Flexible and cost efficient optical 5G transport

Paolo Monti

Optical Networks Laboratory (ONLab)
Communication System Department (COS)
KTH Royal Institute of Technology
Sweden

Acknowledgements

- Matteo Fiorani (KTH)
- Jonas Mårtensson (Acreo)
- Björn Skubic (E///)
- Rhean Raza (KTH)
- Ahmad Rostami (E///)
- Lena Wosinska (KTH)

Kista 5G Transport Lab

The creation of a research eco-system in Kista

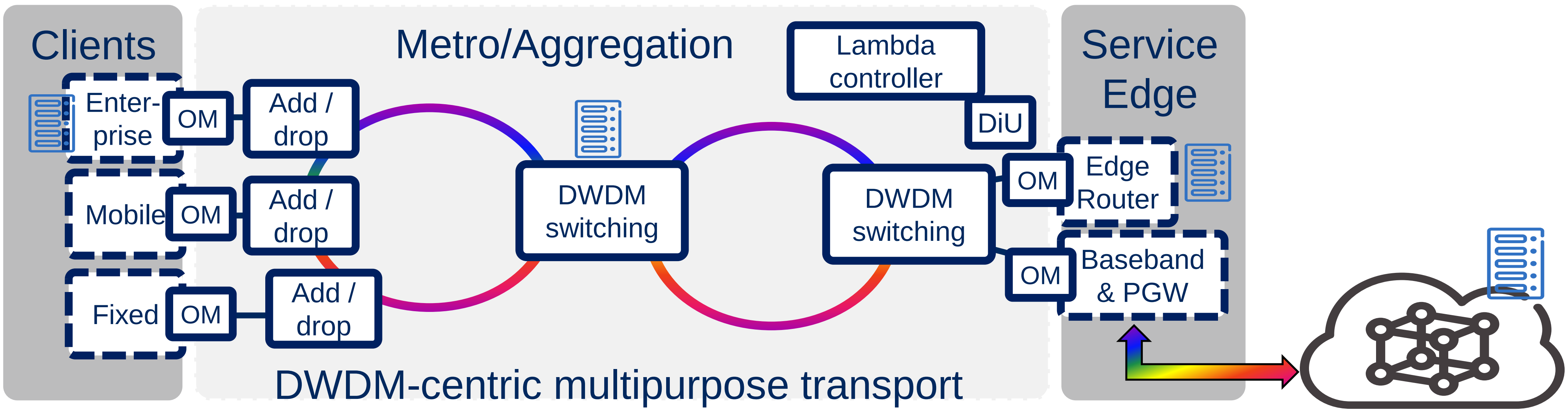
K5 vision

“Show how transport network can be a platform for applications, user and networks services”

Service providers

Transport provider

- Challenges
  - Programmability and flexibility of transport resources for dynamic services
  - Integration between: radio, transport, processing resources
  - Utilize traffic dynamicity to optimize: data center bulk transfer & people movements (radio)
- Demo platform based on DWDM-centric multipurpose transport

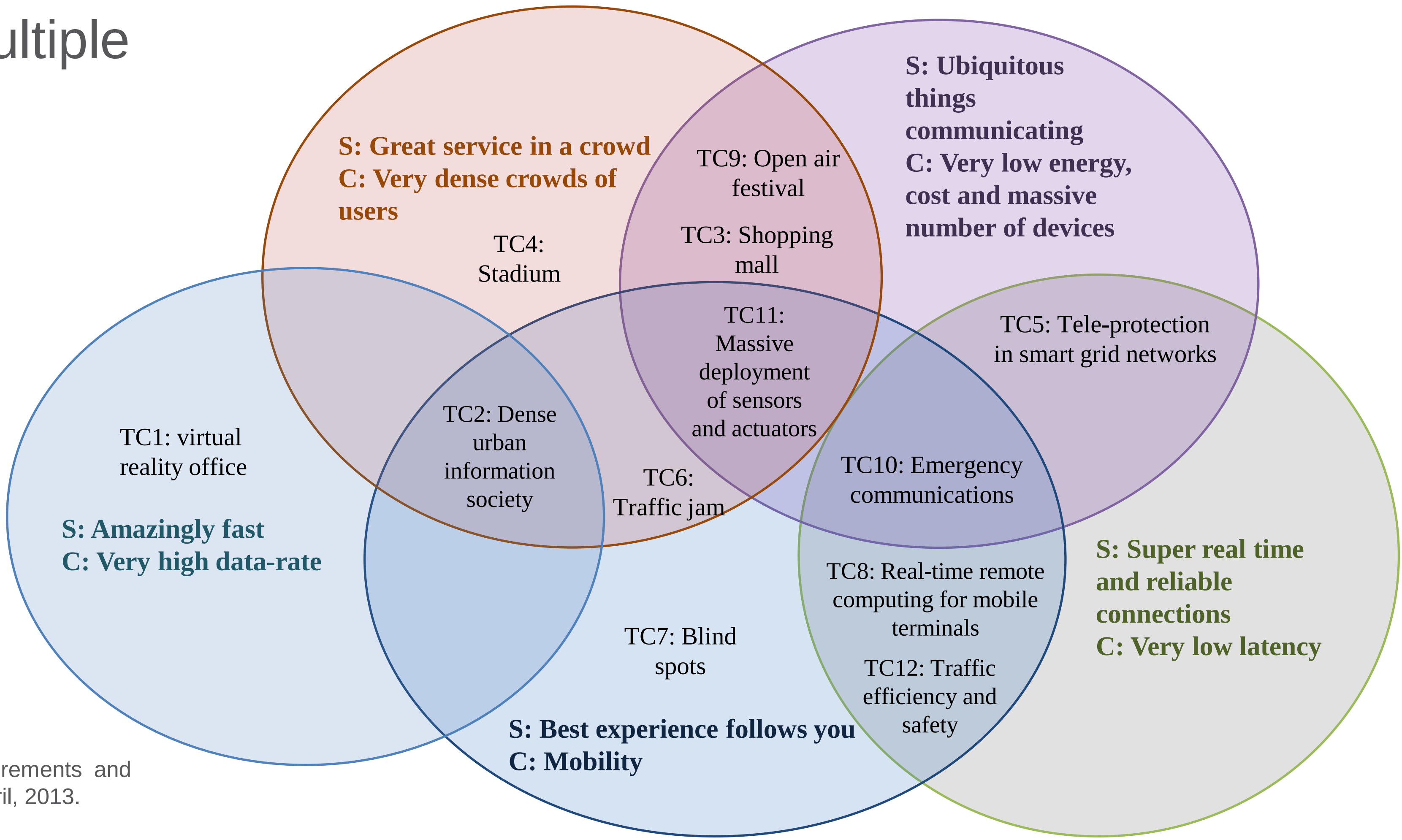


Outline

- 5G Networks → 5G transport challenges
- Programmable and flexible transport resource provisioning
- Control plane: orchestration (e.g., SDN)
  - Resource abstraction in a SDN-controlled C-RAN
- Data plane: architectural options for (virtualized) network functions
  - Power vs. cost
- Conclusions

