Mobility and Future Internet

Networking Lab.
Department of Computer Engineering
Kyung Hee University

May 7, 2013

Choong Seon Hong

Outline

- Introduction to MIPv4, MIPv6, and PMIPv6
- Current Internet Architecture
- Why ID/Locator Separation Architecture?
- ID/Locator Separation Architecture Overview
- Related Works on ID/Locator Separation
- Proposed ID/Locator Separation-based Lightweight Mobility Architecture in Wireless Sensor Network
- Conclusion
- MobilityFirst

Mobile IPv4

Motivation for Mobile IP

- TCP session needs to keep the same IP address for the life of the session
- IP needs to change the IP address when mobile node moves to a new location

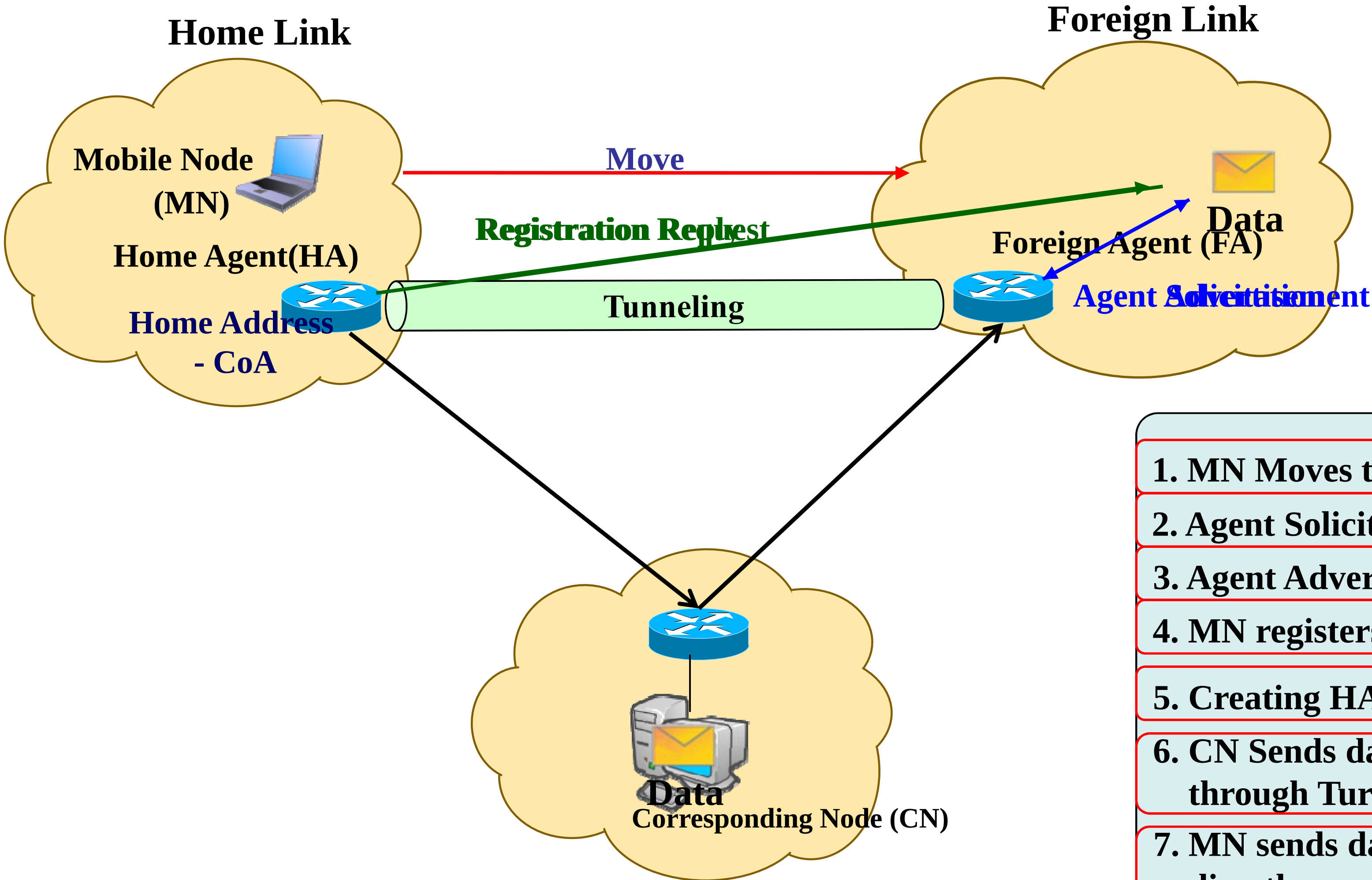
Mobile Node has two IP addresses (2-tier addressing)

- Home-of Address (HoA) : its identifier
- Care-of Address (CoA) : its locator

New Entity : Home Agent (HA), Foreign Agent (FA)

- Router on the home link and foreign link
- Tracks the MN's current point of attachment

