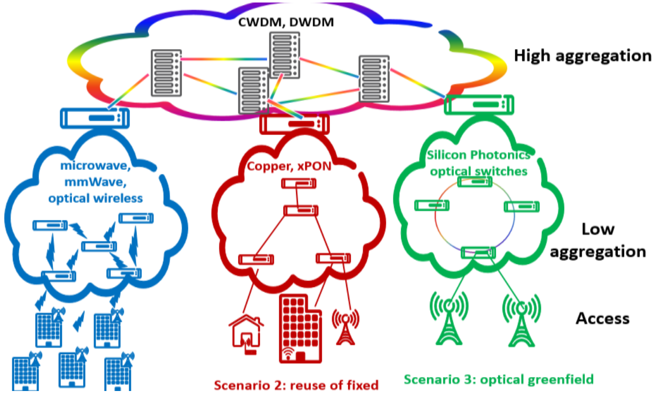

- Scenario 1 wireless links (microwave, mmWave, or optical wireless) used when wired options are not feasible
- When a fixed access network (copper or optical) is already in place (Scenario no. 2), operators can reuse it also for carrying mobile fronthaul and backhaul
- Fulfilling 5G requirements **like low latency and symmetric downstream/upstream delay planned for future 5G real-time services, synchronization may require some effort**
- Scenario no. 3 represents greenfield optical installations absence of legacy constraints - enables introduction of latest optical architectural concepts and novel transmission technologies (e.g., WDM 100 Gbit/s transceivers and low-cost silicon photonic optical switches) to increase network capacity while minimizing cost per Gbit/s

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Copper access technologies

- Widely deployed as Ethernet LANs, DSL or telephony local loops, and Cable-TV coax networks.
- Carry backhaul and fronthaul over short distances
- Ethernet cabling is abundant in enterprise and commercial buildings
- 1 Gbit/s (1000BASE-T) and 10 Gbit/s (10GBASE-T), 25 and 40 Gbit/s are being standardized
- Prospect of a massive deployment of 5G indoor small cells makes Ethernet a suitable technology for 5G-Crosshaul, both for fronthaul and backhaul.

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Optical fiber access and transport technologies

- Passive Optical Network (PON)
- Upcoming XGS-PON (symmetrical 10 Gbit/s) and TWDM PON (ITU-T G.989, Time and Wavelength Division Multiplexing PON 40 Gbit/s and 80 Gbit/s capable based on 10 Gbit/s carriers) should meet bandwidth and latency requirements of NGFI traffic
- Coarse WDM (CWDM) can provide a total capacity of about 219 Gbit/s using two fibers for uplink and downlink, enough to transport up to 18 channels of most demanding CPRI configuration
- Dense WDM (DWDM) supports a higher number of channels (e.g. 48 channels, 100 GHz spaced) with a channel bit rate up to 100 Gbit/s.

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Multiplexing strategies for a unified fronthaul and backhaul transport

Physical layer multiplexing - achieved by means of WDM, dedicating each wavelength either to backhaul or fronthaul

WDM - multiplex traffic of different-vendor radio systems that need to share transport infrastructure

Time Division Multiplexing

Natively defined in fronthaul interfaces like CPRI - may be useful to mix fronthaul and backhaul traffic on same wavelength channel

Packet based multiplexing

Packet based multiplexing makes sense especially in presence of multiple sources with load dependent data rate on attempts to exploit advantages of statistical multiplexing gain

CPRI streams can be sent over a packet-switched network such as Ethernet or IP-MPLS

a) a jitter compensation buffer is necessary to match delay accuracy requirements

b) a careful QoS engineering design must be used to limit packet delay variation through network using current high-end switches but subject to a careful engineering of latency budget(estimated in 100 μs one-way)

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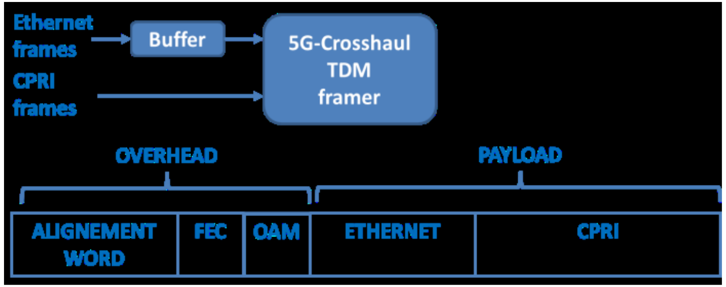

- 5G-Crosshaul proposes a new, simplified and less time-sensitive circuit multiplexing approach, where multiplexed frame is synchronous to fronthaul client signal, on attempts to avoid any degradation of synchronization accuracy.
- Multiplexing of Ethernet with a fronthaul client signal (e.g. CPRI) is performed by using a buffer for clock adaptation before Ethernet line
- Operation, Administration and Management (OAM) contains pointer to CPRI and Ethernet frame portions

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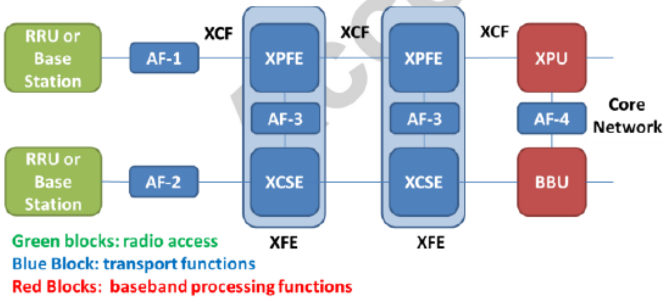

5G-Crosshaul architecture

RRUs: radio terminals performing no, partial or full baseband processing. Former and latter cases correspond to pure backhaul of non-split radio base stations and pure fronthaul of RRUs using CPRI or similar protocols, respectively;
XPFE: 5G-Crosshaul Packet Forwarding Element, used to exploit statistical multiplexing gain in new generation packet based fronthaul interfaces;
XCSE: 5G-Crosshaul Circuit Switching Element, used to cross-connect constant bit rate fronthaul traffic (e.g. CPRI) from legacy RRUs or to offload XPFE in case of congestion;
XPU: 5G-Crosshaul Processing Unit, based on general purpose processors so that baseband processing functionalities can be virtualized and software reconfigured;
BBU: current baseband processing units based on dedicated hardware.

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"At this point, I'm taking it one paradigm at a time."