GENI LTE: A Mobile Edge Computing Platform

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OUTLINE

- Scope of Work
- GENI Refresher
- GENI Wireless Footprint
- Intro to LTE
- Research Motivation
- Campus Deployment Kit
- Application and Experiments

Scope of Work

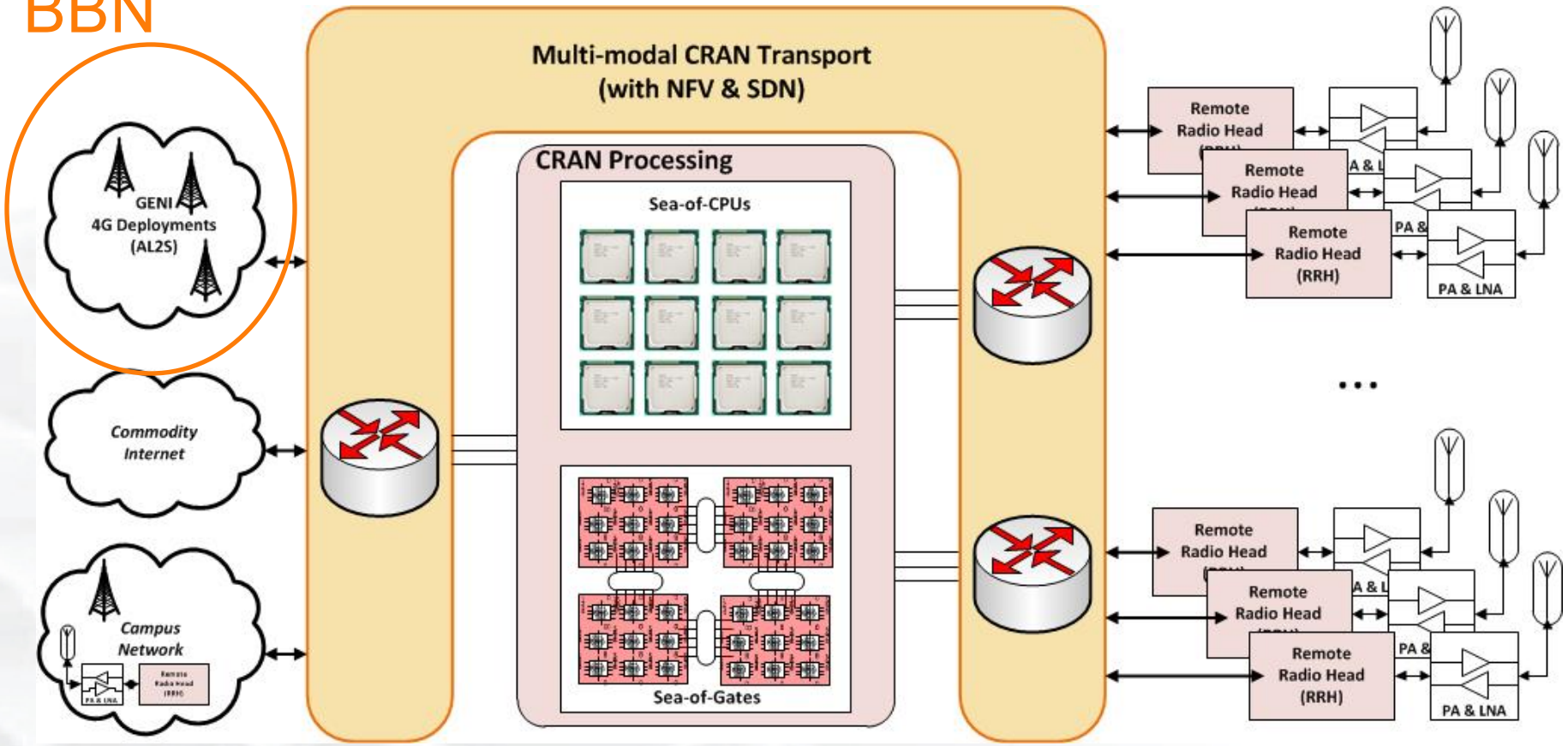
(1) Enabling experimentation with LTE radio technology which is becoming ubiquitous as the next-generation radio air interface for cellular systems worldwide.

(2) Providing GENI sites a turnkey blueprint for deployment of current/future cellular systems.

(3) Providing a Mobile Edge computing platform in form of 4G LTE and GENI Racks connected via high speed backbone networks

