A Perspective on Cloud and Virtual Radio Access Networks for 5G

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Outline

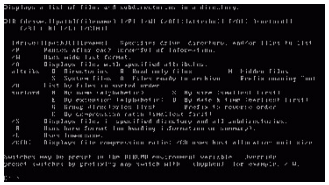
- Motivation.
- Users and Services Trends.
- Architectures.
- Resource Management.
- Conclusions.

Learning from PCs (1)

- Mainframes dominated, until PCs took over when computers were extended to the mass market.
- An operating system based on windows had a crucial importance in the spread of PCs.
- Easiness of use is essential for the mass market.

(IBM, 1972)

(Apple, 1986)



(Wikipedia, 1972)

(Microsoft, 2007)

(PhotosCom, 2008)

(Nokia, 2007)

Learning from PCs (2)

- Initially, PCs had performance metrics that were orders of magnitude below the current ones (ZX Spectrum, 1982, 3.5 MHz, 16 kB, 0 GB).

(*Sinclair, 1982*)

- There's a race in wireless systems between services made available to users and data rates made available by terminals/networks.

(*Nadine Meade, 2000*)

Learning from Cars

- In the beginning, the goal was for faster cars.
- Then, cars evolved for increased comfort and safety of passengers.
- Nowadays, cars are being sold for energy efficiency.
- Speed is no longer important!

(*T Ford, 1927*)

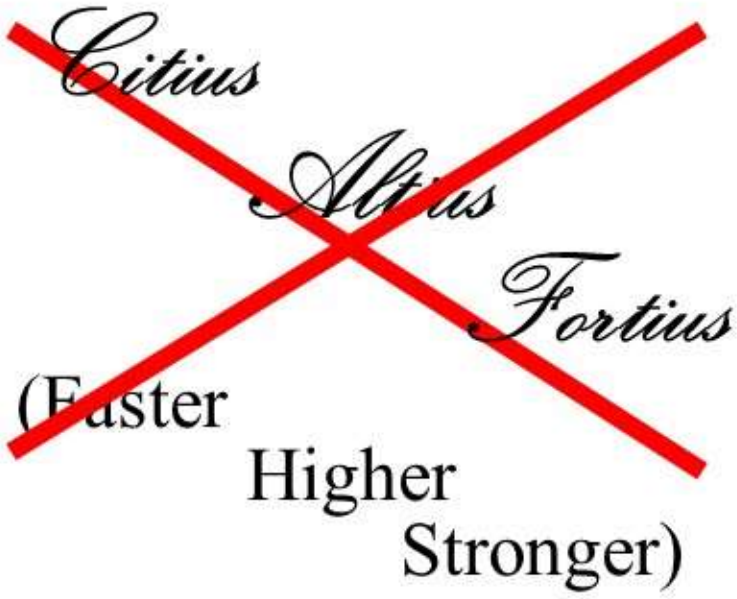
(*BMW, 1978*)

(*Lexus, 2008*)

Which Perspective?

- The Olympic Games motto applied to current systems (i.e., more of the same, but just better), is a too shortfall goal.

- Now, more than ever, one should have a disruptive view of the future.



Terminals

- Terminals are varied, serving different usages and services:

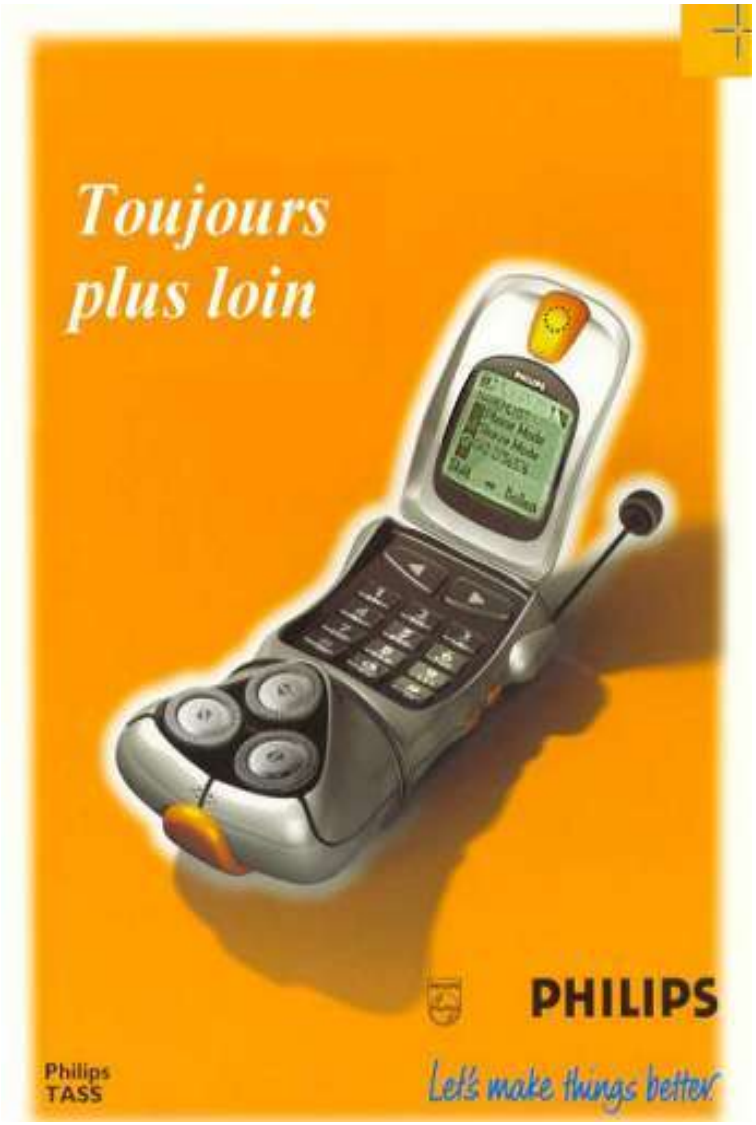
(*BigCircle, 2012*)

(*Apple, 2014*)

(*techclones, 2013*)

(*tomsguide, 2013*)

More Terminals



Information Access

- The paperless society will have a huge impact on networks:
  - media is being consumed in portable devices;
  - daily commuters will need a lot of information on an instantaneous basis.

(*Apple, 2010*)

(*musingsfrommedway, 2010*)

Location Awareness

- Location based services are being introduced these days, upon user demand.

(*Unwired, 2007*)

- The opposite is being introduced as well, i.e., the environment being aware that the user is present.

(*Minority Report, 2002*)

Internet of Things

- Today's systems are still based on a person being the end user.

(*Kenwood, 2007*)

- Future systems are considering machine-to-machine communications as being, potentially, more important.

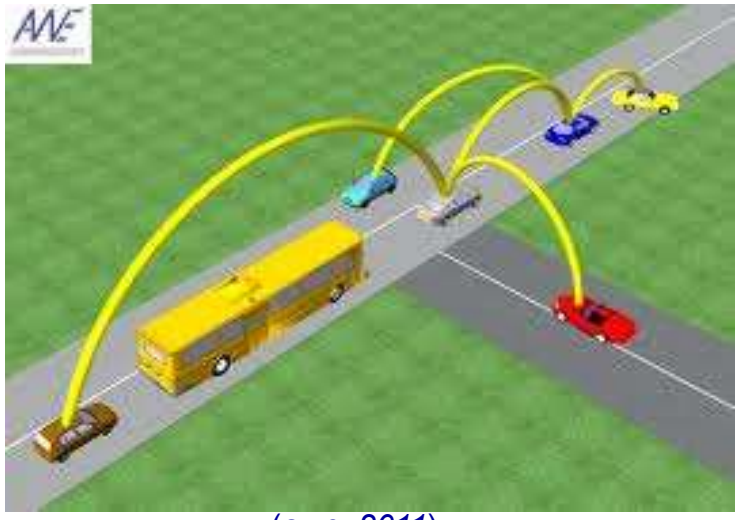
(*DHD, 1998*)

- Sensor networks are emerging as one of the "killer" network structures of the future.

(*SensorProd, 2007*)

Vehicular Communications

- Vehicular communications are a major area under development:
  - vehicle-to-vehicle;
  - vehicle-to-infrastructure.



(*awe, 2011*)

(*car2car, 2008*)

Smart Cities

- Smart Cities are getting a lot of attention lately, encompassing:
  - Public information and training
  - Emergency warnings
  - Health, inclusion and assisted living
  - Intelligent Transportation Systems
  - Environment, Energy Efficiency, and Smart Grids.

(*colourdesign, 2010*)

(*photoaki, 2010*)

What services? (1)

- Mobile 3D Internet:

  visualisation of 3D images from a terminal.

- Real-time ad hoc communities:

  extending social networks into happenings on the spot.

- Prosumers:

  users playing a decisive role as producers and consumers of contents.

(*Builder AU, 2008*)

(*FutureLab, 2008*)

(*enriquedans, 2006*)

What services? (2)

- Context aware mobile web:

  physical and social awareness of users' experience.

- Interactive context aware games:

  games adapted to the user's physical environment.

- Augmented reality:

  combination of virtual with real life objects.

(*DanceInternational, 2005*)

(*UniversalStudios, 2007*)

(*Spectrum, 2008*)

Current Perspective

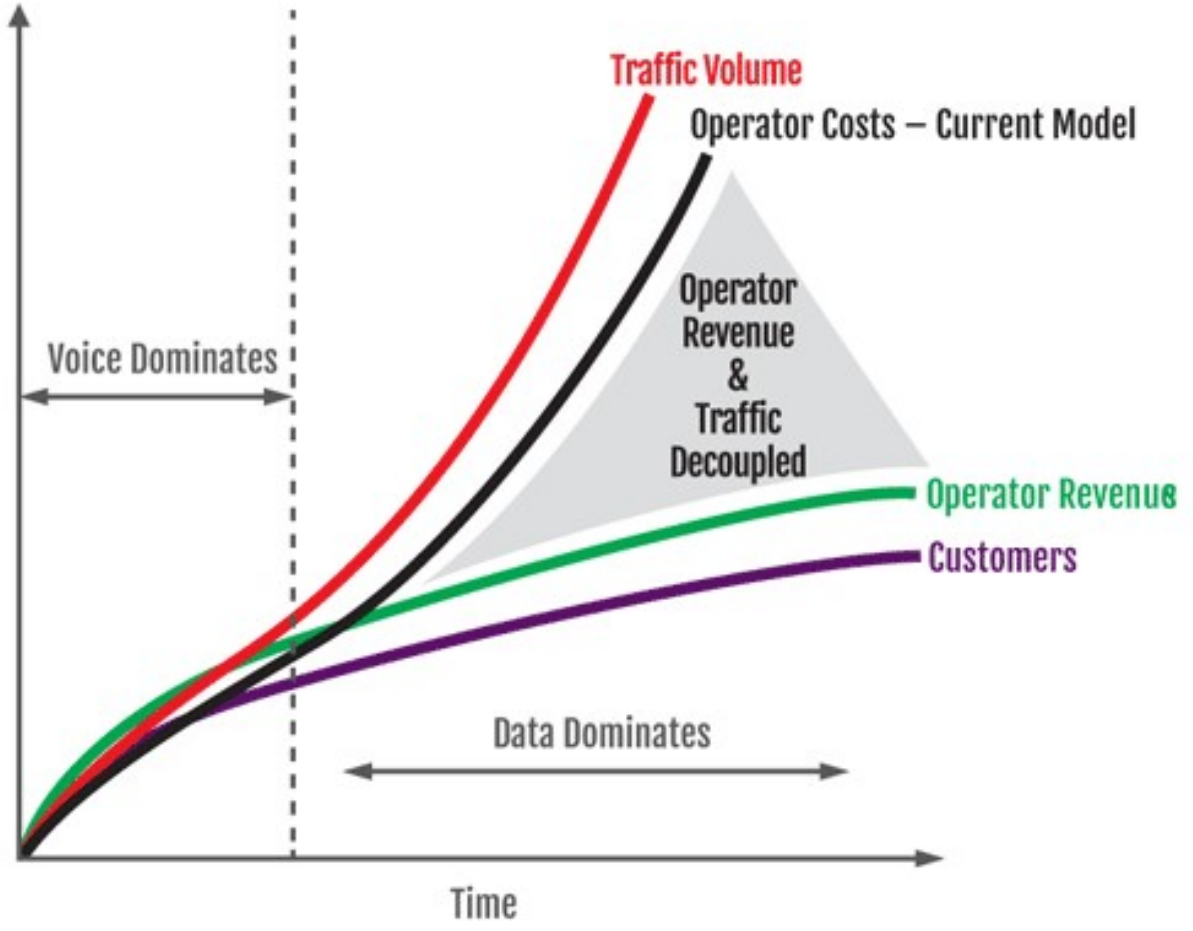
- Today's wireless systems are still very much used in the perspective of "one size fits all".

