EU FP7 Project iJOIN

iJOIN: **I**nterworking and **JOIN**t Design of an Open Access and Backhaul Network Architecture for Small Cells based on Cloud Networks

Functional Split Options for Centralized RAN with Imperfect Backhaul

46. Treffen der VDE/ITG-Fachgruppe 5.2.4
Mobilität in IP-basierten Netzen

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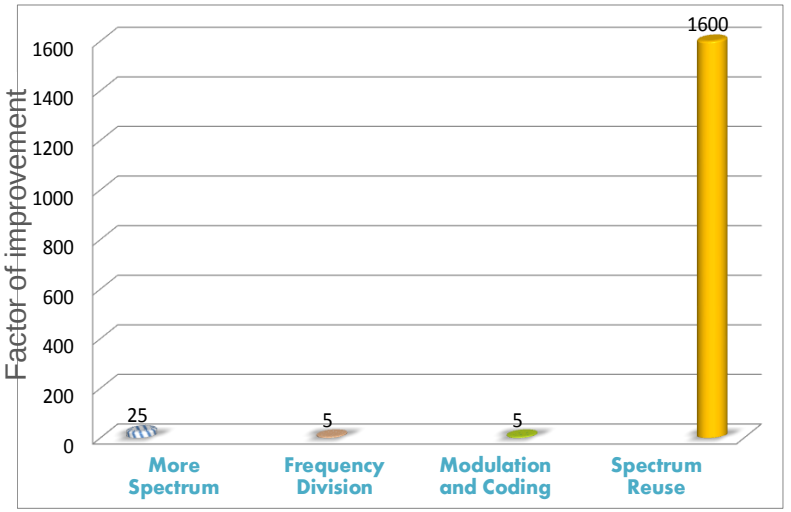
Key enablers to satisfy data demands

Small Cells

- 50% Total cost of ownership (TCO) savings
- Four-fold increase in density until 2014
- Worth about 6.1bln USD until 2014

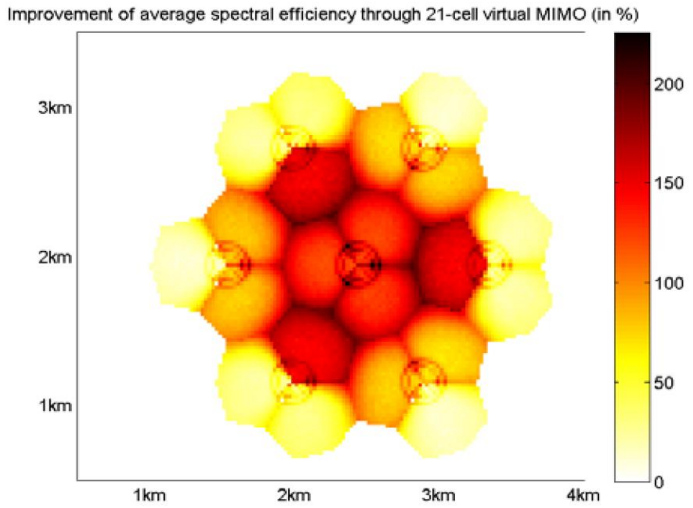
➔ Small-cells are *the* option to handle higher rates and to improve energy/cost-efficiency



Centralised Processing

- C-RAN handles inter-cell interference, allows for higher utilisation and to avoid peak-provisioning
- Up to 50% energy-saving
- 20%-50% OPEX reduction, 15% CAPEX reduction
- Requires high capacity and low delay backhaul

➔ Centralisation is an option to implement the network but requires more flexibility than today



How the “Cloud” changes the picture …

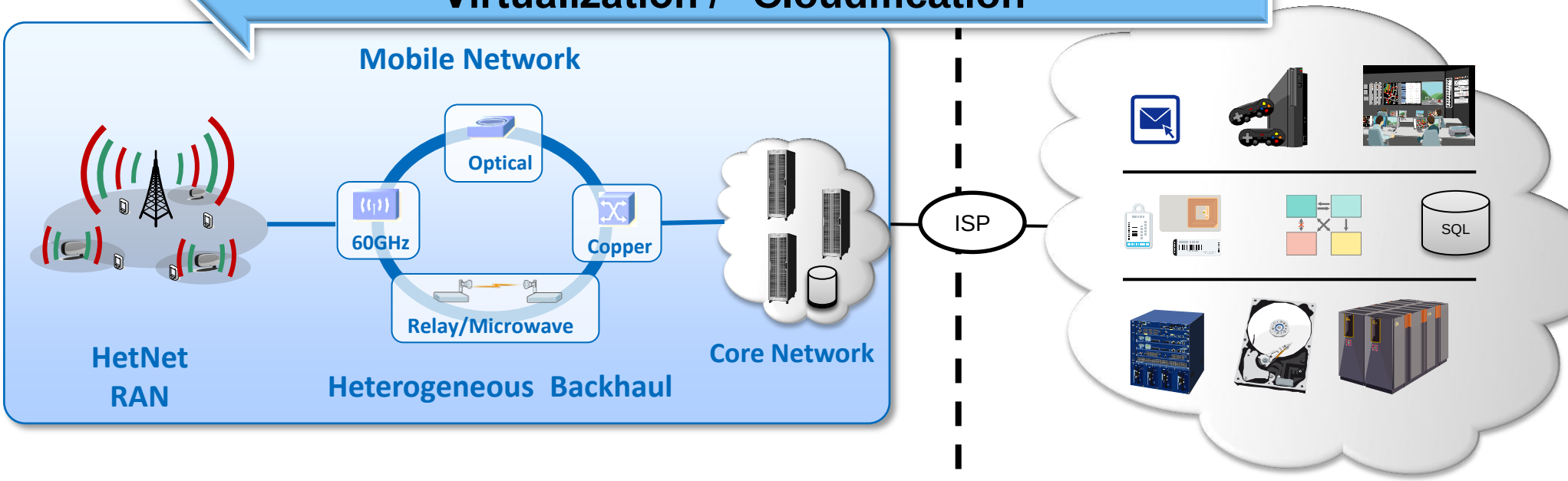
The communication realm

- C-RAN
- RAN-Sharing
- SDN
- SDR
- NFV
- vEPC
- SDN

The IT world

- SaaS
- PaaS
- IaaS
- On-demand
- Broad access
- Pooling
- Elasticity
- Measured

