IEEE 5G and Beyond Testbed Workshop

ORBIT Pilot

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IEEE 5G Testbeds Working Group

Main Workgroup Objectives

- Leverage IEEE community's strong simulation, measurement and calibration capabilities for testbeds by developing testing standards and calibration methods
- Inventory types of testbeds that are available, serve as facilitator for setting up a testbed federations and make them available to IEEE community
- Collaborate with the vendor and research community to expand existing testbeds with next generation of technologies (as they become available).
- Organize workshops related to 5G experimental aspects (including use case scenarios).
- Propose and drive development of (future) testbed requirements
- Coordination with other development efforts (PAWR, ONF, 5G-PPP, etc)

5G: Technical Challenges

Faster Cellular Radios Access ~1-10 Gbps ~1000x capacity

- Wideband PHY
- Cloud RAN arch
- Massive MIMO
- mmWave (60 Ghz)
- Multi-Radio access
- HetNet (+WiFi, etc.)
- …

Low-Latency/ Low-Power Access Network For Real-Time IoT

- Custom PHY for IoT
- New MAC protocols
- RAN redesign
- Light-weight control
- Control/data separation
- Network protocol redesign
- ….

New Spectrum & Dynamic Spectrum Access

- 60 Ghz & other new bands
- New unlicensed/shared spectrum
- Dynamic spectrum access
- Spectrum sharing techniques
- Non-contiguous spectrum
- Network/DB coordination methods
- ….

Next-Gen Mobile Network

- Mobile network redesign
- Convergence with Internet
- Clean-slate Mobile Internet
- Software Defined Networks
- Open wireless network APIs
- Cloud services & computing
- Edge cloud/fog computing
- Virtualization, NFV
- ….

5G: Capacity, Capacity, Capacity

Research Viewpoint

$$1000 = 10 \times 10 \times 10$$

$$\frac{bits/sec}{km^2} = \frac{bits/sec/Hz}{cell} \times \frac{cell}{km^2} \times Hz$$

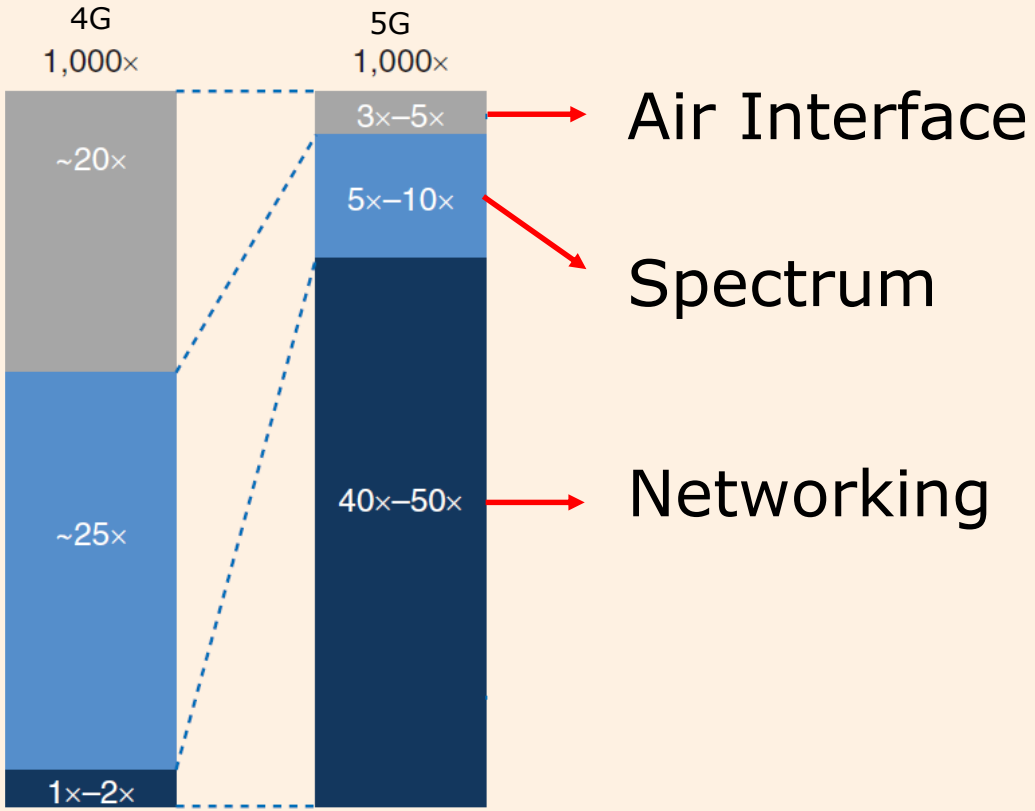
Spectral efficiency

Cell density

Bandwidth

Giuseppe Caire: "Massive MIMO: implementation issues and impact on network optimization" 2016 Tyrrhenian International Workshop on Digital Communications (TIW16)

Industry Viewpoint



Qian (Clara) Li,Huaning Niu, Apostolos (Tolis) Papathanassiou, and Geng Wu: "5G Network Capacity" IEEE vehicular technology magazine, March 2014

5G: Capacity, Capacity, Capacity (cont'd)

	Academia	Industry
Spectral Efficiency/Air Interface	Massive MIMO: Serve 10-20 users per sector with 100-200 antennas per BS	• Coordinated Multipoint Tx/Rx • 3-D/Full-Dimensional MIMO • New Modulation and/or Coding Schemes
Cell Density/Networking	Small Cells & Heterogeneous SoNs: From 300m to 90m cell radius on average	• Cell Densification • WLAN Offloading • Integrated MultiRAT Operation • Device-to-Device • Joint Scheduling, Nonorthogonal Multiple Access • Information and Communication Technology Coupling
Bandwidth/Spectrum	mmWaves: From 2-6 GHz to 20-60 GHz	• More Licensed and Unlicensed Spectrum, mmWaves • Licensed Shared Access • Unlicensed Spectrum Sharing

