THE
UNIVERSITY
OF UTAH

PhantomNet

An end-to-end mobile network testbed

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Why another mobile network testbed?

- Mobile networking growing traffic-wise and growing in importance
  - Mobile devices increasing in sophistication and becoming the "compute platform of choice"
- Current network architectures (LTE/EPC) are packet based
  - But under the hood look a lot like their circuit switched forebears
- Major technology trends reshaping the way we do things
  - Cloud computing, software defined networking, network function virtualization
- Current measurement studies
  - From the "outside", no ground truth

Need a realistic "playground" where as a community we can:

- **explore/invent mobile network architectures in an end-to-end manner**
- **look "under the hood" of existing mobile network architectures**
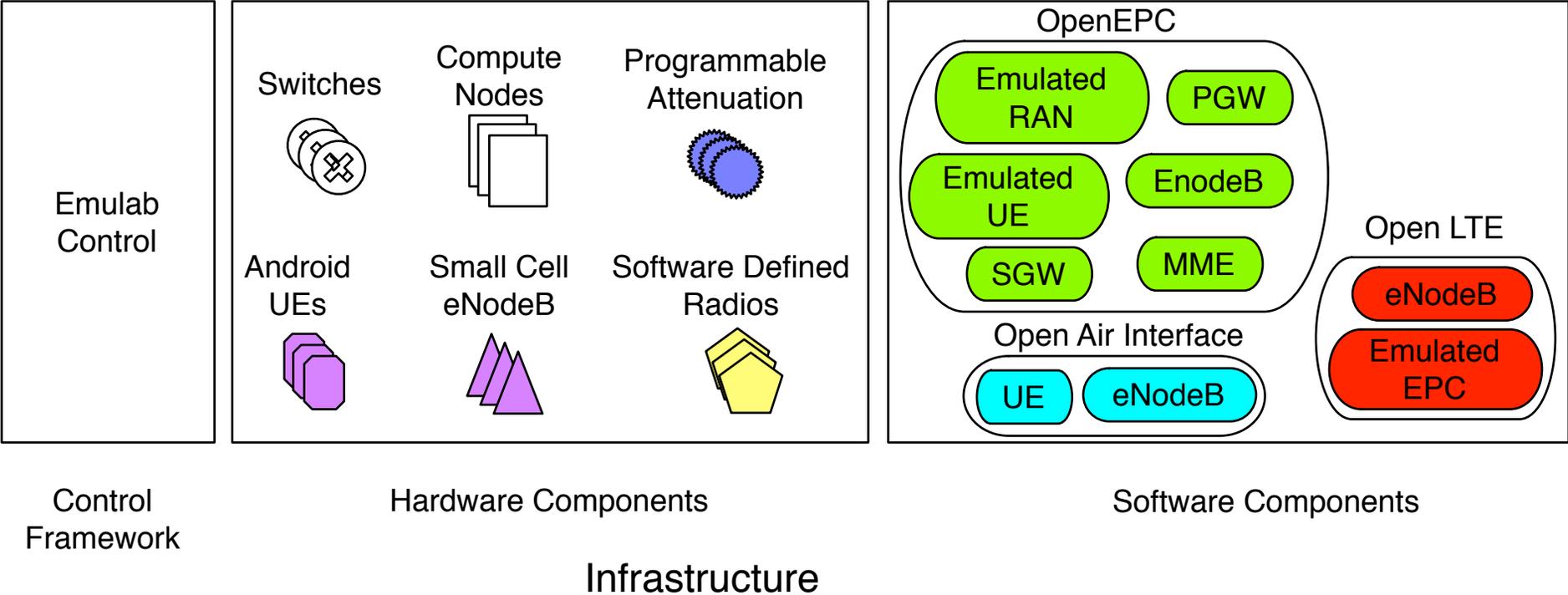
PhantomNet

Programmable end-to-end mobile testbed to enable research at the intersection of mobile networking, cloud computing and software defined networking

- Diverse mix of hardware and software resources
- Remotely accessible and sharable (time and space)
  - Emulab style
- Enables end-to-end mobile networking research
  - Endpoints
  - Radio Access Network (RAN)
  - Mobile Core Network
  - Cloud
  - Software Defined Networking (SDN)
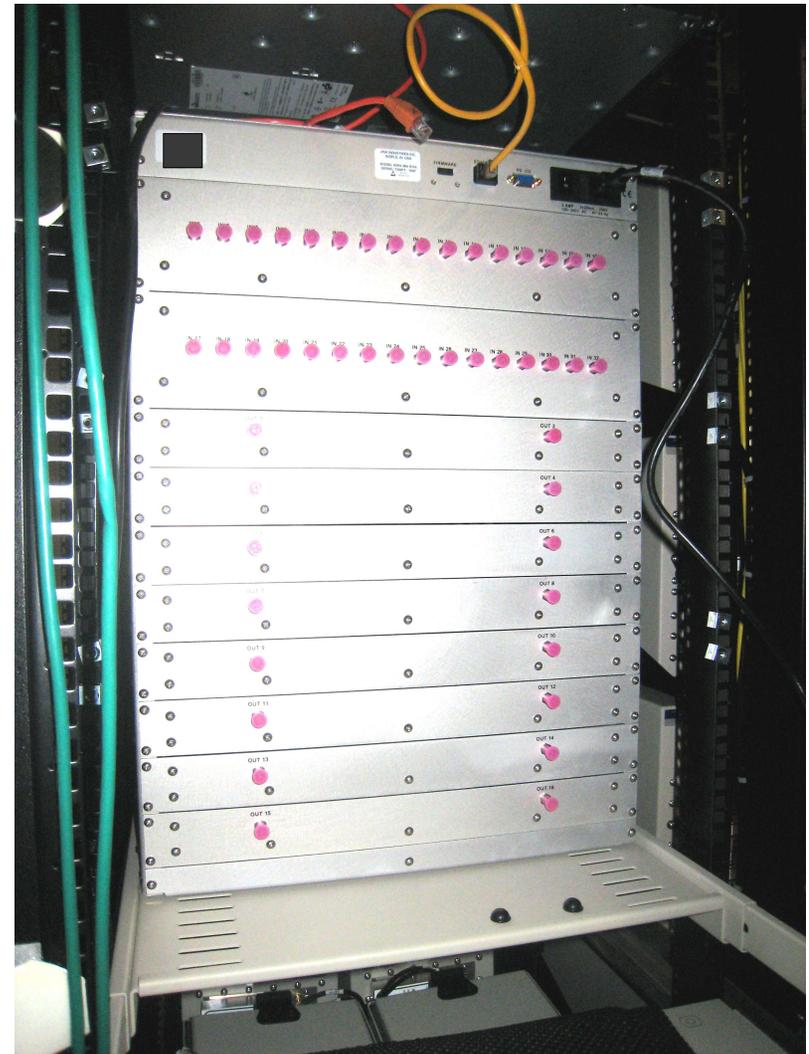
What does PhantomNet give you?

