A World Leading SFI Research Centre

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CONNECT
Centre for Future Networks

Harnessing AI in Optical and Wireless Networks

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CONNECT and IPIC research centers

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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 sfi For what's next

Presentation summary

- Where it all started: Open Networks
- Where we stand
- Experimental research enabling high-impact
- From ML models to Digital Twin of Optical Network
- Radio applications

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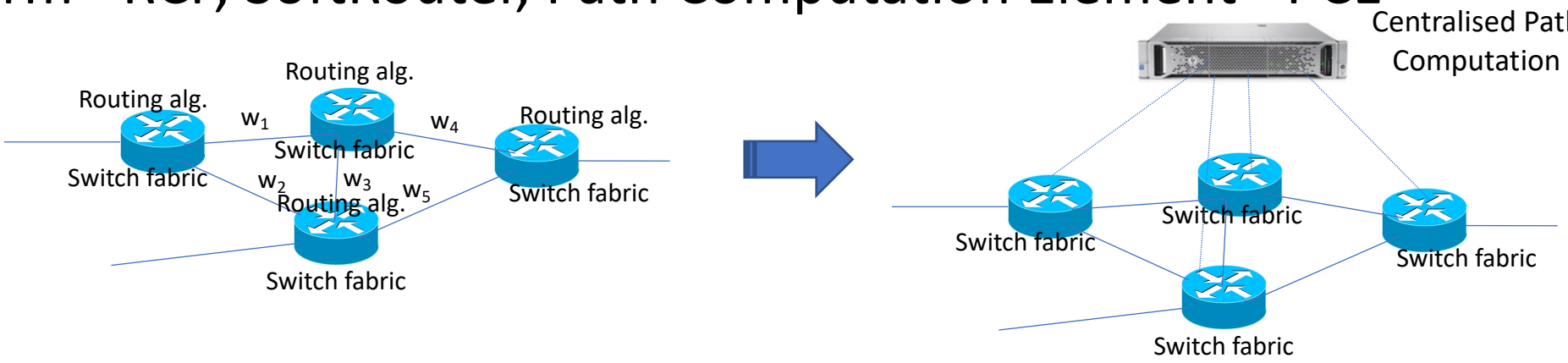
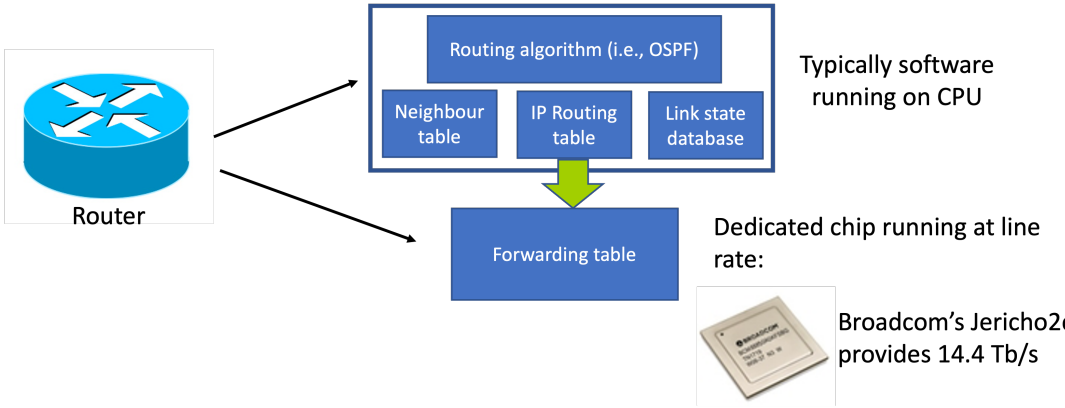
OpenFlow: Separation of control and data planes

- It actually started earlier, at the beginning of the 2000s, with work like IETF Forwarding and Control Element Separation (ForCES), Routing Control Platform - RCP, SoftRouter, Path Computation Element - PCE



- But OpenFlow managed to have it implemented in hardware switches
  ➔ Use of merchant silicon



The Network Virtualisation and Open Networking Trend in RAN

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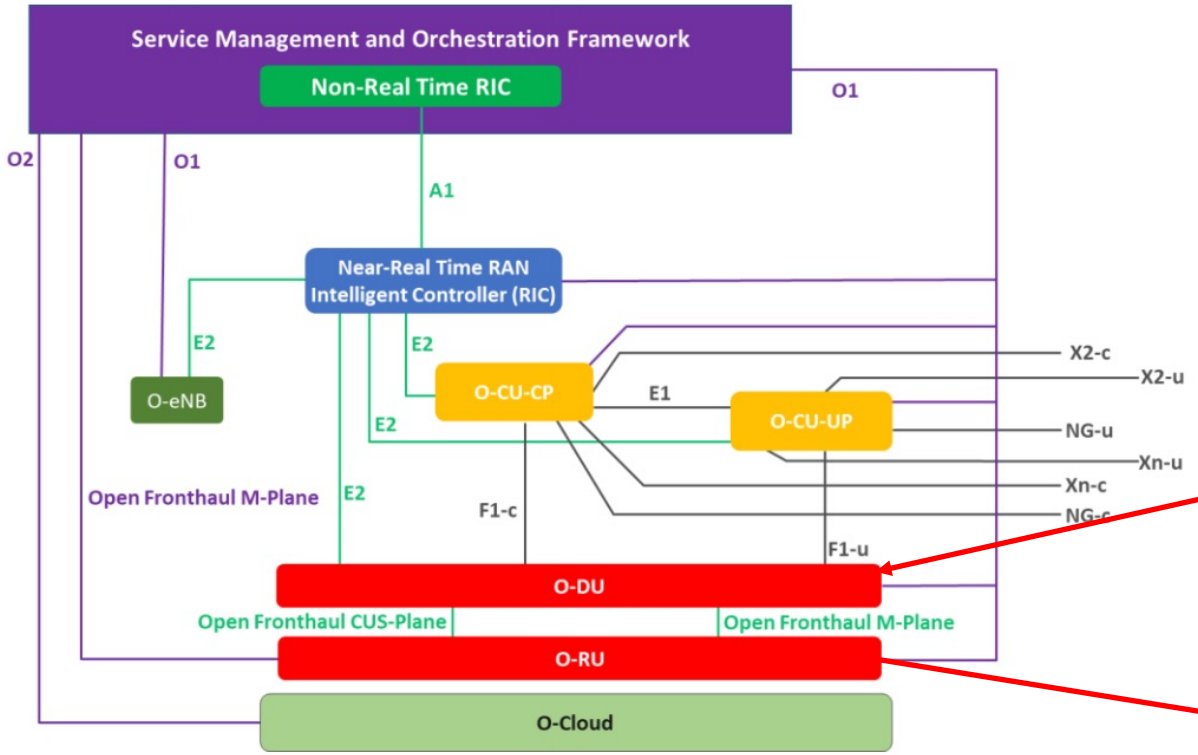
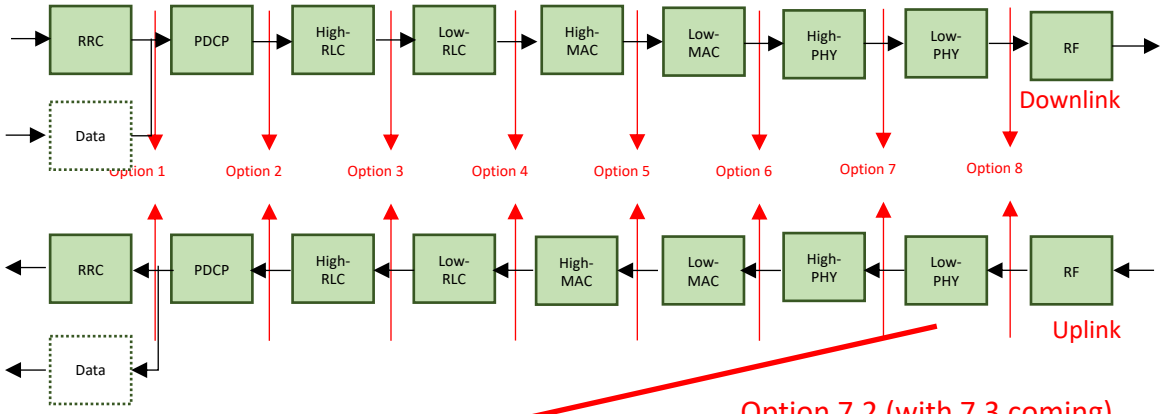
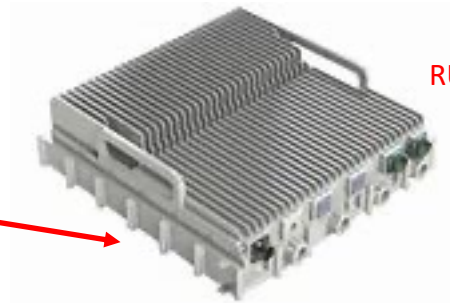
- Open networking in mobile base stations

OpenRAN





Option 7.2 (with 7.3 coming)



RU

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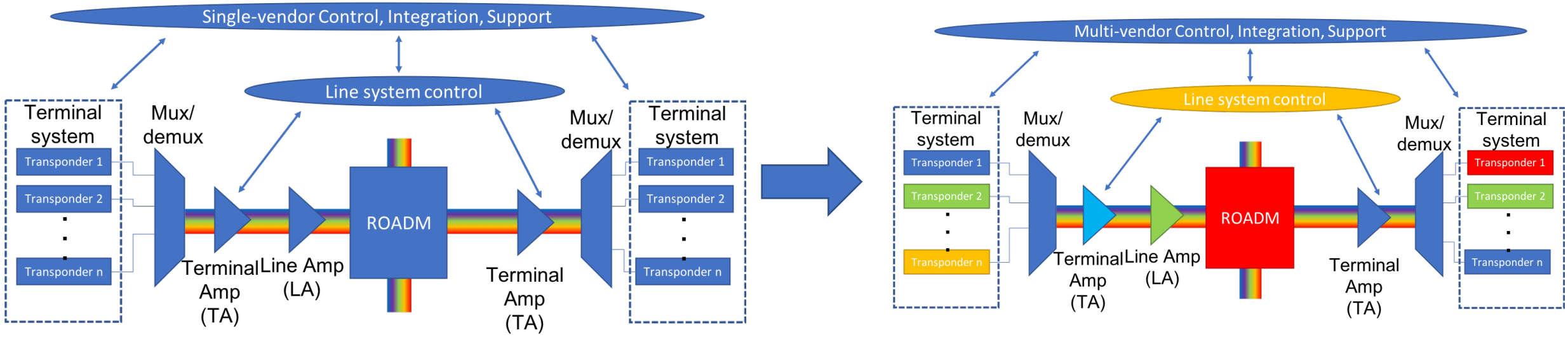
Opening the optical layer

- This is a difficult one!
- Optical transmission is analogue, meaning that different devices have different behavior (unlike digital)
- Nonetheless now there are SDN-controlled ”whitebox” devices, like ROADMs, amplifiers and transponders..



