Fronthaul architecture towards 5G

Multiplexing gains analysis

Challenges/solutions for fronthaul network

Aleksandra Checko, MTI

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In collaboration with:

MTI Radiocomp: Andrijana Popovska Avramova, Morten Høgdal, Georgios Kardaras

DTU: Michael Berger, Henrik L. Christiansen

EU project HARP consortium

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IEEE 1914.1 TF
NGFI
Bomin Li (bomin.li@comcores.com)

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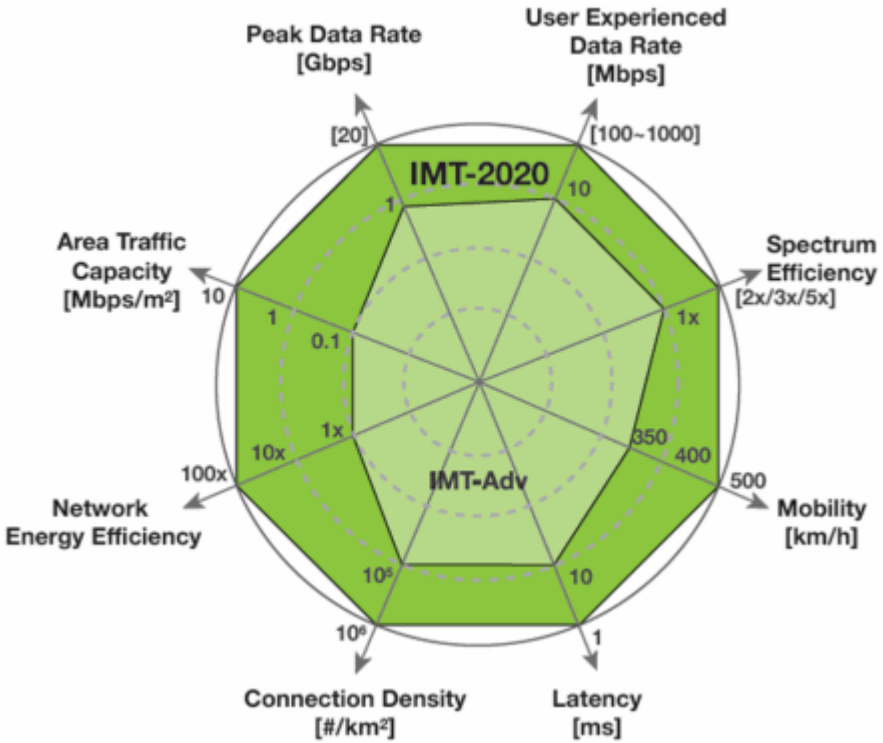
Date: 2016-08-23			
Author(s):			
Name	**Affiliation**	**Phone [optional]**	**Email [optional]**
Aleksandra Checko	MTI (Microelectronics Technology, Inc.)		aleksandra.checko @mtigroup.com

5G requirements and challenges



Source: netmanias

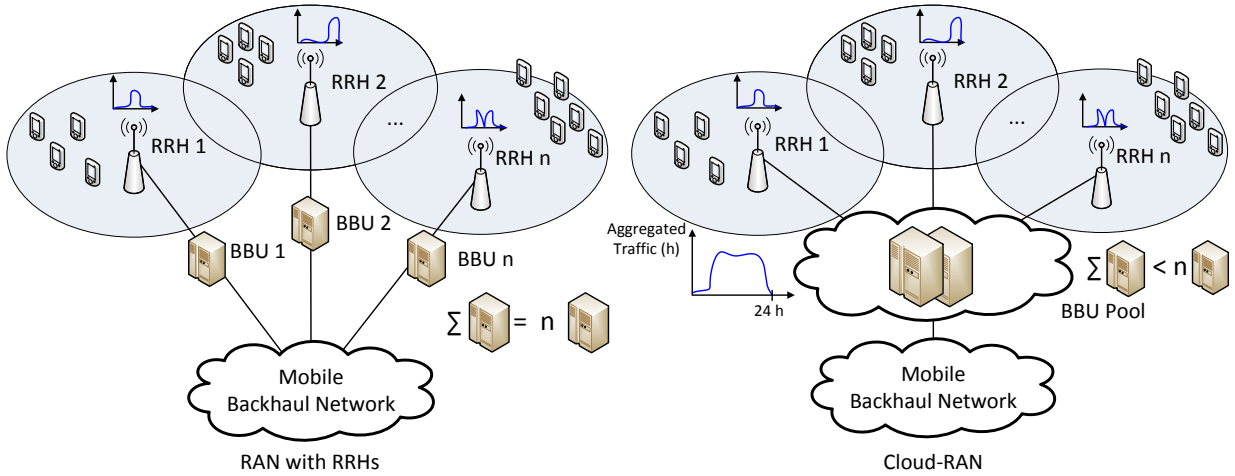
- To carry **20Gb/s** as I&Q signals (64-QAM ¾) over CPRI will require a CPRI data rate of at least **325Gb/s**

→ Not acceptable for NGFI

- New functional split is needed
  - *User processing in BBU*
  - *Cell processing in RRH*
  - *Split functions, still benefit from C-RAN (e.g. CoMP)*

→Variable bit rates on fronthaul

- Agenda for today
  - *How big are the multiplexing gains in C-RAN?*
  - *How to optimize fronthaul network?*