Diverse mix of hardware and software resources

Emulab Control

Switches

Compute Nodes

Programmable Attenuation

Android UEs

Small Cell eNodeB

Software Defined Radios

OpenEPC

Emulated RAN

PGW

Emulated UE

EnodeB

SGW

MME

Open Air Interface

UE

eNodeB

Open LTE

eNodeB

Emulated EPC

Control Framework

Hardware Components

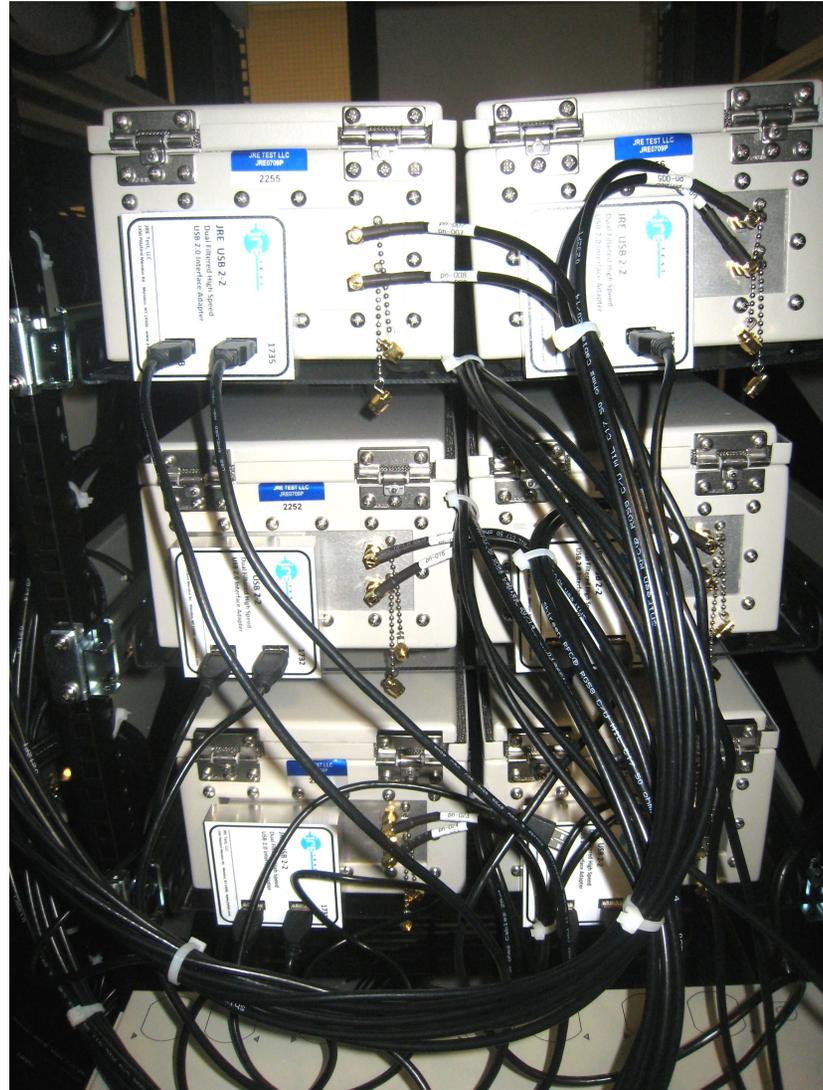Software Components

Infrastructure

General purpose hardware

Programmable attenuator + Faraday boxes for radio gear

OTS small cells + SDR kits
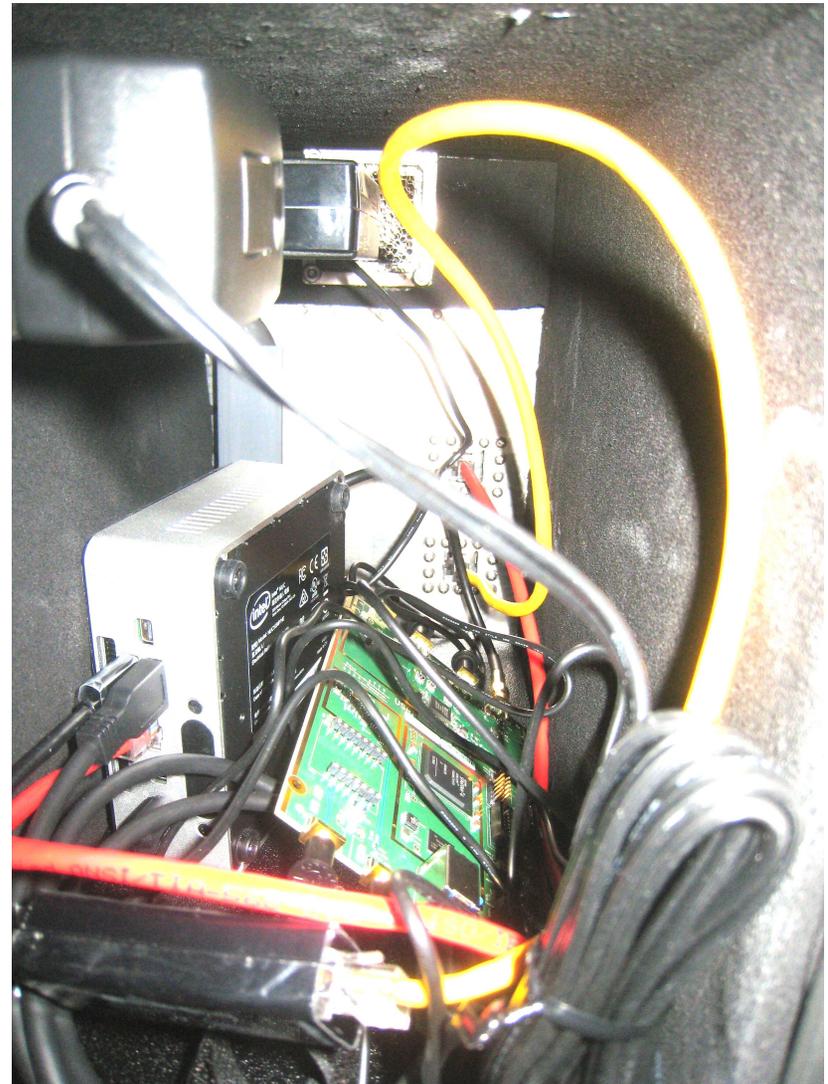
OTS Android phones (Nexus 5)

