iCirrus

intelligent Converged Network consolidating Radio and optical access aRoundUSer equipment

Flexible Ethernet Fronthaul

Nathan J. Gomes

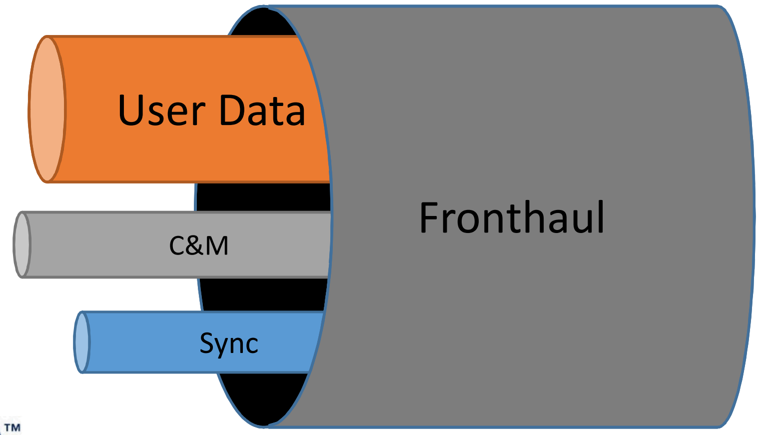
iCIRRUS Project Coordinator/Technical Manager
Communications Research Group, University of Kent, UK

Overview

- Mobile fronthaul
  - State-of-the-art, challenges
- Moving the functional split and the new, flexible fronthaul
- Transport requirements for the new, flexible fronthaul
  - Delay variation challenges
- Implications

Mobile Fronthaul

- Reliable transport of 3 basic flows
  - User Data
    - IQ samples in current fronthaul
  - Control and Management (C&M)
    - BBU <-> RRH (DU <-> RU)
    - Higher layer eNB <-> UE, UE <-> ePC
  - Synchronisation
    - Frequency
    - Phase/Time

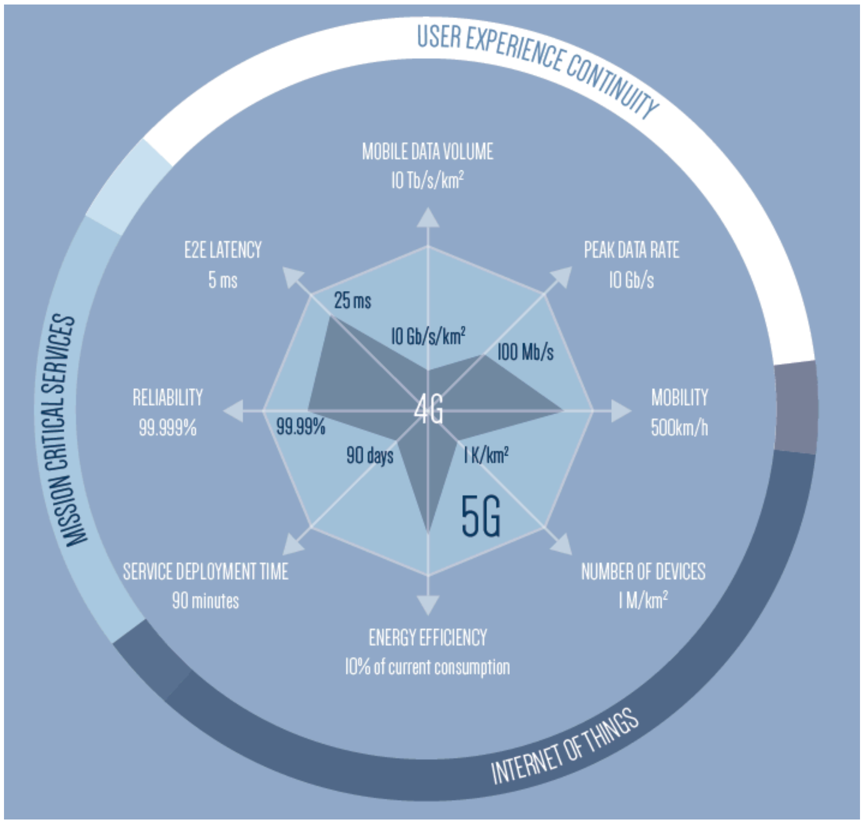


Currently used fronthaul technology overwhelmingly based on Common Public Radio Interface (CPRI)

Advantages:
Fully centralised ->
maximises virtualisation benefits
Synchronous, TDM-based ->
inherently robust to timing

Disadvantages:
Sampled waveforms -> high bit-rates!
Multiple antenna streams -> high-bit rates!!
Little or no statistical multiplexing gains in aggregation
-> high bit-rates!!!