Studying multiplexing gains

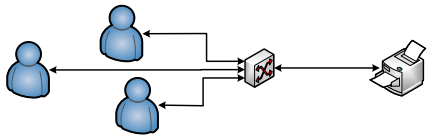
- towards quantifying benefits of C-RAN

Multiplexing and pooling gain defined

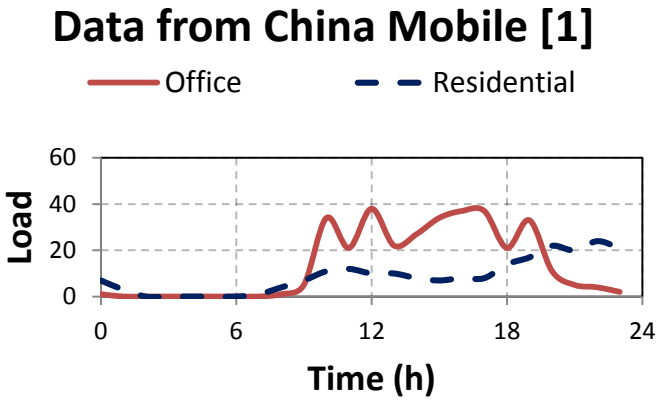
Exploring the tidal effect

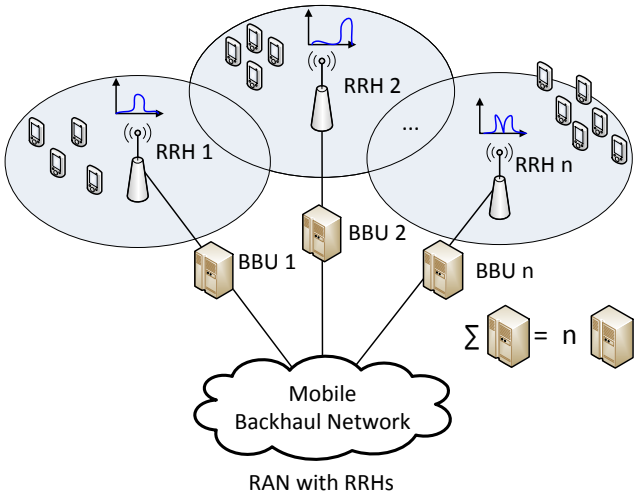
Exploring different application mixed and measurement methods

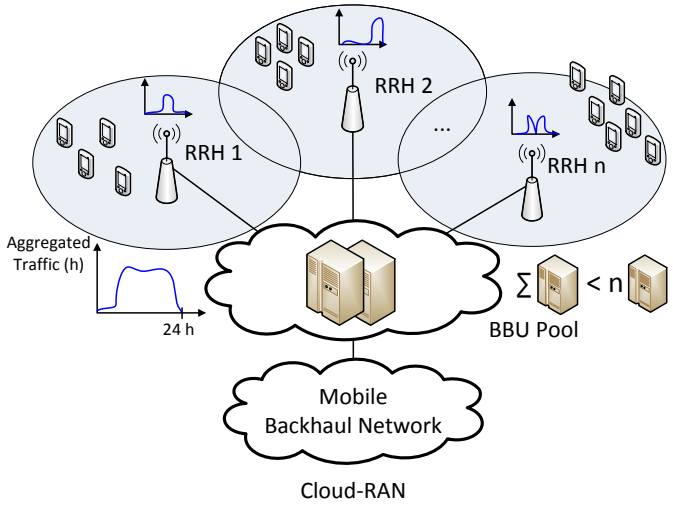
Multiplexing gains are available for any shared resources



$$MG_{printers} = \frac{\#people}{\#printers}$$





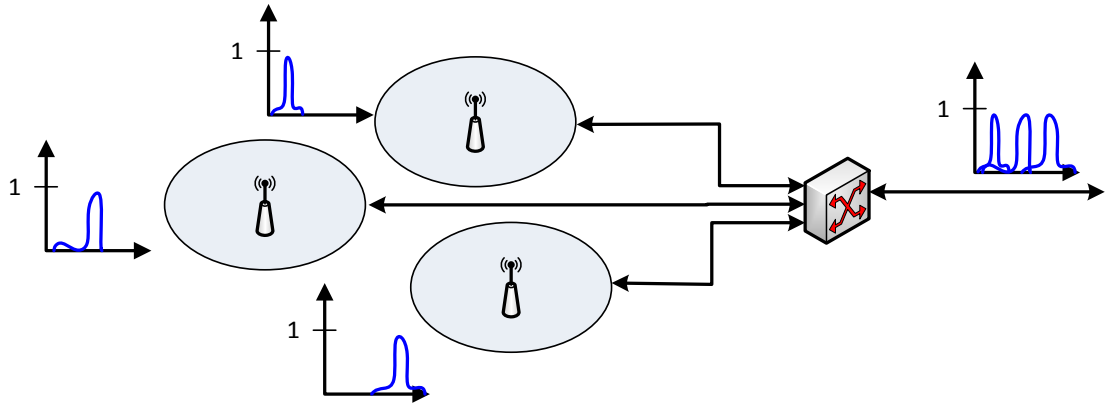


How big are the multiplexing gains in C-RAN?