Unboxed phone and SDR kit

Intel 5th Gen
NUC core i5
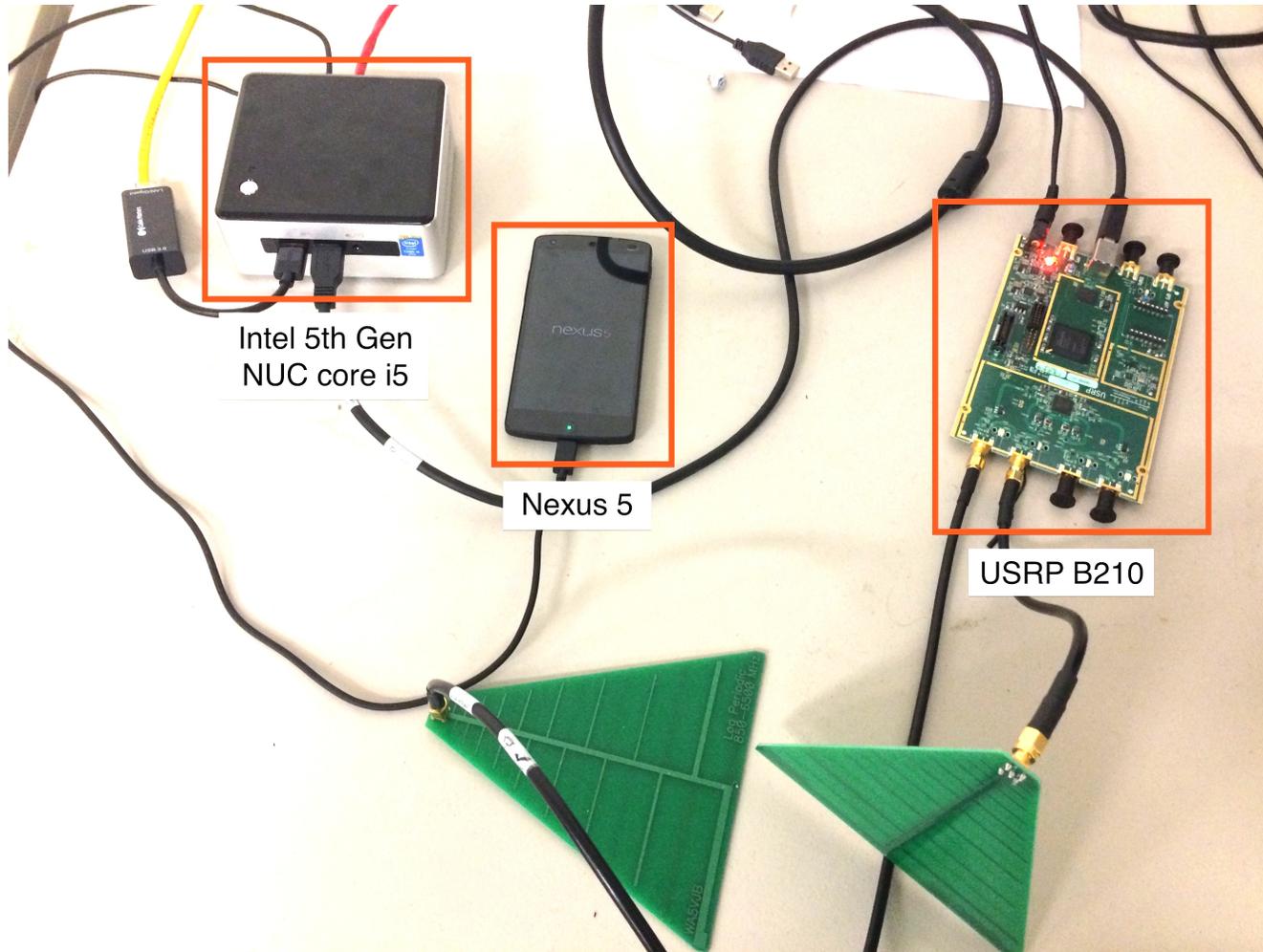
Nexus 5

USRP B210

Summary of mobile hardware
(excluding the general purpose compute hardware)

- COTS UE nodes (28 x Nexus 5)
- COTS eNodeBs (8 x ip.access E-40 small cells)
- SDR-equipped nodes (12 x Intel i5 NUC with USRP B210)
- 32 x 16 programmable RF attenuator matrix (JFW Industries)

Software components

- Full featured evolved packet core EPC software
- Emulated user equipment (UE) and radio access network (RAN)
- Not open source
  - We have source license
  - Binary license for PhantomNet users
  - Access for users with own source license

Software components

- Open source 3GPP LTE implementation
- Subset of Release 10 functionality
- Works on various SDR kits and in simulated mode
- More mature than openLTE
 - active development

Software components


openLTE alpha
An open source 3GPP LTE implementation.

- Open source 3GPP LTE implementation
- Works with GNU radio and various SDR kits
- E-UTRAN only implementation
- Implements enough of MME functionality for NAS to work
- Somewhat immature
  - active development

How do you use PhantomNet?