5G challenges

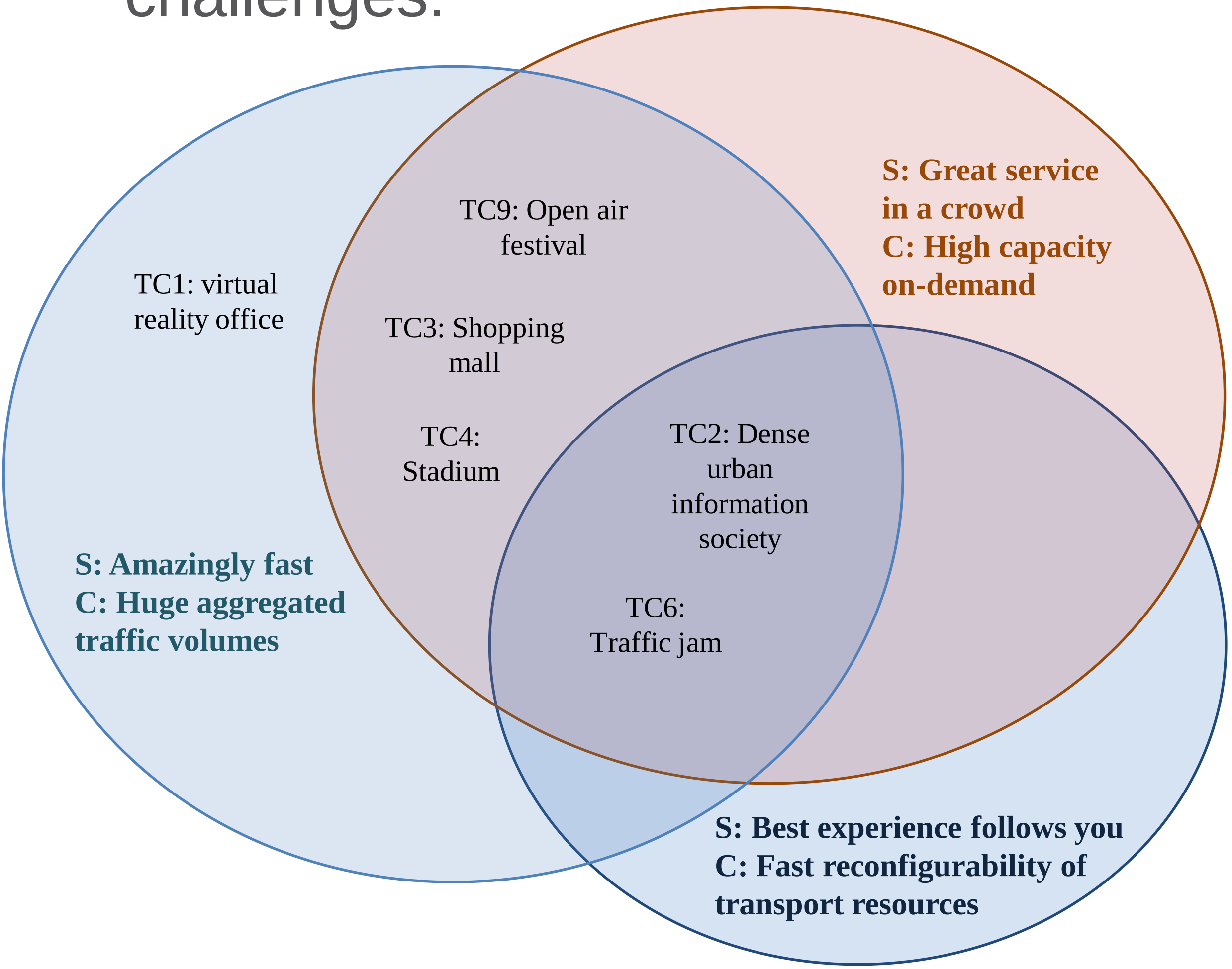
- The METIS 2020 project: laying the foundation of 5G[1]
- 5G defined in terms of ***scenarios*** (**S**) supported
- Each scenario introduces a ***challenge*** (**C**)
- Each scenario multiple ***test cases*** (**TC**)



[1]METIS deliverable D1.1, "Scenarios, requirements and KPIs for 5G mobile and wireless system", April, 2013.

5G transport challenges

- The 5G challenges → transport challenges:



- **Very high data rate** → huge aggregated traffic volumes
- **Very dense crowds of users** → provide high capacity on-demand
- **Best experience follows you** → fast reconfigurability of transport resources

- The **massive number of connected devices** not a major issue: the traffic from a large number of machines over a geographical area will be aggregated
- **Latency**: to be investigated: new applications with extreme delay requirements e.g., ITS, mission critical M2M, and their requirements on transport

M. Fiorani, P. Monti, B. Skubic, J. Mårtensson, L. Valcarenghi, P. Castoldi, L. Wosinska, “Challenges for 5G Transport Networks”, *in Proc. of IEEE ANTS,* 2014.

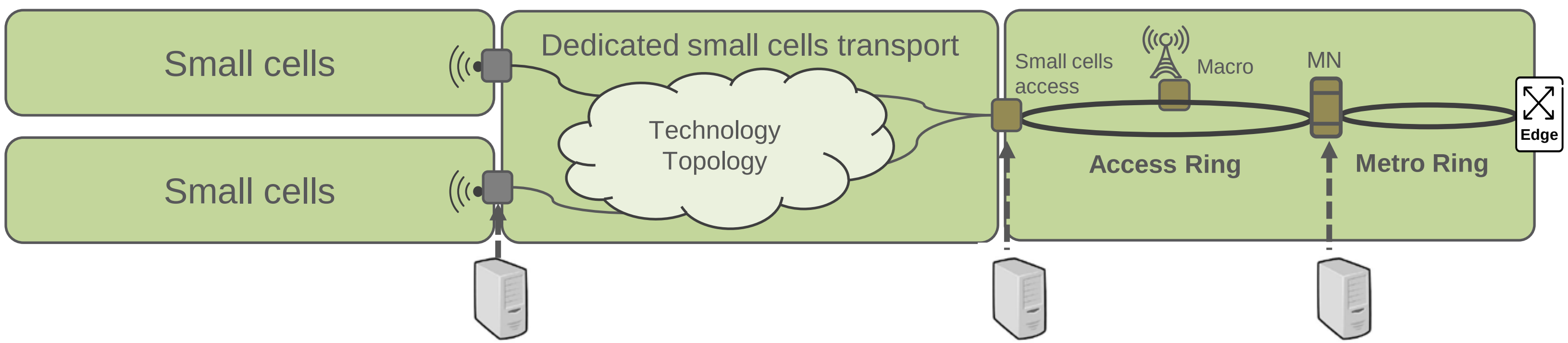
How to tackle transport challenges?

- Two main directions for provisioning high capacity on-demand and in a flexible way
- **Overprovisioning**: high capacity on-demand with (possibly) fast resource reconfiguration is satisfied thanks to the ubiquitous availability of ultra-high capacity transport
  - Pros: relatively low complexity at the control plane
  - Cons: potentially high cost because of inefficient use of network resources
- **“Intelligence”** in the transport infrastructure
  - **Dynamic resource sharing:** re-configurable systems for dynamically sharing limited transport resources
  - **Network functions virtualization (NFV)**: dynamically push network functions to different locations, e.g., closer to the users so that a portion of the traffic requests can be served locally

M. Fiorani, P. Monti, B. Skubic, J. Mårtensson, L. Valcarenghi, P. Castoldi, L. Wosinska, “Challenges for 5G Transport Networks”, *in Proc. of IEEE ANTS,* 2014.

