MobilityFirst Architecture and Protocol Evaluation on GENI

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WINLAB 

MobilityFirst Project: Collaborating Institutions

RUTGERS (LEAD)

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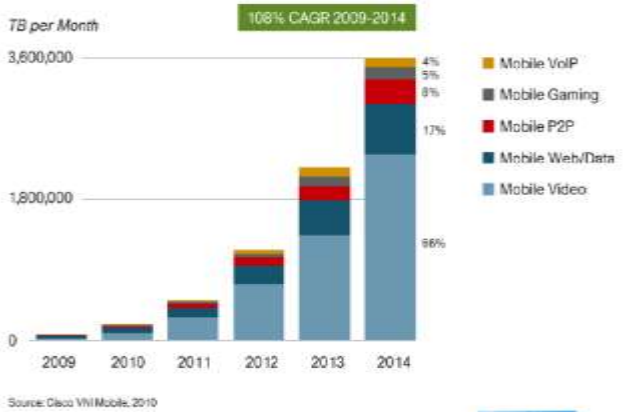
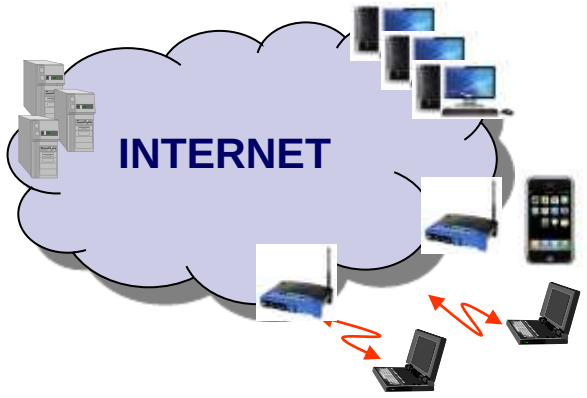
Vision: Mobility as *the* key driver for the future Internet

- Historic shift from PC's to mobile computing and embedded devices…
  - ~4 B cell phones vs. ~1B PC's in 2010
  - Mobile data growing exponentially – Cisco white paper predicts 3.6 Exabytes by 2014, significantly exceeding wired Internet traffic
  - Sensor/IoT/V2V just starting, ~5-10B units by 2020

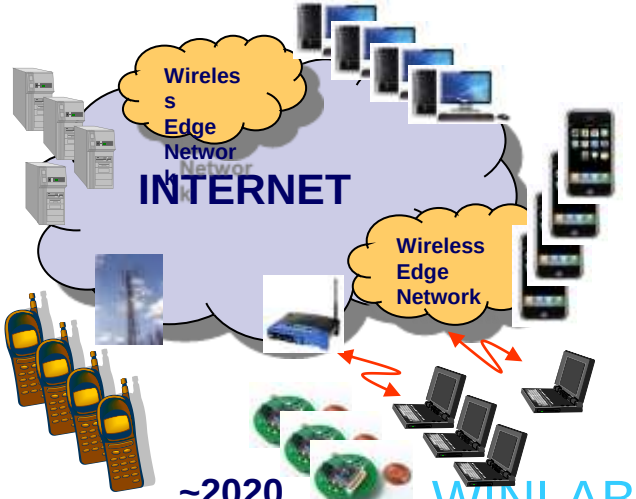


~1B server/PC's, ~700M smart phones



~2010

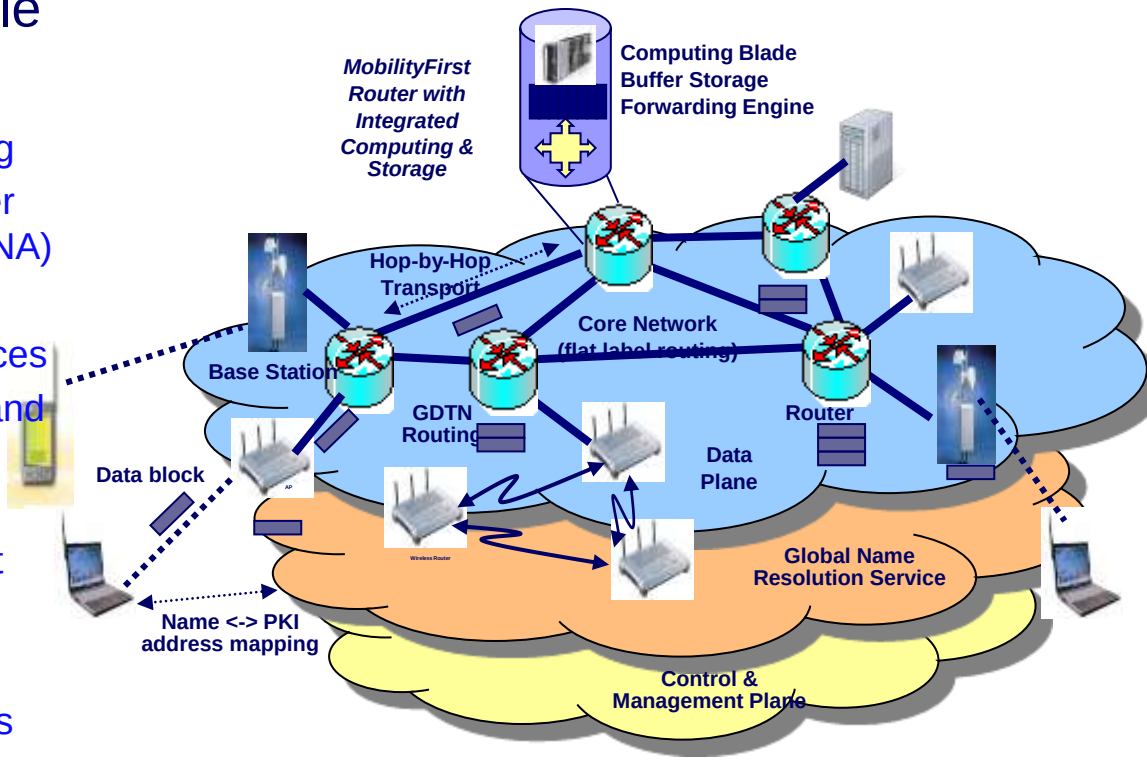
~2B servers/PC's, ~10B notebooks, PDA's, smart phones, sensors



~2020

Architecture: *MobilityFirst* Network Overview

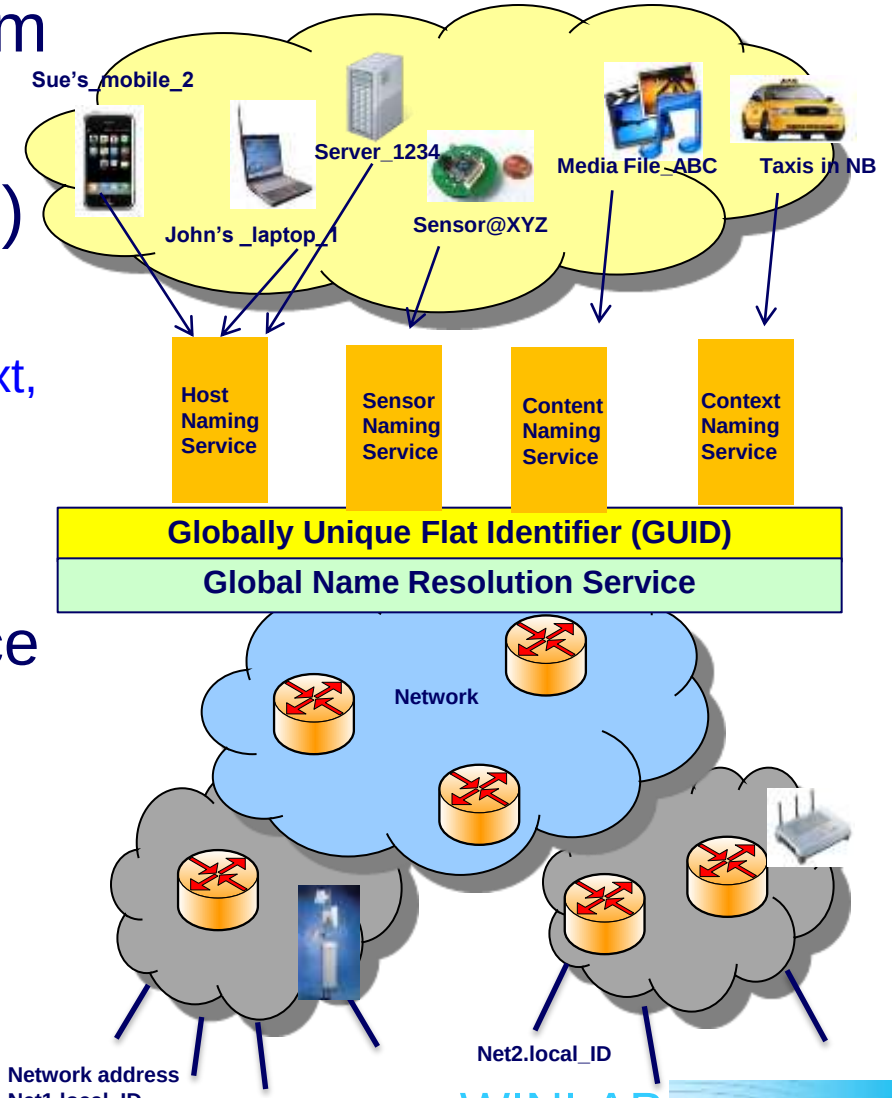
- MF Arch designed to meet emerging mobile/wireless service requirements at scale
- Key MF protocol features:
  - Separation of naming & addressing
  - Public-key globally unique identifier (GUID) and flat network address (NA)
  - Storage-aware (GDTN) routing
  - Multicast, multipath, anycast services
  - Flexible inter-domain boundaries and aggregation level
  - Early binding/late binding options
  - Hop-by-hop (segmented) transport
  - Support for content & context
  - Strong security and privacy model
  - Separate mgmt & computing layers



- Several new protocol components, very distinct from today's TCP/IP ….

