ORBIT 10 Years Later

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Orbit Project Rationale

- Wireless testbeds motivated by:
  - cost & time needed to develop experimental prototypes
  - need for reproducible protocol evaluations
  - large-scale system studies (...emergent behavior)
  - growing importance of cross-layer protocol studies
  - creation of communities for wireless network research
- ORBIT: open-access multi-user facility for experimental wireless networking research primarily in unlicensed bands
  - ~24/7 service facility with remote access
  - open interfaces for flexible layer 2,3 & cross-layer protocols
  - extensive measurements at PHY, MAC and Net layers
  - support for wide range of radio system scenarios

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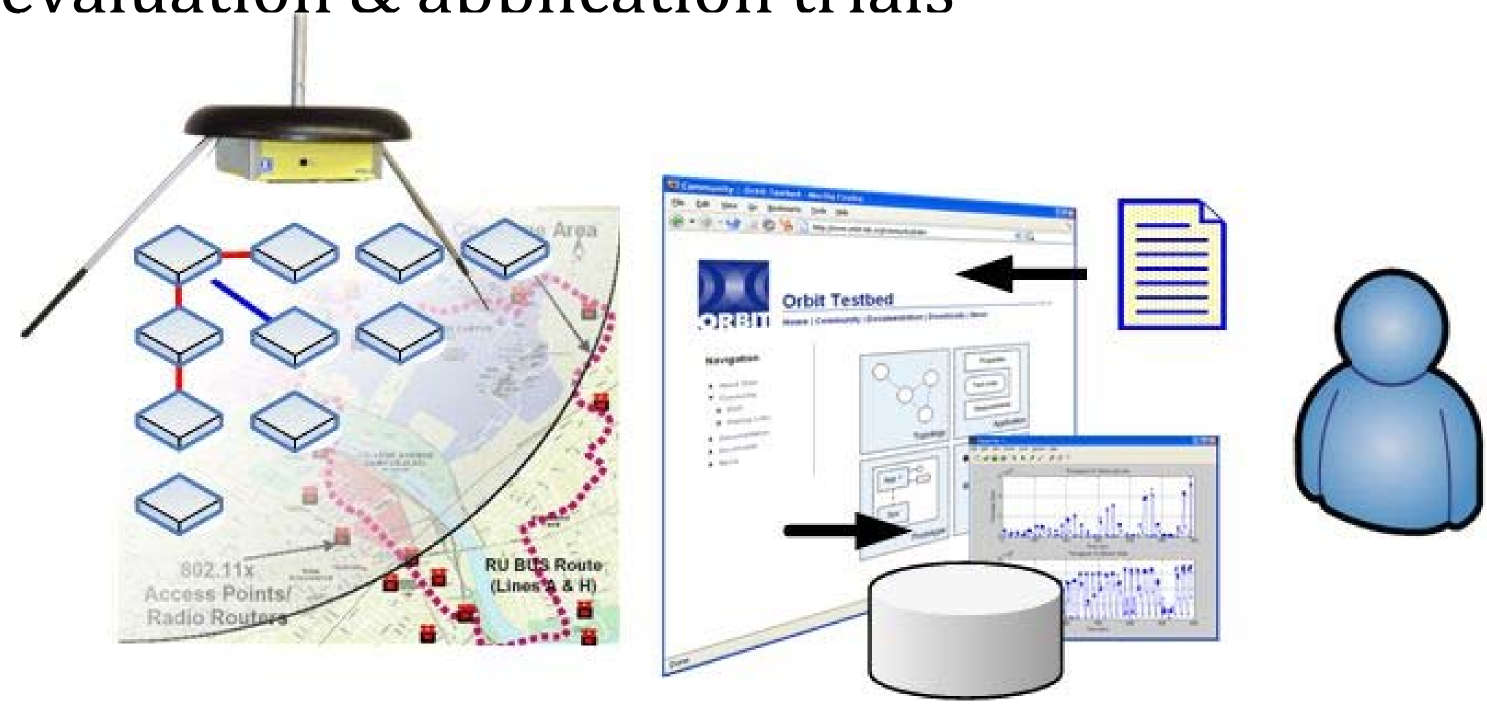
ORBIT: *Open Access Research Testbed for Next-Generation Wireless Networks*

- Proposal: Build radio grid emulator (phase I) and field trial network (phase II)
- Emulator used for detailed protocol evaluations in reproducible complex radio environments
- Field trial network for further real-world evaluation & application trials



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Original Orbit co-PI's

- **WINLAB, Rutgers University**
  - Dipankar Raychaudhuri
  - Ivan Seskar
  - Max Ott
  - Wade Trappe
  - Manish Parashar
  - Yanyong Zhang
- **Columbia University**
  - Henning Schulzrinne
- **Princeton University**
  - Hisashi Kobayashi
- **IBM Research**
  - Arup Acharya
- **Lucent Bell Labs**
  - Sanjoy Paul
- **Thomson**
  - Kumar Ramaswamy

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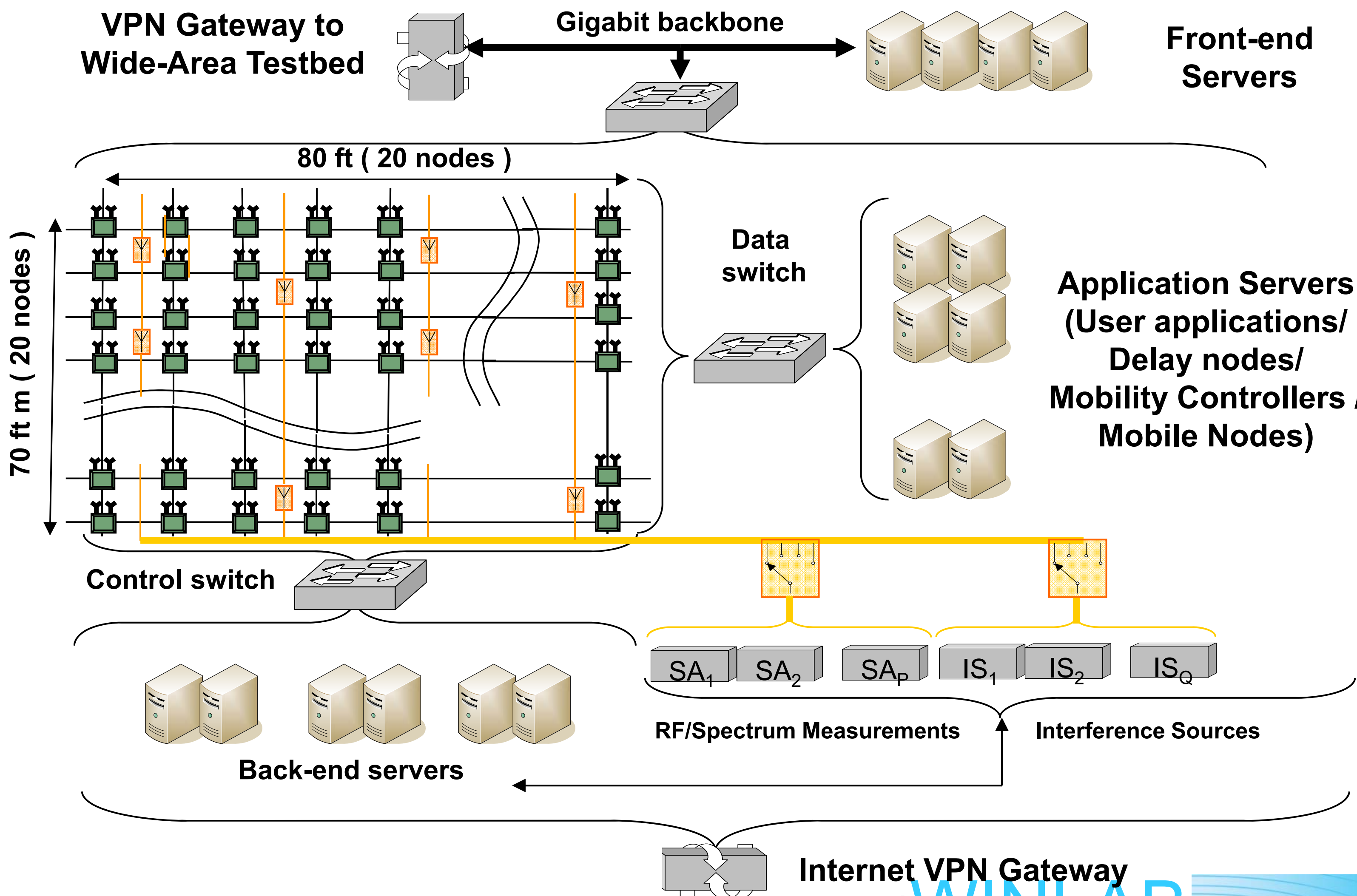
Orbit Hardware



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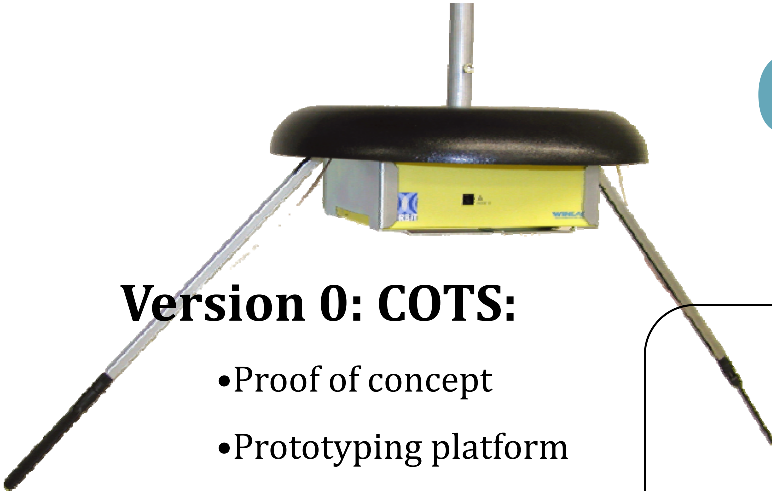
ORBIT Radio Node



Version 0: COTS:

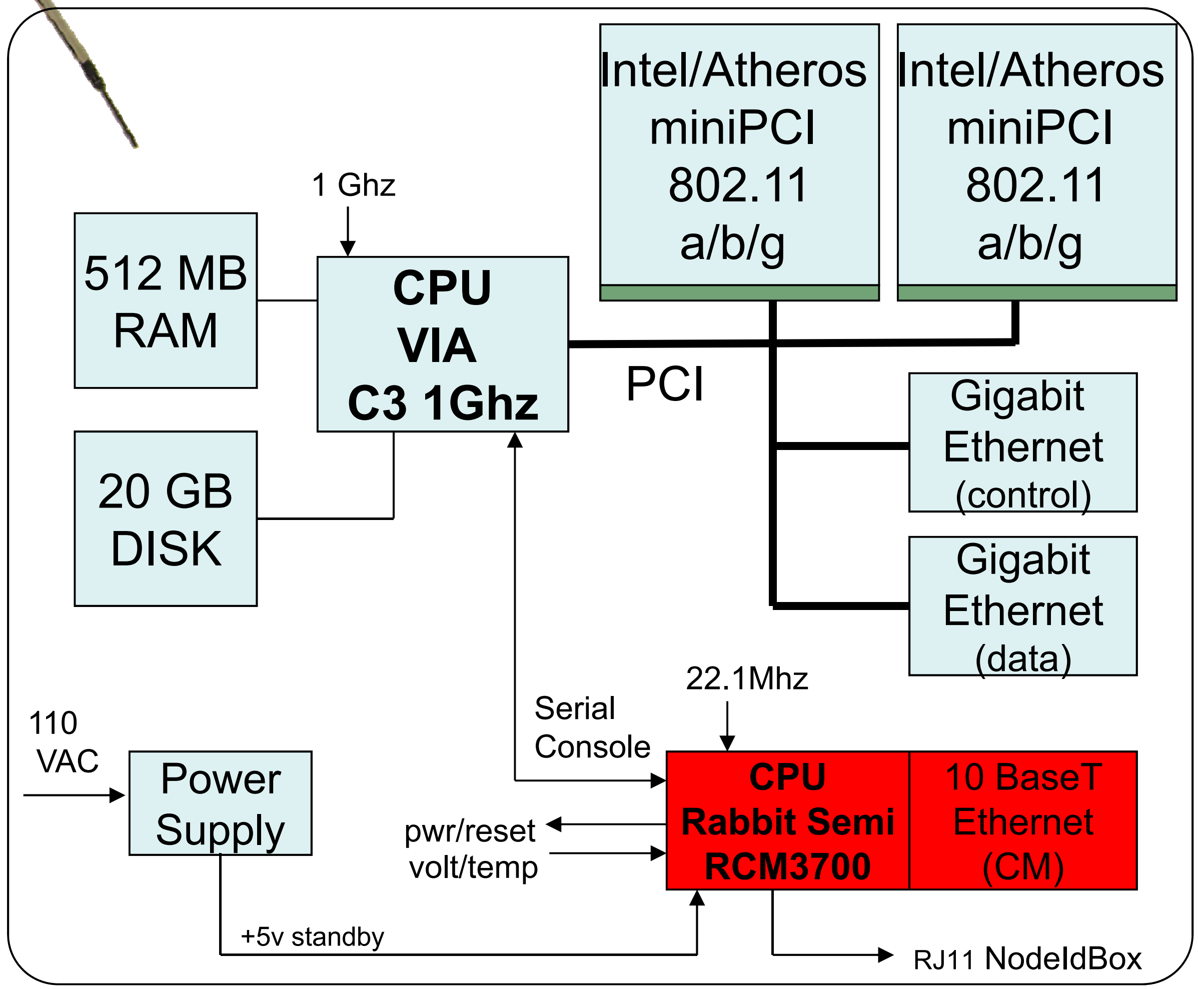
- Proof of concept
- Prototyping platform