Multiplexing gains are available for any shared resources

- Variable bit rate on the fronthaul network
  - Bursty traffic

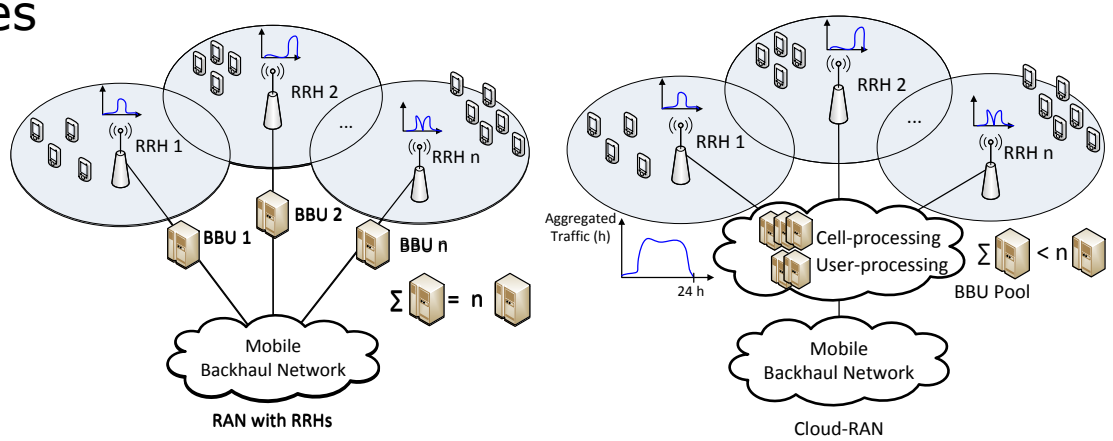
$$MG = \frac{\sum^{cells} SingleCellLinkResources}{AggregatedLinkResources}$$



- BBUs in the pool – Pooling Gain (PG)
  - Processing resources
  - Power

$$PG_{processing} = \frac{\sum^{cells} BBResources_{RAN}}{BBResources_{BBUpool}}$$

$$PG_{power} = \frac{\sum^{cells} BBPower_{RAN}}{BBPower_{C-RAN}}$$



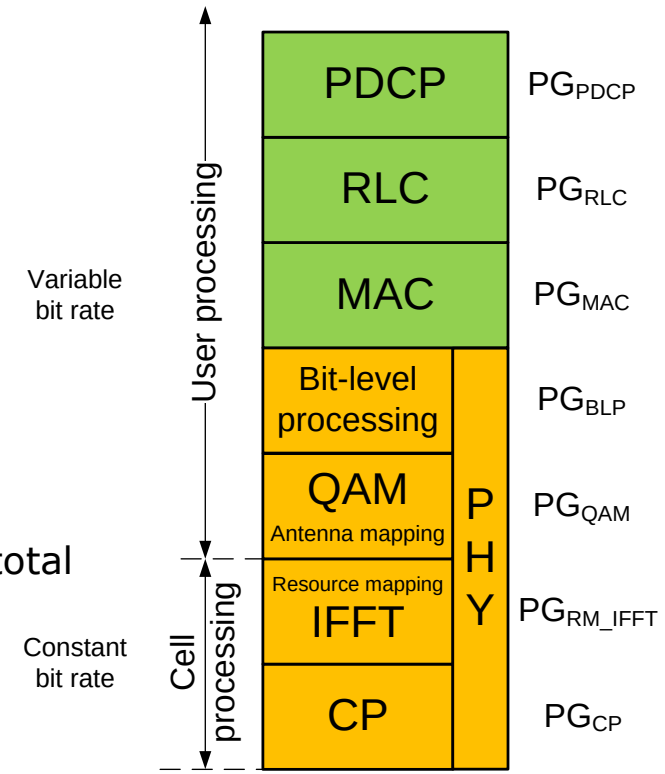
Multiplexing gains in C-RAN

Sources

- Aggregation of bursty traffic
- Tidal effect
- Different functional splits
  - On BBU/fronthaul

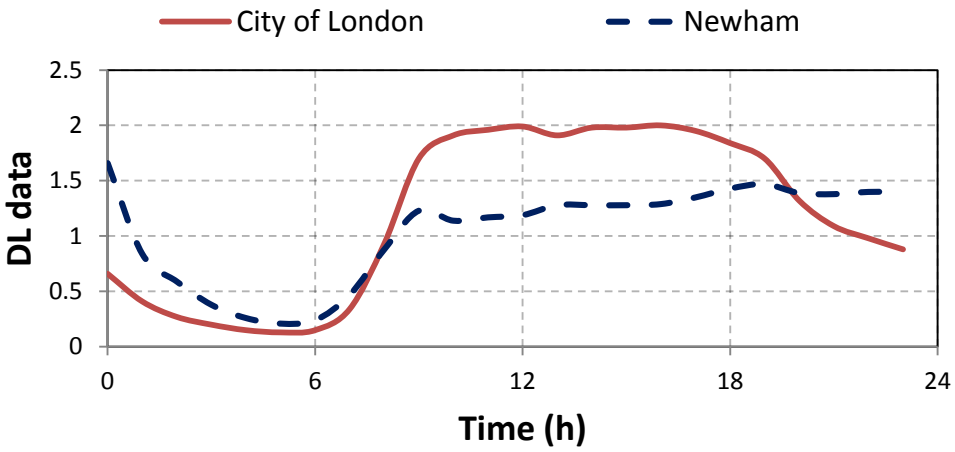
Impact energy and cost savings

- On user-data dependent resources
- Processing: ctrl + cell + user / MG
  - 3-12% on downlink, 17-33% on uplink of total baseband processing [2]
- Power: ctrl + cell + user / MG
  - 2-24 % of total base station consumption [2]