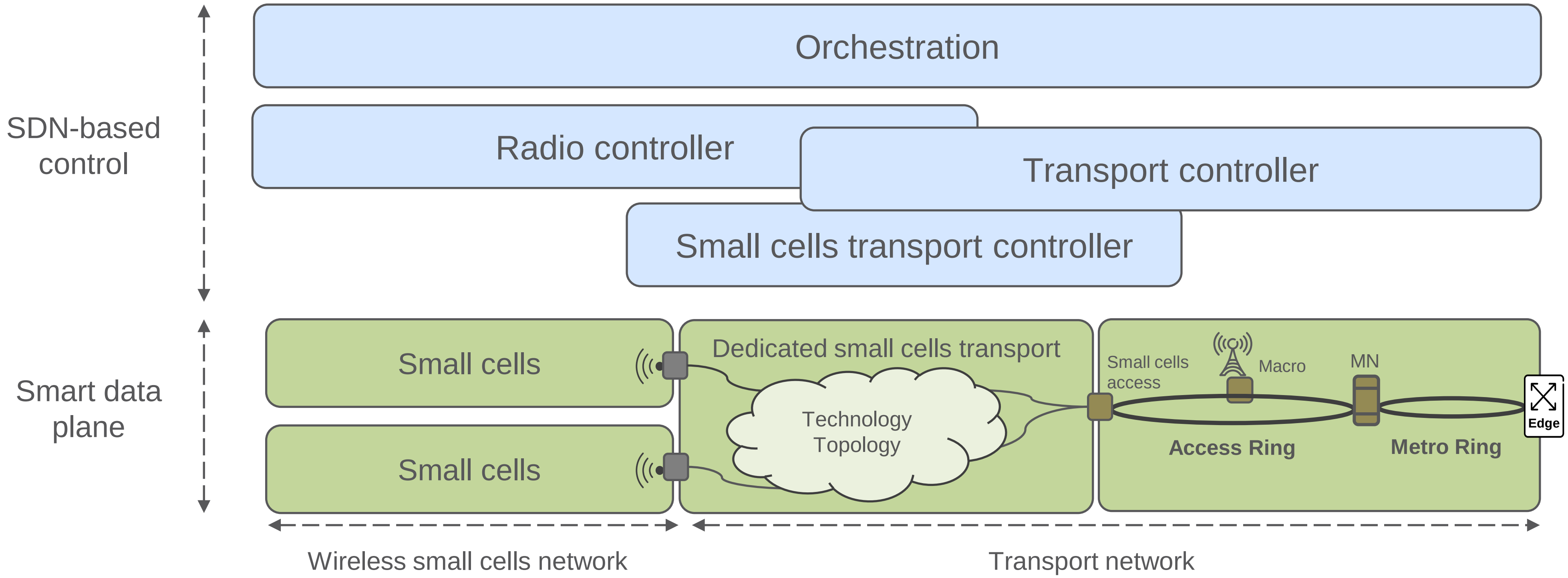
Network function virtualization

- The type of resources that can be dynamically virtualized depends on:
  - User traffic type
  - Business model (agreement between wireless and transport providers)
- Example of resources that can be virtualized:
  - Wireless network functions: BB processing, evolved packet core (EPC)
  - Transport network functions: packet aggregation
  - Cloud resources: cache/storage
- Servers needs to be available in different network locations:



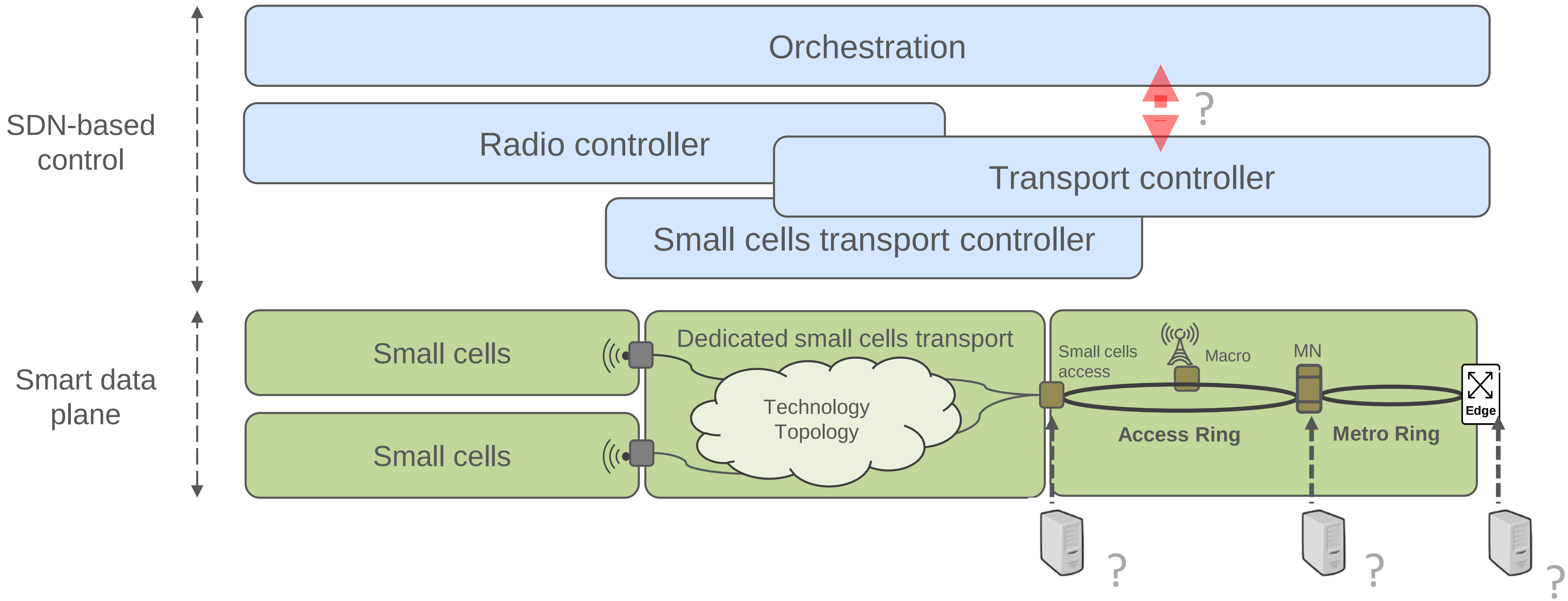
How to add intelligence to transport?

- Programmability/flexibility (resource sharing and/or NFV) puts requirements on the control plane
- A SDN based control plane with end-to-end orchestration could provide a framework for such a scenario
- One of the many possible control plane architecture might be:



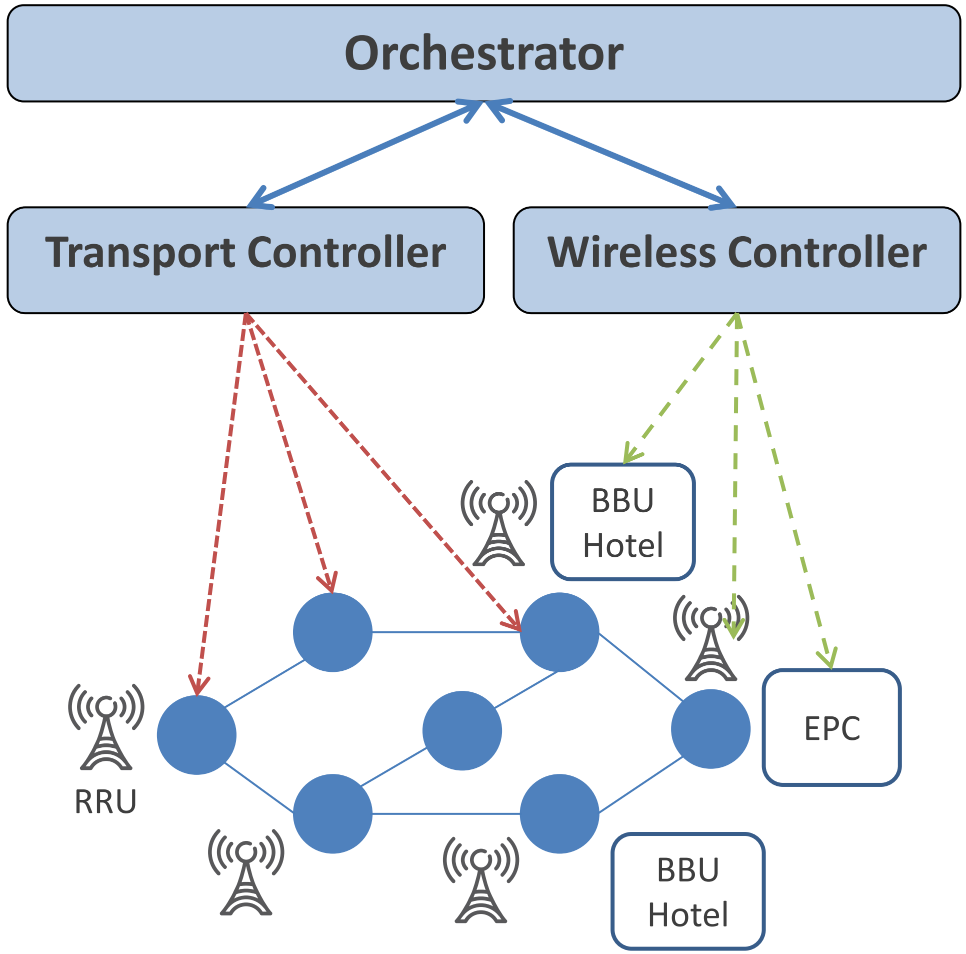
Two interesting open questions

- If orchestration helps in using resources efficiently → what's the best level of details to be used to advertise the availability of transport resources?
- What are good (i.e., power/cost) architectural options that allow the placement of NFV?