Version 2: Custom design:

- Functional requirements
- Manageability
- Power consumption
- Cost

Other attached devices:

- Bluetooth
- ZigBee
- GNU Radio



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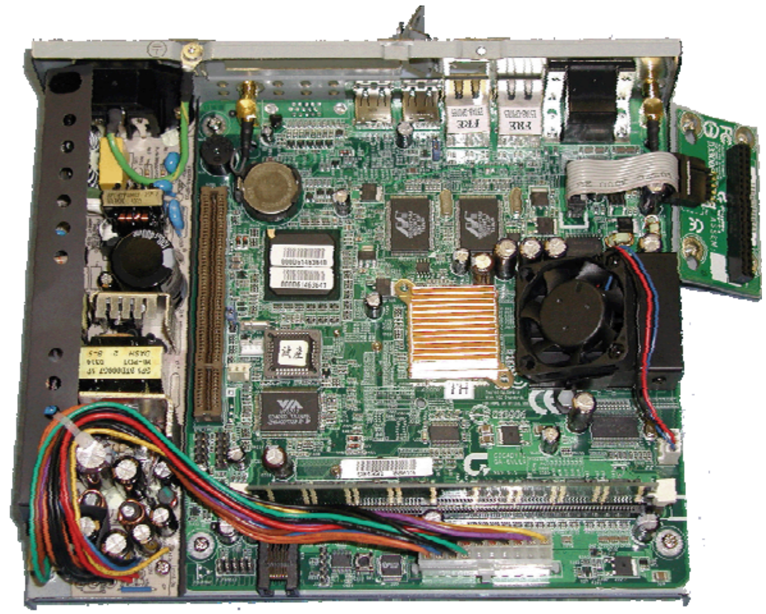
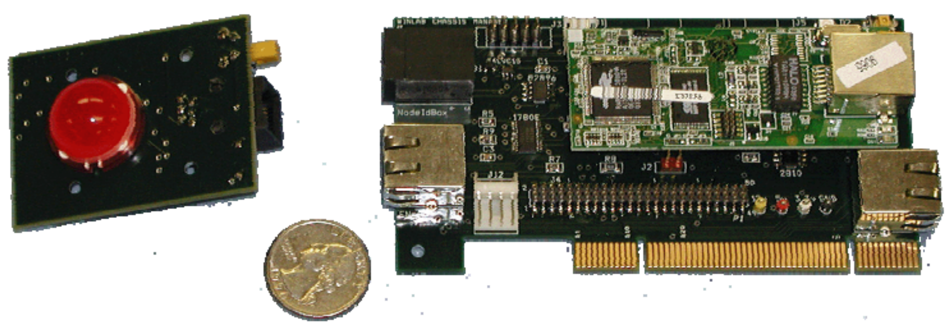
ORBIT Radio Node Photo Album



ORBIT Radio Node
with integrated Chassis Manager



Non-Grid Node
Chassis Manager

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Wireless Devices

802.11 a/b/g

802.11 n/AC

Bluetooth

ZigBee Motes

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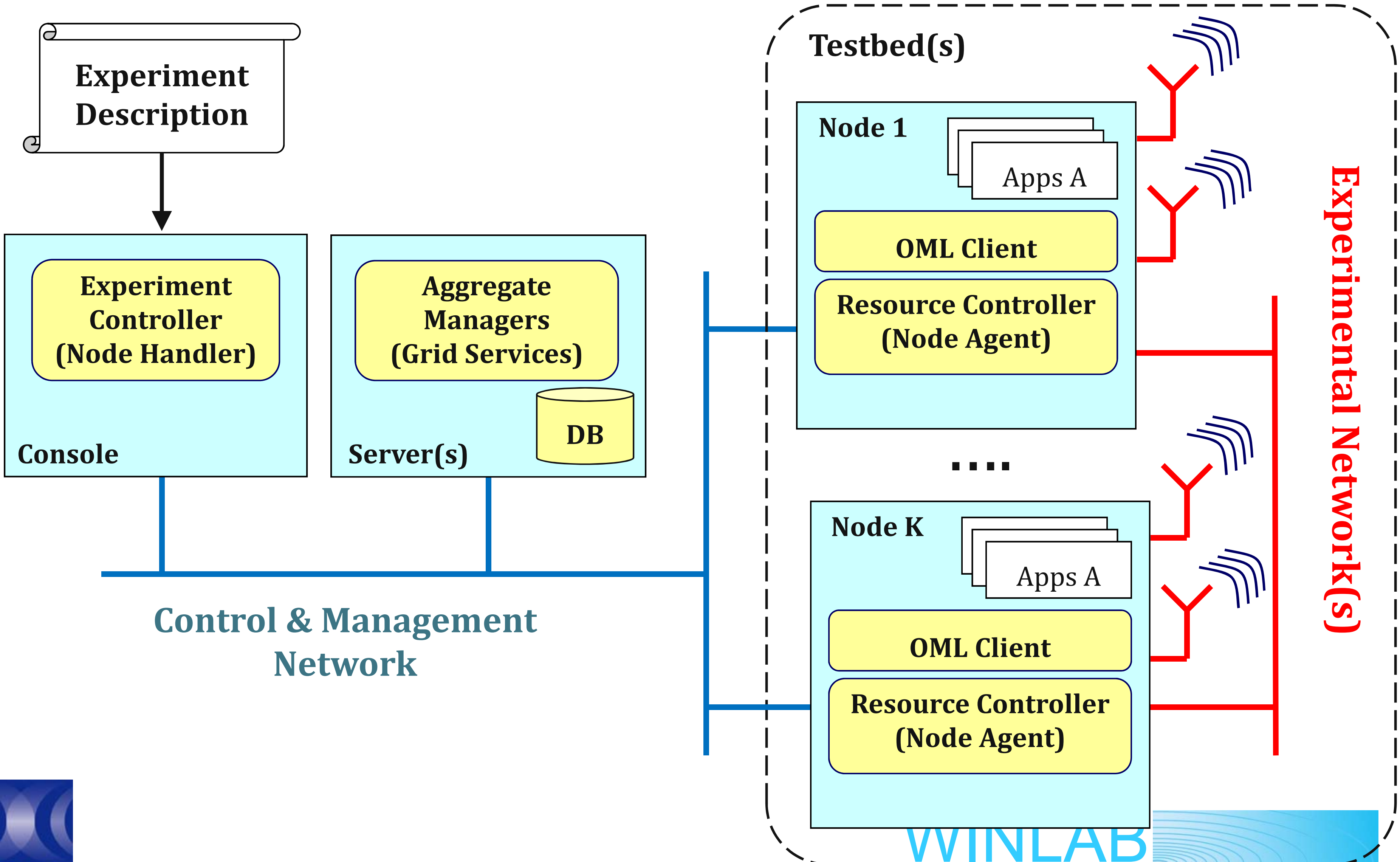
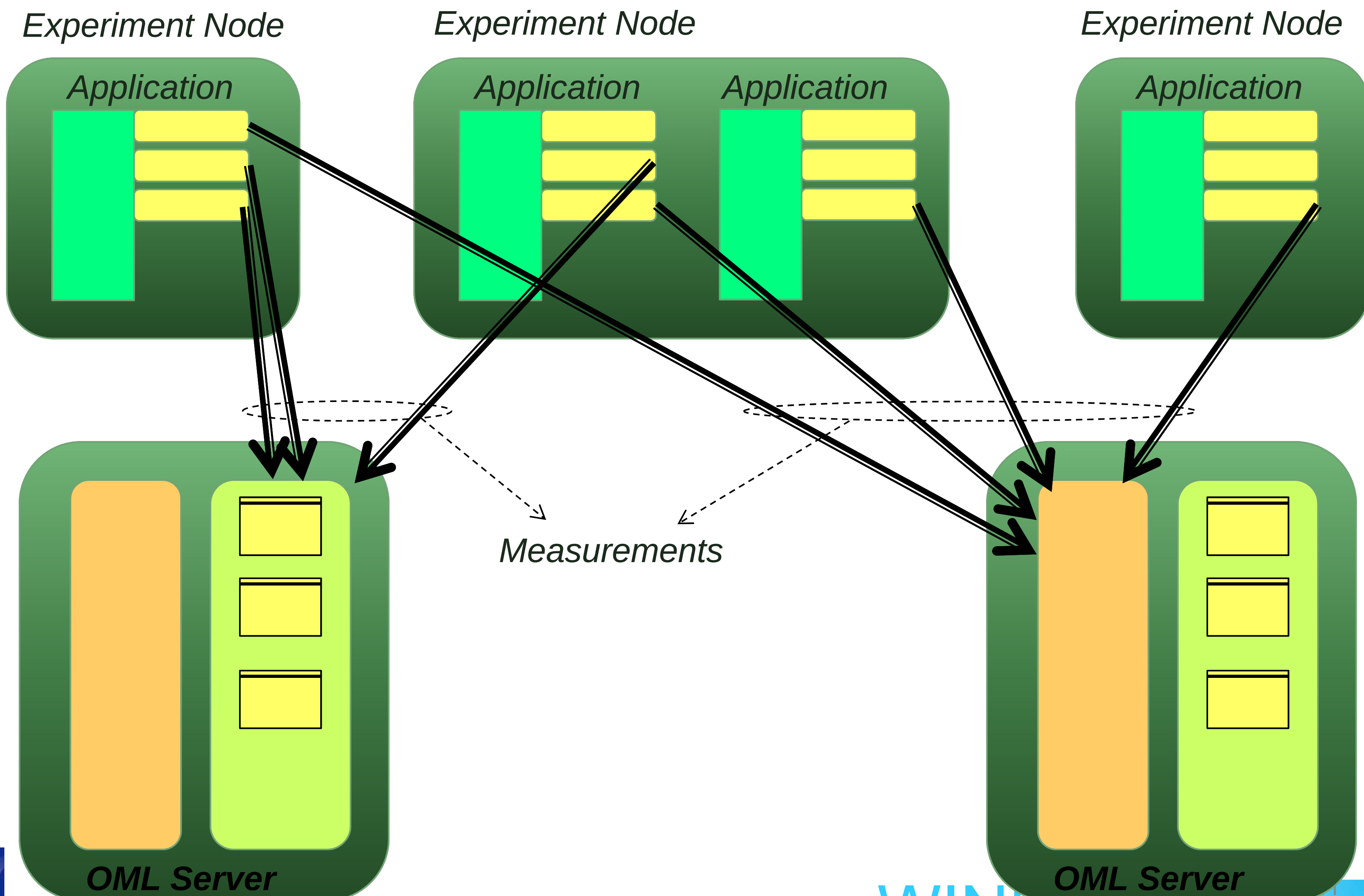
OMF - Experimenter View