The bit-rate challenge



[Source: 5G PPP Vision Paper, 2015]

Current CPRI/ORI interfaces		Projected requirements	
Line rate	Example Use	Possible uses	Approx. line rate*
614.4 Mb/s	10 MHz LTE channel, with 8B10B encoding	1 GHz (mm-wave), 1 antenna	35 Gb/s
4.9152 Gb/s	8 x 10MHz (multiple antennas, 8B10B)	100 MHz, 8 antennas (sectors/ MIMO /CoMP)	28 Gb/s
10.1376 Gb/s	10 x 20 MHz (multiple antennas, 64B66B)	500 MHz, 8 antennas (sectors/ MIMO/ CoMP)	141 Gb/s
24.33024 Gb/s	24 x 20 MHz (multiple antennas, etc)	500 MHz, 16x8 massive MIMO	2.25 Tb/s

*assumes < 10% overhead

Use of Ethernet in the fronthaul

Advantages

- Use of commodity equipment, or lower-cost, industry-standard equipment
- Sharing of equipment with fixed access networks
- Ethernet OAM functions standardised
- Use of switches/routers to enable statistical multiplexing gains and lower the aggregate bit-rate requirements of some links?
- Use of standard IP/Ethernet network switching/routing functionality, including moves to functional virtualisation and overall network orchestration
- Monitoring through compatible hardware probes.

Challenges

- Does not solve fundamental bit-rate problem
- Destroys synchronisation, timing inherent in a TDM stream
  - SyncE, IEEE 1588v2 PTP, IEEE 1904.3 …
- Aggregation, switching units make timing problems worse (queuing, contention…)
  - Range of IEEE802.1 proposals, pre-emption, stream filtering, queuing, forwarding, including 802.1CM TSN for fronthaul

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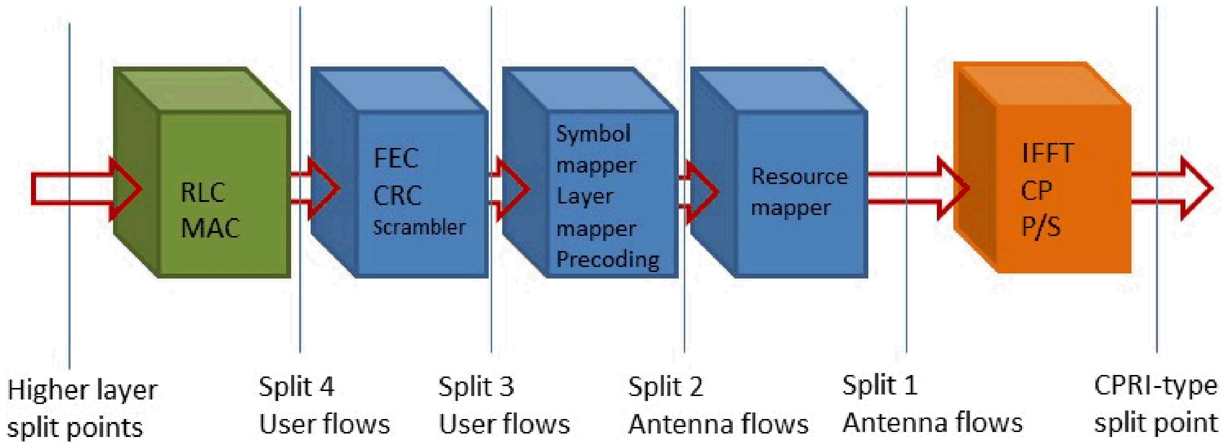
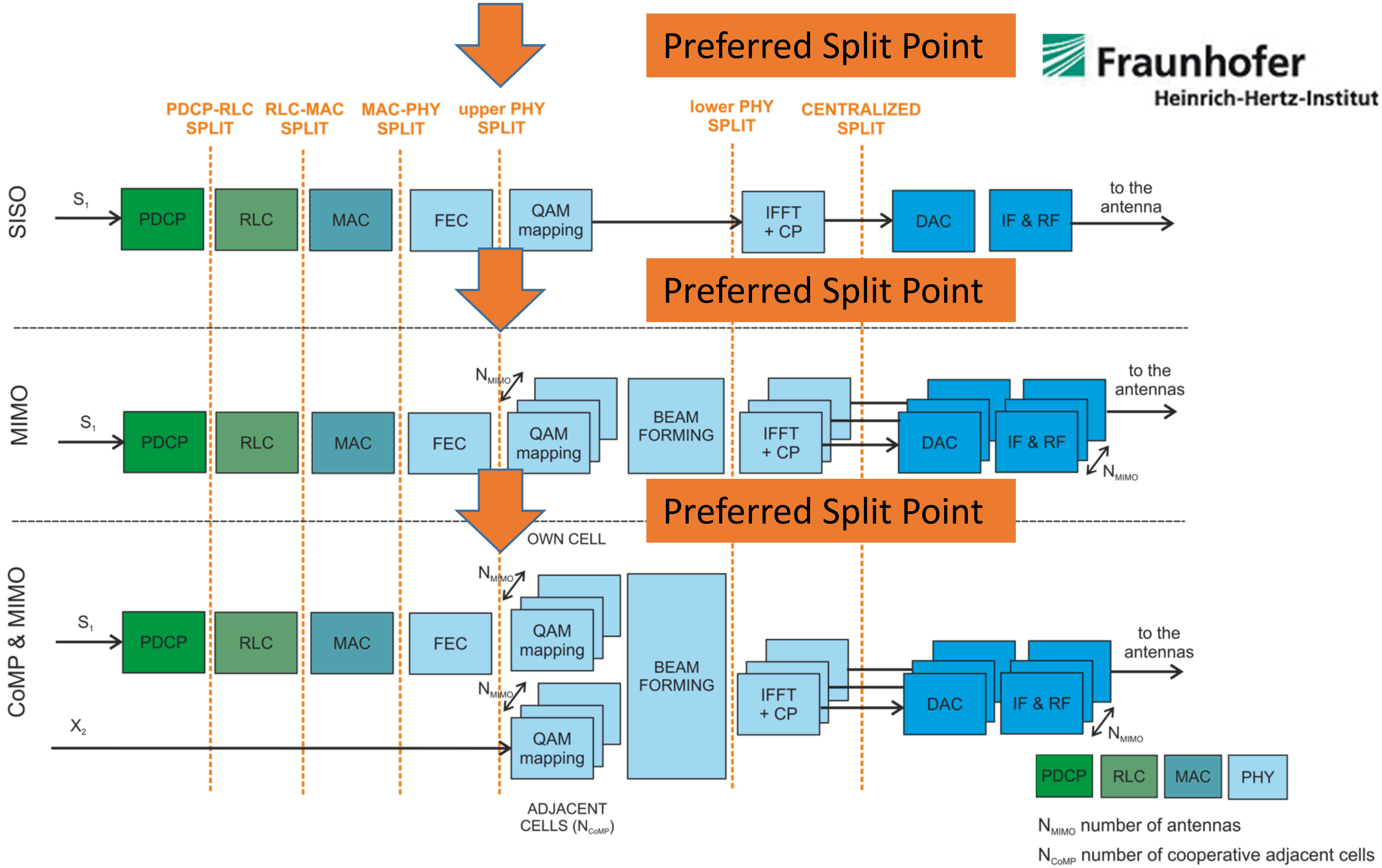
Moving the functional split point*