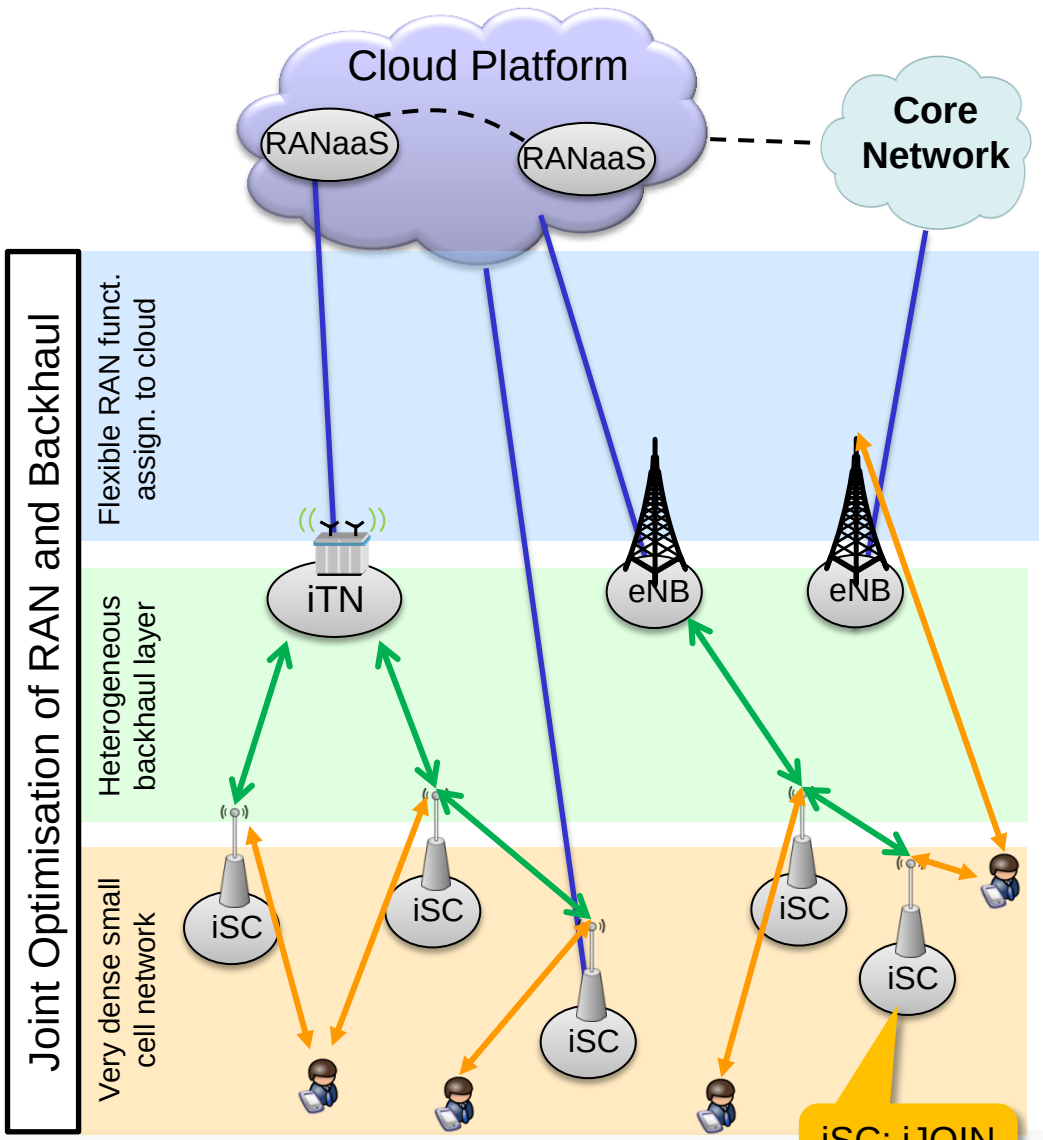
Virtualization / “Cloudification”



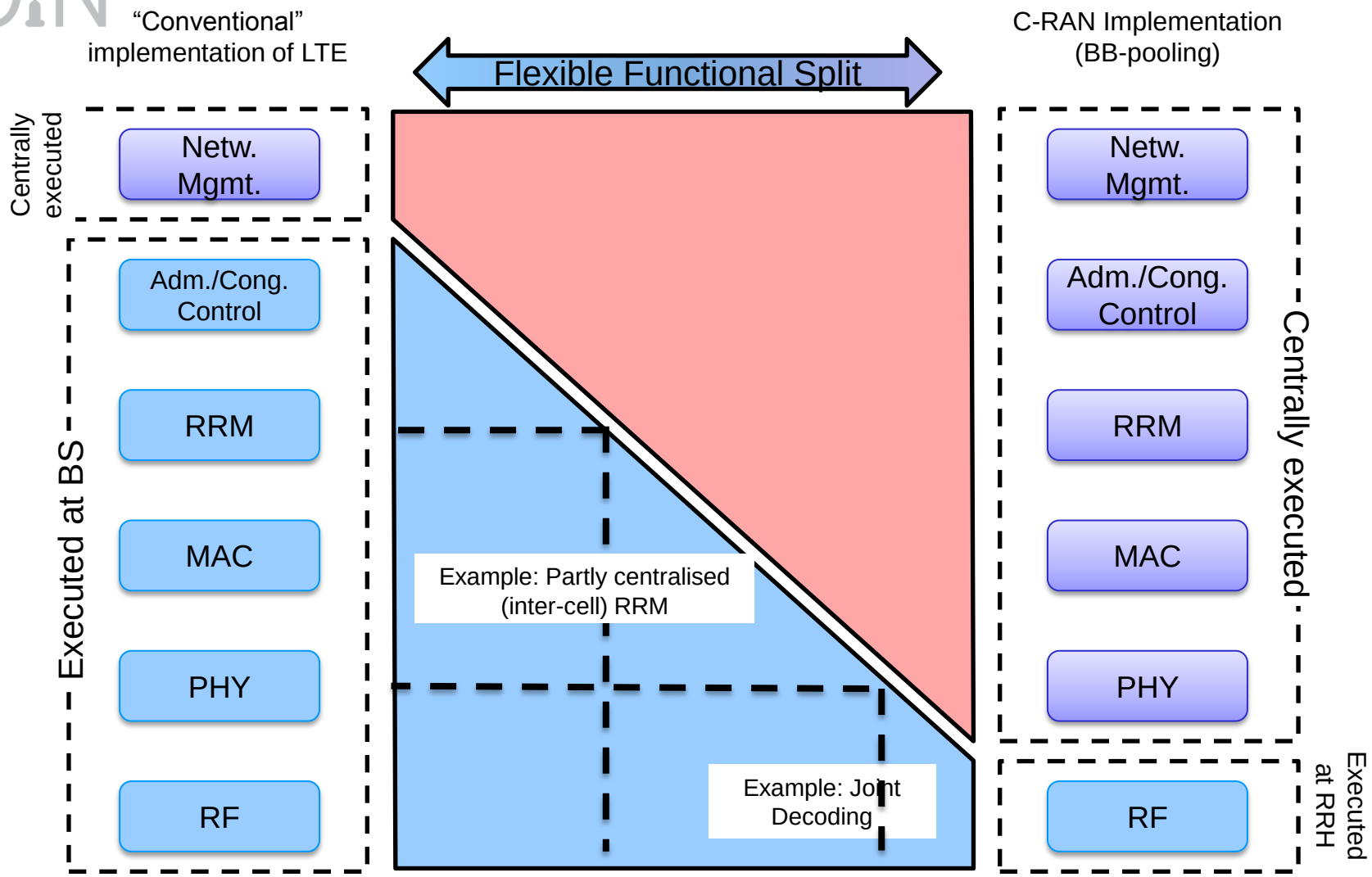
Key Concepts

- **Flexible centralisation through RANaaS (RAN-as-a-Service)**
  - Push RAN functionality into cloud-like platforms
  - Simplified RAN management and flexible small-cell solutions
  - Reduce complexity & cost through elastic & flexible function assignment
  - Higher energy-efficiency through computational diversity and higher utilisation

