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CONNECT Centre for Future Networks

From central office cloudification to optical network disaggregation

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Trinity College Dublin
The University of Dublin
Ireland's European Structural and Investment Funds Programmes 2014-2020
Co-funded by the Irish Government and the European Union
European Union
European Regional Development Fund
Science Foundation Ireland For what's next
Arizona

Summary

- Cloudification an evolving trend of network convergence
  - Physical convergence in access-metro
  - Functional convergence as cloud central office (cloud-CO)
  - Current view of network cloudification

- Cloudification use cases:
  - Enabling fixed/mobile convergence
  - Enabling true multi-tenancy

- Network architecture is support of functional convergence
  - Functional/architectural convergence
  - Dynamic optical networking
  - Machine learning for quality of estimation improvement
  - Optical network disaggregation

- Conclusions: full convergence trend

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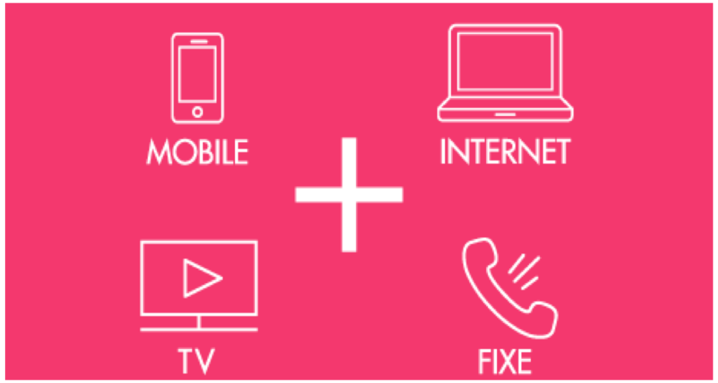
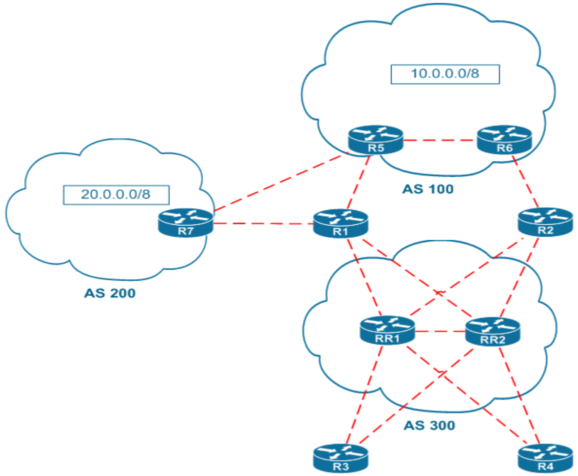
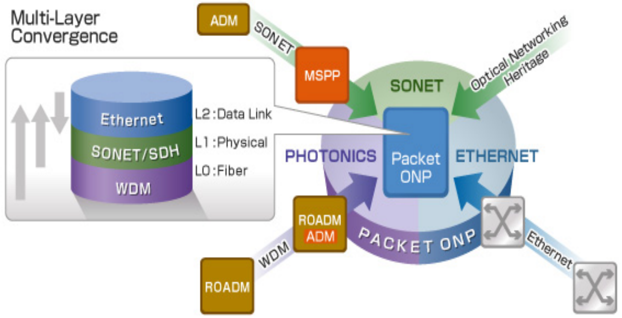
Definition of network convergence I: according to Google



Telco heads perspective: triple/quadruple play and voice/data (also Wikipedia)

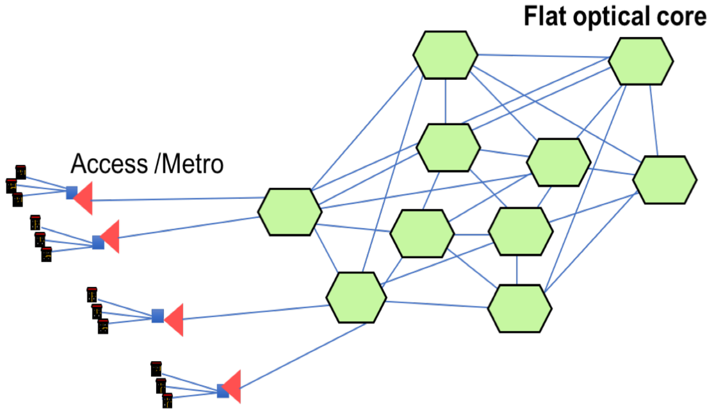


IP heads perspective: convergence of distributed protocols

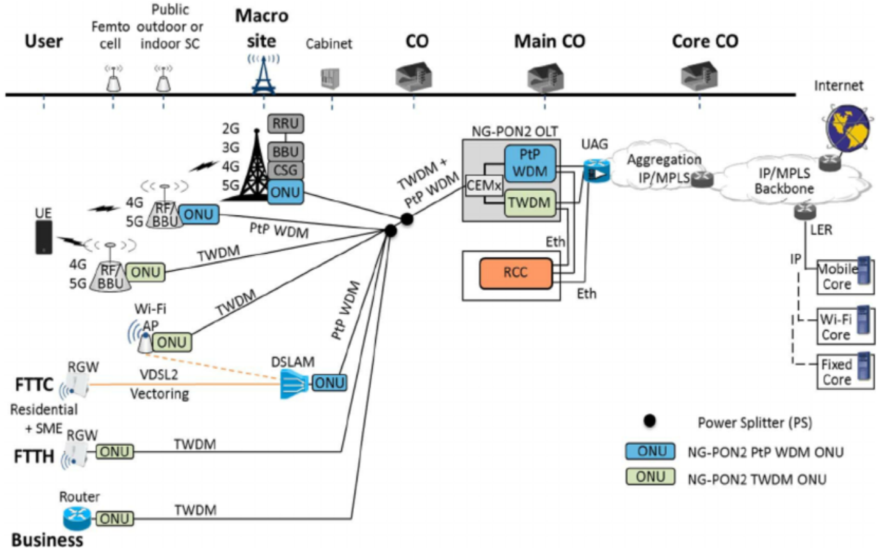


Telco vendors perspective: packet-optical convergence

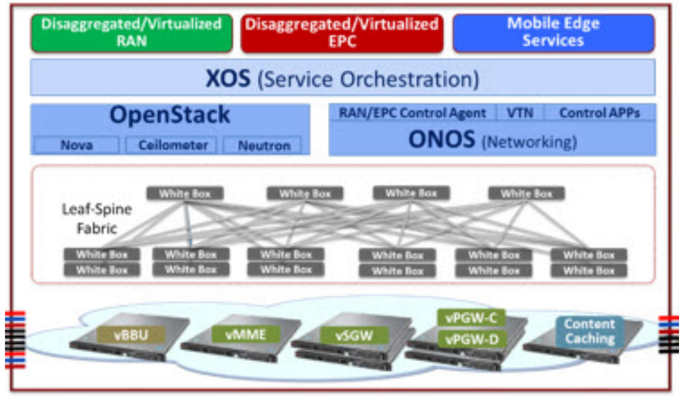
Definition of network convergence II: according to our research community



Convergence of access and metro networks



Convergence of fixed and mobile networks



Convergence of networking functionalities and services into Data centre (e.g., NFV)

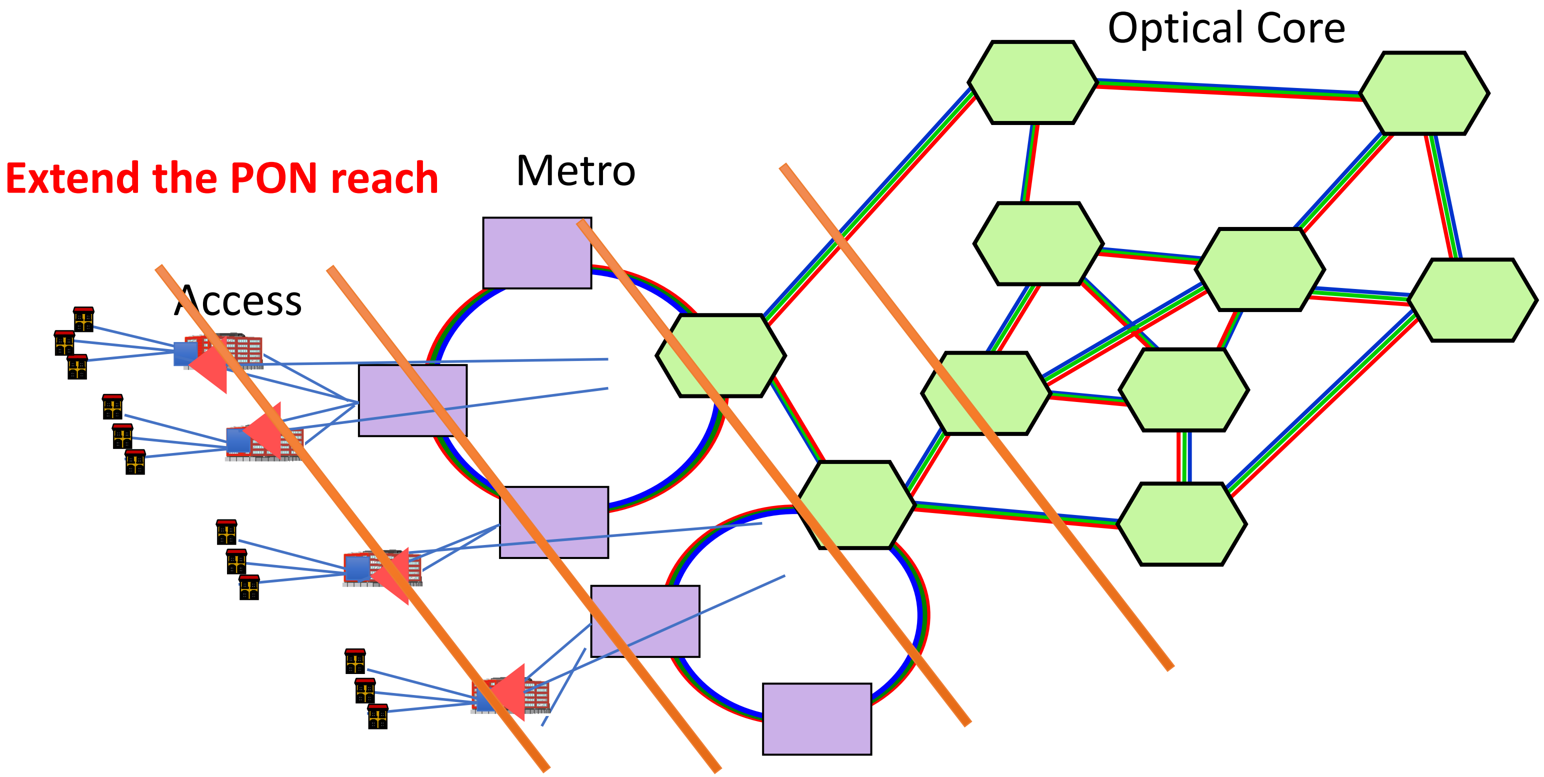
What is convergence good for?