Softwarization in Wireless Networks

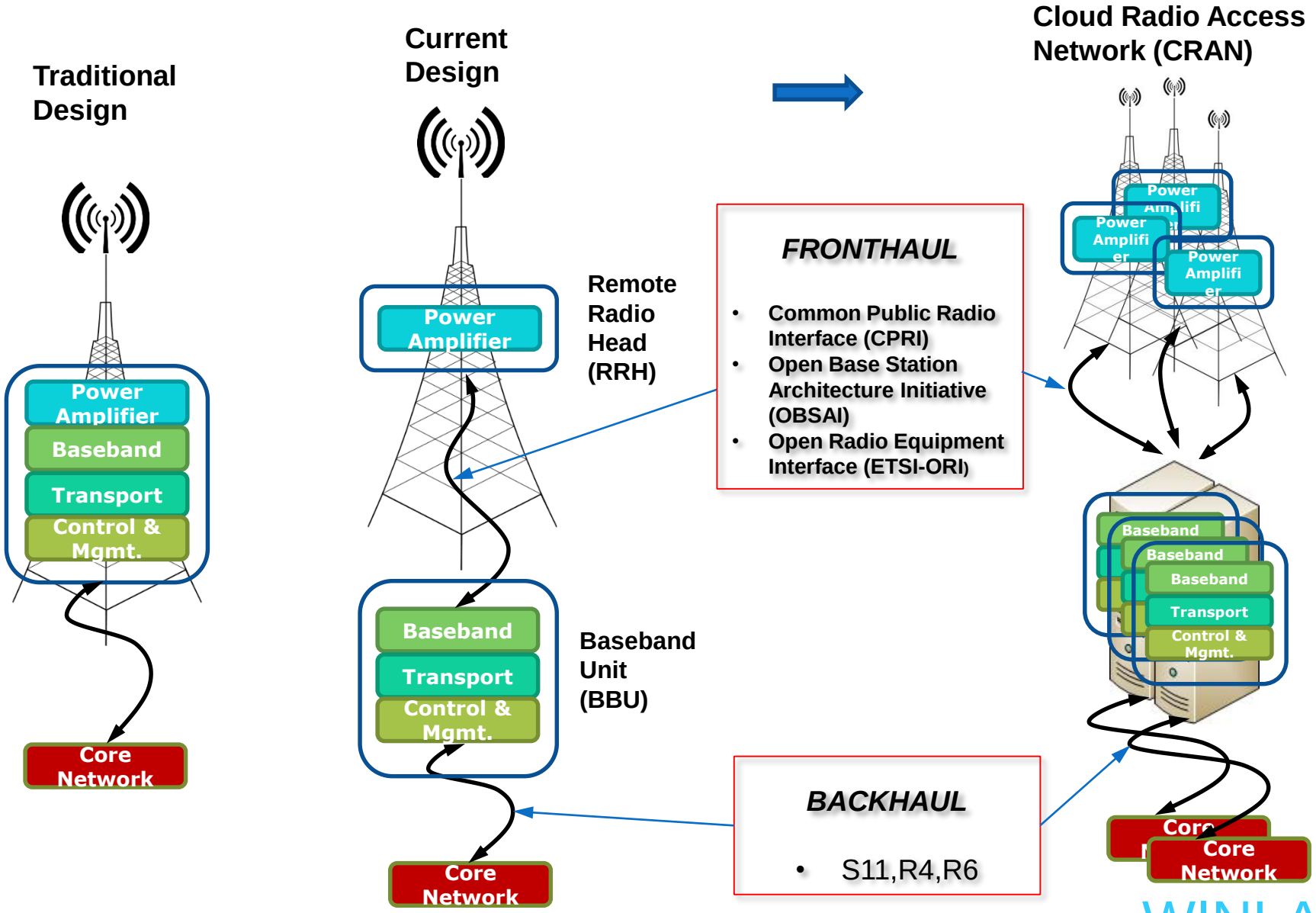
In radio access networks - Agility in spatial, temporal and frequency dimensions enabling:

- Fine-grained physical layer/network programmability
- Flexibility in spectrum management
- Dynamic provisioning
- Heterogeneous deployments.

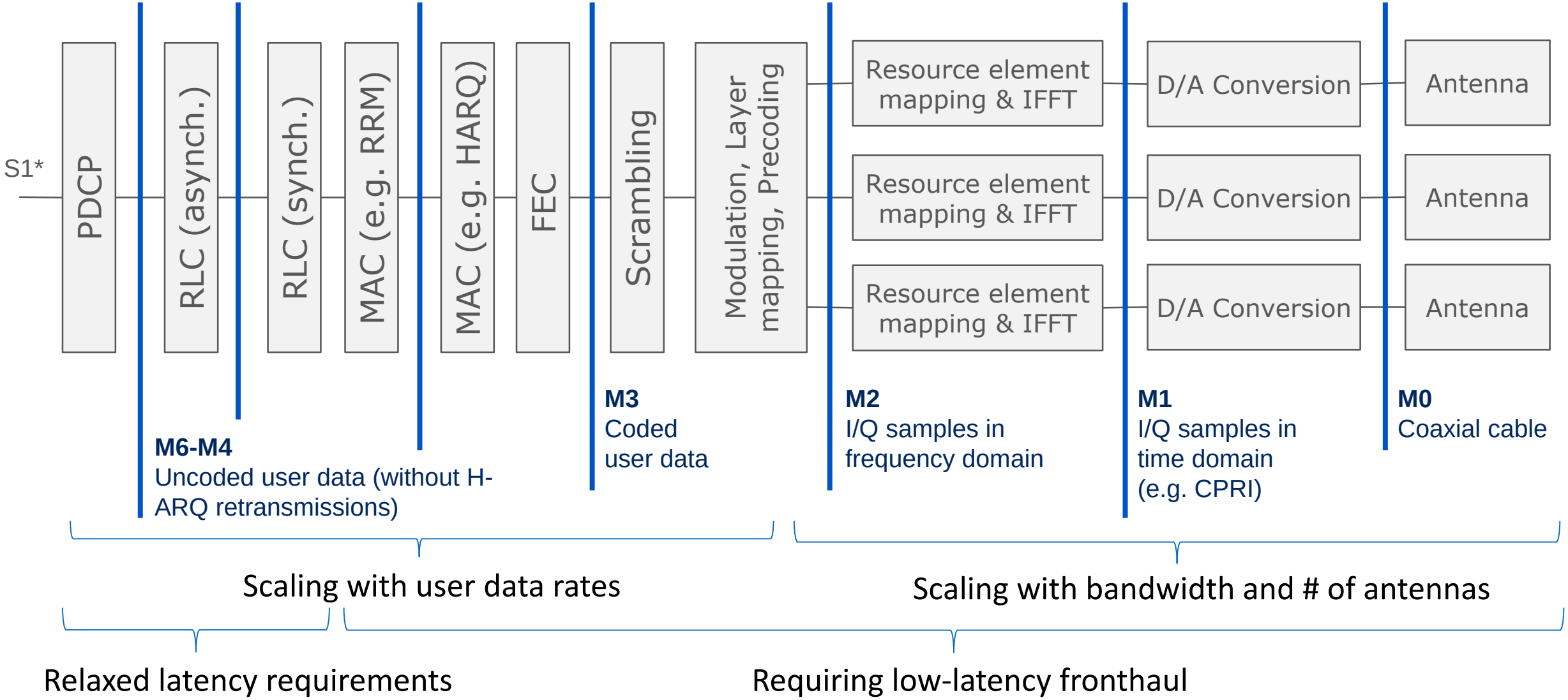
In mobile edge networks - Extend softwarization from the conventional data center to the edge of wireless networks:

- Enable on demand service deployment at the most effective locations based on application requirements
- Automate service establishment/maintenance mechanisms (in a timely fashion)

Basestation Architecture Evolution



Basestation Architecture Evolution (cont'd)



Courtesy: METIS-II Consortium

Example: OpenAirInterface eNodeB and UE

Challenge : Efficient base band unit implementation that uses general-purpose x86 processors (GPP) for base-band processing

- front-end, channel decoding, phy procedures, L2 protocols

- Key elements:
  - Real-time extensions to Linux OS
    - x86-64 multicore arch
  - Real-time data acquisition to PC
  - SIMD optimized integer DSP
    - 64-bit MMX → 128-bit SSE2/3/4 → 256-bit AVX2
    - iFFT/FFT, Channel Estimation, Turbo Decoding
  - SMP Parallelism
    - Master-worker model

Courtesy: Navid Nikaein, Eurecom/Open Air Interface

OAI Roadmap: Strategic Areas

5G Modem
new waveform, Carrier aggregation, Full-duplex Radio, Relaying, Massive MIMO

Software-defined 5G system
Cloud-native RAN, Juju/OpenStack, MEC API, SDN/NFV, Ethernet Fronthaul

Heterogeneous 5G Network
Ultra-dense network, Unlicensed bands, Coexistence and Aggregation

Large-Scale Emulation
Realistic experimentation, Channel models, Performance, PHY abstraction, System Integration

Test and measurements
Interoperability / Compliance, System Integration, Channel Sounding, Design Validation

