FUTEBOL
Federated Union of Telecommunications Research Facilities for an EU-Brazil Open Laboratory

CONNECT Networks of the Future

Experimenting along the road to 5G

Adding adaptability to access networks

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WRNP
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Trinity College Dublin

Est. 1592

CONNECT

- A 70 M€ Irish research centre in communications and networks
- Broad international collaborations
- Experience in hosting Brazilian students (e.g., doutorado sanduiche) and collaborating with Brazilian academia

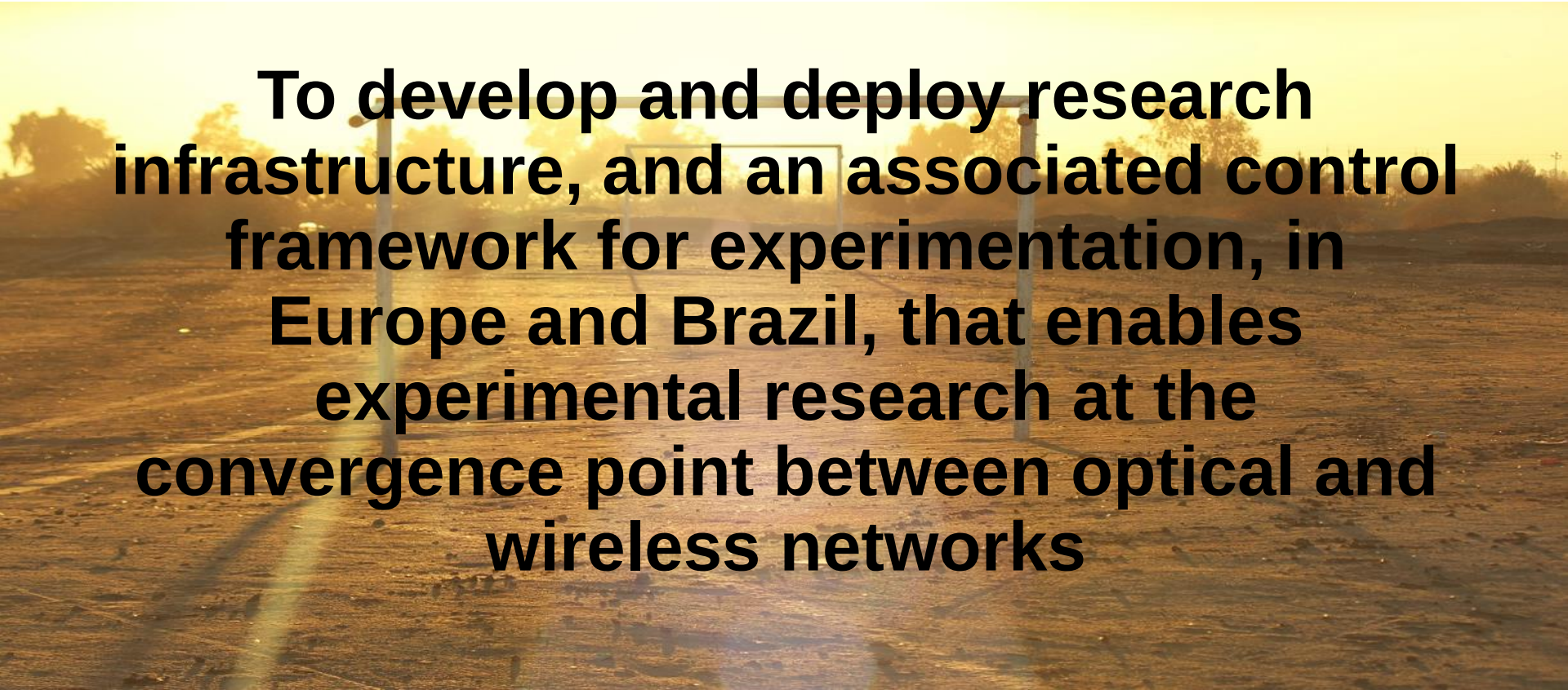
Rapid Prototyping and Experimentation

- Media Rich Applications
- M2M/D2D applications
- Audio-visual media processing
- service platforms
- privacy/security services
- cloud services
- mobile services
- network performance monitoring
- network optimization
- virtualization techniques
- cognitive networking
- optical/wireless interface
- optical architectures
- cyberphysical systems
- sensor networks
- wireless/mobile architectures
- spectrum management
- software/cognitive radio platforms
- PHY layer signal processing