- Look back at all definitions:
  - It’s about making one network or system do multiple things…
  - …without loss in performance!
  - Save capital costs:
    - use less infrastructure (more efficiently)

  - Save operational costs :
    - number of personnel with different skills,
    - training involved
    - cross-domain experts,…

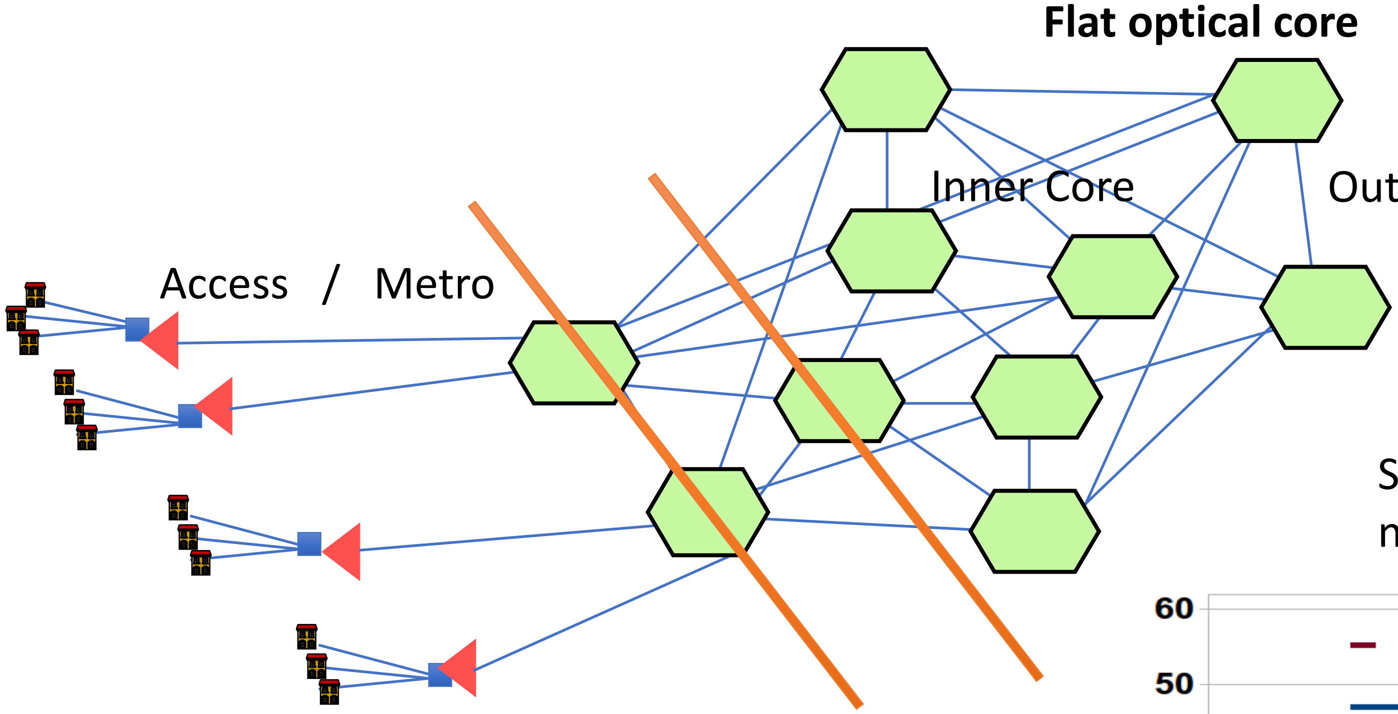
Convergence example I: LR-PON

- Our previous work on spatial consolidation in EU FP7 DISCUS:
  - Extend optical access reach to reach core: reach up to >100Km

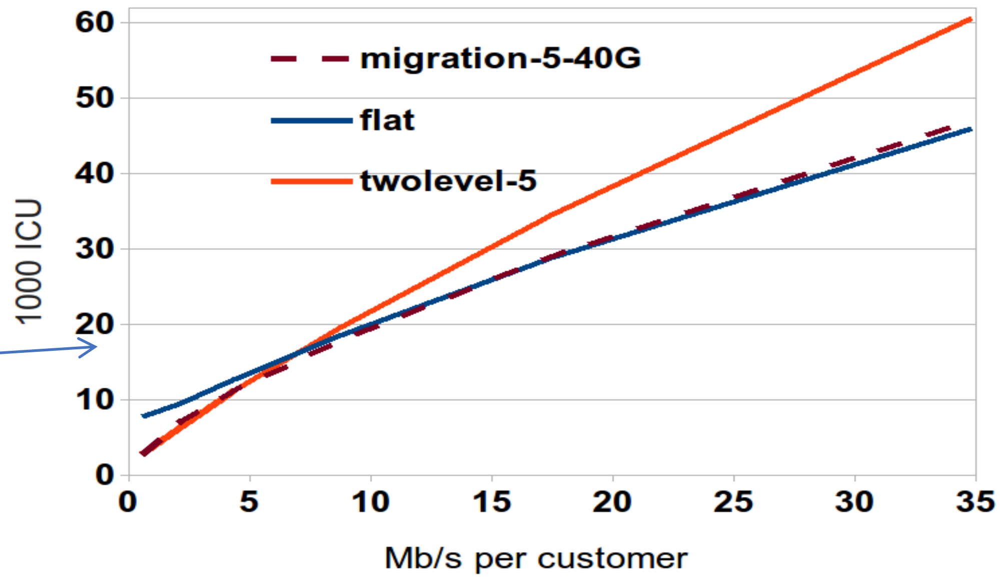


M. Ruffini, L. Wosinska, M. Achouche, J. Chen, N. J. Doran, F. Farjady, J. Montalvo, P. Ossieur, B. O'Sullivan, N. Parsons, T. Pfeiffer, X.-Z. Qiu, C. Raack, H. Rohde, M. Schiano, P. Townsend, R. Wessaly, X. Yin, D. B. Payne, DISCUS: An end-to-end solution for ubiquitous broadband optical access. IEEE Com. Mag., vol. 52, no. 2, February 2014

Convergence example I: LR-PON



Study carried out for UK network, using 75 MC nodes

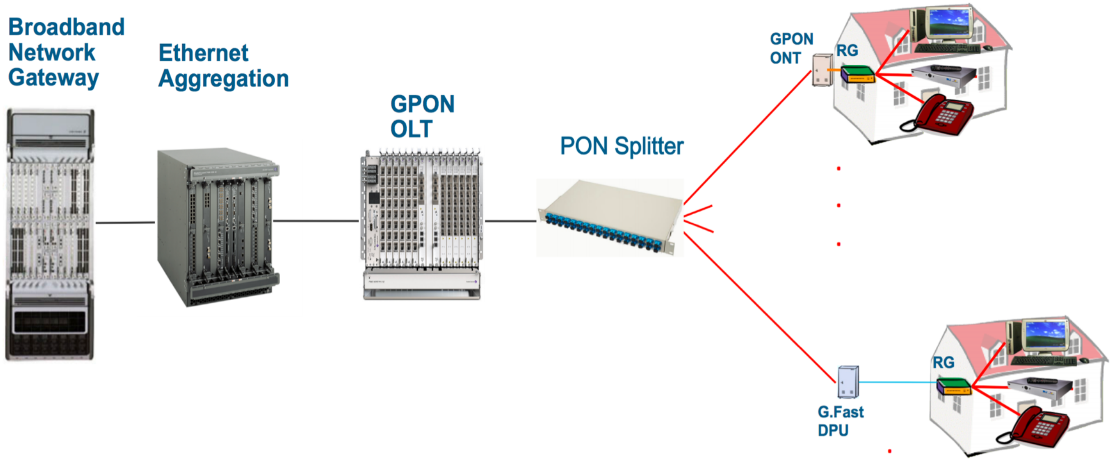


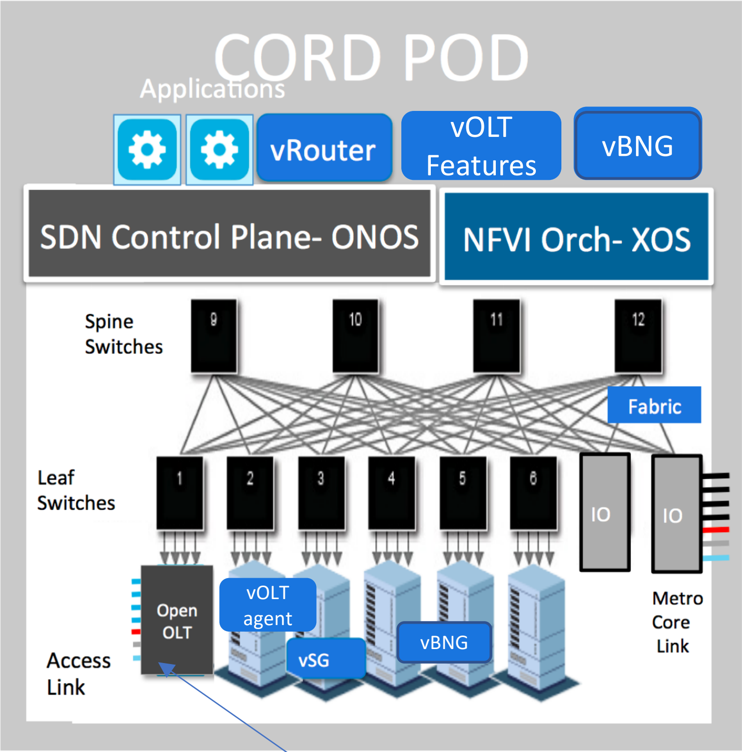
Flat core becomes the cheaper option when traffic is above a given threshold

C. Raak et al., Hierarchical Versus Flat Optical Metro/Core Networks: A Systematic Cost and Migration Study, ONDM 2016

Convergence example II: Cloud-Central Office

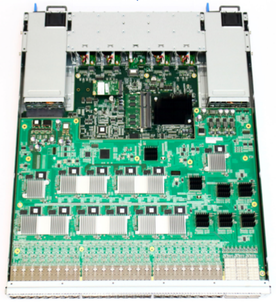
- Getting SDN and NFV into the central office:
  - Software and programmability a main enabler of convergence
  - E.g., enables tighter orchestration of resources (see fixed/mobile)





Commodity Hardware

Source: http://opencord.org/



- Driven my development, not by standard
- Being trialed by several operators world-wide
  - E.g., AT&T recently carried out trials on XGS-PON using OLT white boxes

Convergence example II: Cloud-CO (Mobile)

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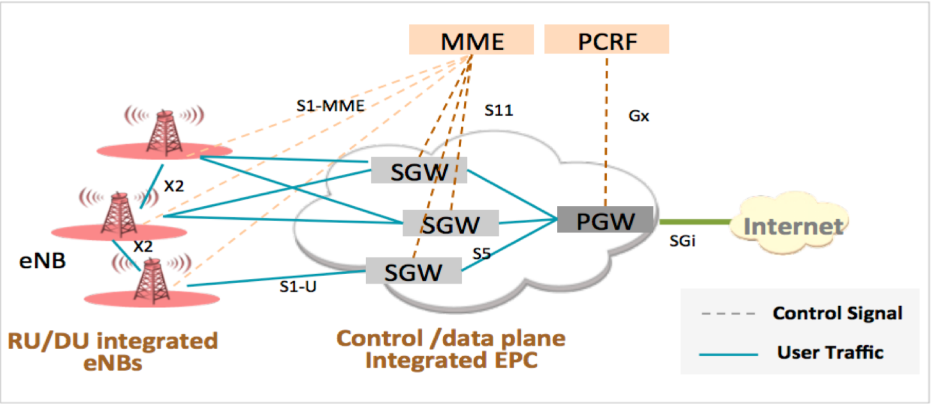
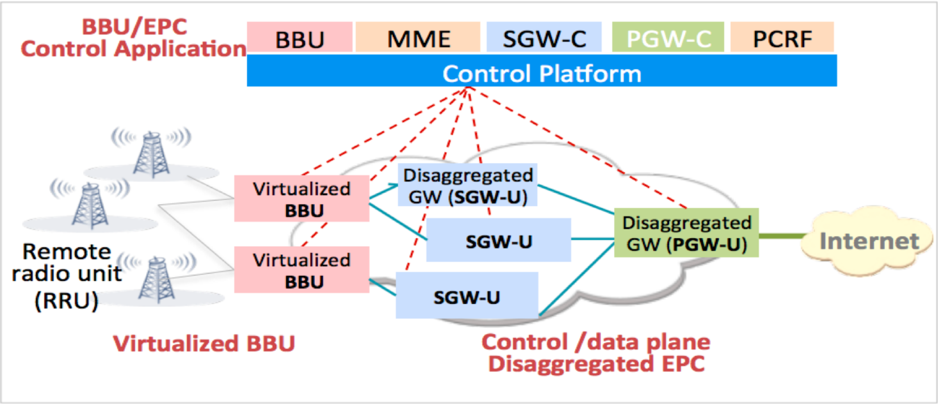
Traditional Architecture