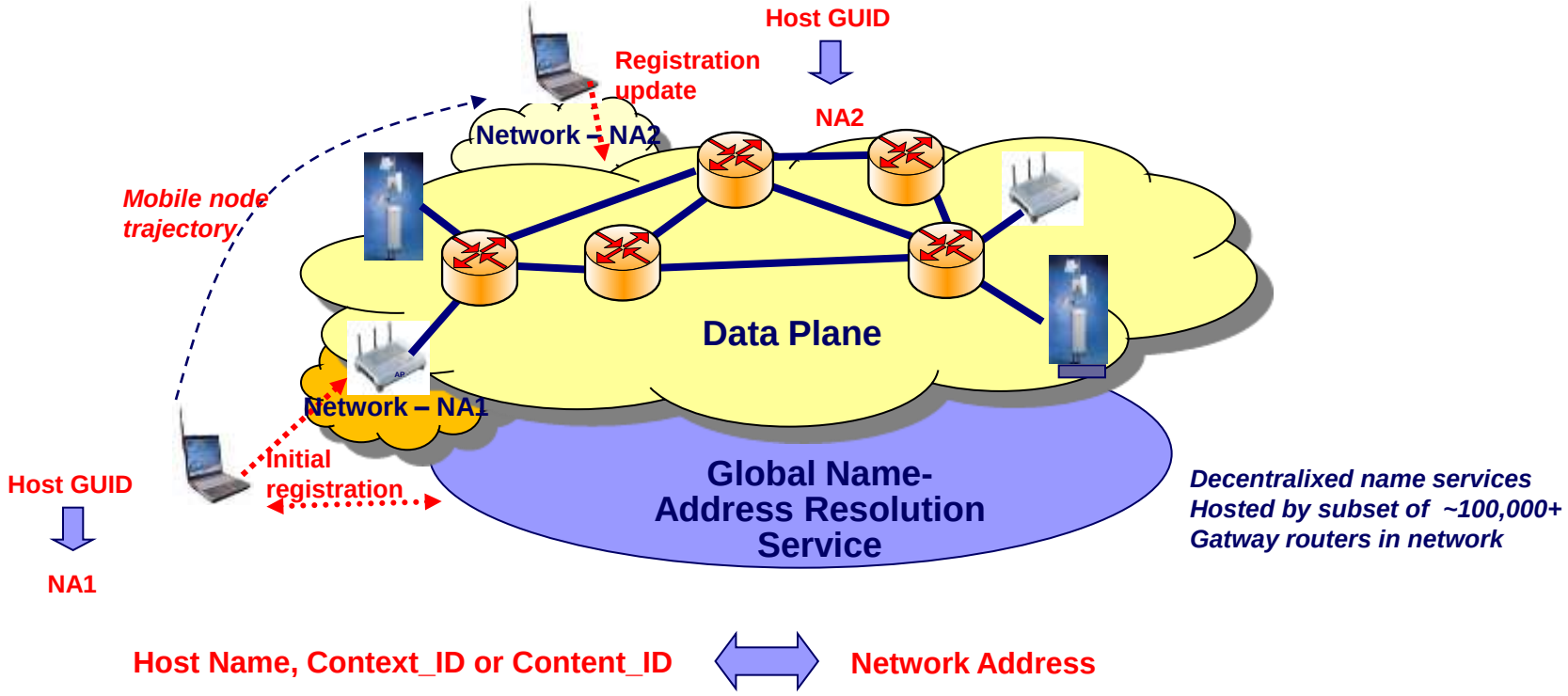
Architecture Concepts: Name-Address Separation

- Separation of names (ID) from network addresses (NA)
- Globally unique name (GUID) for network attached objects
  - User name, device ID, content, context, AS name, and so on
  - Multiple domain-specific naming services
- Global Name Resolution Service for GUID → NA mappings
- Hybrid GUID/NA approach
  - Both name/address headers in PDU
  - "Fast path" when NA is available
  - GUID resolution, late binding option



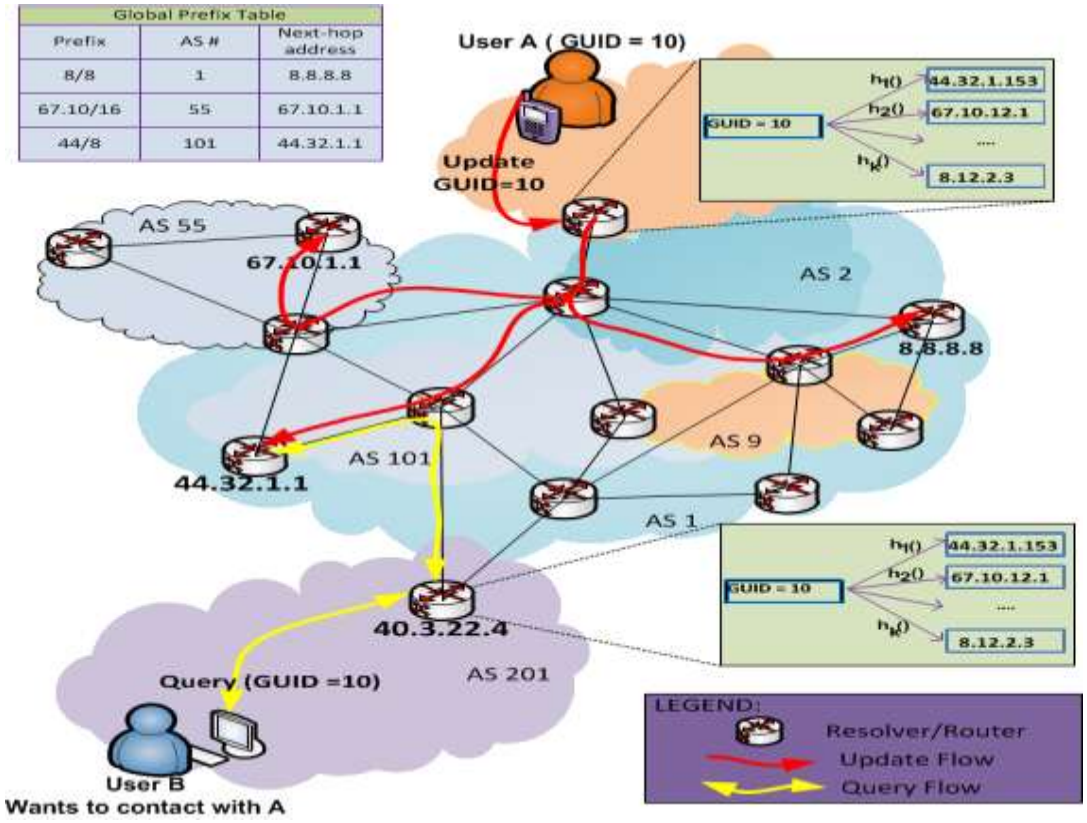
Architecture Concepts: Global Name Resolution Service for Dynamic Name <-> Address Binding

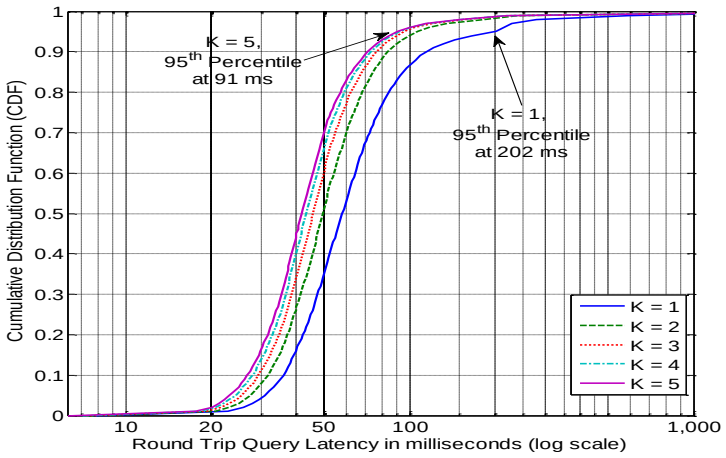
- Fast Global Name Resolution a central feature of architecture
  - GUID <-> network address (NA) mappings
- Distributed service, possibly hosted directly on routers
  - Fast updates ~50-100 ms to support dynamic mobility
  - Service can scale to ~10B names via P2P/DHT techniques, Moore's law



