Optical Fronthaul Solutions

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iCirrus

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http://www.icirrus-5gnet.eu/

NIRVANA

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Overview

- 5G: C-RAN, mobile fronthaul and massive MIMO
- Mobile fronthaul for 5G: defining new RAN functional split points
- Example bit-rate requirements for a fronthaul/xhaul supporting massive MIMO
- Latency/latency variation and the new xhaul architecture
- iCIRRUS Ethernet fronthaul/xhaul demonstrators
- Summary

C-RAN and mobile fronthaul

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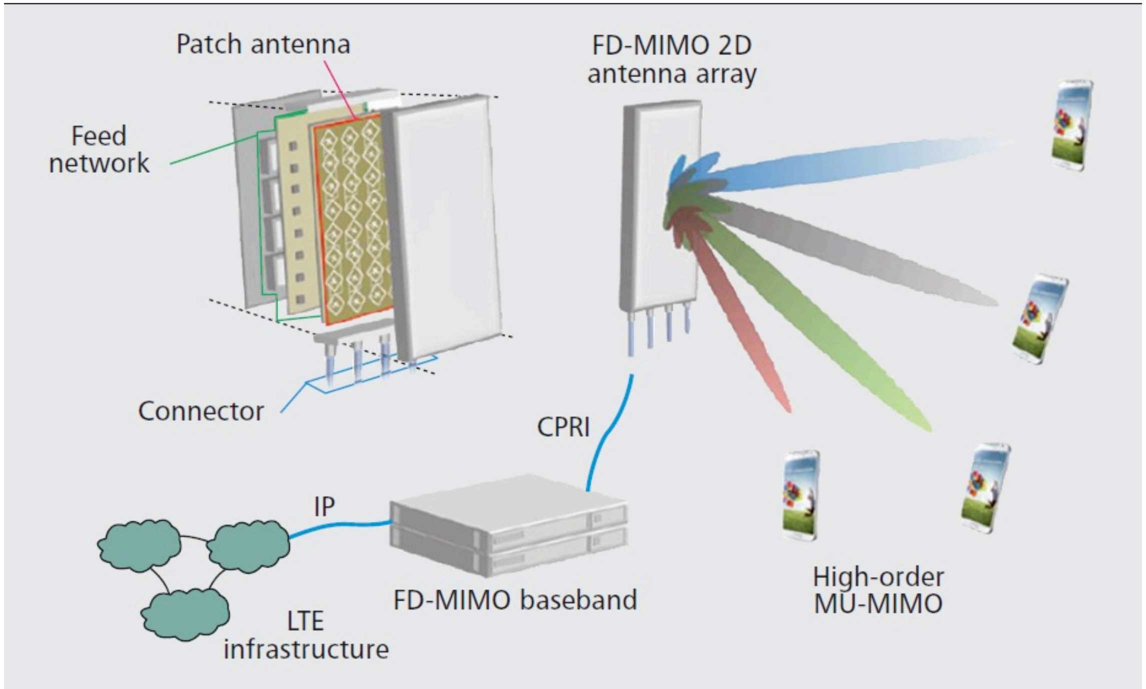
- Centralised-RAN brings energy, space, shared equipment savings
  - Was seen as distinct from small cell architecture
  - Less backhauling, more scope for cooperation…
- Cooperative-RAN – centralised base stations enhance cooperation, joint processing of signals
- Cloud-RAN – pooling of functions in generalised, shared hardware
- Evolution towards virtualised RAN
  - Small cell architecture part of the overall RAN concept

Massive MIMO (FD-MIMO)



From **Kim et al**., "Full dimension MIMO (FD-MIMO): the next evolution of MIMO in LTE systems", *IEEE Wireless Communications Magazine*, April 2014

Current mMIMO Active Antenna Systems may have 64, 128 or 256 antenna elements to form beams

Can be used to form single beam or multiple beams, by grouping elements into subarrays

Other antenna systems possible: e.g. lens antennas using elements for different feed points to lens (number of beams limited by feed points and RF chains)

FD-MIMO baseband prior to CPRI transport: every antenna element (digitized) RF signal is transported

Possibility for analog beamforming: phase and amplitude weights sent, CPRI transported RF signal for each beam

Mobile fronthaul for 5G

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!!!