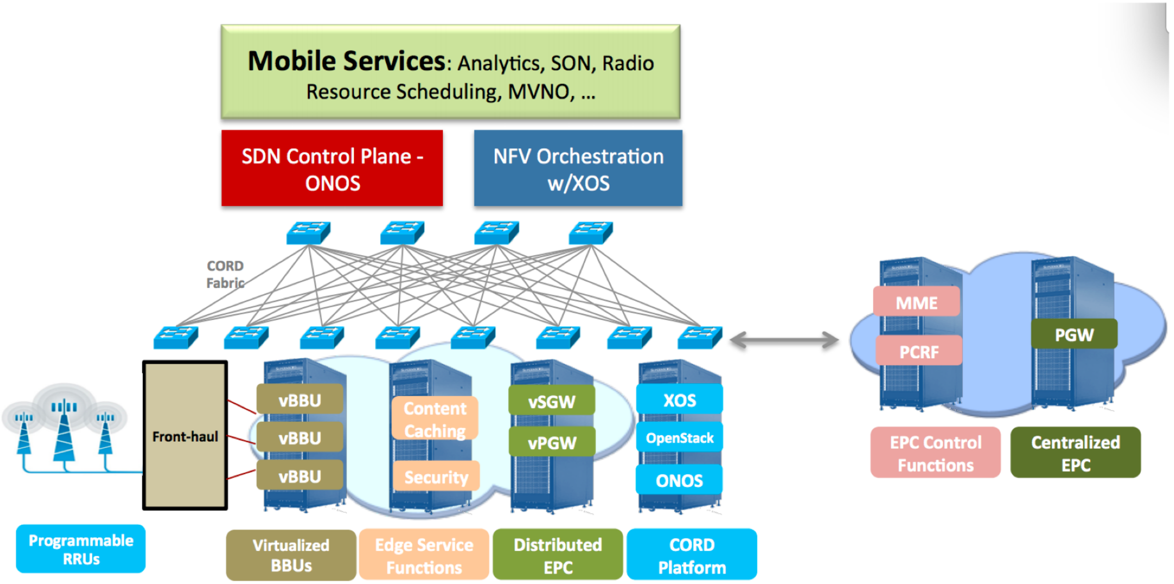


with proprietary boxes & solutions

Target Architecture



with commodity H/W & open source/open API



Source: http://opencord.org/

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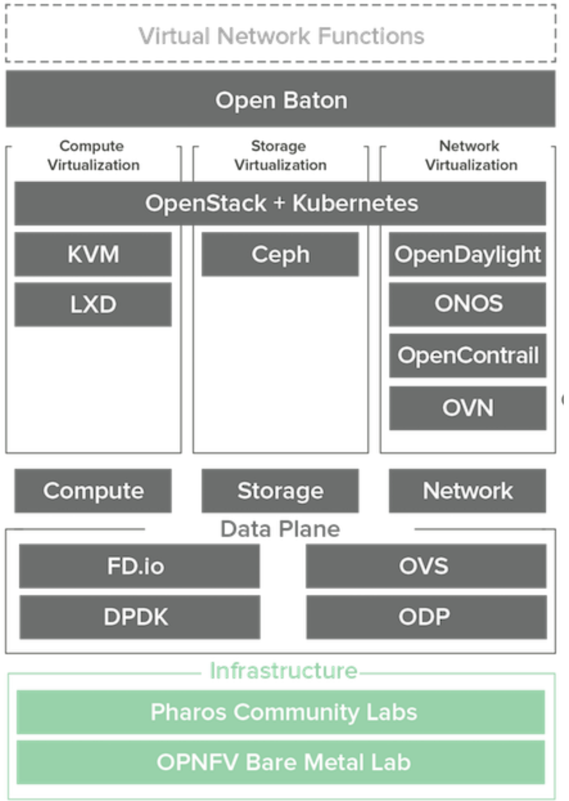
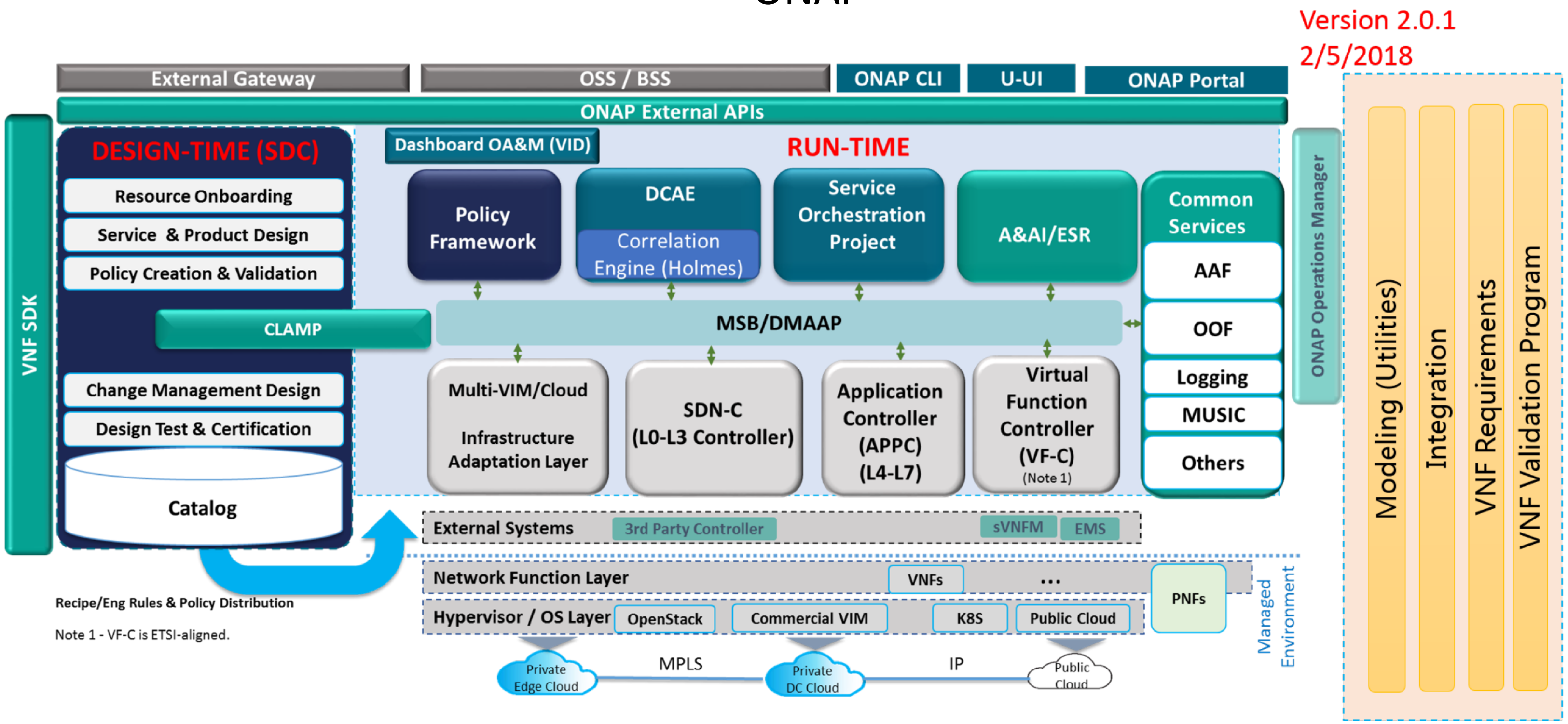
… and more…

- Standardisation of the Cloud Central Office Concept (BroadBand Forum)
- Although it's really when you see the design associated with a software implementation that this starts making more sense…

OPNFV

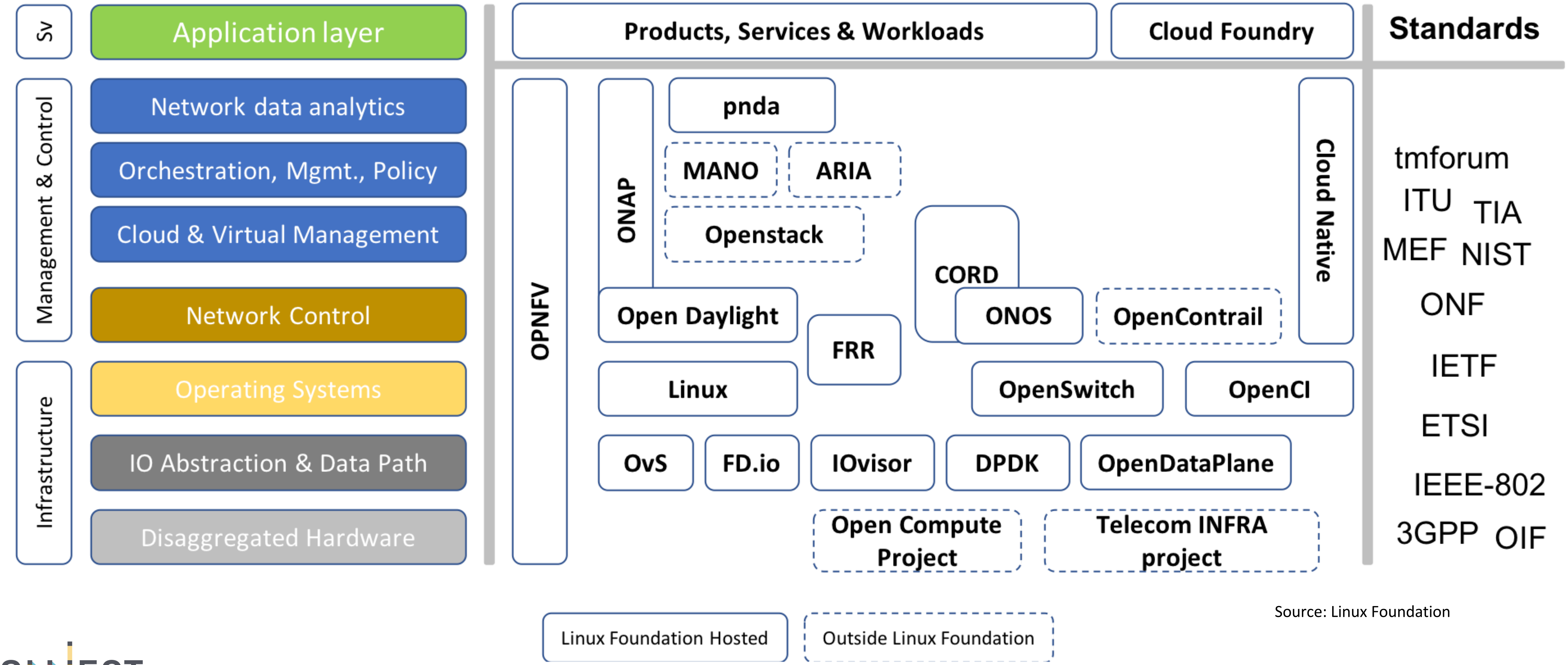


ONAP



Activities in network virtualisation

- Many activities progressing in parallel across different groups… here's an overview