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Open Ireland: Ireland's Open Networking Testbed

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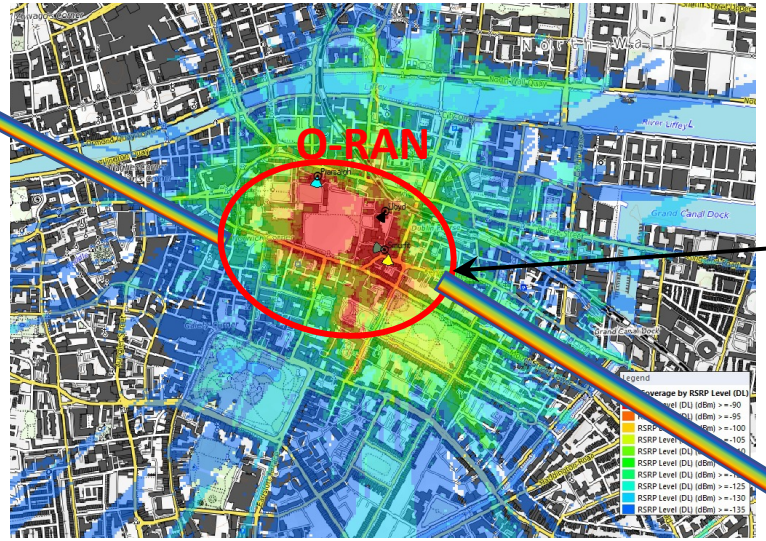
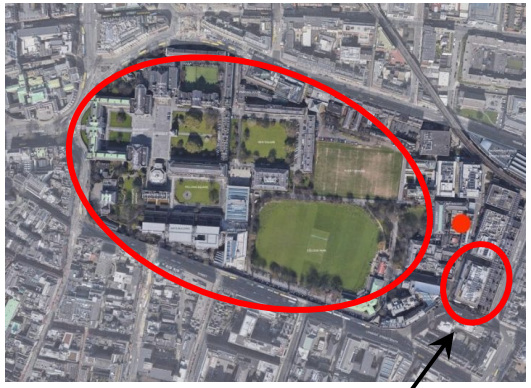
www.openireland.eu

Reconfigurable and **Lego-like** topology reconfiguration with following blocks:

- 1,700km fibre, **SDN ROADMs**, **amplifiers and coherent Tx** (Cassini), virtual PON, OSA, etc.
- **5G O-RAN** (outdoor and indoor); **OpenSource 5G** (OAI and SRS)
- **Edge cloud**, L2 switching, P4 programmability



Based in Trinity College campus



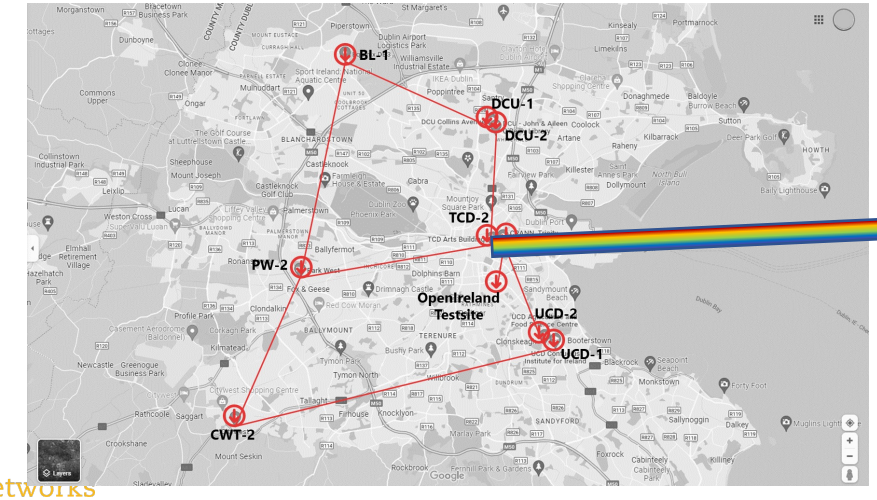
O-RAN

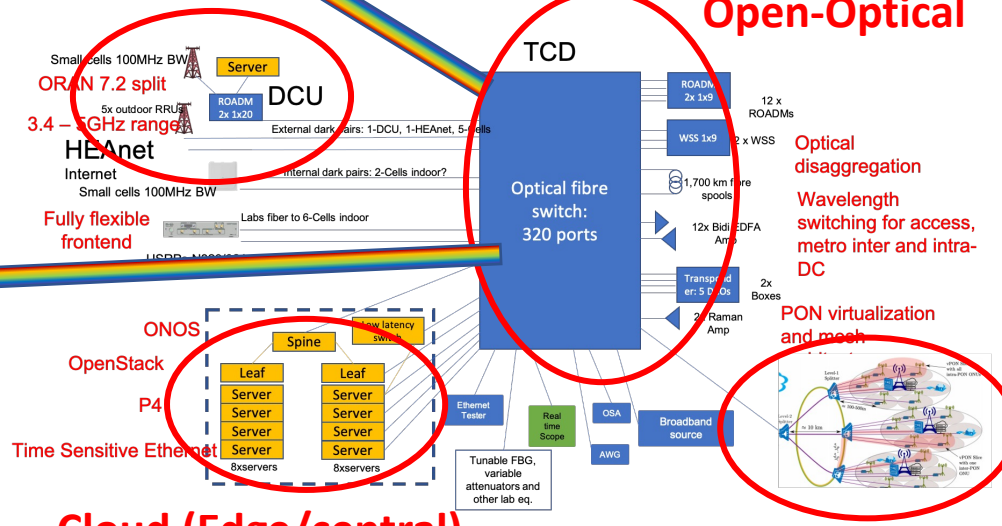
CONNECT research centre building

SDR

Open-Optical

Dark Fibre to HEAnet Dublin metro network





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ComReg 100MHz spectrum license

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Existing 3.6 GHz for 5G | **Upper 4 GHz band for 5G**

Region		A-Lot		3560 - 3620		B-Lots		
Borders Midlands & West South West East South East Dublin City and Suburbs Cork City and Suburbs Galway City and Suburbs Limerick City and Suburbs Waterford City and Suburbs	Guard Band	Airspan	State Services	Vodafone	Imagine Airspan	Meteor	Three	CONNECT
Frequency Range (MHz)		3410 - 3435	3410 - 3475	3475 - 3580	3580 - 3615	3615 - 3700	3700 - 3800	3850 - 3950

Upper N77 band: 3.8 – 4.2 GHZ

- 5G spectrum enables experimentation with commercial devices (smartphones and future AR, smart cities, etc)
- Use AI to solve complex network interference optimization problems based on real data
- Put together interesting 5G demos, such as smart intersection…

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Worldwide reach… and further plans

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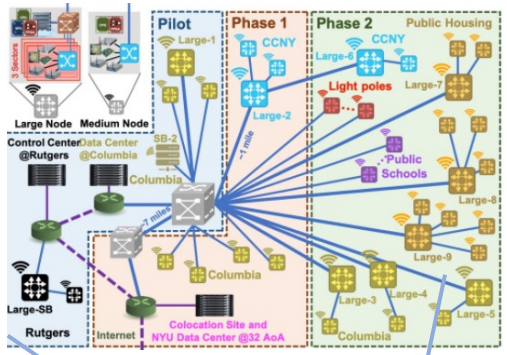
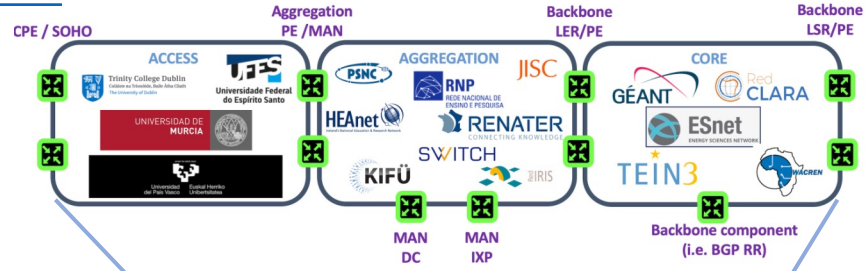
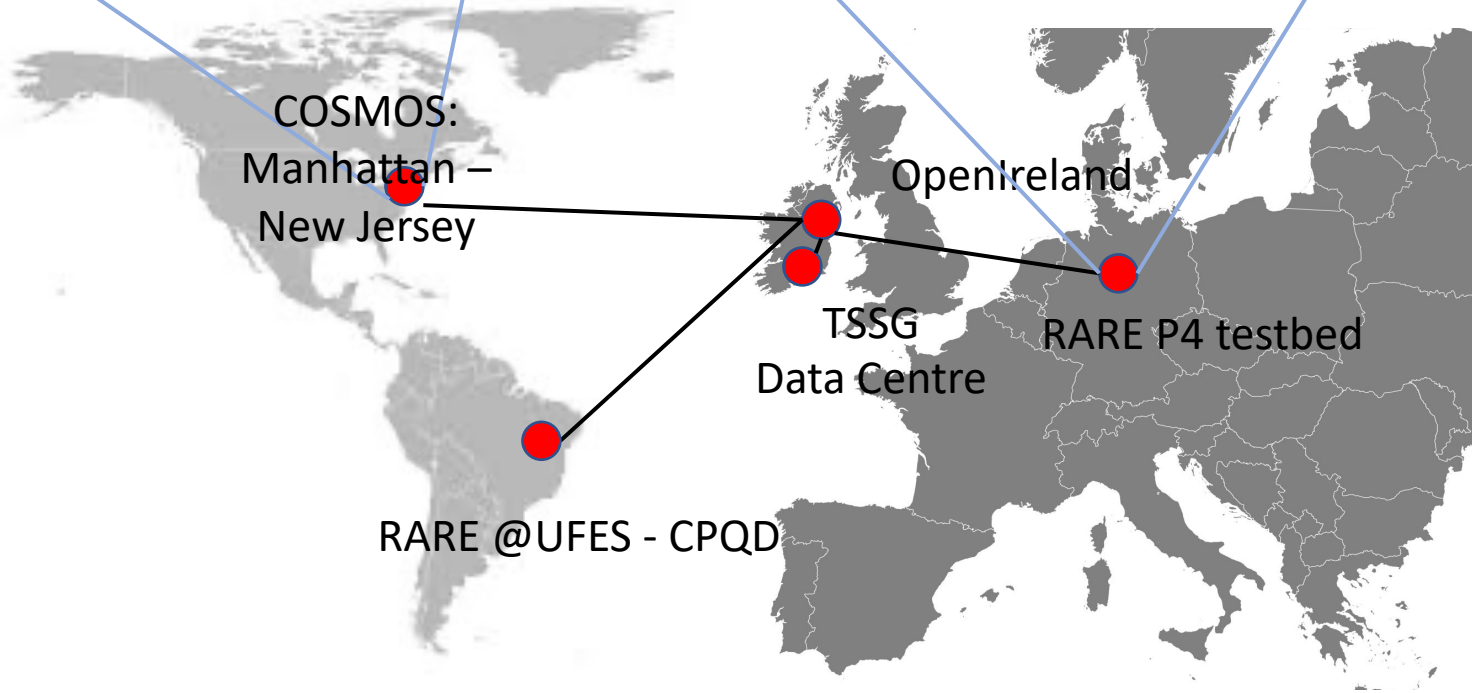
https://wiki.cosmos-lab.org/wiki