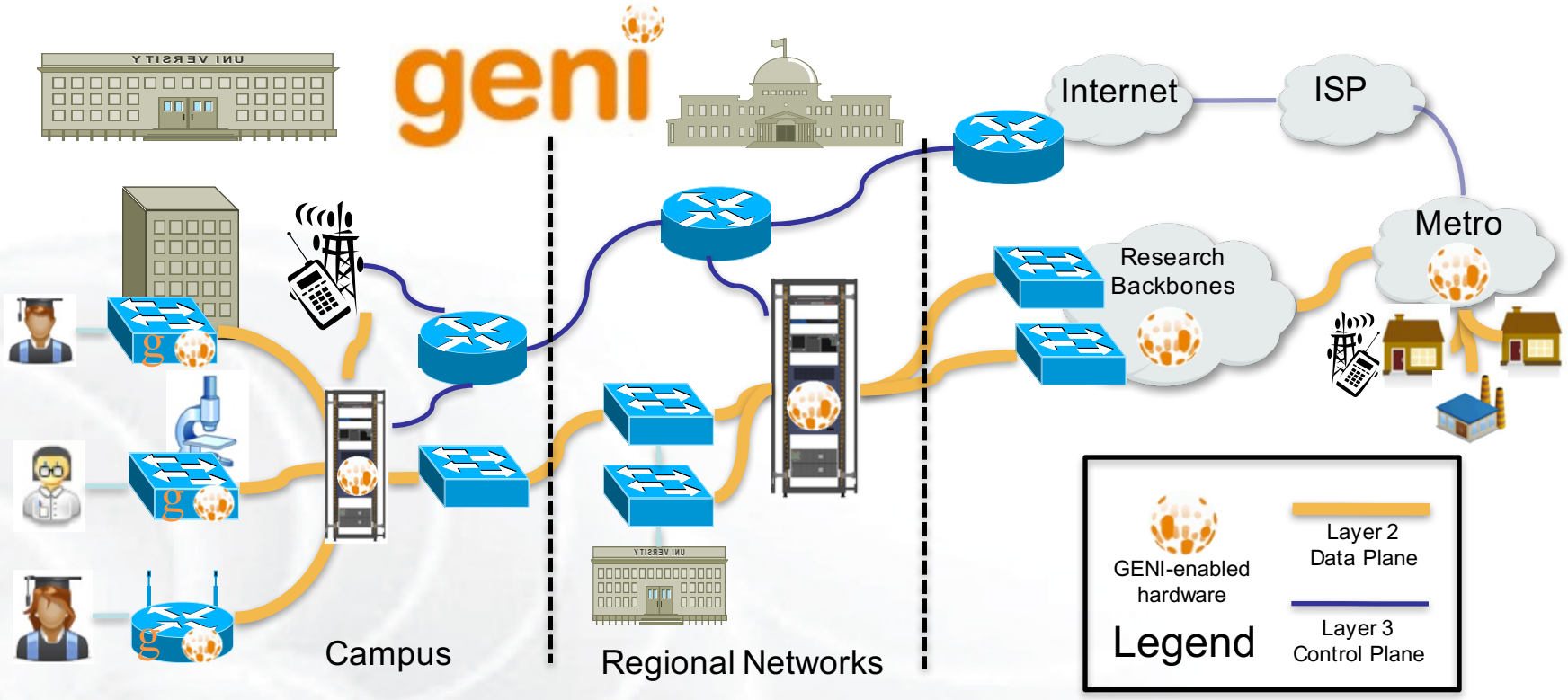
ORBIT Extension: Proposal

BBN



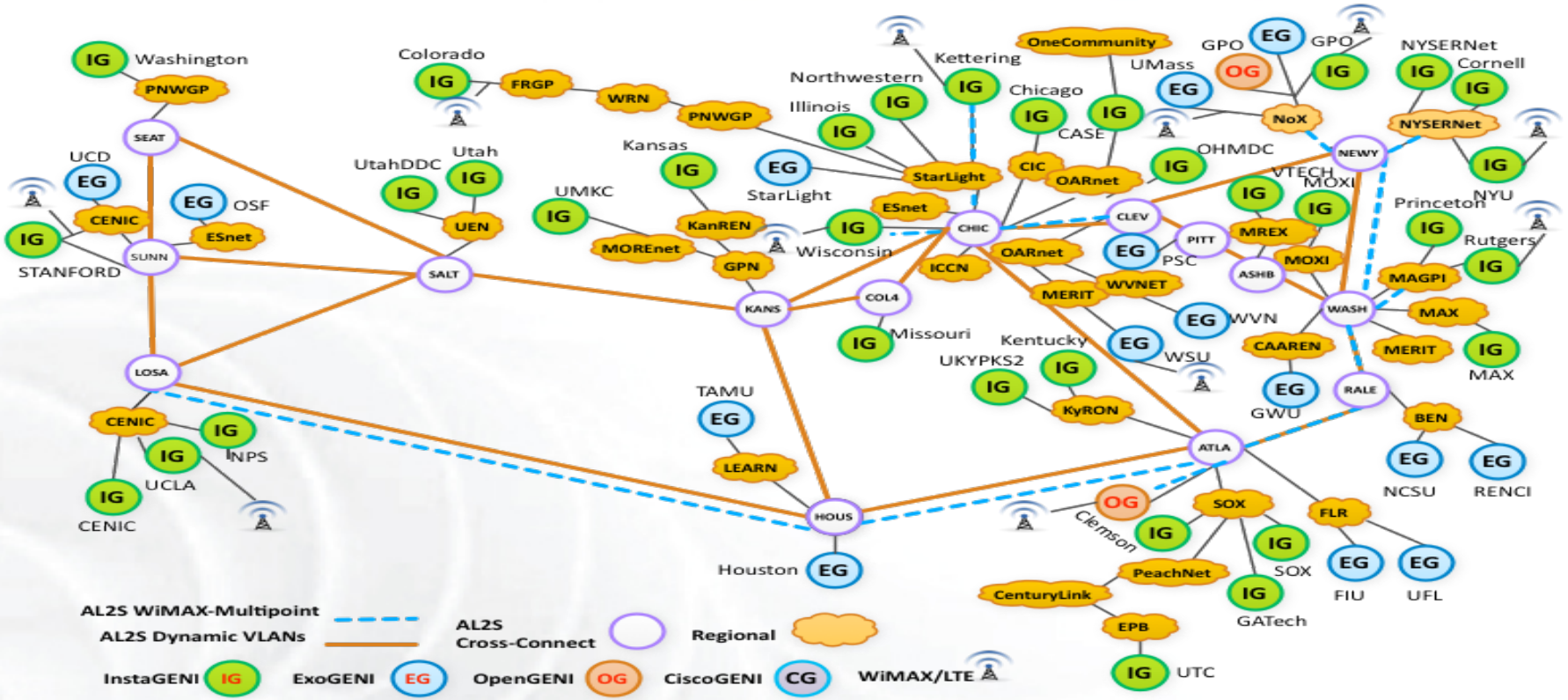
PI(s): Dipankar RayChoudhuri, Ivan Seskar, Wade Trappe *(Rutgers University)*

GENI Network Architecture



- Flexible network / cloud research infrastructure
- Layer 2 VLANS and Access to Programmable Switches
- Distributed cloud (racks) for content caching, acceleration, etc.
- At Scale experimentation with deep programmability and network Isolation via Slices

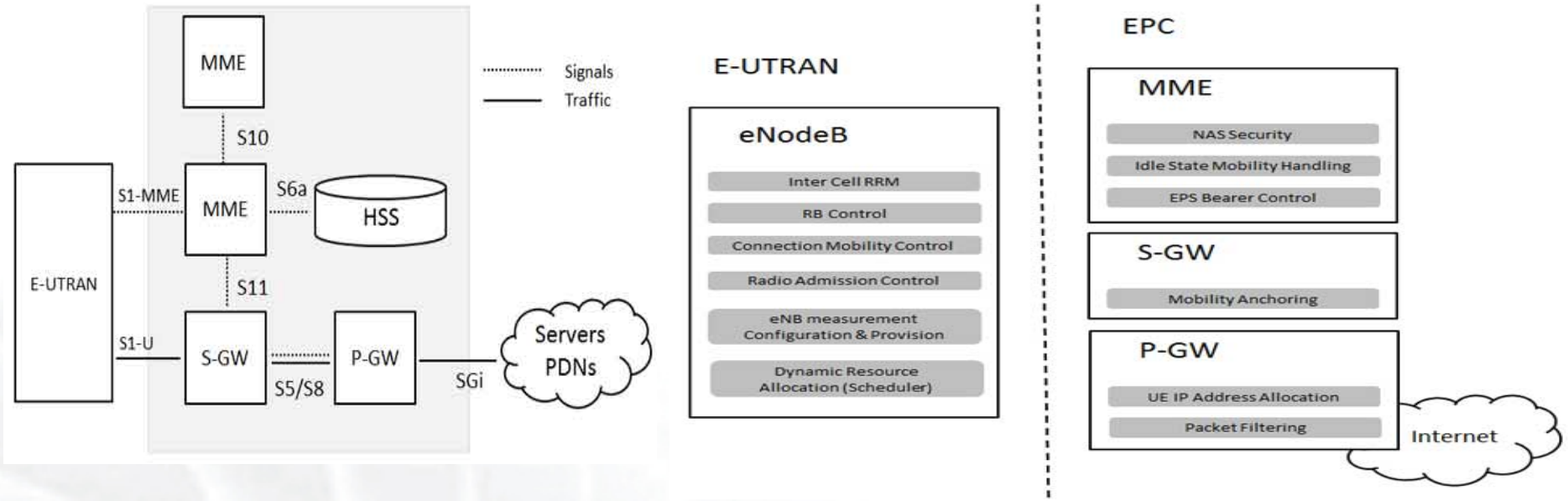
GENI Wireless 2016



- 26 Wimax + 10 LTE Base Stations in 13 Sites
- 90 android handsets available to experimenters
- 36 wireless (yellow) nodes

- Operation in 2.5-2.7GHz EBS spectrum.
- Sliced, virtualized and interconnected through AL2S/Internet2

Intro to Long Term Evolution (LTE)

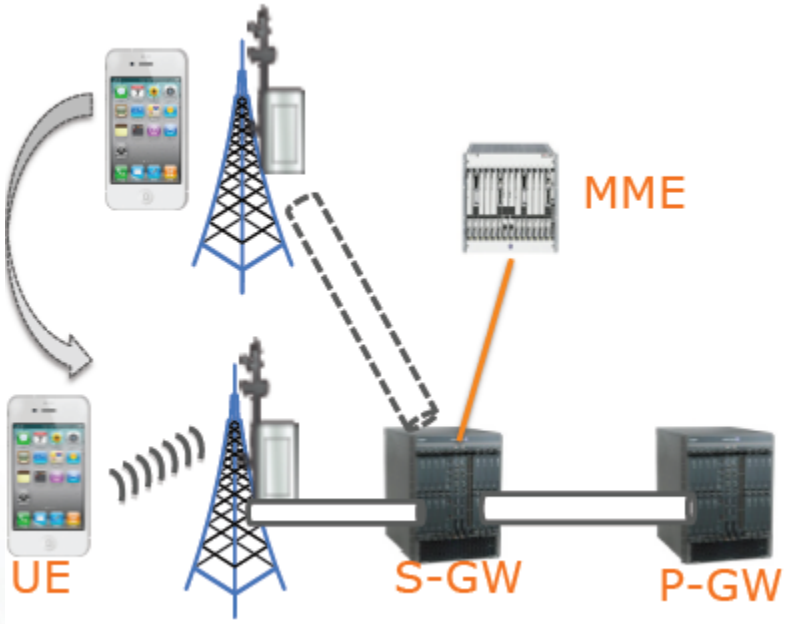


Components of a LTE Network:

- ✓ eNodeB: Evolved Node B
- ✓ EPC: Evolve Packet Core
- ✓ MME: Mobility Management Entity
- ✓ S-GW: Service Gateway
- ✓ P-GW: Packet Gateway
- ✓ HSS: Home Subscriber Server

Intro to LTE contd..