- Remotely accessible
- Users request hardware and software resources for their experiment
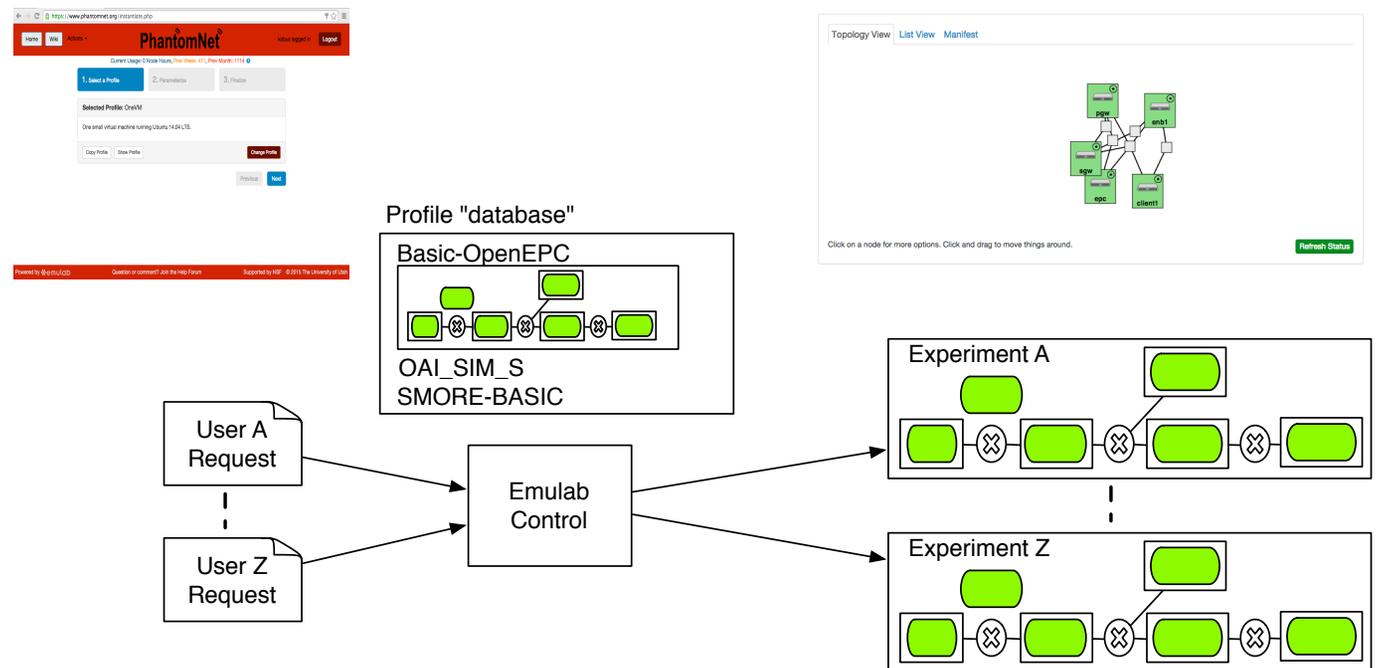- Emulab control framework allocates and instantiates
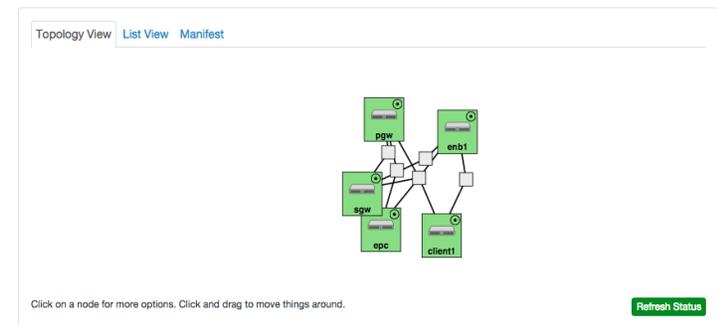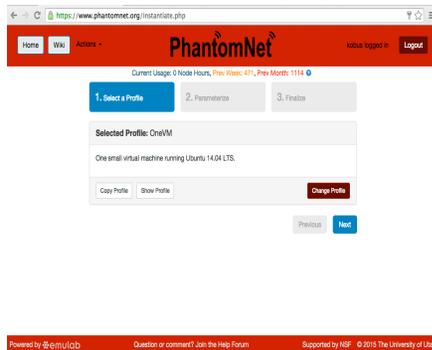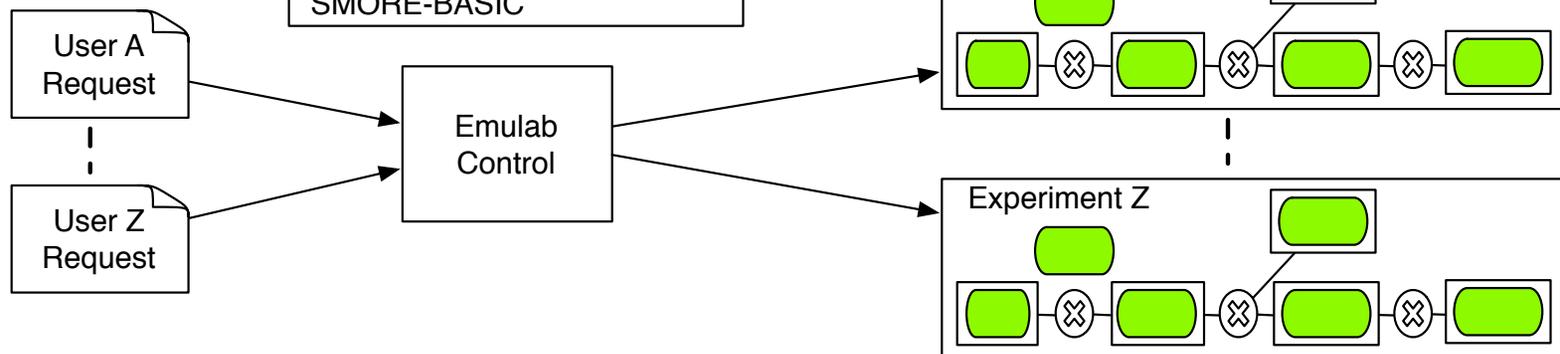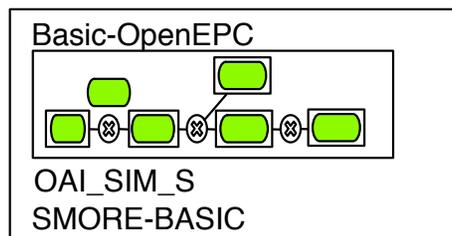
How do you use PhantomNet?

- Profile driven: "canned" experiment
  - Select from profile database
  - Gets instantiated with all dependencies intact
- Typical workflow:
 - Start from existing profile -> Modify for your experiment -> Create new profile

What can you do with PhantomNet?