Current CPRI interfaces		Projected requirements	
Line rate	Example use	Possible use	Approx. line rate*
614.4 Mb/s	10 MHz LTE channel with 8B10B coding	1 GHz bandwidth, 1 antenna	50 Gb/s
4.9152 Gb/s	8 x 10 MHz with 8B10B	8 x 100 MHz	40 Gb/s
10.1376 Gb/s	10 x 20 MHz with 64B66B	10 x 400 MHz	200 Gb/s
24.33024 Gb/s	24 x 20 MHz with 64B66B	128 x 1 GHz	6.4 Tb/s

RAN functional splits

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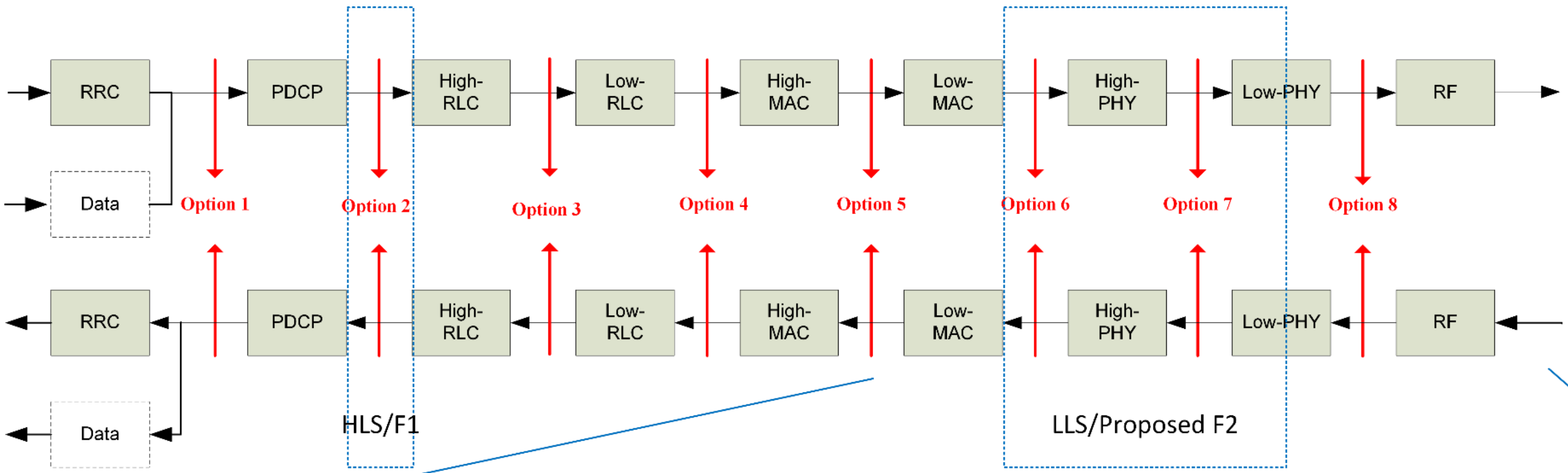
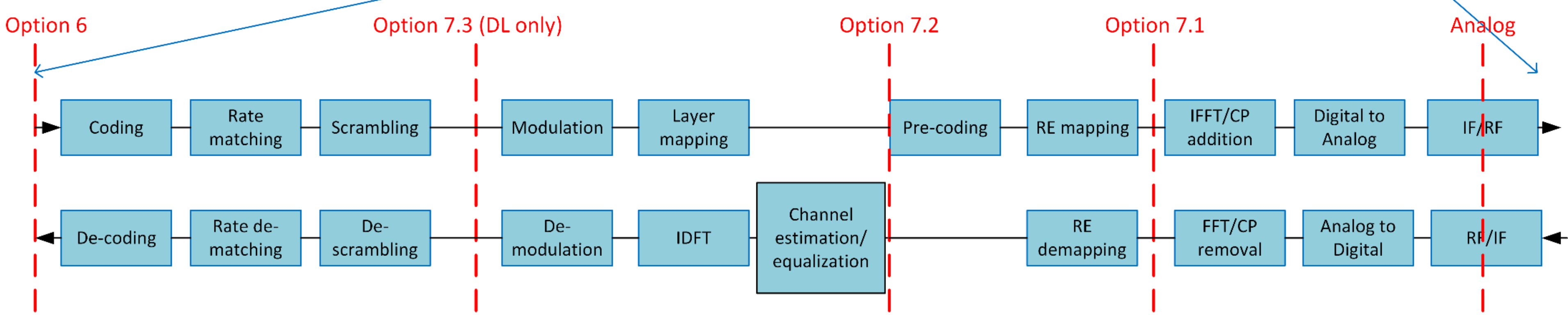
3GPP Functional Split points