Transport resources abstraction: the C-RAN use case

- BBUs are placed in hotels connected to one (or more) network nodes
- Communications between RRUs and BBUs use CPRI protocol
- Connections are routed to the EPC via a BBU Hotel
- Orchestration implies knowledge of condition of the wireless and the transport network
- Tradeoff between abstraction level (i.e., performance) and complexity (i.e., scalability, messaging overhead)

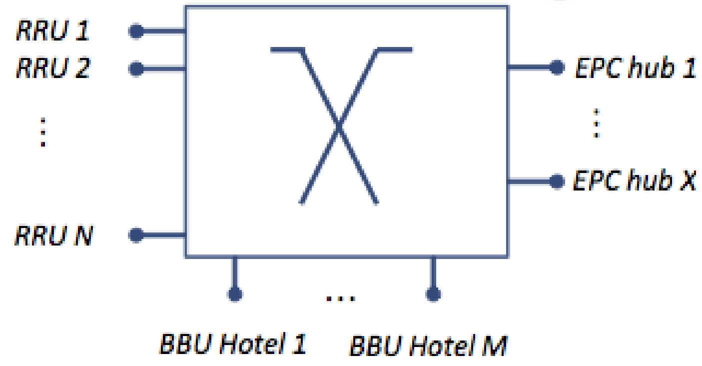


M. Fiorani, A. Rostami, L. Wosinska, P.Monti, "Transport Abstraction Models for a SDN-Controlled Centralized RAN", *IEEE Communication Letters*, to appear, 2015.

Transport abstraction options

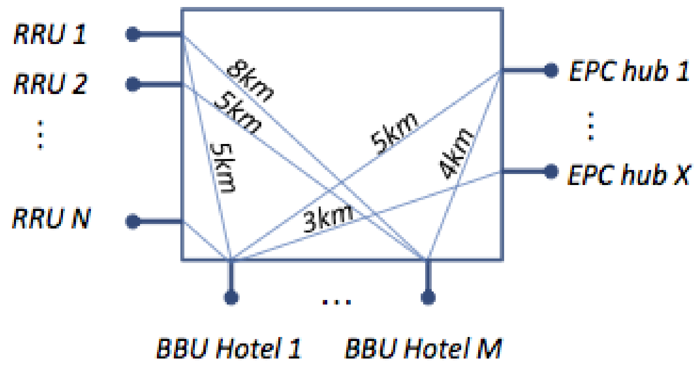
Big Switch Basic

- Transport network presented to the orchestrator as a single node (switch)
- No updates between transport controllers and orchestrator required



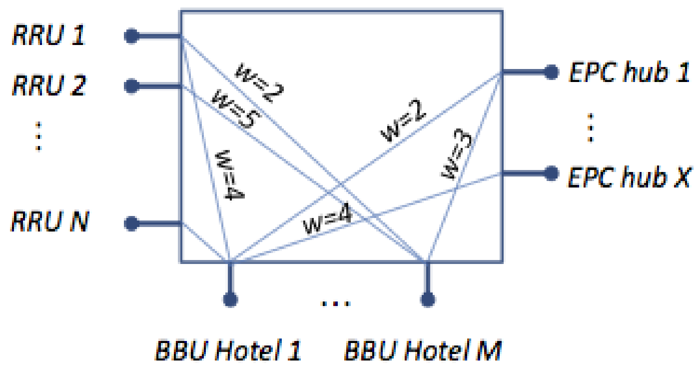
Virtual Link with Constant Weights

- Transport network presented to the orchestrator as a number of potential connections (virtual links) among switch ports
- Each virtual link is assigned a constant weight
- Whenever *connectivity is lost* between 2 switch ports corresponding *virtual link* is *deleted*
- Updates between controller and orchestrator are required



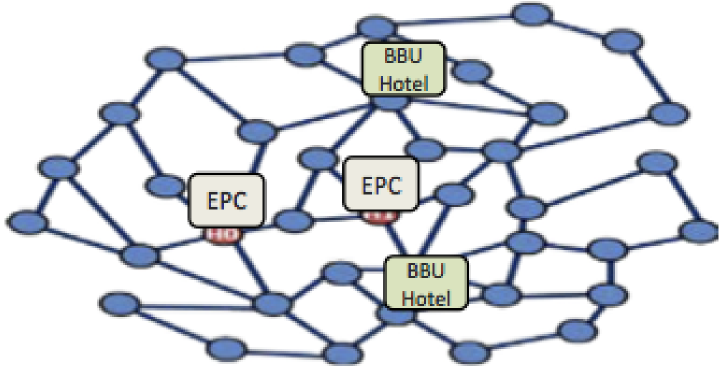
Virtual Link with Variable Weights

- Transport network presented to the orchestrator as a number of potential connections (virtual links) switch ports
- Each virtual link is assigned a variable weight, i.e., # of wavelenght between 2 switch ports
- Updates between controller and orchestrator are required

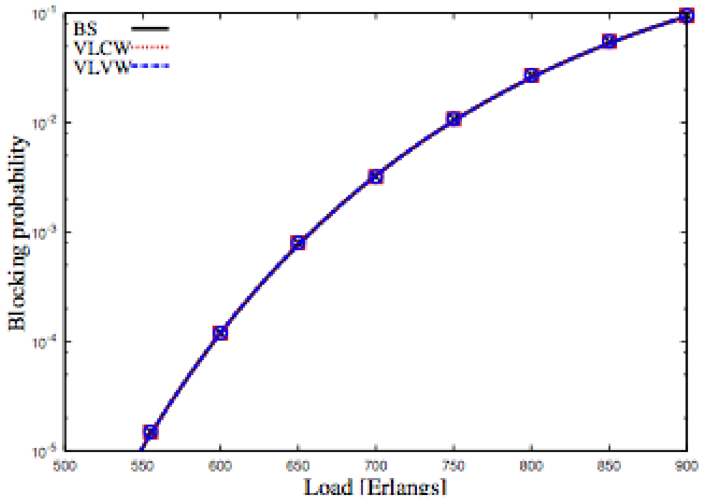


Performance results

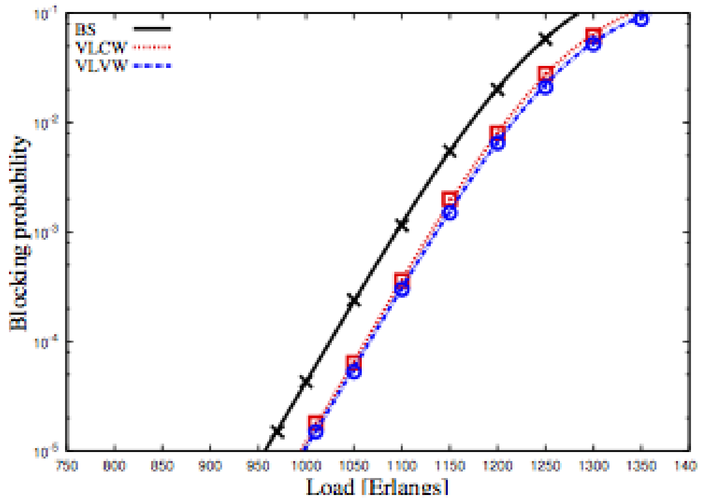
- 38 nodes, 2 BBU Hotels, EPC accessible via two node