Source: Linux Foundation

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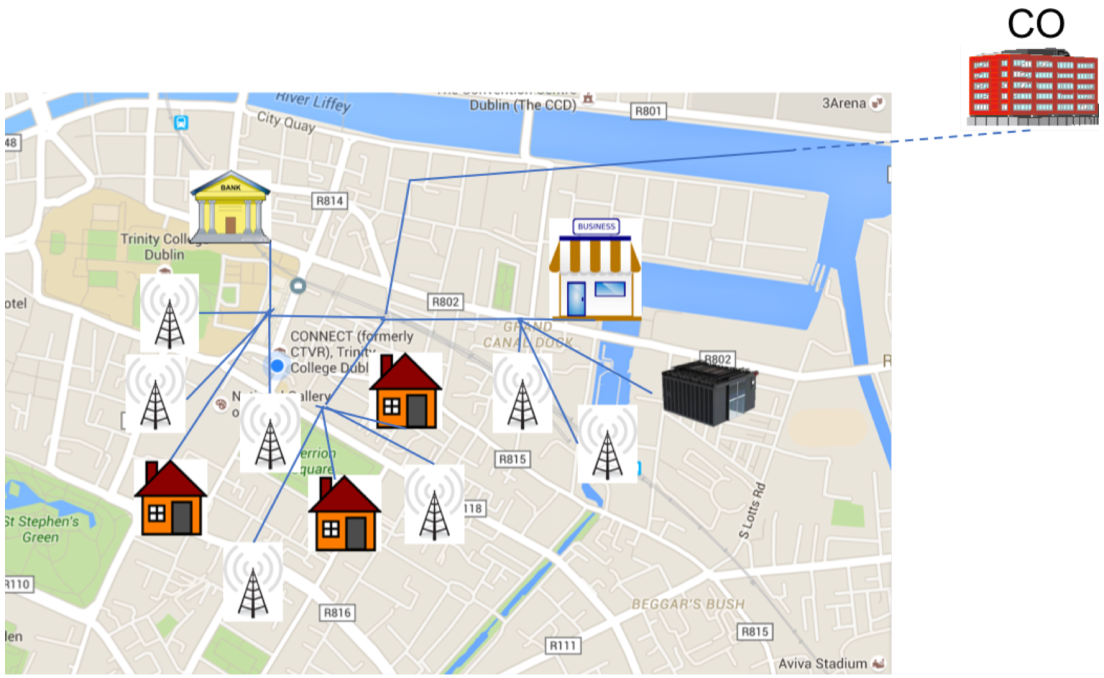
Use case I:
Virtualisation as enabler for fixed mobile convergence

Our work at TCD on Variable-rate fronthaul

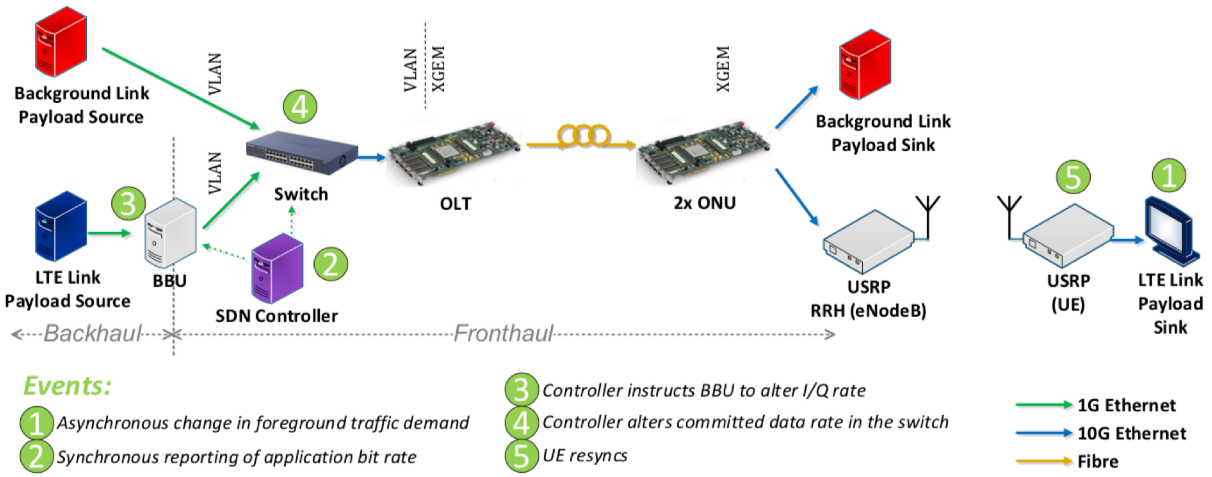
It applies to full C-RAN (i.e. most benefit if split 8 is chosen)

The idea is to change the cell wireless bandwidth depending on actual cell throughput:

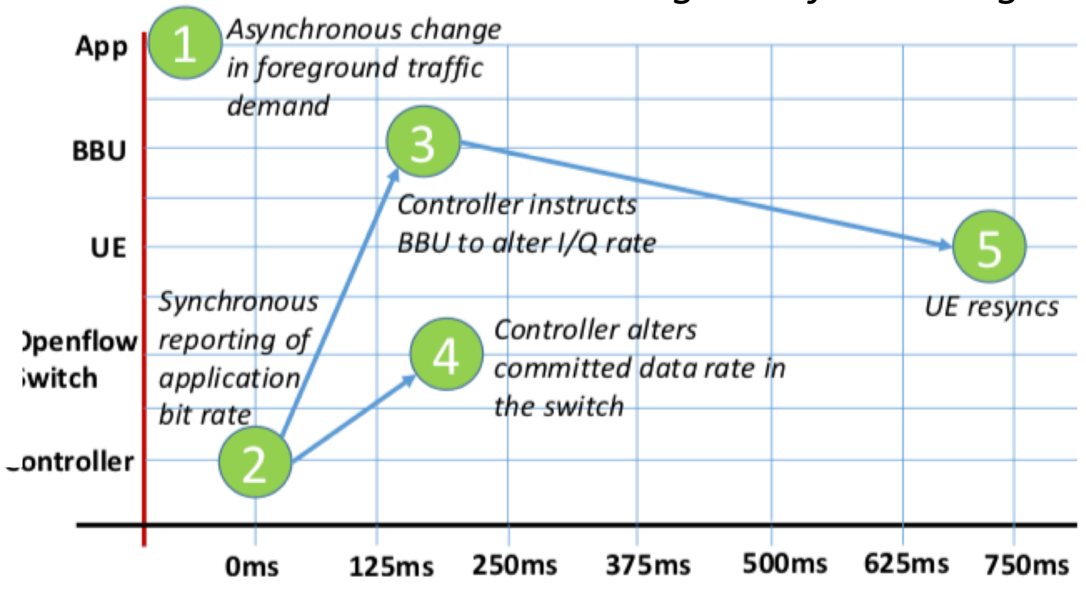
- Allows reuse of wireless bandwidth across nearby cells
- Makes transport rate proportional to cell throughput
- Coordinates capacity across wireless, optical and cloud resources



Some experimental results



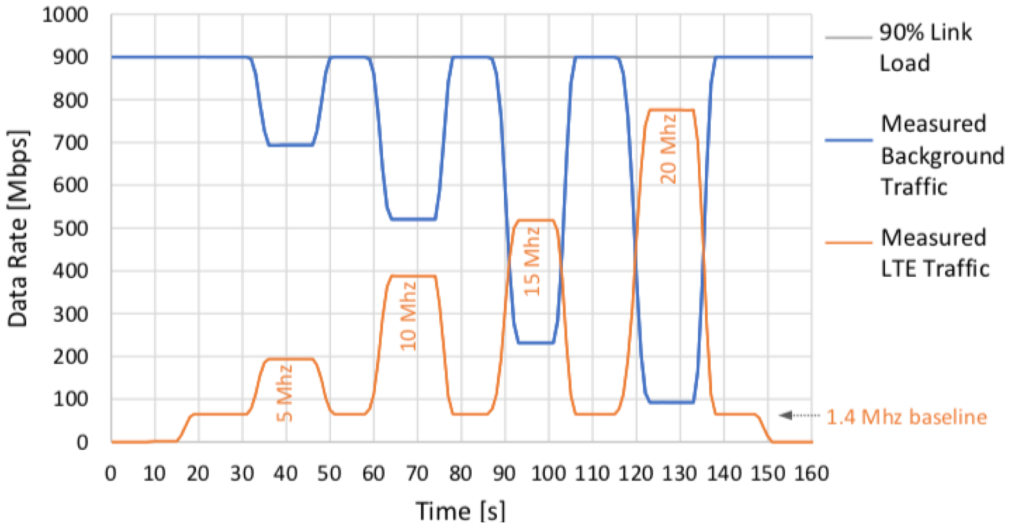
Time diagram of switching events



Pedro Alvarez, Frank Slyne, Christian Bluemm, Johann M. Marquez-Barja, Luiz A. DaSilva, Marco Ruffini, Experimental Demonstration of SDN-controlled Variable-rate Fronthaul for Converged LTE-over-PON. OFC 2018

Wireless Bandwidth	PRB Number	Fronthaul Rate	Max Cell Capacity
1.4 MHz	6	61 Mbps	1.8 Mbps
3 MHz	15	121 Mbps	4.584 Mbps
5 MHz	25	182 Mbps	7.736 Mbps
10 MHz	50	364 Mbps	15.264 Mbps
15 MHz	75	485 Mbps	22.92 Mbps
20 MHz	100	730 Mbps	30.576 Mbps