Mobile IPv4 Operation

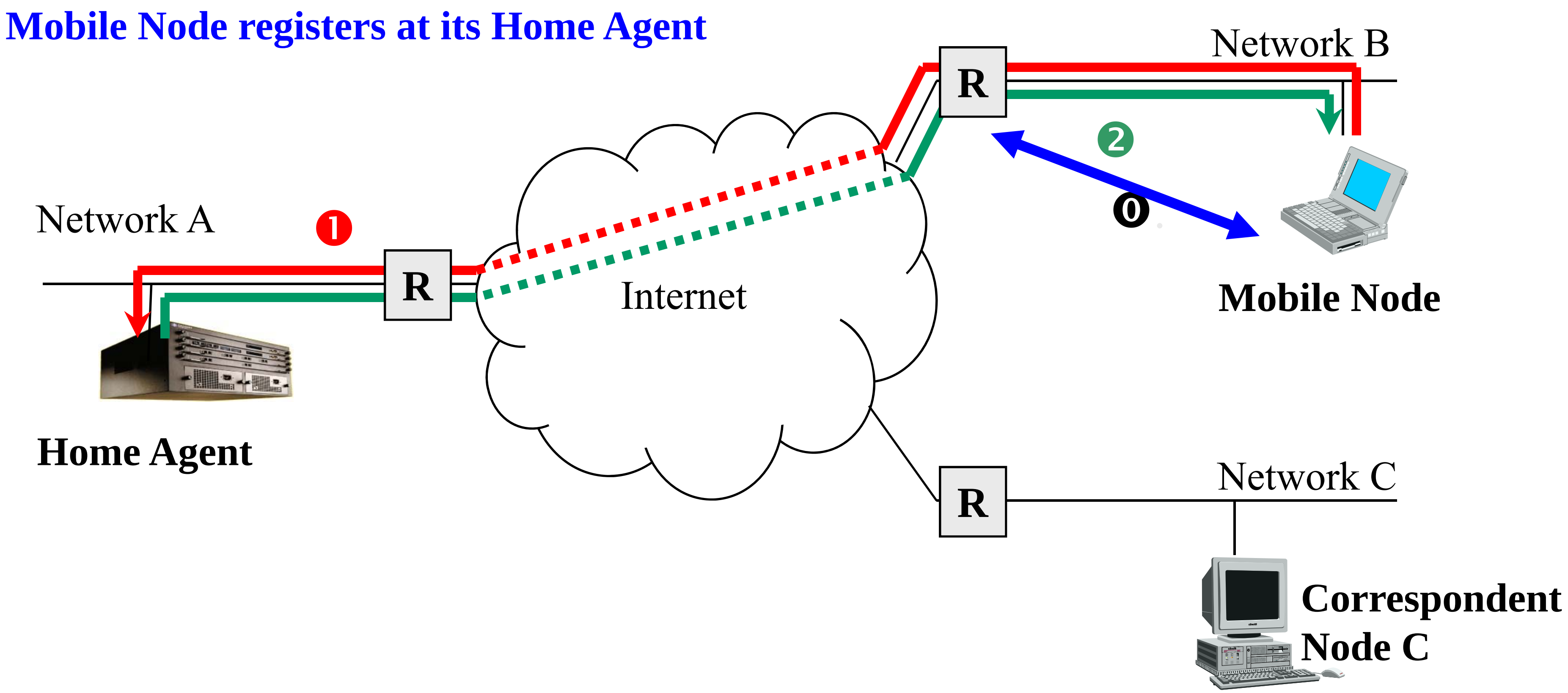


1. MN Moves to FA
2. Agent Solicitation
3. Agent Advertisement
4. MN registers CoA to HA.
5. Creating HA Turnneling
6. CN Sends data to MN through Turnneling
7. MN sends data to CN directly

Mobile IPv6

- C.Perkins et al., "Mobile Support in IPv6", RFC 3775, June 2004.
- Address Auto-configuration
  - Movement detection by monitoring advertisement of new prefix
- Mobile IPv6 defines a new IPv6 protocol, using the Mobility Header
  - Home Test Init / Home Test
  - Care-of Test Init /Care-of Test
  - Binding Update / Binding Acknowledgement
  - Binding Refresh Request / Binding Error
- Binding Updates to CN as well as HA in the context of Route Optimization
- Home Address destination option
  - Replace MN's CoA with MN's HoA for the source address of packets sent from MN to CN
- Type 2 Routing Header option
  - Replace MN's CoA with MN's HoA for the destination address of packets sent from CN to MN