Protocol Design: Direct Hash GNRS

- Fast GNRS implementation based on DHT between routers
  - GNRS entries (GUID <-> NA) stored at Router Addr = hash(GUID)
  - Results in distributed in-network directory with fast access (~100 ms)

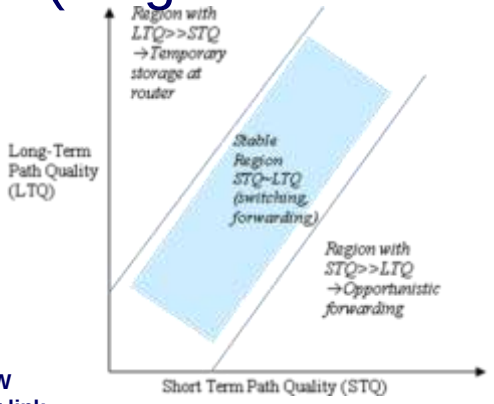


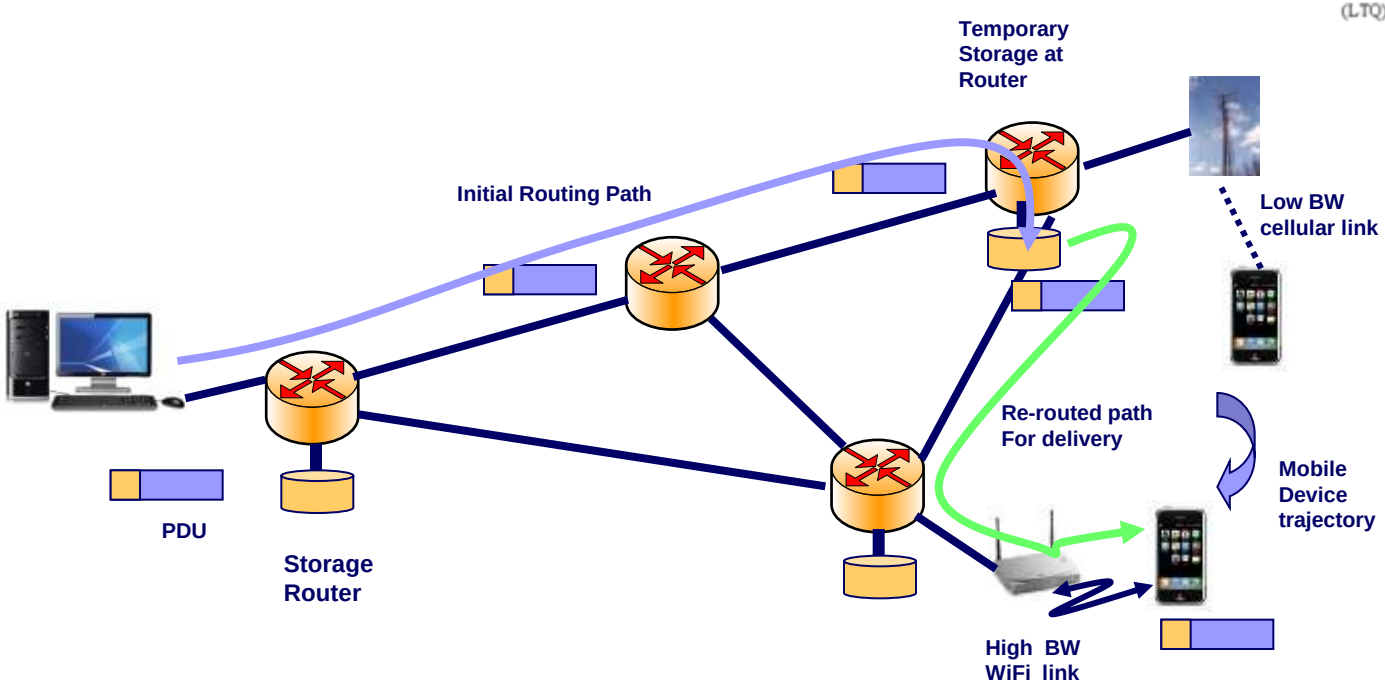


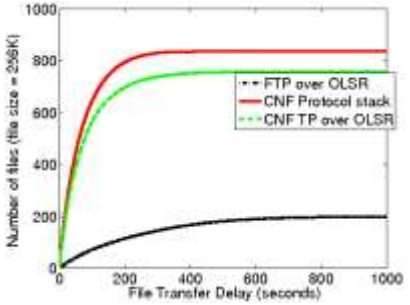
Internet Scale Simulation Results Using DIMES database

Protocol Design: Storage-Aware Routing (GSTAR)

- Storage aware (CNF, generalized DTN) routing exploits in-network storage to deal with varying link quality and disconnection
- Routing algorithm adapts from switching (good path) to store-and-forward (poor link BW/short disconnection) to DTN (longer disconnections)
- Storage has benefits for wired networks as well..