- Evolved packet core (EPC) with OpenEPC components
- Core elements: physical or virtual machines
- Emulated RAN
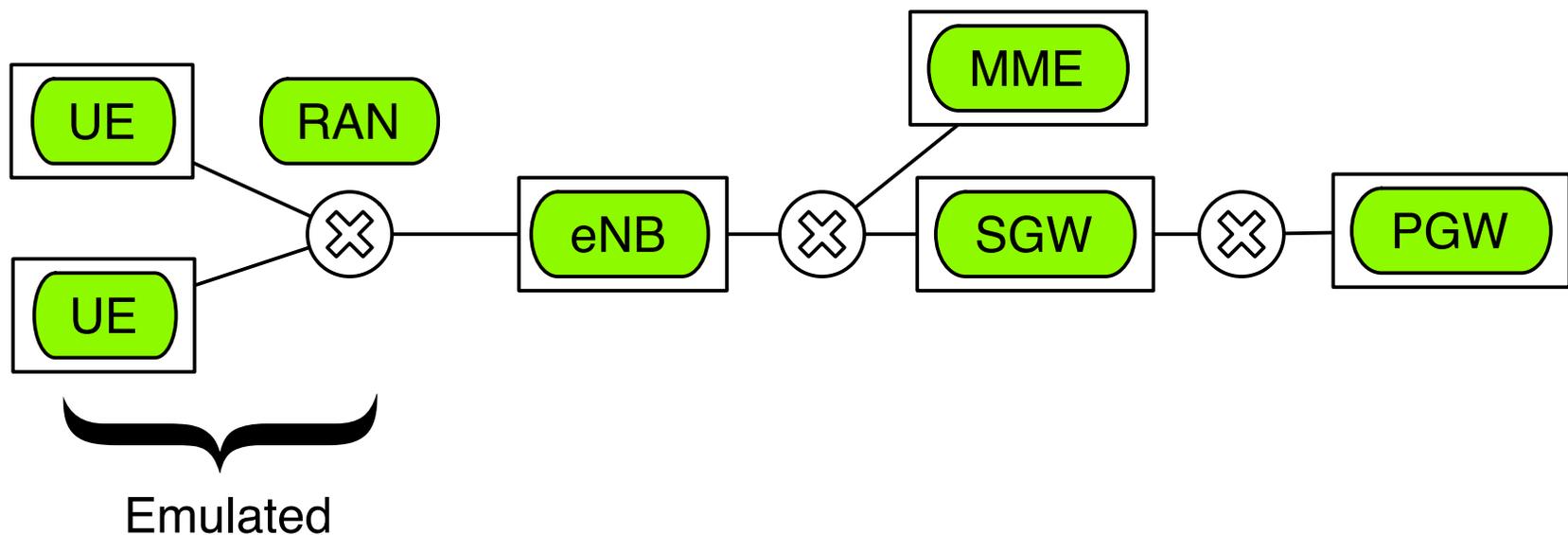
Emulated

What can you do with PhantomNet?

- Evolved packet core (EPC) with OpenEPC components
- Real RAN:
  - Off-the-shelf user equipment (UE) (Android devices)
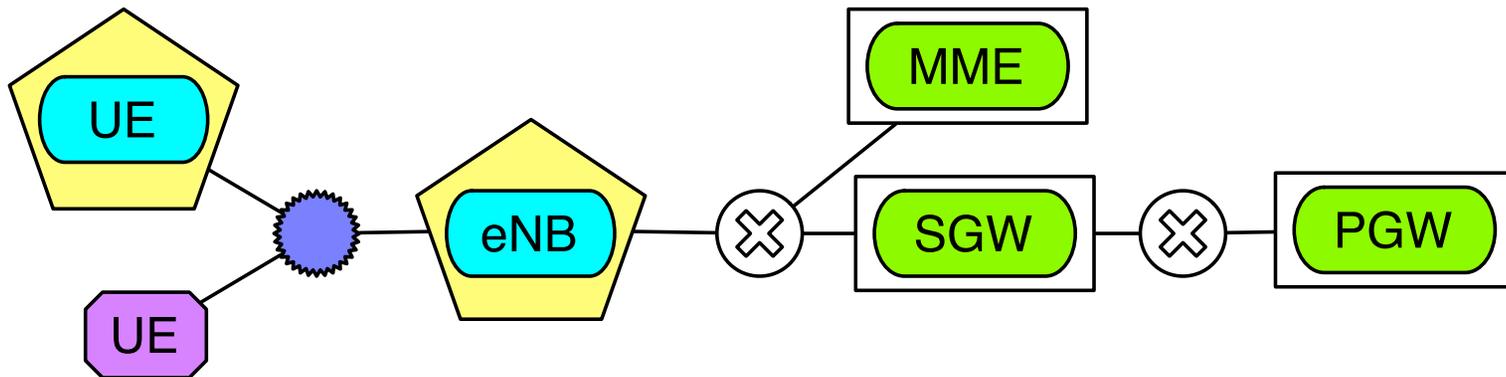 - Off-the-shelf base station (eNodeB) (ip.access small cell)
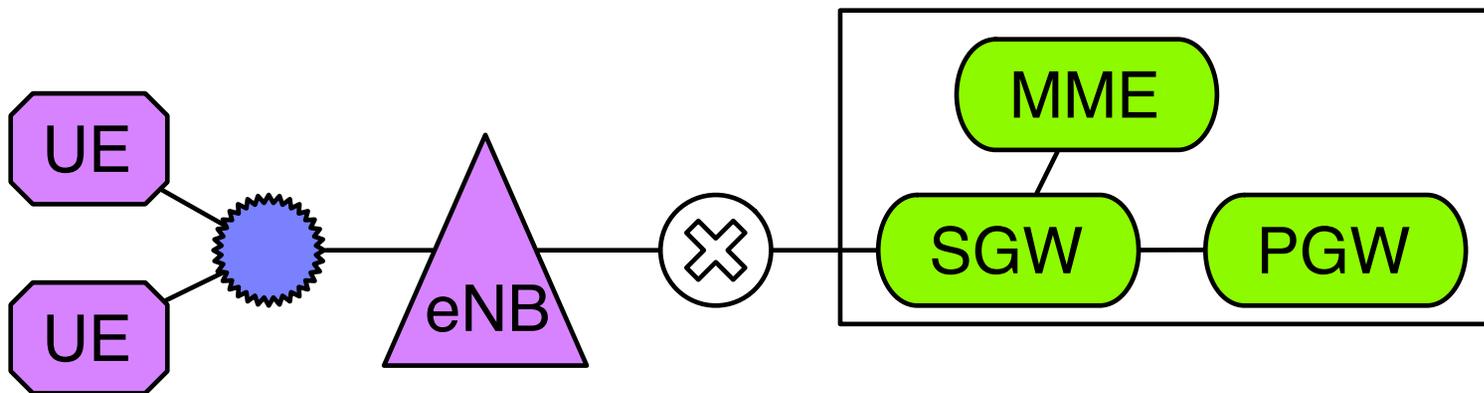
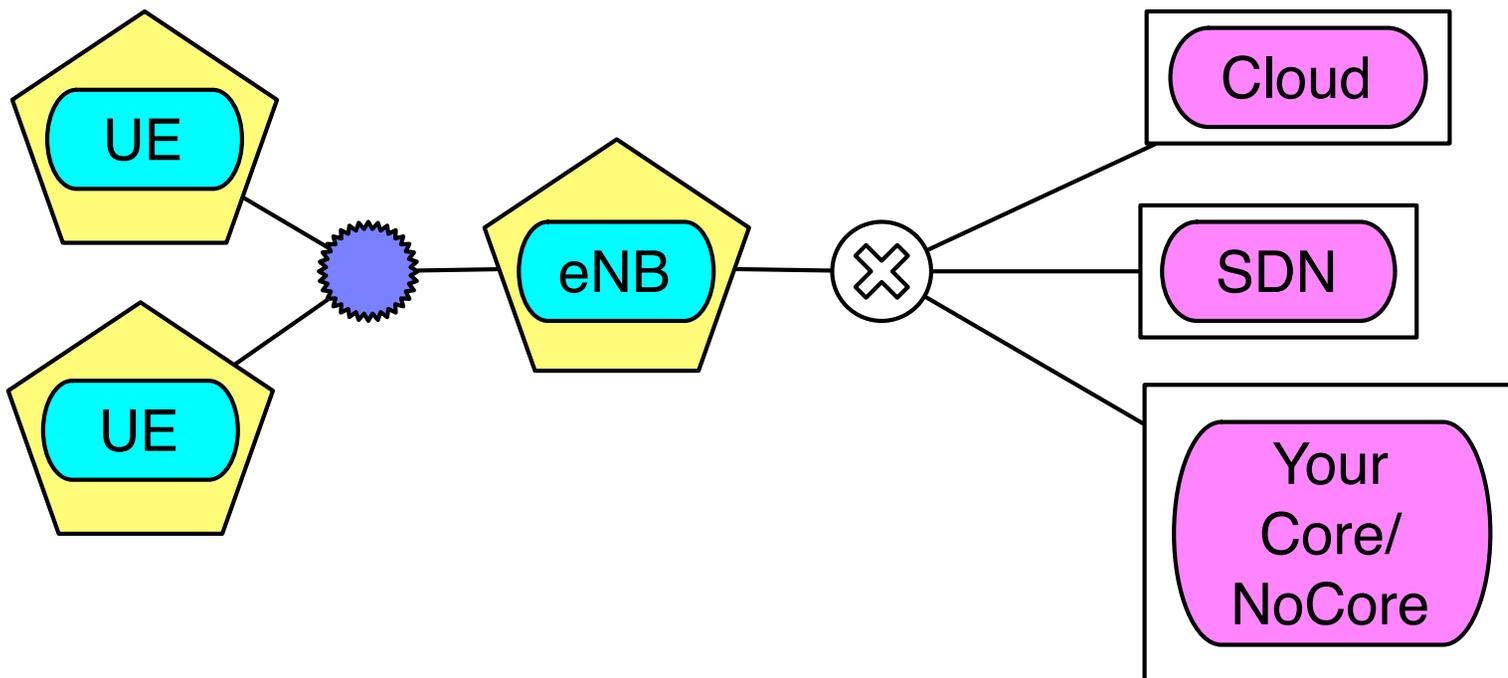# What can you do with PhantomNet?