- PHY layer monitoring
- RF design
- antennas
- optical technologies
- thermal strategies
- energy harvesting strategies
- microelectronic circuits
- smart sensors

Introducing FUTEBOL

- A 3 M€ research project co-funded by the European Commission and the Rede Nacional de Ensino e Pesquisa (RNP)
  - Part of a competitive process called the Coordinated EU-Brazil Calls, focusing on problems in ICT
- Coordinated by Trinity College Dublin and UFRGS
  - 3 universities (Trinity College, University of Bristol, IT Aveiro), 2 research centres (VTT, imec), 1 company (Intel) in Europe
  - 5 universities (UFRGS, UFMG, Unicamp, UFC, UFES) in Brazil

The Goal of FUTEBOL



To develop and deploy research infrastructure, and an associated control framework for experimentation, in Europe and Brazil, that enables experimental research at the convergence point between optical and wireless networks

FUTEBOL will facilitate the co-design of **wireless** and **optical** network resource management through experimentation

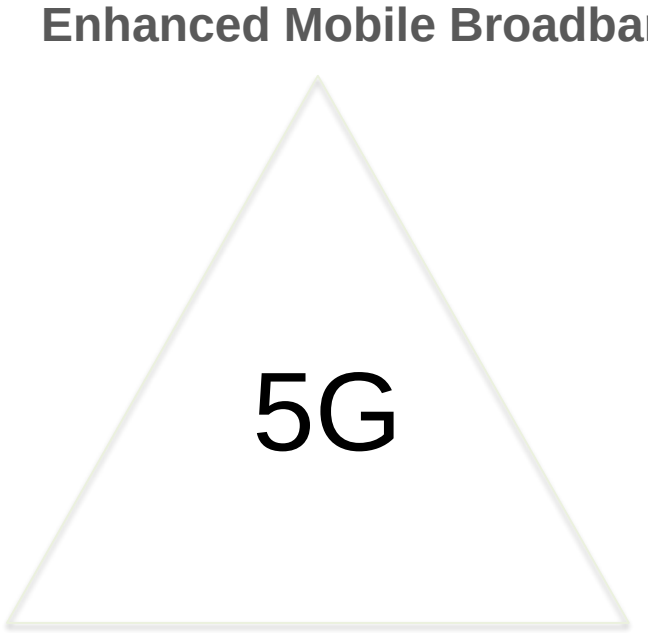
$ 10B market for NFV, SDN, virtualization in 2015 alone