- We're no longer in the era of voice centric networks, hence, service differentiation must be used.

(*AutomationClinc, 2013*)

Operators' Key Problem

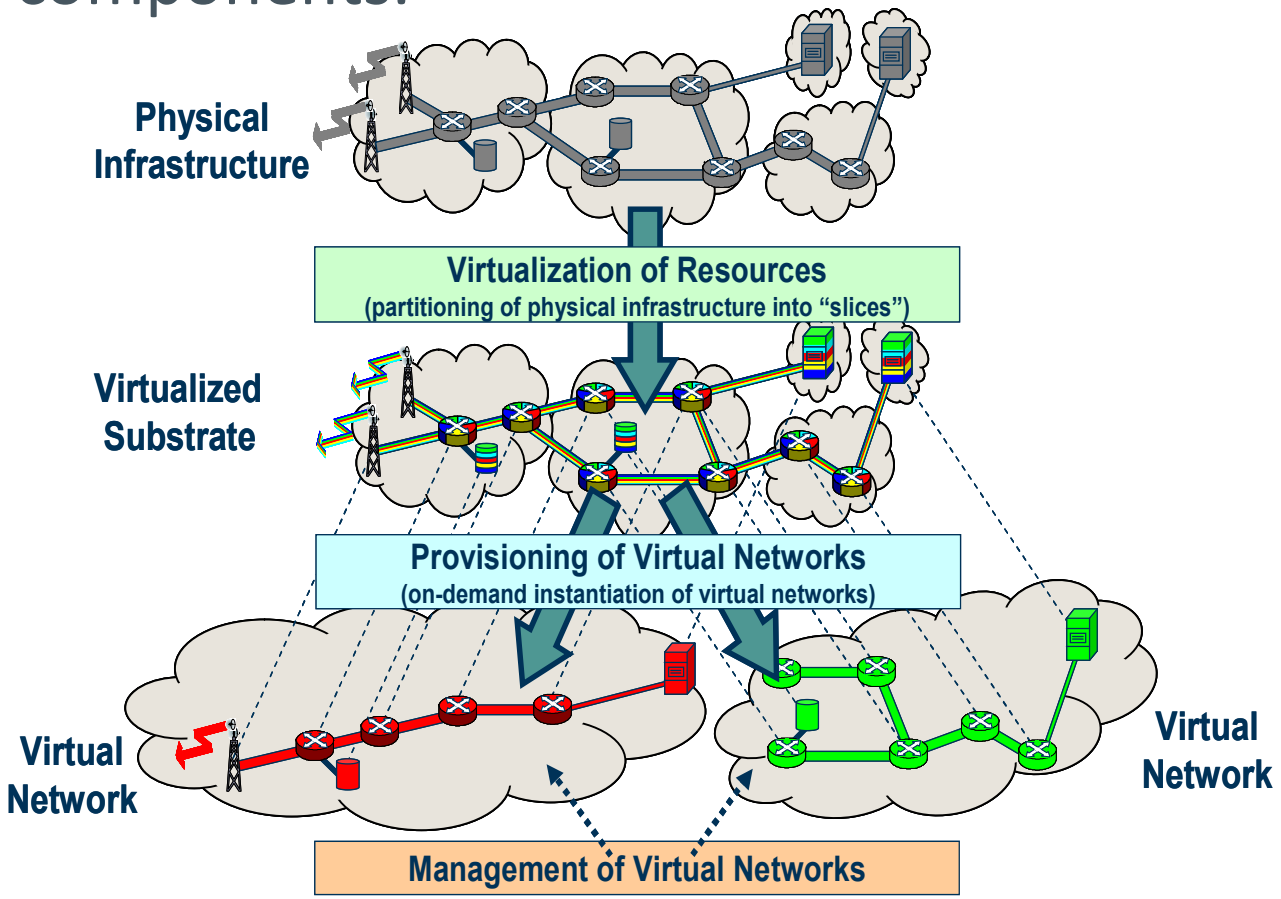
- How to "break the laws of physics"?



(*Accenture, 2013*)

Network Virtualisation

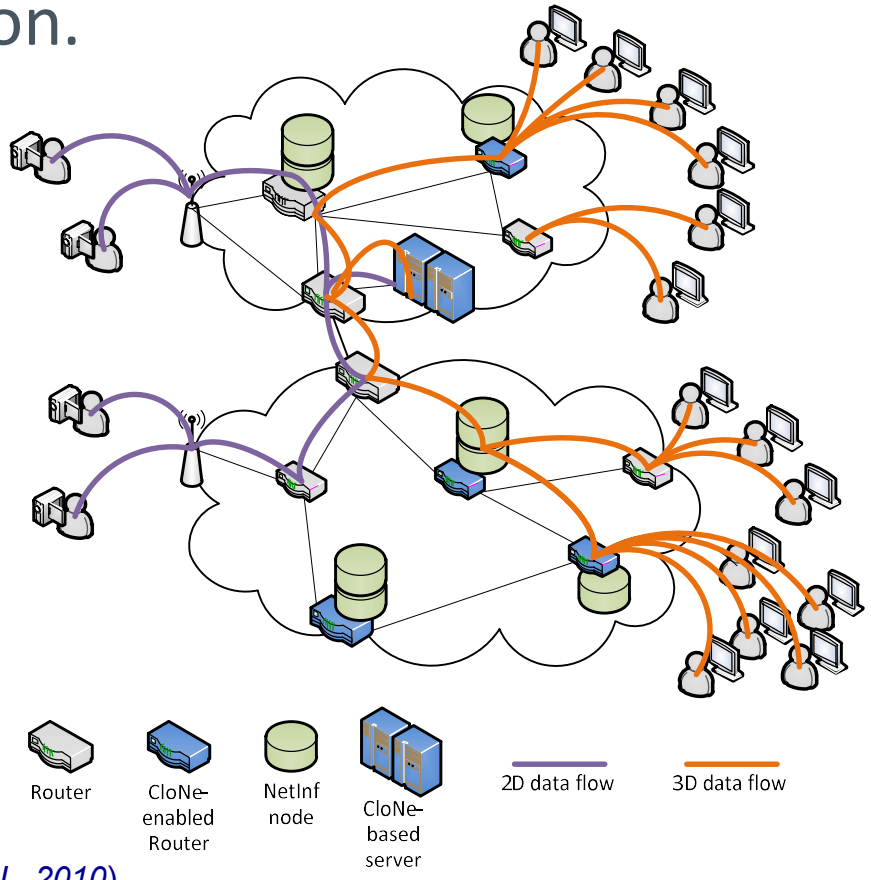
- Networks will be virtualised at both the radio and fixed components.



(*4WARD, 2008*)

Cloud Networking

- Cloud computing and networking will provide a very efficient means to process and distribute information.

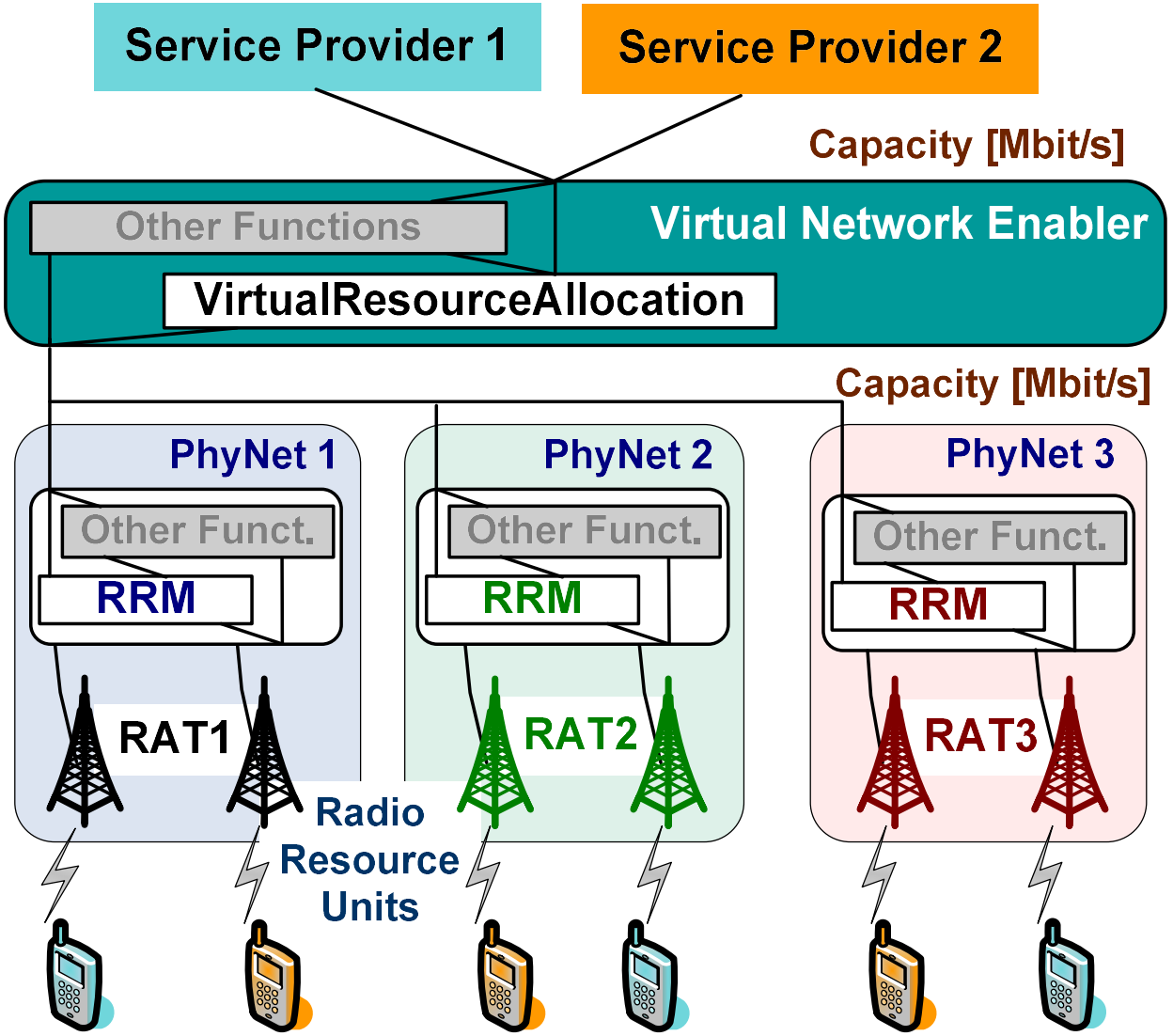


(*SAIL, 2010*)