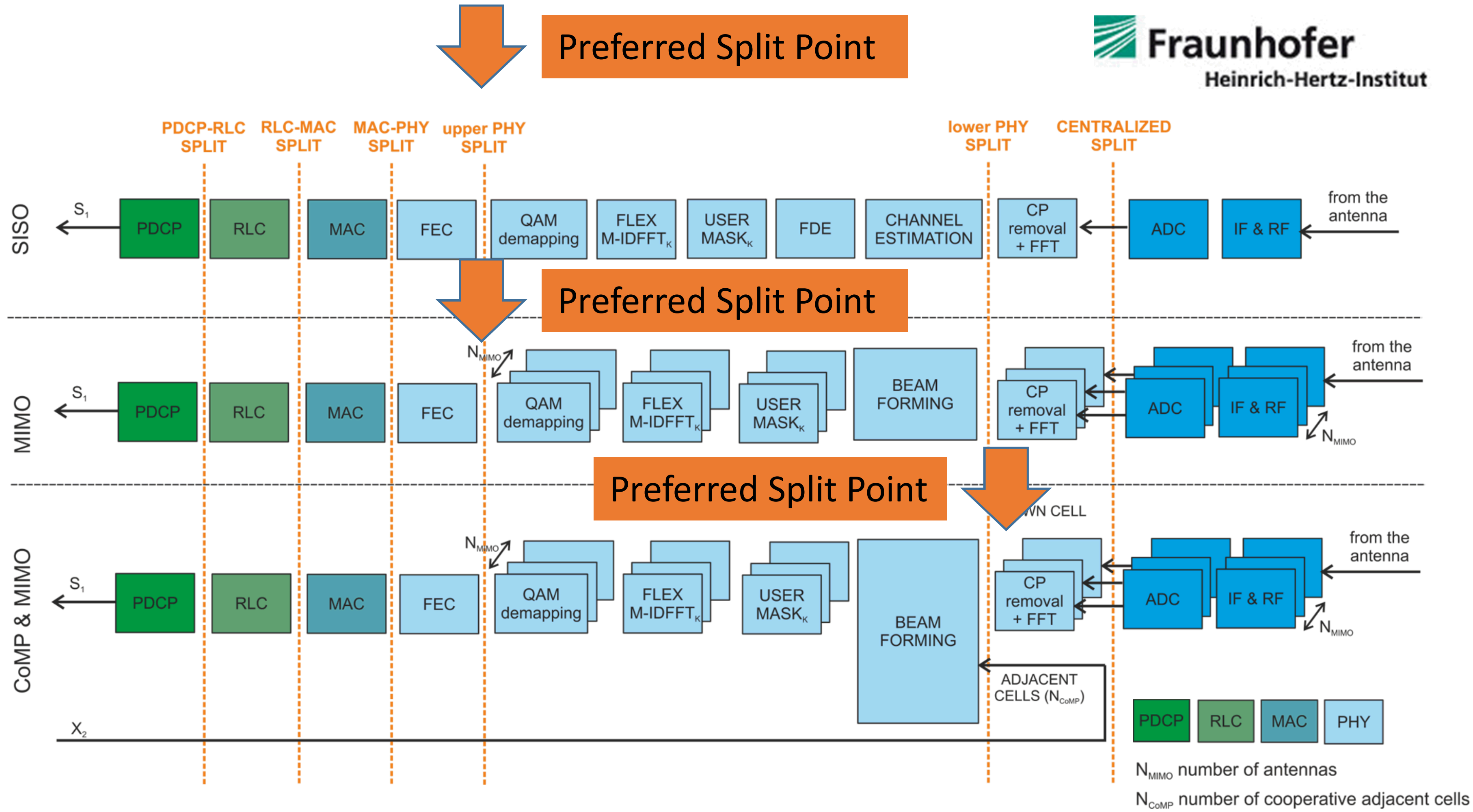
Split 1: symbols for *used* subcarriers only, but constant bit-rate
Split 2: unused resource block symbols not transported, stat mux gains now possible
Split 3: Layer mapper for multiple antenna streams moved, precoding at remote unit – large bit-rate reductions for CoMP/MIMO
Split 4: Moves remaining PHY layer functions to remote unit