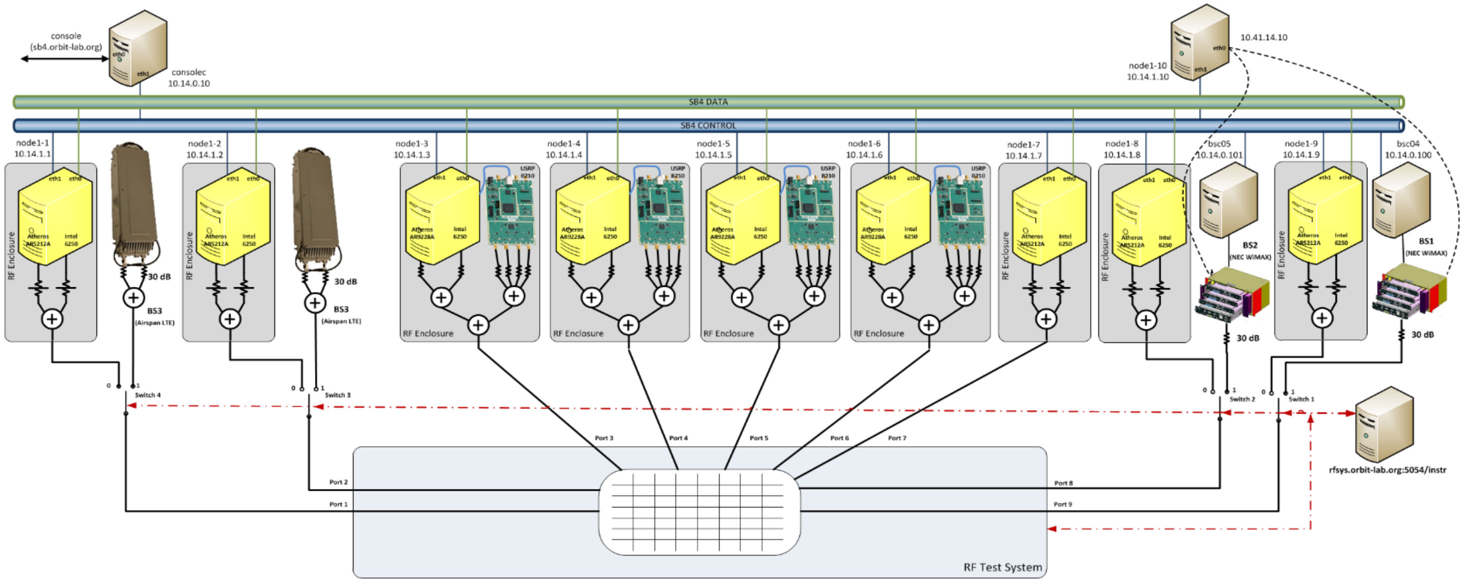


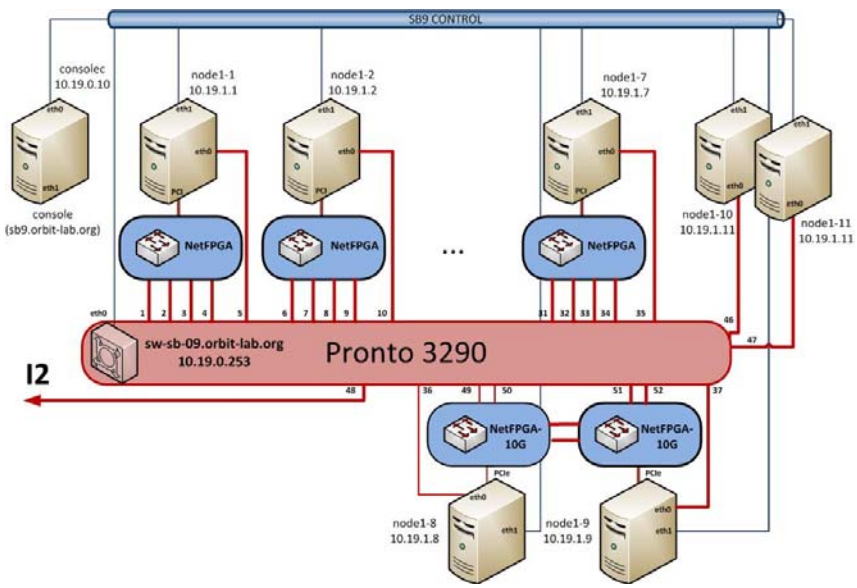
OML – Measurement Collection



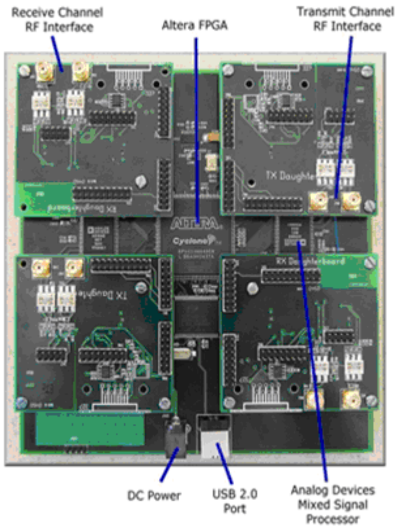
ORBIT Grid

Sandboxes: SB4 & SB9





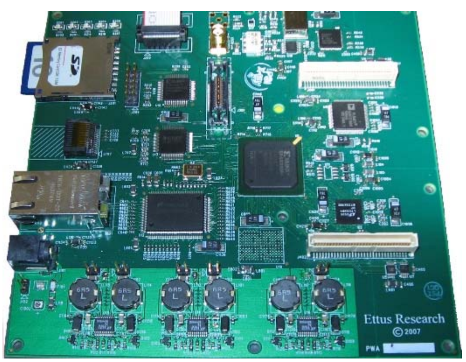
Cognitive Radio Platforms



USRP

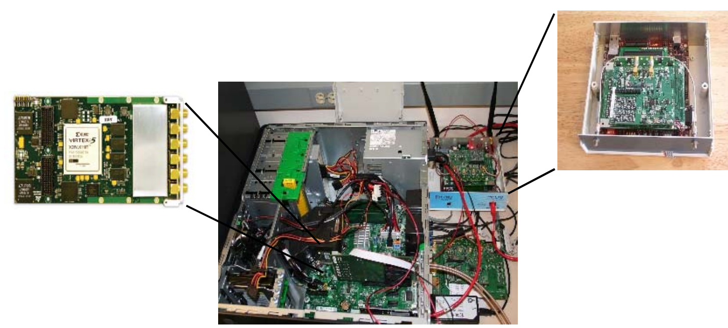

RICE WARP Platform


U. Of Colorado



USRP2


RST SDR System


WINLAB WINC2R System

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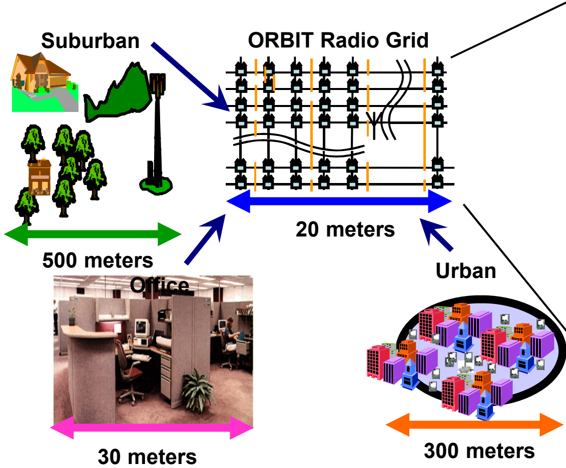
Cognitive Experiments at Scale (2008)

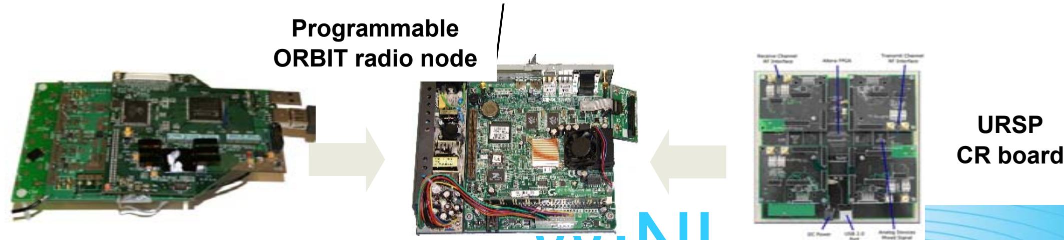
- ORBIT radio grid testbed currently supports ~22/USRP and USRP2 (GNU) radios, 100 low-cost spectrum sensors, WARP and WinC2R platforms
- Plan to reach ~64 cognitive radio nodes (Q2 2009)



Radio Mapping Concept for ORBIT Emulator

400-node Radio Grid Facility at WINLAB Tech Center

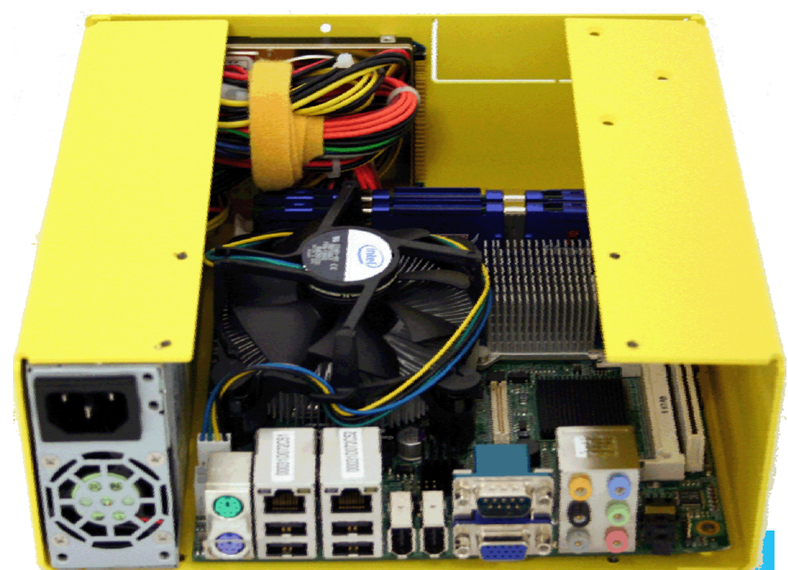
Current ORBIT sandbox with GNU radio



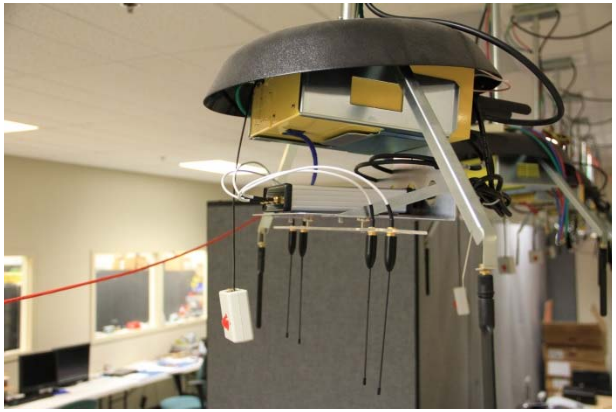
ORBIT Radio Node (Version 4)

- 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.



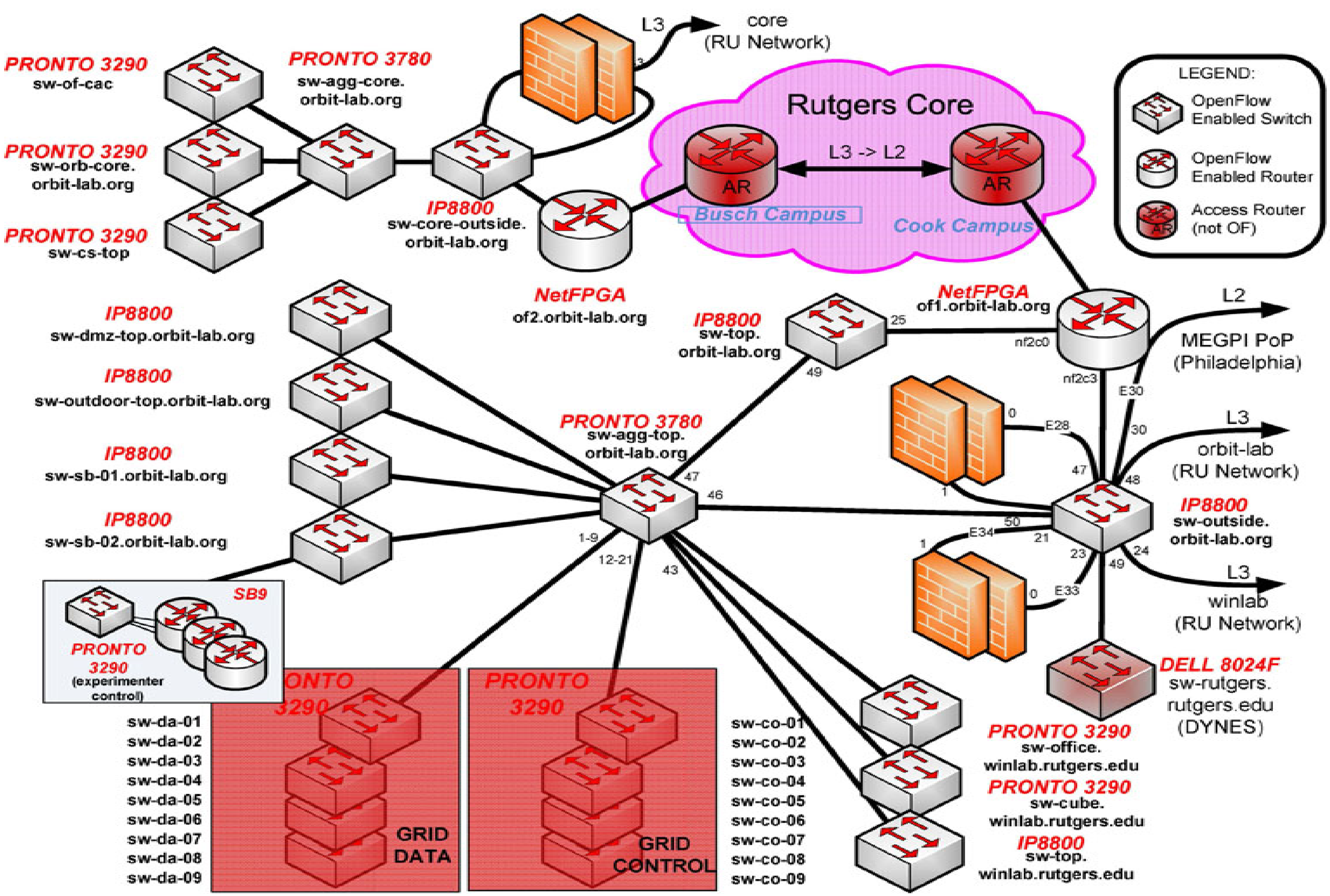
New SDR Devices: USRP B210 / USRP X310



- Xilinx Spartan-6 FPGA
- Dual channel AD9361 RFIC transceiver (70 MHz – 6 GHz with 56 MHz baseband)
- USB 3.0 connectivity

- Xilinx Kintex-7 FPGA (XC7K410T)
- 2 x 10 Gigabit Ethernet
- 1 x SBX RF Daughterboard (400-4400 MHz Rx/Tx with 120 MHz baseband)
- 1 x CBX RF Daughterboard (1200-6000 MHz Rx/Tx with 120 MHz baseband)

SDN (2010)