- Evolved packet core (EPC) with OpenEPC components
- Real RAN:
  - Off-the-shelf user equipment (UE) (Android devices)
  - SDR-based UE (USRP with OAI)
  - SDR-based base station (eNodeb) (USRP with OAI)

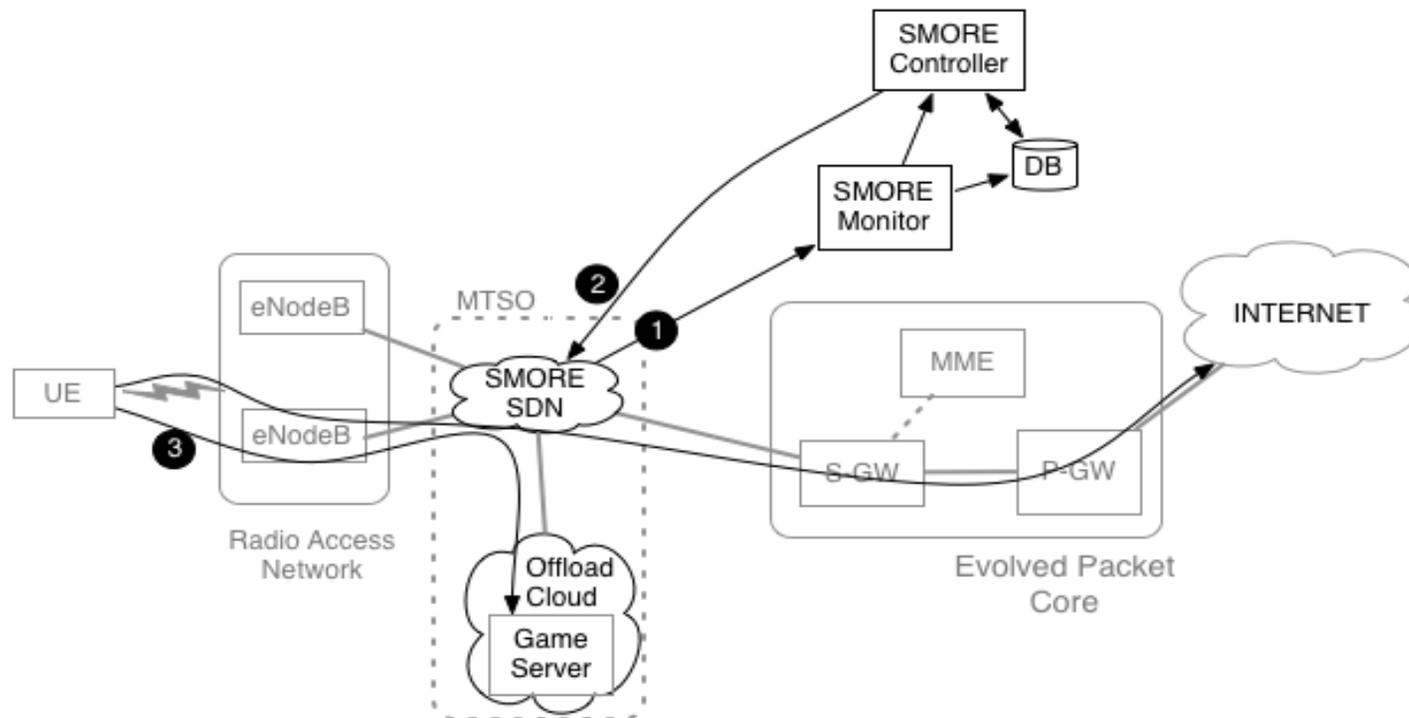# What can you do with PhantomNet?