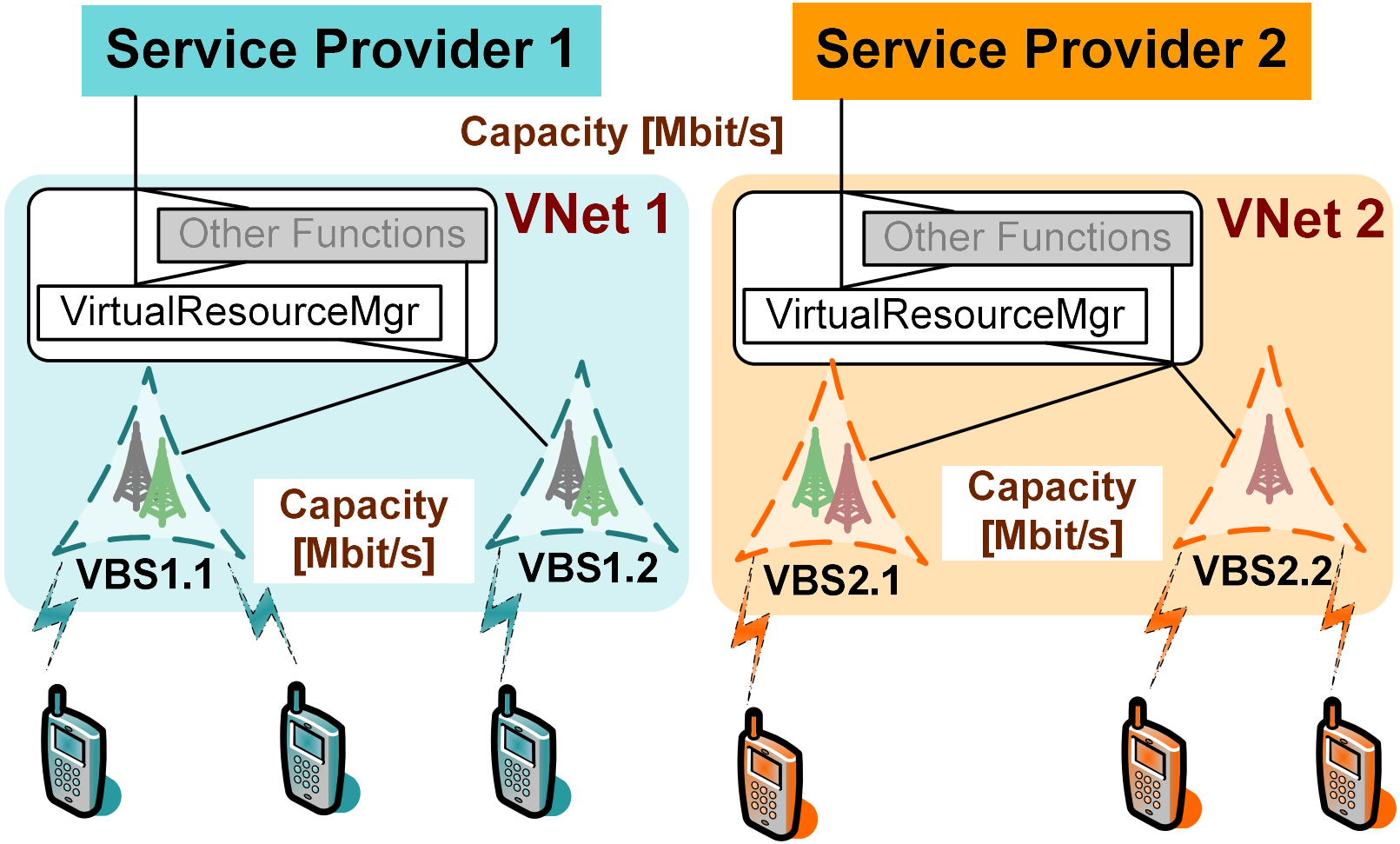
Objectives

- Virtualisation of network resources, enabling the deployment of many virtual networks, with different requirements, over physical networks.
- Optimisation of physical resource usage over a cluster of heterogeneous wireless resources.
- Complete splitting between physical functionalities (radio) and signal processing ones (computers) in the network, by taking a cloud architecture.
- Optimisation of processing resource usage over a pool of computer processors in data centres.
- It’s imperative to decrease operators’ costs!

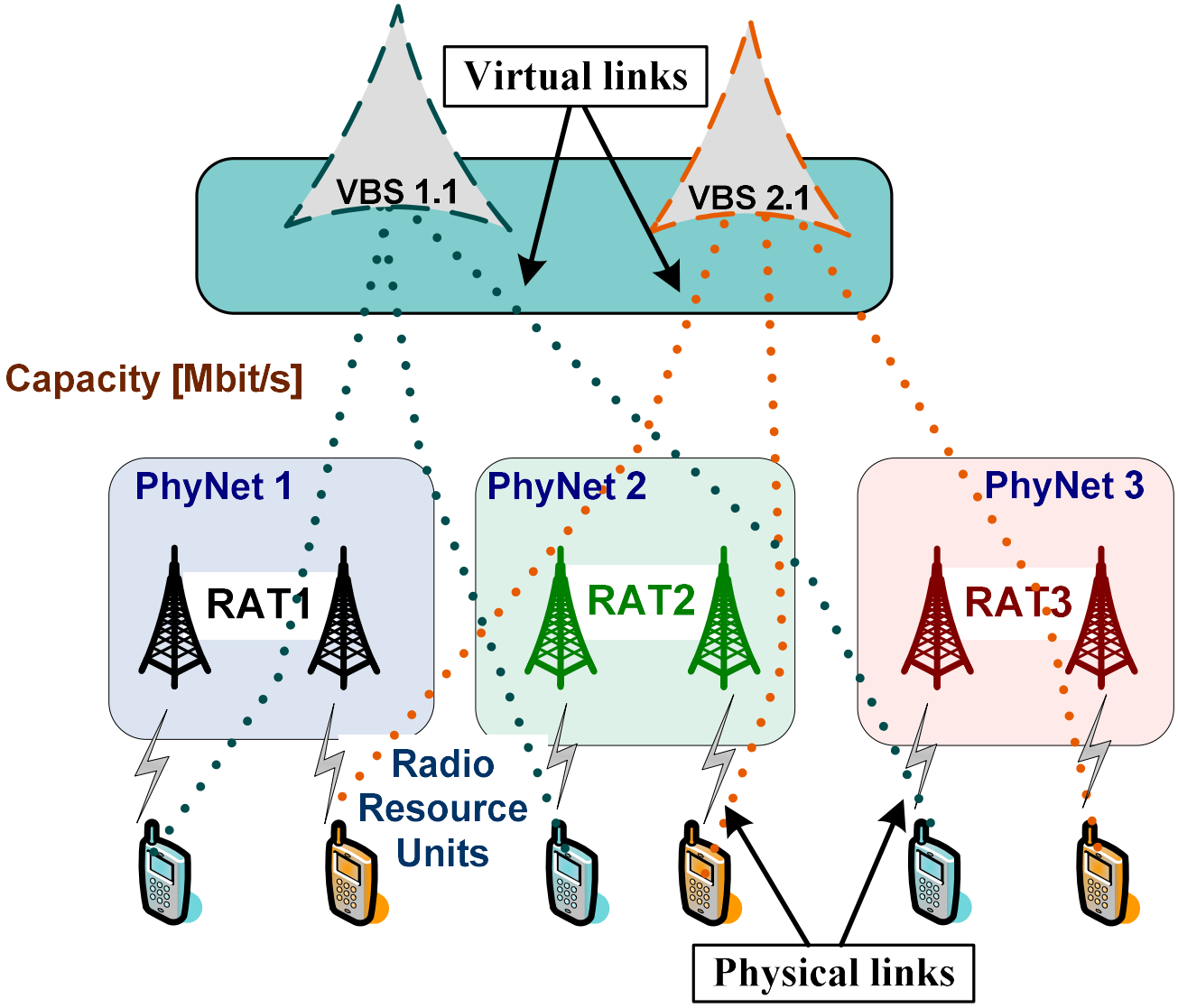
Physical Network Architecture



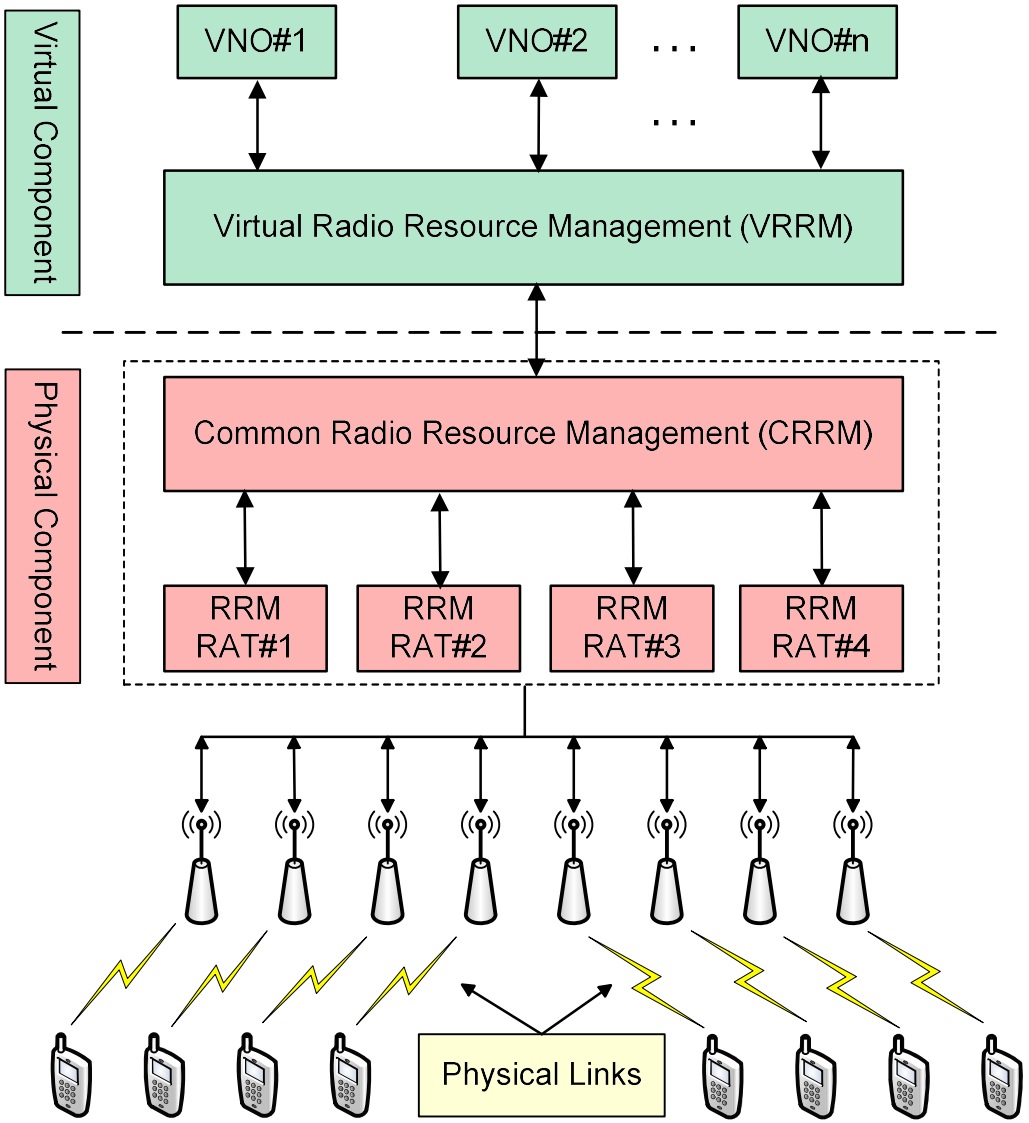
Virtual Logical Network Architect.