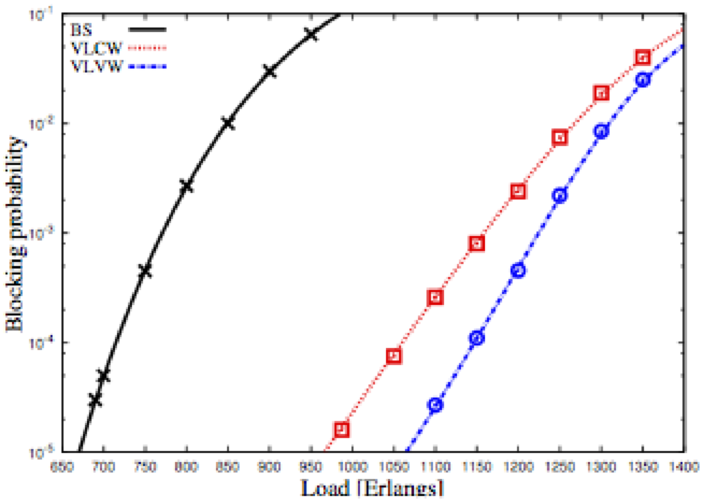
(a) Metro topology.



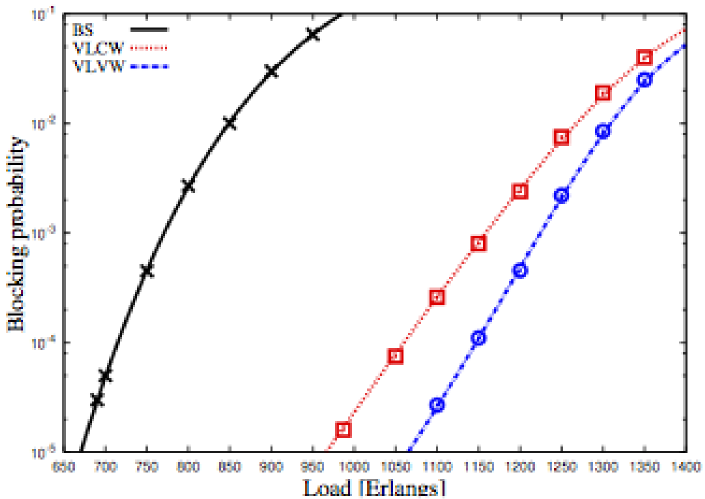
(b) $\eta = 0.5$.



(c) $\eta = 0.9$.



(d) $\eta = 1.0$.



(e) $\eta = 1.1$.

Blocking probability values for η=1.

Parameter	Load	BS	VLCW	VLVW
W=256	1160	0.1440	0.0010	0.0002
W=128	570	0.1433	0.0010	0.0002
W=64	280	0.1431	0.0010	0.0002
h=100	1150	0.1440	0.0010	0.0002
h=50	1160	0.1440	0.0010	0.0002
h=25	1170	0.1440	0.0010	0.0002
$\sum_{i=1}^{N_H} D_{BBU}^i$=11	1160	0.1440	0.0010	0.0002
$\sum_{i=1}^{N_H} D_{BBU}^i$=9	940	0.1418	0.0010	0.0002
$\sum_{i=1}^{N_H} D_{BBU}^i$=7	730	0.1408	0.0010	0.0002

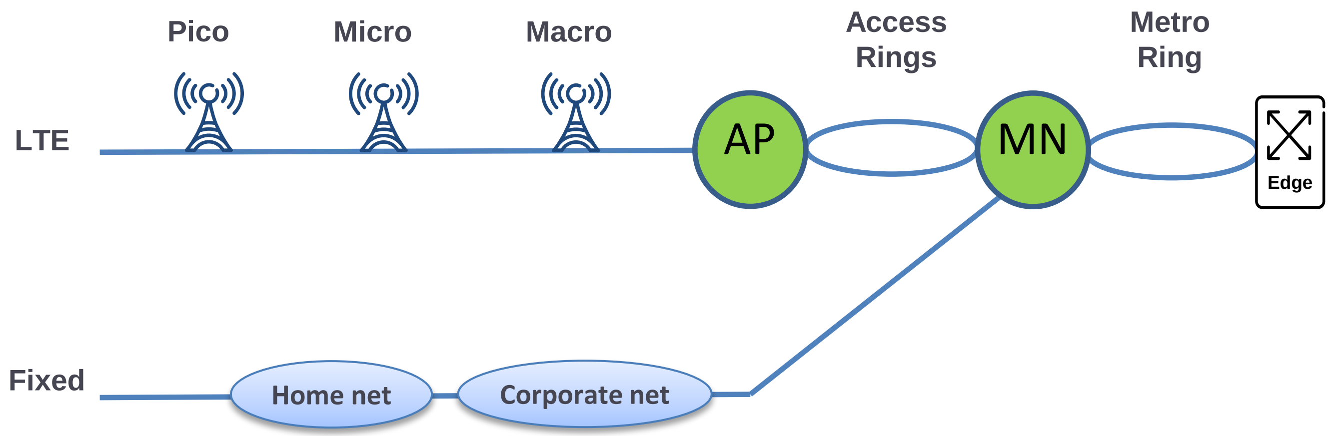
(f) Sensitivity analysis.

- η = ration of amount of radio resources vs. transport resources

$$\eta = \frac{\left\lceil (1+b) \cdot \sum_{i=1}^{N_H} N_{BBU}^i \right\rceil}{W \cdot \sum_{i=1}^{N_H} D_{BBU}^i}$$

Data plane options for NFV

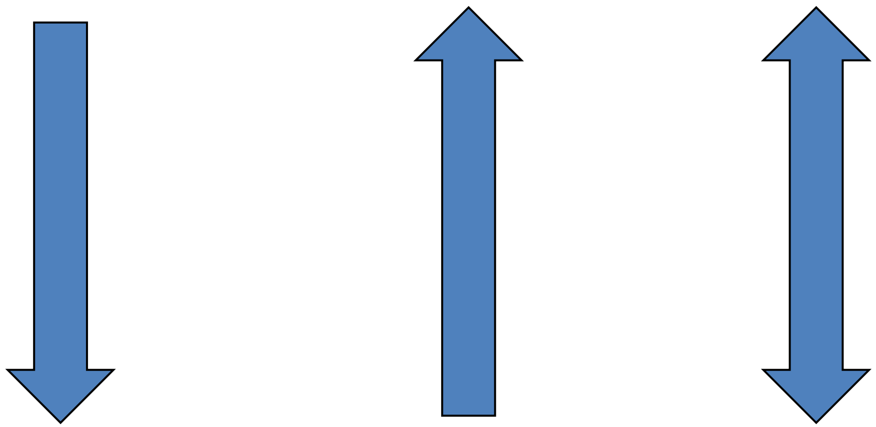
- “Metro simplification” is a power/cost efficient architecture allowing for the reduction of the number of local exchanges (i.e., simplification)[1]
- Two types of rings
  - Optical access ring: collects the traffic from mobile network
  - Optical metro ring: aggregates and transmits toward the service edge



[1] Skubic B., Pappa I., “Energy consumption analysis of converged networks: Node consolidation vs metro simplification”, *OFC/NFOEC*, 2013

KPIs and objective

- Architectures for metro simplification:
  - Optical DWDM switching
  - Electronic packet switching
  - Electronic packet switching + caching



Complexity
required number of complex network components

Capacity
required number of optical channels

Power/Cost?