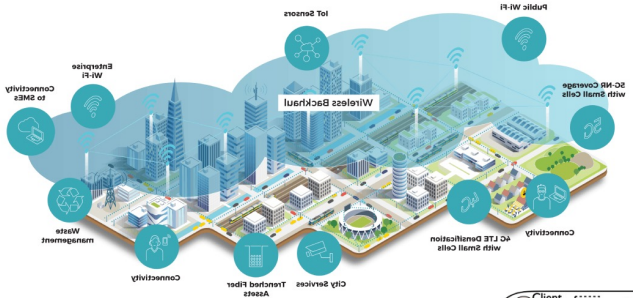




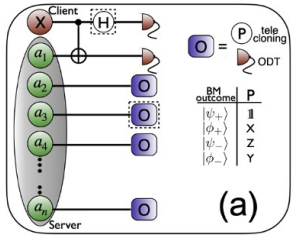
Foundation testbed in CONNECT2
Starting point for further exploration:

⇒ ***mmWave and THz experimentation***

⇒ ***Connected City Infrastructure***



⇒ ***Quantum Internet***



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Why is this important?

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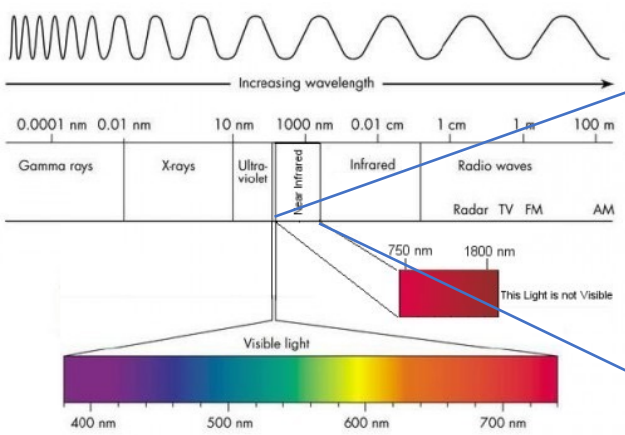
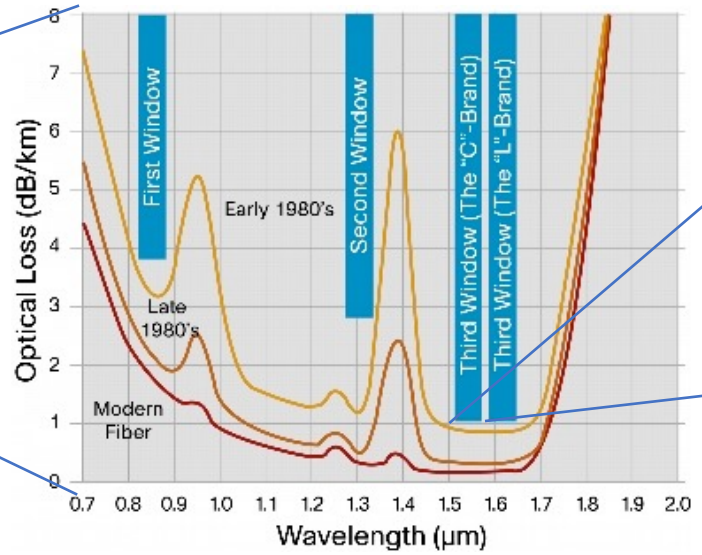
- For operators it's about competition, meaning:
  - Lower cost and better features
  - Avoid vendor lockdown: ability to change and mix and match

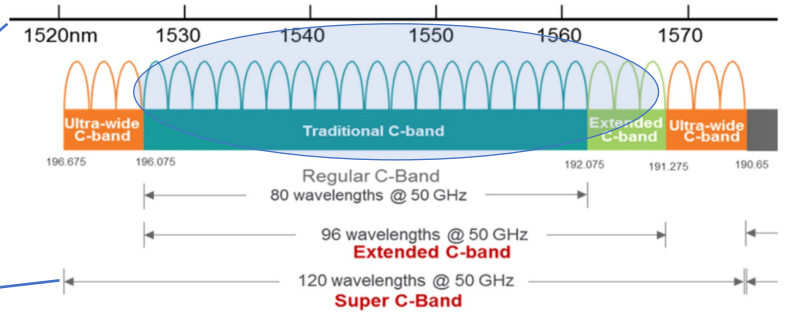
- But we're not operators, so why?
  - Because we can now do what only vendors (and operators) could do before.

- And the biggest focus is by far in the control plane (we're not competing with silicon vendors!)
  - Use of intelligent decision making, which in open network has become ever more important (because opening the system brings in more uncertainty of component behavior, which can potentially reduce performance)

Optical Spectrum as a Services (OSaaS)







96 * 200Gb/s = up to 19.2Tb/s

- It makes sense to only lease a small bit of the 4,800 GHz available
- E.g., 400 GHz lease is a target for today: 0.8 – 3.2 Tb/s

HEAnet interested is OSaaS

Testing ADVA new flexible equipment

ADVA interest in new research on this field

Use OpenIreland for experiment

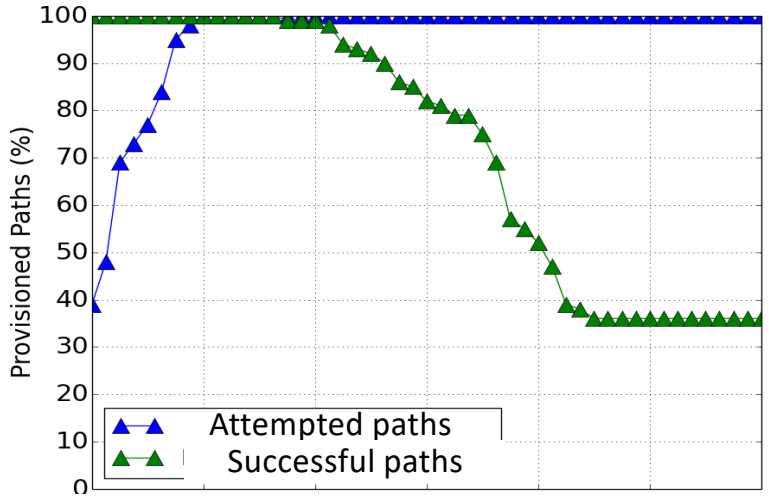
Future extension to Europe-wide links (GÉANT)

It’s all about margins

You are close to the cliff edge:

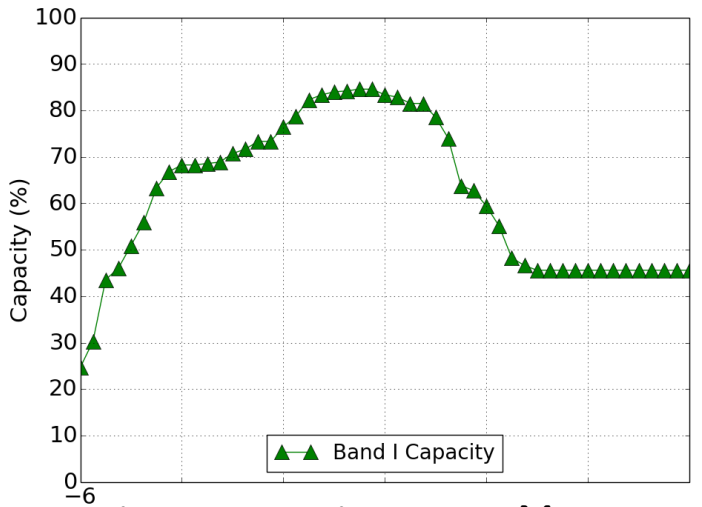
- The closer you get the better (the more efficient you are)
- How safe is it to get closer to the edge, when you can’t see it clearly?