- Role your own…

What can you do with PhantomNet?

Mobile networking "lego" kit...

Some of the things PhantomNet has been used for

SMORE: Software-Defined Mobile Network Offloading Architecture

- Problem: Existing mobile architectures are highly centralized -> long delay
- Solution: Offload traffic with low latency requirements to "in-network" cloud platforms

# SMORE: Software-Defined Mobile Network Offloading Architecture

- Approach:
  - Deploy SDN fabric inside mobile network
  - Intercept and redirect low-latency traffic
  - Either on-demand or subscription based

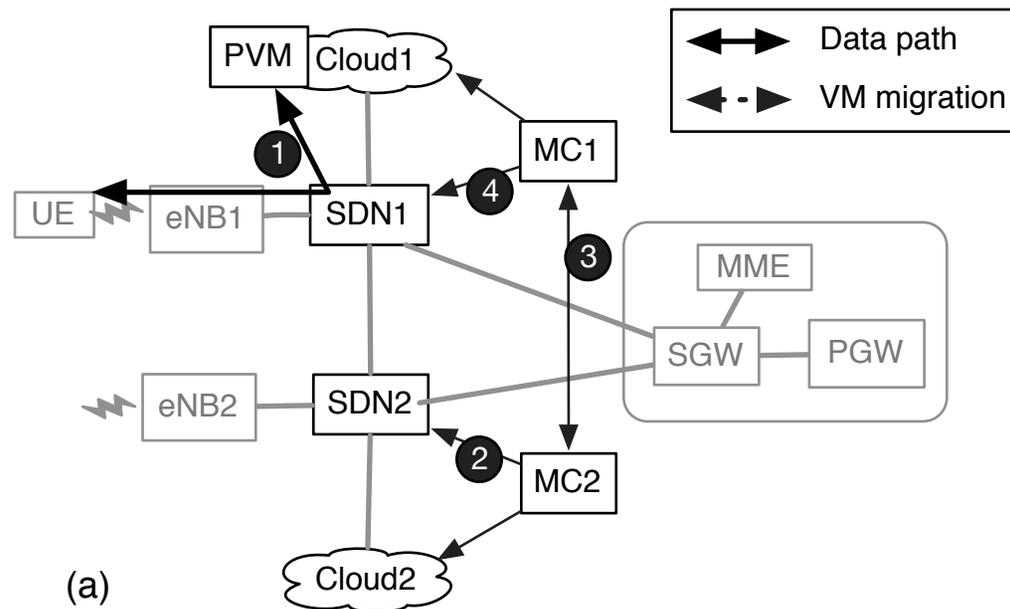# MobiScud: A Fast Moving Personal Cloud in the Mobile Network

- Inspired by Cloudlet work
  - Want a personalized VM to follow you around as your mobile device moves in the real world
- Example use case:
  - Google glass for Alzheimer patient
  - Performs personalized face recognition with processing in the cloud
  - Requires low latency…

MobiScud: A Fast Moving Personal Cloud in the Mobile Network
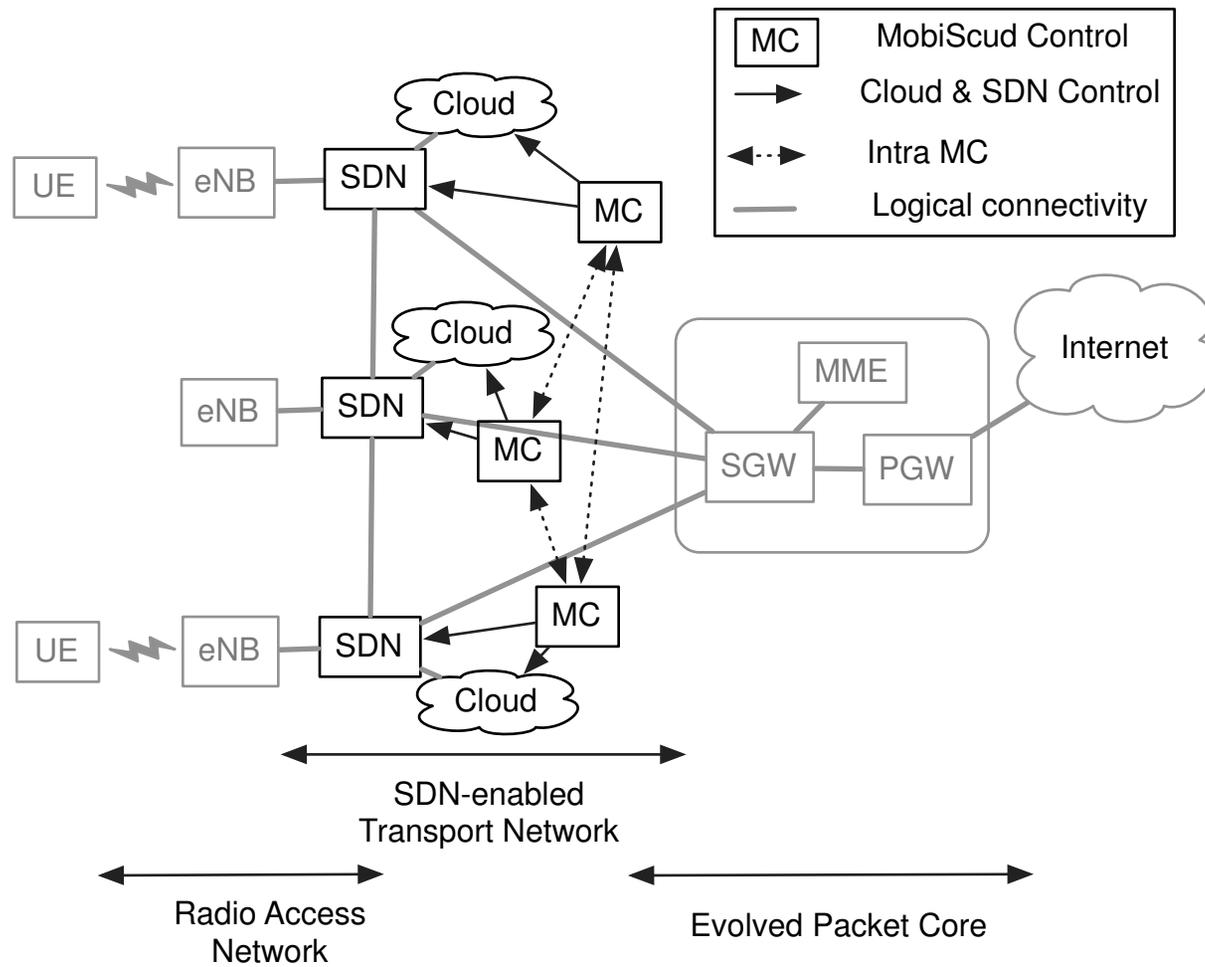
MobiScud: A Fast Moving Personal Cloud in the Mobile Network