PRONTO 3290
sw-of-cac
PRONTO 3290
sw-orb-core.
orbit-lab.org
PRONTO 3290
sw-cs-top
PRONTO 3780
sw-agg-core.
orbit-lab.org
IP8800
sw-core-outside.
orbit-lab.org
L3
core
(RU Network)
Rutgers Core
L3 -> L2
AR
AR
Busch Campus
Cook Campus
LEGEND:
OpenFlow Enabled Switch
OpenFlow Enabled Router
Access Router (not OF)
NetFPGA
of2.orbit-lab.org
NetFPGA
of1.orbit-lab.org
IP8800
sw-top.
orbit-lab.org
L2
MEGPI PoP
(Philadelphia)
IP8800
sw-dmz-top.orbit-lab.org
IP8800
sw-outdoor-top.orbit-lab.org
IP8800
sw-sb-01.orbit-lab.org
IP8800
sw-sb-02.orbit-lab.org
PRONTO 3780
sw-agg-top.
orbit-lab.org
L3
orbit-lab
(RU Network)
IP8800
sw-outside.
orbit-lab.org
L3
winlab
(RU Network)
SB9
PRONTO
3290
(experimenter control)
PRONTO
3290
GRID
DATA
PRONTO
3290
GRID
CONTROL
sw-da-01
sw-da-02
sw-da-03
sw-da-04
sw-da-05
sw-da-06
sw-da-07
sw-da-08
sw-da-09
sw-co-01
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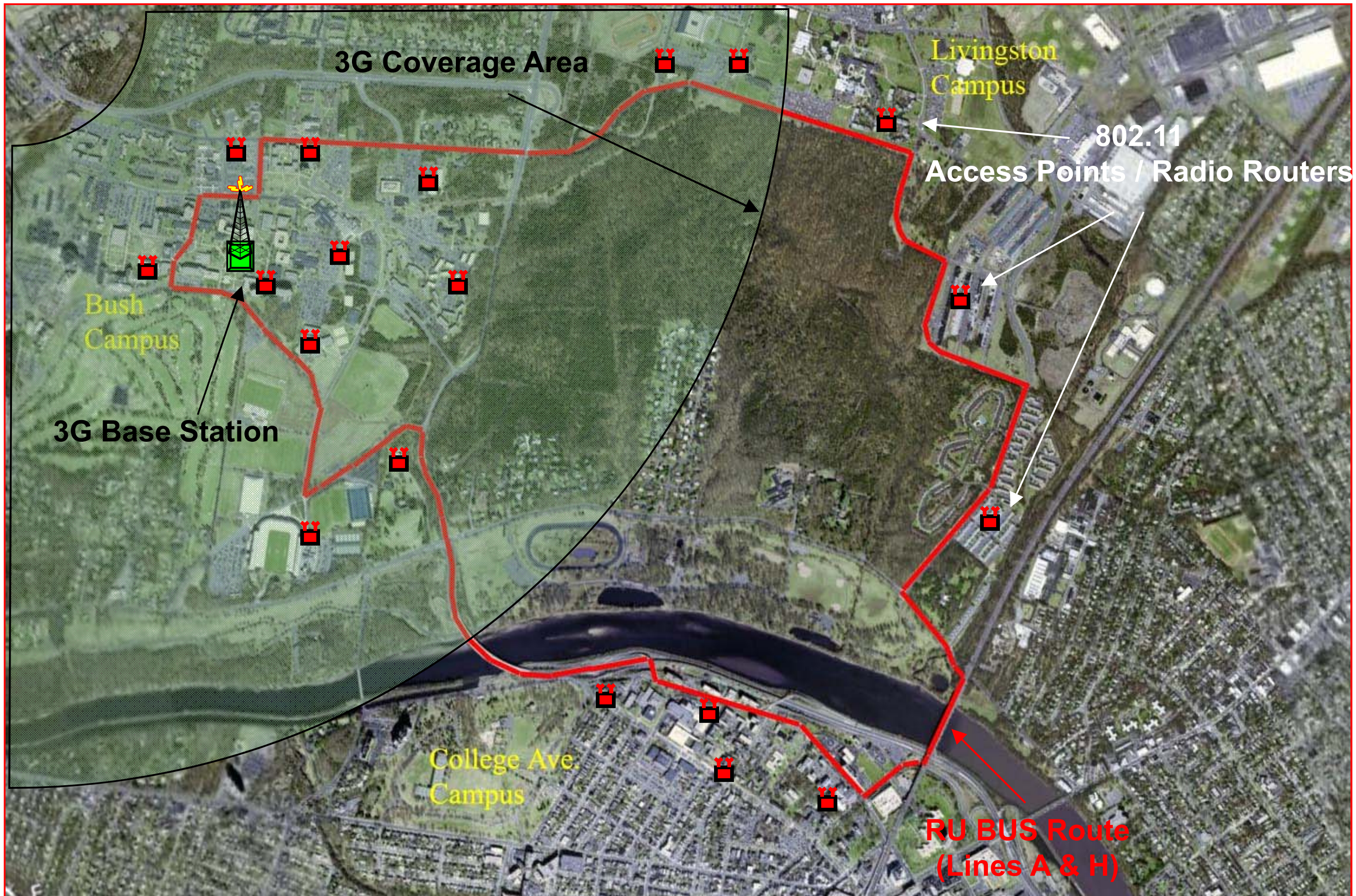
DELL 8024F
sw-rutgers.
rutgers.edu
(DYNES)
PRONTO 3290
sw-office.
winlab.rutgers.edu
PRONTO 3290
sw-cube.
winlab.rutgers.edu
IP8800
sw-top.
winlab.rutgers.edu

ORBIT: Field Trial Plan (Phase II)



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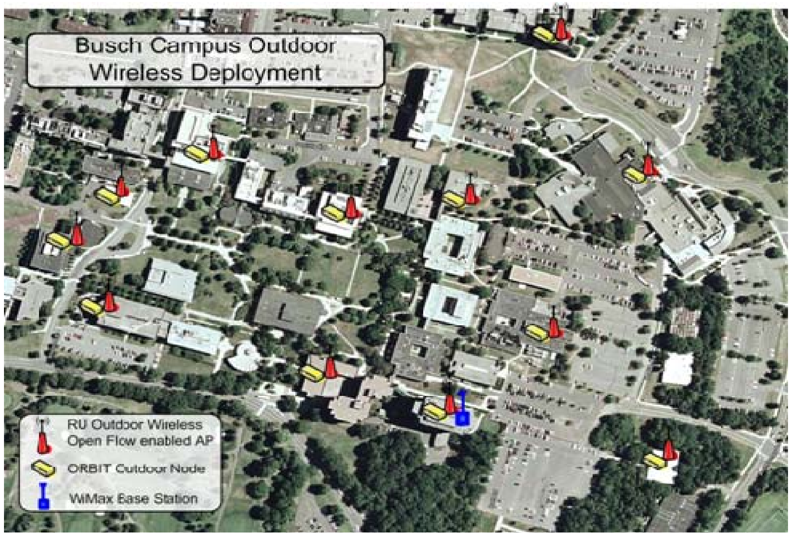
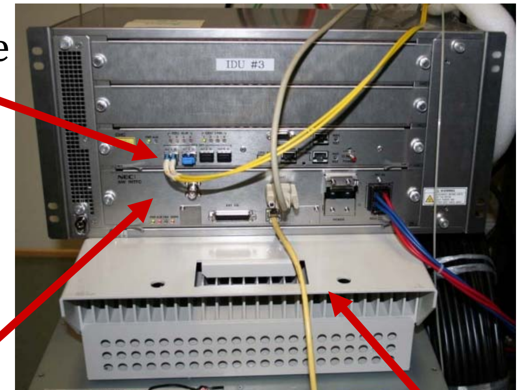
ORBIT Outdoor Infrastructure



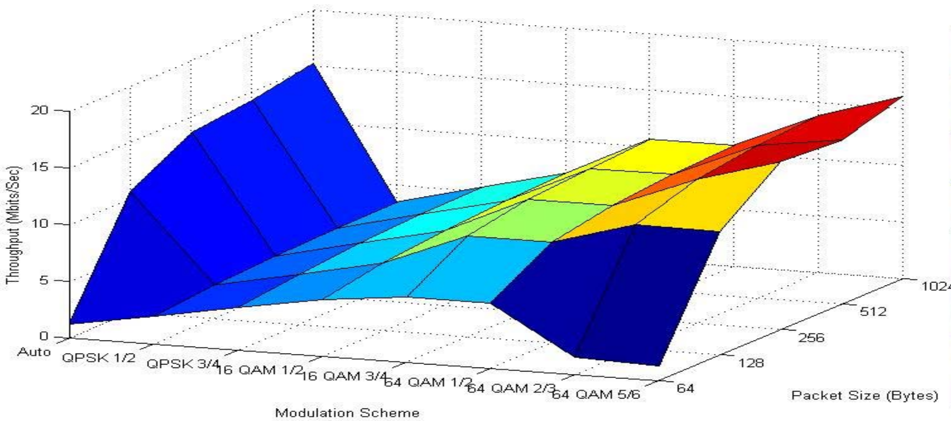
RF Module (sector)

Base Module

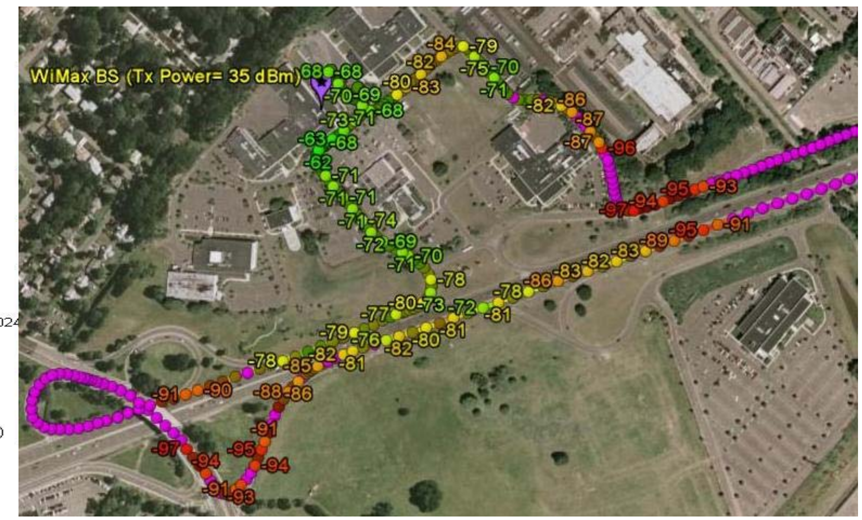


Outdoor Unit (ODU)

Omni-directional antenna
(elev. < 6ft above roof!)



Experimental readings at one location
CINR = 29 RSSI = -51



Rt. 1 Campus Coverage of the WiMAX base station

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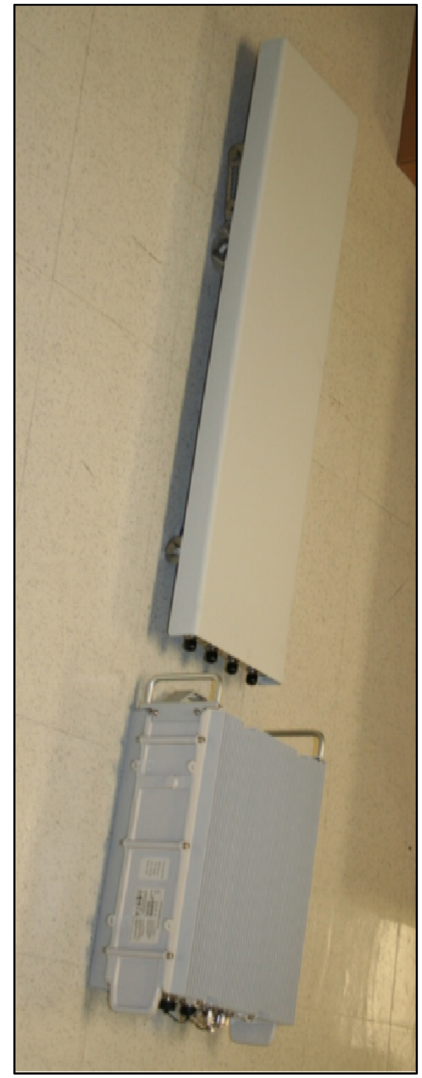
WiMax BS Platforms

NEC
Profile A

Airspan
Profile C

PHY	**Access mode**	**SOFDMA / TDD**
	Frequency	**2535 ~ 2605 MHz**
	DL:UL ratio	**35:12, 26:21, 29:18**
	Channel BW	**10 MHz , 8.75 MHz**
	FFT size	**1024, 512**
	Frame duration	**5ms**
	TX output Power	**35dBm / 40dBm (max)**
	# of sectors	**3**
MAC	**Head compression**	**PHS**
	ARQ	**HARQ / CC, ARQ**
	MBS support	**Single BS, multiple BS-MBS**
	Resource management	**Power control, mode control (idle, sleep etc.)**
Networking	**IP protocols**	**IPv4, IPv6**
	Bridging / Routi ng	**Transparent L2 switch, Bridging**
	Packet handling	**802.1Q VLAN, PHS**)**



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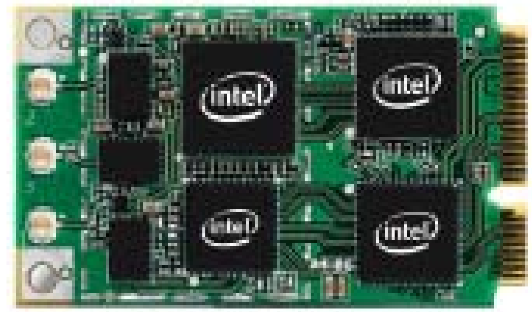
Mobile Platforms

ORBIT Node



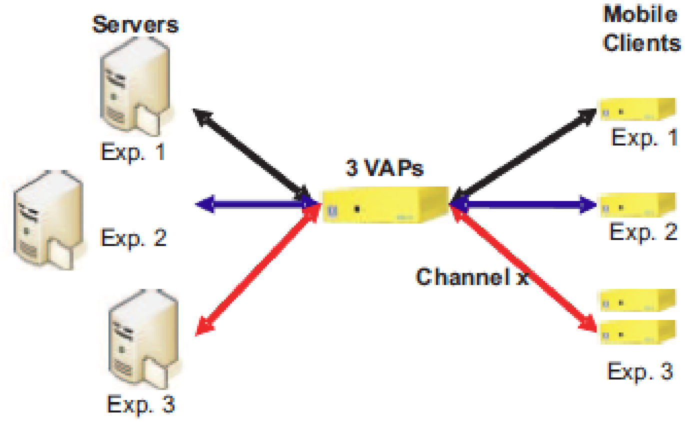
Intel 5150/5350
mini-PCI express card for
laptops with Linux driver