$ 1.5T value IoT will add to the economy by 2019

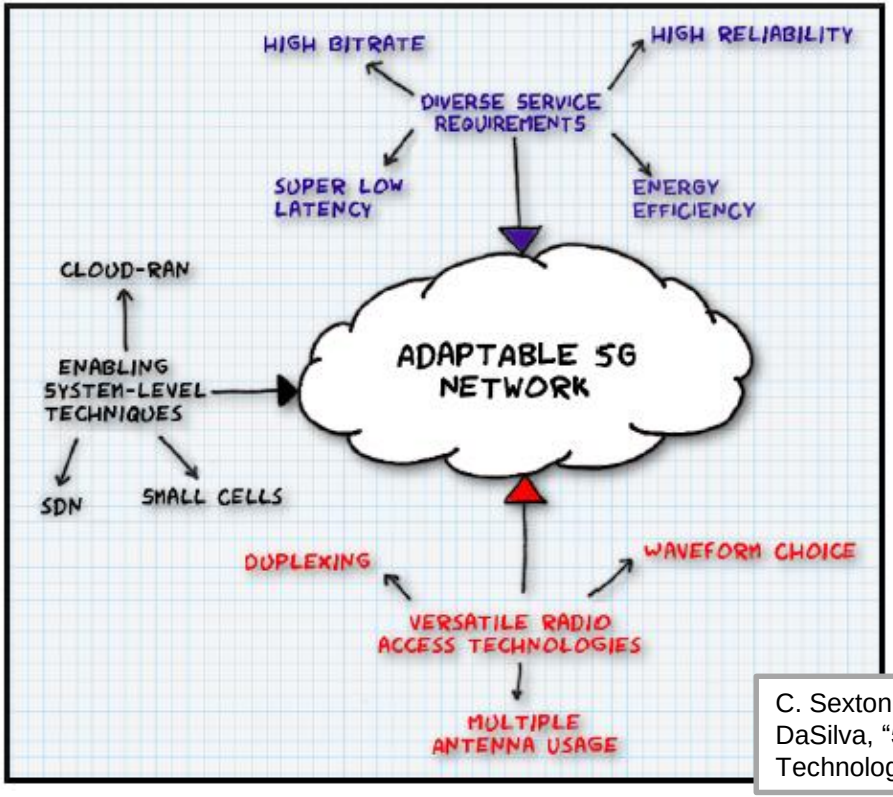
$ 2.7B small cell market by 2017

SDR testbed in Trinity College (a FUTEBOL testbed)

5G requirements



How to achieve it?



Network slicing

Virtualisation

Sharing

C. Sexton, N. Kaminski, J. Marquez Barja, N. Machetti, and L. A. DaSilva, “5G:Adaptable Networks Enabled by Versatile Radio Access Technologies ,” **IEEE Communications Surveys and Tutorials**, 2017.

1. Radio virtualisation

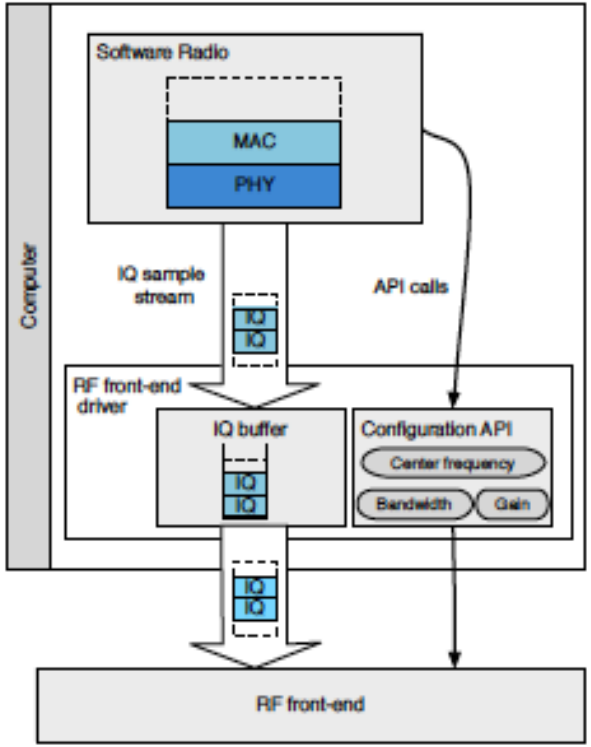
- The process of abstracting a physical radio and slicing it into VRs holding certain corresponding functionalities and isolating each other