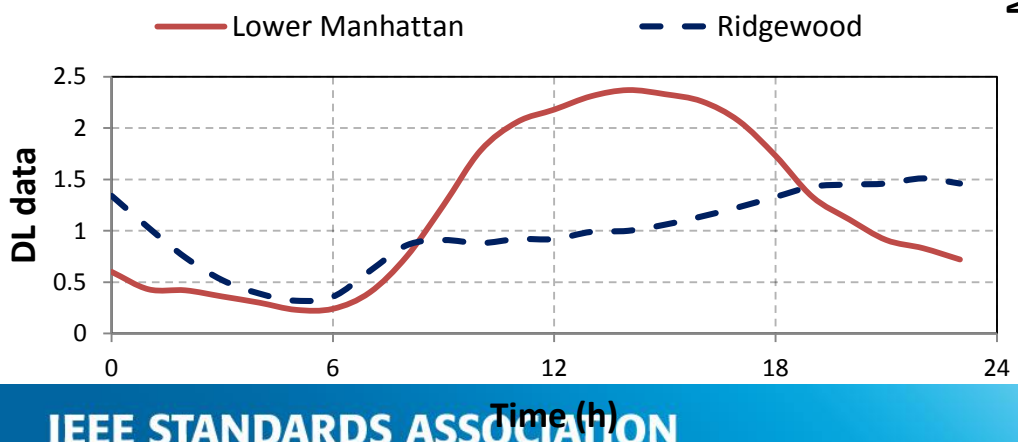


Exploring tidal effect – analytical approach

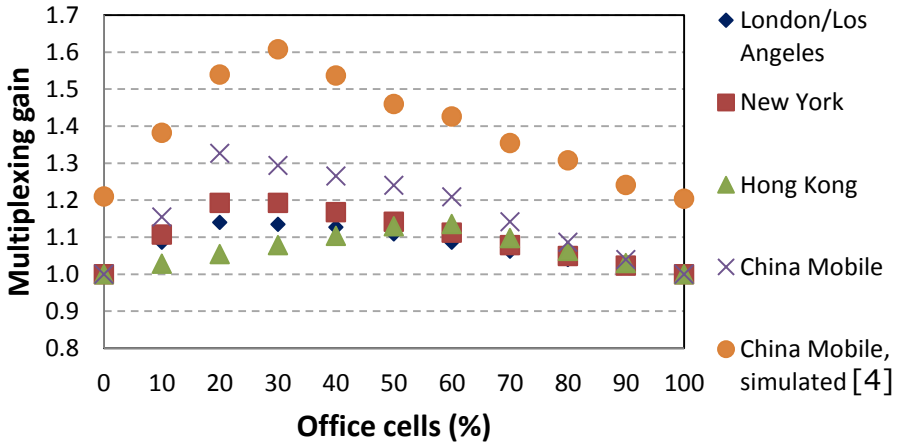
Traffic in London, from MIT/Ericsson [3]



Traffic in New York, from MIT/Ericsson [3]