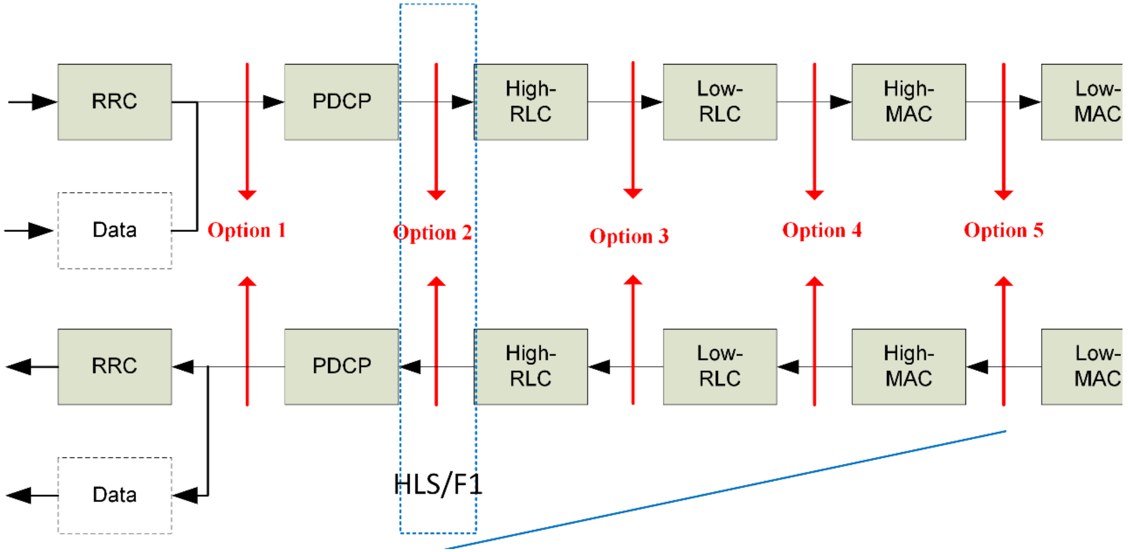
Lower layer split options

Example 128T128R requirements

Assume 10 individual beams:
1GHz BW mmW system allows 5Gbps per beam; 100MHz BW sub-6GHz system allows 1Gbps per beam

Backhaul (user) data rates:
Up to 50Gbps per antenna for mmW; up to 10Gbps per antenna for sub-6GHz
Some statistical multiplexing gains …

HLS/F1 data rate requirements similar to backhaul. All beamforming at distributed/remote radio units.