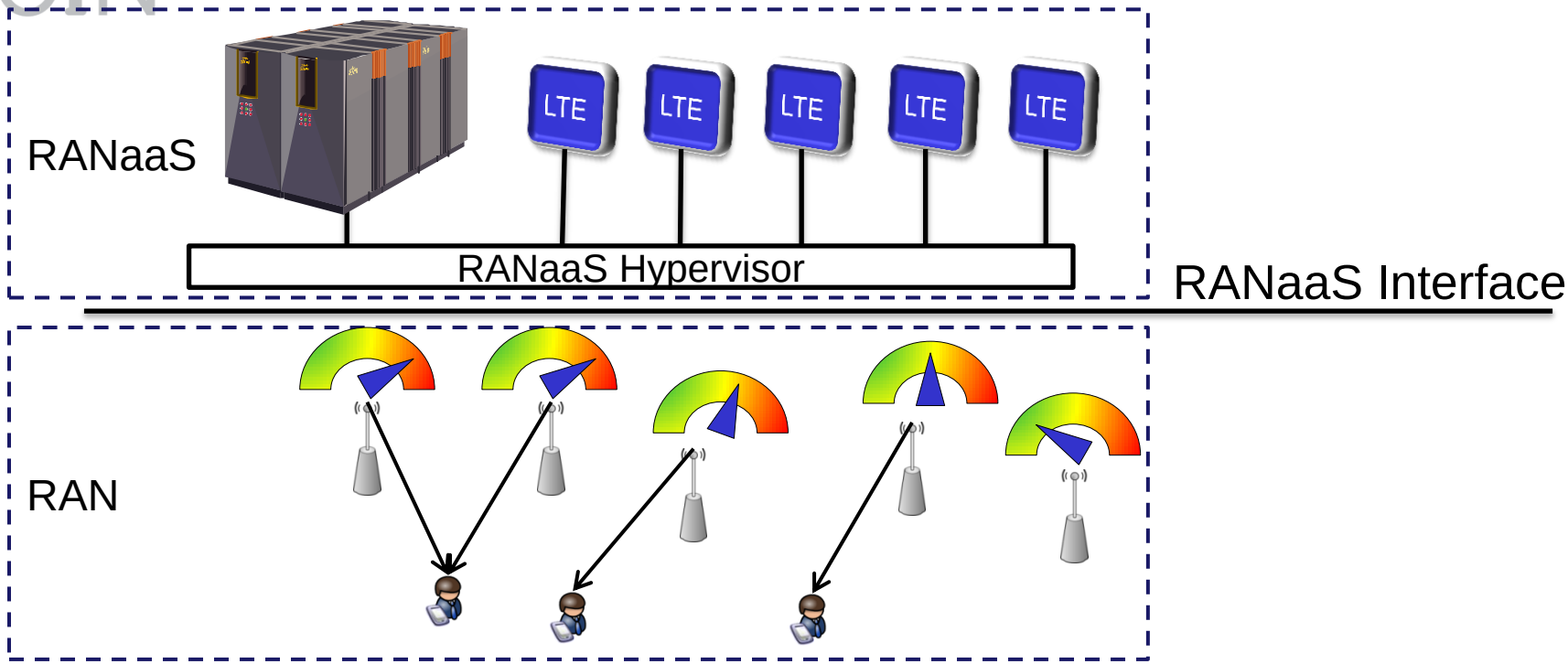
- **Joint design and optimisation of RAN and backhaul**
  - Interworking of access and backhaul network
  - Optimise for flexible centralisation
  - Optimise backhaul for small cells
  - Consider heterogeneous backhaul network (fibre and wireless)
  - Relax backhaul requirements through dynamic provisioning (“on-demand”)