Mobile IPv6 Operation



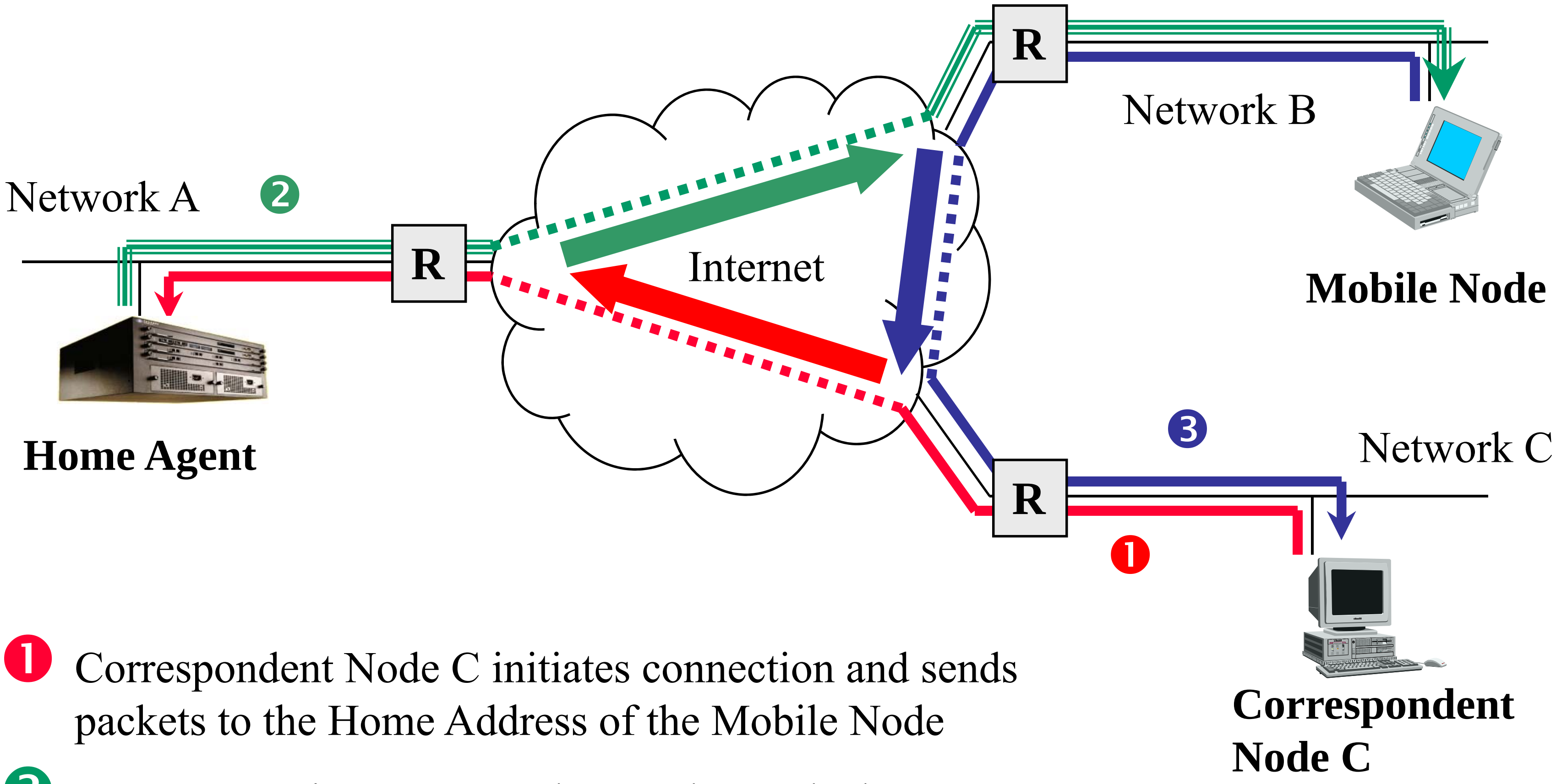
⓿ Mobile Node used Auto-configuration and Neighbor discovery to obtain a global IPv6 address. (No Foreign Agent needed)

❶ Mobile Node sends Binding Update to HA

❷ Home Agent replies with Binding Acknowledgement to MN

Mobile IPv6 Operation

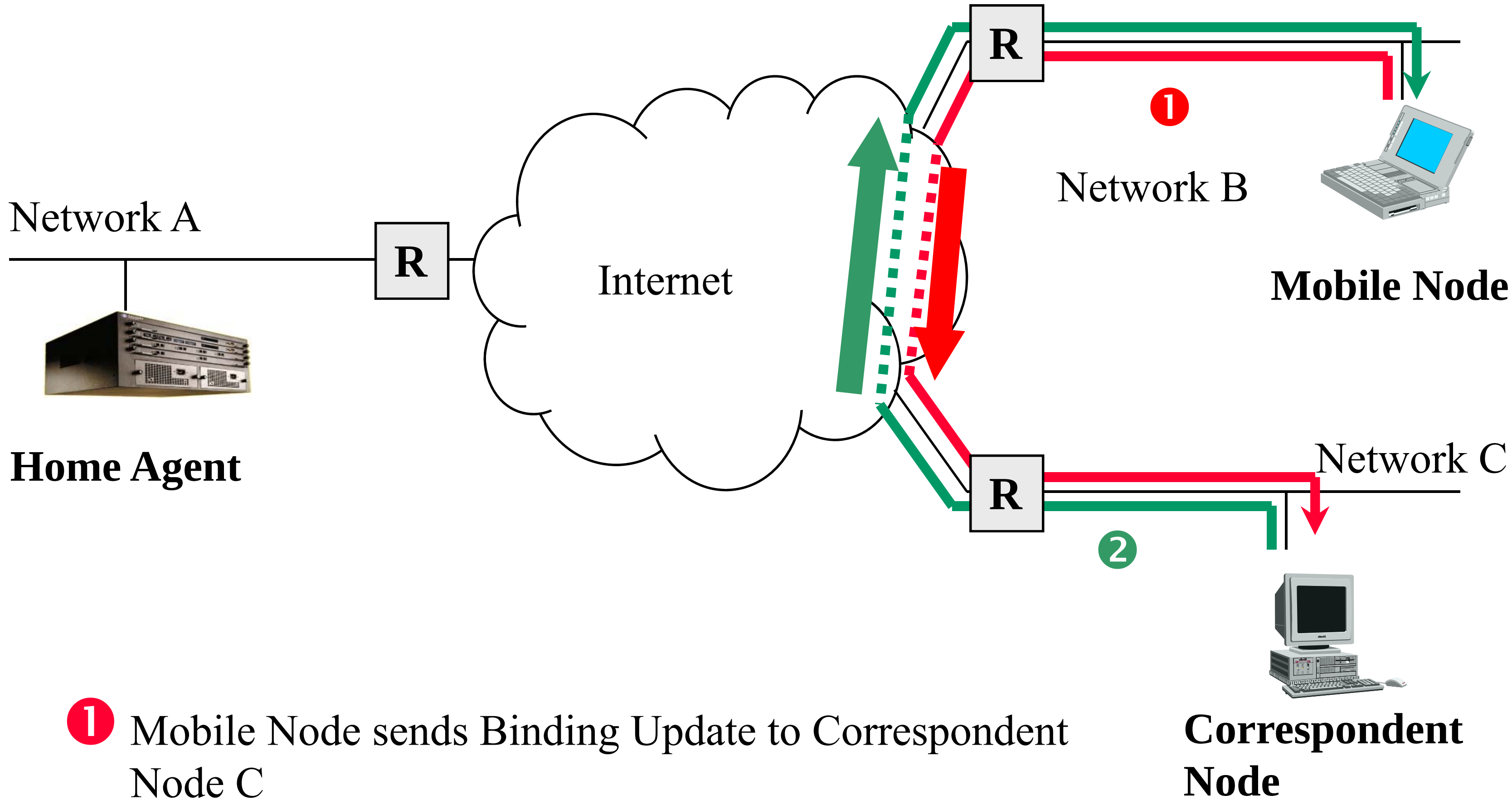
Triangular Routing during Initial Phase



1. Correspondent Node C initiates connection and sends packets to the Home Address of the Mobile Node
2. Home Agent intercepts packets and tunnels them to the Mobile Node
3. Mobile Node sends answer directly to Host C