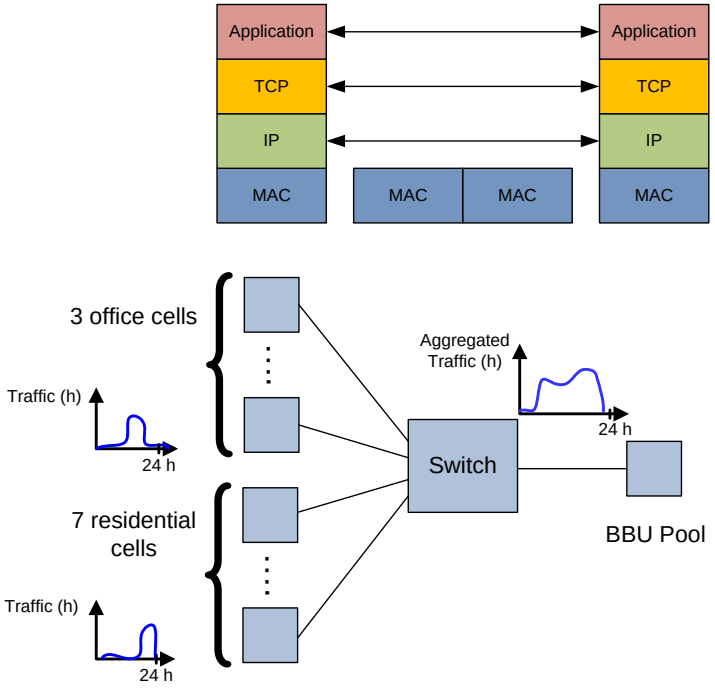


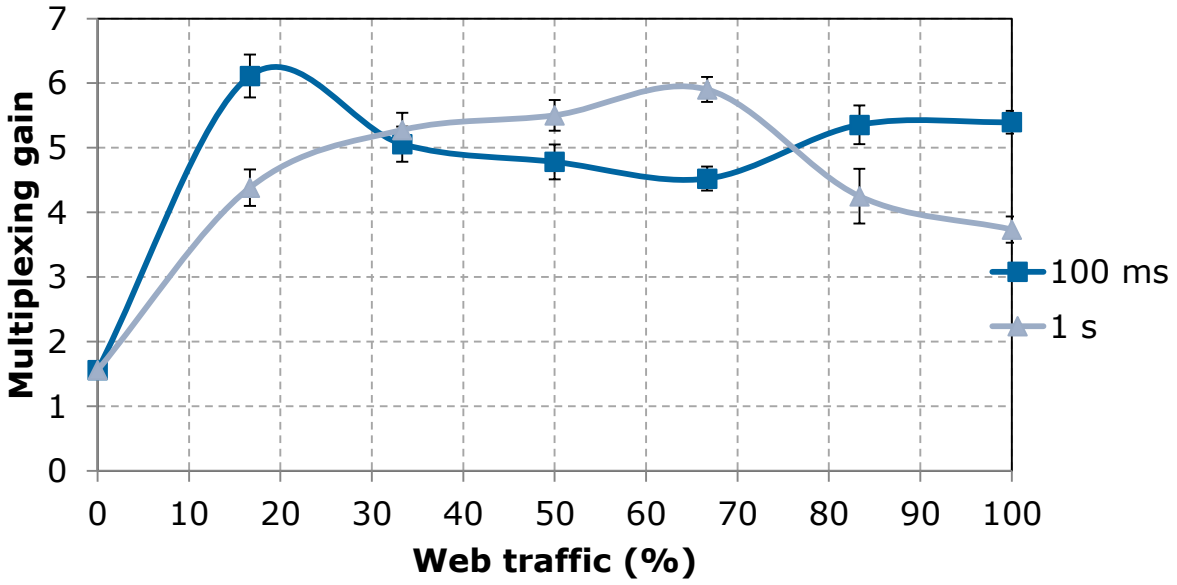
Multiplexing gain for different locations, for different mix of office and residential cells



[4]

Exploring application mix – OPNET simulations [5]





Results for 30% office, 70% residential cells, web and video traffic

Traffic burstiness contributes to multiplexing gain up to 6

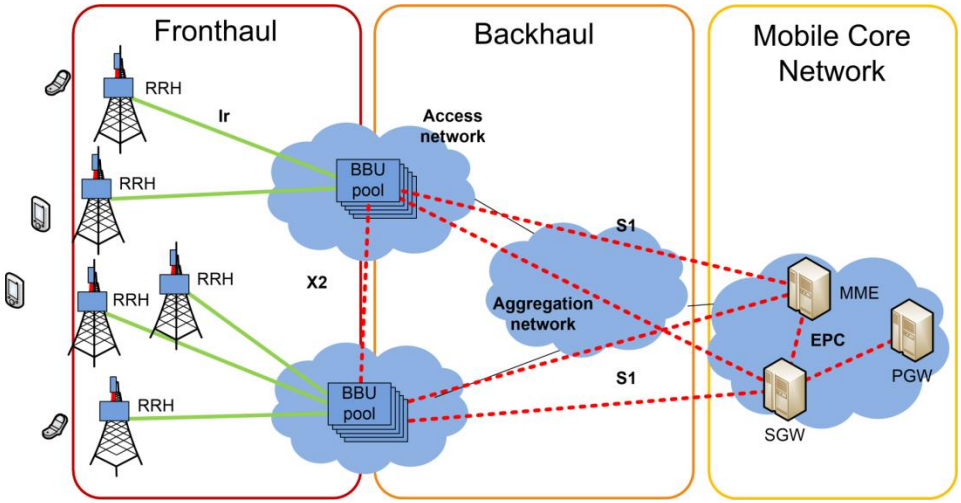
Discussion

- PG from analyzing compute resource utilization, in Giga Operations Per Second (GOPS): 1.09 - 1.37, source: Werthmann et al. [6]. Tidal effect not accounted.
- PG based on population in different districts in Tokyo: 4, source: Namba et al. [7]

- MG from tidal effect: 1-1.3
- MG from traffic burstiness: up to 6
- Fraction of it impacts baseband resources (3-33%) to achieve PG

→ MG up to 6 achievable on fronthaul, fraction of it achievable on BBU side

→ New functional split should result in bursty traffic being as "low" as possible (closest to BB-RF – traditional RRH BBU split) to benefit from C-RAN (e.g. spectral efficiency)