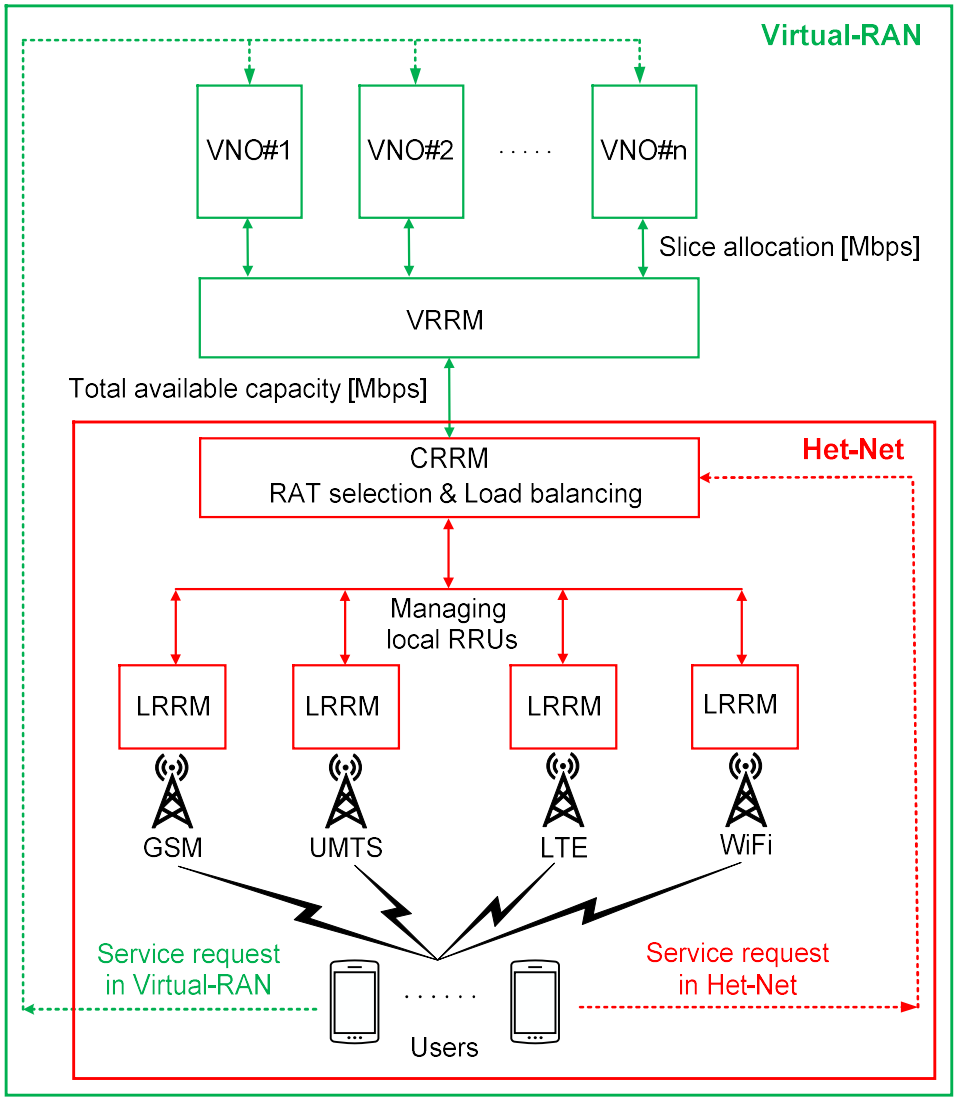
Virtual Wireless Access



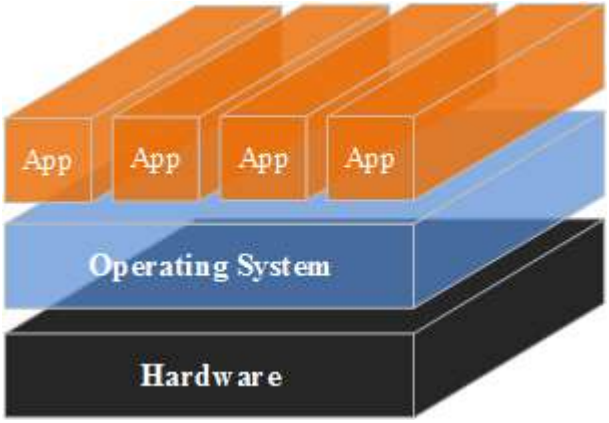
Virtual Network Architecture



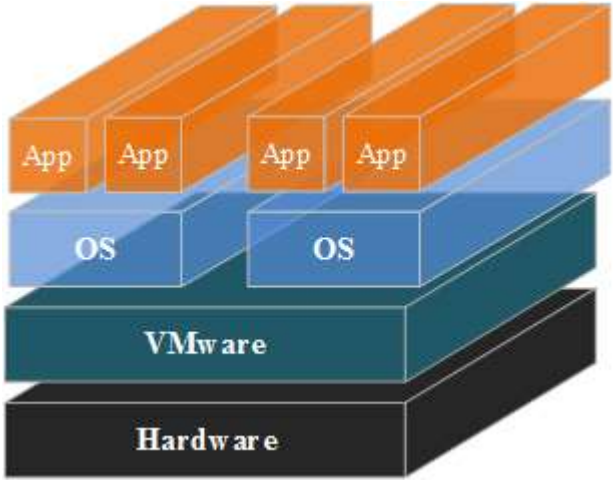
Heterogeneous vs. Virtual RANs



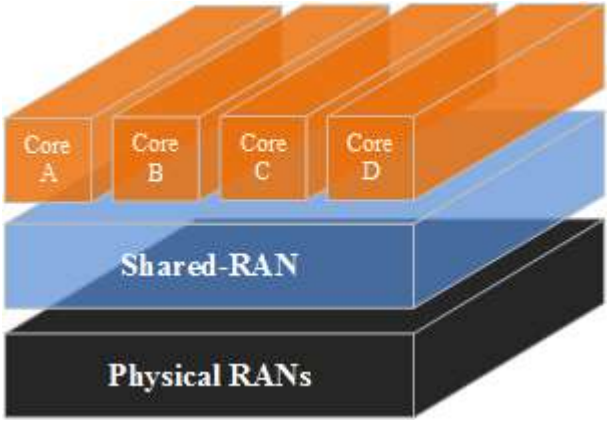
Virtualisation vs. Sharing



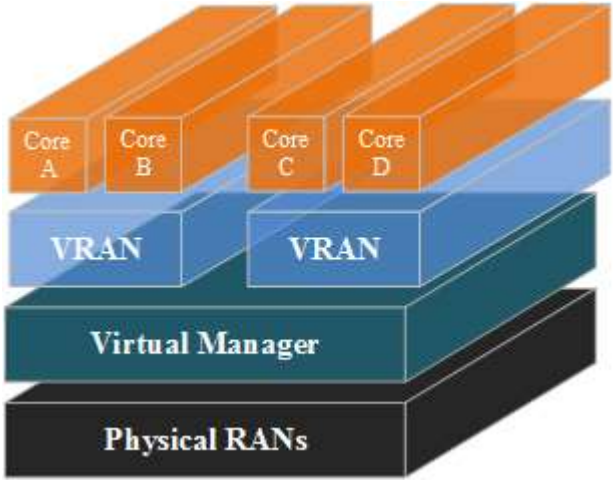
Machine Sharing



Machine Virtualisation



RAN Sharing



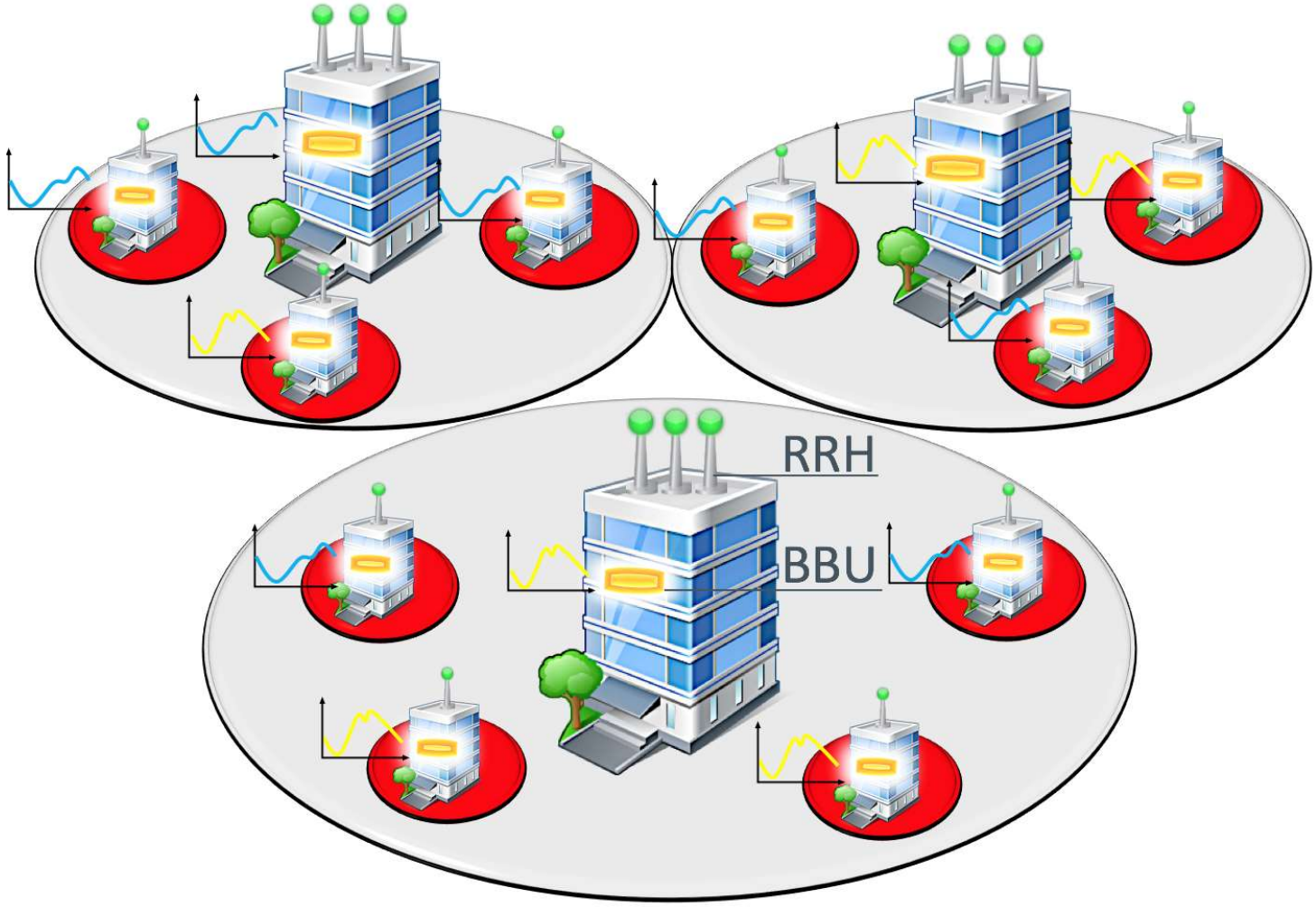
RAN Virtualisation

Challenges in Virtualisation

- The achievement of an efficient resource usage is very challenging, since:
  - radio resources are subject to fading and interference, so their performance needs to be characterised from a statistical viewpoint;
  - different services have different requirements, depending on usage and application, which impose different constraints;
  - different VNOs may have different SLAs, which lead to different conditions of operation.