*U Doetsch et al, Bell Labs Tech J, 2013; P Rost et al, IEEE Comms Mag, 2014; China Mobile, NGFI White Paper, 2015

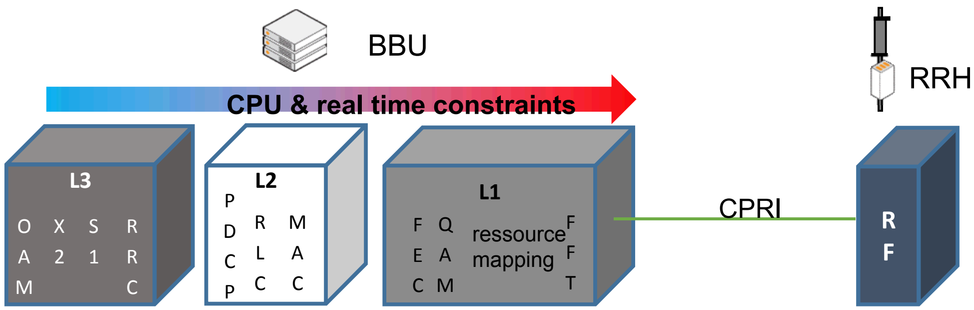
A Preferred Functional Split: Downlink

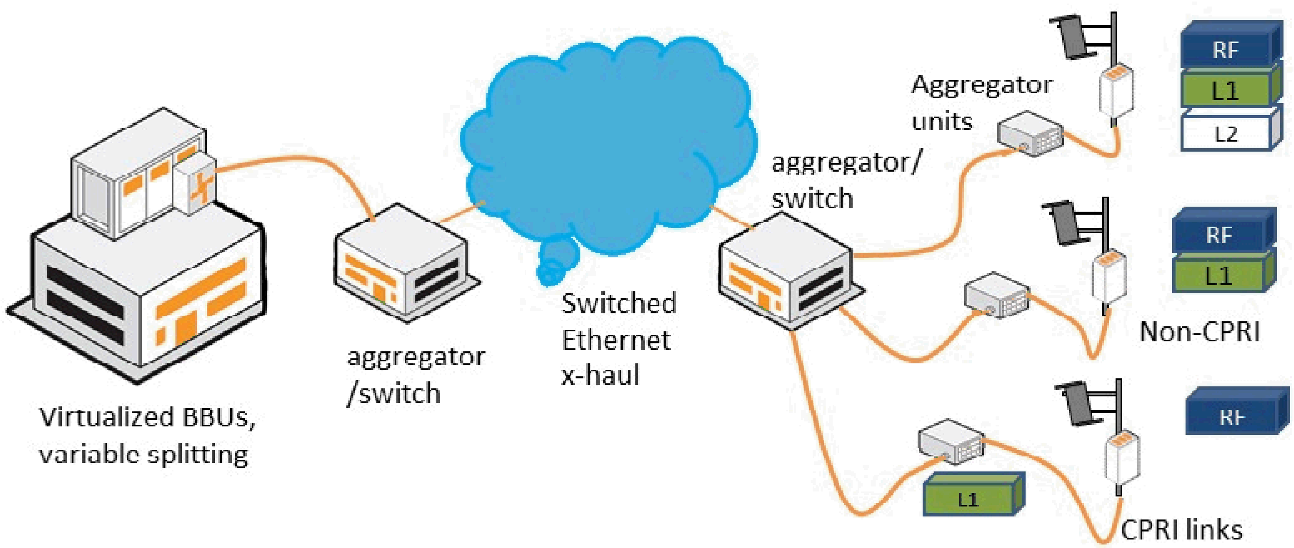


A Preferred Functional Split: Uplink