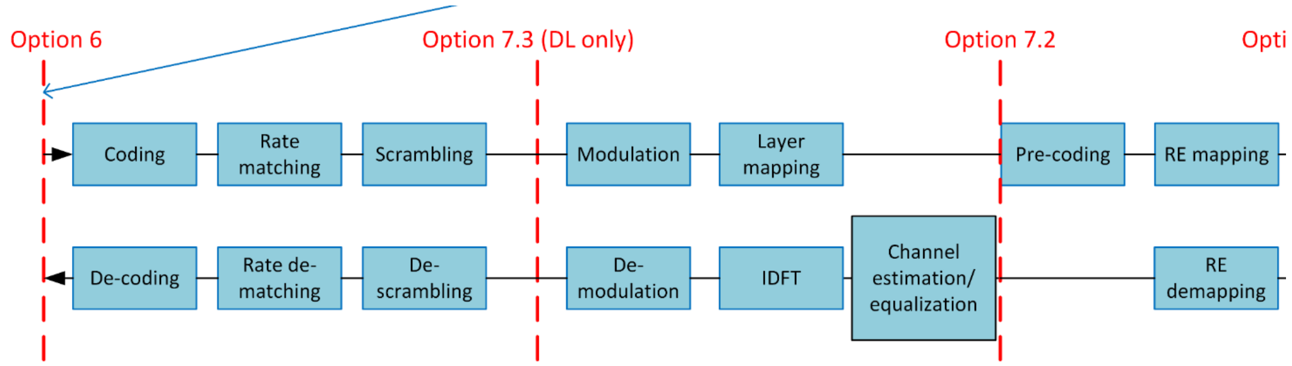


128T128R LLS

Option 6: overhead is approx. 40%
100Gbps fronthaul will provide for one 1GHz BW antenna; two antennas through statistical multiplexing

Option 7.3 (DL only): small, further increase in overhead

Option 7.2 DL: layer mapping centralized. Send each beam, with precoding weights to be applied at antenna elements. Similar to above.
UL: Frequency domain symbols available for all used resource blocks prior to signal combining, estimation, equalization. Requires Tb/s rates, unless some analog BF used and soft-decisions sent



128T128R LLS (2)

Option 7.1 DL: precoding and mapping centralized, so every antenna element needs signal; Tbps unless analog beamforming used – 2 x 100 Gbps

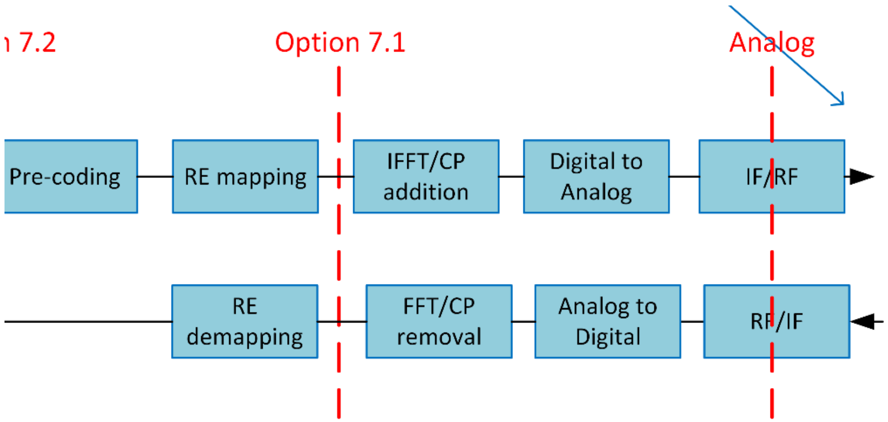
UL: similar requirements to DL

Analog options: transmit radio signals for every element (close to 200GHz for 1GHz BW mmW system)