Fronthaul transport network

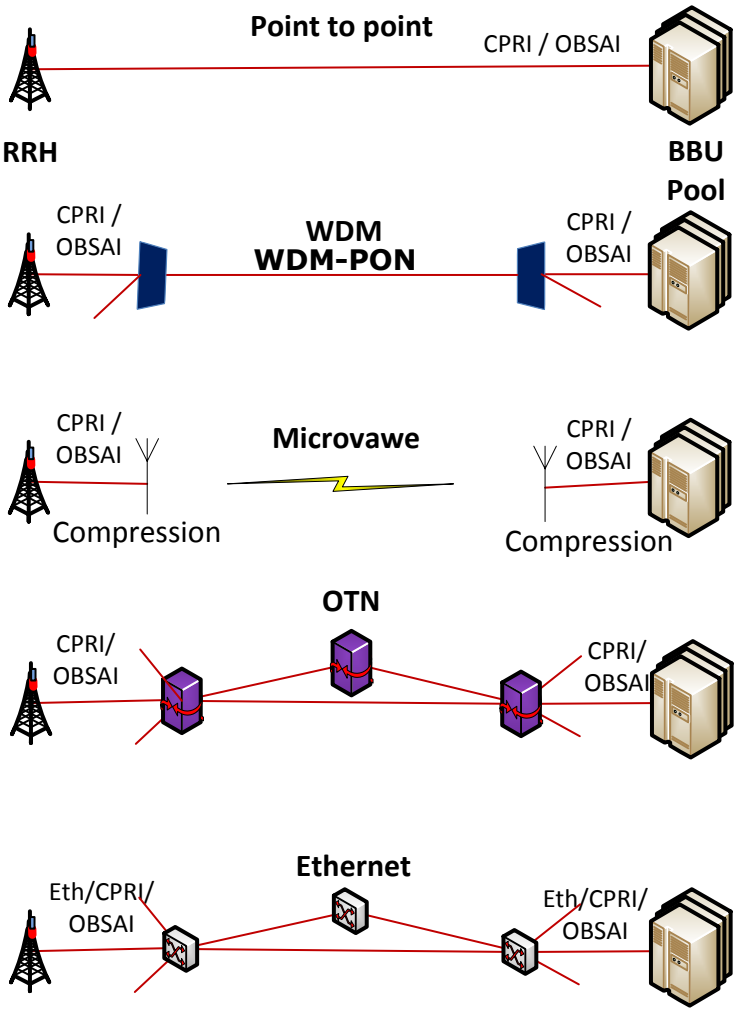
- Towards NGFI

Transport options

Synchronization challenge: application of IEEE 1588

Delay challenge: application of TSN

Possible transport solutions



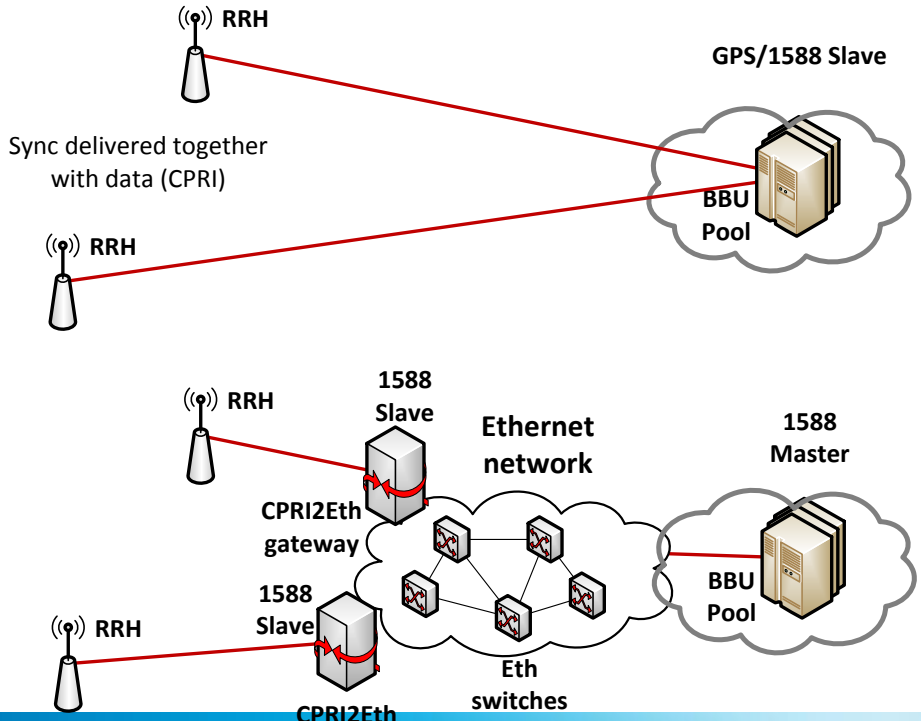
Technology is ready

(capacity not necessarily)

Shared Ethernet for cost-saving and flexibility [8]

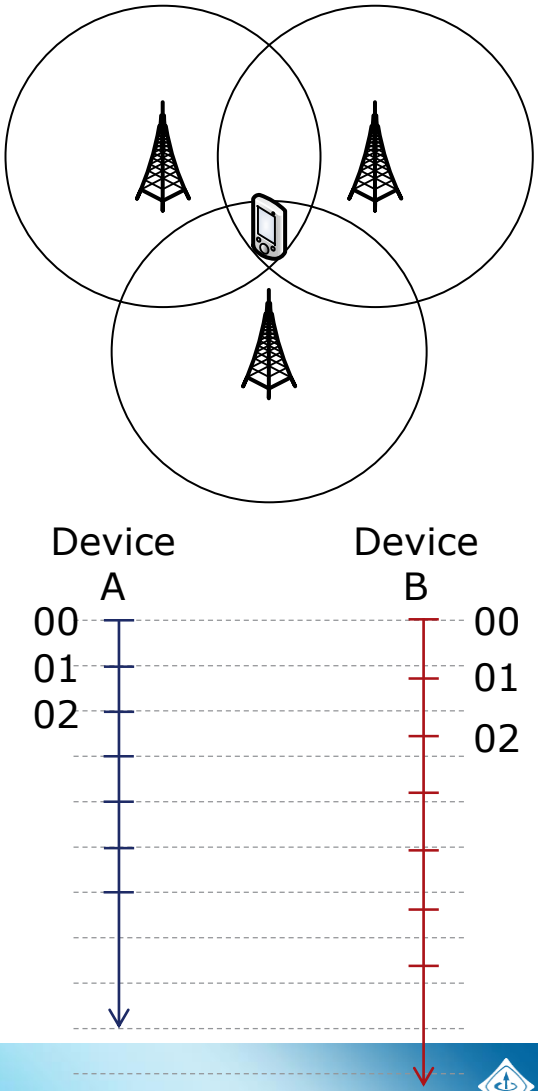
- ✓ Widely deployed (reuse!)
  - ✓ Dedicated links
  - ✓ Shared links
- ✓ Aggregation
  - ✓ Multiplexing gains on BBU and links
- ✓ Switching