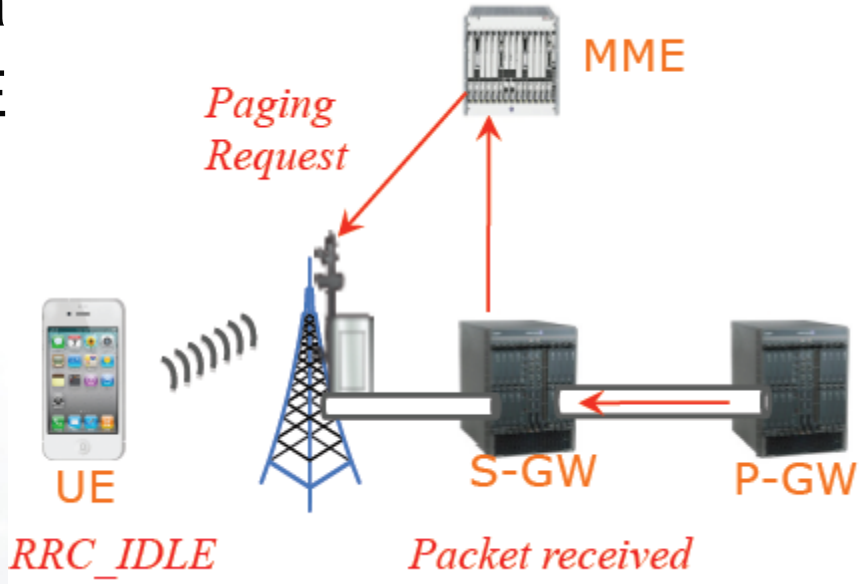
- Handoff without change of SP GW – (S1 handoff)
- Results in up to **33 control messages** in total across SGW, MME and eNBs.
- Handoff with change of S-GW or MME has more overhead



Source: "Rethinking Cellular architecture and Protocols for IoT Communication",KK Ramakrishan, Koushik Kar, Zubair Shafiq

Paging

- If S-GW receives a packet to a UE in IDLE state, inform MME
- MME pages UE through base station
- Results in **15 to 19 control messages** between S-P GW, MME and eNB



Source: "Rethinking Cellular architecture and Protocols for IoT Communication",KK Ramakrishan, Koushik Kar, Zubair Shafiq

Research Motivation

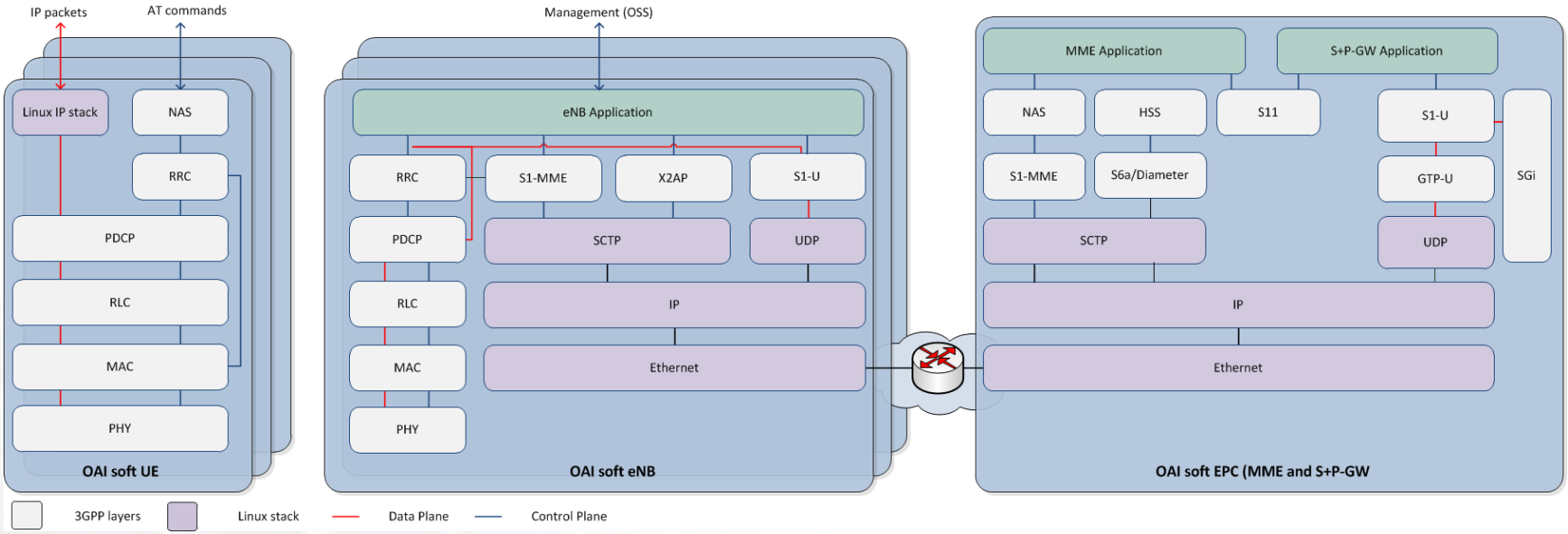
- Deploy GENI Network slicing concepts in EPC by setting up OpenVswitch to map different client GTP (uplink/downlink) tunnel pair to VLAN(s).

- Experimentation with next generation cellular and core network systems (5G,Mobile SDN, Cloud-RAN, Virtualized EPC)

- Provide a campus kit for ~$20K for turnkey access to LTE technology.

- Strip S-x's protocol overhead from user plane.

Open Air Interface (OAI) platform

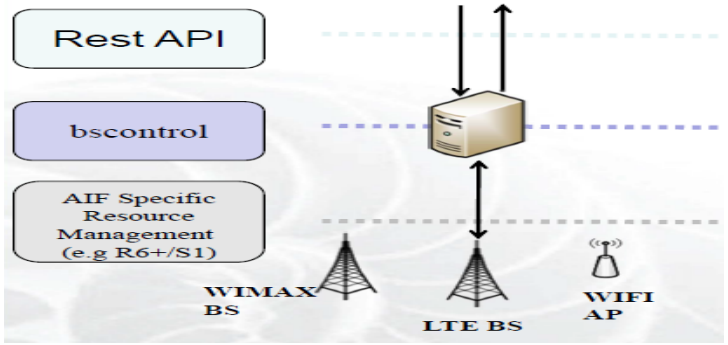


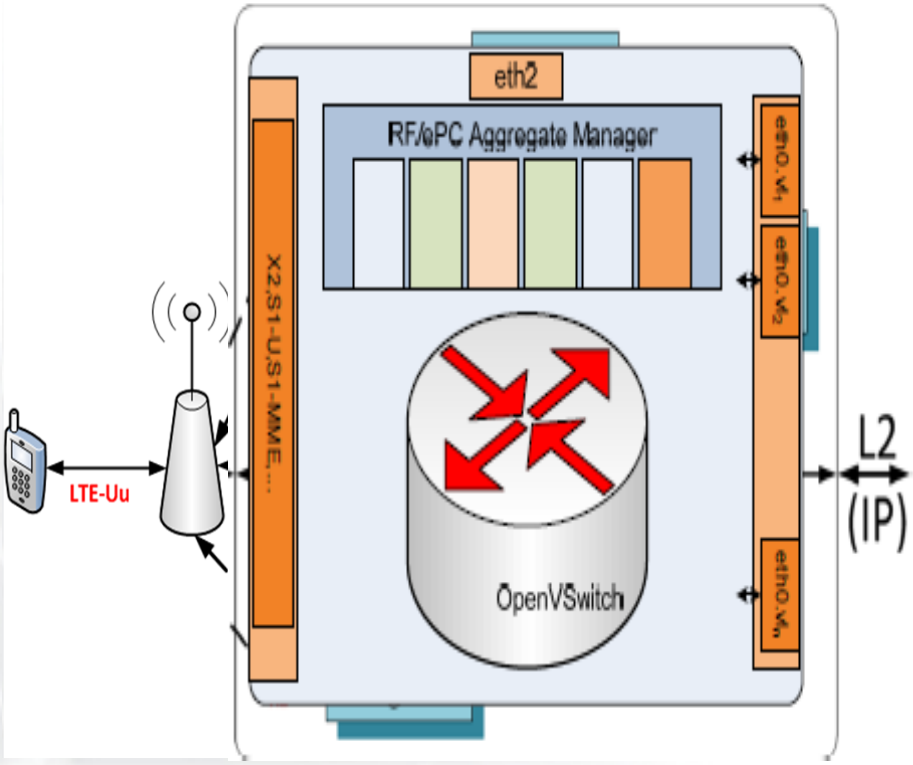
- Commercial UE OAI eNB + Commercial EPC *
- Commercial UE OAI eNB + OAI EPC *
- Commercial UE Commercial eNB + OAI EPC *
- OAI UE Commercial eNB + OAI EPC *
- OAI UE Commercial eNB + Commercial EPC *
- OAI UE OAI eNB + Commercial EPC
- OAI UE OAI eNB + OAI EPC