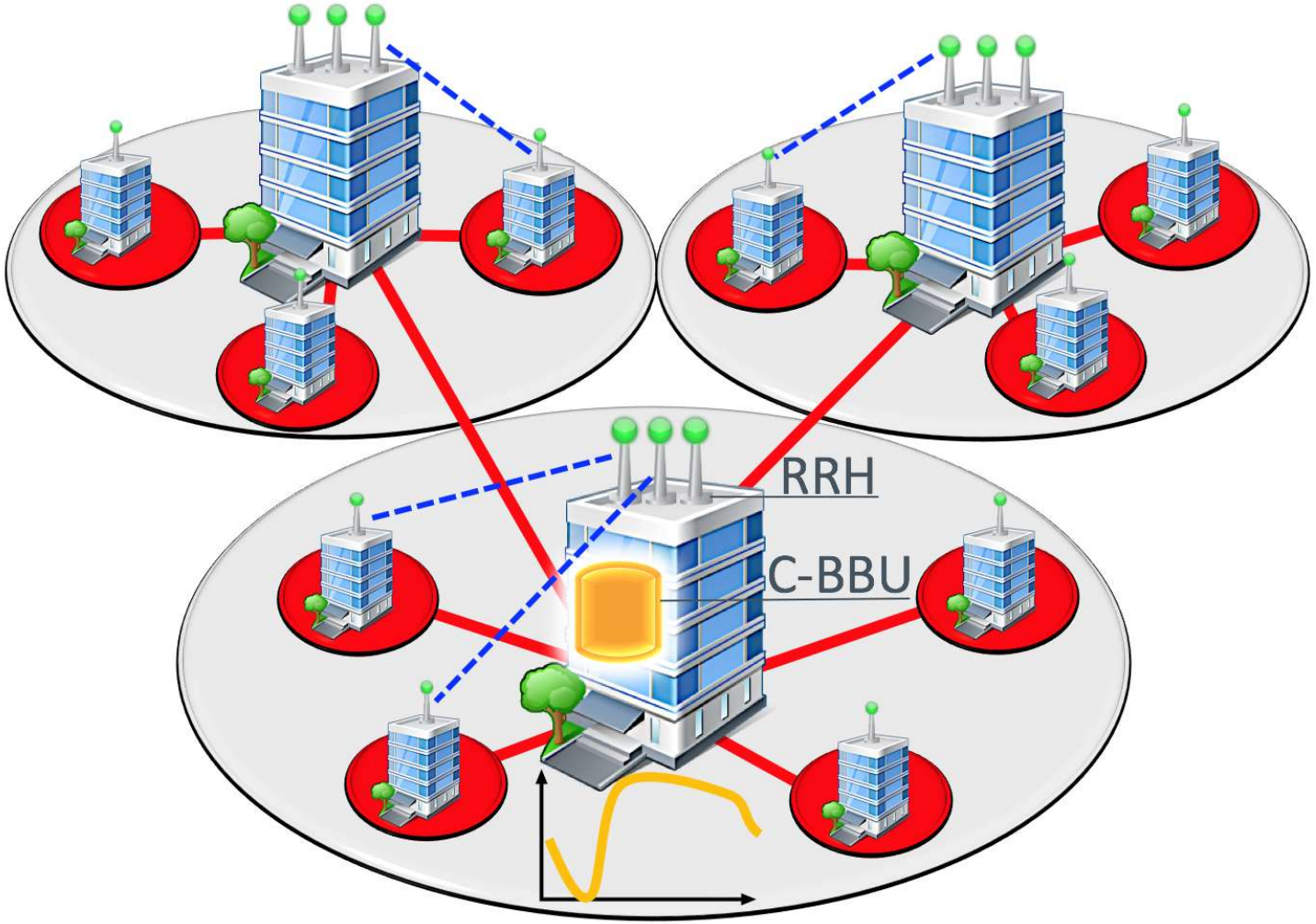
Traditional RAN

- Each base station has its own processing capabilities.



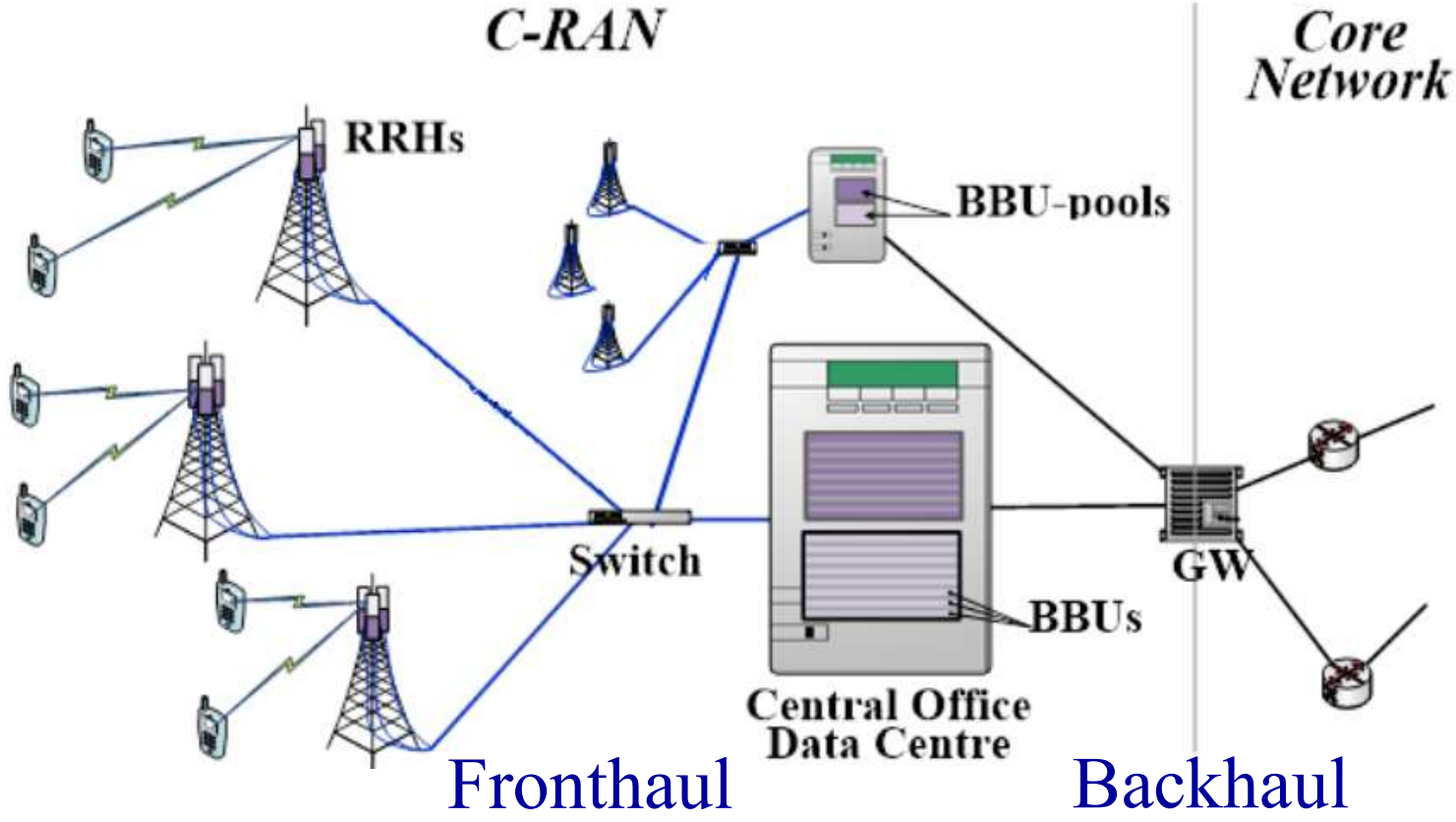
Cloud-RAN

- There's a joint processing of base stations.



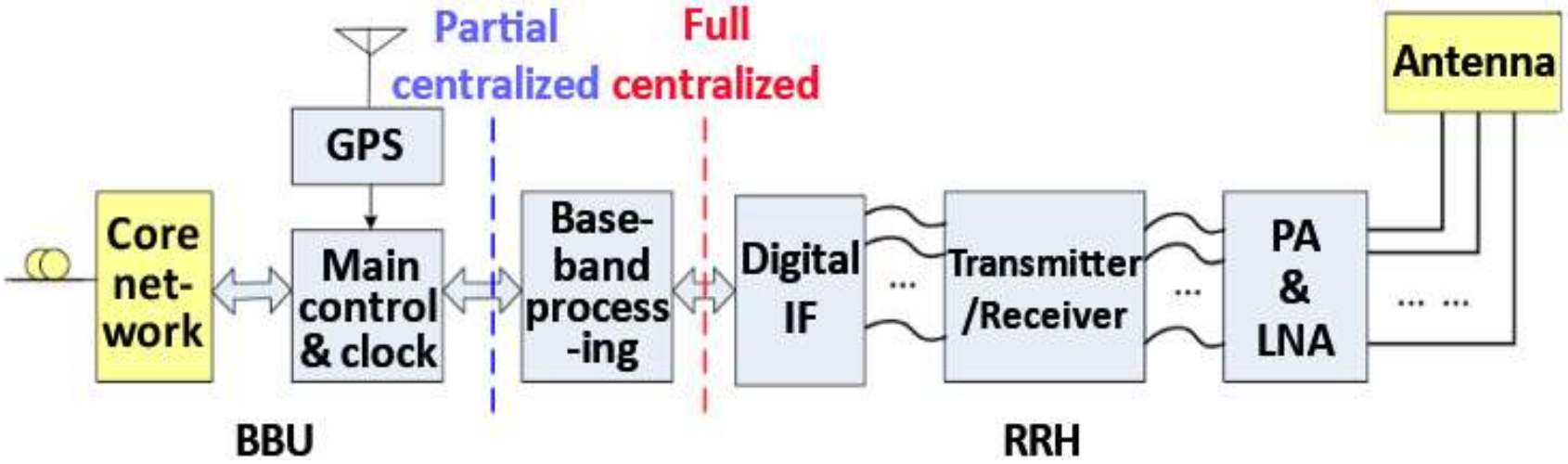
Cloud-RAN Architecture

- The main functional split is of the base station into:
  - RRH: Remote Radio Head;
  - BBU: Base-Band processing Unit.