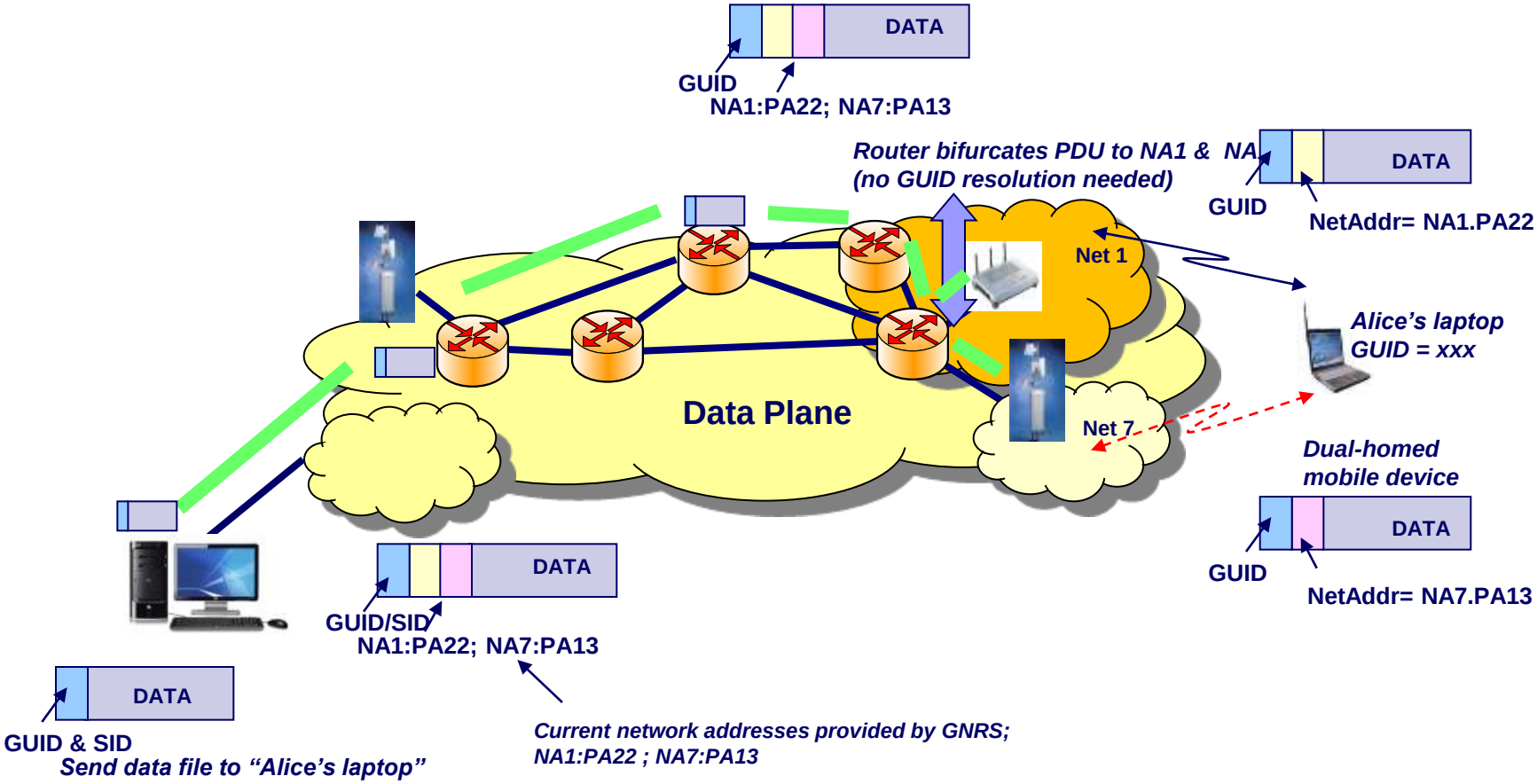




Sample CNF routing result

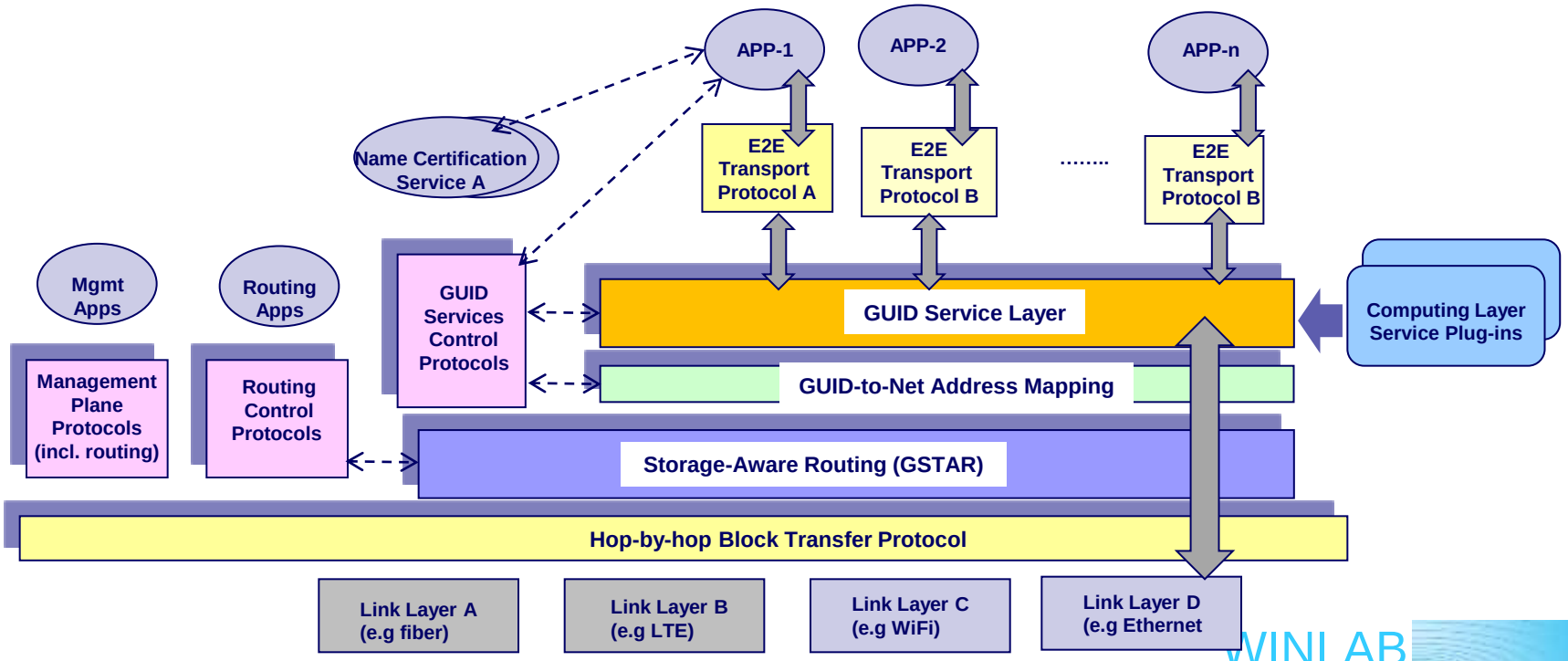
Example: GUID/Address Routing Scenarios – Dual Homing, Partial Disconnection

- The combination of GUID and network address helps to support new mobility related services including multi-homing, anycast, DTN, context, location …
- Dual-homing scenario below allows for multiple NA:PA's per name

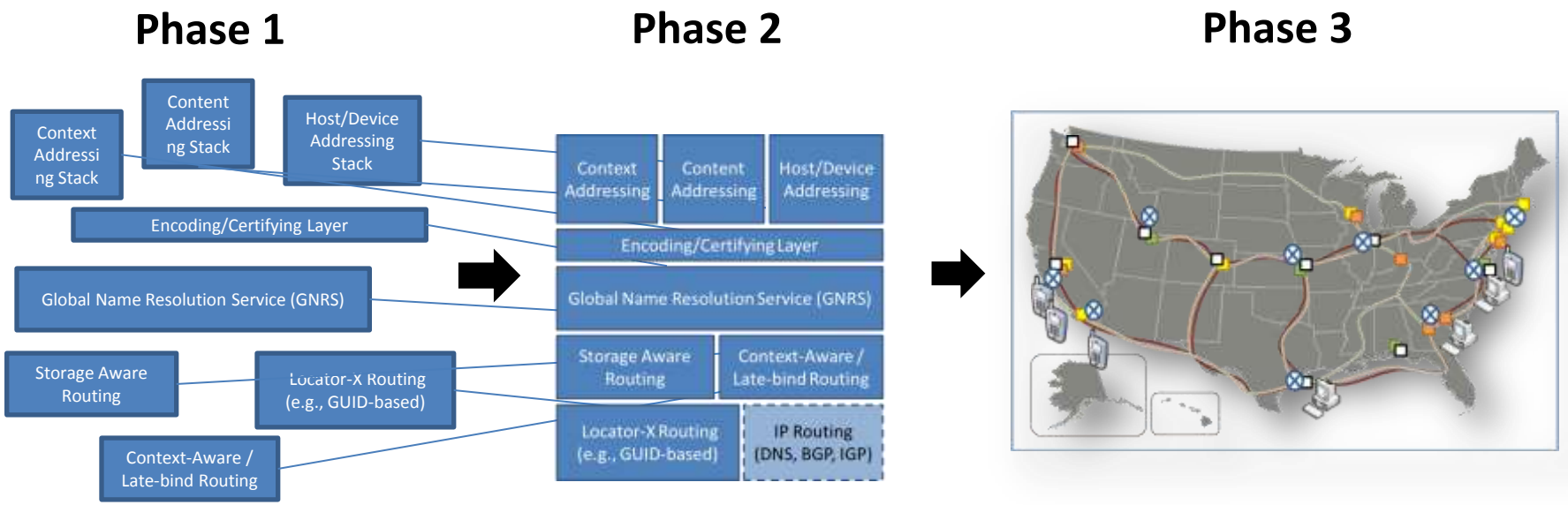


Protocol Design: MF Stack

- Core elements of MF protocol stack
  - GUID services layer, supported by control protocols for bootstrap & updates
  - GUID to network address mapping (GNRS) for dynamic mapping of GUID
  - Generalized storage-aware routing (GSTAR) with supporting control protocols
  - Reliable hop-by-hop block transfer between routers
  - Management plane protocol with its own routing scheme
  - Multiple TP options and plug-in programmable services at GUID layer