Key concepts: flexible functional split

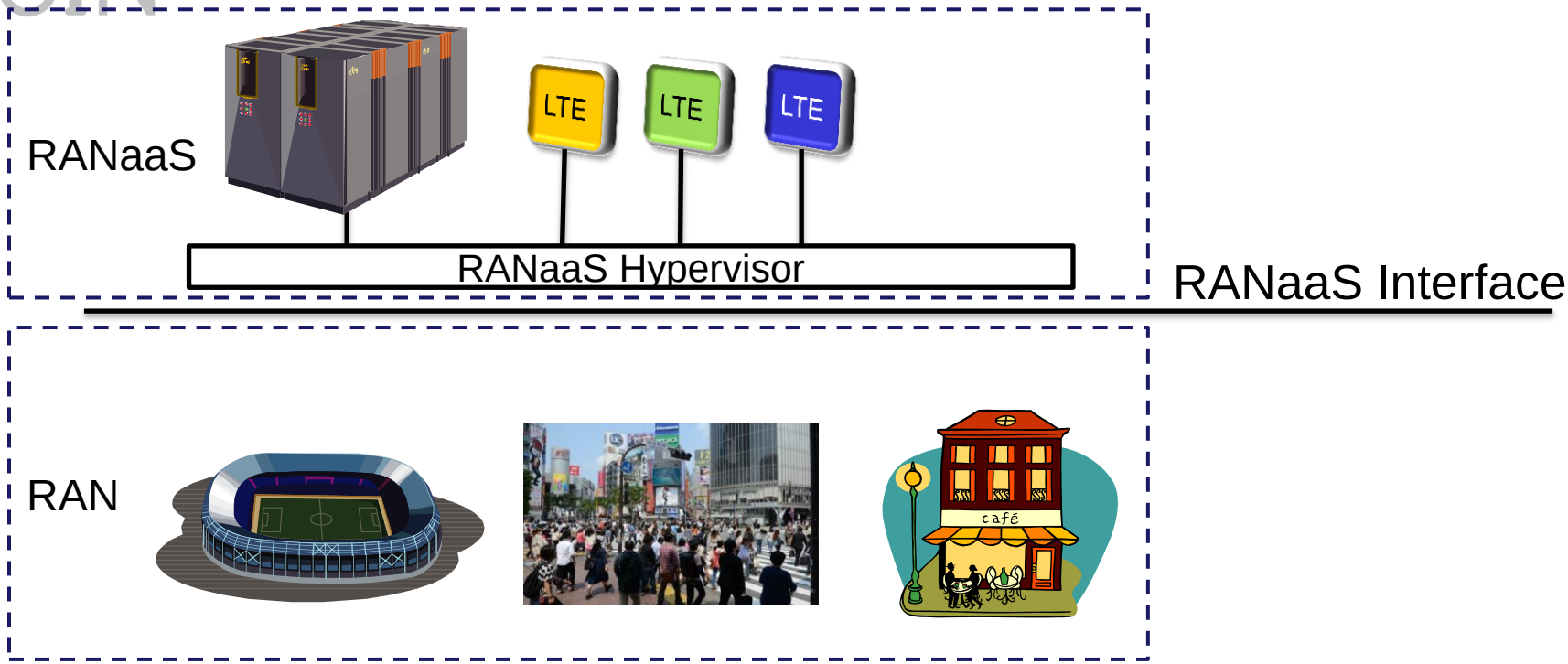


Key concepts: exploit centralization gains



- Coordination gains: e.g. ICIC, joint precoding, joint decoding, …
- Computational diversity
  - Exploitation of temporal and spatial traffic fluctuations
  - Efficiently use available resources, scale resource according to needs (resource pooling, elasticity)

Key concepts: service and function agility



- Localized optimization
  - Optimization based on purpose, deployment, …
  - Using software implementation rather than configuration (SON)
  - Fast deployment of tailored software depending on location and use case

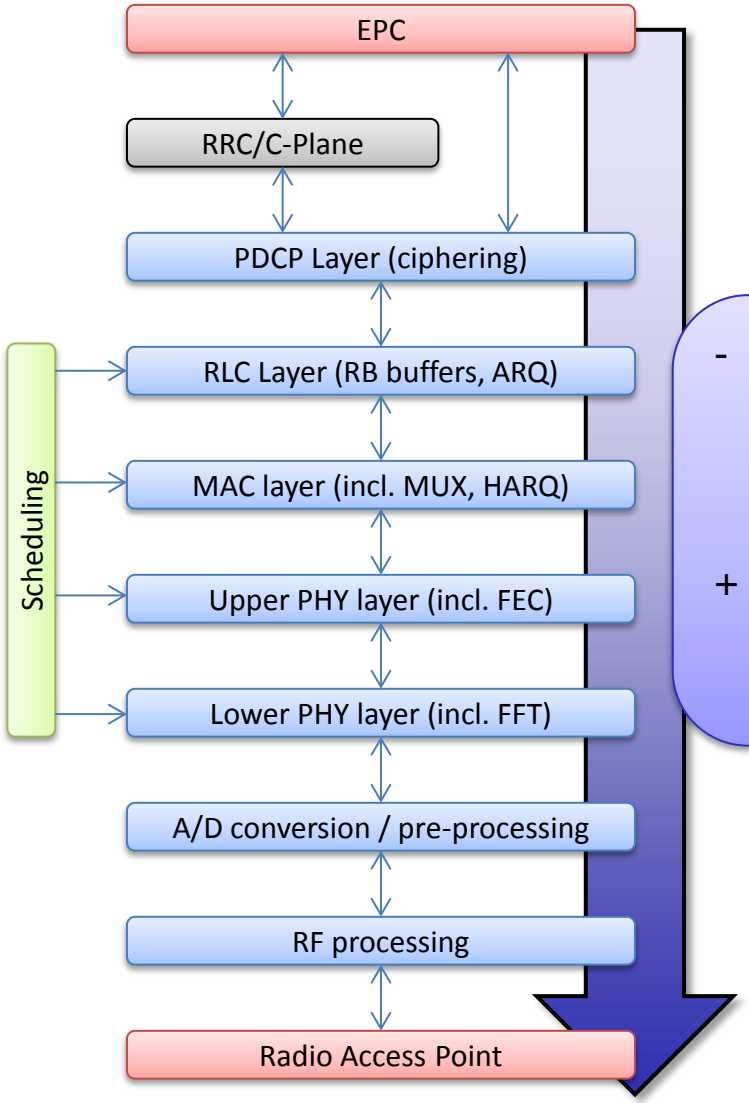
Challenges

- Functional split of RAN protocol stack
- Computational resource provisioning
- “cloudified” RAN architecture
- Utilization efficiency
- Cloud platform latency/U-plane capabilities

Challenge: Where to split?

- **Constraints and requirements**:
  - Backhaul characteristics (latency, bandwidth)
  - 3GPP requirements (latency, bandwidth, protocol stack)
  - Computational resources

- **Benefits:**
  - Multiplexing gains (computational resources, user traffic)
  - Coordination gains (interference mitigation, cancellation, load balancing, ...)
  - ..are an operator-defined optimization target!