RF Platform


Low cost BS, Soft RRH

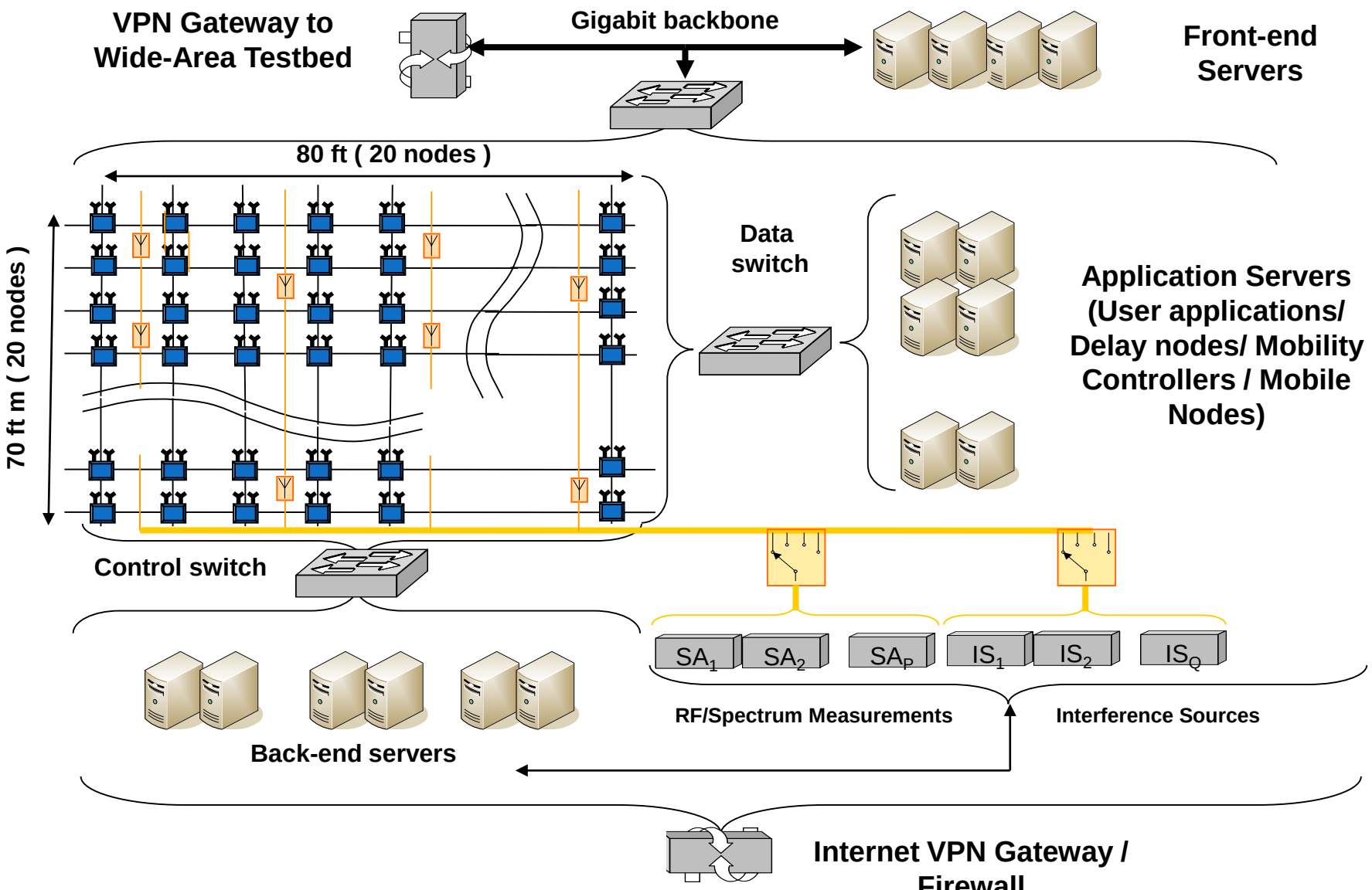
IoT

Courtesy: Raymond Knopp, Euricomm

IEEE 5G Testbed Pilot Program

- Identify testbed, tools and matching experiment types
- Define usage models
- Set the guidelines for access and use (including considering local regulations)
- Identify AAA methodology (including potential federation models)
- ***Start a trial with the ORBIT testbed to help with the requirements/policies development***

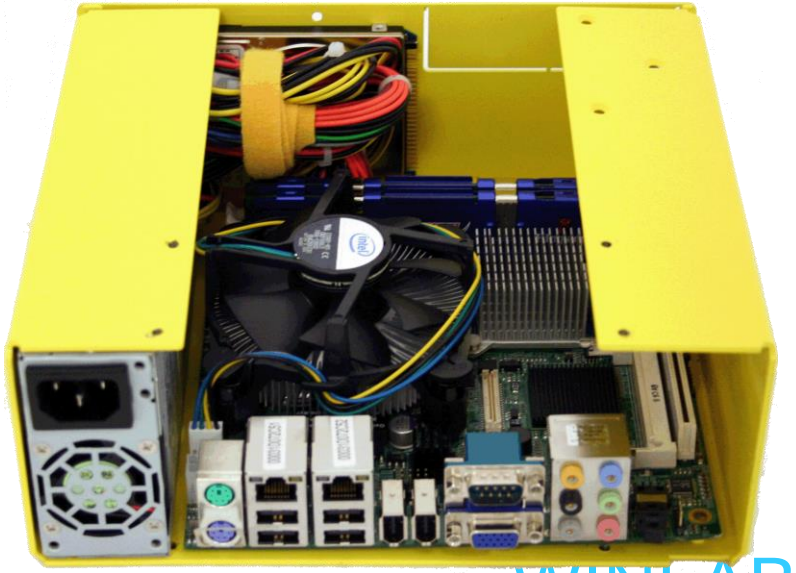
Orbit Testbed: Hardware



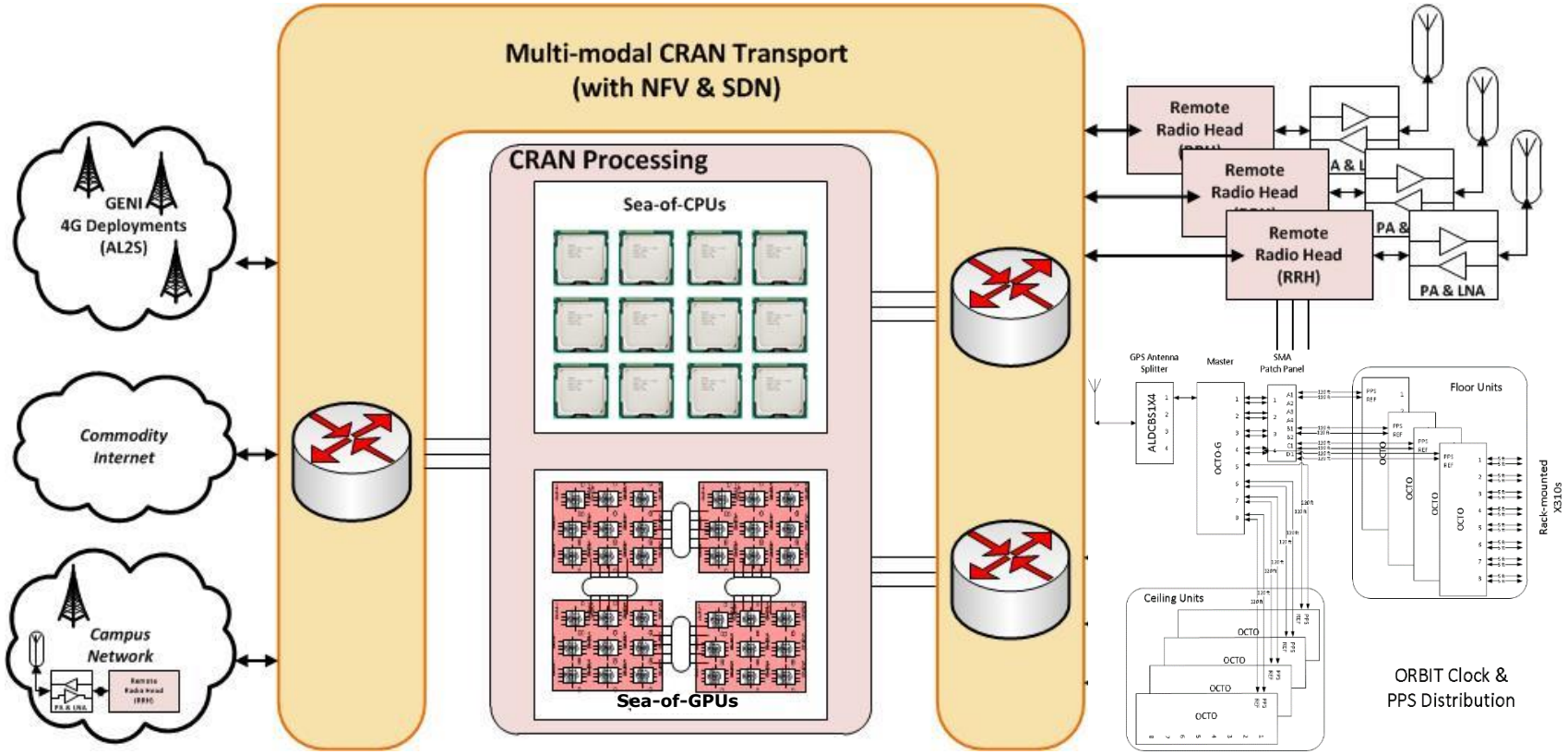
ORBIT Radio Node (Version 4)

- I7-4770 3.4 GHz Q87T Express chipset
- 16 GB DDR3
- 2 x Gigabit Ethernet ports
- PCI-Express 2.0 X16
- 2 x Mini-PCIexpress socket
- 8 x USB 3.0
- OOB Mgmgt.