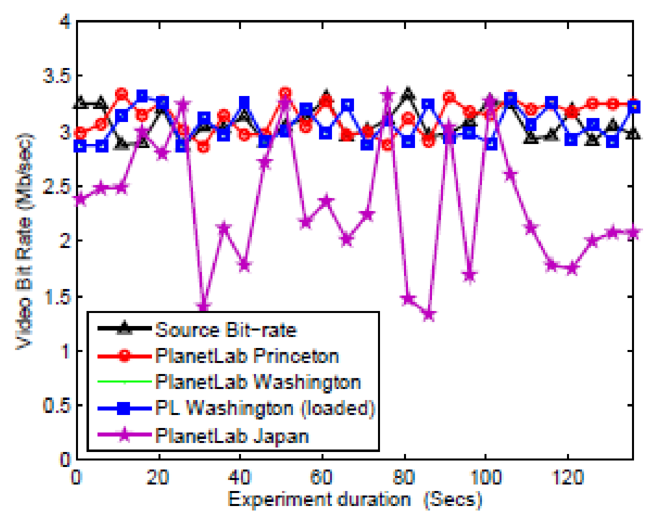
Support for mobile experiments

HTC EVO 4G
Android based
portable platform

Scale: Integrated ORBIT – PlanetLab Experiments

```
#------------ACCESS POINT----------#
defNodes('AccessPoint', [11,20])
{|node|
node.prototype("test:proto:mvlcrelay",
    {'duration' => prop.duration})
    #802.11 Master Mode
    node.net.w0.mode = "master"
    node.net.w0.type='a'
    node.net.w0.channel="48"
    node.net.w0.essid = "link1"
    node.net.w0.ip="192.168.7.1"
}
#--------------CLIENT-------------#
defNodes('Client', [19,2])
{|node|
node.prototype("test:proto:mvlcdest",
    {'duration' => prop.duration})
    node.net.w0.mode = "managed"
    #802.11 Managed Mode
    node.net.w0.type='a'
    node.net.w0.channel="48"
    node.net.w0.essid = "link1"
    node.net.w0.ip="192.168.7.7"
}
#----------- PlanetLAB nodes----------#
defPNodes('[21,3,[21,5]')
```





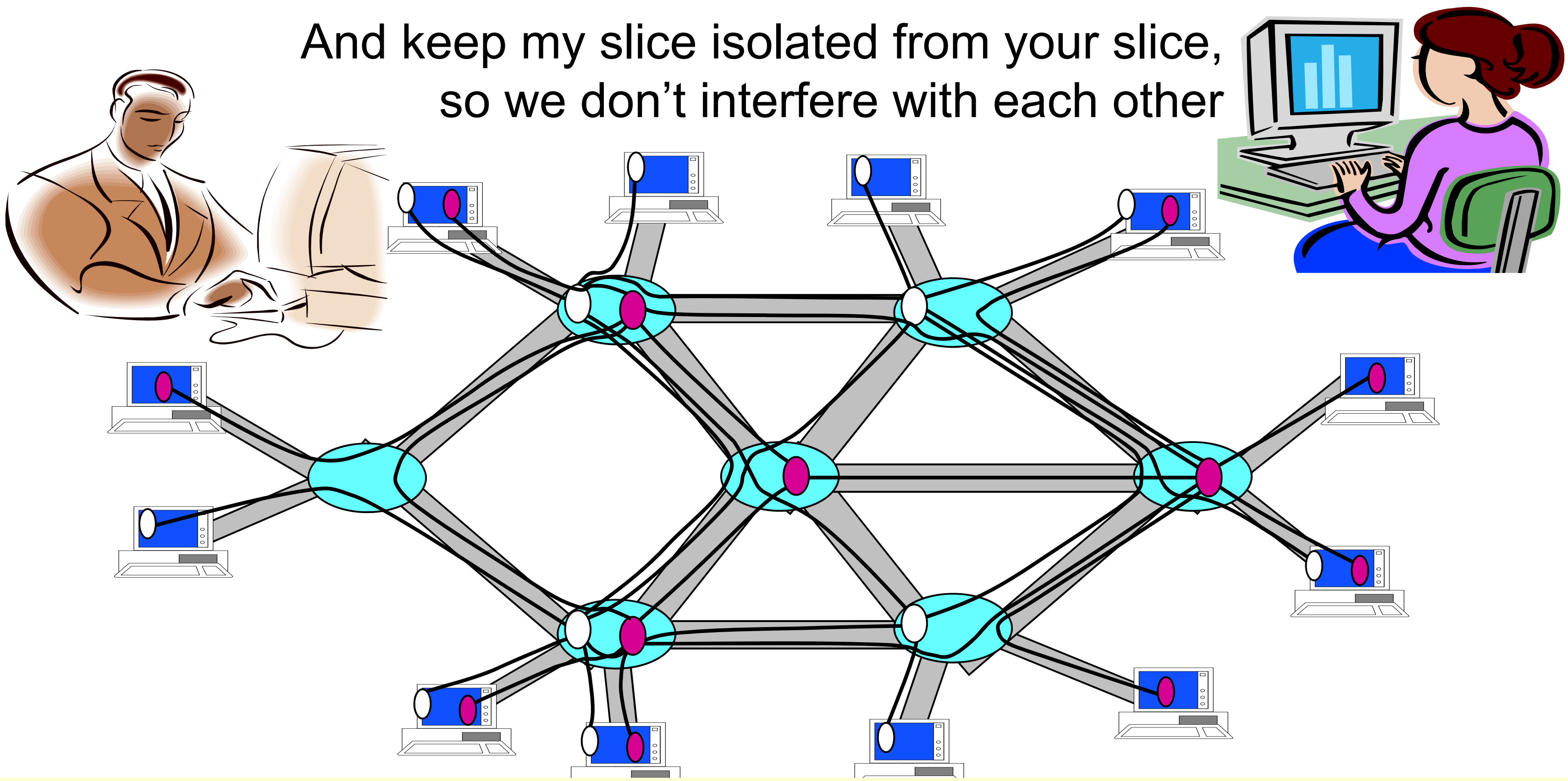
Streaming Video Performance

GENI & FIA

Revolutionary GENI Idea: Slices and Deep Programmability

Install the software I want *throughout* my network slice (into firewalls, routers, clouds, …)

And keep my slice isolated from your slice, so we don't interfere with each other



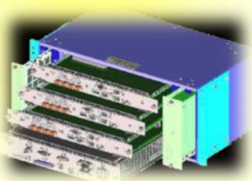
We can run many different "future internets" in parallel

Courtesy: Chip Eliot, GENI GPO

Enabling “at scale” experiments

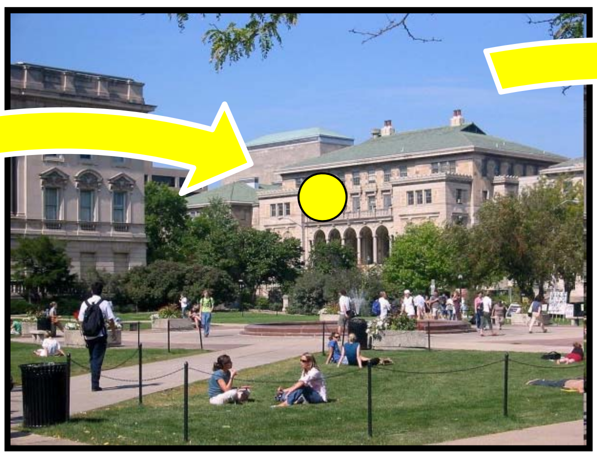
- **How can we afford / build GENI at sufficient scale?**
  - Clearly infeasible to build research testbed “as big as the Internet”
  - Therefore we are “GENI-enabling” testbeds, commercial equipment, campuses, regional and backbone networks
  - **Students are early adopters / participants in at-scale experiments**
  - Key strategy for building an at-scale suite of infrastructure

HP ProCurve 5400 Switch

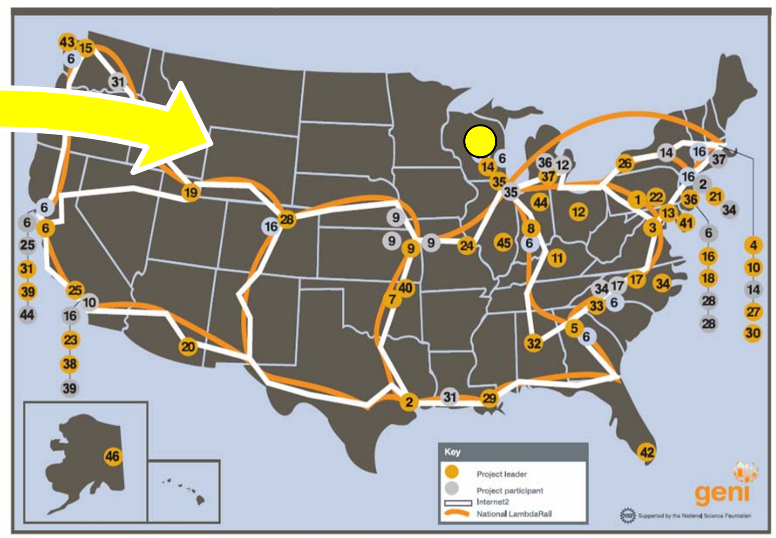


NEC WiMAX Base Station

GENI-enabled equipment



GENI-enabled campuses, students as early adopters



“At scale” GENI prototype

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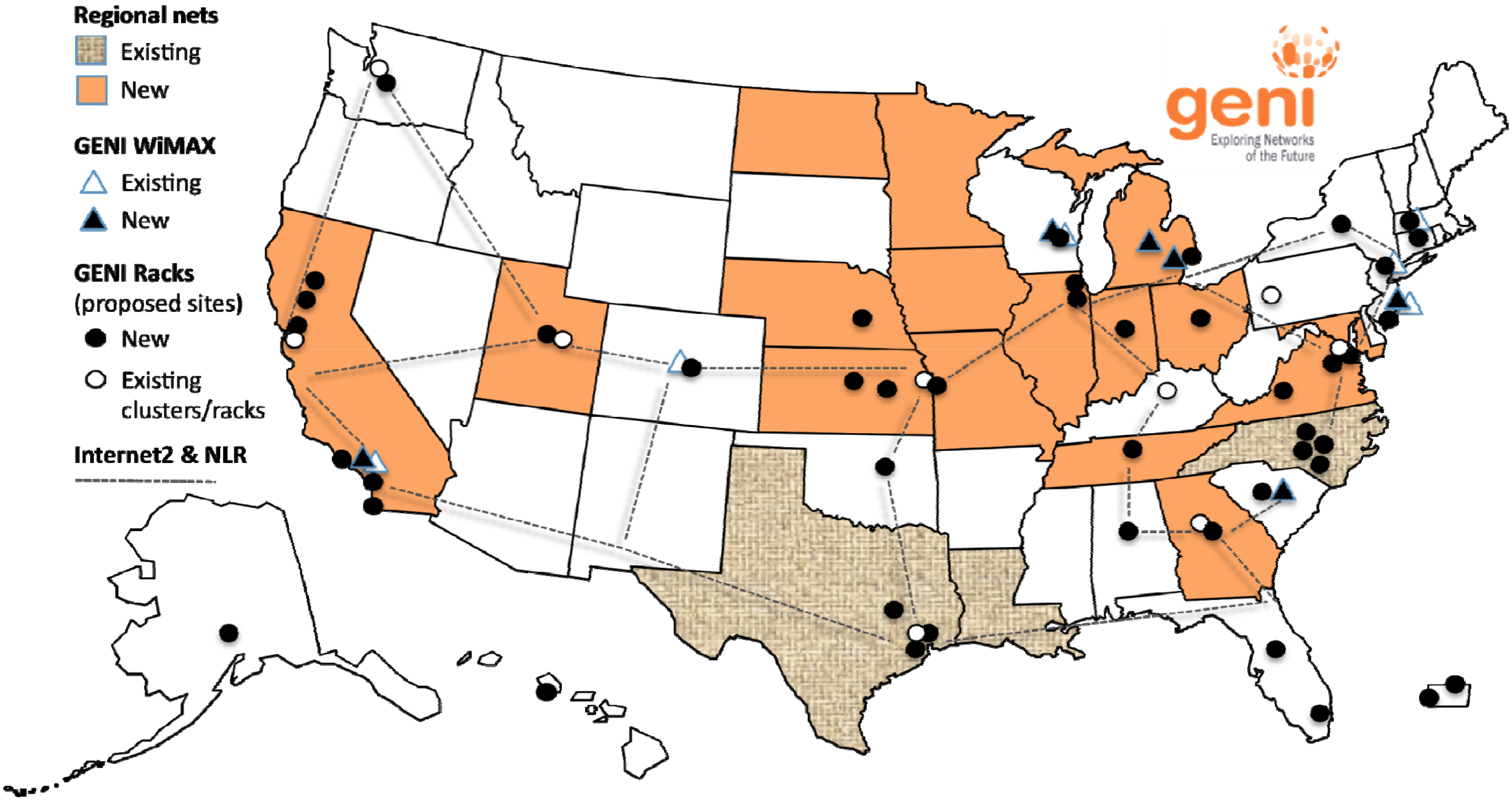
Courtesy: Chip Eliot, GENI GPO

Campus photo by Vonbloompasha

GENI's Footprint



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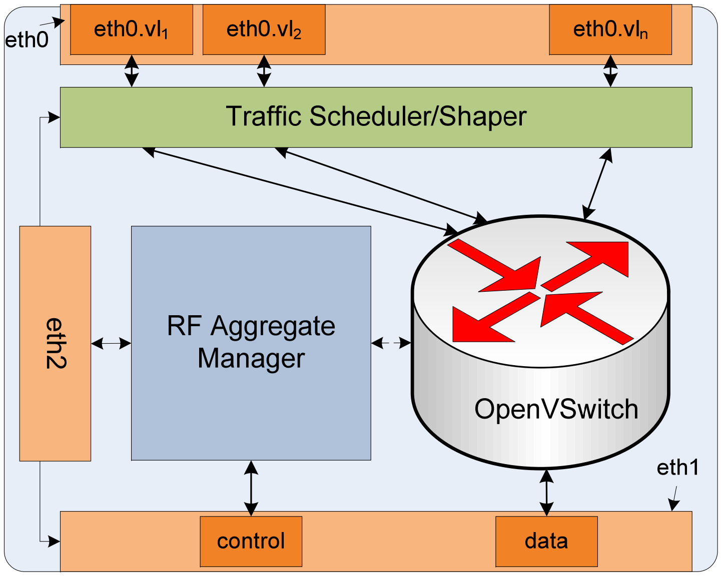
"Opening" of WiMAX & LTE