Prototyping and Evaluation: Execution Summary



Prototype

Standalone Modules

Evaluation

Simulation and Emulation

Integrated MF Protocol Stack and Services

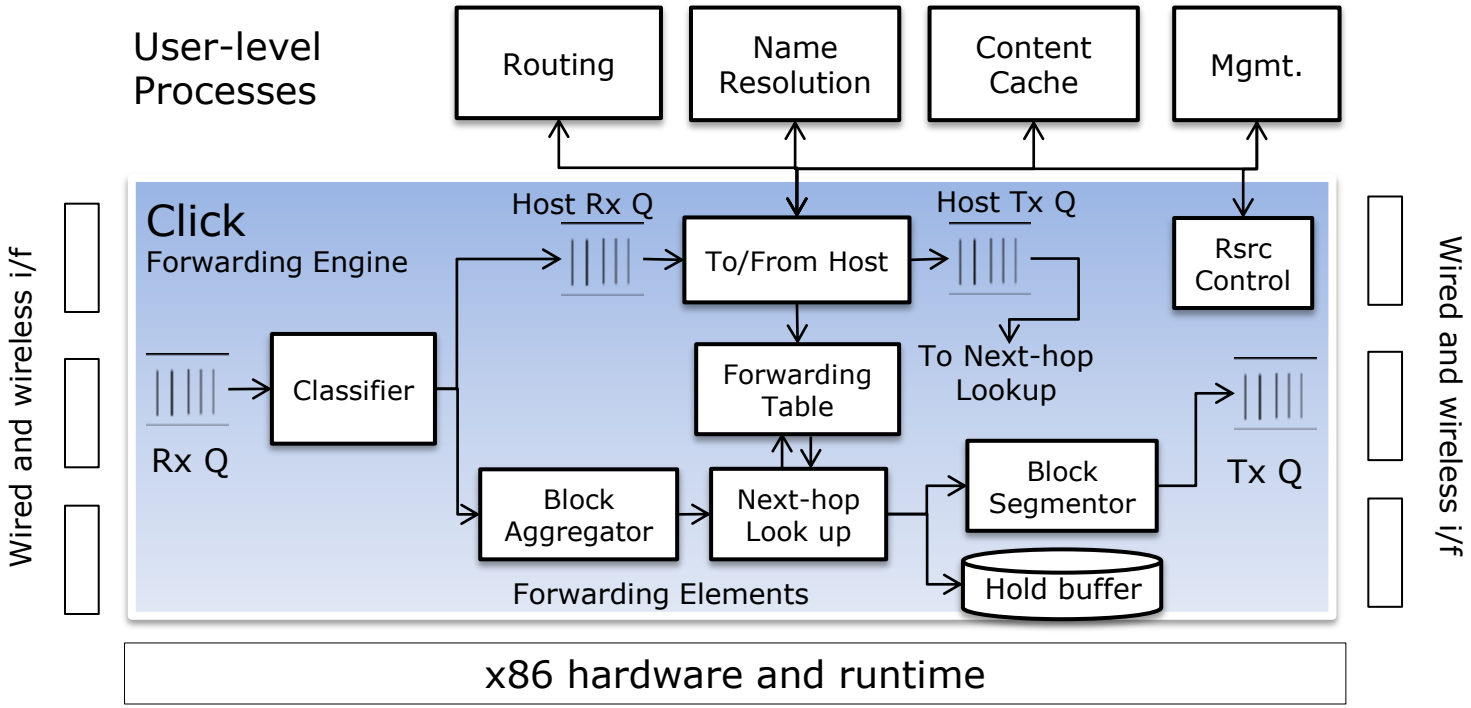
Smaller Scale Testbed

Deployable s/w pkg., box

Distributed Testbed
E.g. 'Live' on GENI

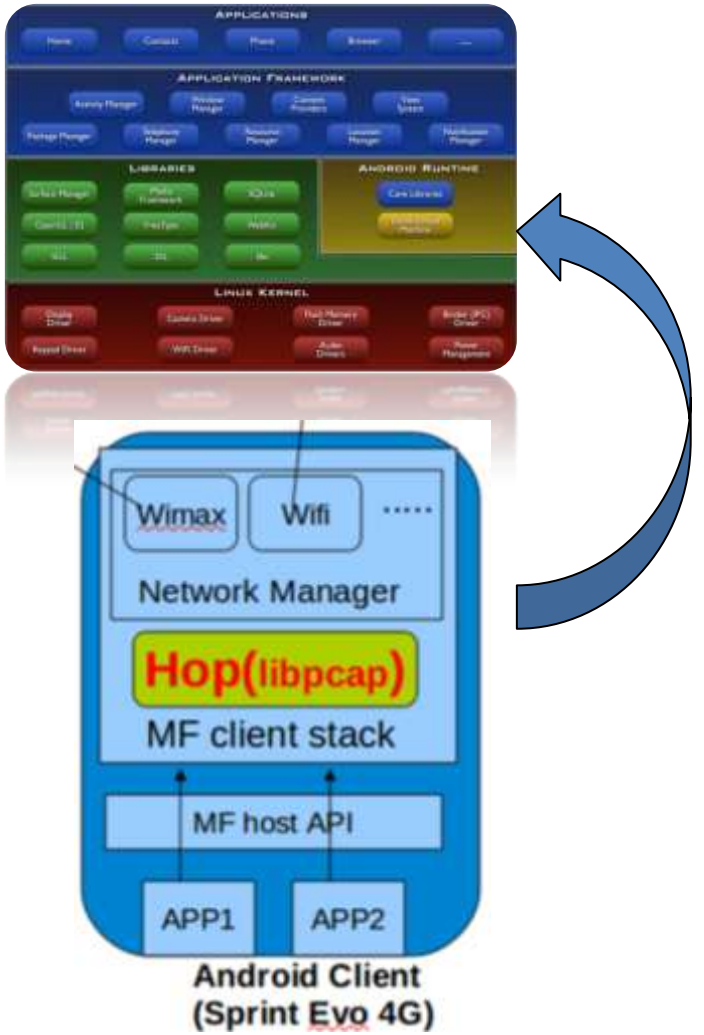
MobilityFirst Prototype: Click-based Router

- Linux-based implementation with Click modular router as forwarding engine
- Two-level abstraction: fast path as Click elements, slow path as user-level processes (control and support services)



MobilityFirst Prototype: Android/Linux Client Implementation

- Device: HTC Evo, Android 2.3
  - Unbranded and *rooted*
  - Development: SDK, NDK, flash a modified kernel (if required)
  - WiFi, WiMAX interfaces
- Modules in Android's MF stack
  - MF-socket API - user level library
  - Transport layer
  - Storage aware routing
  - SHIM layer support for multi-homing
  - 1-Hop reliable data transfer
- MF-socket API
  - open, send, send_to, recv, recv_from
  - User policies for resource use and intentional data receipt



MobilityFirst Prototype: Network Architecture

- Edge networks NA-1, NA-2 connected to global core network
- Each of NA-1, NA-2 are contained MF routing domains
- Each WiMAX BSS and WiFi AP is associated with a MF Router
- Node **a** is **multi-homed** within a network
- Node **c** is **multi-homed** across 2 networks