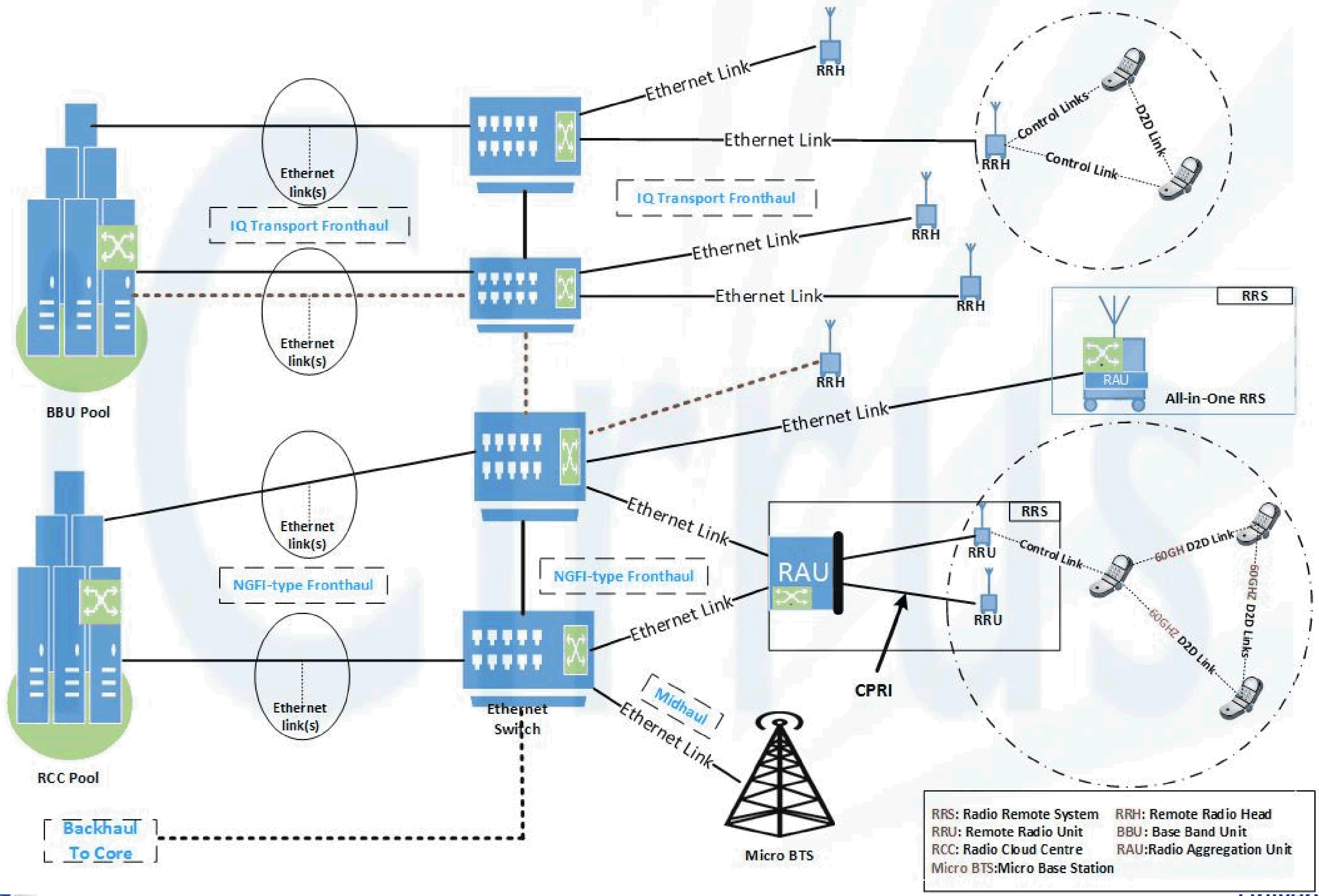
The flexible functional split in an Ethernet fronthaul





Different functions moved between vBBU and remote units
Some functions may reside in intermediate, aggregator units
Because transport is Ethernet, different splits can coexist