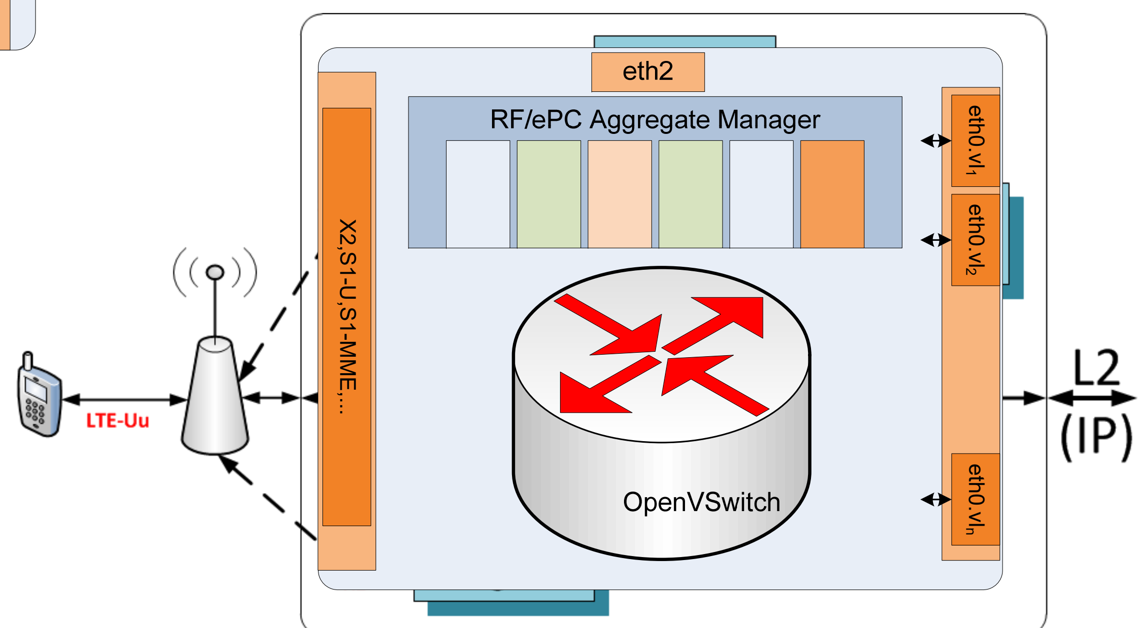


WiMAX

- Exposed all controllable parameters through API
- Removed all default IP routing, simplified ASN controller*
- All switching purely based on MAC addresses
- Implemented the datapath virtualization and *VNTS* shaping mechanism in click/openvswitch for slice isolation

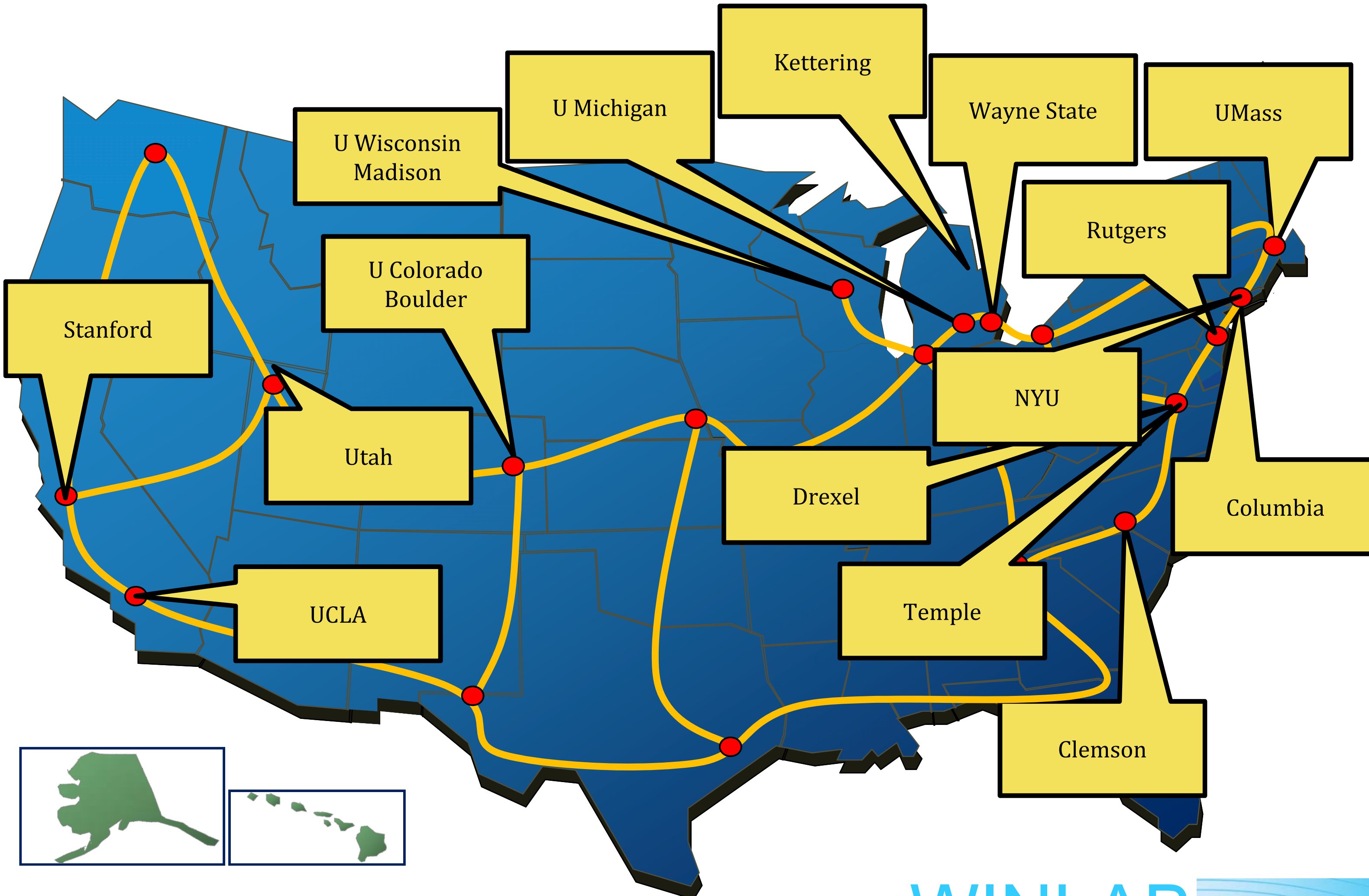
LTE

- Exposed all controllable parameters through the same REST based API
- Implemented the datapath with openvswitch
- *Current development: ePC replacement with open source (i.e. simplification/elimination of LTE control protocols)*



GENI Wireless Deployment

- 26 WiMAX and LTE BS on 14 campuses
- SDN (Click and OVS based) datapath/backbone
- 10 mini-ORBIT deployments some with SDRs



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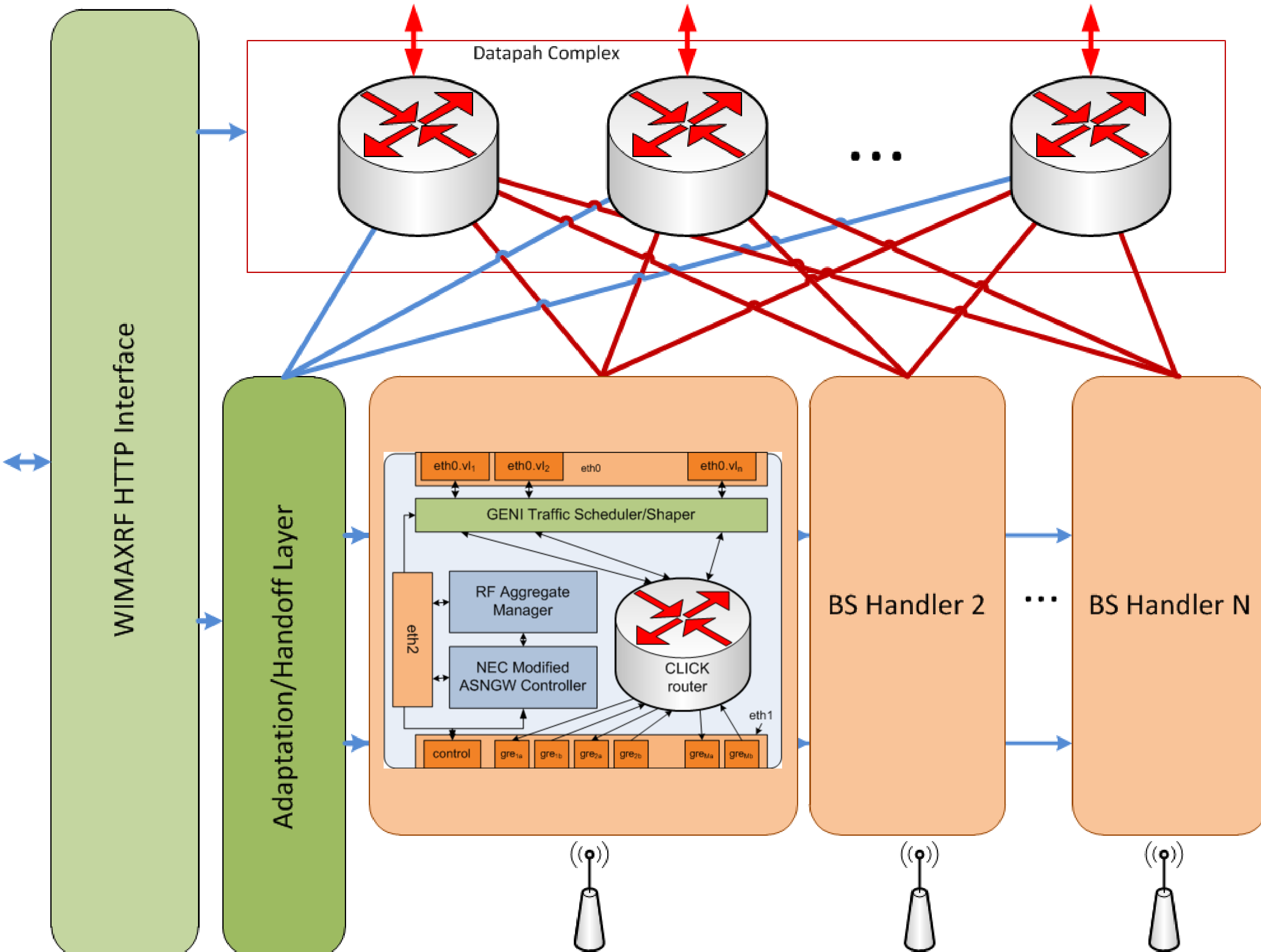
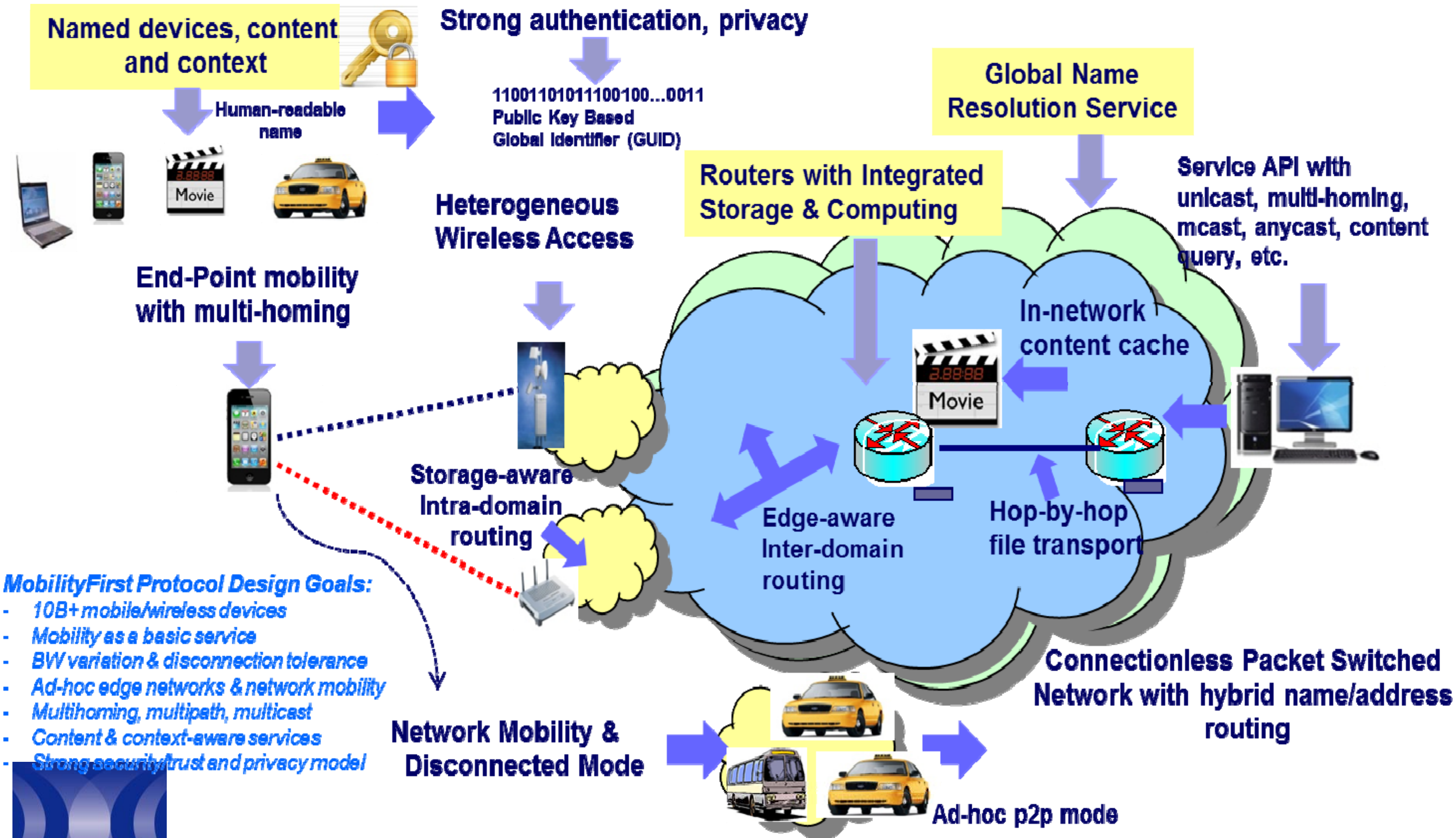
LTE eNodeB Platforms