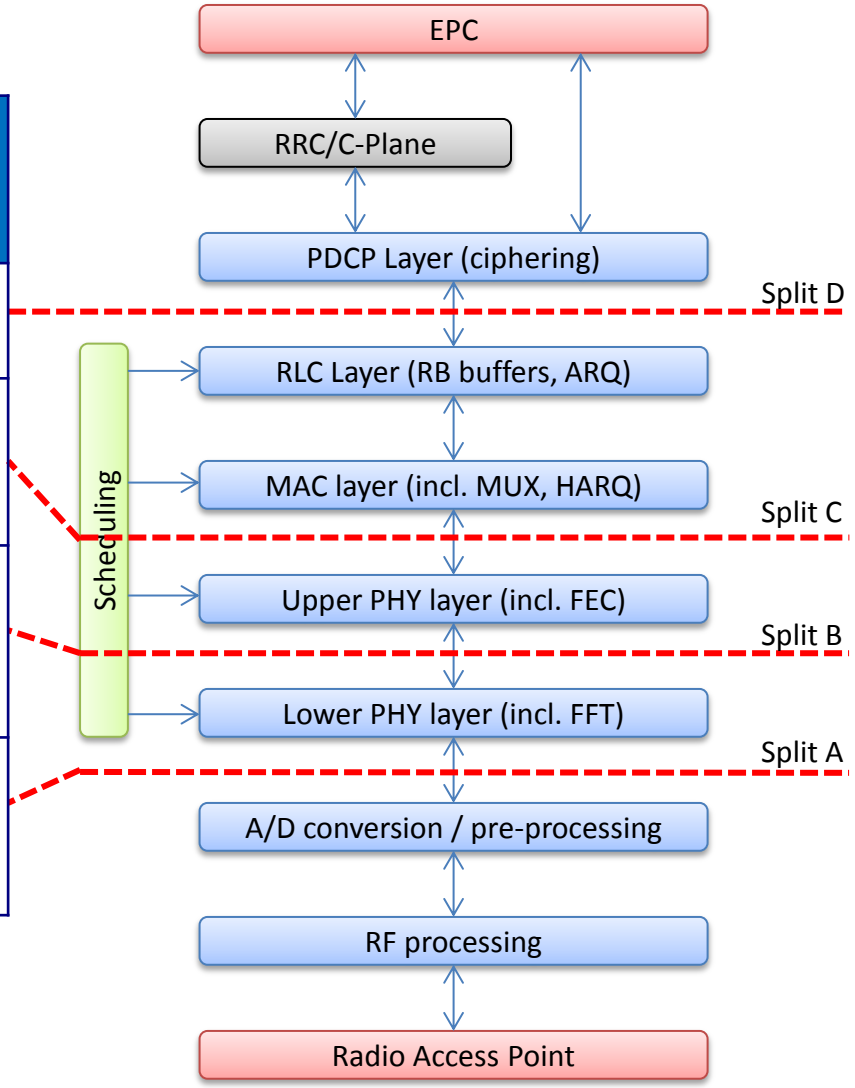


- **higher requirements** (more bandwidth, lower latencies, higher comp. effort)

+ **gains** from coordination, diversity, joint processing

Functional Split Options

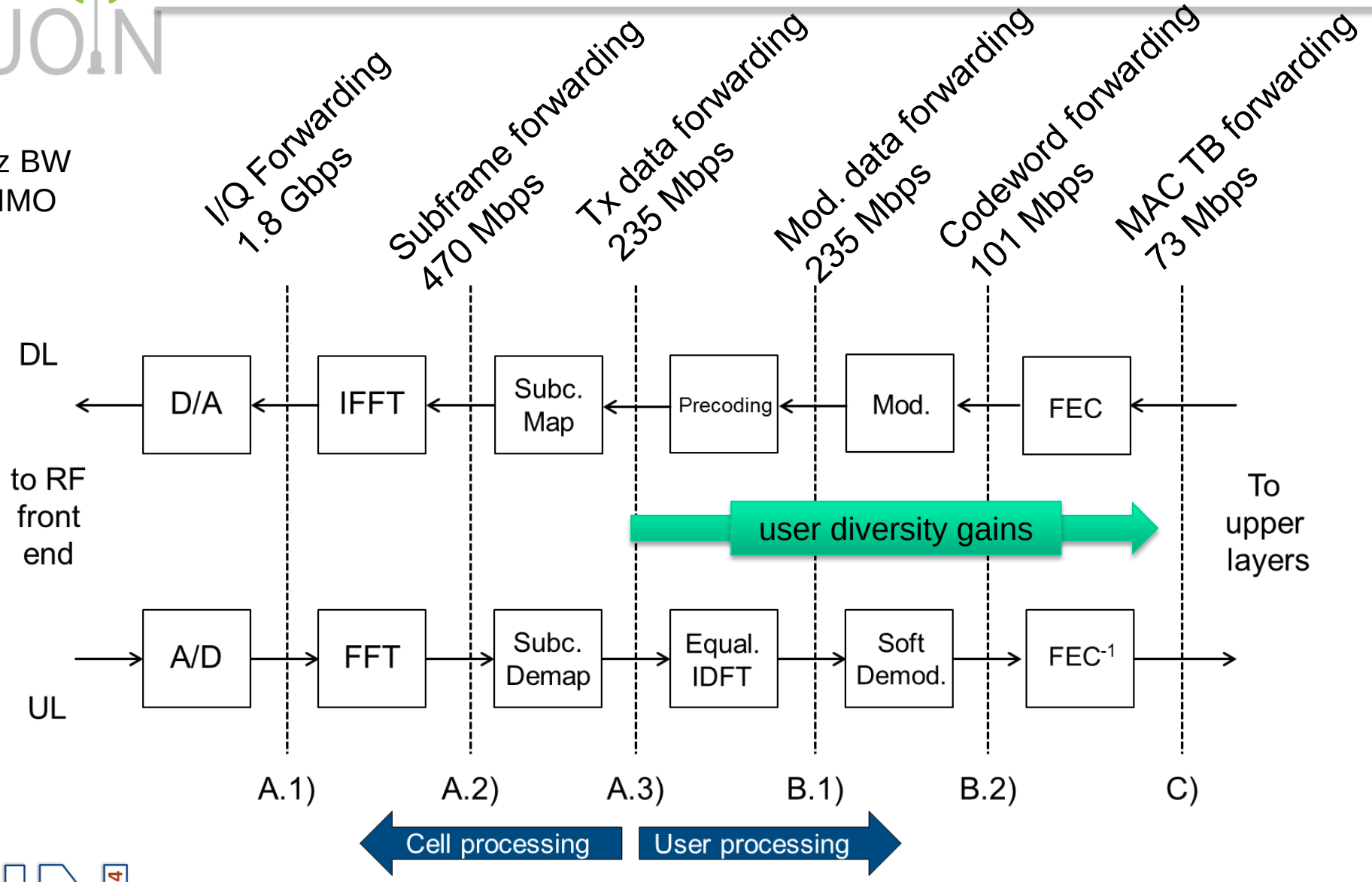
Split option	Lowest layer centralized	RTT requirements	Bandwidth requirements	Centralization scheme	Main centralization gains
D	PDCP	> 50ms	U-Plane + C-Plane overhead	Centralized connection control	Load balancing, energy efficiency
C	MAC	<3 ms (HARQ sched.)	U-Plane + C-Plane overhead	Coordinated resource allocation	Interference mitigation, cooperative schemes
B	FEC	~ 1ms (HARQ + FEC processing time)	U-plane + redundancy (~ +30%)	Coordinated resource allocation, central FEC	Computational diversity
A	FFT/IFFT	5 µs (CIPRI)	Quantized symbols (several Gbps)	Full PHY centraliz-ation	Centralized precoding, joint decoding