- Xeon E5-2600v3 with 18 cores
- 64 GB DDR4
- 2 x 10G Ethernet ports
- 2 x Gigabit Ethernet ports
- PCI-Express 3.0 X16
- 8 x USB 3.0
- OOB Mgmgt.



5G Experimentation: Cloud RAN



CloudLab based CPU/GPU deployment

5G Experimentation: Massive-MIMO

- 40 USRP X310s
  - Available FPGA resources:

Resource Type	Number
DSP48 Blocks	58K
Block Rams (18 kB)	14K
Logic Cells	7.2M
Slices (LUTs)	1.5M

  - RF 2 x UBX-160 (10 MHz - 6 GHz RF, 160 MHz BB BW)
  - 2 x 10G Ethernet for fronthaul/interconnect
  - Four corner movable mini-racks (4 x 20 x 20 -> 1 x 80 x 80)
- > 500+ GPP Cores/CloudLab Rack
- Number of GPU platforms
- 32x100G SDN aggregation switch

5G Experimentation: High Density

ORBIT Grid (this morning)

Goals of Federation

- Make it easy for experimenters to use multiple testbeds
  - Single account
  - Single (or small number) of tools, choice of tools
- Multiple testbeds
  - To scale up
  - To use/combine special resources (e.g. wireless robots)
  - Redundancy (e.g. testbed in maintenance)
  - To re-use experiments (class exercises, scientifically, …)
  - To compare environments (e.g. wireless, openflow hardware, …)

Basics of GENI Federation

- Partitioned trust
  - All identities and assertions verified cryptographically
  - No federation member can forge credentials for other members
- Separate Authentication and Authorization
  - Authentication: "Who is this user?" (Member Authority)
  - Authorization: "Why are they allowed to use the facility?" (Slice Authority)
- Use untrusted tools as much as possible
  - Eg. multiple portals
  - "Speaks-for" for accountability
- Federation established by a trusted third party (Clearinghouse)
- Anyone can join more than one federation
  - As simple as adding and removing root certificates

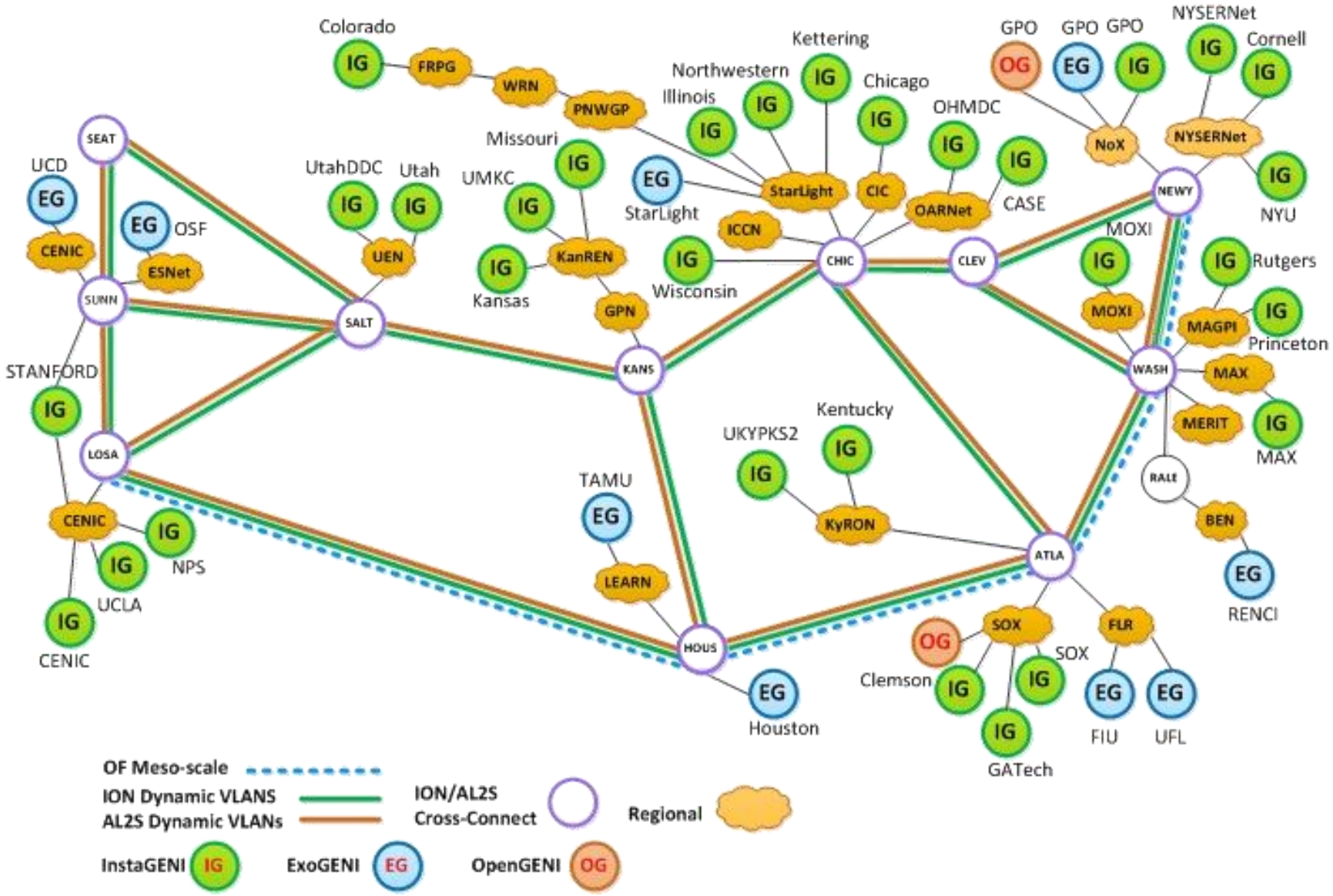
Courtesy: Robert Ricci, University of Utah