Margin = safety distance (signal to noise ratio) you decide to keep, not being sure where you stand with respect to the edge



More conservative Margins More aggressive

Network capacity



More conservative Margins More aggressive

10 dB difference makes the difference between a 100G and 400G channel

Experimentation on Optical Spectrum as a Service (OSaaS)

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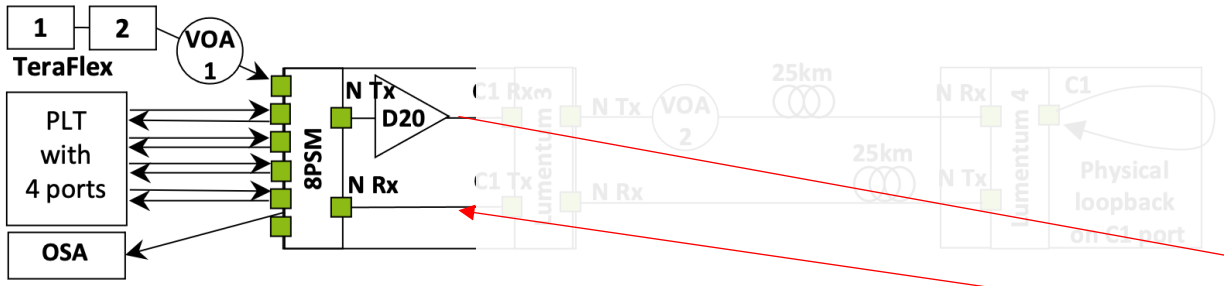
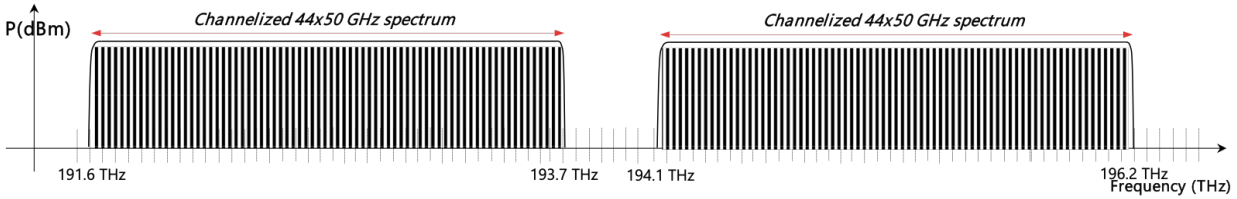
OpenIreland

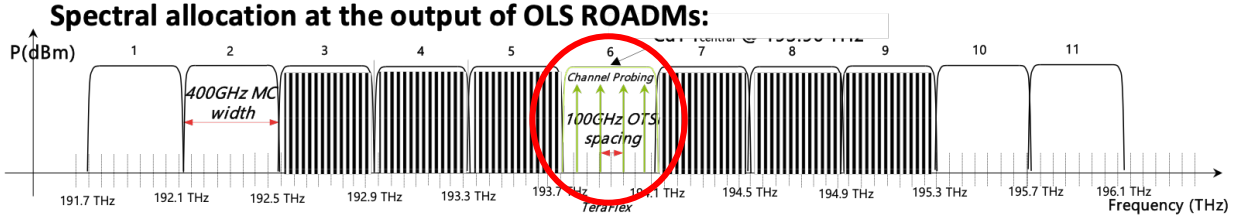
Channel loading, Lumentum 1 and 2



Spectral allocation at the output of channel loading ROADMs:

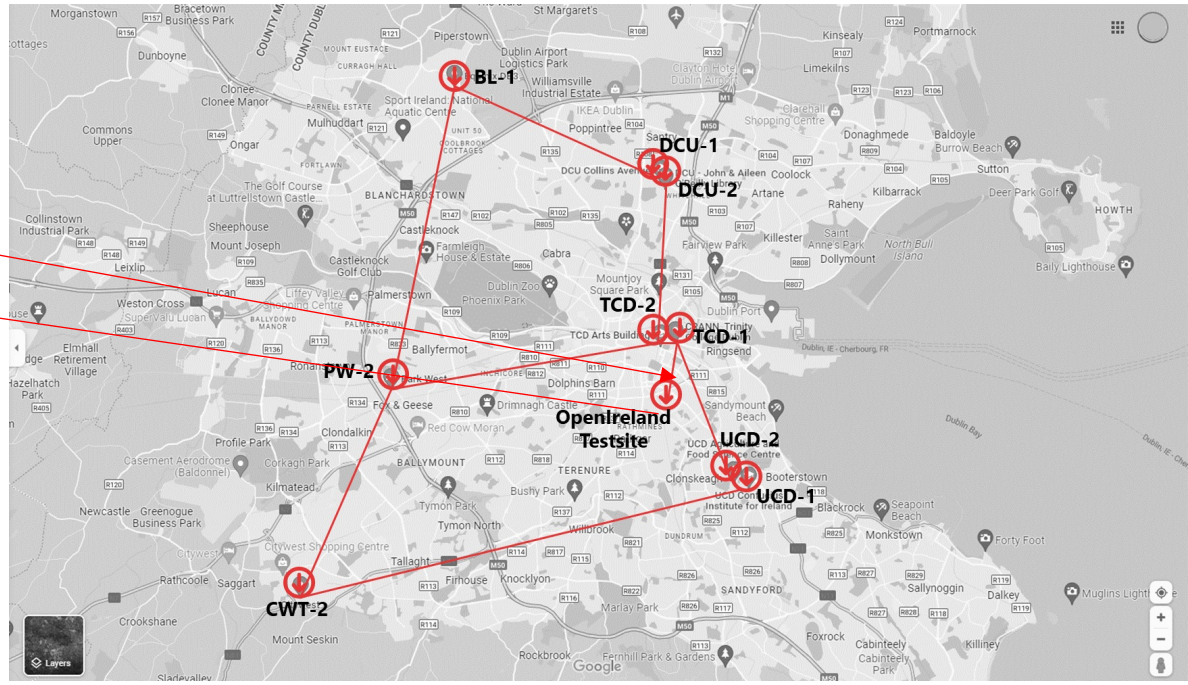


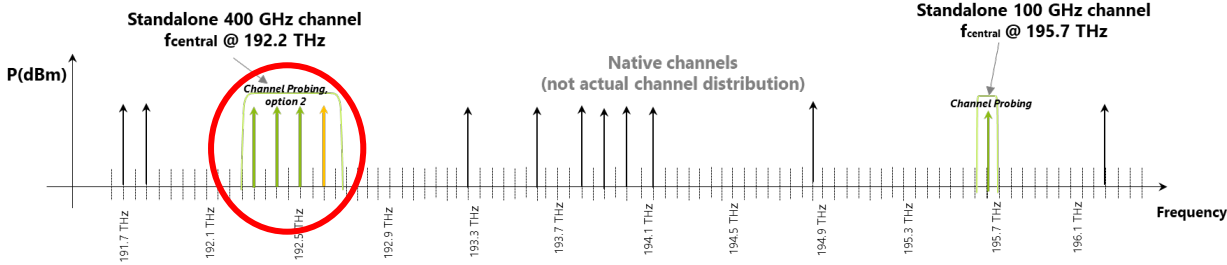
Spectral allocation at the output of OLS ROADMs:



- Measuring discrepancy between GSNR measured on single transceiver and GSNR in OSaaS environment
- Measurement for different baud rate and modulation formats