Mobile IPv6 Operation

Route Optimization Operation



❶ Mobile Node sends Binding Update to Correspondent Node C

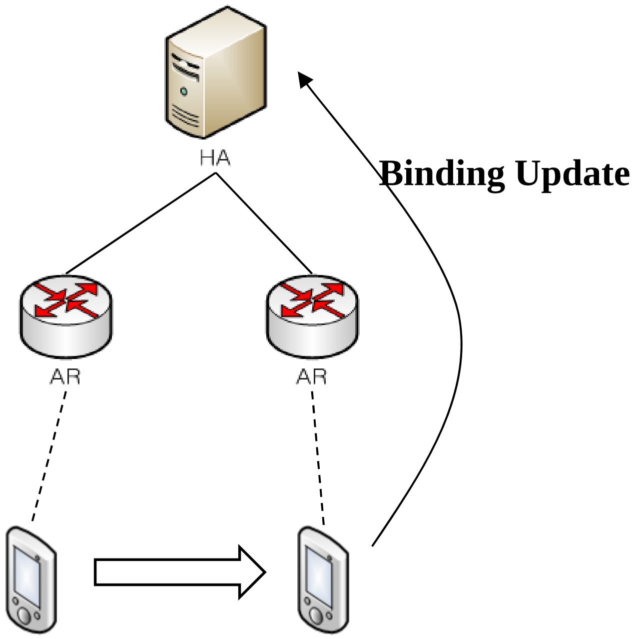
❷ Now Correspondent Node can address the CoA of the Mobile Node directly

Mobile IPv4 vs Mobile IPv6

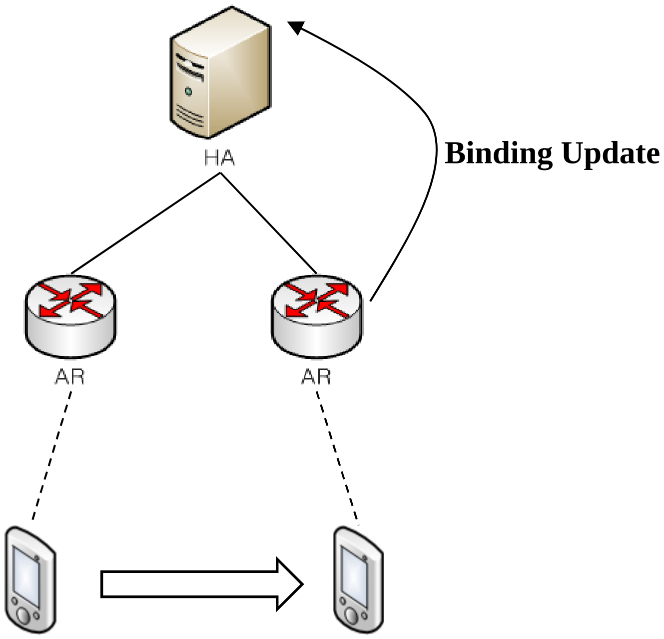
- There is no need for Foreign Agents since the MH can use the *Address Auto-configuration* protocol to obtain a dynamic care-of address
- Binding updates are supplied by encoding them as TLV destination options in the IP header
- IPv6 provides security protocols hence simplifying the authentication process
- Route Optimization is Mandatory
- Return Routerability is checked for the security reason

Proxy Mobile IPv6

- **Network-based Mobility**
  - **Mobility handled by the network, often transparent to the mobile node**
  - **Directly or indirectly triggered by the mobile node**
- **Host-based Mobility**
  - **Mobility handled by the mobile node**
  - **Full involvement of the mobile node**