- Objective:
  - Assess power consumption/cost of different architectures for metro simplification
  - Identify the most promising solution(s)

Scenario: very dense urban area

Scenario:

1. CO service area: 2 km^2
2. Macro: 60 (30 per km^2)
3. Micro: 600
4. Pico (indoor): 6000
5. Buildings (in 2 km^2 area): 400
6. Businesses: 10 per building
7. Homes: 50 per building
8. People: 200k
9. People (office): 160k
10. People (res): 40k
11. Devices: 200k-2M

Service Requirements :

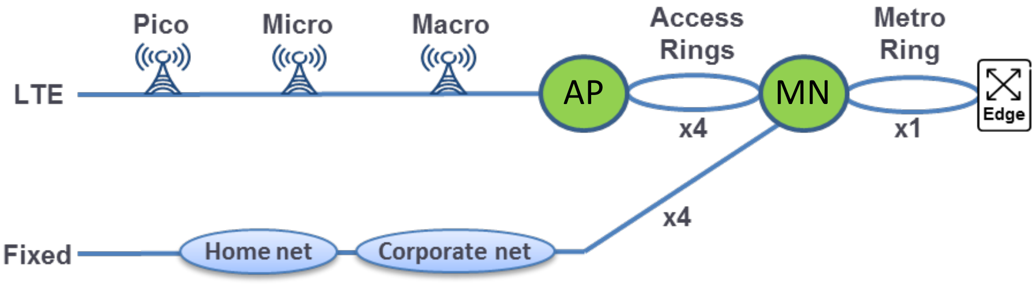
1. Macro: 228 Mb/s
2. Micro: 90 Mb/s
3. Pico (indoor): 132 Mb/s
4. Residential user: 16 Mb/s
5. Business user: 202 Mb/s

	Number per AP	Rate [Gbps]	Traffic [Gbps] per AP	Total Traffic [Gbps] for 60 APs
LTE				
Macro	1	0.228	0.228	13.7
Micro	10	0.090	0.9	54
Pico	100	0.132	13.2	792
Fixed				
Residential	333	0.016	5.33	320
Business	67	0.202	13.47	808

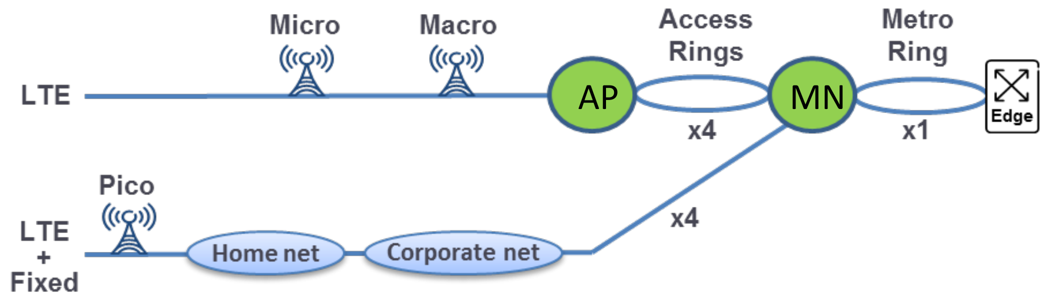
** Note that only LTE backhaul (no CPRI) is assumed.

M. R. Raza, M. Fiorani, B. Skubic, J. Mårtensson, L. Wosinska, P. Monti, "Power and Cost Modeling for 5G Transport Networks," *in Proc. of IEEE ICTON,* 2015

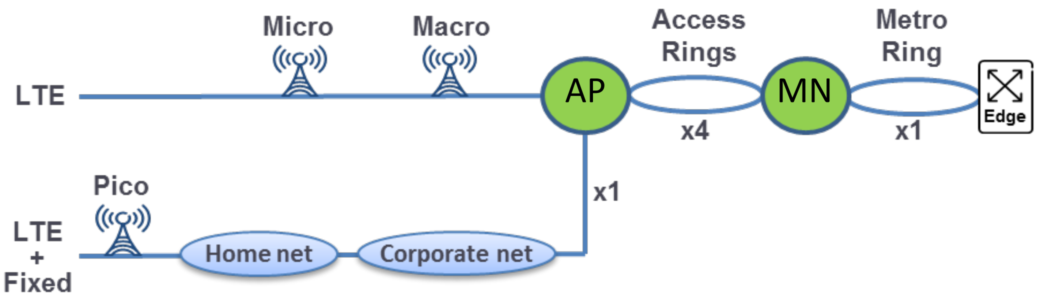
Data plane architecture options



Deployment A



Deployment B



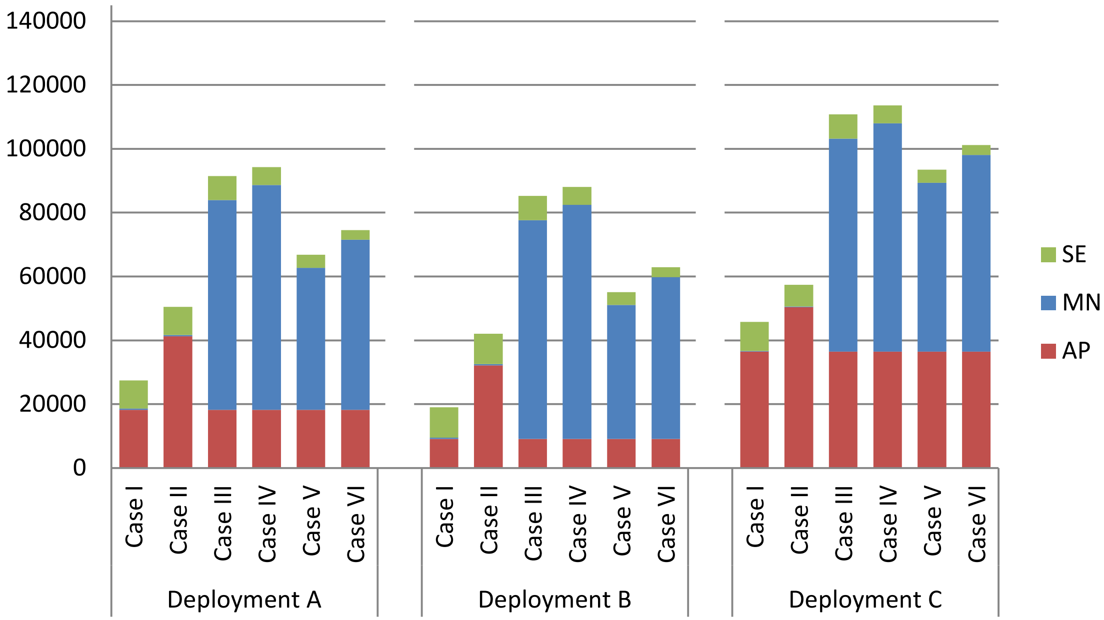
Deployment C

Case I = optical switching at MN / no caching
Case II = optical switching at MN / caching at AP
Case III = electronic switching at MN / no caching
Case IV = electronic switching at MN / caching at MN
Case V = electronic switching at MN (hybrid 10G/100G) / no caching
Case VI = electronic switching at MN (hybrid 10G/100G) / caching at MN