HEAnet
Ireland's National Education & Research Network

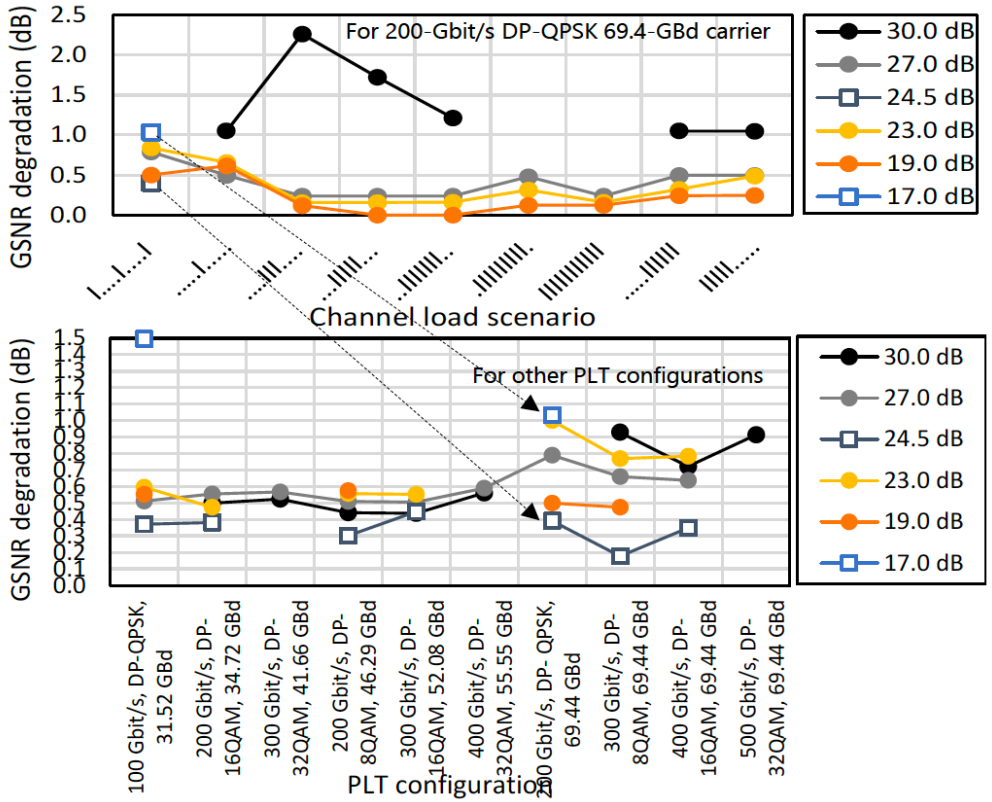




OSaaS Results – defining the required operator margins

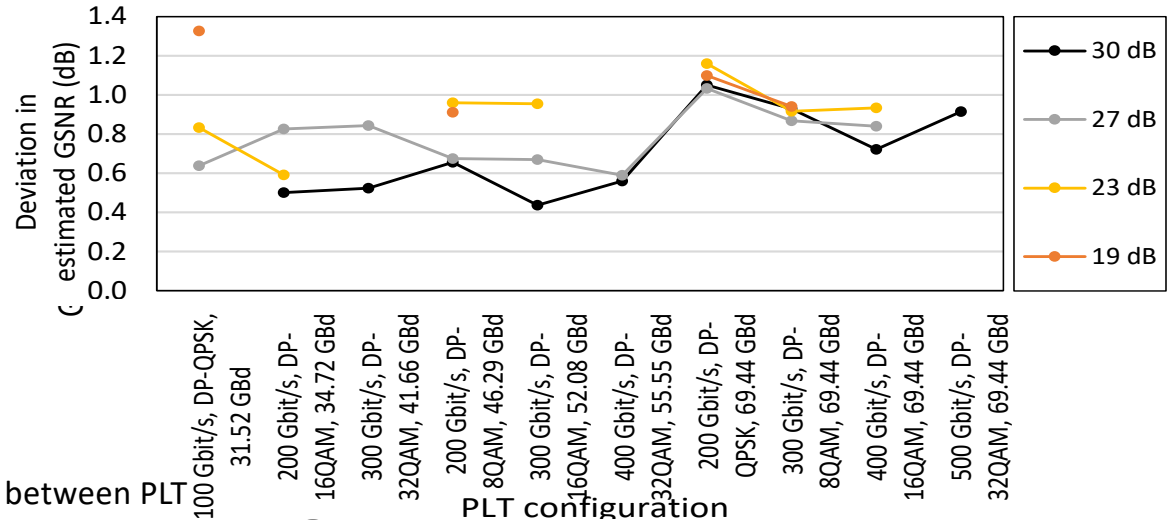
Degradation from direct neighboring channels

HEAnet results represented in 17 dB and 24.5 dB

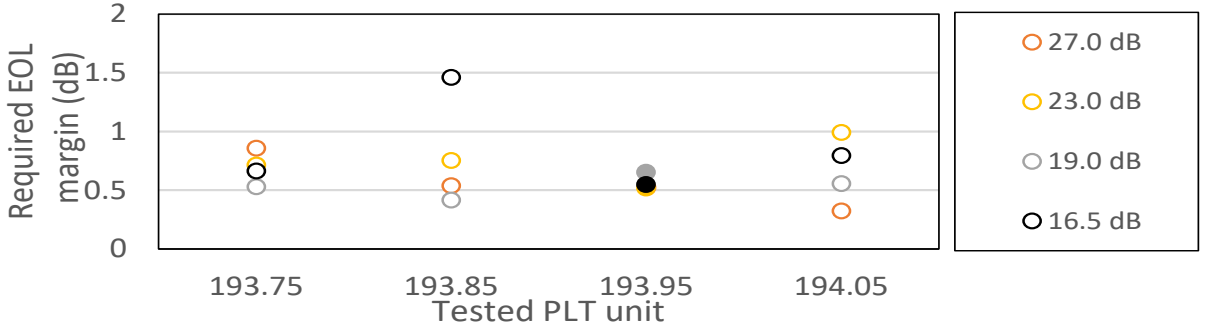


- Worst measured discrepancy is 1.5 dB (Margin to be used)
- OpenIreland and HEAnet use cases behave similarly

Degradation from end of life channel load



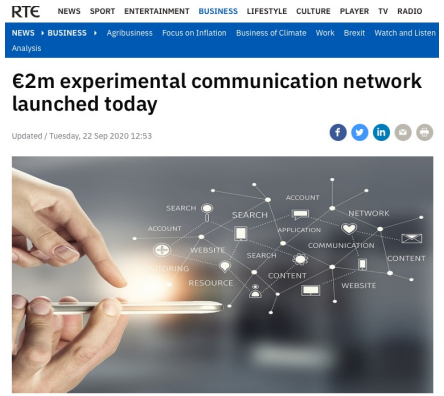
Variation between PLT units



- Worst measured discrepancy is 1.4 dB additional margin to be considered for end of life (i.e., that more and more channels will be added throughout the service lifetime).

Impact is recognized !

- IBEC award to Open Ireland for Academic achievement of the year
- TCD Innovation awards
- Featured multiple times in Irish Times, RTE and other technology venues



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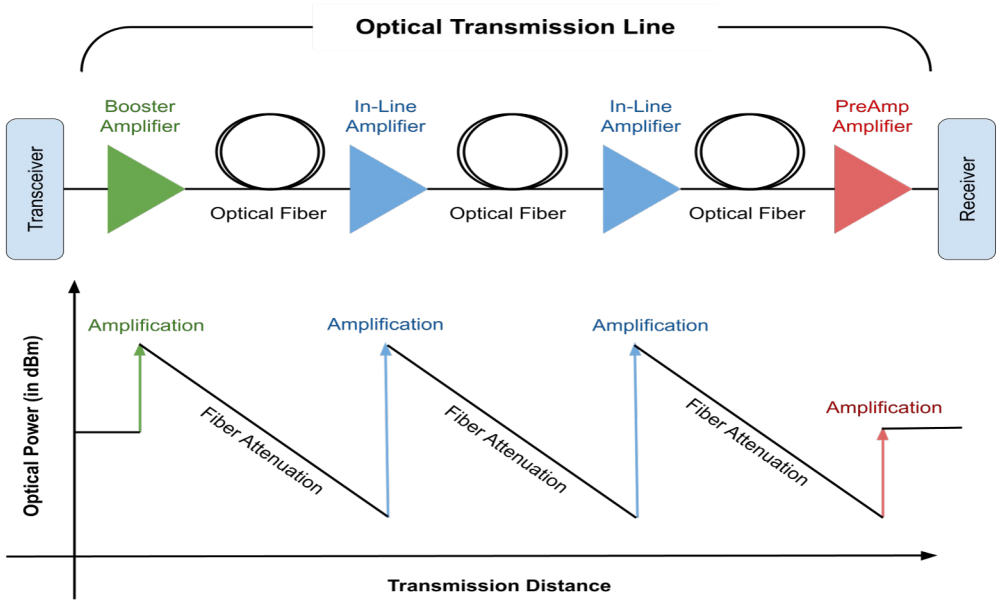
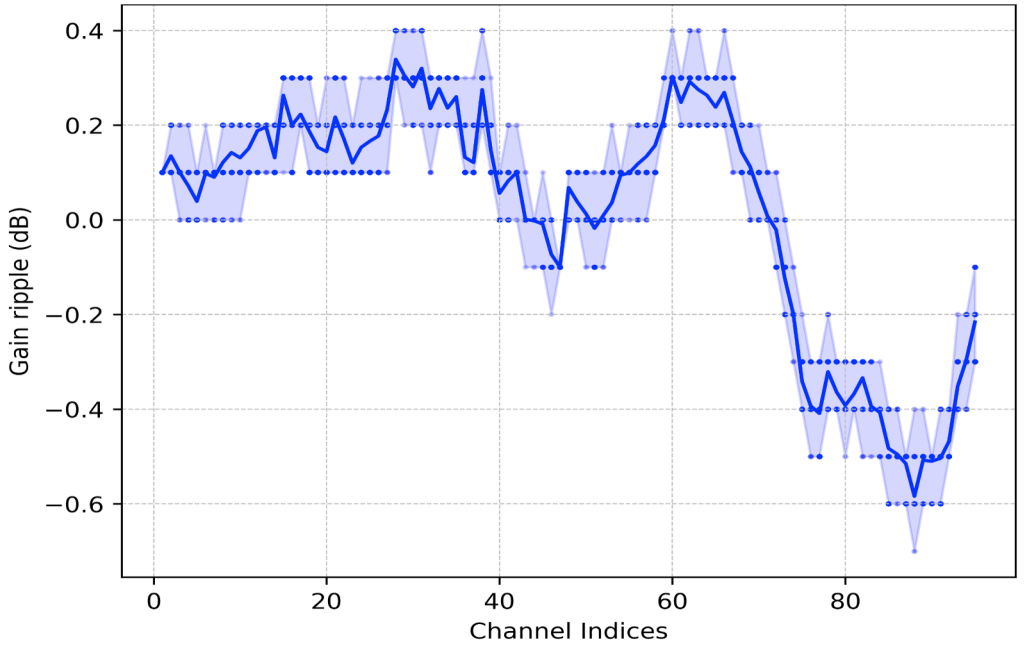
Transfer learning for EDFA modeling