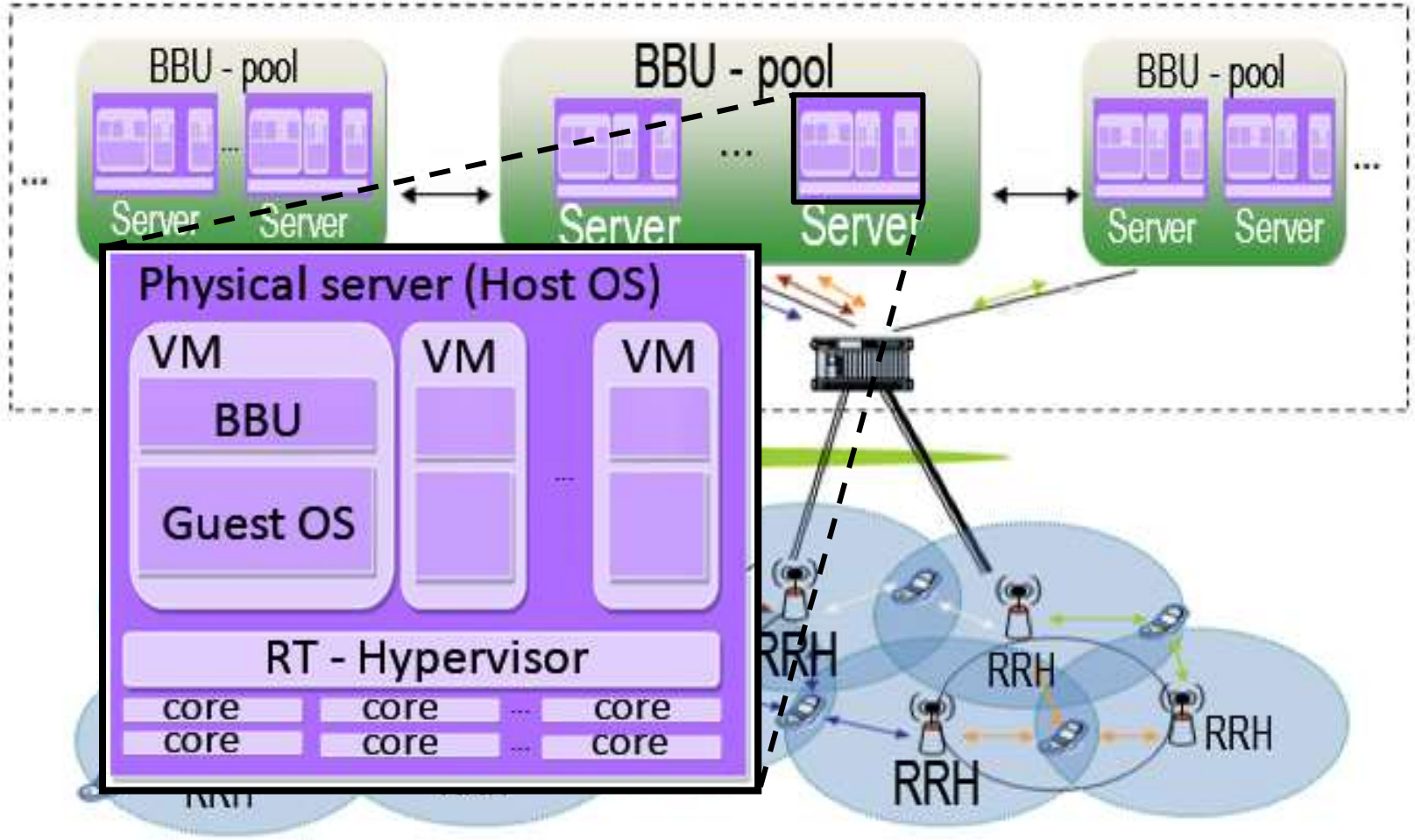
The Splitting of Functionalities

- The functional split depends on the architecture perspective.



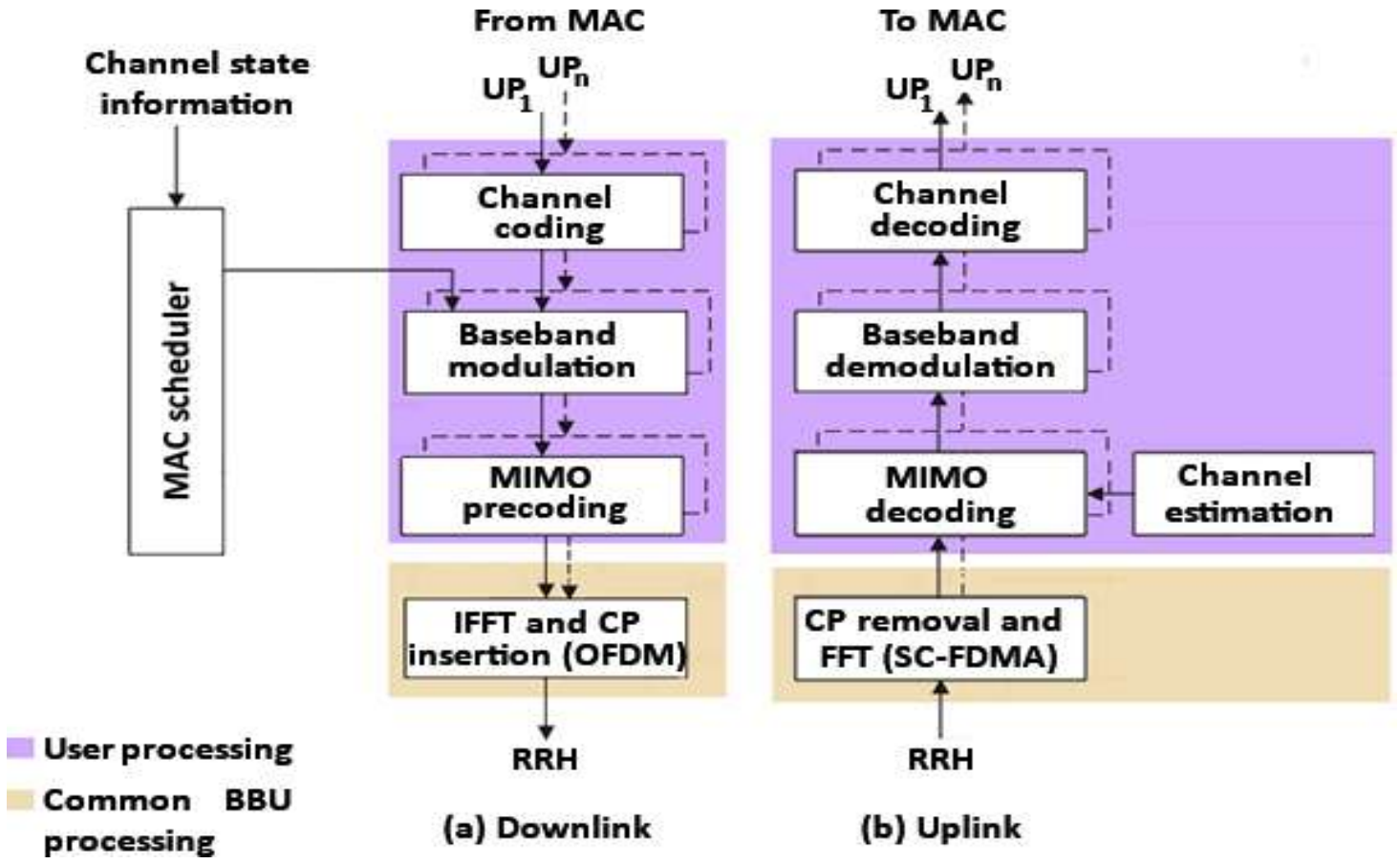
Pools of BBUs

- Pools of BBUs increase processing efficiency.



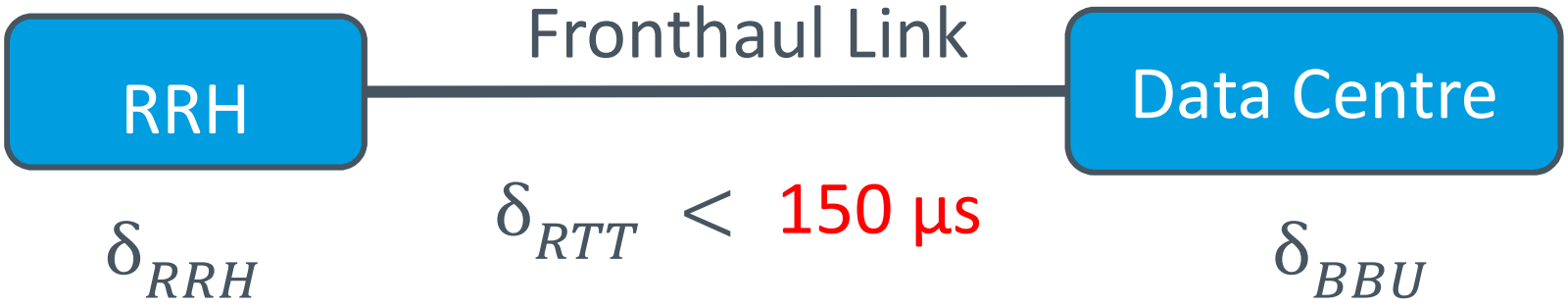
Functional Processing Capacity

- The required processing capacity for each function needs to be taken into account.



The Latency/Distance Problem

- The latency in between RRH and BBU can be a problem, imposing a maximum distance in between them.