Measured fronthaul vs. best effort traffic



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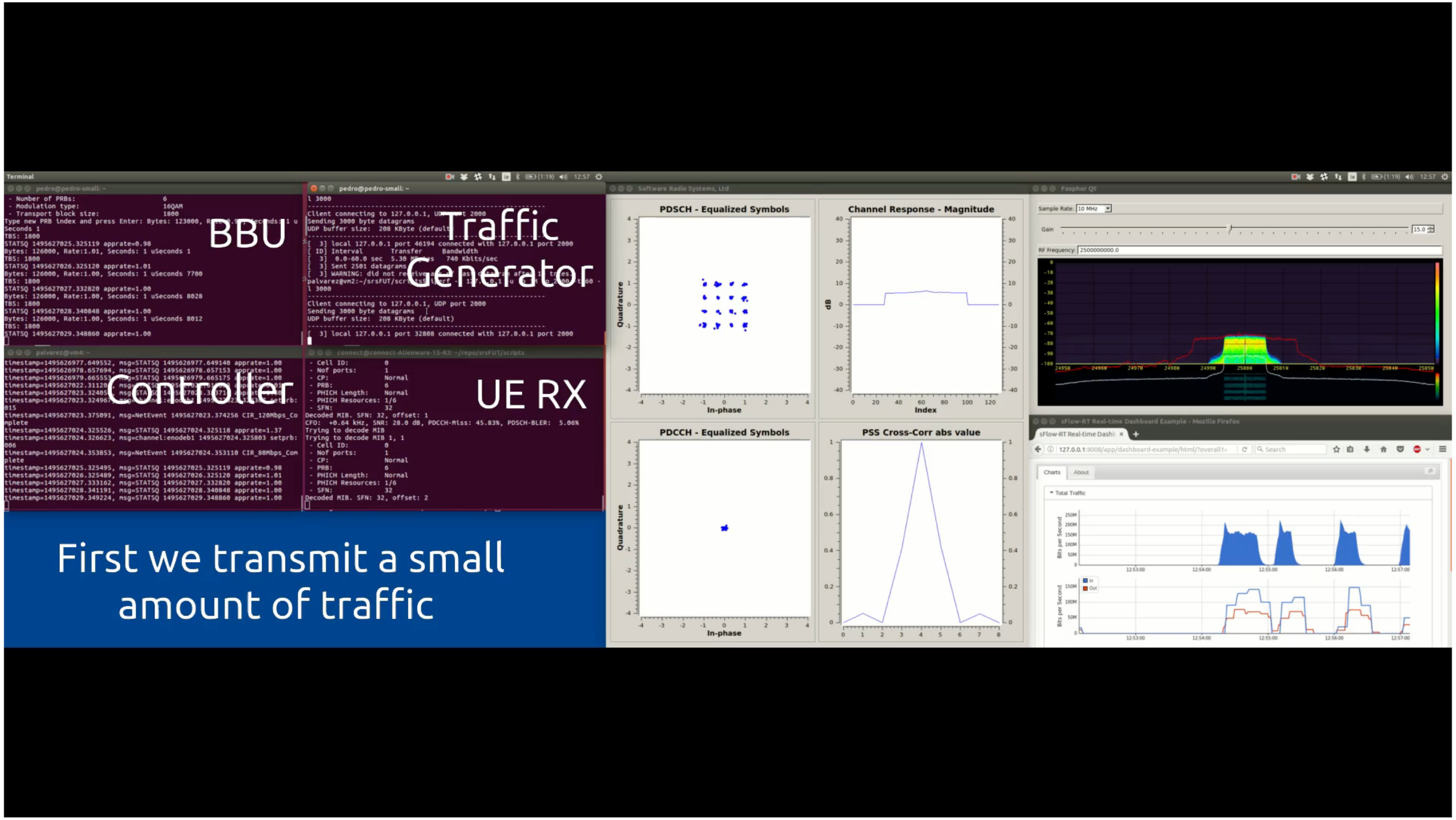
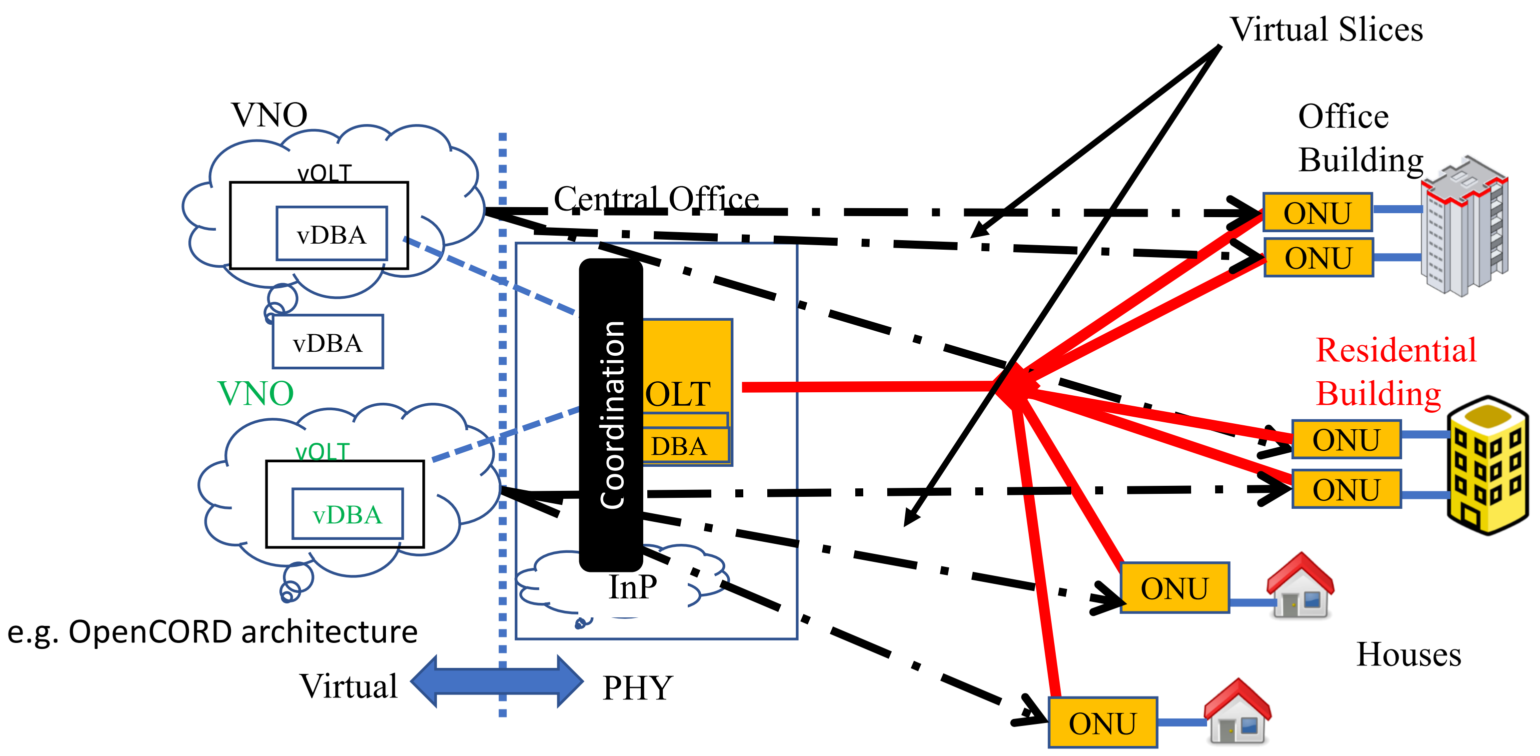
Fixed-mobile convergence with variable rate fronthaul over PON

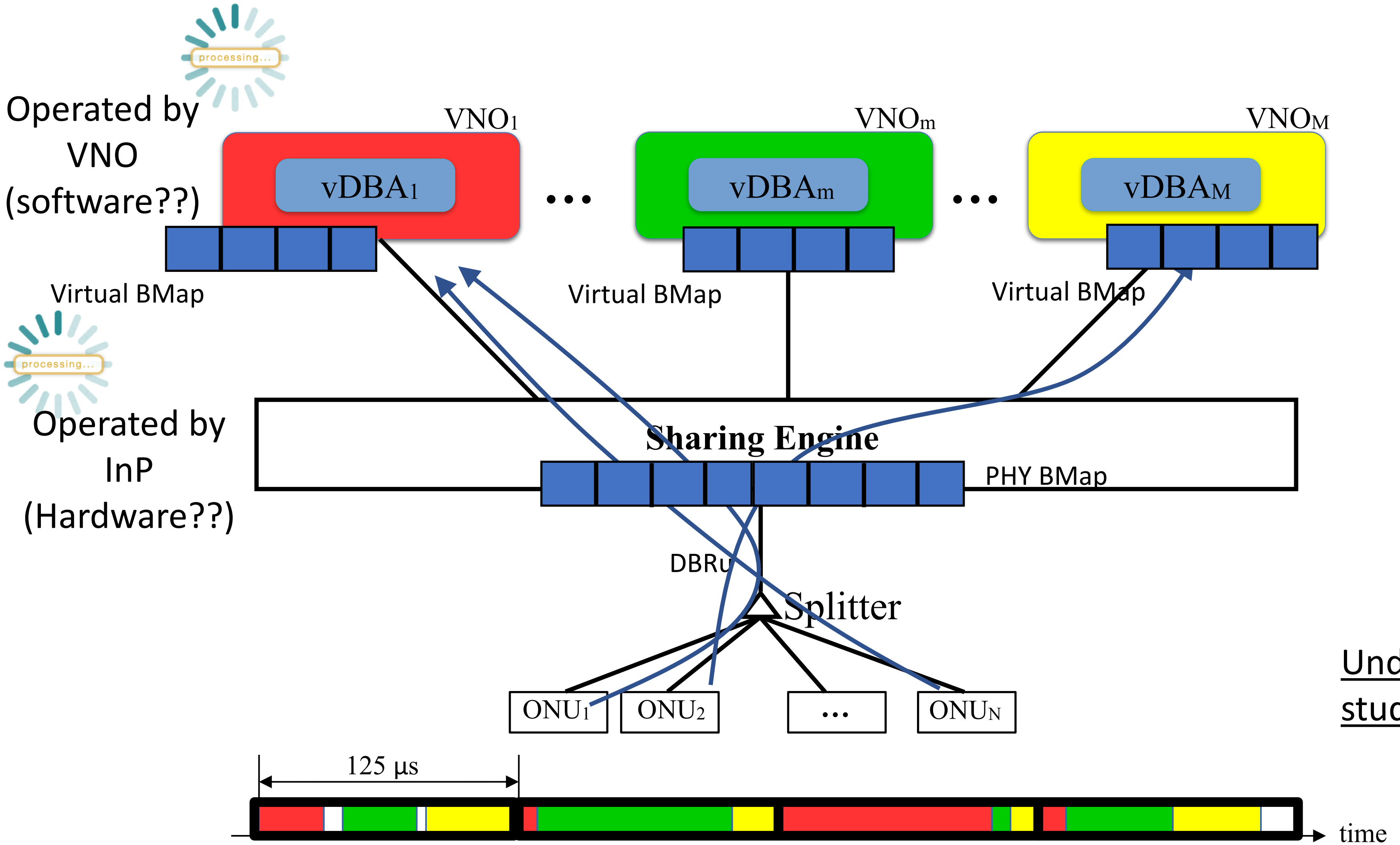


Use case II: Virtualisation as enabler for true multi-tenancy

Our work at TCD on virtual DBA (vDBA)



vDBA – sharing engine details



Under discussion at BBF study group SD-402

Amr Elrasad, Nima Afraz, and Marco Ruffini, Virtual Dynamic Bandwidth Allocation Enabling True PON Multi-Tenancy. Proc. of Optical Fibre Communications conference (OFC), March 2017