Successes in GENI Federation

- 142 aggregates federated
- Moderately heterogeneous
  - Clusters
  - Wireless
  - Backbone networks
  - Existing testbeds
- Includes international resources
- Reasonably broad and consistent tool support
- Adding a new federate is easy (from a clearinghouse standpoint)
- Decentralized model / autonomous facilities
- Model is used for multiple testbeds / federations
- Multiple overlapping federations

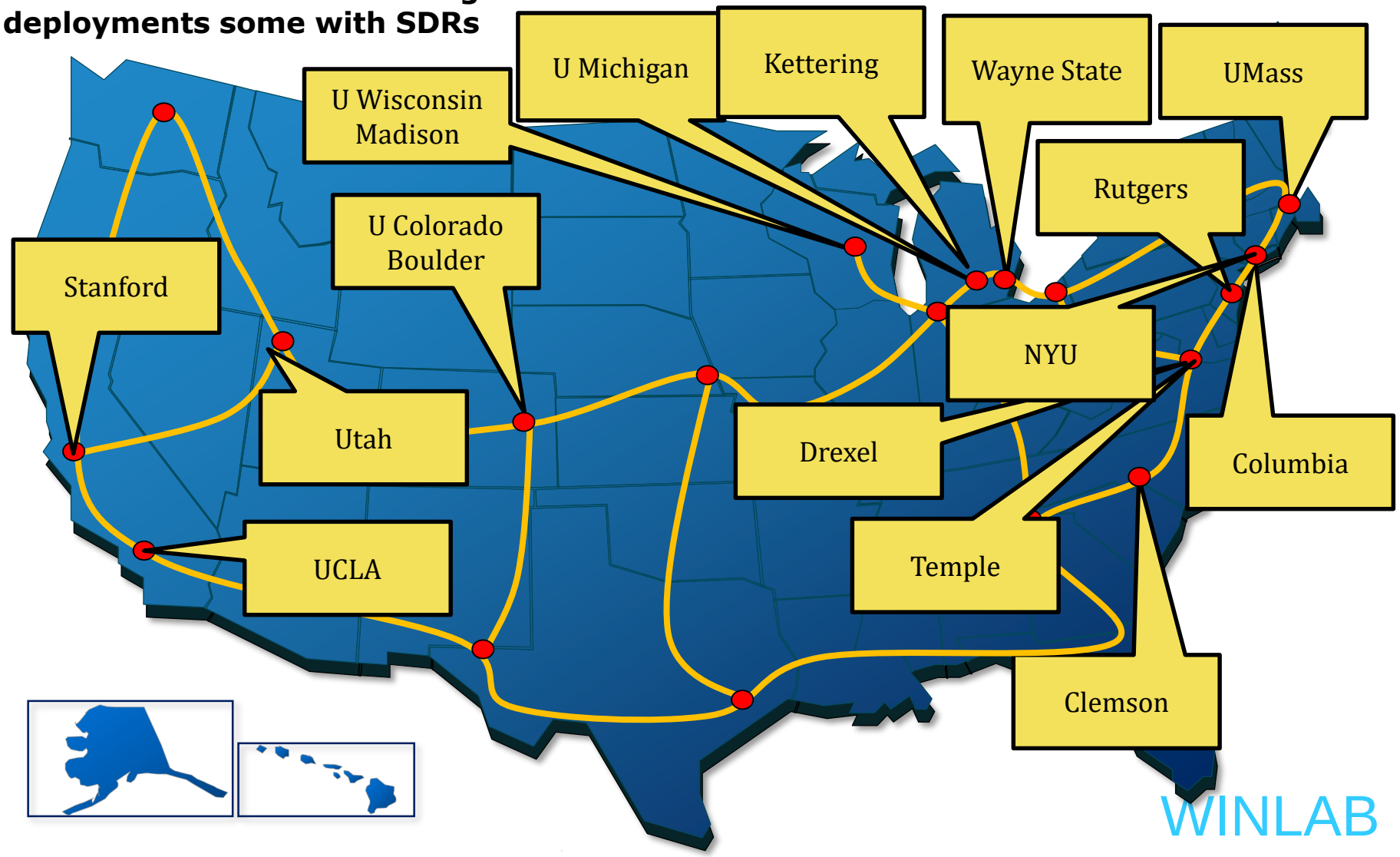
Courtesy: Robert Ricci, University of Utah