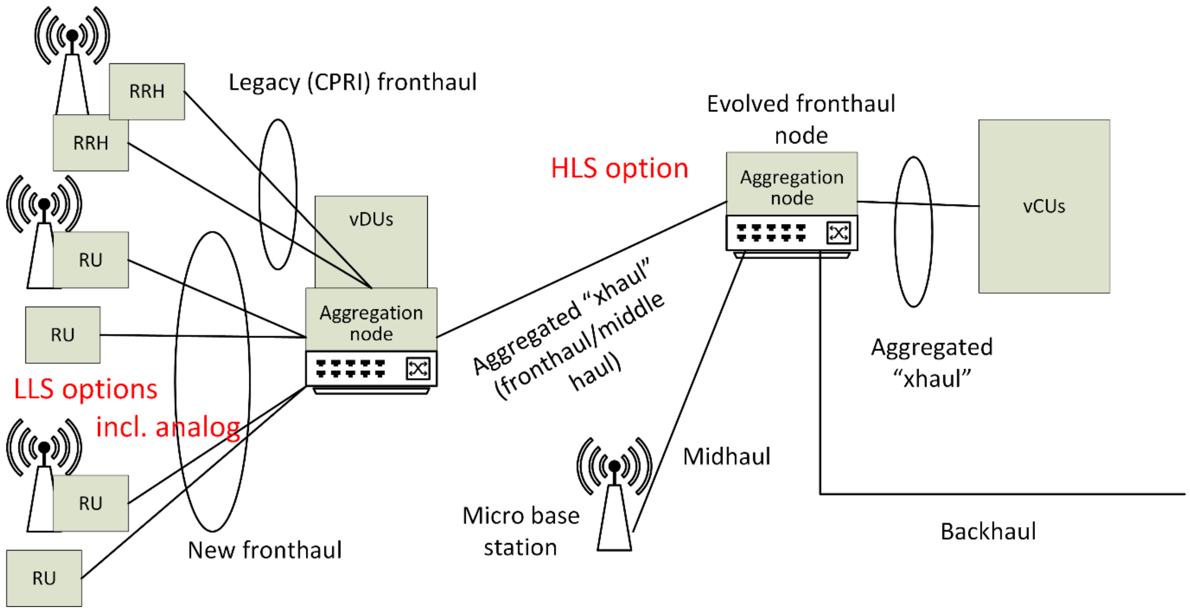
analog beamforming - >12 GHz

highly linear link needed

complexity in formation of multiplexes



Converged xhaul architecture



Split point used depends on functions used for user/radio streams. E.g., CoMP needs access to individual antenna streams from different RUs/RRHs

Delay and delay variation important – need to meet radio frame timing requirements, especially for coordinated transmission/reception

Possibility for playout buffers to minimise effect of latency variations, but need for absolute time synchronisation

Latency/latency variation

F1/HLS: requirements similar to backhaul; some resource coordination may impact on latency requirements

Packet-based transport with statistical multiplexing gains; PON framing (TCONTs etc) all possible

LLS: options 6, 7.3, 7.2 can all benefit from statistical multiplexing with packet-based (Ethernet) transport

But all require low latency (well within radio frame durations)

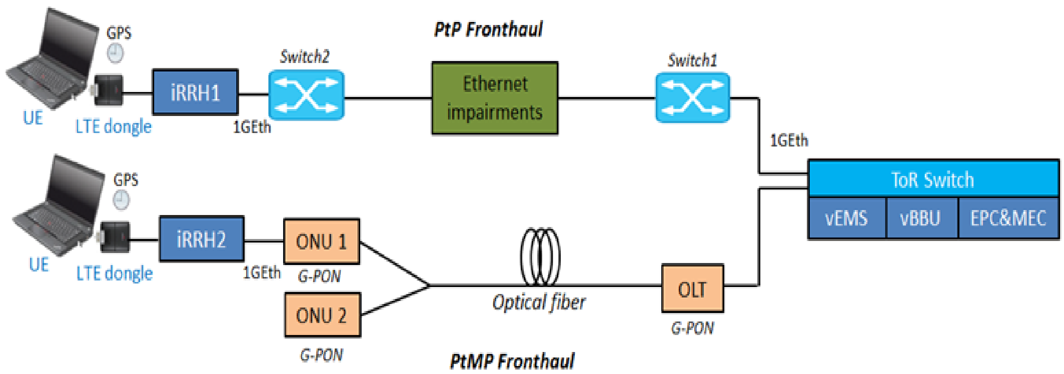
Waveform replay from buffers can mitigate against delay variations (packet jitter) but accurate timing (Precision Timing Protocol) needed, especially for joint transmission/reception (PTP must be delivered with negligible latency variation)