Ip.access	Amarisoft (USRP)	OAI (USRP)	Airspan
			
Rel 8.9	Rel 12	Rel 8.6	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)

4G (WiMax/LTE): Larger Picture



FIA: MobilityFirst Architecture Summary



MobilityFirst Protocol Design Goals:

- *10B+ mobile/wireless devices*
- *Mobility as a basic service*
- *BW variation & disconnection tolerance*
- *Ad-hoc edge networks & network mobility*
- *Multihoming, multipath, multicast*
- *Content & context-aware services*
- *Strong security/trust and privacy model*

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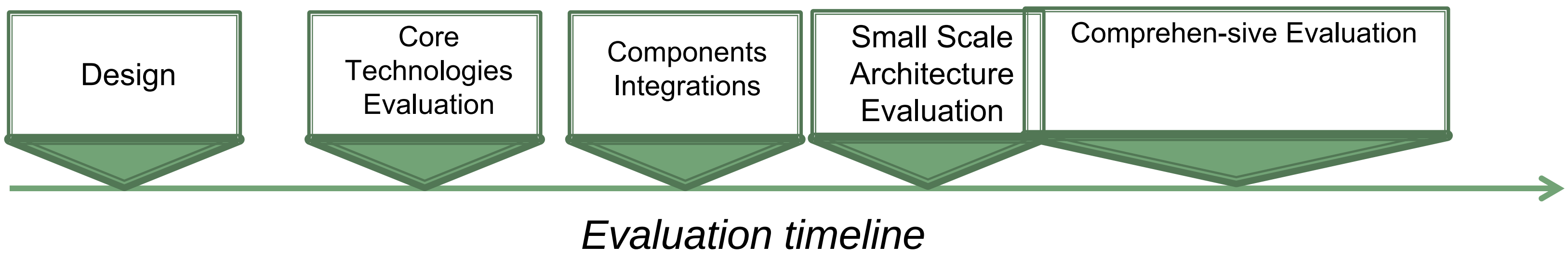
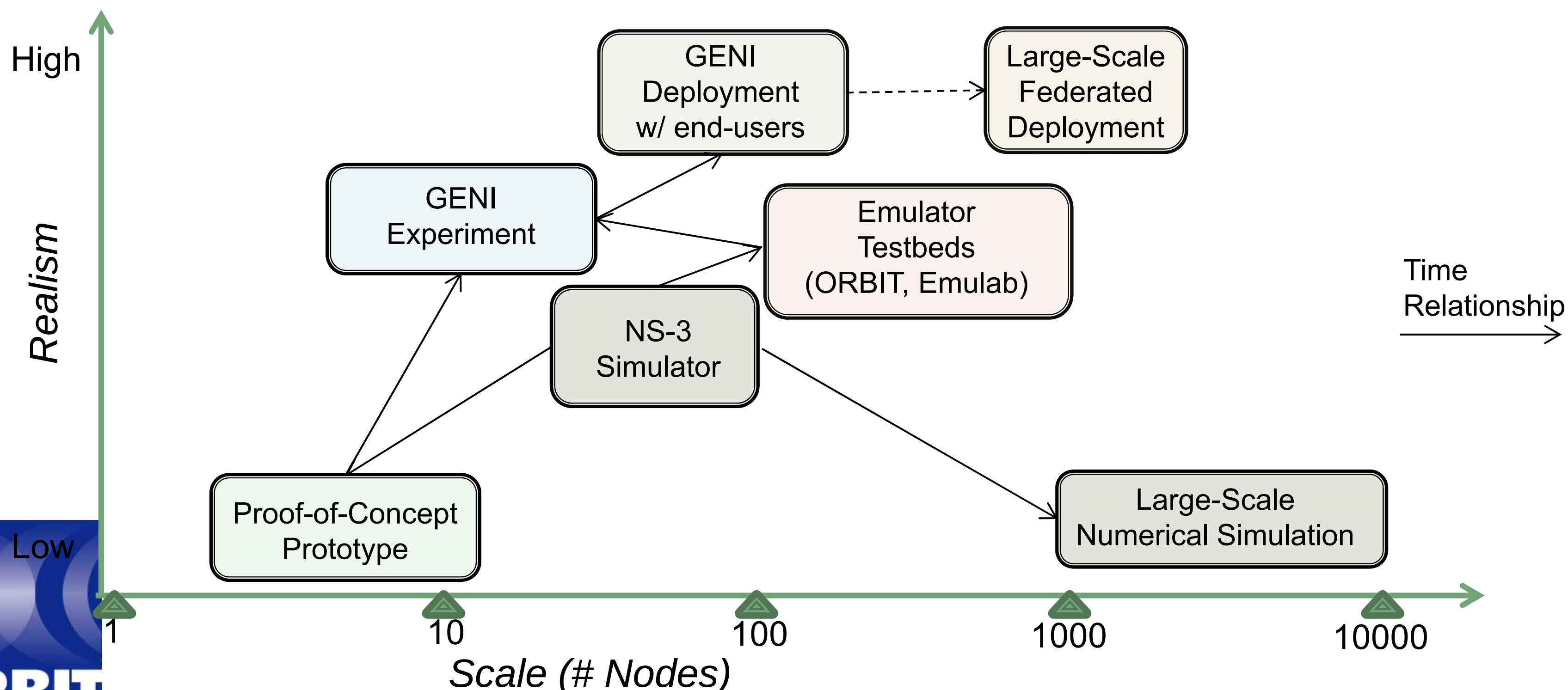
MobilityFirst Architecture Evaluation Characteristics and Requirements

- Mobile nature generates particular requirements for experimentation scenarios.
- Named oriented architecture requires coexistence of multiple routing paradigms at ones.

MobilityFirst Characteristics	Mobility as the norm	Hybrid name based routing	Direct addressability of all network principals	In-network services
Expected Scenarios	High levels of mobility	Strict performance requirements for name resolution service	Support for coexisting multiple routing algorithms	Flexible service support and deployment
	Device heterogeneity			Reliance on software

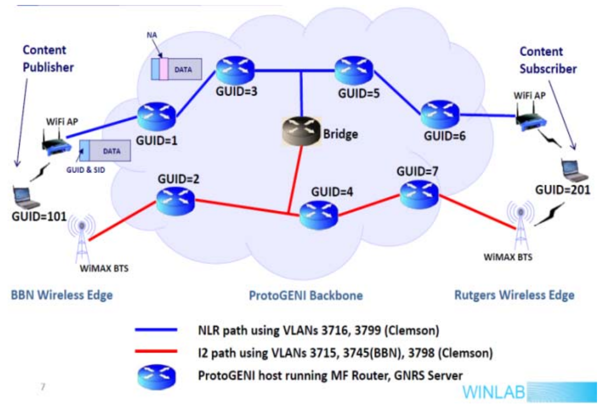
Architecture Evaluation Timeline



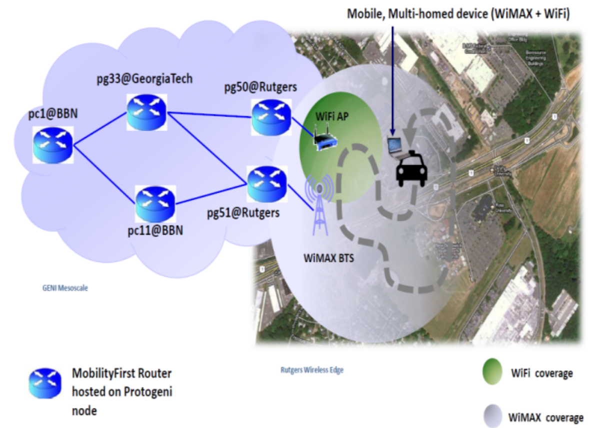


MobilityFirst on GENI: Selected Experiments

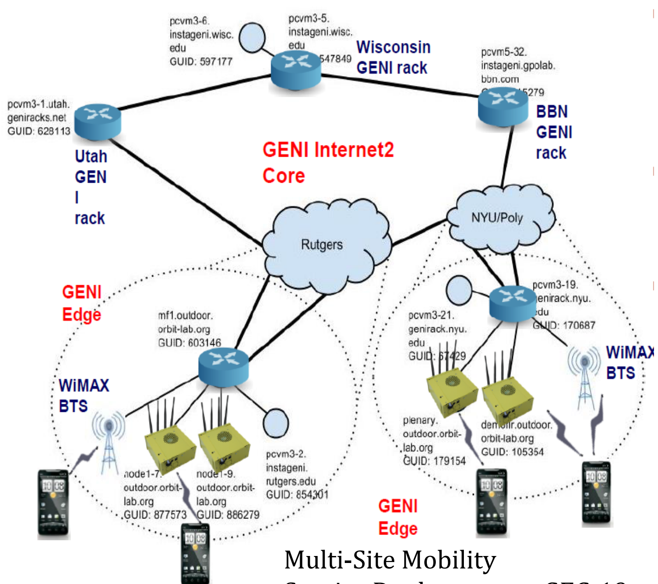
- GENI has been an integral part of MF evaluation methodology since the project started in 2010 ....



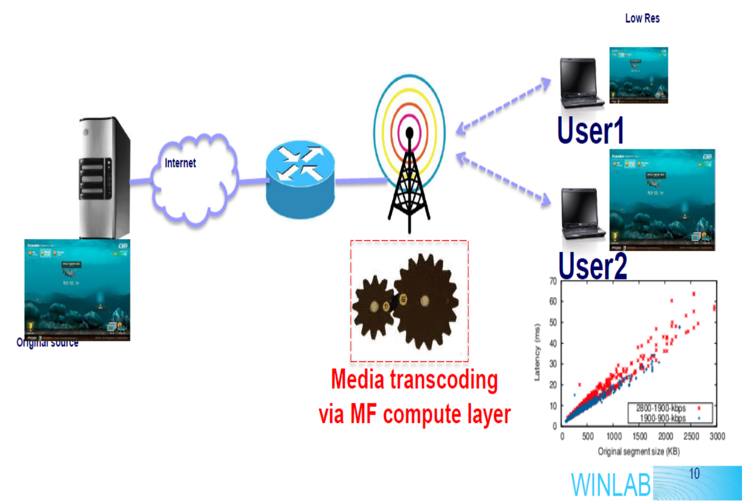
Content Delivery Scenario – GEC-12



Mobility with Dual-Homing – GEC-13



Multi-Site Mobility Service Deployment – GEC-19



Video Delivery with In-Network Transcoding– GEC-21

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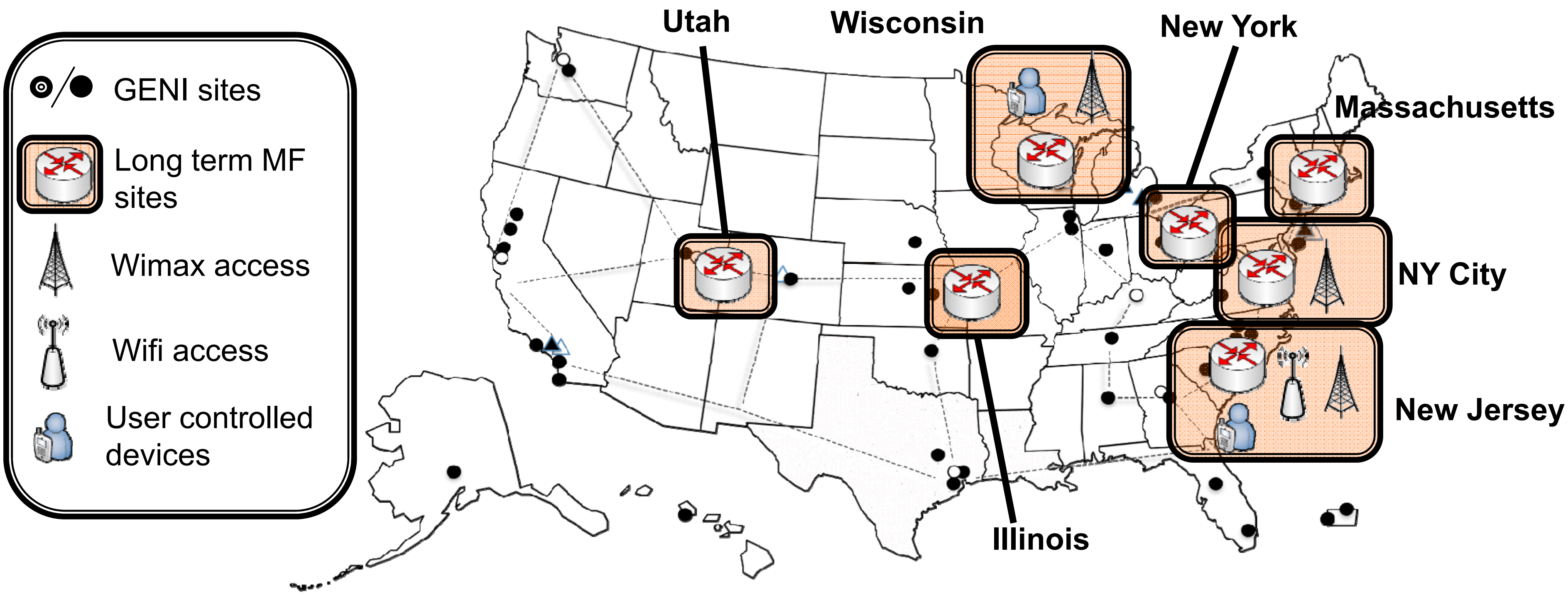
Current Service Deployment in GENI



- Internet2 (1/10 Gbit) backbone
- Long running MobilityFirst slice of computing/routing resources on the GENI infrastructure: 7 different sites, 2 physical machines and 14 virtual machines, 3 sites WiMax enabled, 1 site LTE/WiFi.
- Used to evaluate network and system services deployed under real world like conditions.