Courtesy: Navid Nikaein, Eurecom/Open Air Interface

Slicing a LTE Network

- Bscontrol GENI Aggregate Manager(AM) interfaces L2 VLAN(s) with GTP Tunnel on datapath.
- Implementation using OpenVswitch.
- Northbound REST API based to expose control parameters to experimenters.





4G Base Station Hardware

AirHarmony

Located closer to the end user, providing much higher aggregate data rates

TDD LTE

Max Transmit Power: 30 dBm per Tx

2 x 2 MIMO:

Operational Frequency Bands:

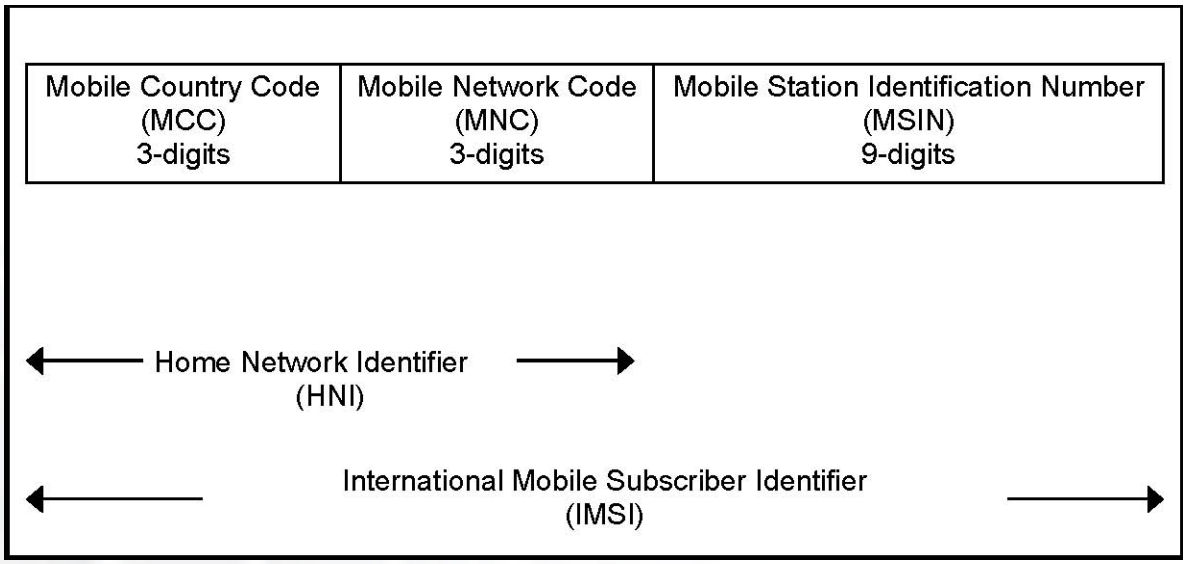
7 and 41 (2.6 GHz),12, 13, 14 and 17 (700 MHz), 20 (800 MHz), 40 (2.3-2.4 GHz), 42 and 43 (3.4-3.8 GHz)

LG Nexus 5, Samsung Galaxy S4
Android 5, AT commands
Test SIM

USB Dongles

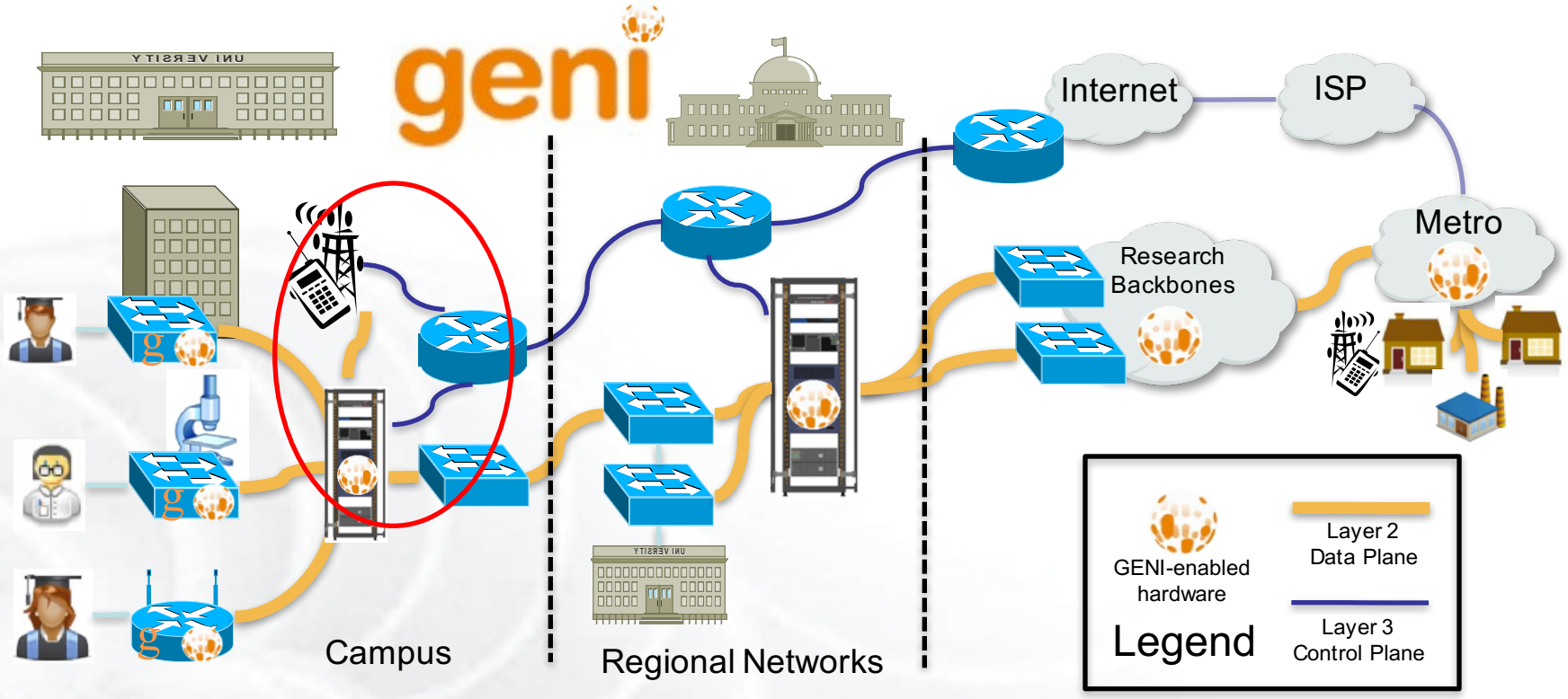
Netgear 341U, Sierra Wireless, Greenpacket LTE CPE
Linux Driver
Test SIM

GENI LTE HNI



- ✓ IMSI used for determination of the mobile terminals home network
- ✓ Filed application with imsiadmin to issue GENI wide HNI code for all sites.
- ✓ HNI will be configured in central EPC Instance.
- ✓ Client SIM devices will connect to this code.