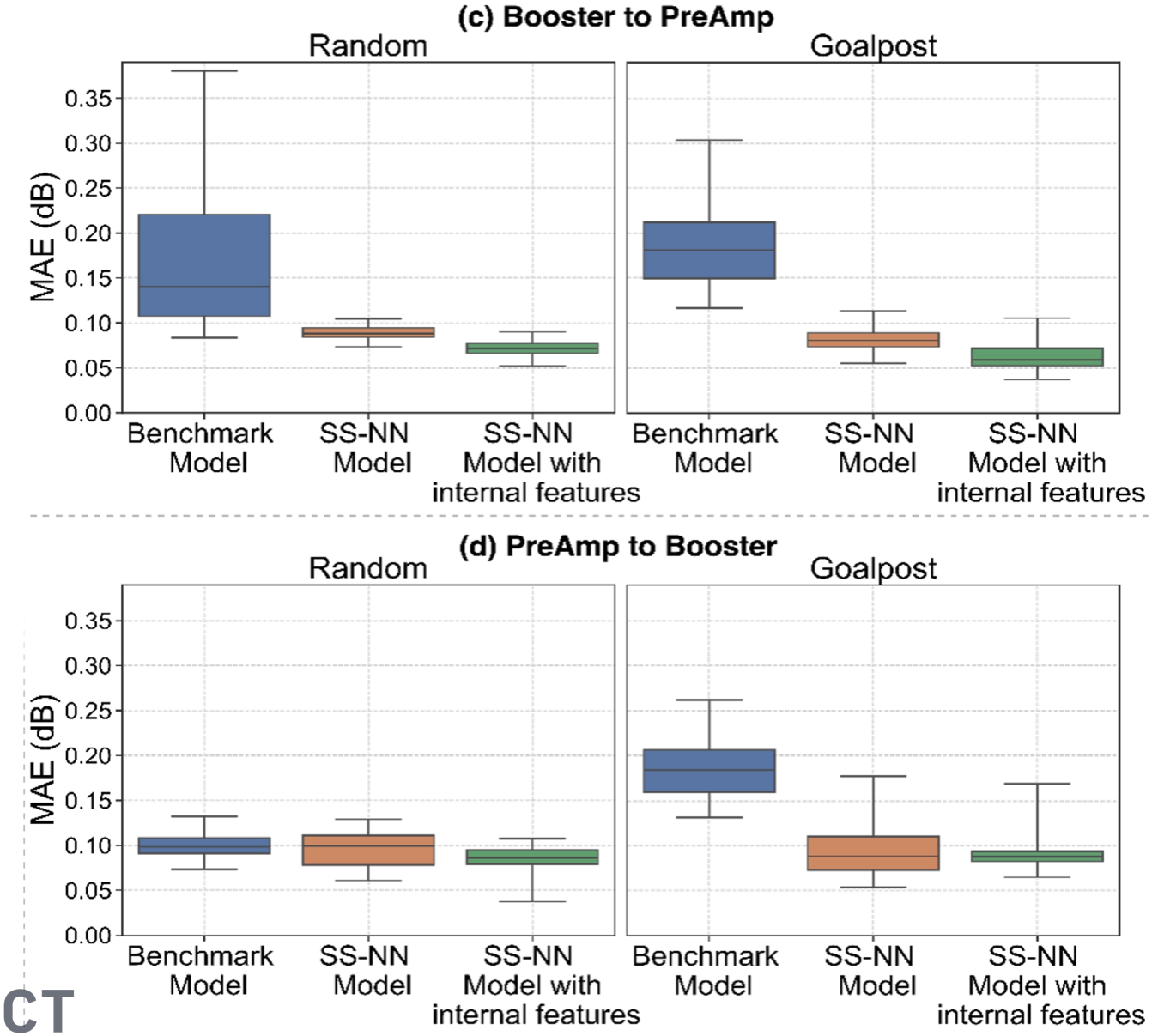




- Different WDM channels undergo different amplification and noise figure, causing:
  - Different power levels
  - Different noise levels
  - QoT Degradation when adding and dropping signals dynamically

- Spectral shape dependency, Vendor Inconsistencies and Fabrication errors make modeling the gain-function a highly non-convex problem.

Results - TL to Cross EDFA Type



- MAE within 0.11 dB for B→P transfer
- MAE within 0.17 dB for P→B transfers

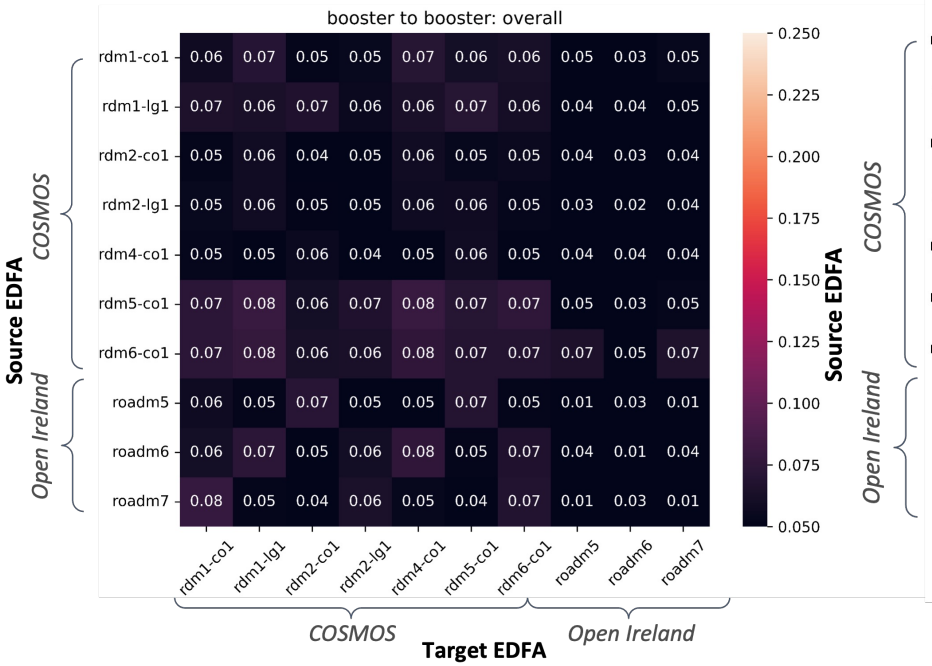
[1] Z. Wang, et al. Transfer Learning-based ROADM EDFA Wavelength Dependent Gain Prediction Using Minimized Data Collection. OFC 23, paper Th2A.1.

** Boxplot distribution of MAE across 22 EDFAs of (a) Booster to PreAmp TL and (b) PreAmp to Booster TL. The boxes denote the interquartile range, and the whiskers denote the min/max.*

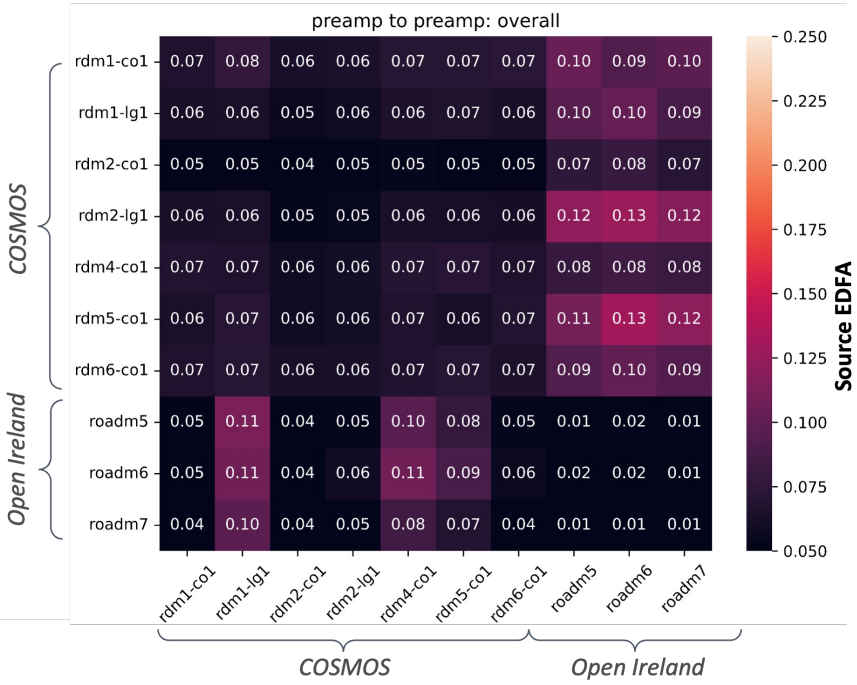
Transfer learning

- Learn from a base model, then use additional data points from a target device to transfer the model

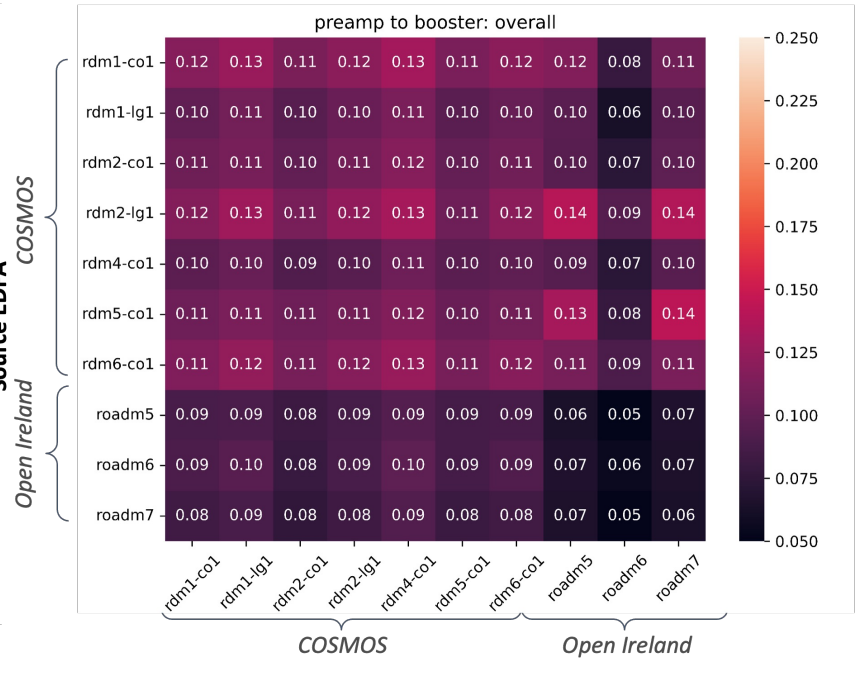
Booster amp to booster amp



Preamp to Preamp



Preamp to Booster



One-shot transfer learning

	MAE
Before Transfer	0.8308
1 Obs	0.1341
2 Obs	0.0908
3 Obs	0.0802

Digital Twin on OpenIreland and Mininet-Optical

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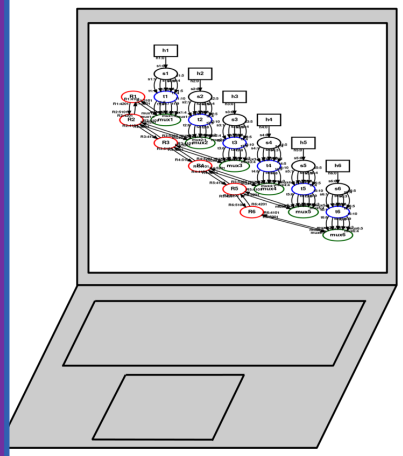
Digital Twin AI