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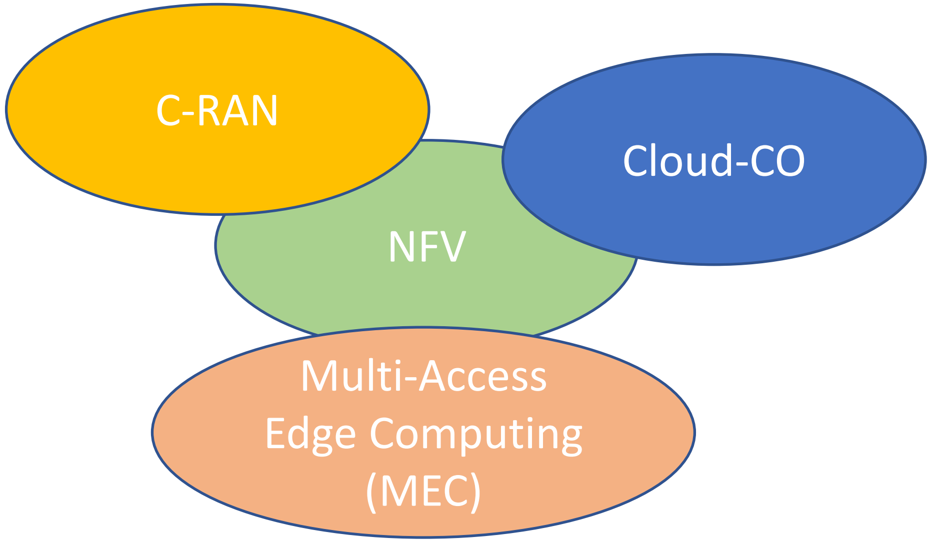
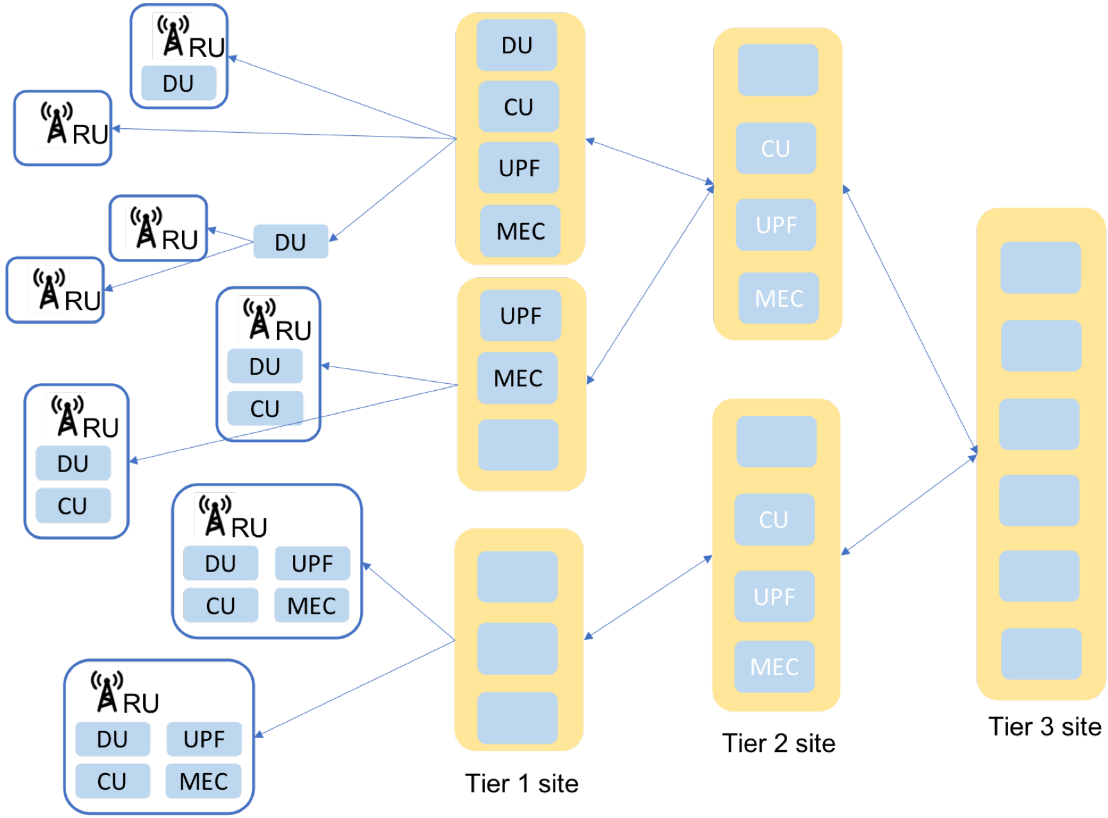
Network convergence for 5G



Should be consider different manifestations of the same trend / ecosystem



UPF Location	Tier 1	Tier 2	Tier 3
Relative number of sites	1000	100	10
Transport latency (1-way)	0.6 ms	1.2 ms	4.2 ms
Estimated 5G latency (RTT)	9.2 ms [eMBB]	10.4 ms [eMBB]	16.4 ms [eMBB]
	2.2 ms [URLLC]	3.4 ms [URLLC]	9.4 ms [URLLC]

Source: NGMN

Functional and architectural convergence for 5G

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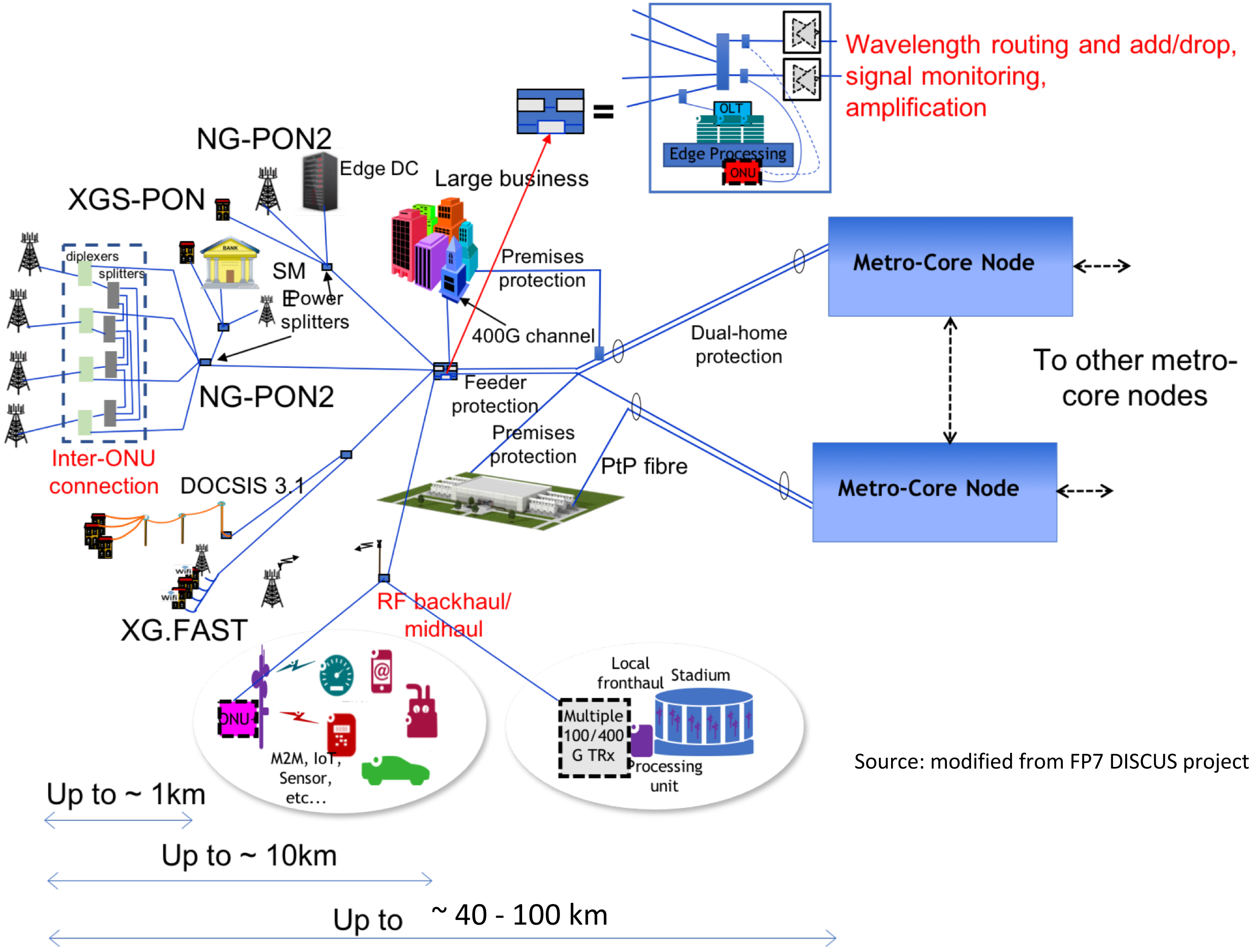
- The physical access-metro architecture needs to supporting this cost-effectively
  - High capacity, dynamic demand, low latency, reliability, diversity of requirements
- For example, include dynamic/reconfigurable optics with local termination of signals:
  - Inter-ONU
  - OLT and computation at power split point
  - Optics across computation node boundaries



Source: modified from FP7 DISCUS project

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Need for dynamic optical networking?

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- This idea has been around for some time: although the speed of dynamic path creation is a subjective concepts (a few hours.. a few days)

- What it can enable:
  - A converged SDN/Orchestration layer can provide capacity across highly dense 5G networks enabling statistical multiplexing of resources (provide wavelengths to cells dynamically)
  - Wavelengths could cross the cloud-CO / DC hard boundary and terminate in top of rack switches or even servers (bypass congestion, minimize latency)

- Some issues:
  - Power excursions still exist and can impair existing channels, besides making success of new channels uncertain
  - Models for the optical system can be further improved (e.g., use of machine learning)

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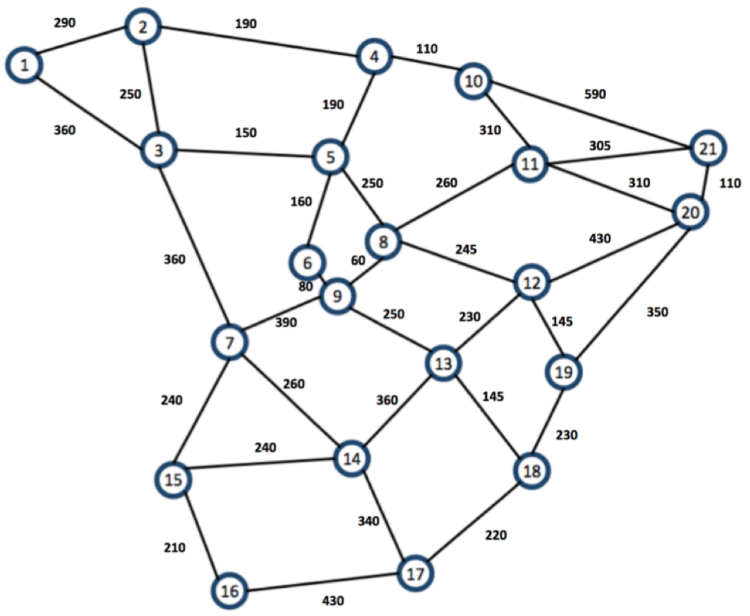
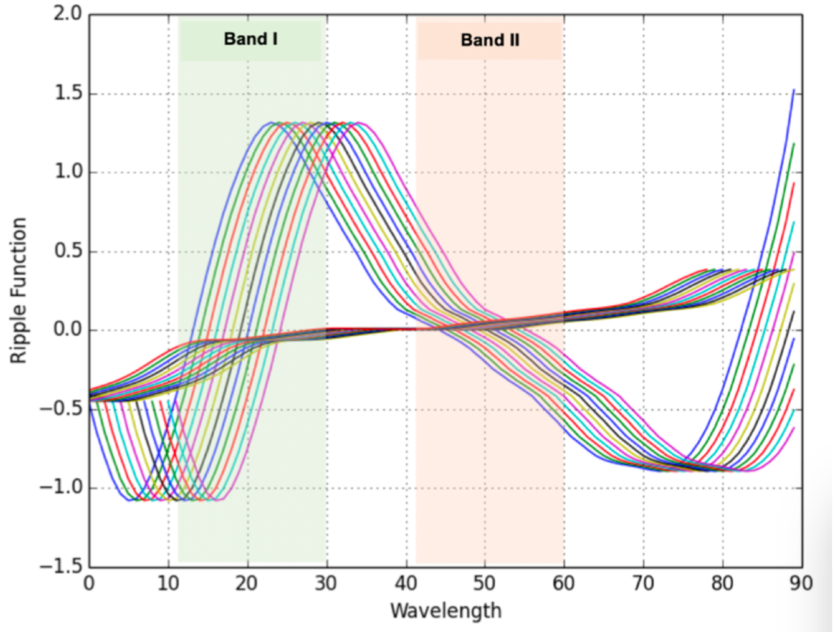
Sample study