- ! Fronthaul cost savings vs problems with delays and synchronization
  - ! *Synchronous CPRI vs asynchronous Ethernet*
  - ! Data delay: 100-400 us, ≈constant



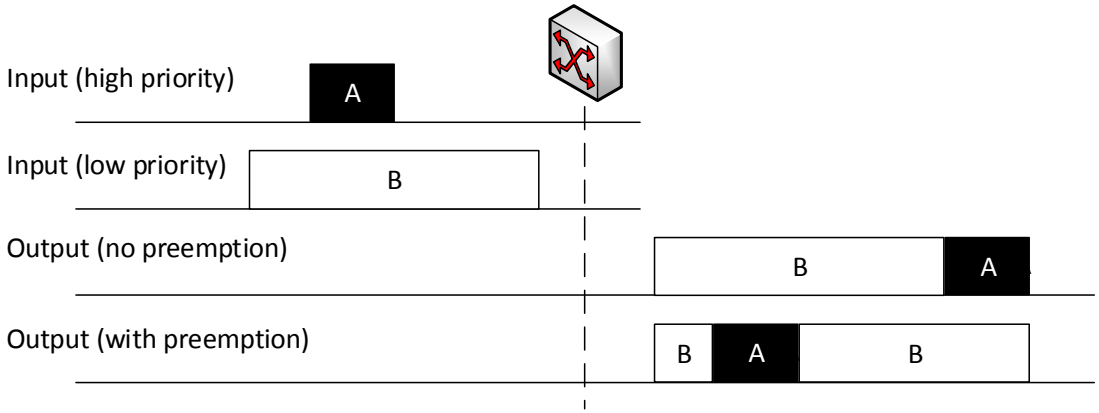
Timing in fronthaul

- Timing is really important
  - *Frequency of transmission*
  - *Handover, coding, cooperative techniques, positioning*
- Requirements (4G)
  - *Frequency error LTE – A TDD/FDD: ±50 ppb*
  - *Phase error LTE-A with eICIC/CoMP: ± 1.5 - 5 µs, MIMO: 65 ns, positioning: ± 30 ns*
  - *What are the requirements for RoE and 5G?*
- Current solutions for timing distribution
  - *GPS*
  - *PHY layer clock – SyncEth*
  - *Packet-based timing*
    - IEEE 1588v2 (PTP)
  - *Multiple*



How to reduce queueing delays?

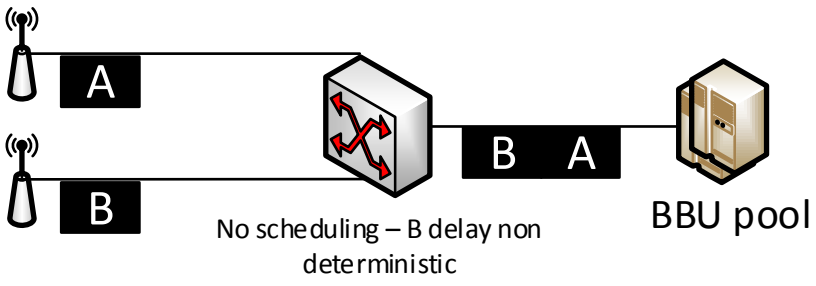
Preemption (switch upgrade required)

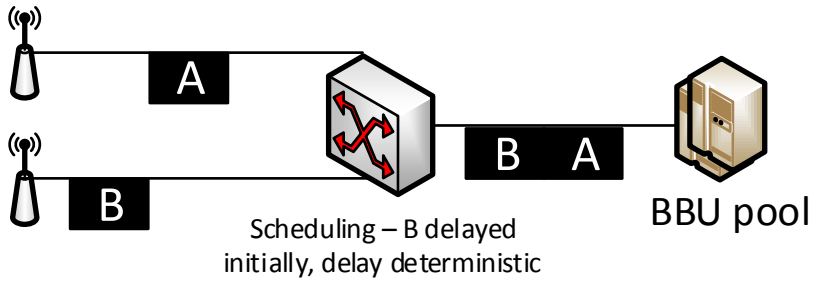


IEEE 802.1, Time Sensitive Networking task force

- Frame preemption (802.1Qbu)
- Scheduled traffic (802.1Qbv)
- Time-Sensitive Networking for Fronthaul (profile definition, 802.1CM)