- Routing
- Lightpath Provisioning
- Monitoring
- Device Configuration

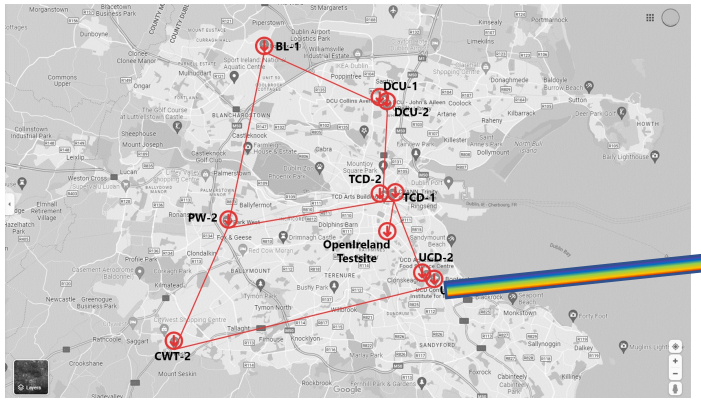
Southbound Interface

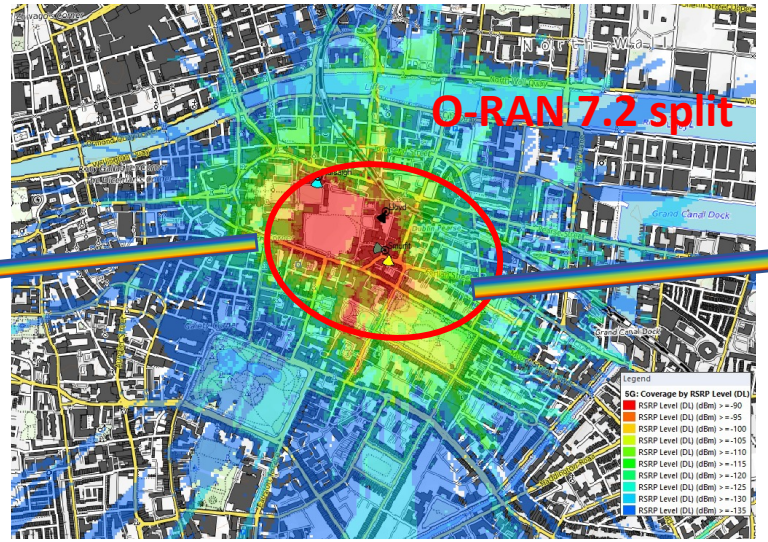
NETCONF Agent



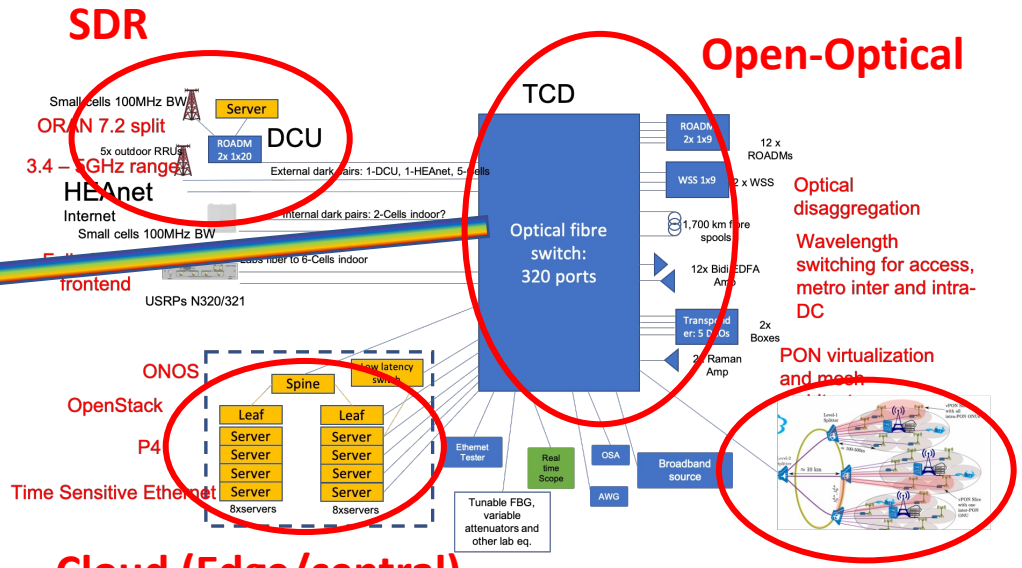
Virtual network in Mininet-Optical

NETCONF Agent





SDR



Open-Optical

Optical disaggregation

Wavelength switching for access, metro inter and intra-DC

PON virtualization and mesh

Cloud (Edge/central)

Virtual PON

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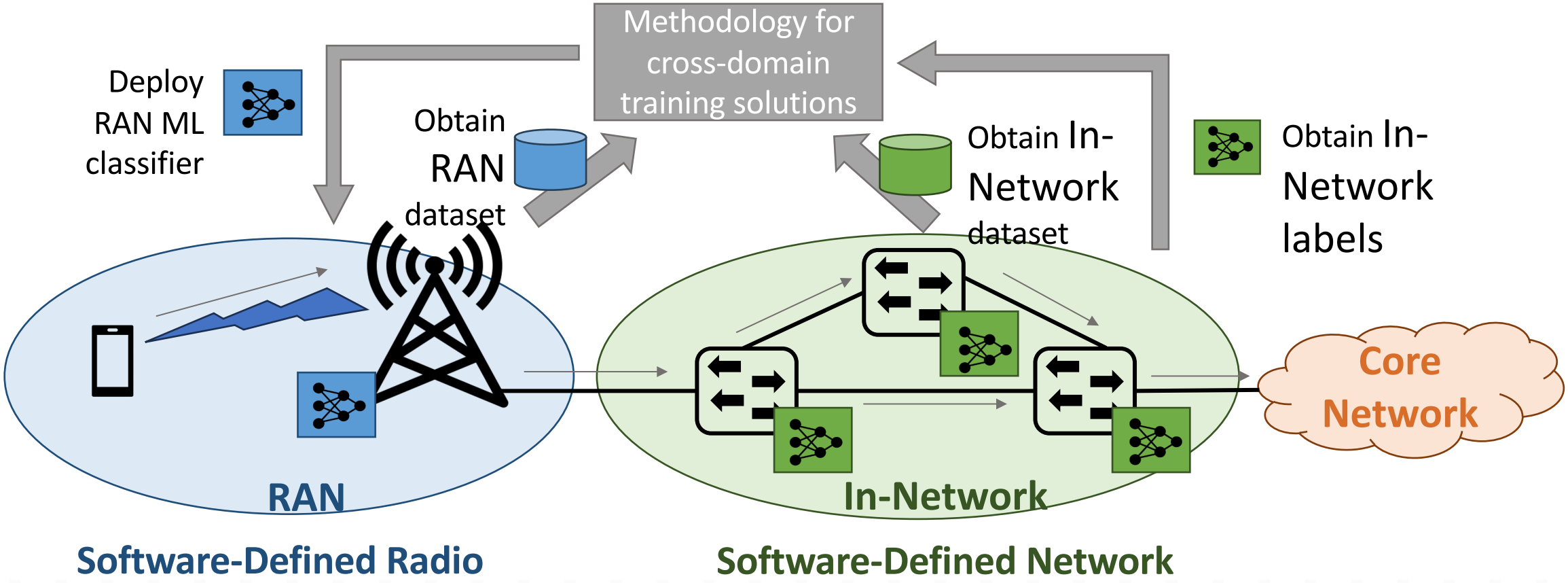
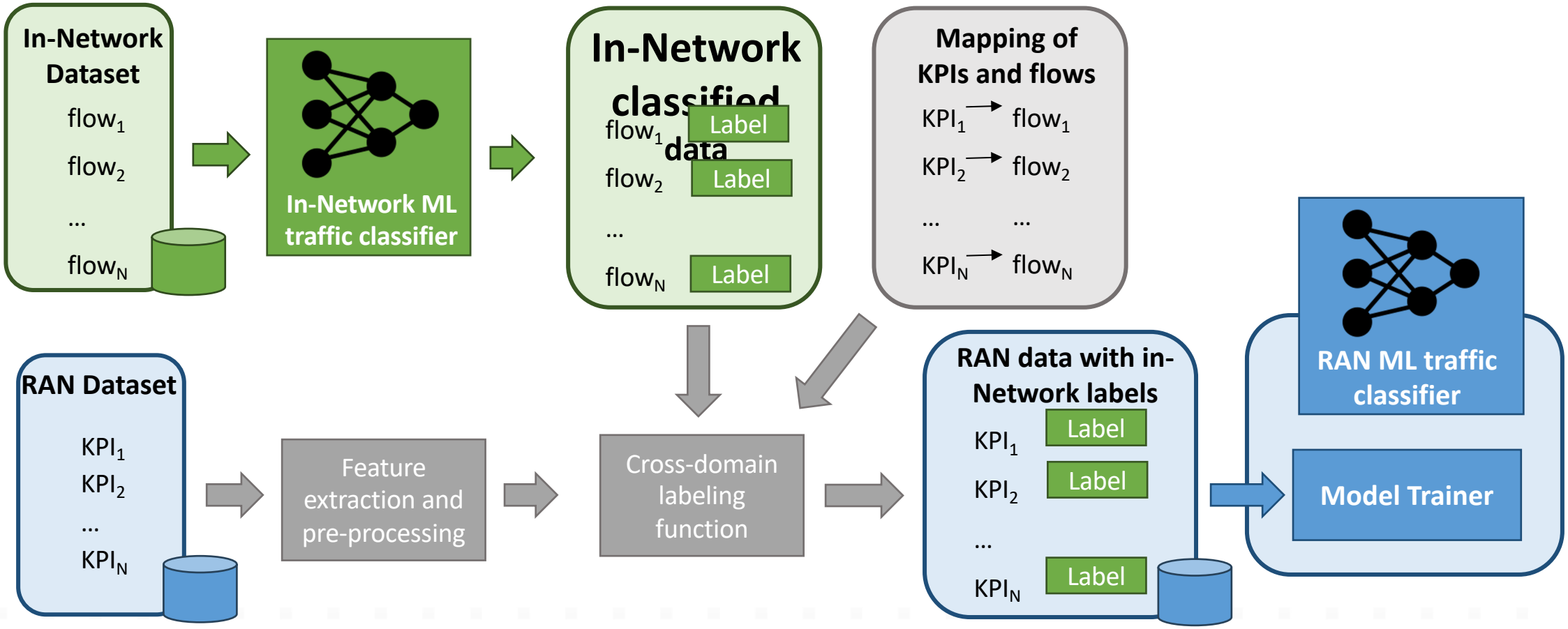
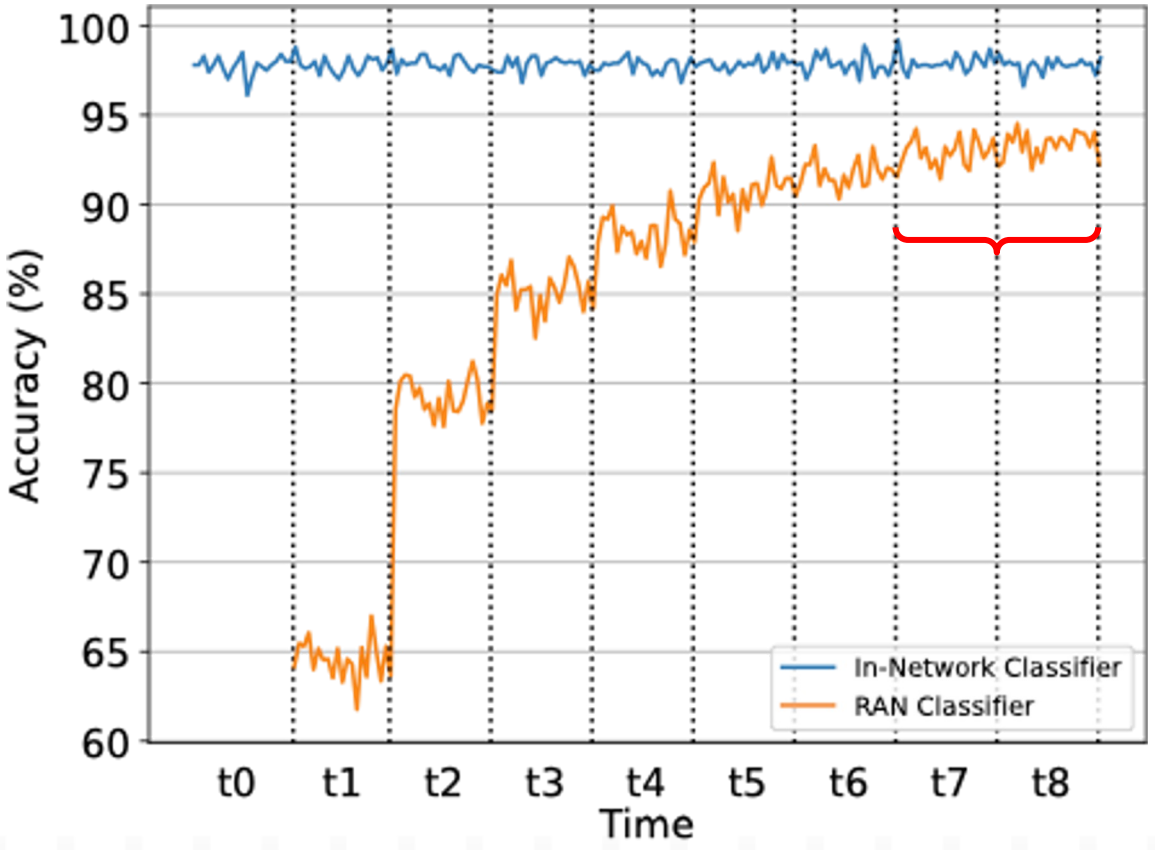
Cross-Domain AI Framework