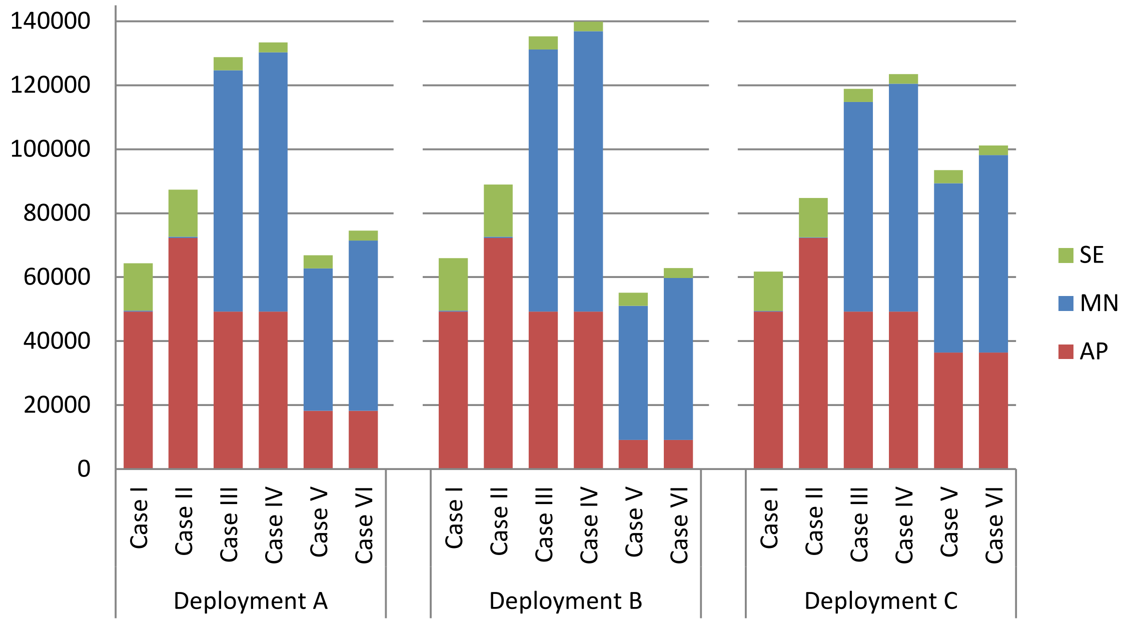
M. R. Raza, M. Fiorani, B. Skubic, J. Mårtensson, L. Wosinska, P. Monti, "Power and Cost Modeling for 5G Transport Networks," *in Proc. of IEEE ICTON,* 2015

Power consumption evaluation

Power consumption (W) at 10 Gbps



Power consumption (W) at 100 Gbps



Case I = optical switching at MN / no caching

Case II = optical switching at MN / caching at AP

Case III = electronic switching at MN / no caching

Case IV = electronic switching at MN / caching at MN

Case V = electronic switching at MN (hybrid 10G/100G) / no caching

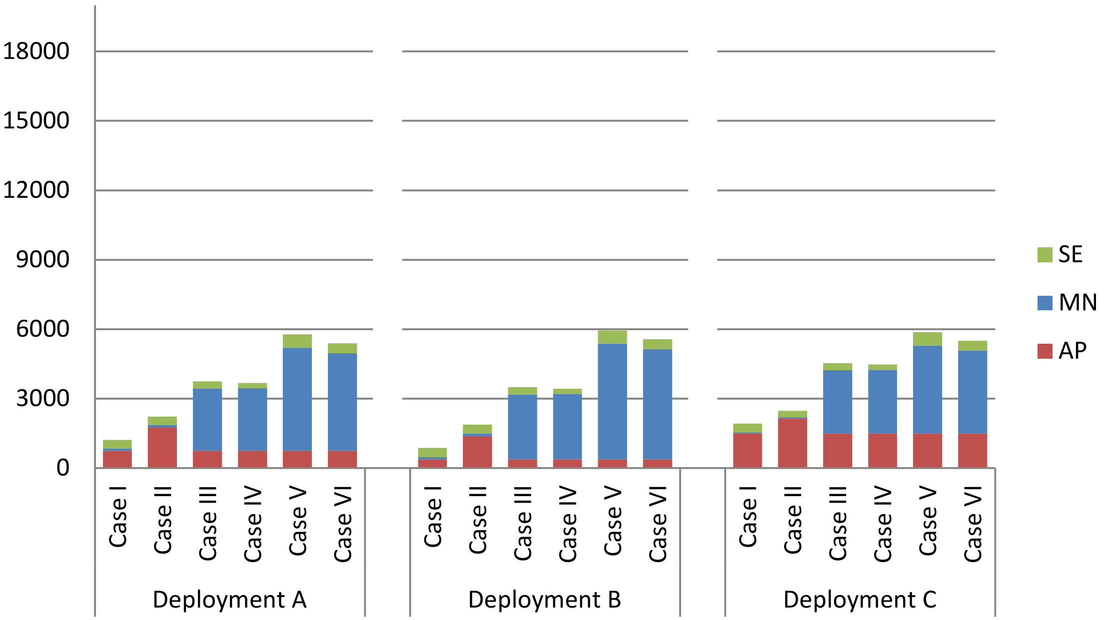
Case VI = electronic switching at MN (hybrid 10G/100G) / caching at MN

	Power Consumption [Watt]	Cost [CU] in Year 2014	Cost [CU] in Year 2018
Ethernet 10 Gbps port	38	1.56	0.89
Ethernet 100 Gbps port	205	28.89	10
WSS 10 Gbps / 100 Gbps	20	5.56	3.89

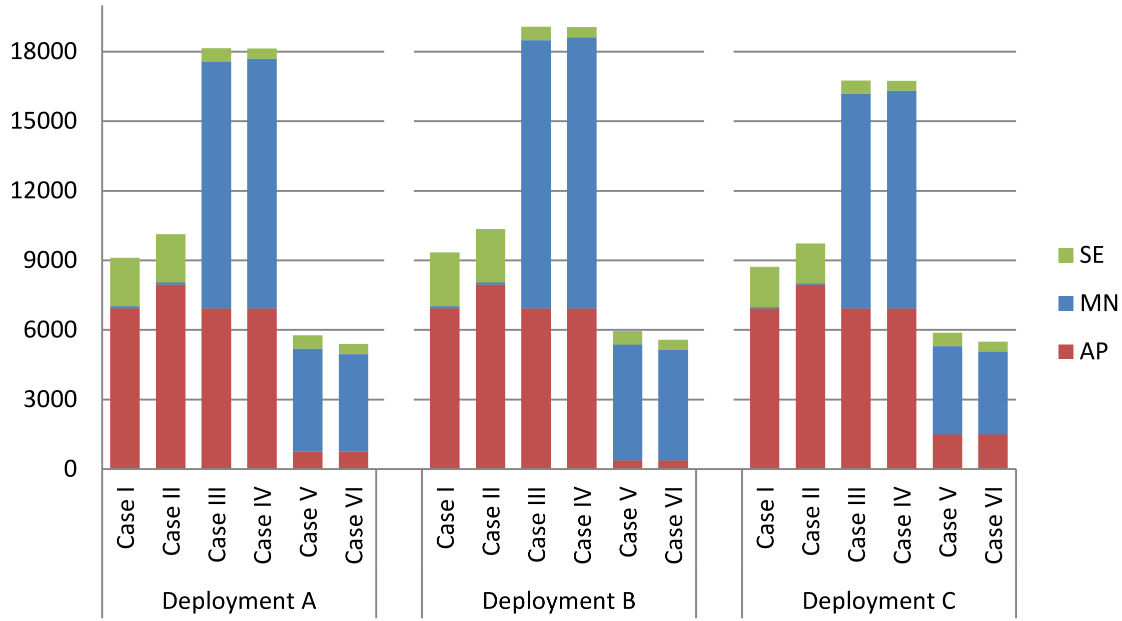
M. R. Raza, M. Fiorani, B. Skubic, J. Mårtensson, L. Wosinska, P. Monti, "Power and Cost Modeling for 5G Transport Networks," *in Proc. of IEEE ICTON,* 2015