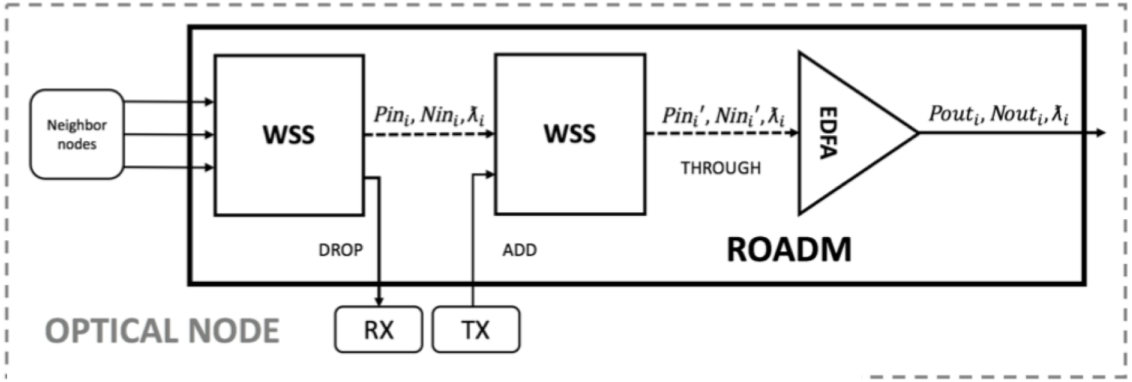
- Mininet simulation of SDN-controlled ROADM network
  - Physical layer includes OSNR, non-ideal EDFA gain flatness, SRS, …
  - Amplifier behavior not fully known: gain flatness varies depending on
    - Amplifier model
    - Individual device
    - External conditions
    - …

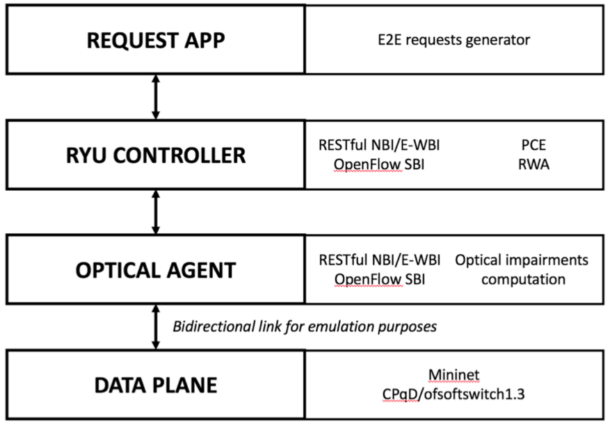
- Use of same margin across all channels is typical
  ➔ $OSNR_{est}$ + Margin > $OSNR_{th}$ (QPSK, 8QAM, 16QAM)