GENI Network Map

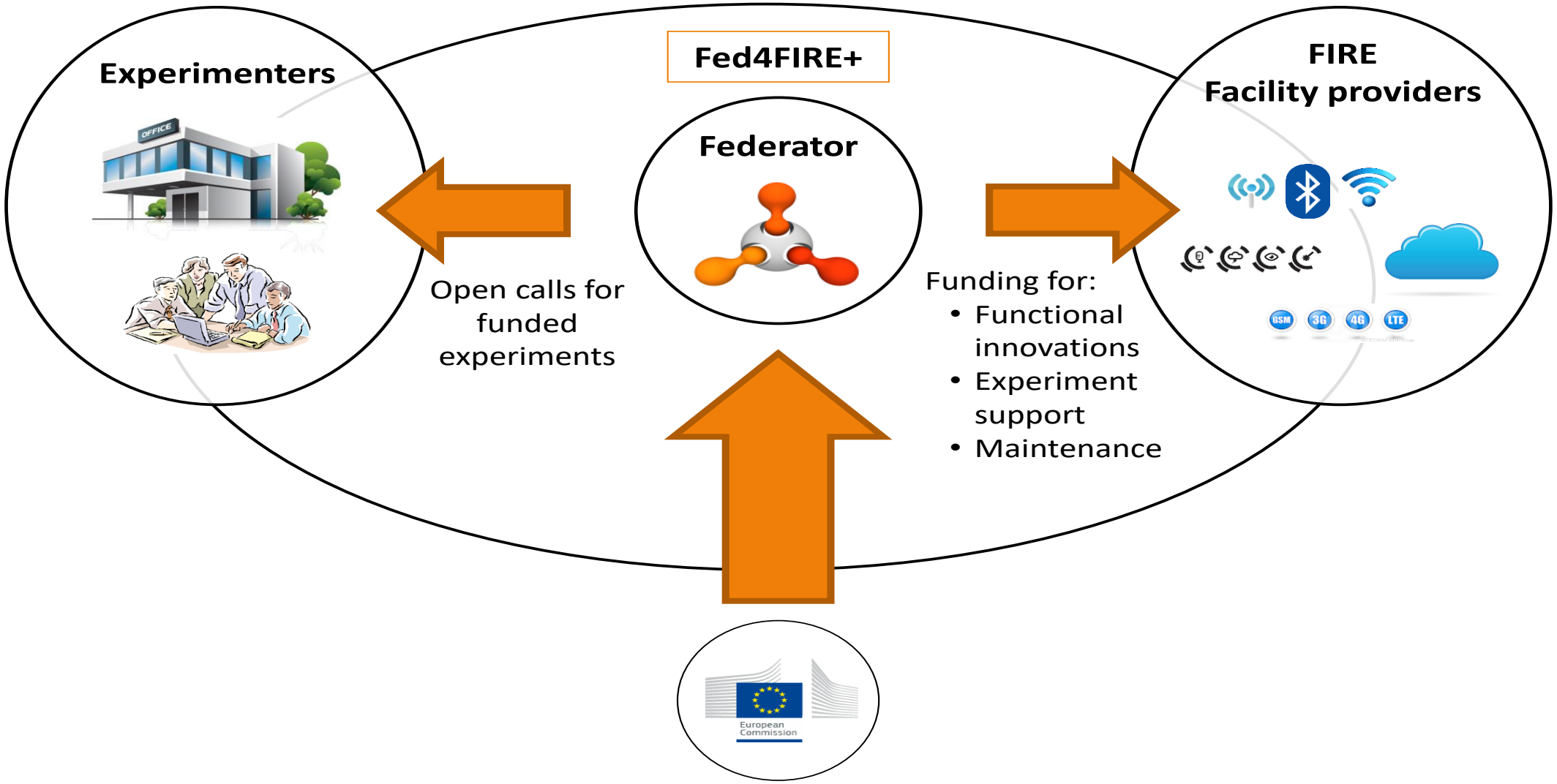


GENI Wireless

- **32 LTE and WiMAX BS on 14 campuses**
- **SDN (Click and OVS based) datapath/backbone**
- **Sliced, virtualized and interconnected through Internet2**
- **10 mini-ORBIT deployments some with SDRs**

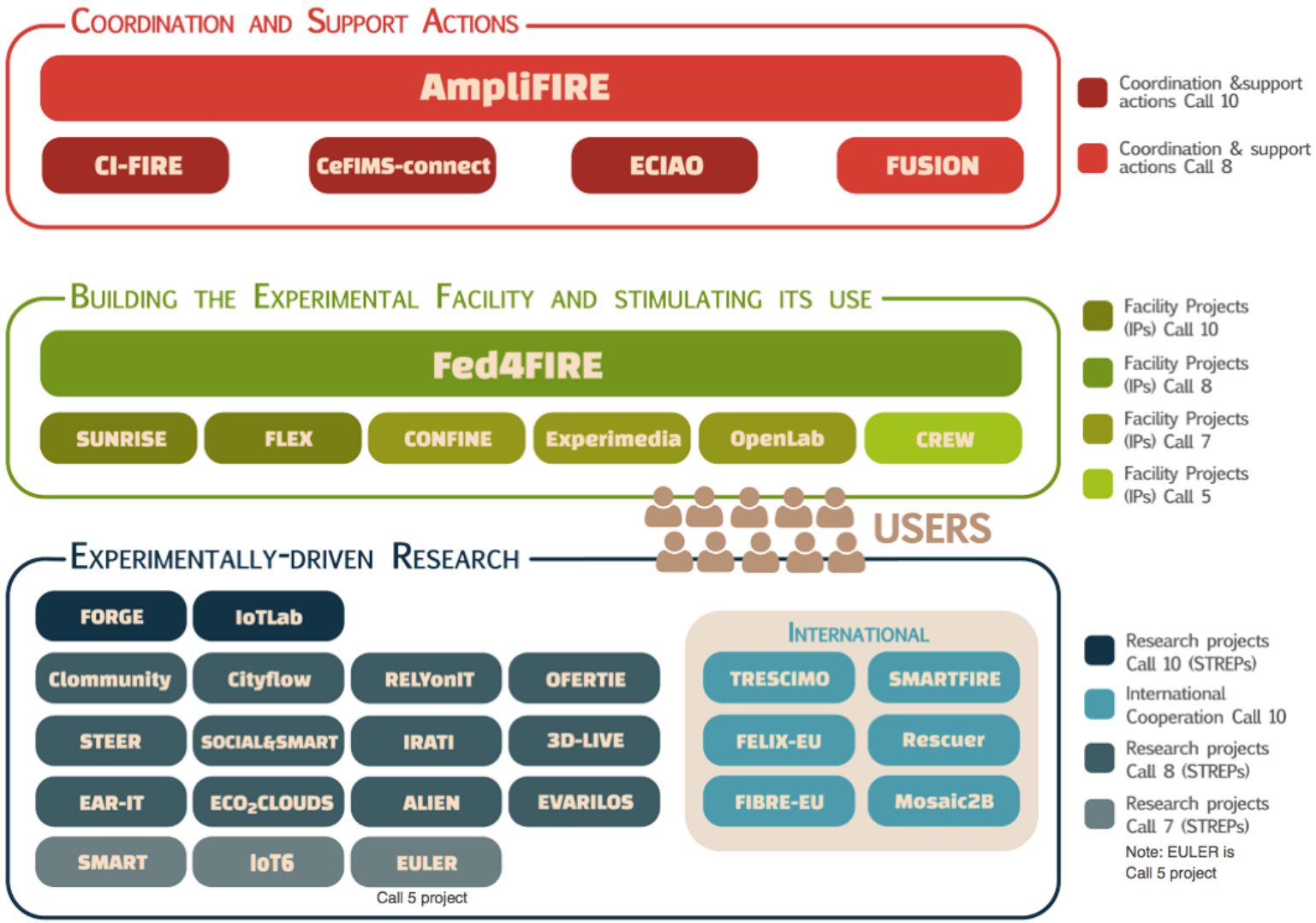


Model from Fed4FIRE



Courtesy: Brecht Vermeulen, imec

European FIRE projects framework



Source figure: FIRE Brochure 2014 (AmpliFIRE)