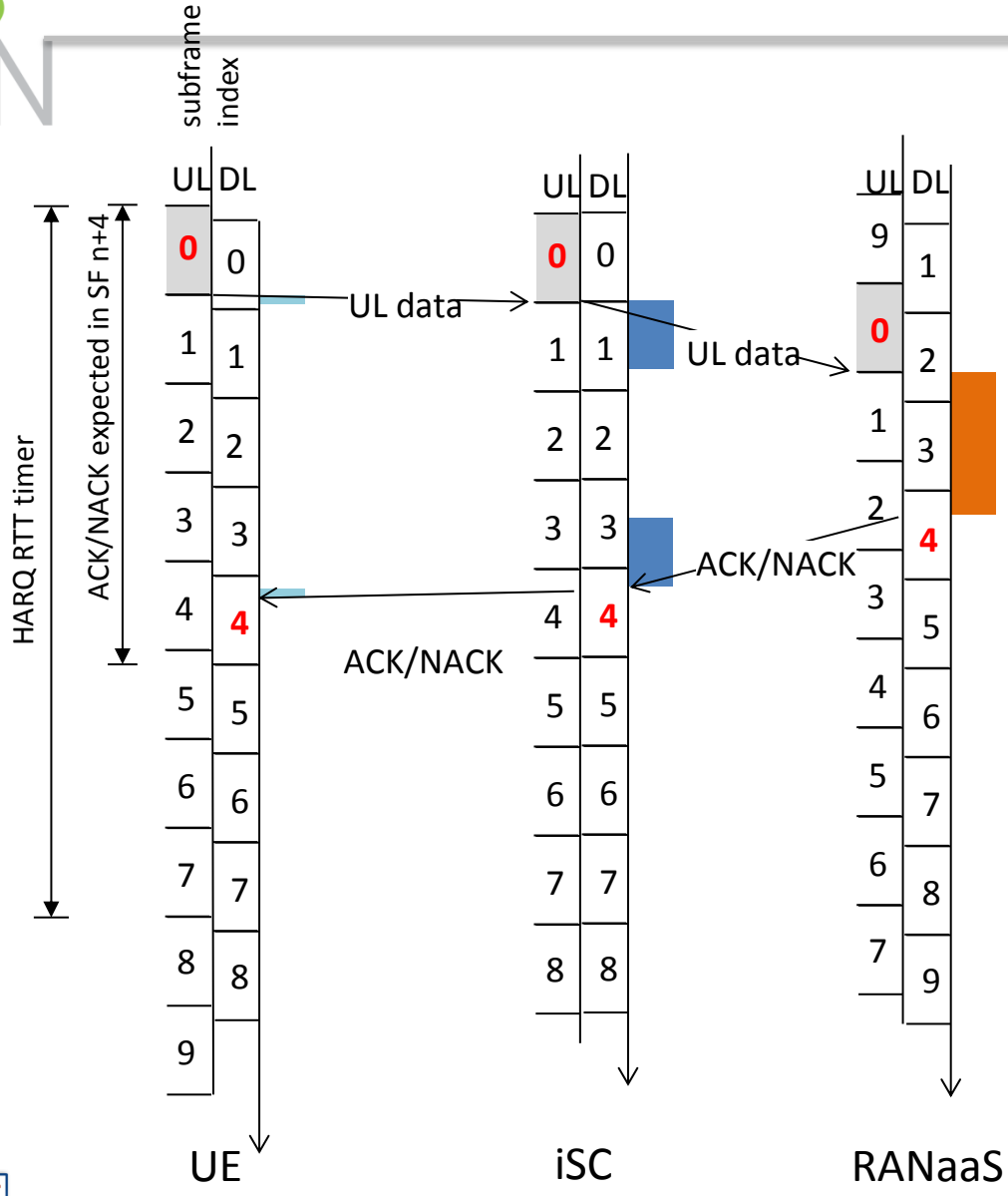
For more information see iJOIN deliverables D2.2, D3.2

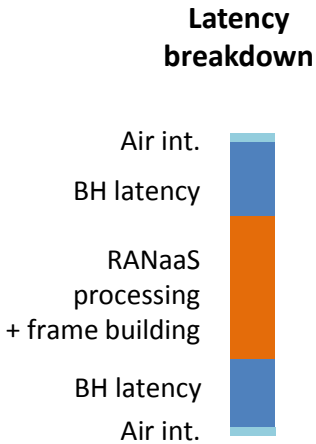
Bandwidth requirements (DL)