(a)

- Coordinate offloading to in-network cloud, with mobile handover, with VM migration

MobiScud: A Fast Moving Personal Cloud in the Mobile Network

(b)

- Coordinate offloading to in-network cloud, with mobile handover, with VM migration
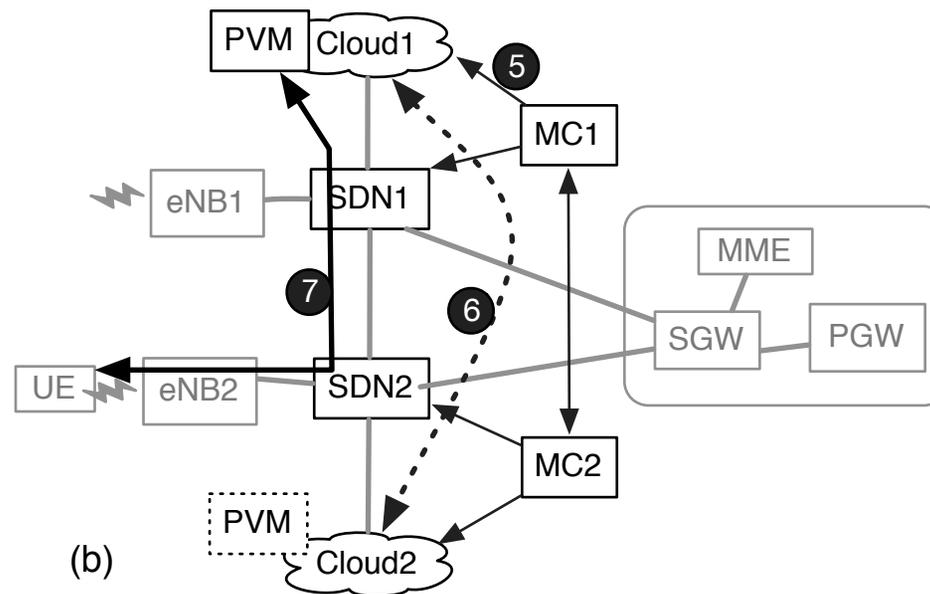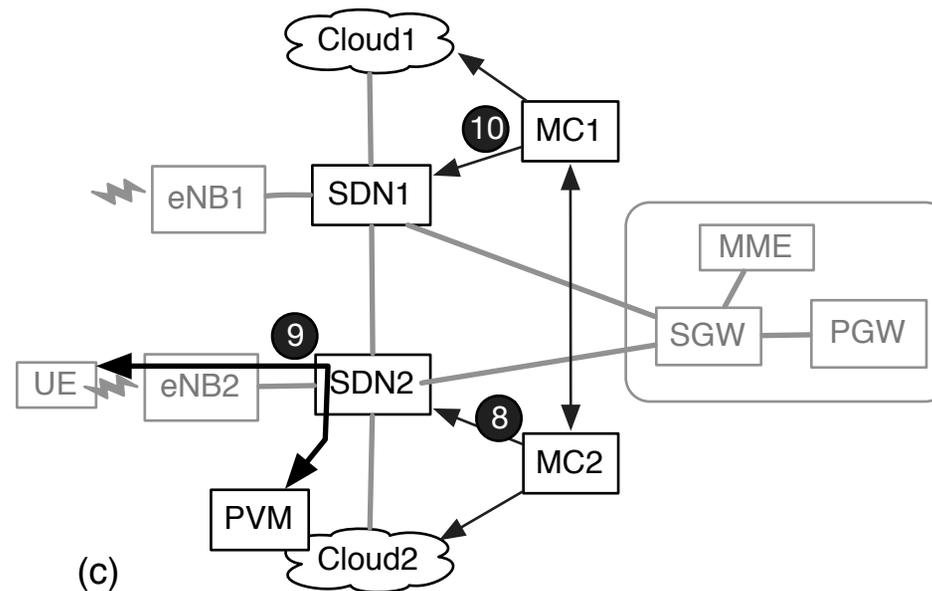
MobiScud: A Fast Moving Personal Cloud in the Mobile Network

(c)

- Coordinate offloading to in-network cloud, with mobile handover, with VM migration

More recent efforts

- KLEIN: A Minimally Disruptive Design for an Elastic Cellular Core
  - Using NFV to make make mobile core elastic
- P2P Offloading in Mobile Networks using SDN
  - Using SDN to do P2P more efficiently
- SIMECA: SDN-based IoT Mobile Edge Cloud Architecture
  - An IoT service abstraction using SDN, NFV and mobile edge cloud
- Proteus: A network service control platform for service evolution in a mobile software defined infrastructure
  - Mobile service evolution in a mobile software defined infrastructure

Resources available
(kick-start your research and teaching)

- Publish our use case as profiles and self-help tutorials
  - https://www.phantomnet.org
  - https://wiki.phantomnet.org/wiki/phantomnet
- Documentation on developing own profiles
  - All our examples are open source
- Examples:
  - 4G with OpenEPC
  - 4G with OAI
  - Using OTS phones and eNodeBs
  - NFV-based mobility-as-a-service
  - Combining SDN and mobile networking (SMORE)
  - Controlling Android apps
  - Obtaining FAPI traces from the RAN

Resources available
(kick-start your research and teaching)

- Have used PhantomNet for teaching
  - Grad level Advanced Networking course
  - Lab assignment:
    - Combined SDN with mobile networking
    - Used OpenEPC plus OVS GTP extensions we developed
    - Students had to develop the "glue code" in between
  - **Material is available for others…**

Advertising

- We will be doing PhantomNet tutorials at:

SIGCOMM 2016

GLOBECOM 2016

Demo setup

User access

User-provided
ADB host

OpenEPC Core
on Cloud platform

MME

SGW

PGW

ADB Proxy

UE in isolation box

UE

Attenuator
Matrix

eNB

OTS eNodeB
in isolation box