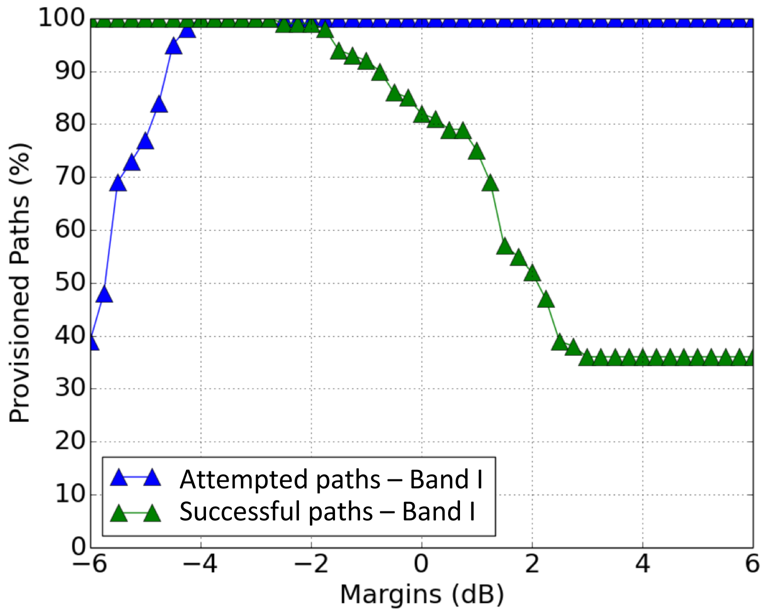




Sample study

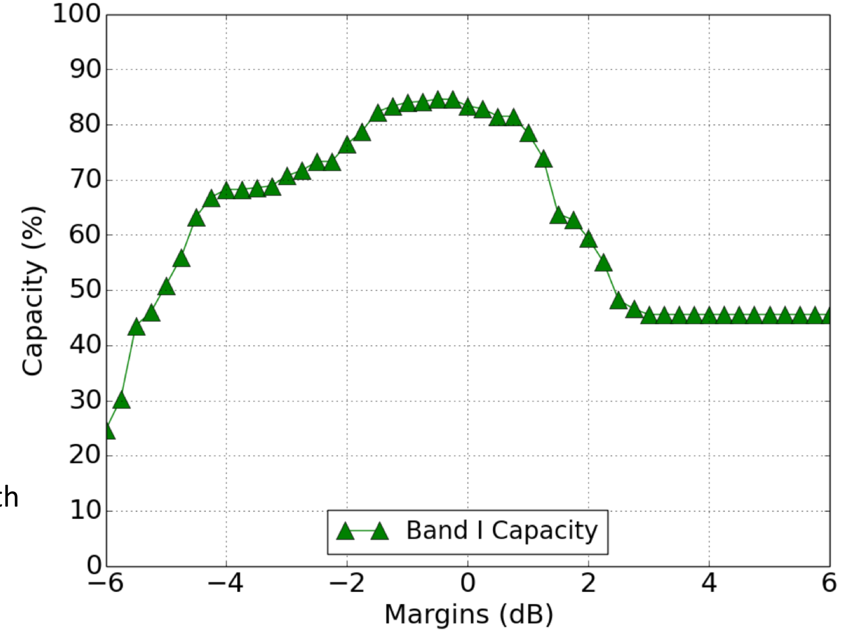






Estimation assumes flat amplifier gain

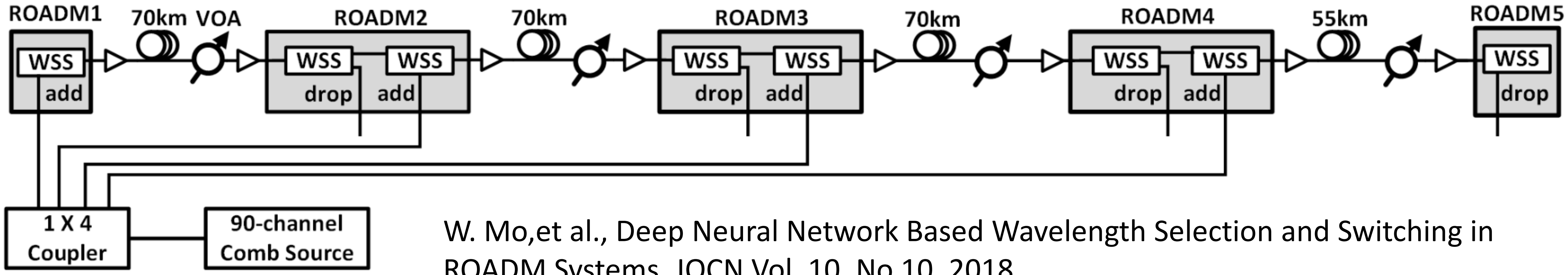
$OSNR_{est} + Margin > OSNR_{th}$



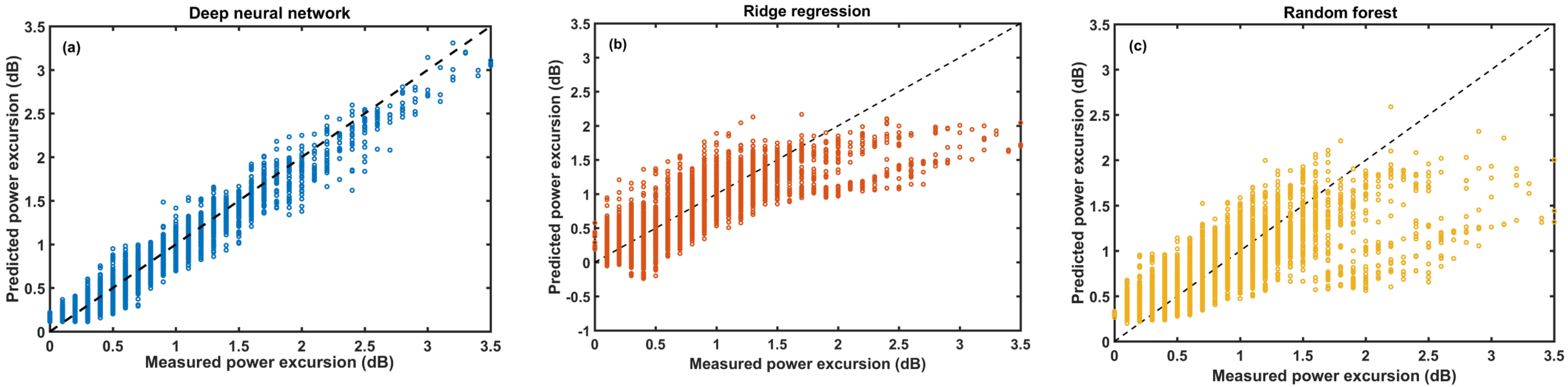
More conservative ⟷ More aggressive

X axis: how conservative are the margins

Deep Learning Shown Effective for Predicting Optical Signal Powers



W. Mo,et al., Deep Neural Network Based Wavelength Selection and Switching in ROADM Systems. JOCN Vol. 10, No 10, 2018.

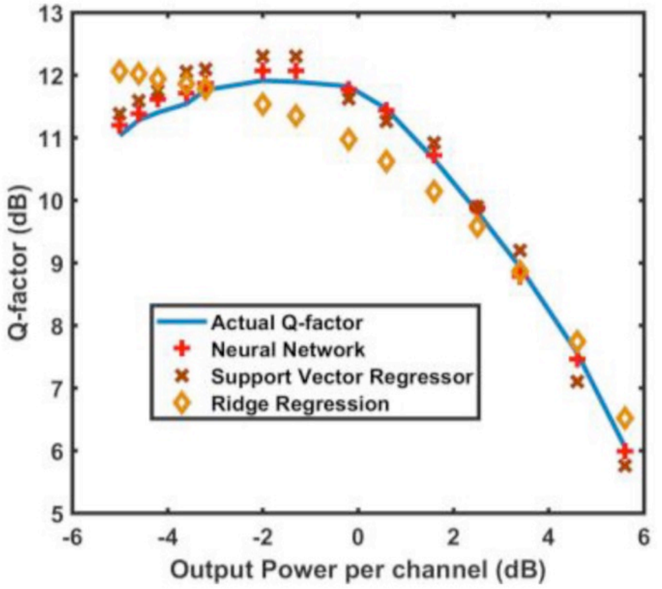


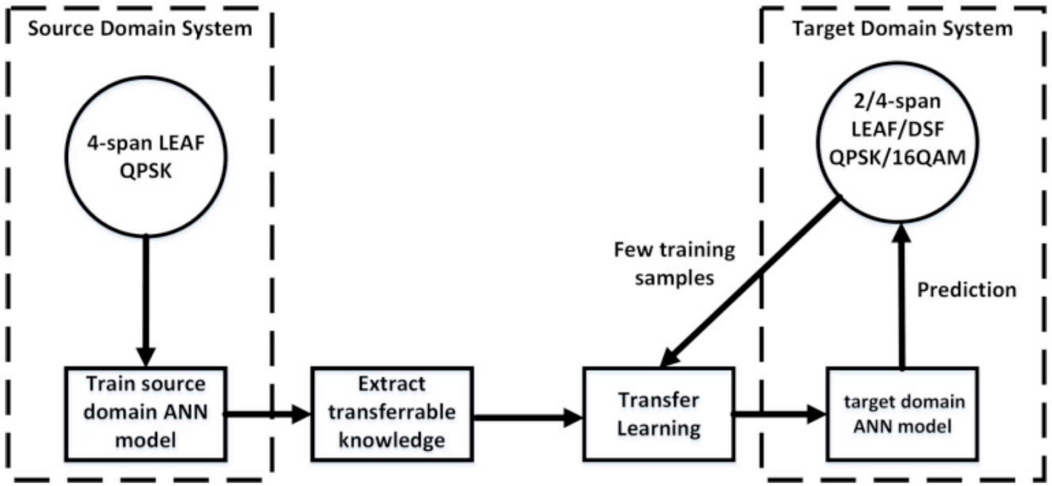
Deep learning (left) shown to accurately predict optical signal power which is main determinant of signal quality, based on the channel configuration alone.

Deep Neural Network Machine Learning for QoT based Wavelength Assignment

- Improve Quality of Transmission (QoT) estimation and wavelength assignment
- Transfer learning for real time prediction

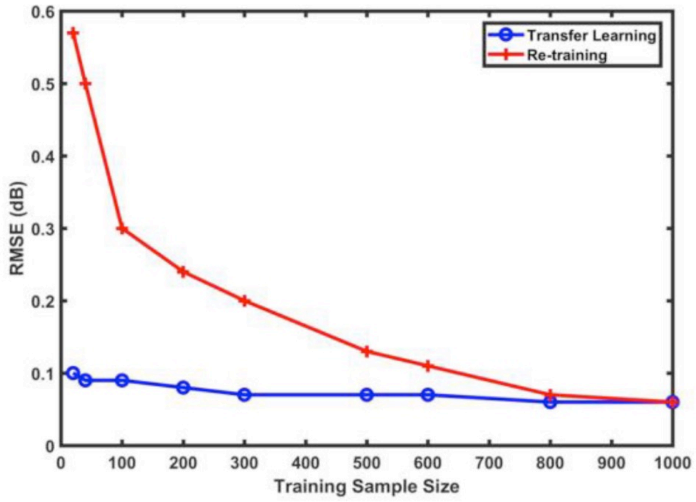
Q-Factor Prediction





Transfer Learning

4 span Leaf / 16QAM



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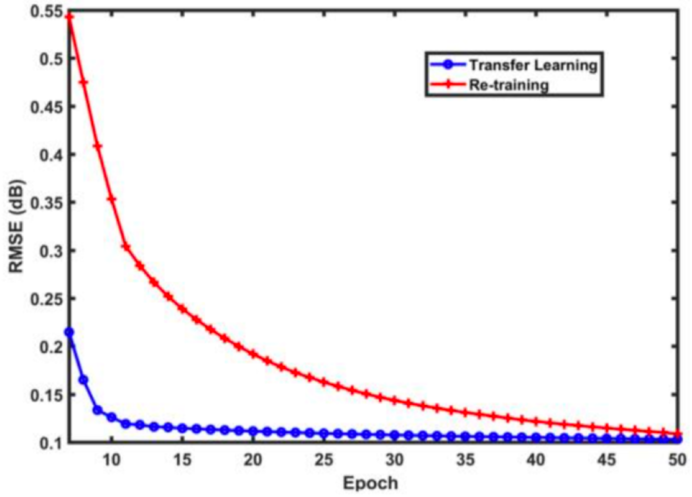


W. Mo, et. al. ANN-Based Transfer Learning for QoT Prediction in Real-Time Mixed Line-Rate Systems. Paper W4F.3, OFC 2018

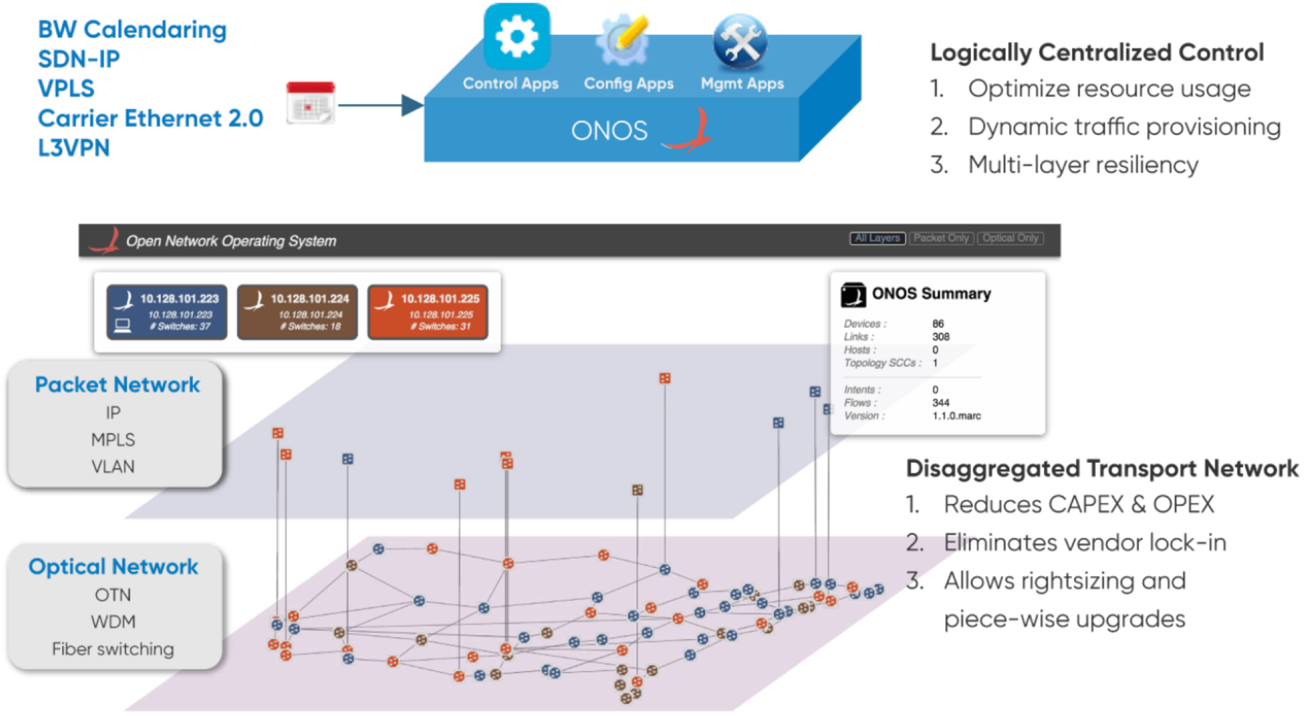
Open Disaggregated Transport Network

Pros:

- Open market of component from multiple vendors brings cost down
- No vendor lock-down, faster network upgrades
- Possibility of full integration with other control layers to achieve dynamic, fast, end-to-end optical re-configurability.

Challenges:

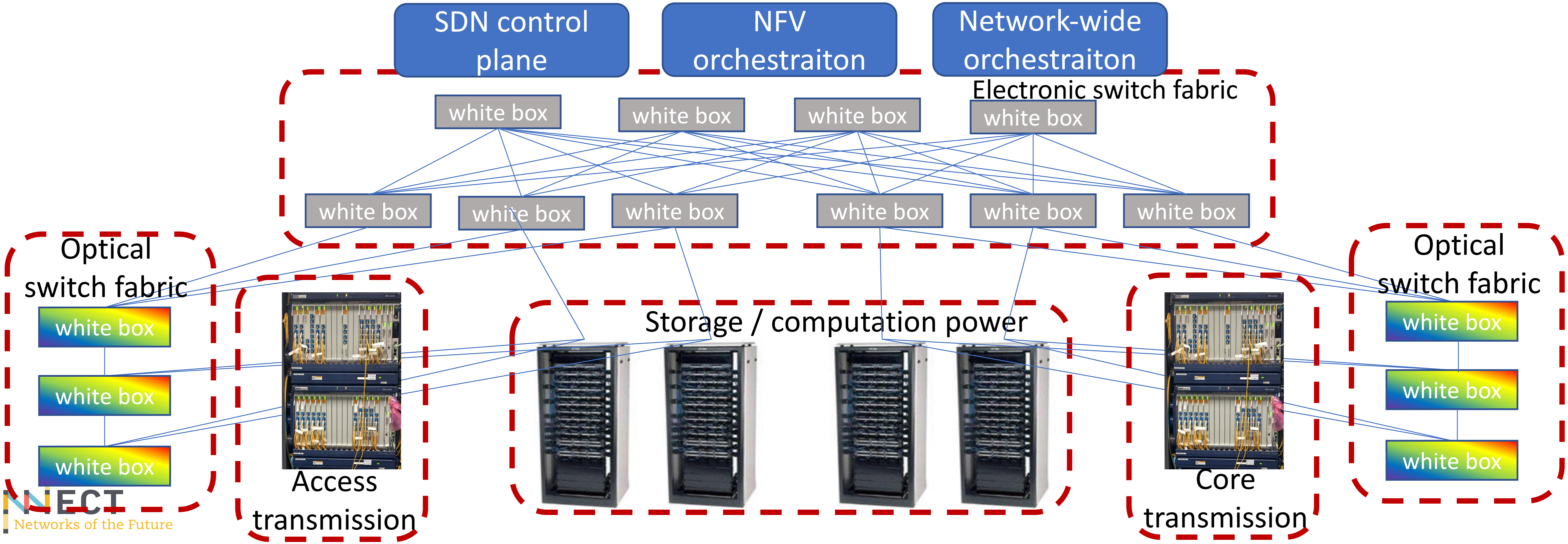
- Building an end-to-end analog system
  - How to do end-to-end system optimization with components whose behavior is not well known?
  - Avoid use of large margins
- Could this hinder research investment from transponder manufacturers?



Source: https://www.opennetworking.org

Conclusions: The fully converged view

- As central offices turn into Cloud CO, **<u>everything (network/computation node)</u>** will look more like a DC:
  - Core of servers/switches: *<u>white boxes has brought much innovation already</u>*
  - SDN/NFV/Orchestration control and management: *<u>more to come, on per-flow availability/reliability</u>*
  - Optical switching technology: *<u>much more to come</u>*
    - <u>starting from highly reconfigurable ROADMs/metro transmission …</u>
    - <u>…to progressive integration with electronic switching fabric</u>
  - Edge of few types of (optical) transmission technology: *<u>more to come in photonic integration technology</u>*



Thank you for your attention!

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