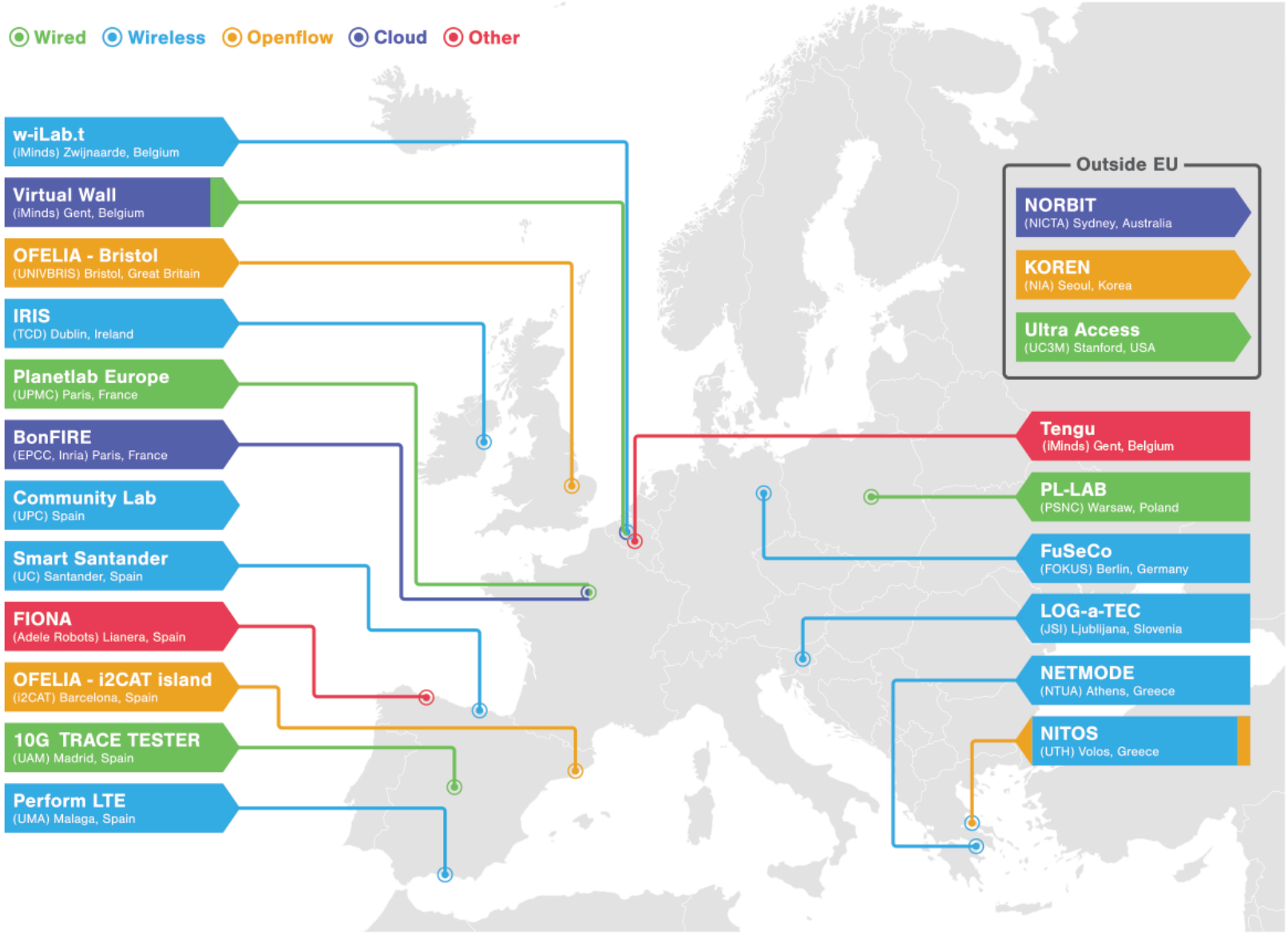
Courtesy: Brecht Vermeulen, imec

Fed4FIRE – general info

- Total budget: 7.75 MEUR with 42 partners (2012-2016)

Courtesy: Brecht Vermeulen, imec

Fed4FIRE assets – facilities (doc.fed4fire.eu)



Courtesy: Brecht Vermeulen, imec

Fed4FIRE+ Objectives

The Fed4FIRE+ project has the objective to run and further improve Fed4FIRE's "best-in-town" federation of experimentation facilities for the Future Internet Research and Experimentation initiative. To achieve this, the project has defined a set of sub-objectives:

- **To further exploit, enlarge and build a federated set of facilities** upon the foundations laid out by the FP7 project Fed4FIRE;
- **To aim for an open federation** to the whole FIRE community and beyond, for experimentation by industry and research organisations, through the organization of **Open Calls and Open Access mechanisms**;
- **To continuously upgrade and improve the facilities** and include technical innovations, focused towards increased user satisfaction (user-friendly tools, privacy-oriented data management, testbed SLA and reputation, experiment reproducibility, service-level experiment orchestration, federation ontologies, etc.)
- **To create an open market-place** for customers of testing services by **brokering across federated testbed resources**.

Courtesy: FED4Fire+ Consortium

More Info @

5g.ieee.org/testbeds

www.orbit-lab.org

www.geni.net

www.fed4fire.eu/

geniwireless.orbit-lab.org

www.winlab.rutgers.edu

www.openairinterface.org

metis-ii.5g-ppp.eu