20MHz BW
2x2 MIMO



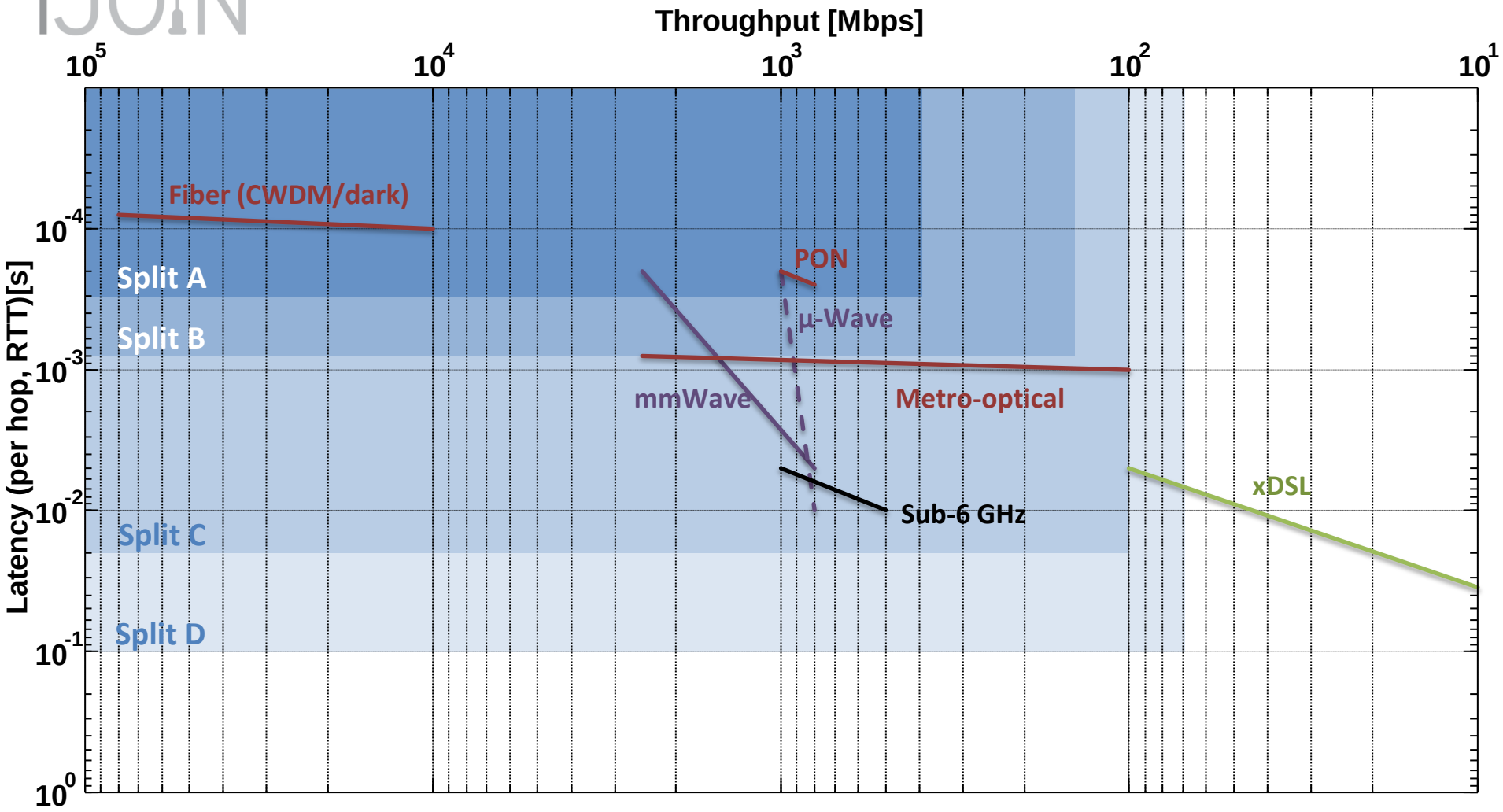
Latency requirements: HARQ



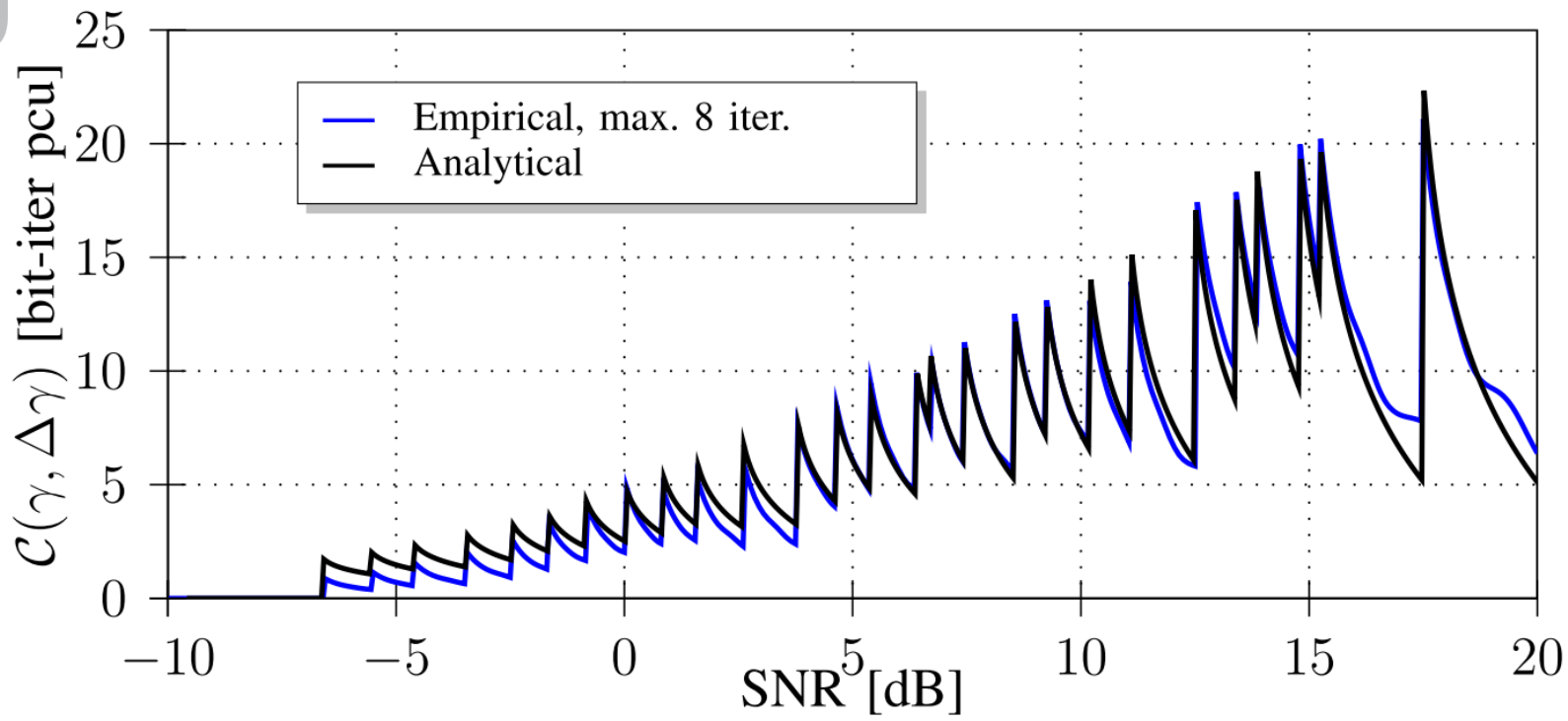


"Latency bottleneck", applies to all splits with centralized MAC

Mapping functional splits to backhaul types



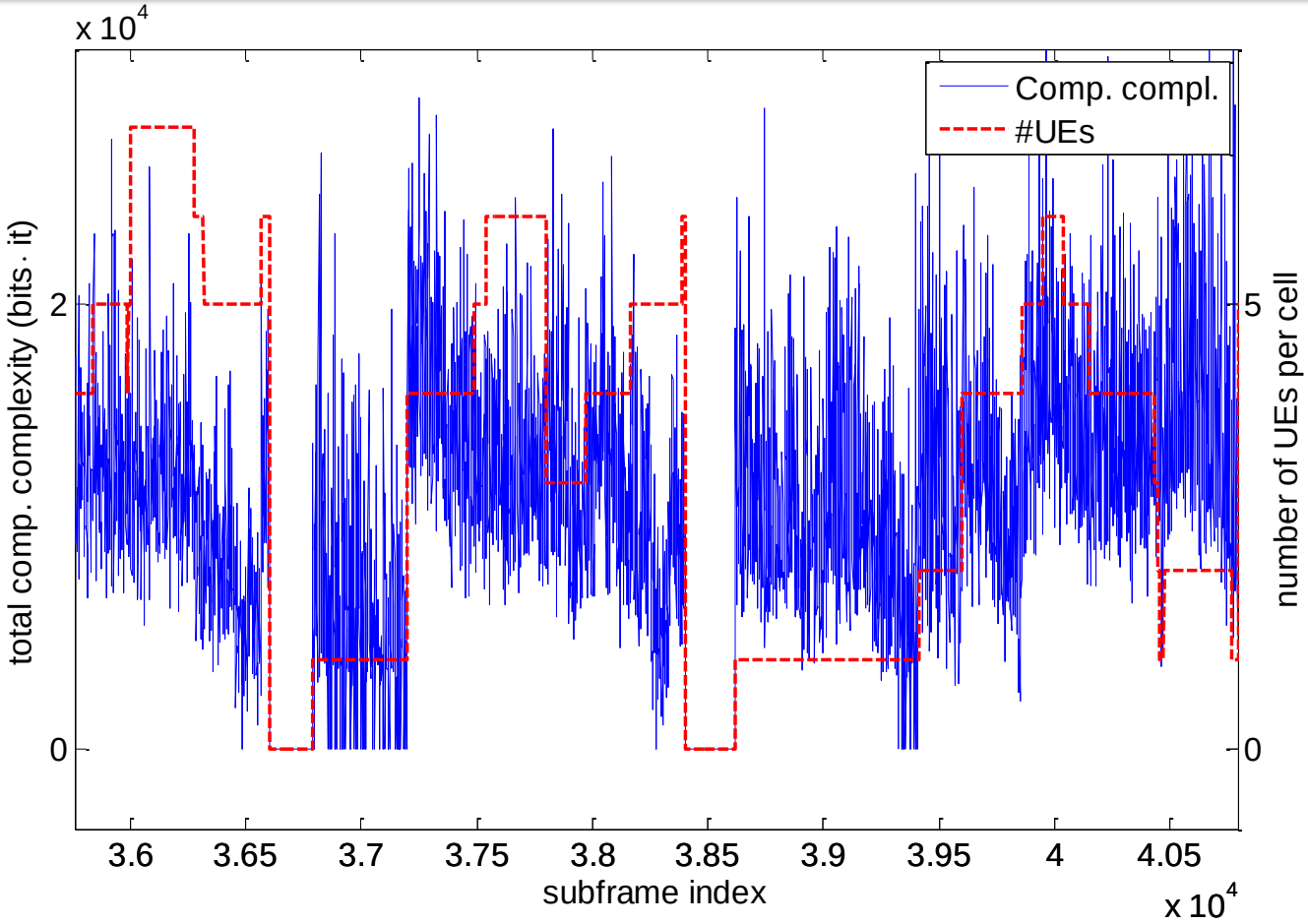
Challenge: computational complexity



P. Rost, S. Talarico, M. Valenti, *The Complexity-Rate Tradeoff of Centralized Radio Access Networks*, submitted to IEEE TWC

- Main contributor to computational complexity is the turbo decoding (UL)
- Strongly non-linear complexity in SNR, depends on modulation and coding scheme
- **Computational outage**: TB cannot be decoded within time budget (<3 ms)

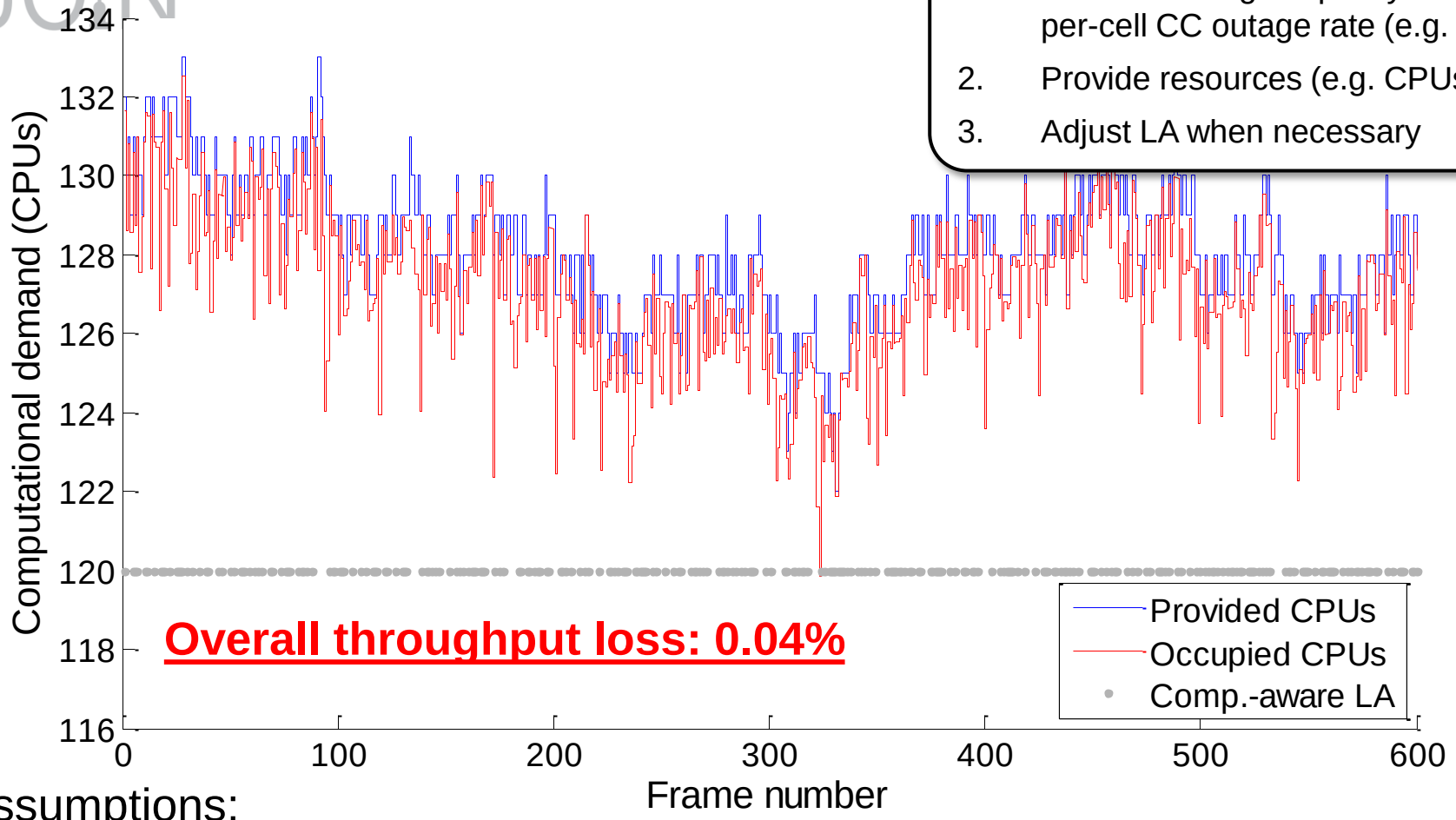
Computational complexity: cell level



- System-level results for per-cell CC
  - Correlation between #UEs and CC?
  - Impact of scheduling, resource allocation?

Joint RAN/cloud resource provisioning

1. Estimate outage capacity based on per-cell CC outage rate (e.g. 1%)
2. Provide resources (e.g. CPUs)
3. Adjust LA when necessary



- Assumptions:
  - 456 cells/142 base stations (macro+small cell), 1200 users
  - 96 GFlops per CPU

Conclusions

- **New paradigms**
  - RANaaS: Apply Cloud principles to RAN operation
  - Flexible functional split: adapt level of centralization to backhaul capabilities
  - Increase utilization efficiency by joint cloud/RAN resource management

- **New insights**
  - Feasible functional splits of the LTE protocol stack
  - “Cloud-aware” link adaptation: first step towards RAN operation on commodity hardware
  - Many more results available on www.ict-ijoin.eu, e.g. feasible splits, BH dimensioning, data center placement, CoMP, commodity HW implementation, …

- **Outlook:**
  - RAN cloudification will be integral aspect of 5G
  - IT companies will continue to push into telco space
  - Technical challenges remain: RAN-capable cloud platforms

Thank you for your attention!