A) Host-based Mobility Management



B) Network-based Mobility Management

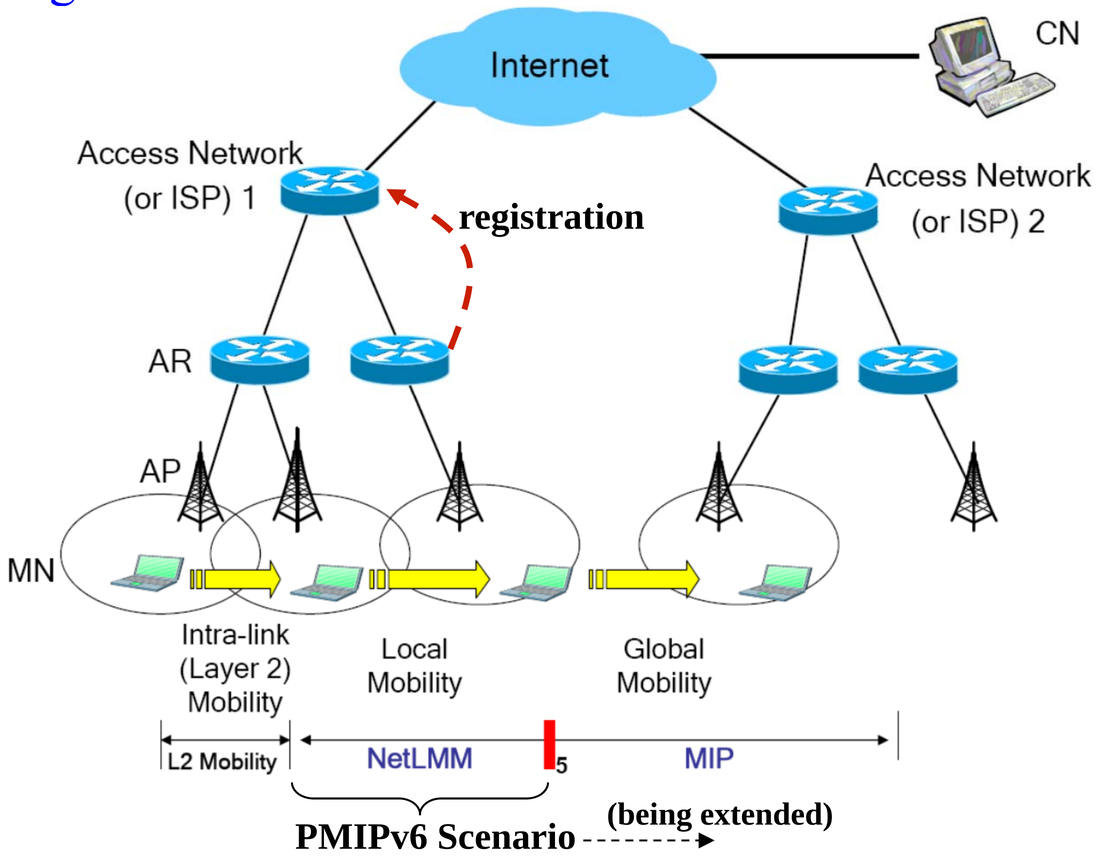
Proxy Mobile IPv6

- Host-based Mobile IPv4/v6 (RFC 3344/3775) has not been yet deployed that much.
  - Why host-based MIP is not deployed yet?
    - ✓ Too heavy specification to be implemented at a small terminal
      - RFC 3344 (MIPv4): 99 pages
      - RFC 3775 (MIPv6): 165 pages
    - ✓ Battery problem
    - ✓ Waste of air resource
  - No Stable MIPv4/v6 stack executed in Microsoft Windows OS

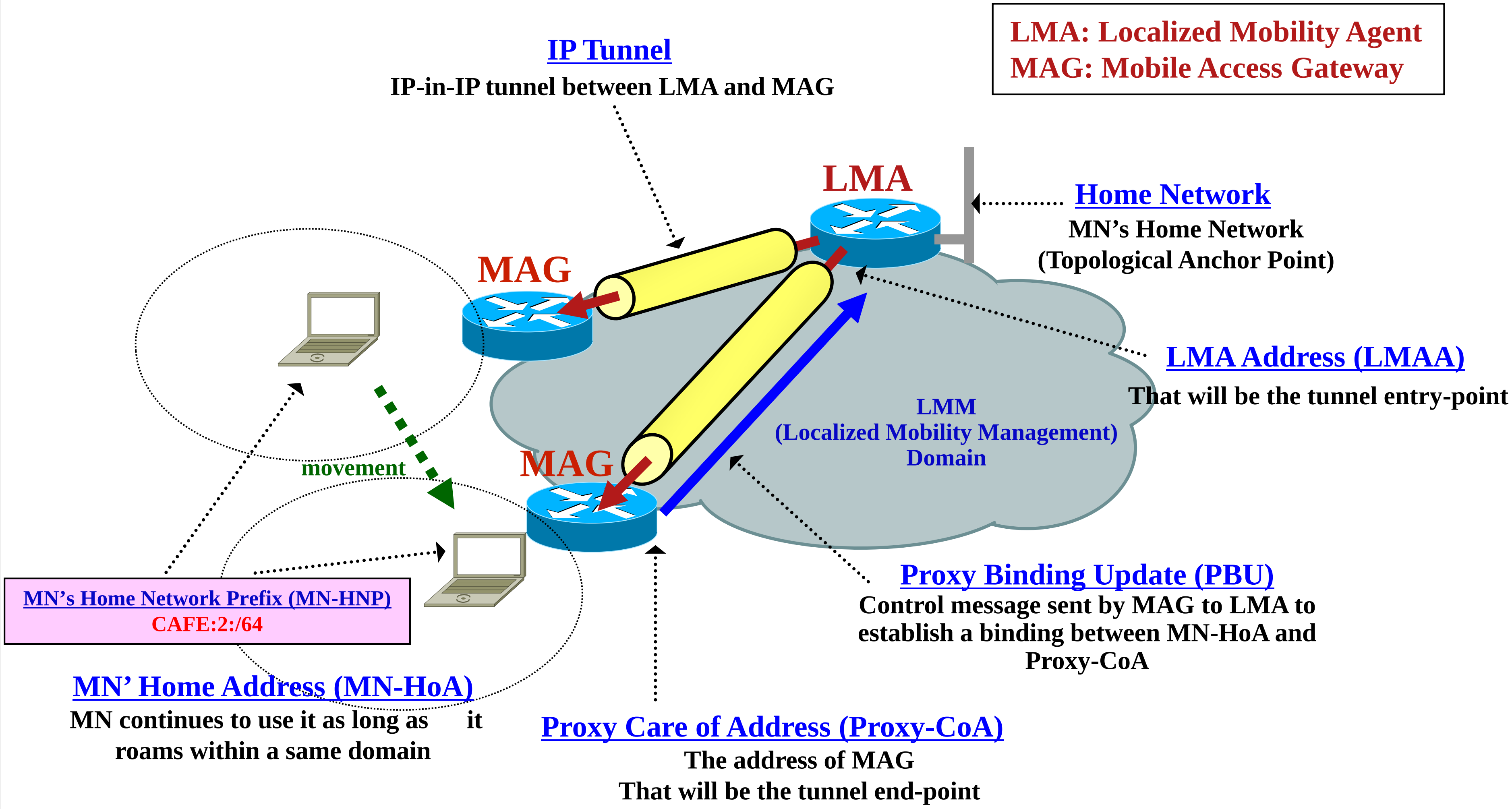
- 3GPP, 3GPP2 and WiMAX operators are showing their STRONG interests for <u>network-based IP mobility solution</u>
  - They are even now deploying their non-standardized network-based IP mobility solution (not Mobile IPv4/v6!).