WiFi AP

WiMAX BSS

MF Router

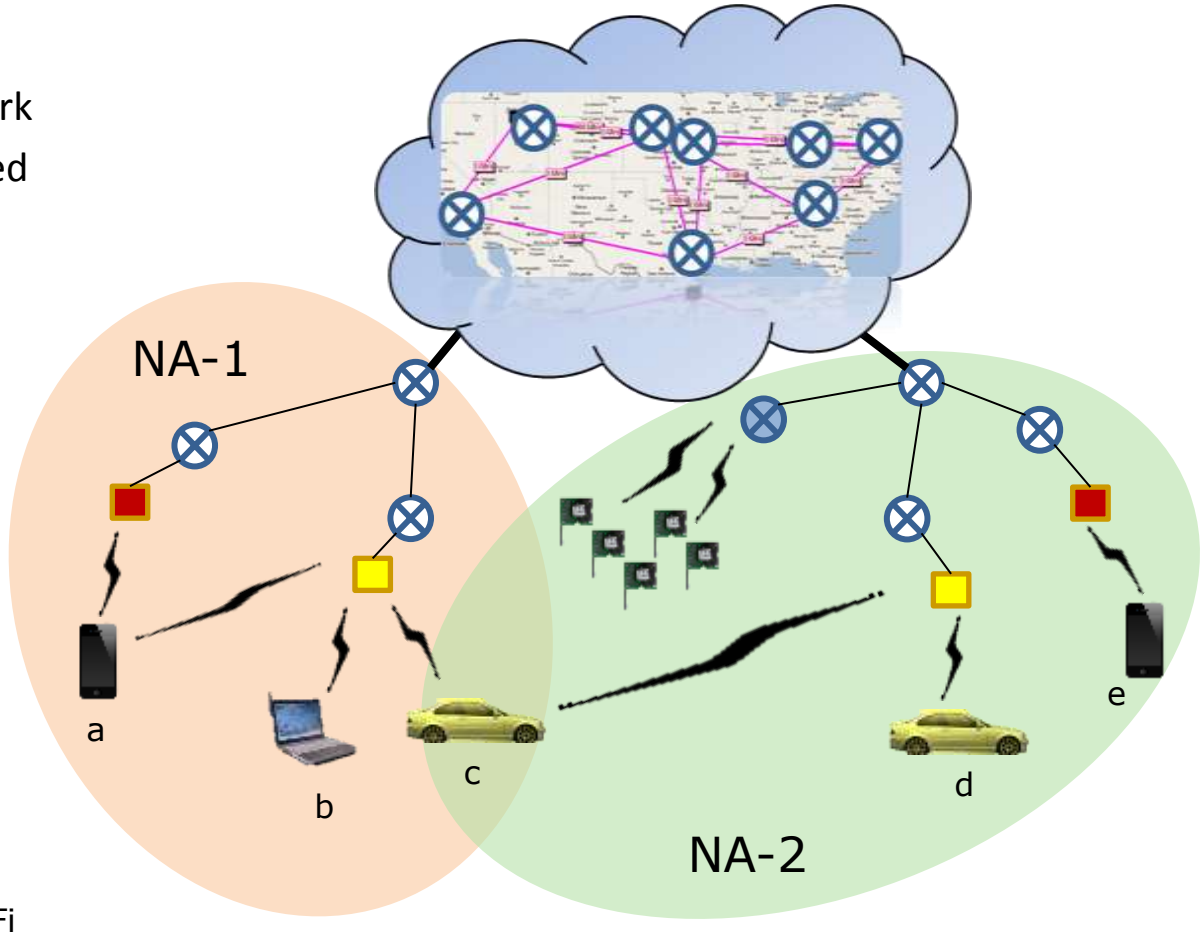
Android Client w/ WiMAX + WiFi

Linux PC/laptop w/ WiMAX + WiFi

Vehicular node w/ WiMAX

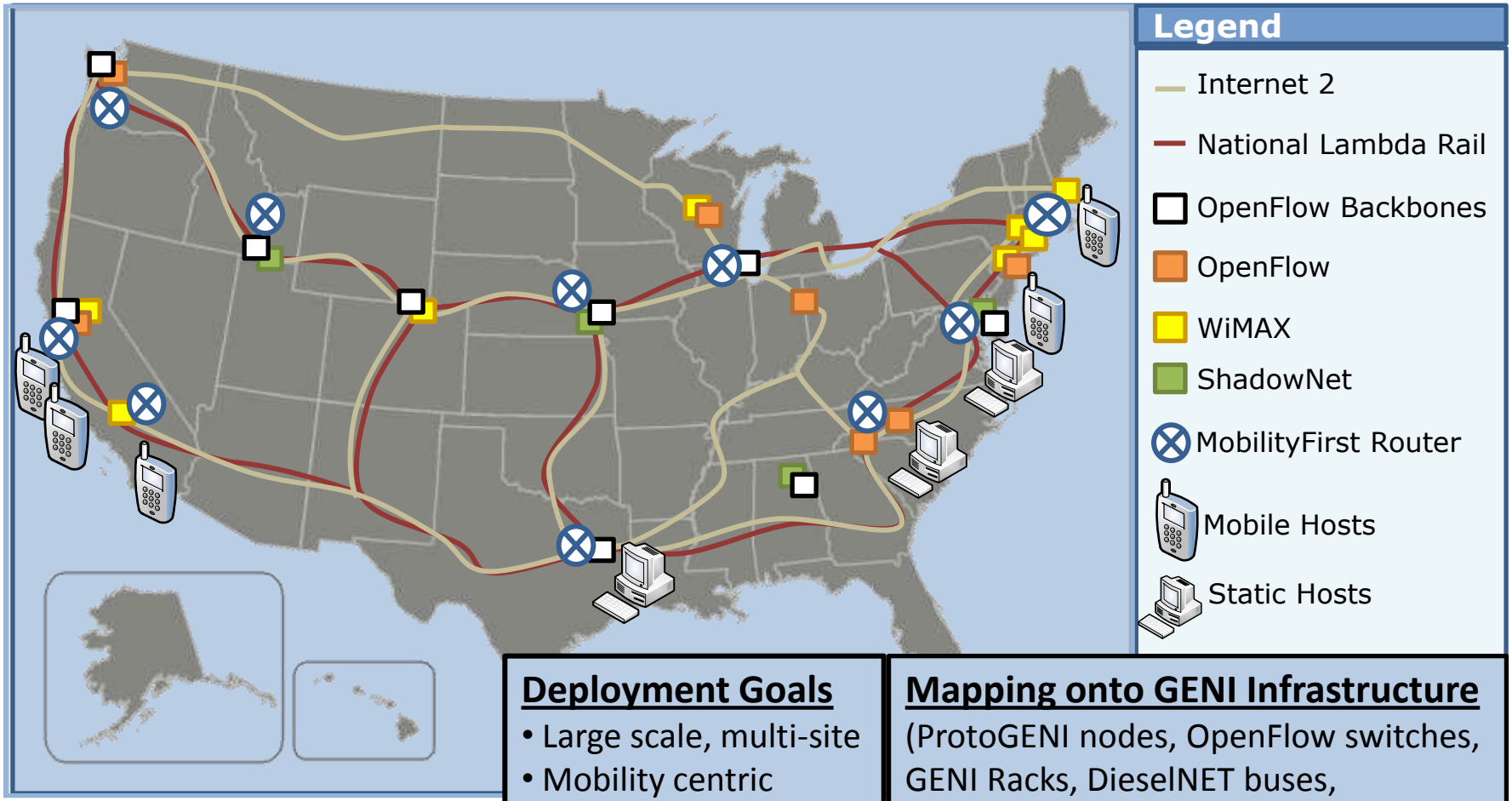
Sensor node

MF Sensor GW



Ad hoc networks: Nodes can form ad hoc networks which are named and can attach to existing networks to be globally reachable themselves

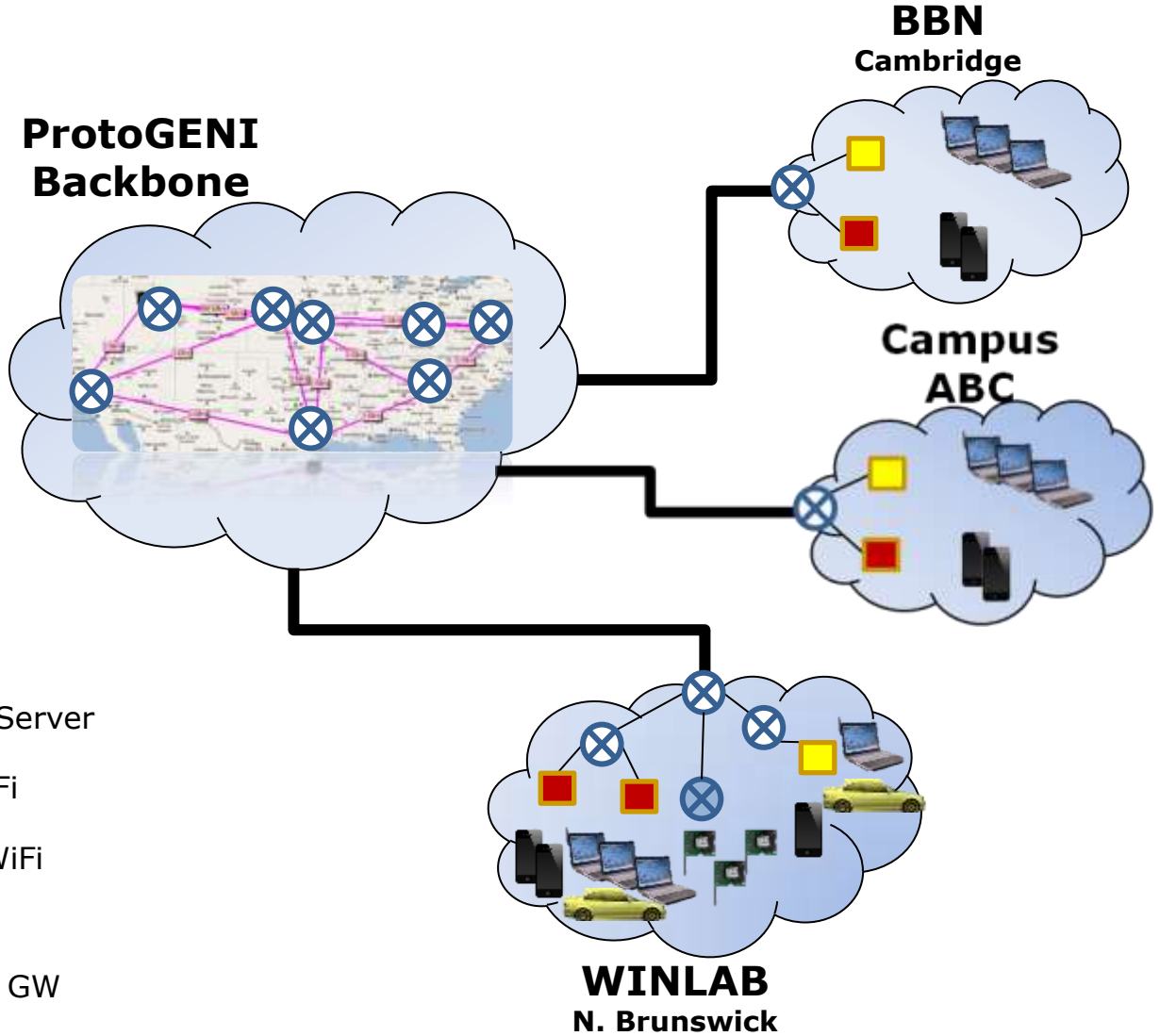
GENI Deployment: Phase 3 on Multiple Sites



Deployment Goals
- Large scale, multi-site
- Mobility centric
- Realistic, live

Mapping onto GENI Infrastructure
(ProtoGENI nodes, OpenFlow switches, GENI Racks, DieselNET buses, WiMAX/outdoor ORBIT nodes)