LLS: 7.1 and Analog – no statistical multiplexing benefits*

Signal buffering may still be required for delay equalization

*except for changes in number of beams

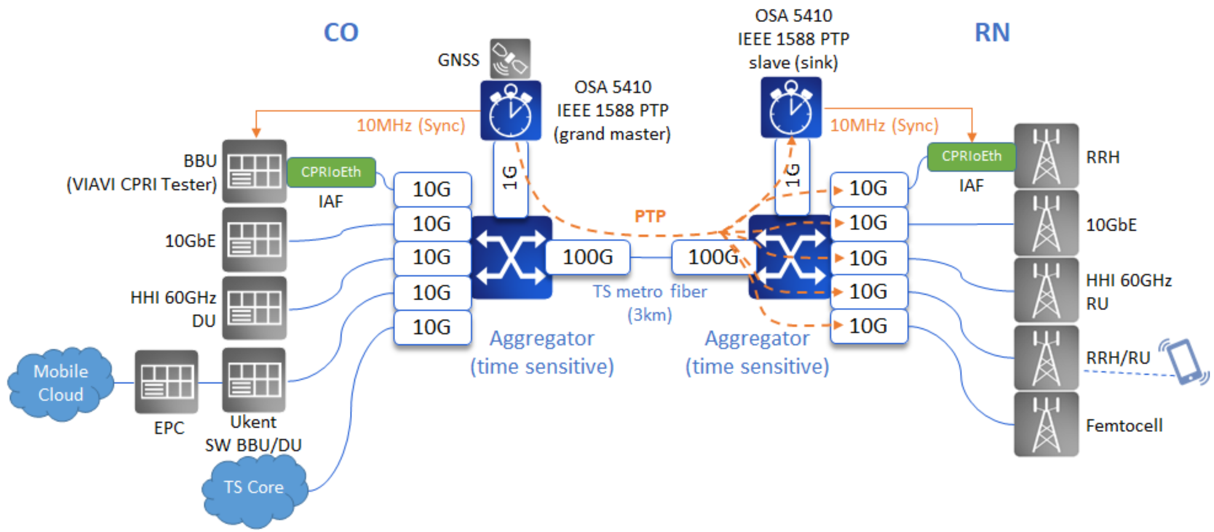
iCIRRUS demonstrators (1)



HLS/F1 implemented:

1. For point-to-point Ethernet
2. For Ethernet over a point-to-multipoint GPON

iCIRRUS demonstrators (2)



Ethernet xhaul trunk between aggregators simultaneously carried:

1. CPRI over Ethernet
2. Ethernet background traffic
3. Upper-PHY (approx. option 7.3) split for high-bit-rate 60 GHz
4. MAC-PHY (option 6) split for LTE
5. Backhaul
6. PTP (IEEE 1588)

Gap-filling Time-Sensitive Networking method used in aggregators (less than 100 ns packet jitter)

Summary

- Extending existing approaches for fronthaul transport wil… unsustainably high bit-rates for later 4G, 5G and be…
- Functional splitting of RAN can mitigate t…
- Ethernet in the fronthaul:
  - reduced cost and ca… …unctional splits
  - delay and de…
- Data … …ng benefits depend on split
- … …ement depends on split point; waveform …ing, PTP transport with TSN are possible
- N… …o examine radio functionality requirements (how beam forming is performed, need for CoMP JT/JR)
- Not covered (here): need to seamlessly operate in a virtualised RAN environment, with envisioned network slicing approaches and NFV/SDN

Need to jointly consider wireless/mMIMO/CoMP requirements with split point definition and fronthaul transport

Thank you

Any Questions?