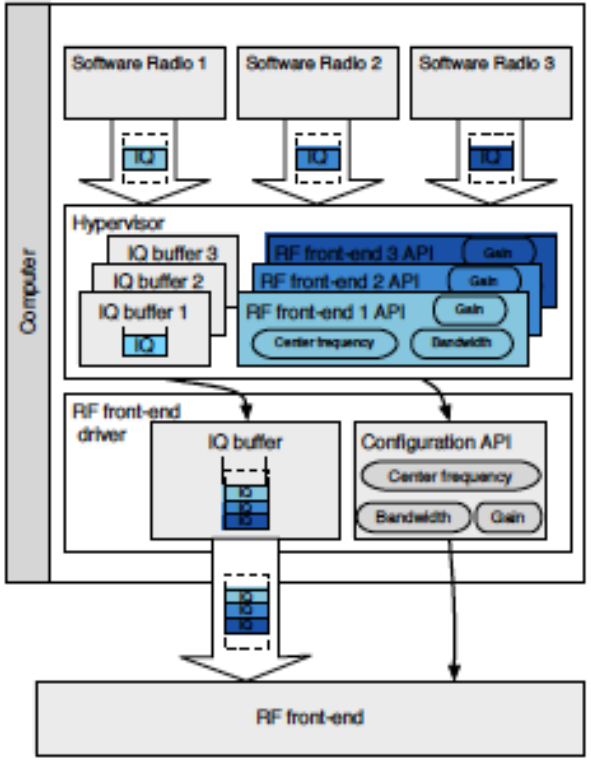
- Enables more flexible deployment of versatile infrastructure with multi-programmable air interfaces

- HyDRA: a software-defined virtualisation layer that enables the implementation of multiple programmable air interfaces on top of on RF front-end