GENI Deployment:
WiMAX and WiFi Edges at Rutgers and BBN



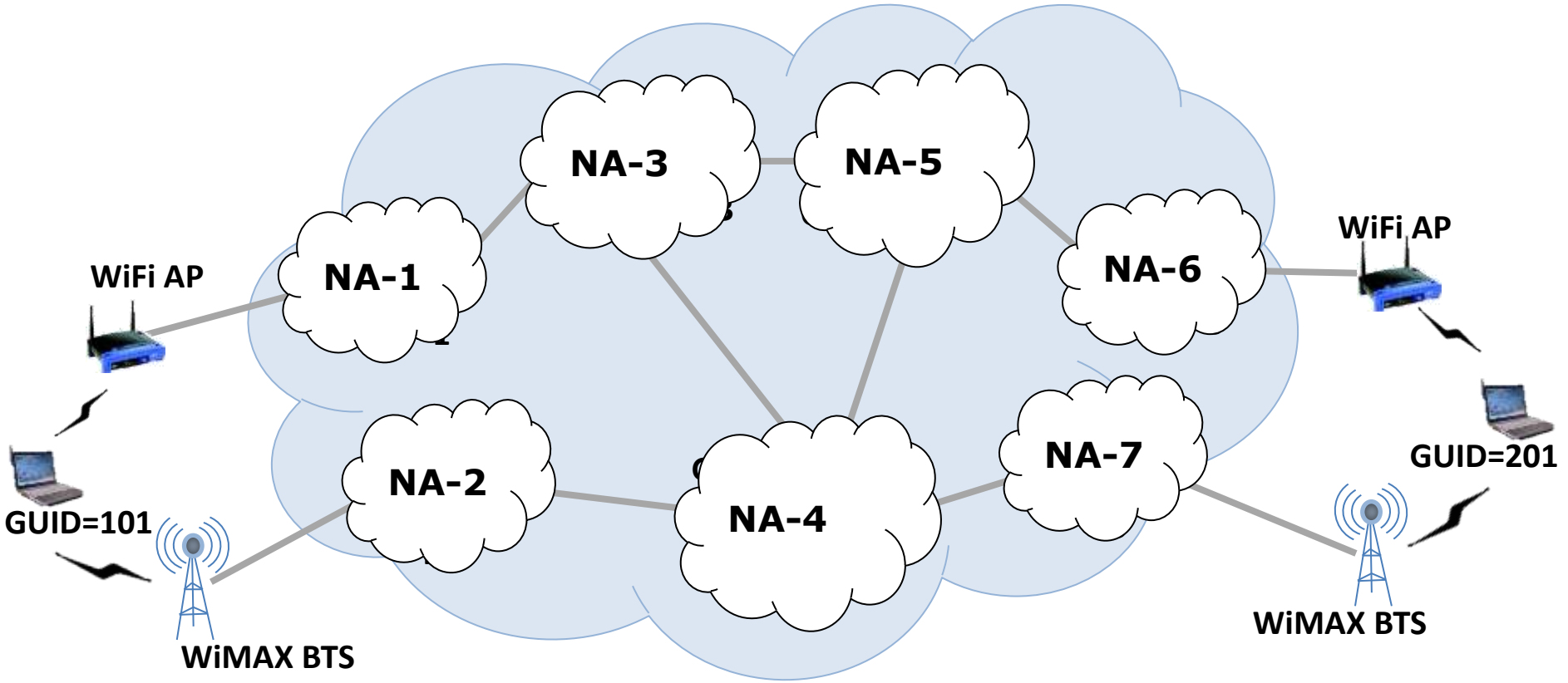
- WiFi AP
- WiMAX BSS
- MF Router + Name Resolution Server
- Android Client w/ WiMAX + WiFi
- Linux PC/laptop w/ WiMAX + WiFi
- Vehicular node w/ WiMAX
- Sensor node
- MF Sensor GW

RUTGERS

GEC-12 Experiment: Overview

- Network: Edge networks connected to Protogeni backbone
  - **WiFi** and **WiMAX** at edges. Mobile hosts and access network.
- Deployed MF components:
  - MF prototype router with **Storage Aware Routing** and **Name Resolution Service**
  - MF Clients including **Linux PC/laptops/Android Phone** (and vehicular nodes)
- Applications: Edge to edge content delivery
- Demonstration Focus:
  - Multi-homing - convergence of WiFi and WiMAX
  - Network-level adaptation to mobility (varying link quality) and disconnection