Challenges in Cloud

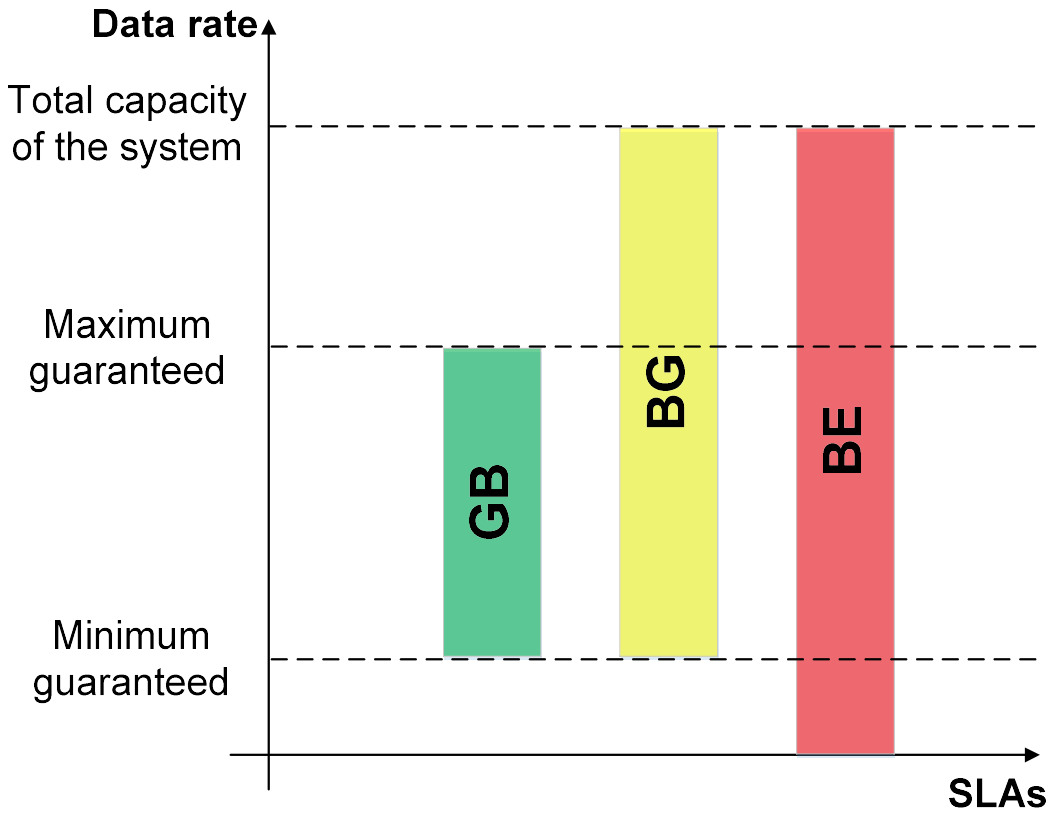
- The achievement of an efficient resource usage is very challenging, since:
  - the number of users, and the usage of services is very dynamic, requiring a statistical viewpoint;
  - one needs to design the network for the “busy-hour”, and the design of data centres capacity needs to done in an optimised way;
  - latency, hence, distance, is a key constraint;
  - the design of the network should take advantage of the low (human) usage during the night.

Scenario for an Optimised Allocation

- Given a heterogeneous network, mixed of cellular (e.g., GSM, UMTS, LTE, and 5G) and WLAN (WiFi), the goal is to get an optimised and fair allocation of resources, for a given configuration of:
  - VNOs,
  - data centres,
  - services,
  - users' profiles,
  - network configuration.

VNOs' SLAs

- Three general VNOs' SLAs types can be considered:
  - Guaranteed Bitrate (GB);
  - Best effort with minimum Guaranteed (BG);
  - Best Effort (BE).



Services' Classes

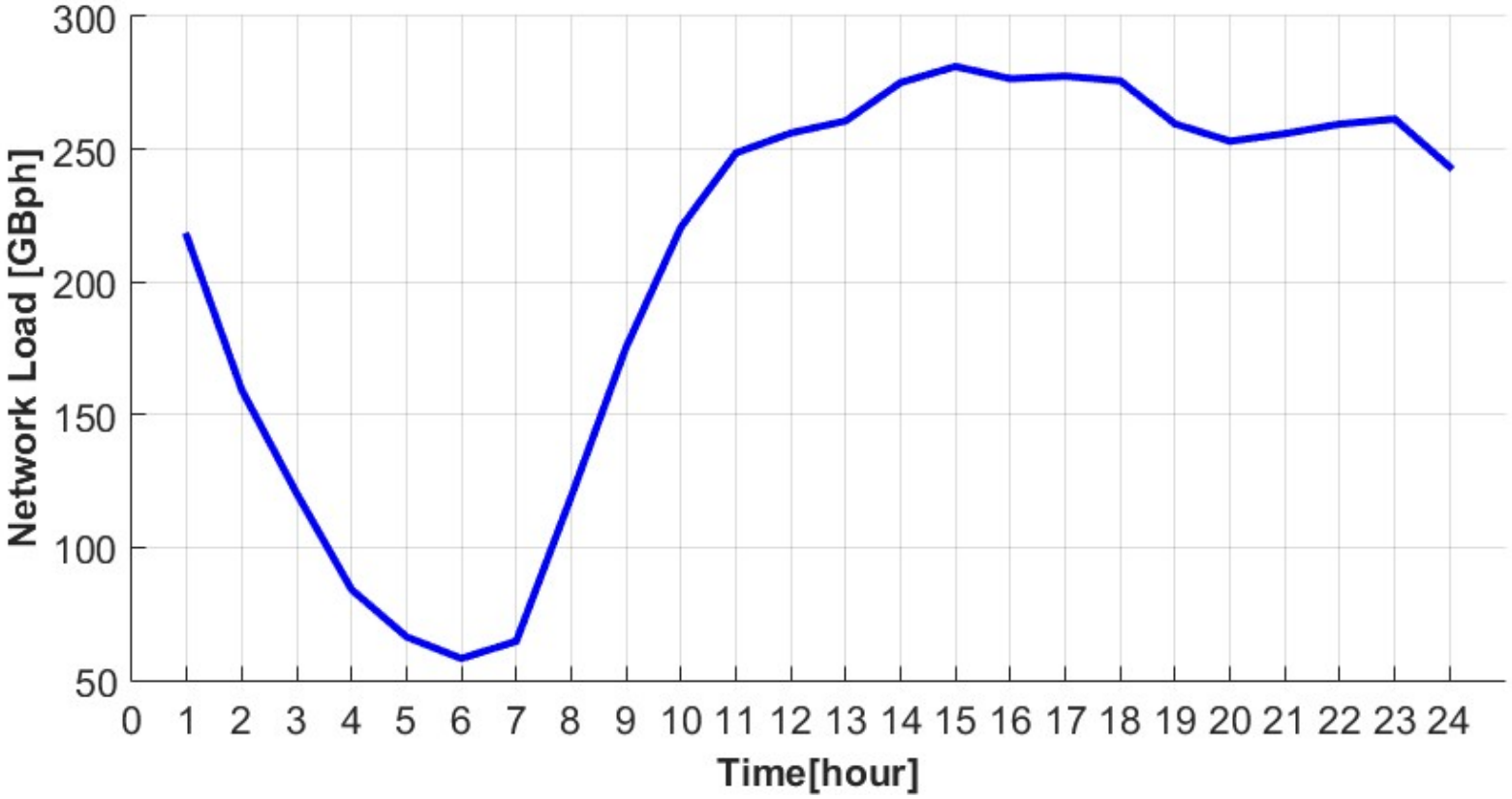
Service class	Conver-sational	Strea-ming	Inter-active	Back-ground
Real time	Yes	Yes	No	No
Symmetric	Yes	No	No	No
Switching	CS	CS	PS	PS
Guaranteed rate	Yes	Yes	No	No
Delay	Minimum Fixed	Minimum Variable	Moderate Variable	High Variable
Buffer	No	Yes	Yes	Yes
Bursty	No	No	Yes	Yes
Example	voice	video-clip	www	email

Services Examples

Voice / Video Calls
Music / Video Streaming
File Sharing
Web Browsing
Social Networking
Intelligent Transport Services
e-Health
Surveillance
Smart Metres
Email
Messaging

Human Service Usage

- Network deployment and management need to take advantage of human service usage, which is very much associated with daily activities.



VNO Types at Virtual Base Stations

- Guaranteed (GRT) at the VBS:
  - Minimum Contracted Data Rate, $R_{\min}^{VBS}$
  - Penalty: $p^{GRT} = \sum_{i=1}^{N_{TF}} p_i^{GRT}$
- Best Effort (BEF) at the VBS:
  - Reference Contracted Data Rate, R_{ref}^{VBS}
  - Penalty: $p^{BEF} = \sum_{i=1}^{N_{TF}} p_i^{BEF} - \xi_{R_{ref}} \cdot N_{TF}$

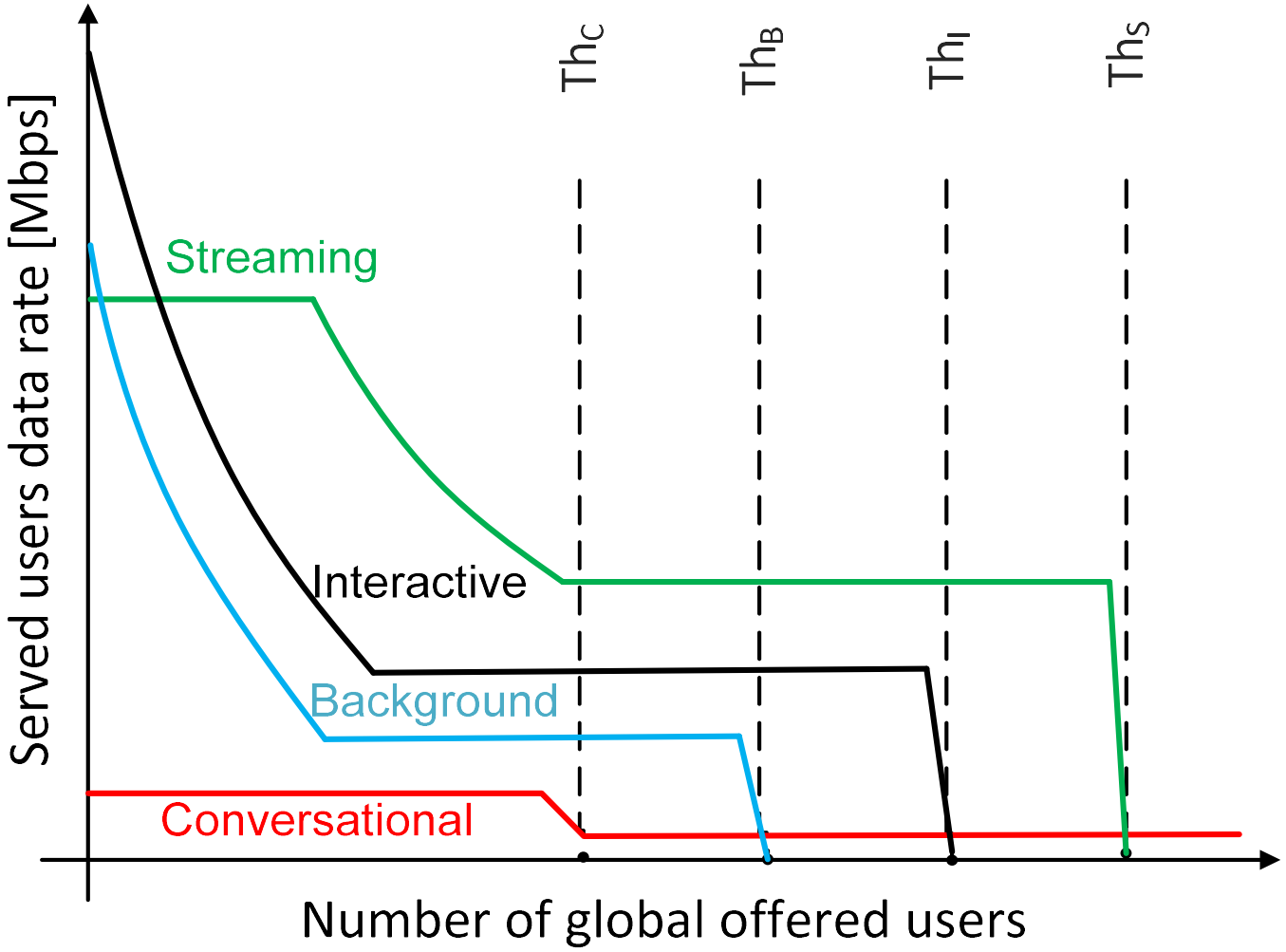
  where
  - p_i^{GRT}, p_i^{BEF}: penalties in time frame i, of N_{TF} ones.
  - $\xi_{R_{ref}}$: out of contract time frames, [%].