The iCIRRUS converged "xhaul" or "flexhaul" concept



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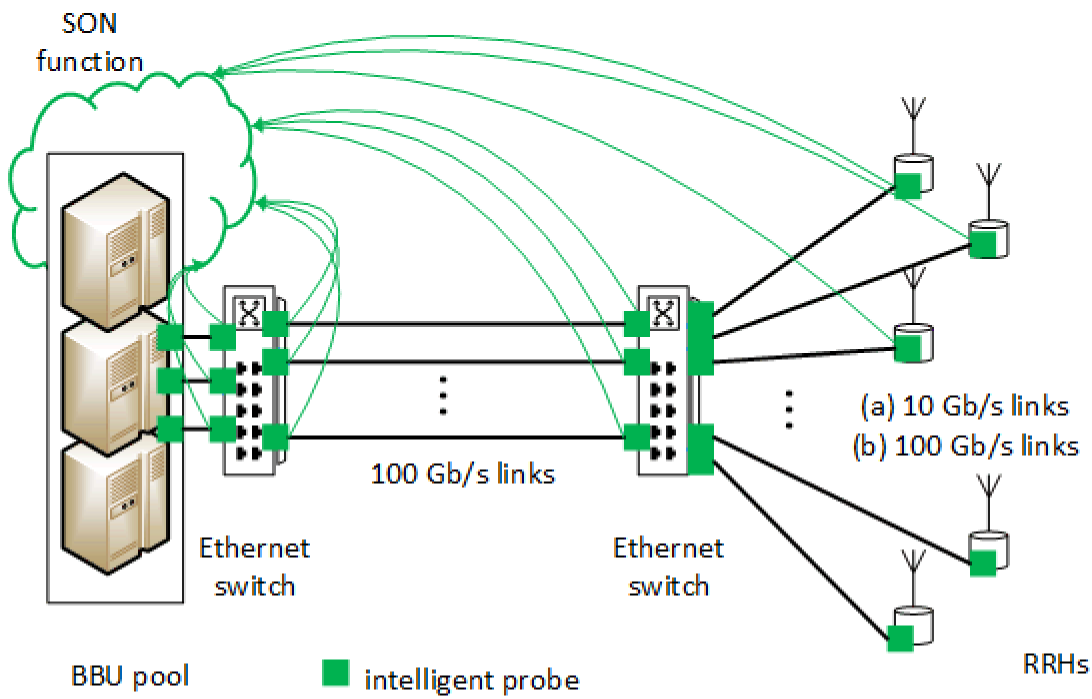
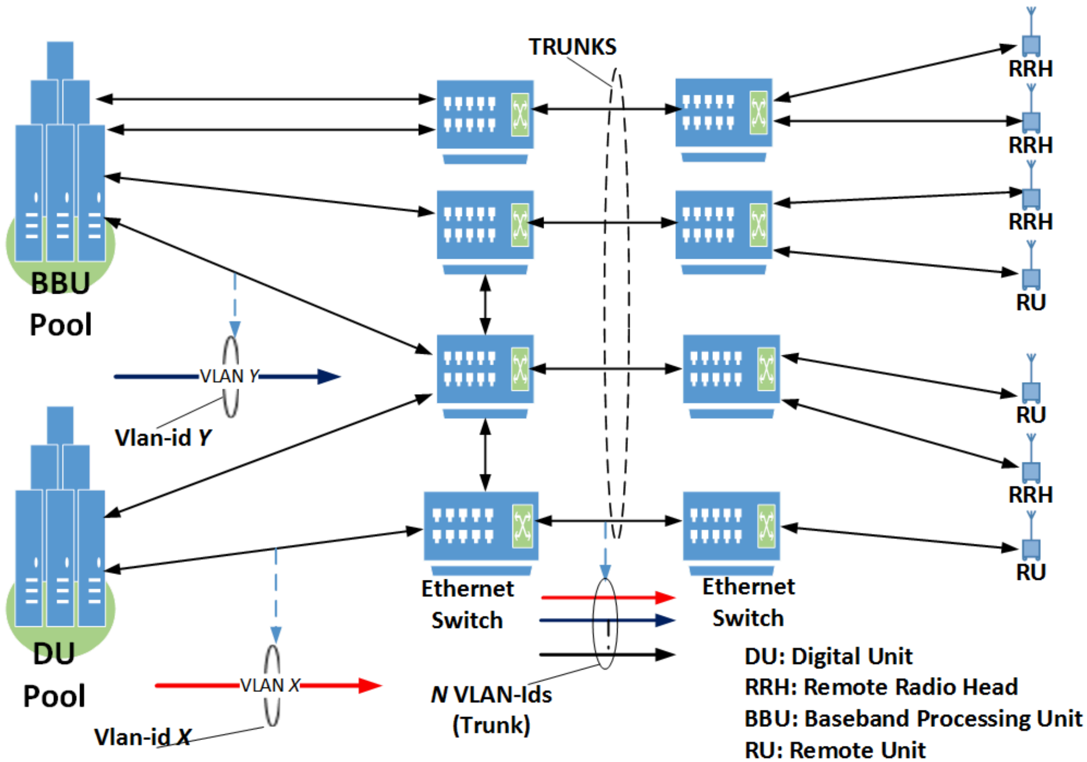
Aggregator/switch and aggregated link requirements



Low-latency switching required:

Cut-through operation (will require all links to be high-speed)
No contention/queuing

Use of layer 2 switching/forwarding and priority mechanisms



VLANs used to separate flows to RRUs and antennas, layer 2 switching based on VLAN id

Trunks carry large numbers of VLANs

VLAN priority mechanisms can be used to assist meeting timing requirements of different flows

Data transported	Priority requirement
DMRS	High
MAC control primitives	High
Transport blocks, DL (UL)	Medium/(High)
PBCH	High
PRACH	High
Radio "slice"-time domain	High
SRS	Low
PDSCH	Medium