Virtual radio

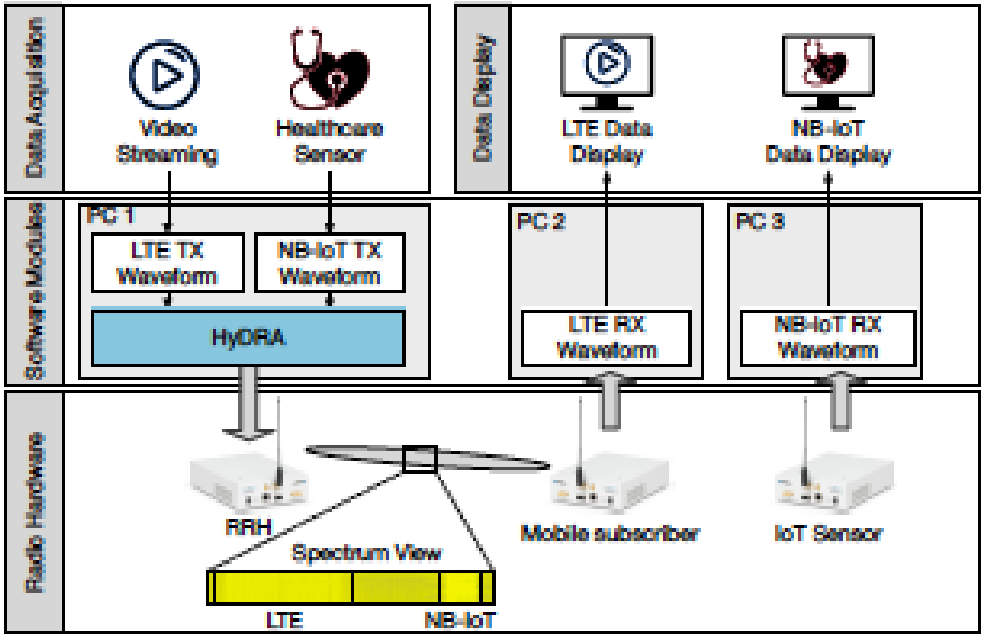
Traditional SDR approach

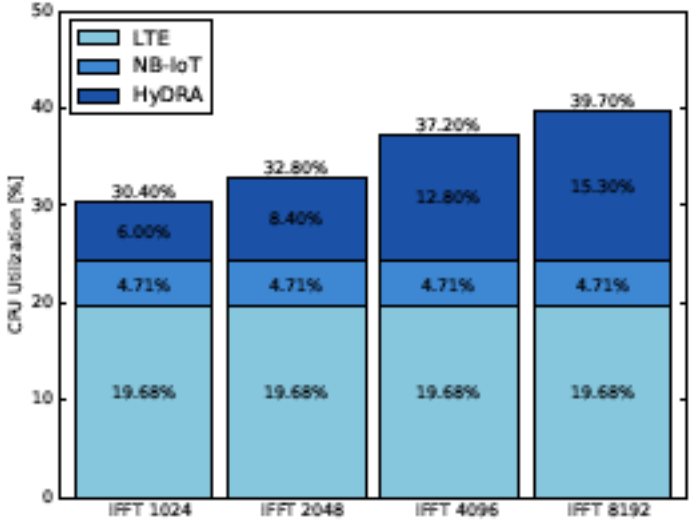




Virtualised SDR approach

HyDRA implementation





M. Kist, J. Rochol, L. A. DaSilva, and C. B. Both, “SDR Virtualisation in Future Mobile Networks: Enabling Multi-Programmable Air Interfactes,” **IEEE ICC**, 2018.

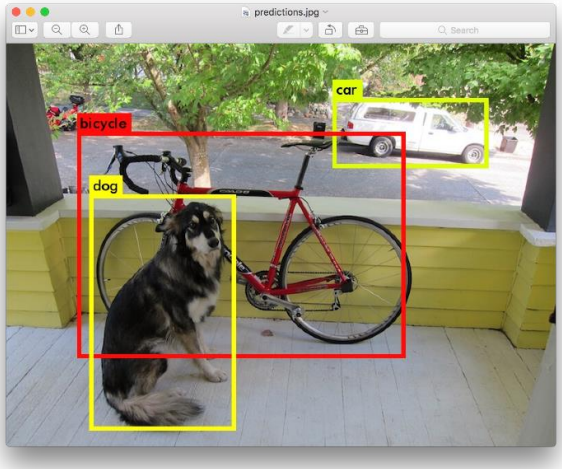
2. Context awareness

- Clear trend towards spectrum sharing in unlicensed, lightly licensed, or licensed spectrum (e.g., LTE in license-free spectrum, sharing of radar bands, mmwave, etc.)

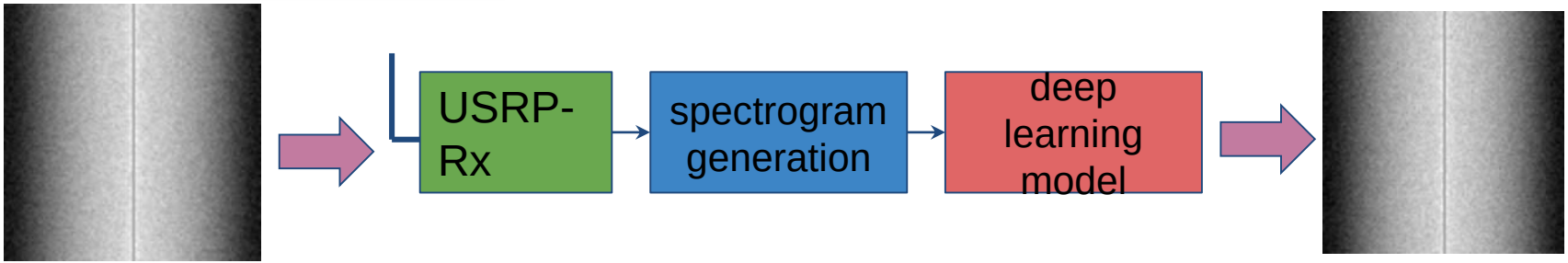
- Technologies sharing spectrum may use very different channelisation, waveforms

- Take advantage of recent advances in machine learning for real-time waveform classification to enable more efficient coexistence

Deep learning for spectrum monitoring



A. Selim, F. Paisana, J. Arokkiam, Y. Zhang, L. Doyle, and L. A. DaSilva, “Spectrum Monitoring for Radar Bands Using Deep Convolutional Networks,” **IEEE Globecom**, 2017.