Proxy Mobile IPv6

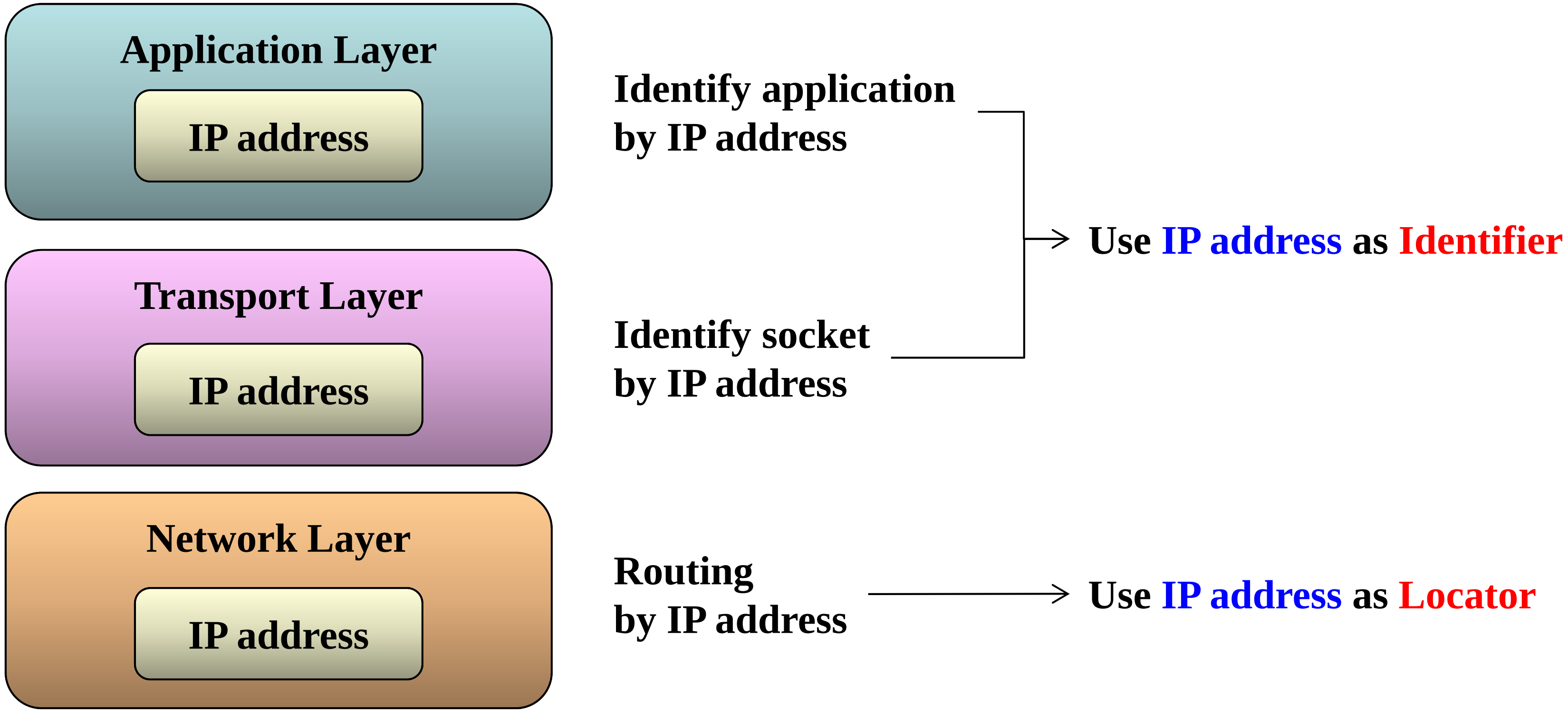
- Goal of PMIPv6
  - PMIPv6 protocol is for providing mobility support to any IPv6 host within a restricted and topologically localized portion of the network and without requiring the host to participate in any mobility related signaling.



Proxy Mobile IPv6 Operation



Current Internet Architecture



- **In the current Internet architecture, <u>IP addresses act as both node identifiers and locators</u>.**

Why ID/Locator Separation Architecture?- Problems of the current Internet

- Roles of IP address in the current Internet Architecture
  - ✓ Two roles combined :
    - End-point Identifiers (names of interfaces on hosts)
    - Locators (names of topological locations)
- Basically, the current Internet architecture requires IP addresses to remain unchanged during a session.
  - ✓ Change of IP address indicates change of endpoint ID.
    - → Communication session or security association terminates

- Multiple roles of IP address are not suitable for mobile environments in the future Internet.
- In the future mobile environments, the demand of mobility and multi-homing needs to change of IP addresses.
  - ✓ Many solutions are proposed for supporting mobility: MIPv4, MIPv6, PMIPv6, mSCTP, mSIP, etc.
  - ✓ These solutions do not integrate nicely mobility control as the form of patch-on
    - → added complexity