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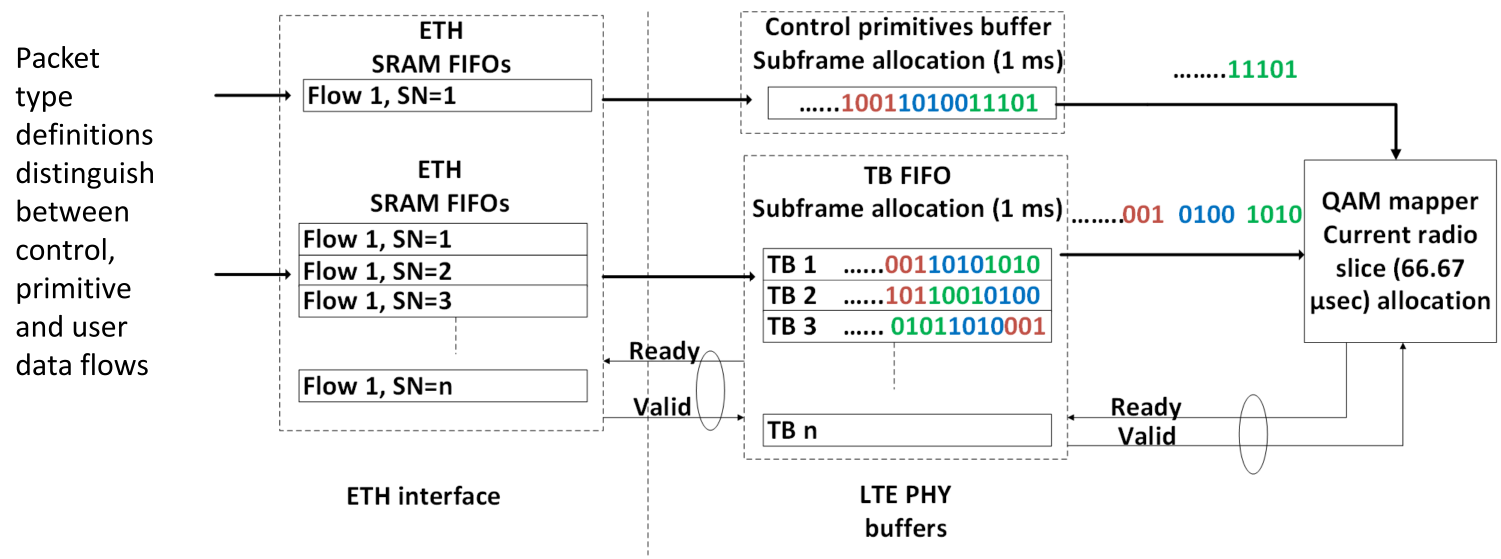
Implications of new functional split

- Data rate reduction and improved network utilisation from statistical multiplexing
- Structural convergence, topology and traffic management become more straightforward
- Dynamic split with virtualised network functions
- Radio (modulation) “waveform” agnostic
- BER: frame loss has different effect than with sampled waveforms (HARQ with user, not whole radio frame)
- Latency and Synchronisation requirements will be different and need consideration: Need to ensure user data arrives in time for prescribed radio frame
  - Impact on 5G definitions:
    - 0.1 ms subframes, reduced symbol periods for IFFT/FFT transformations
    - HARQ timing?
- Modification /extension of some Backhaul interfaces (e.g. some X2 signalling) -> Remote Radio Unit interfaces, for some functions: Additional control interfaces may be required – currently embedded within BBU
- OAM and SON functionality: managing user and application QoS/QoE

➢ Generally, need optical fibre infrastructure

Timing requirements for fronthaul transport



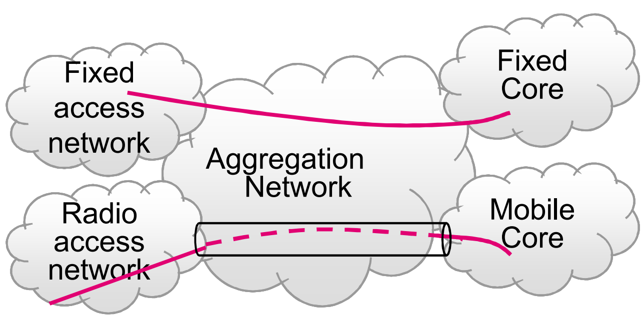
LTE radio slices are made from QAM symbols for each OFDM symbol period
Control primitives will indicate transport blocks making up frame and slice
Numbers of bits for each symbol will vary
LTE PHY transport block buffers filled from Ethernet frame buffers

Network convergence between fixed, Wi-Fi and mobile networks

Today's network architecture

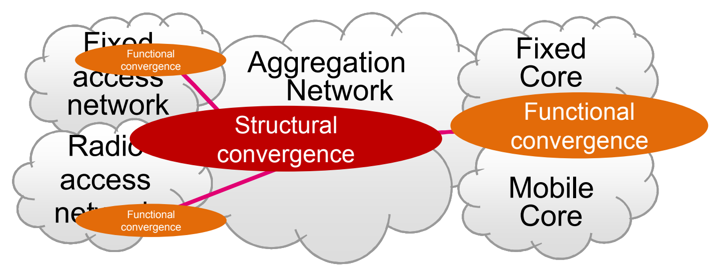
Fixed and mobile networks:

- developed independently of each other
- have only very limited joint usage of infrastructure
- have independent network operation, control and management



Potential converged architecture

- Common architecture for fixed and wireless network requires interaction at different points
  - Structural convergence
    - Simplification and common use of resources e.g. infrastructure, system technology, interfaces and transport mechanisms
    - Focus on access and aggregation network
  - Functional convergence
    - Unification of fixed and mobile network functions
    - Focus on functional placement in home, access, aggregation and core network