GENI Network Architecture



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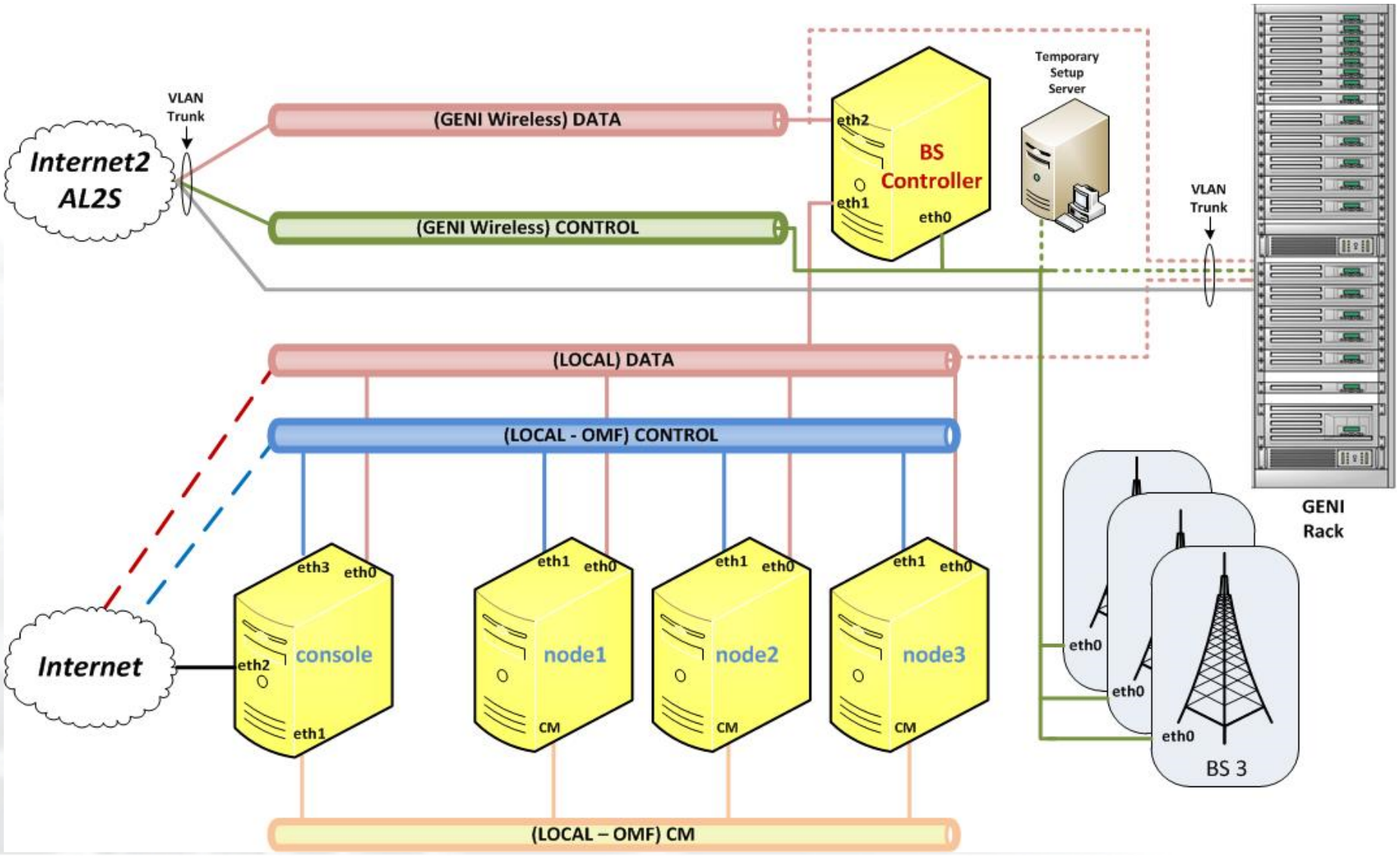
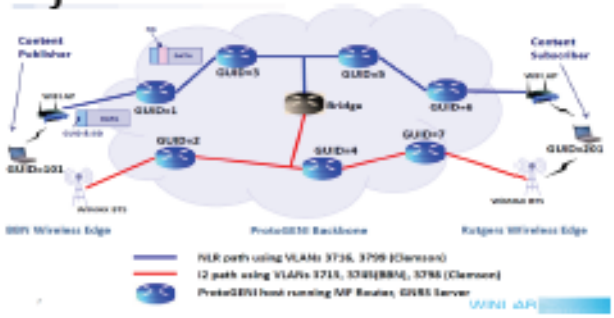
LTE Campus deployment

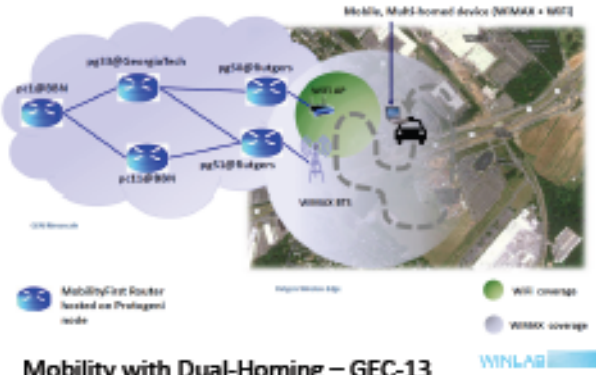


MobilityFirst on GENI: Selected Experiments

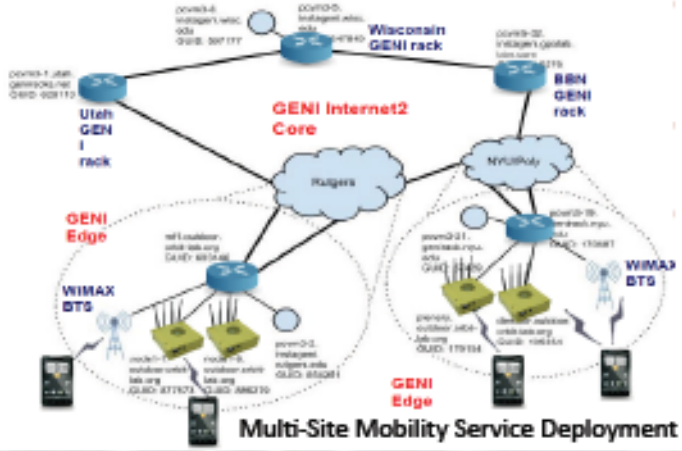
- GENI has been an integral part of MF evaluation methodology since the project started in 2010 ….