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Related Collaboration Projects

OAI (5G software alliance for democratising wireless innovation)	**CREW** (**C**ognitive **R**adio **E**xperimentation **W**orld)	**JUNO** (Virtual Mobile Cloud Network for Realizing Scalable, Real-Time Cyber Physical Systems)
FLEX (**F**IRE **L**TE testbeds for open **EX**perimentation)	**WiSHFUL** (**Wi**reless **S**oftware and **H**ardware platforms for **F**lexible and **U**nified radio and network contro**L**)	**METIS-II** (**M**obile and wireless communications **E**nablers for the **T**wenty-twenty **I**nformation **S**ociety)

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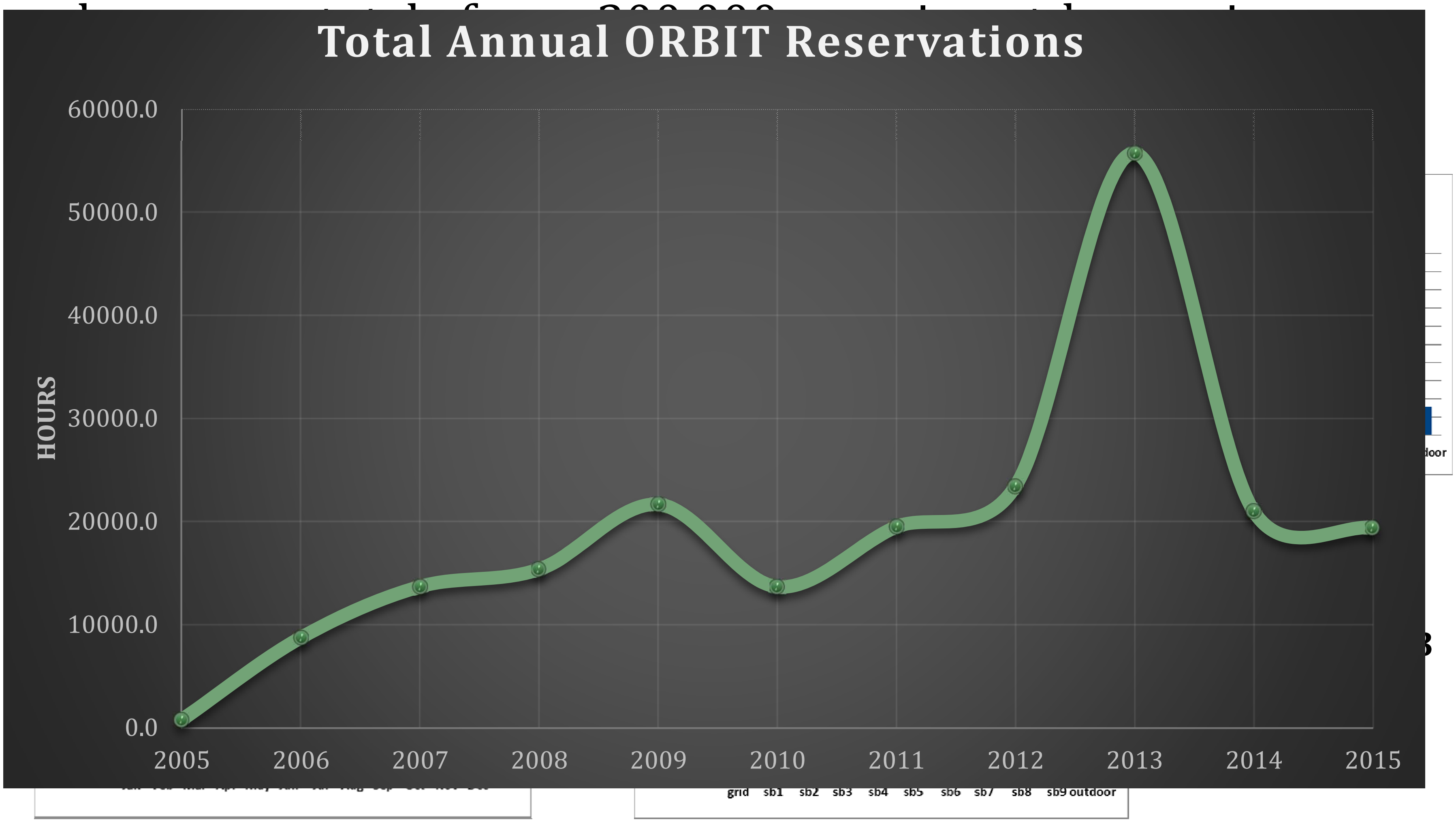
Usage Statistics

- ORBIT has 1300+ registered users in 400+ groups who



ORBIT Grid (this morning)

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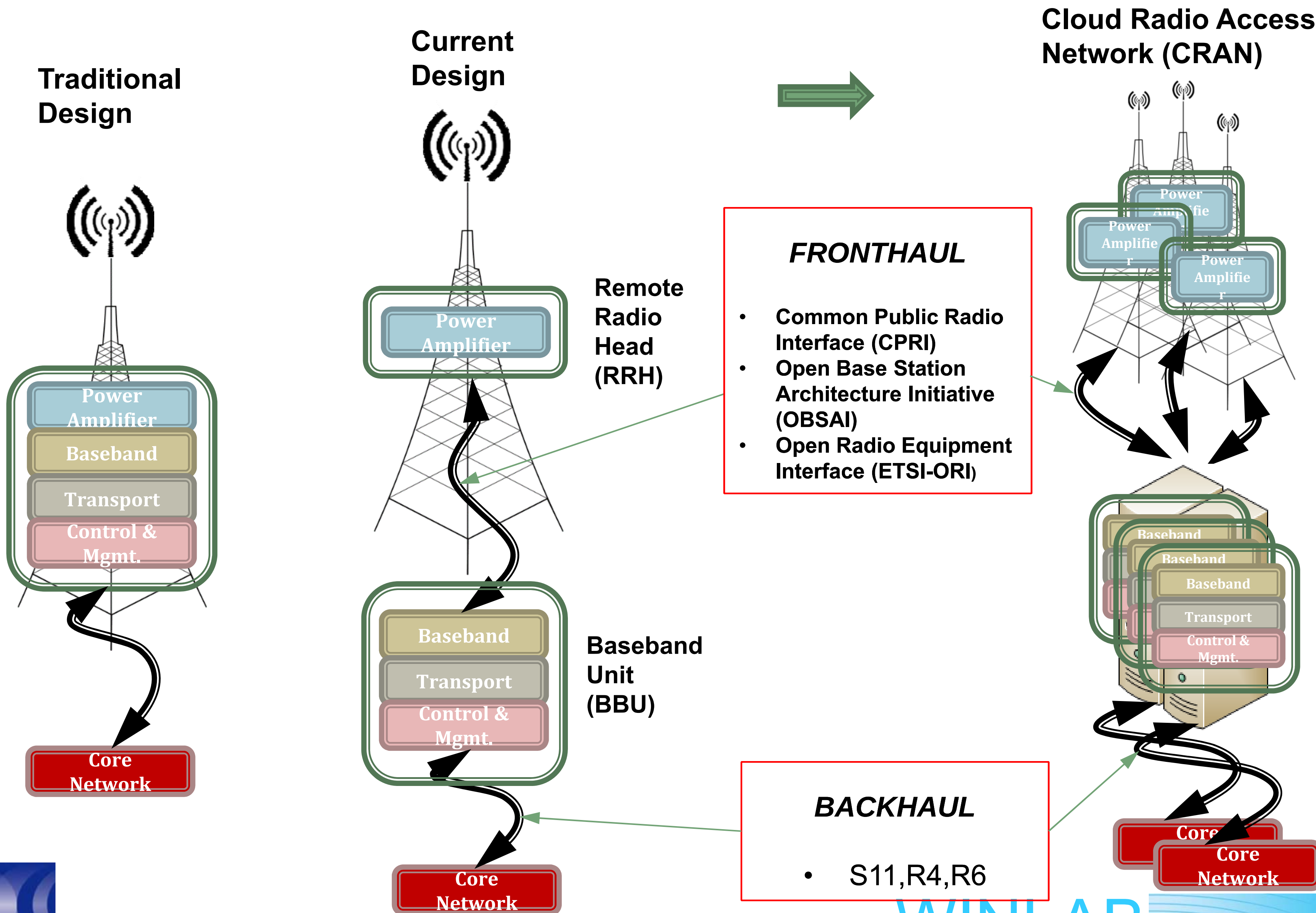
Support For Basestation Architecture Evolution



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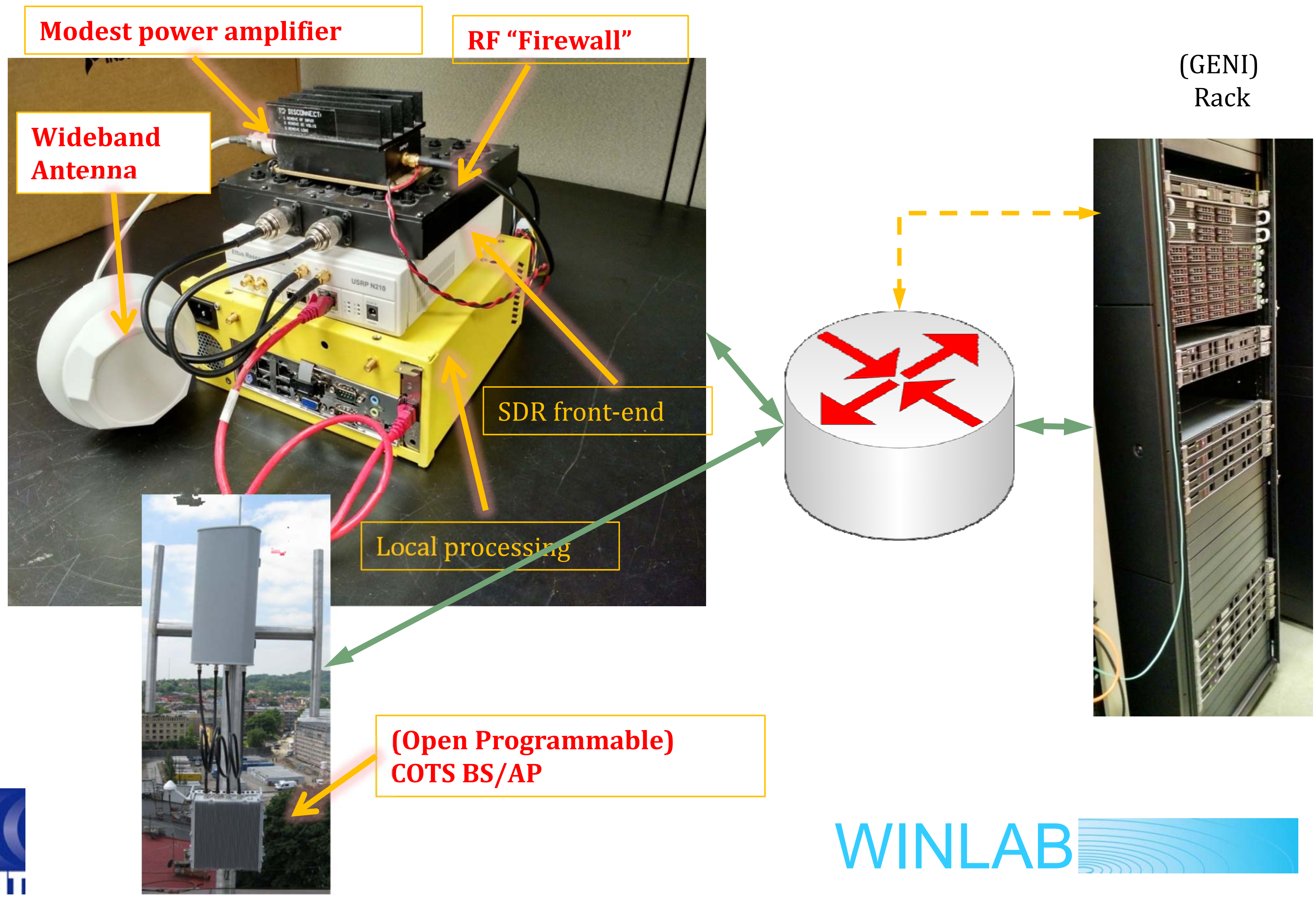
ORBIT Extension: Massive-MIMO

- **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**
- **32x40G SDN aggregation switch**

“Missing Link”: Outdoor Deployable SDR Wireless Units



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