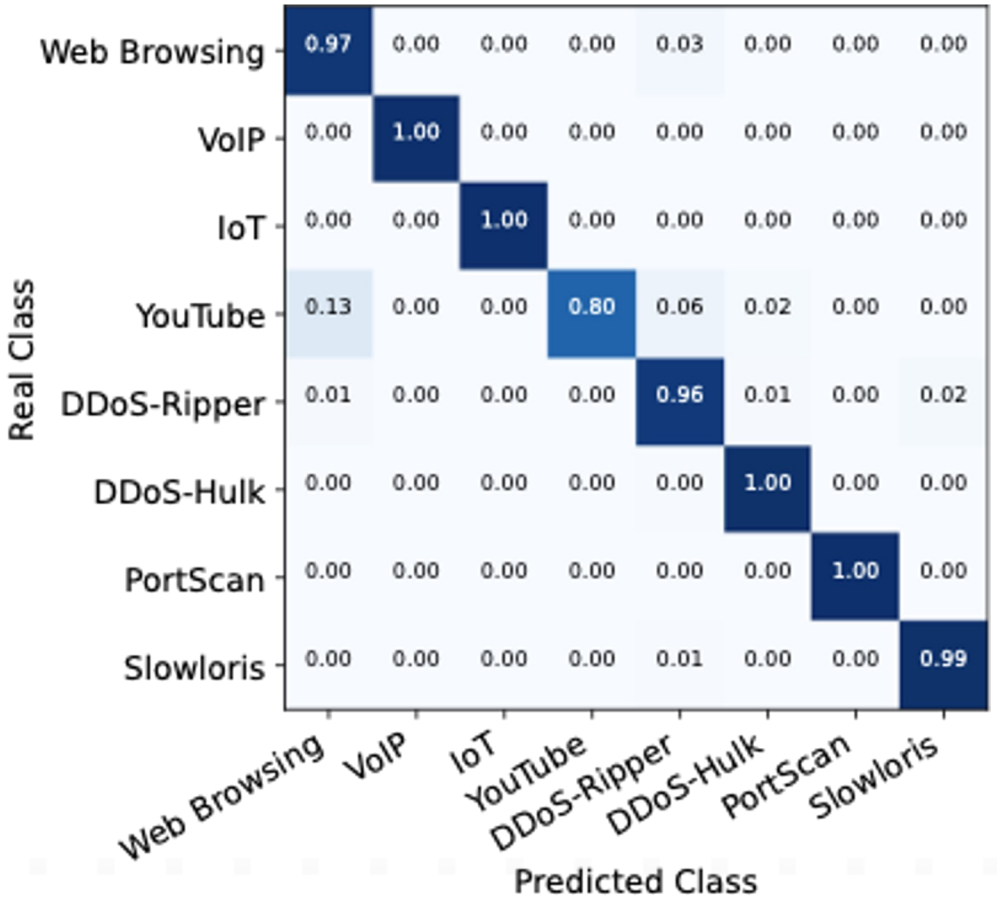
Cross-Domain AI Methodology

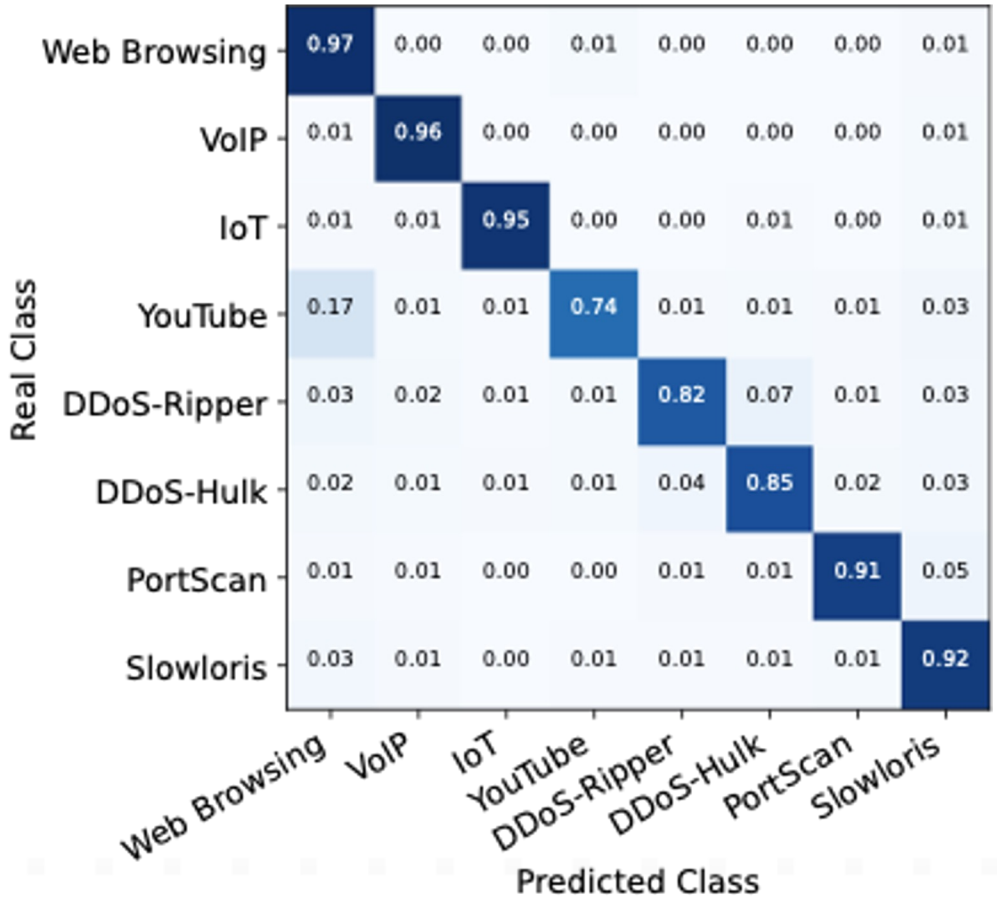


Cross-Domain AI Continuous Training and Operation



Cross-Domain AI Continuous Training and Operation





What's next?

- 6G-One: Industry + Academia Forum for discussion on upcoming network challenges for 6G and open technologies

- DTIF on energy saving in Open RAN with Open Networks support
- SFI Frontiers project on digital twin for optical networks
- EU projects on distributed AI in networks and it's use for fluid networking
- ESB project on use of green energy for DCs
- Quantum networking
- Number of PhD working on data driven networking, AR/VR.
- **Use of OpenIreland testbed and contribution to its development**.

CONNECT
Centre for Future Networks

Thanks to

Eoin Kenny, Dr. Diarmuid Collins, Prof. Dan Kilper, Dr. Frank Slyne, Dr. Merim Dzaferagic, Agastya Raj, Bruno Missi-Xavier…

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