Technology triggers for structural convergence

Technological triggers

- **Heterogeneous radio access networks:**
  - Push structural convergence of mobile, Wi-Fi and fixed access networks because of a significantly larger number of small cell locations and the required coordination of small and macros cells.
- **BBU hostelling and mobile fronthaul technologies:**
  - This centralization of radio access functions enable convergence at central offices where both fixed and mobile traffic are aggregated at the same place.
- **Unified optical access & aggregation network:**
  - Allows structural convergence with converged physical layer supporting heterogeneous access media and services for fixed, mobile and Wi-Fi broadband

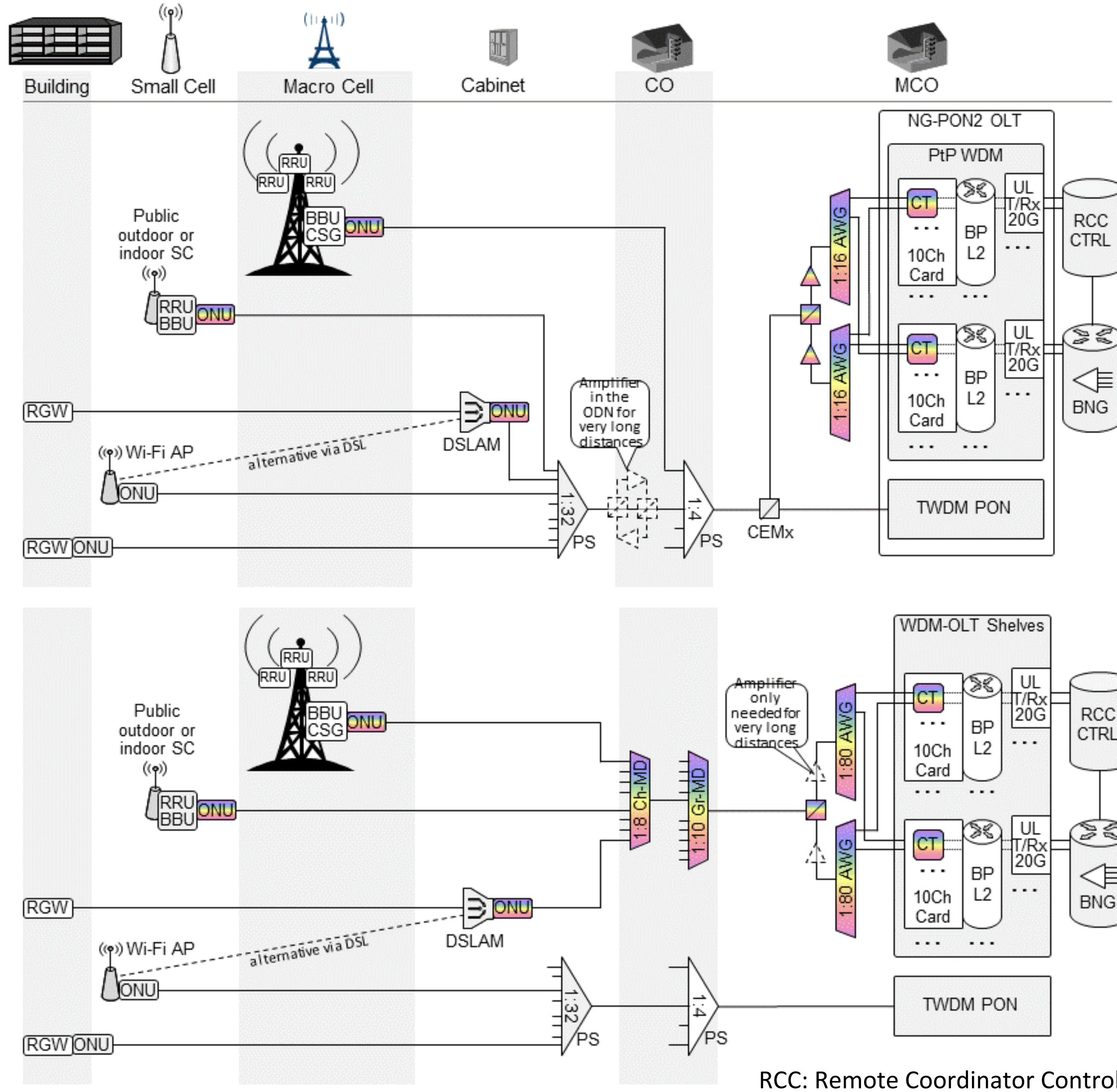
Different convergence architectures

Converged NG-PON2

- ODN co-existence with typically 1:128 split for residential customers due to mass market roll out (16 wavelengths of NGPON2 are delivered to 4 Cabinets)

WR-DWDM PON

- Dedicated ODN for services that require PtP wavelength services, i.e. mobile backhaul and cabinet backhaul (80 wavelengths)



RCC: Remote Coordinator Controller

Cost analysis of structural convergence (Urban area) Variation of SC density, FTTH ratio, fibre availability

- High FTTH ratio and high small cell density favors convergence with mass-market solution (NG-PON2)
- Limited fibre availablity favors convergence with mass-market solution (NG-PON2)