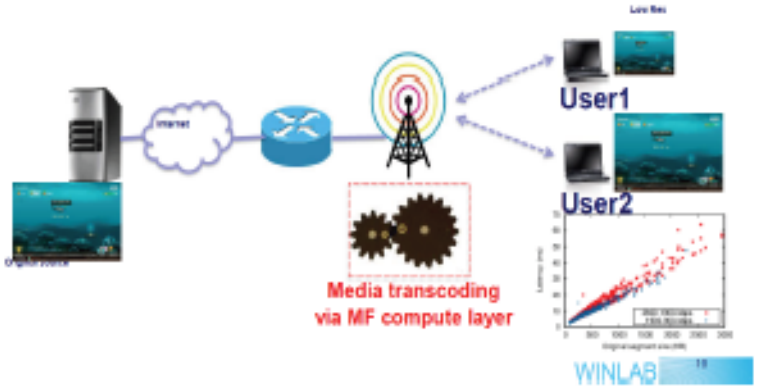
Content Delivery Scenario – GEC-12



Mobility with Dual-Homing – GEC-13



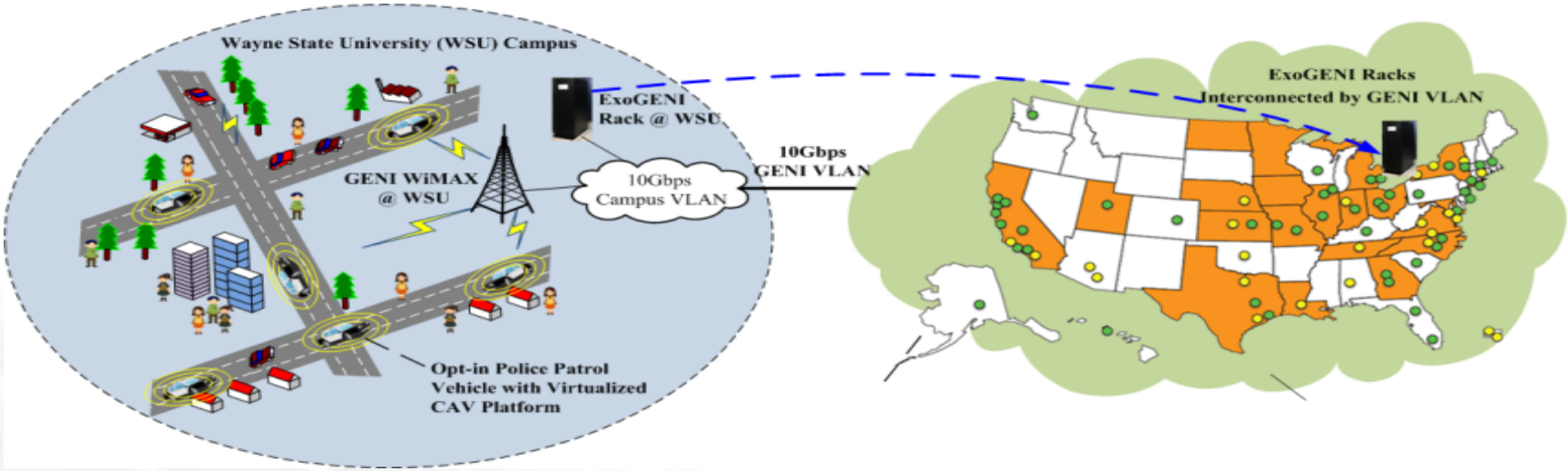
Multi-Site Mobility Service Deployment – GEC-19



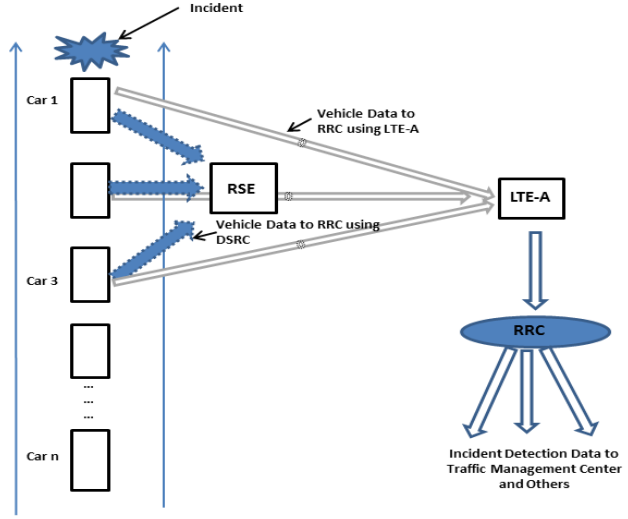
Video Delivery with In-Network Transcoding– GEC-21

* Dipankar Raychoudhuri, Rutgers Univ.

Application and Experiments

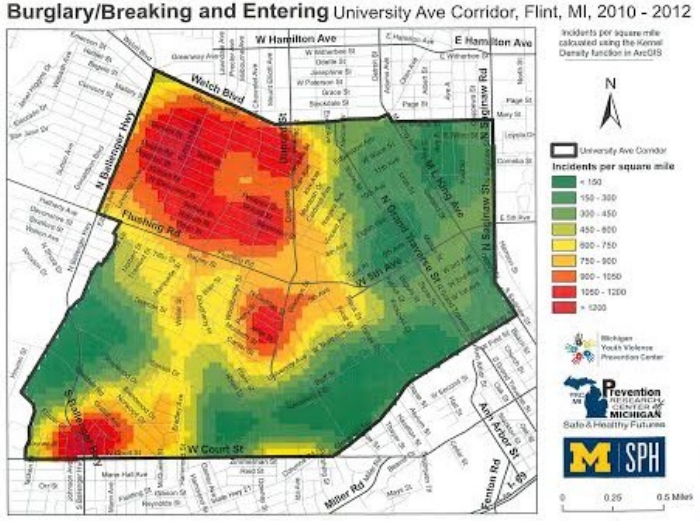


* Hongwei Zhang, Wayne State University



*John Geske and Yunsheng Wang, Kettering University

* Jim Martin and K.C. Wang, Clemson University



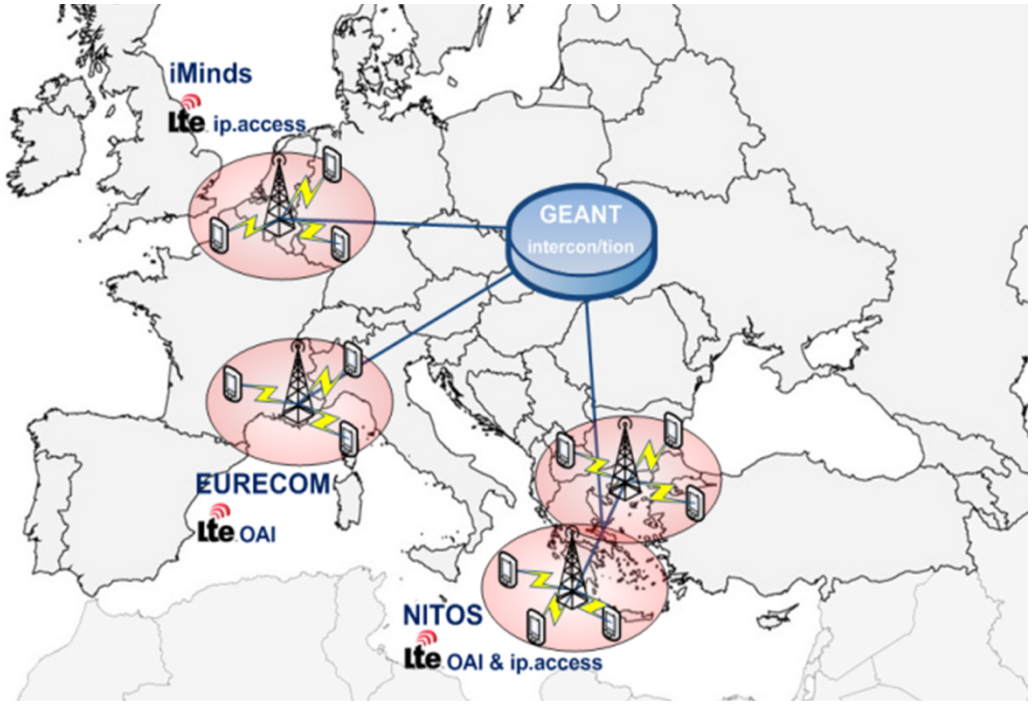
QUESTIONS

Tutorial

- http://witestlab.poly.edu/respond/sites/genitutorial/

FLEX: FIRE LTE testbeds for open experimentation

- Open and highly configurable LTE platforms
- Interaction of the user with the real 4G world.
- Commercial and Open Source equipment



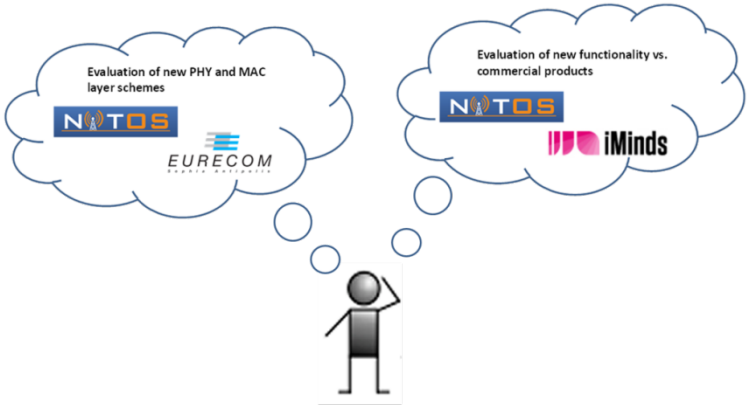
Courtesy: FLEX Consortium

FLEX contribution

- Two operational LTE testbeds:
  - Setup 1: Based on commercial equipment
    - SIRRAN EPC
    - ip.access cellular equipment
    - commercial UE
  - Setup 2: Open Source components
    - OpenAirInterface core network
    - OpenAirInterface eNodeB
    - OpenAirInterface/commercial UE
- ENodeB's, EPC and UE fully integrated with control and management frameworks

Types of Supported Experiments

Indicative experiments for Setup 1	Indicative experiments for Setup 2
Comparison of a new LTE functionality with the commercial approach. Conducting measurements in an urban environment (macro-cells) or in an indoor setup (pico-cells) of a commercial LTE setup. Experimentation with handoffs between macro-cells, pico-cells or small-cells or heterogeneous handovers between cells of different levels (e.g., macro to pico). Experiments with real mobility in a commercial setup in an every day's basis (e.g., monitoring the behavior of a multimedia application that runs on Android phones that are carried by volunteers around the campus).	Experimentation with new PHY layer schemes in LTE that will be implemented from scratch. Evaluation and testing of new scheduling algorithms on the MAC layer of the LTE eNodeBs. Implementation and evaluation of cooperative networking schemes in LTE (where end-users can be packet forwarders between the eNodeBs and other end-users). Evaluation and testing of new rate adaptation algorithms in the MAC layer of LTE.