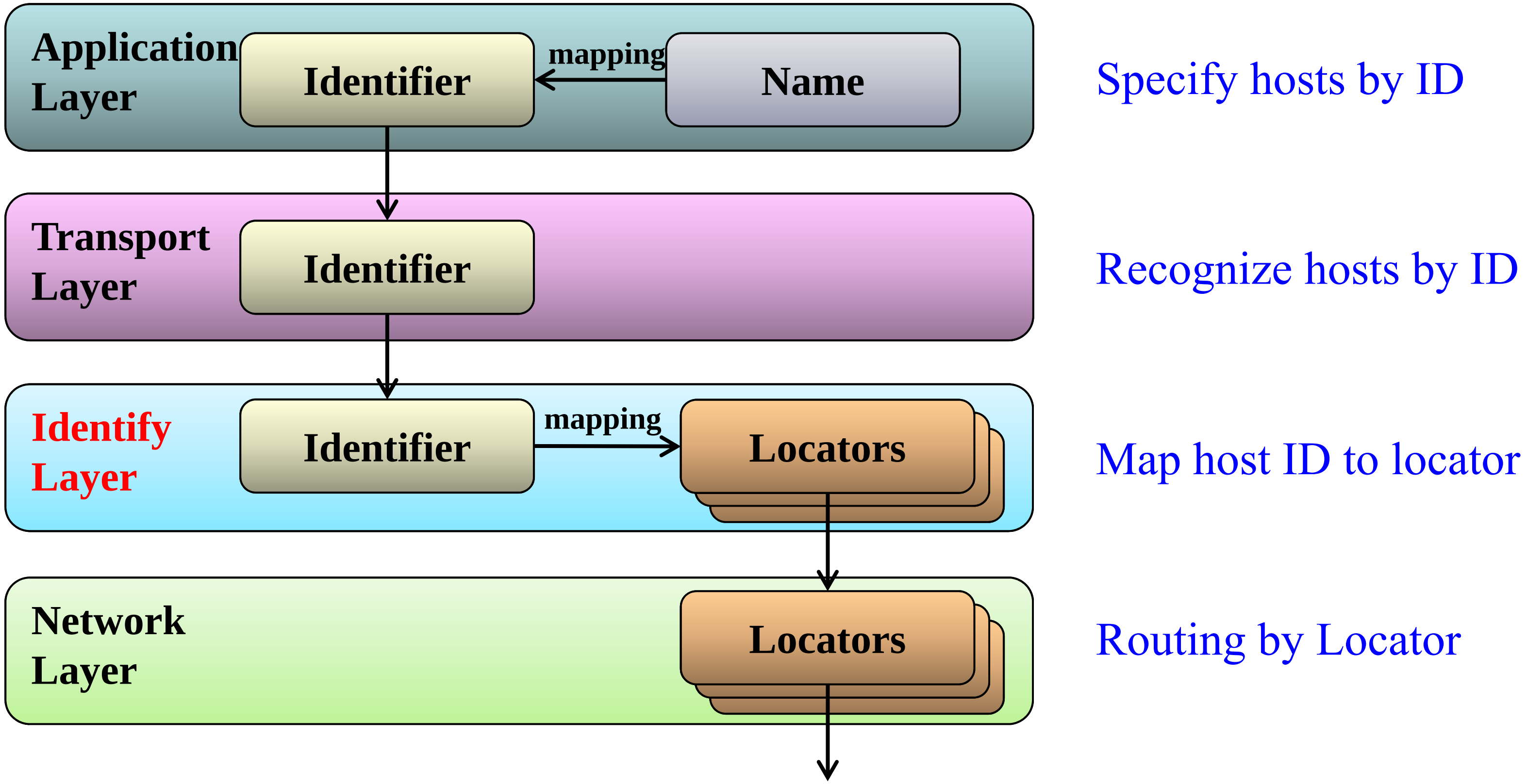
Why ID/Locator Separation Architecture? – New requirements to Internet

- Mobility support for mobile terminals
  - Get new locators on move while keeping IDs
- Mobility support for sensor devices (and group)
  - Quite many sensor nodes to be connected to Internet
  - Hundred billions or more of Internet nodes (Internet of Things)
- Dynamic network configuration for various applications
  - Self-configuration, optimization, dynamic deployment
- More flexible and reliable routing
  - Huge number of routing table entries
- Multi-homing support
  - Switch locators dynamically while keeping IDs
- Separation of data and control paths
- Heterogeneous network support (such as sensor networks)

→ **Solutions : ID/Locator Separation Architecture**

- Separate identifiers used by apps from addresses (locators) used by routing

ID/Locator Separation Architecture Overvi



- New Identify layer on hosts is inserted between network and transport layer
  - Identify layer maps between ID and Locator
- Use of locator is transparent to applications and transport

Related Works on ID/Locator Separation

- IRTF/IETF
  - Routing Research Group (RRG)
    - ✓ Developing a technical framework for ID/locator split-based routing architectures
  - Host Identify Protocol (HIP) Working Groups
    - ✓ Developing an ID/locator split-based host protocols for secure mobility and multi-homing
  - SHIM6 Working Group
    - ✓ Developing protocols to support site multi-homing in IPv6
  - Locator/Identifier Separation Protocol (LISP) Working Group
    - ✓ LISP supports the separation of the IPv4 and IPv6 address space following a network-based map-and-encapsulate scheme
- ITU-T
  - Study Group 13
    - ✓ Y.2015 (2009): General requirements for ID/locator separation in NGN
    - ✓ Y.FAid-loc-split (Q.5/13), Y.ipv6split (Q.7/13) in progress
- AKARI Project : (NICT's initiation to clean-slate design of New Generation Network)
  - Includes research on ID/locator split architectures

Proposed ID/Locator Separation-based Lightweight Mobility Architecture in Wireless Sensor Network

Introduction

- This work focuses on the scheme which supports the mobility for IPv6-based Wireless Sensor Network (i.e., 6LoWPAN).