Experiment Setup : Proposed MF Network Graph



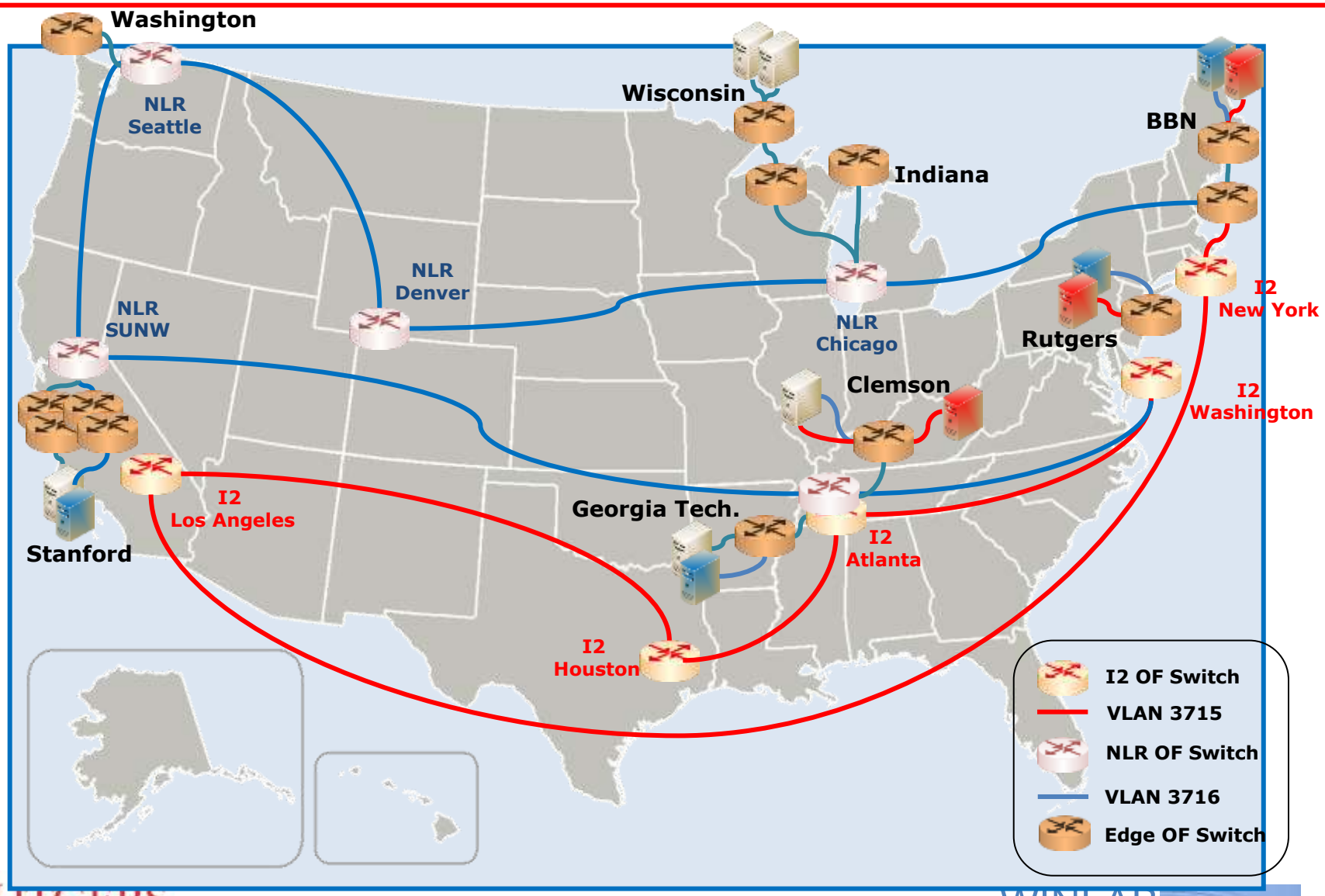
Rutgers Wireless Edge

ProtoGENI Backbone

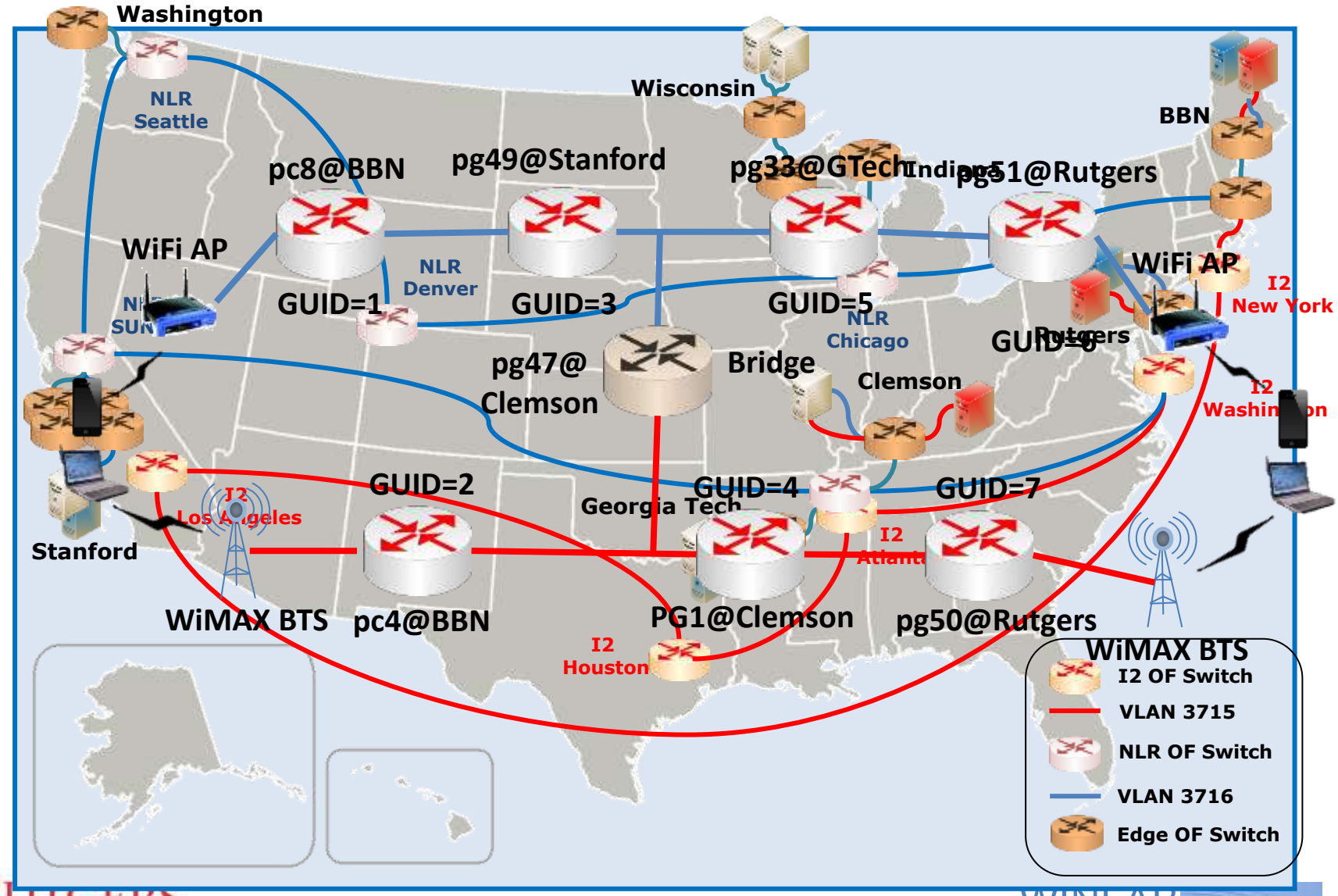
BBN Wireless Edge

ProtoGENI host running MF Router

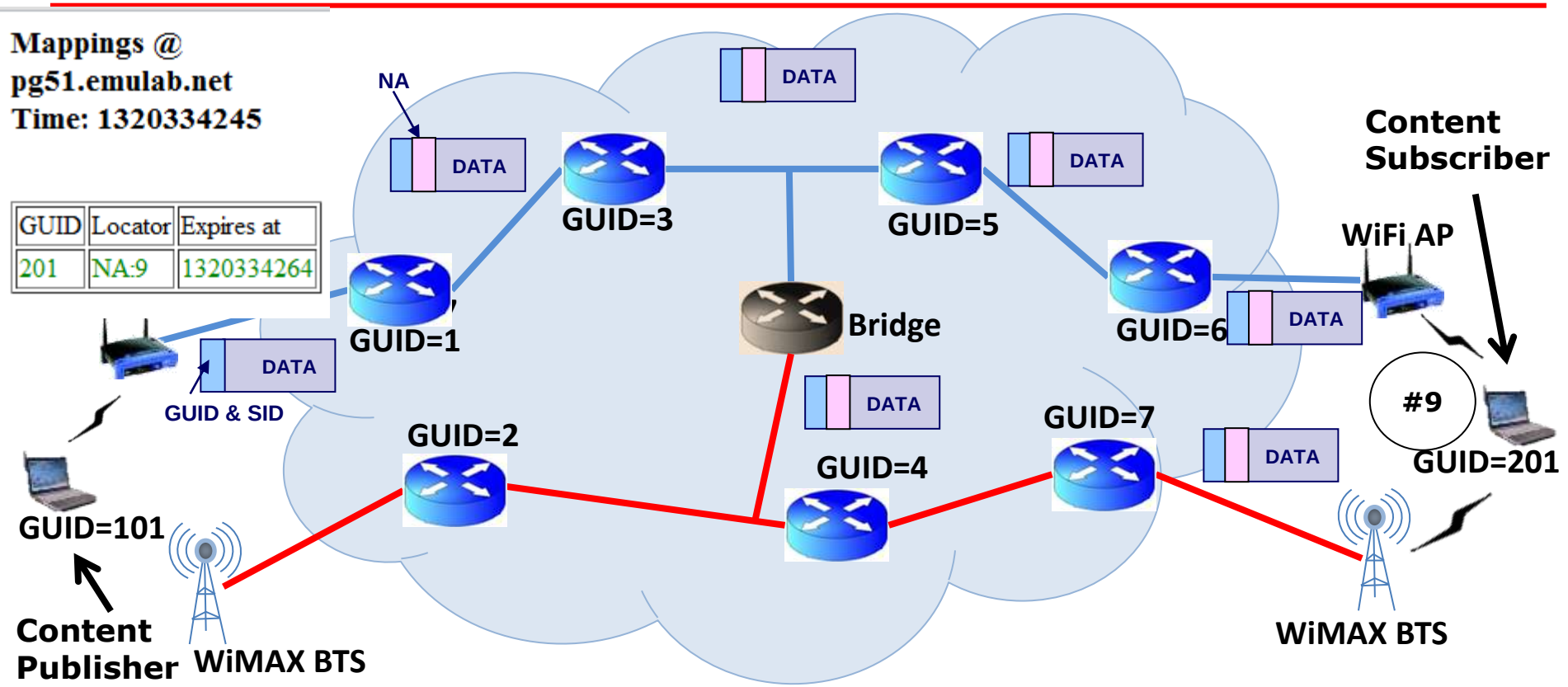
GENI Deployment: Physical Topology



GENI Deployment: Mapping to Logical Topology



Application: Content Delivery to Mobile Hosts



NLR path using VLANs 3716, 3799 (Clemson)

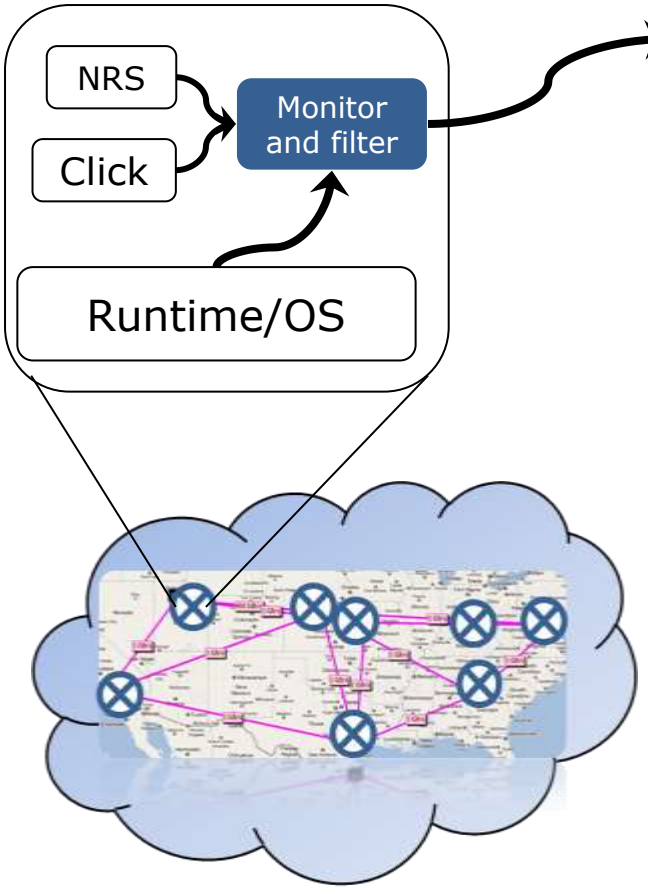
I2 path using VLANs 3715, 3745(BBN), 3798 (Clemson)

ProtoGENI host running MF Router

Visualization

Data collection framework with API, monitors, filters and data warehouse
E.g., Orbit Measurement Library (OML)

MF Network element
e.g. Router



HTTP, XML, JSON

Browser: AJAX/JS/Flash

What's on?

1. Network statistics
2. Packet and flow tracing
3. Routing events
4. Application events

Network map credits: ProtoGENI's Flack tool. http://protogeni.net/trac/protogeni