Courtesy: FLEX Consortium

Open Air Interface (OAI)

- OpenAirInterface.org today and Ecosystem
- Open-source for 5G
- Software Alliance
  - Membership
  - License
  - Strategic member areas

Hardware Platforms **Software Platforms** **LTE in a PC**

EURECOM

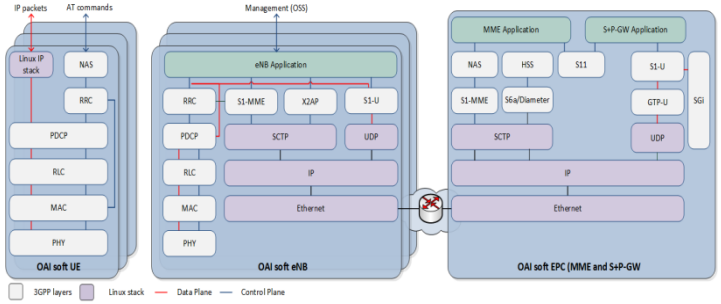
NATIONAL INSTRUMENTS

Ettus Research

Lime microsystems

MYRIAD RF

RUTGERS



Courtesy: Navid Nikaein, Eurecom/Open Air Interface

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OAI Ecosystem (current mailing list)

Europe

ALU (Villarceaux) - Industry ****
Thales (Colombes) - Industry *
Air-Lynx (Velizy) - Industry **
IFFSTAR (Lille) - Research
UBO (Brest) - Research *
Orange (Issy-les-Moulineaux) - Industry

Fraunhofer Erlanagen (Germany) - Research
Fraunhofer Munich (Germany) - Research
TU Berlin (Germany) - Research **
IMST (Kamp-Lintfort, Germany) - Research **
Nat. Inst (Dresden, Germany) - Industry **

TNO (Holland) - Research ***
KCL (UK) - Research **
IMINDS (Belgium) - Research
UMalaga (Malaga, Spain) - Research *
CERTH (Greece) - Research *
IASA (Greece) - Research *
Inov (Portugal) - Research *
NSN (Poland) - Industry *
"some guy called Iardella" (Italy) - Research *

Asia

Kaist (Korea) - Research
KHU (Korea) - Research*
Malaysia Telecom (Malaysia) - Industry
TCS (India) - Industry *
IIT Madras (India) - Research*
IIT Hyderabad (India) - Research*
BUPT (Beijing, China) - Research
Geeflex (China) - Industry **
China Mobile (China) - Industry ****
Keysight (ex Agilent), (China) - Industry ****
CASIA (China) - Research
Various undisclosed institutions (China) -Research/Industry **

North America

Univ. Michigan (Ann Arbour, USA) - Research*
Nat. Inst/Ettus (support, USA) - Industry **
Intel (Oregon, USA) – Industry **
Rutgers Univ. (Rutgers New Jersey, USA) - Research
ALU (Murray Hill - USA) - Industry **
Idaho National Laboratory (USA) – Research**

OAI Soft eNB and UE

- Challenge : efficient base band unit
- OpenAirInterface 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

5G Wireless: Technical Challenges

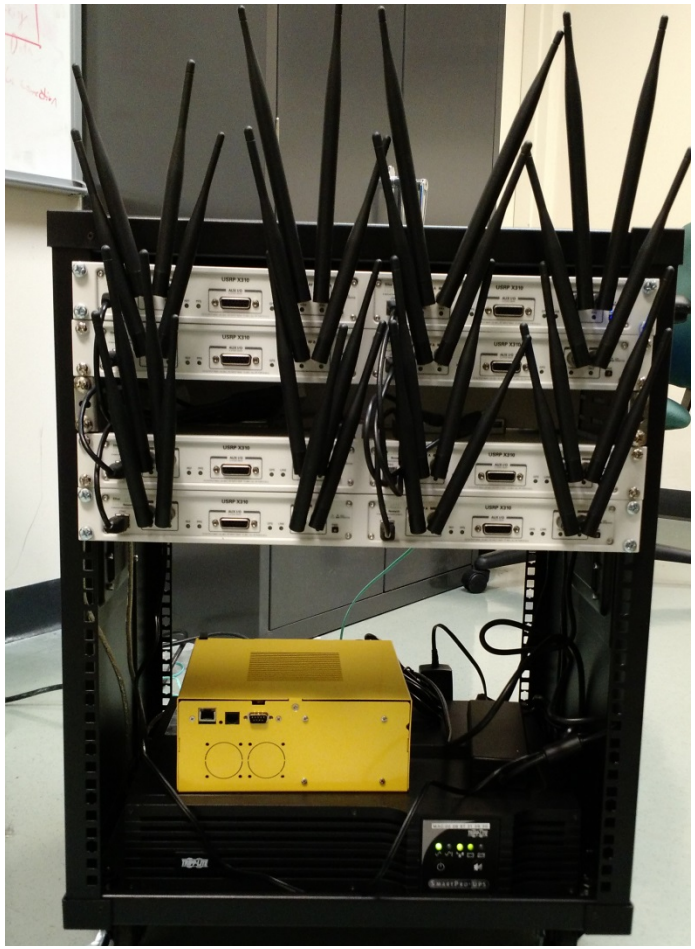
Faster Cellular Radios Access ~1-10 Gbps ~1000x capacity	Low-Latency/ Low-Power Access Network For Real-Time IoT	New Spectrum & Dynamic Spectrum Access	Next-Gen Mobile Network
Wideband PHY	Custom PHY for IoT	60 Ghz & other new bands	Mobile network redesign
Cloud RAN arch	New MAC protocols	New unlicensed/shared spectrum	Convergence with Internet
Massive MIMO	RAN redesign	Dynamic spectrum access	Clean-slate Mobile Internet
mmWave (60 Ghz)	Light-weight control	Spectrum sharing techniques	Software Defined Networks
Multi-Radio access	Control/data separation	Non-contiguous spectrum	Open wireless network APIs
HetNet (+WiFi, etc.)	Network protocol redesign	Network/DB coordination methods	Cloud services & computing
…	….	….	Edge cloud/fog computing
			Virtualization, NFV