Scheduling and source scheduling



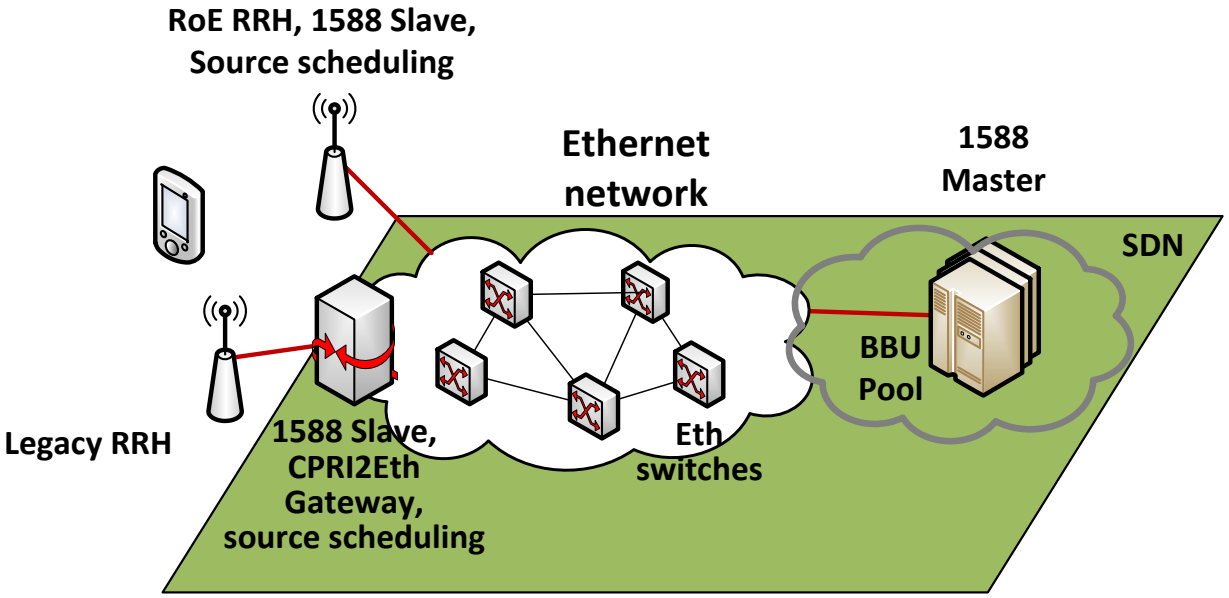


Exemplary architecture

With control solution – e.g. SDN

With synchronization solution – e.g. IEEE 1588

With delay minimization solution – e.g. TSN



Conclusions and final remarks

Costs vs savings

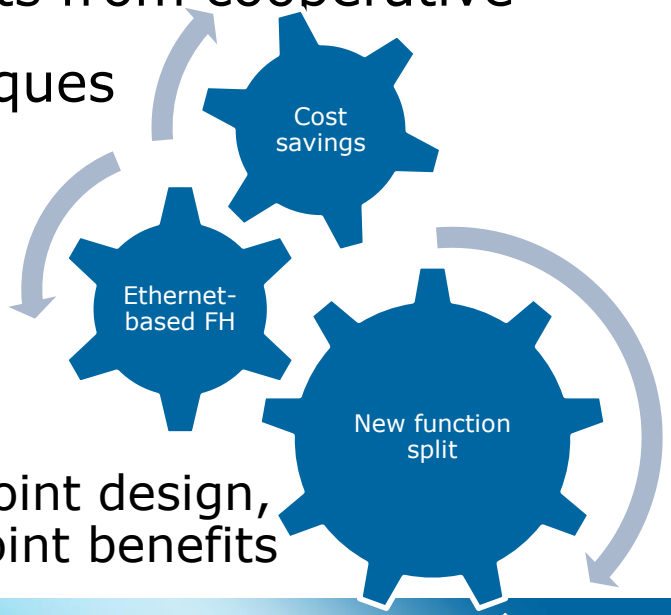
Costs

- 2x2 MIMO, 20 MHz LTE, 15+1 CPRI →2.5 Gbps
- 3 sectors? → 7.5 Gbps
- Tens of BS over long distance? →100+ Gbps

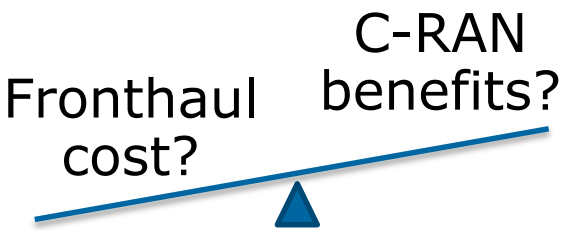
Savings

- *Equipment*
- *Energy*

Benefits from cooperative techniques



Joint design, joint benefits



Re-define fronthaul

Conclusions, proposals to 1914

- Optimal functional split is needed to reduce data rate and benefit from multiplexing gains on fronthaul, while exploiting benefits of C-RAN
- One split probably won't fit all – possible reconfiguration options are interesting
- Multiplexing gains are possible on BBU resources (on 3-33% of resources), and for variable bit rate split also on fronthaul.
- Industry shows a strong interest in packet-based fronthaul.
- Ethernet-based fronthaul with traffic scheduling and/or preemption has the potential to meet mobile networks' requirements while being cost-efficient.

Thank you for your attention

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