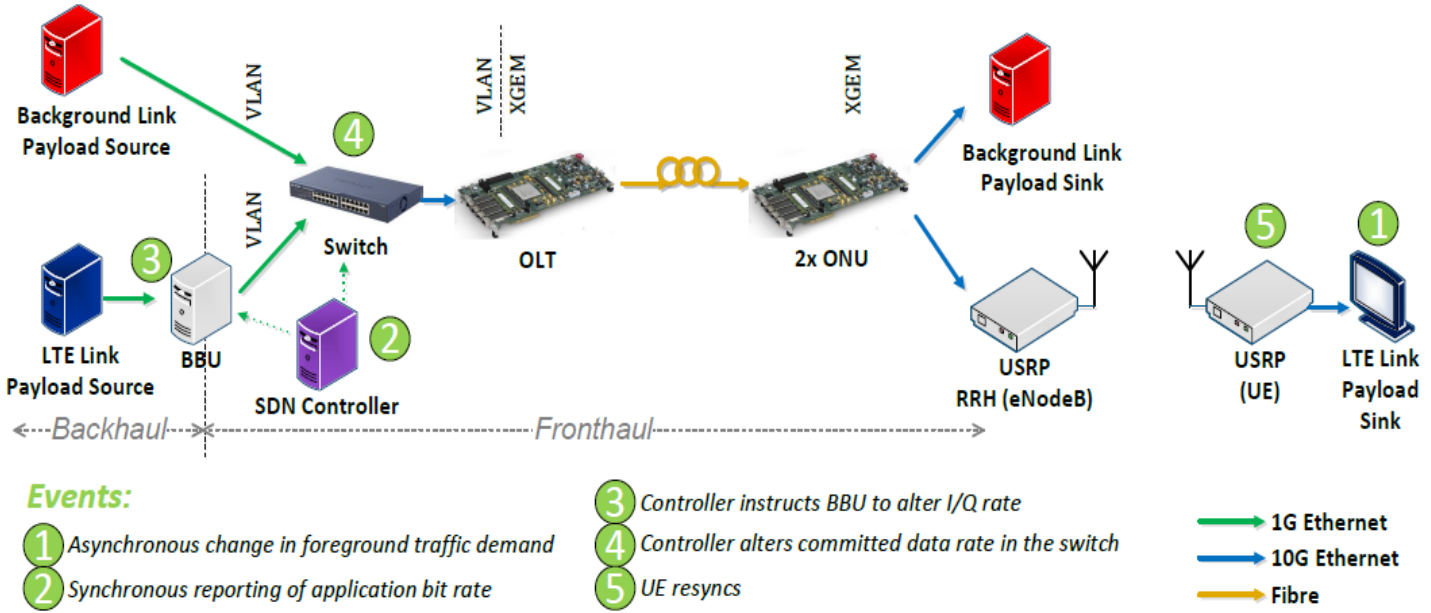
3. Flexible bandwidth fronthaul

- Cloud-RAN brings close integration between SDR and SDN technologies, with an optical network providing the fronthaul between RRHs and BBU pools

- We implement an LTE C-RAN with the RRH and BBU pools connected through a PON

- I/Q samples transmission over the PON consumes significant bandwidth: we proposed and prototyped a flexible bandwidth fronthaul
  - The fronthaul traffic is adapted to other services that share the same PON, e.g. by changing the sampling rate of the RRH

Flexible bandwidth fronthaul



P. Alvarez, F. Slyne, C. Bluemm, J. Marquez-Barja, L. A. DaSilva, and M. Ruffini, “Experimental Demonstration of SDN-Controlled Variable Rate Fronthaul for Converged LTE-over-PON,” **OFC**, 2018.

Concluding comments

- FUTEBOL has been developing research infrastructures in Europe and Brazil to advance research and innovation on integrated wireless-optical telecommunication
- Major advances are required in the network's ability to adapt and self-configure
  - Resource sharing, virtualisation, slicing
- SDR prototyping of solutions of relevance to future networks
  - Radio virtualisation, machine learning for context awareness, dynamic bandwidth fronthaul for C-RAN

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