OBRIT Extension: Current

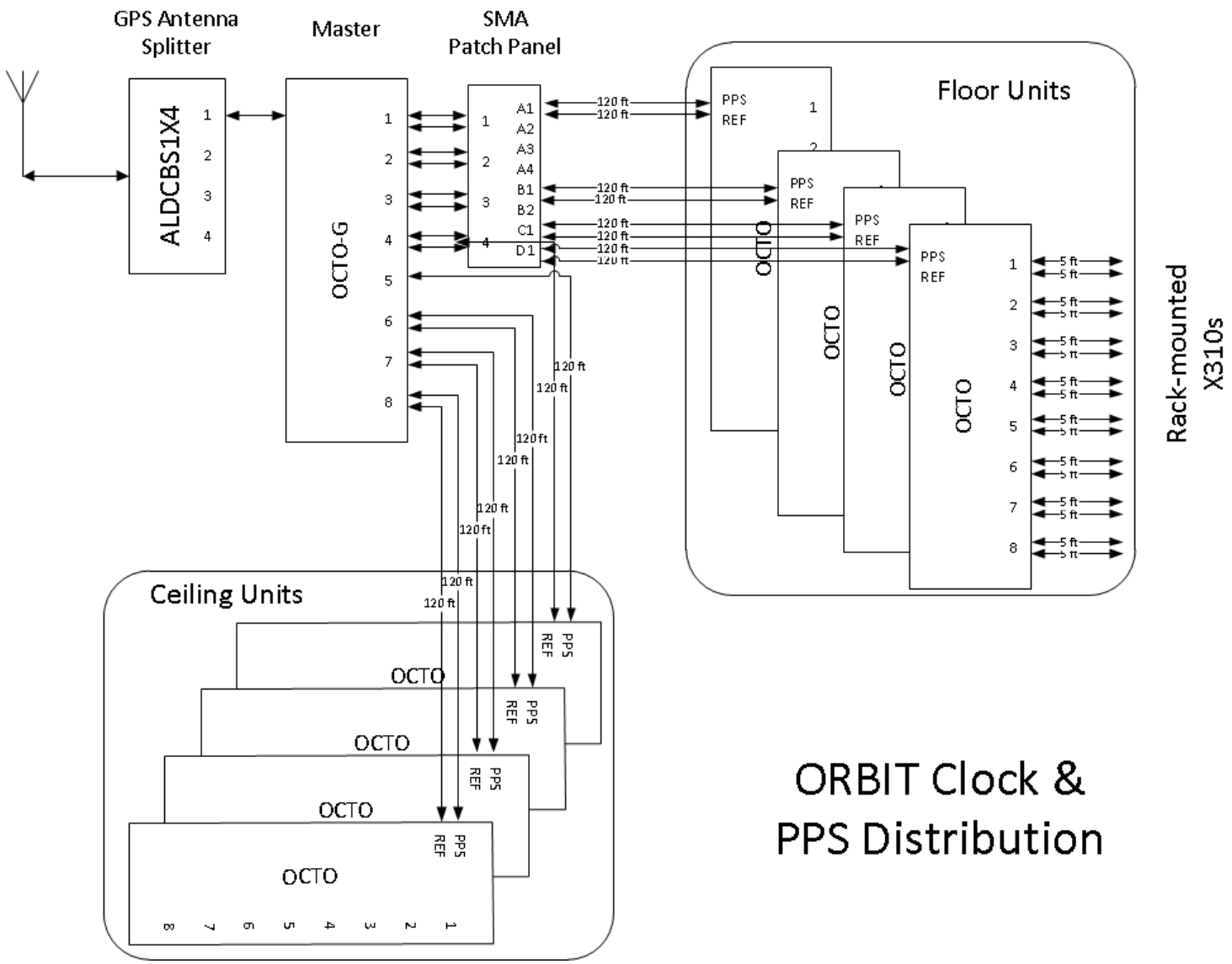
- 40 USRP X310s
  - Available FPGA resources:

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

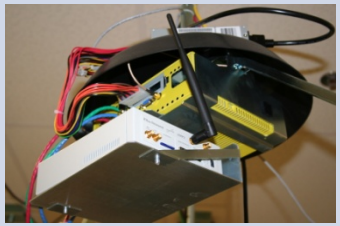
  - RF 2 x UBX-160 (10 MHz - 6 GHz RF, 160 MHz BB BW)
  - 2 x 10G Ethernet for fronthaul/interconnect
  - Four corner movable mini-racks (4 x 20 x 20 -> 1 x 80 x 80)
- > 500+ GPP Cores/CloudLab Rack (?)
- Number of GPU platforms
- 32x40G SDN aggregation switch



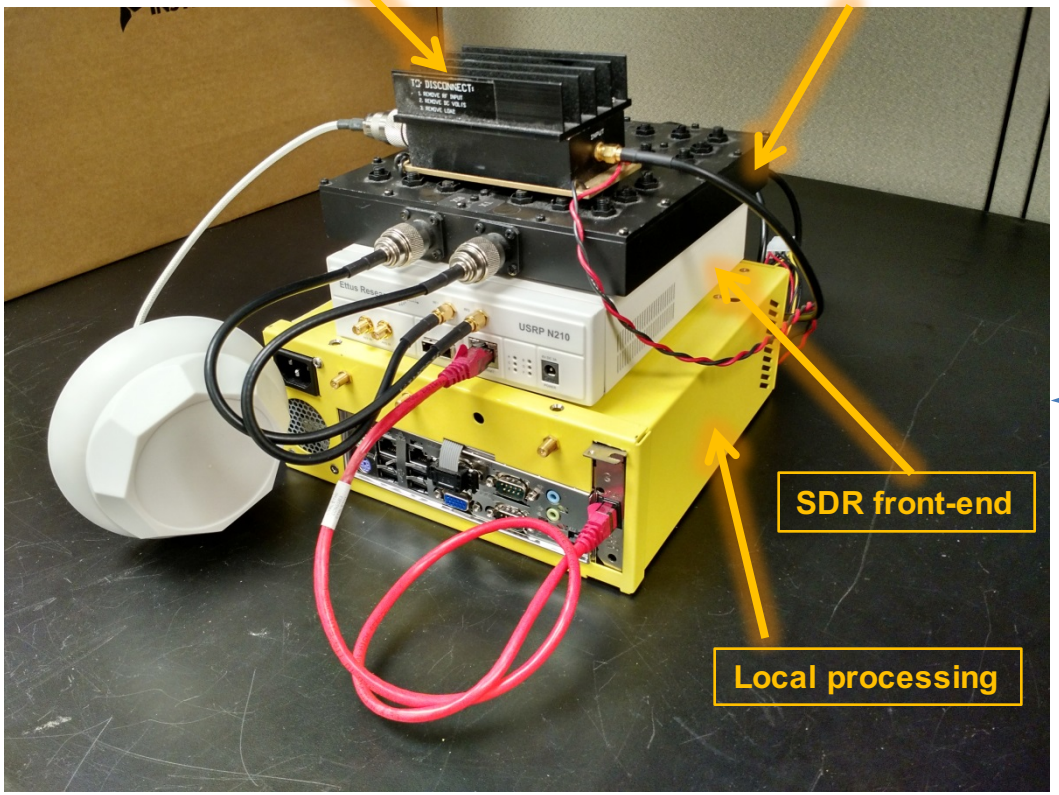
OBRIT Extension: Clock Distribution

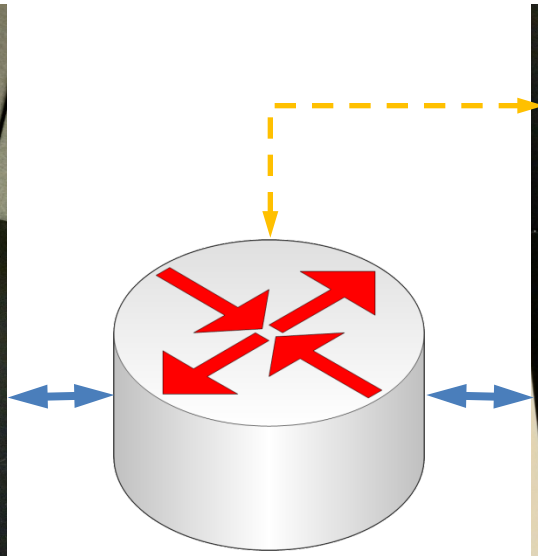


LTE eNodeB (BS) Platforms

Ip.access	Amarisoft (USRP)	OAI (USRP)	Airpsan
			**AirSynergy / Air 4G**
Rel 8.9	Rel 10,12	Rel 8.6,10	Rel 10 (upgreadable)
FDD	FDD/TDD	FDD/TDD	TDD/(FDD)
10MHz	20 MHz	10 MHz	20 MHz
2 x 10 dBm	10 dBm (2 x 10 dBm)	10 dBm (4 x 30 dBm)	2 x 37 dBm (2 x 40 dBm)
13 Mbps	BW limited	20 Mbps	300 Mbps
4 (max idle 64)	BW limited	5 (25)	> 100 (256)

Ideal GENI Wireless Unit





GENI Rack

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