Cost evaluation: the 2014 case

2014: Total Cost (CU) at 10 Gbps



2014: Total Cost (CU) at 100 Gbps

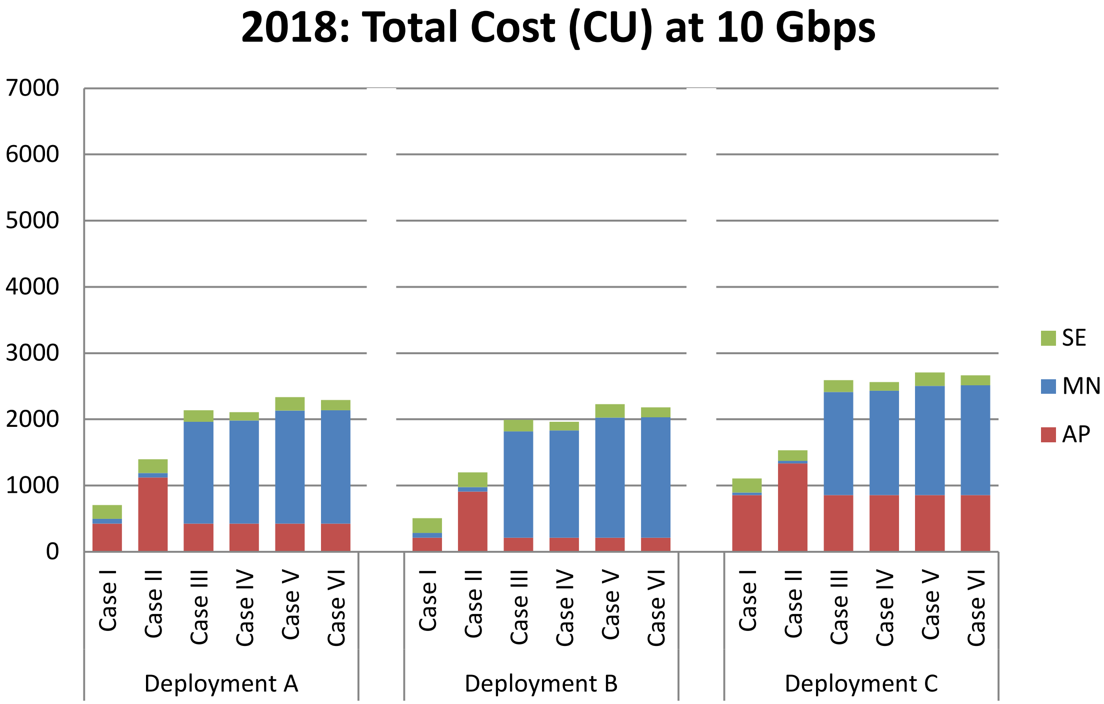


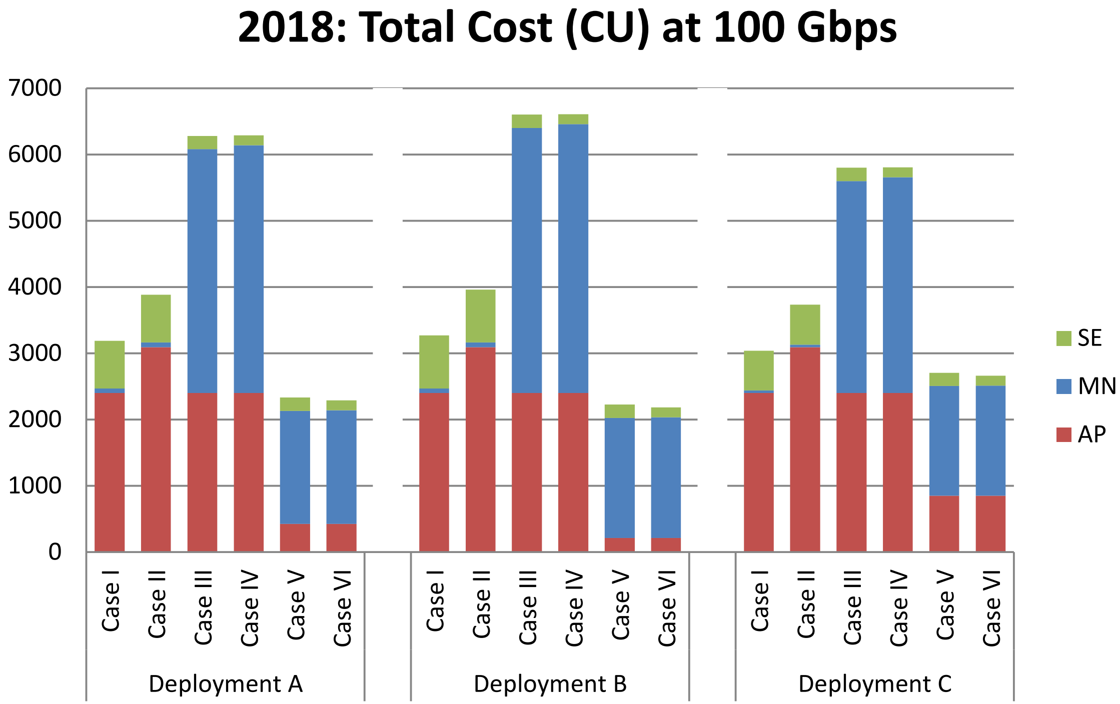
Case I = optical switching at MN / no caching
Case II = optical switching at MN / caching at AP
Case III = electronic switching at MN / no caching
Case IV = electronic switching at MN / caching at MN
Case V = electronic switching at MN (hybrid 10G/100G) / no caching
Case VI = electronic switching at MN (hybrid 10G/100G) / caching at MN

	Power Consumption [Watt]	Cost [CU] in Year 2014	Cost [CU] in Year 2018
Ethernet 10 Gbps port	38	1.56	0.89
Ethernet 100 Gbps port	205	28.89	10
WSS 10 Gbps / 100 Gbps	20	5.56	3.89

M. R. Raza, M. Fiorani, B. Skubic, J. Mårtensson, L. Wosinska, P. Monti, "Power and Cost Modeling for 5G Transport Networks," *in Proc. of IEEE ICTON,* 2015

Cost evaluation: the 2018 case





Case I = optical switching at MN / no caching
Case II = optical switching at MN / caching at AP
Case III = electronic switching at MN / no caching
Case IV = electronic switching at MN / caching at MN
Case V = electronic switching at MN (hybrid 10G/100G) / no caching
Case VI = electronic switching at MN (hybrid 10G/100G) / caching at MN

	Power Consumption [Watt]	Cost [CU] in Year 2014	Cost [CU] in Year 2018
Ethernet 10 Gbps port	38	1.56	0.89
Ethernet 100 Gbps port	205	28.89	10
WSS 10 Gbps / 100 Gbps	20	5.56	3.89

M. R. Raza, M. Fiorani, B. Skubic, J. Mårtensson, L. Wosinska, P. Monti, "Power and Cost Modeling for 5G Transport Networks," *in Proc. of IEEE ICTON,* 2015

Conclusions

- Discussed 5G paradigm and challenges that transport has to face in order to accommodate future 5G networks
- SDN-based control enables orchestration of different actors and allows for a flexible/efficient use of transport resources
  - Defined efficient abstraction strategies on the northbound interface
- Analyzed cost and power performance of a number of data plane architectures that can enable NFV
  - Introducing NFV has an impact in terms of cost and power consumption
  - Hybrid 10G/100G with electronic aggregation might be a good compromise
  - Interesting to investigate the pros/cons when balanced with the wireless benefits, e.g., FH

References

- M. Fiorani, P. Monti, B. Skubic, J. Mårtensson, L. Valcarenghi, P. Castoldi, L. Wosinska, “Challenges for 5G Transport Networks”, in Proc. of IEEE ANTS, 2014
- M. Fiorani, A. Rostami, L. Wosinska, P. Monti, “Transport Abstraction Models for a SDN-Controlled Centralized RAN”, IEEE Communication Letters, to appear, 2015
- M. R. Raza, M. Fiorani, B. Skubic, J. Mårtensson, L. Wosinska, P. Monti, "Power and Cost Modeling for 5G Transport Networks," in Proc. of IEEE ICTON, 2015
- B. Skubic, I. Pappa, “Energy Consumption Analysis of Converged Networks: Node Consolidation vs Metro Simplification”, OFC/NFOEC, 2013
- METIS deliverable D1.1, ”Scenarios, requirements and KPIs for 5G mobile and wireless system”, April 2013

Flexible and cost efficient optical 5G transport

Paolo Monti

pmonti@kth.se
http://web.it.kth.se/~pmonti/