Profile of Radio Channels

- Three approaches can be considered:
  - Optimistic (OP):
    $0.5\ R_b^{max} \leq R_b \leq R_b^{max}$, all RRUs
  - Realistic (RL)
    $0.5\ R_b^{max} \leq R_b \leq R_b^{max}$, half RRUs
    $0 \leq R_b < 0.5\ R_b^{max}$, half RRUs
  - Pessimistic (PE)
    $0 \leq R_b < 0.5\ R_b^{max}$, all RRUs

Service Classes' Behaviour

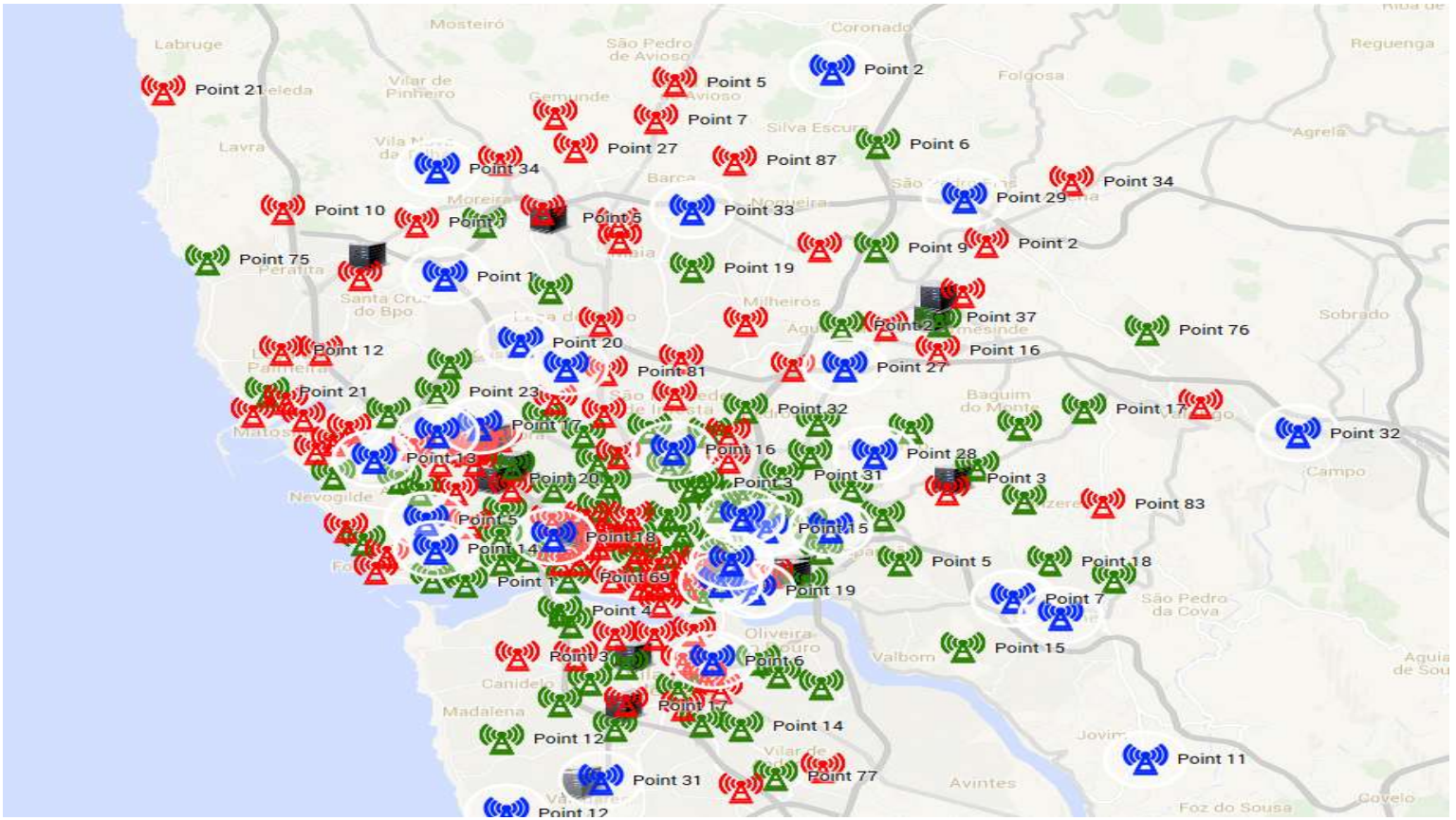
- Data rate allocation will depend on service classes.



Impact of Network Deployment

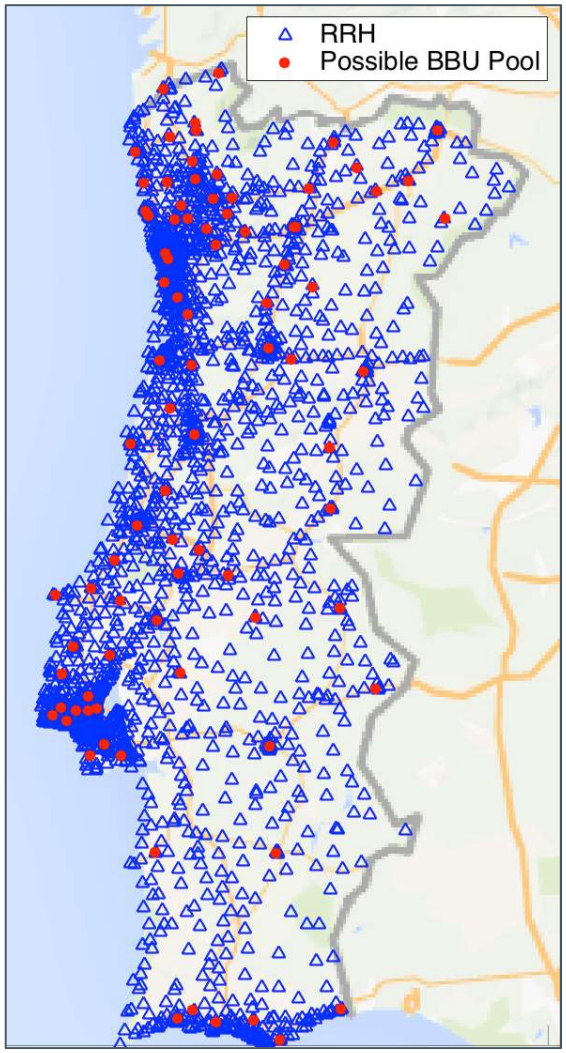
- The location of data centres has to be optimised.

Residential (35.3 %) | Office (39.4 %)| | Mixed (25.3 %) | 19 Pools



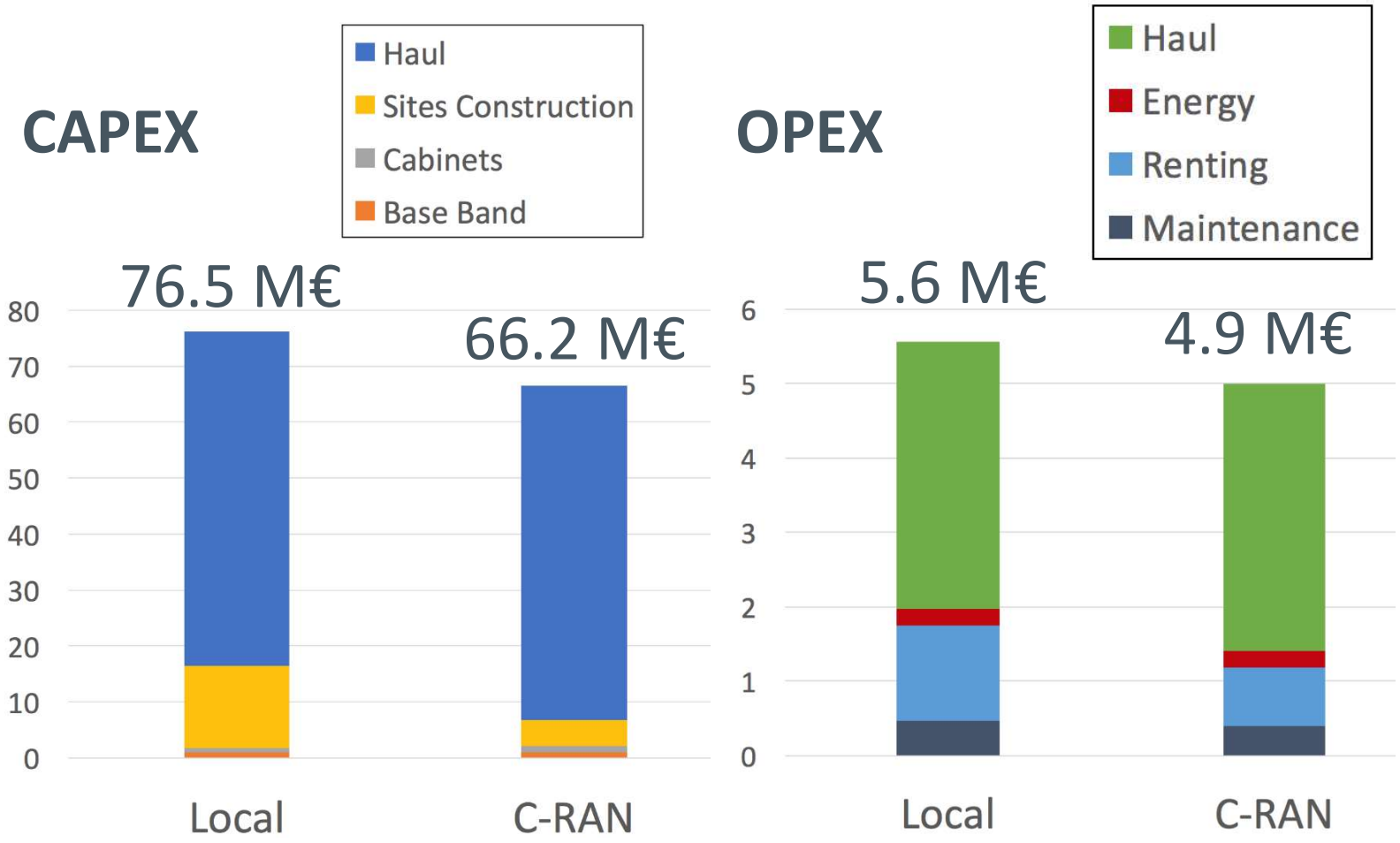
Latency Constraint

- At the national level, latency imposes important constraints.



Savings can be Important

- Important savings can be achieved.



Conclusions

- The evolution of services usage and profile impose major changes in network architectures, new perspectives being required.
- Virtualisation of radio resources, together with cloud networking, are definitely solutions for the evolution of heterogeneous networks.
- Relevant gains can be obtained with these new approaches.

Contributions

- This presentation is based on contributions from:
  - Lúcio Ferreira
  - Luísa Caeiro
  - Sina Khatibi
  - Behnam Rouzbehani
  - Mojgan Barahman
  - Tiago Monteiro
  - Hugo da Silva

Thank you!

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