- Mobility in 6LoWPAN is utilized in realizing many applications where sensor nodes sense and transmit the gathered data to a monitoring server.
  - e.g., Healthcare, Logistics, Intelligent Transport System, etc.

- Enabling sensor nodes with Internet connection ensures that the sensor data can be accessed anytime and anywhere.

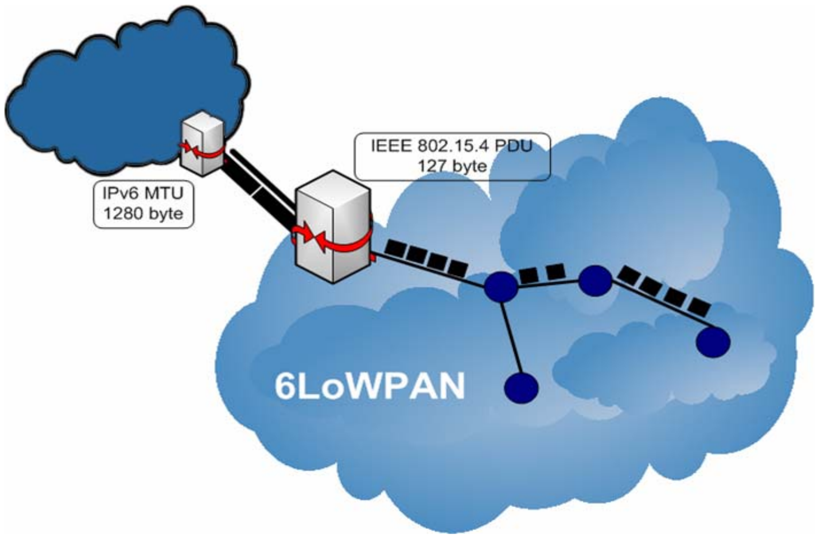
- <u>Propose a lightweight global mobility support scheme for both sensor node mobility & network mobility, based on the new ID/Locator separation architecture.</u>

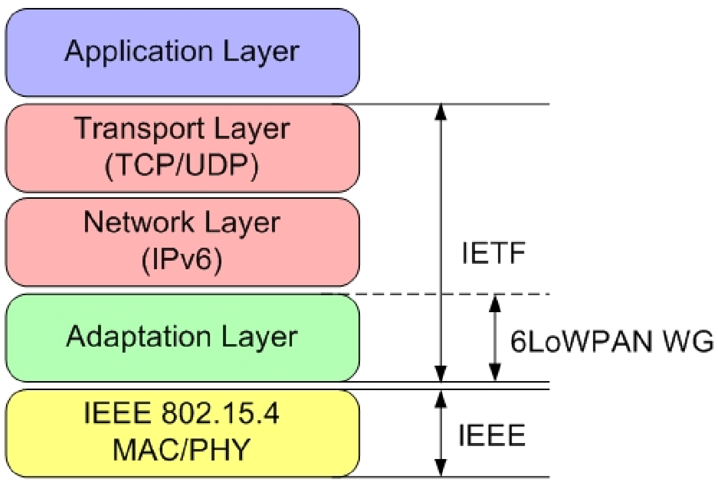
Research Goals

- Sensor devices (and group of them) mobility for Internet of Things
- New ID/Locator separation architecture for 6LoWPAN mobility
- Energy-efficient mobility support
- ID-based communication with location-based routing
- Separation of identifier and locator
- Fully network-based mobility control
- Separation of mobility control from data transport
- Packet route optimization

6LoWPAN Architecture

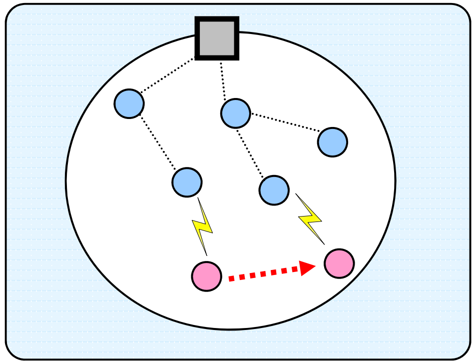
- **No method exists to make IP run over IEEE 802.15.4 networks**
  - ✓ Worst case IEEE 802.15.4 PDU 81 octets, IPv6 MTU requirements 1280 octets
- **Stacking IP and above layers may not fit within one 802.15.4 frame**
  - ✓ IPv6 40 octets, TCP 20 octets, UDP 8 octets + other layers (security, routing, etc) leaving few bytes for data
- **Adaptation Layer**
  - ✓ IPv6 packet Fragmentation, Reassembly, Mesh Routing, Packet Compression, Decompression



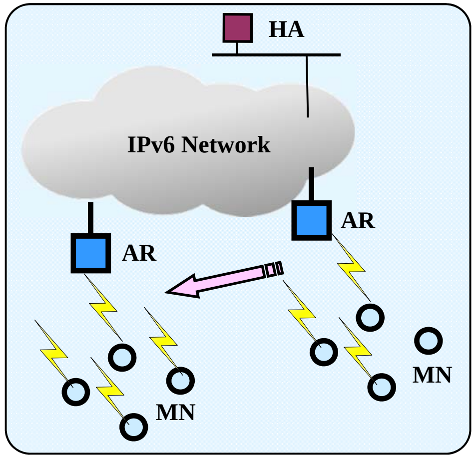


Conventional Mobility Management Protocols in 6LoWPAN

Host-based Mobility Approach



- **6LoWPAN with MANET (Mobile Ad-hoc Network)**
  - ✓ Only Intra-PAN mobility is supported by MANET routing protocol



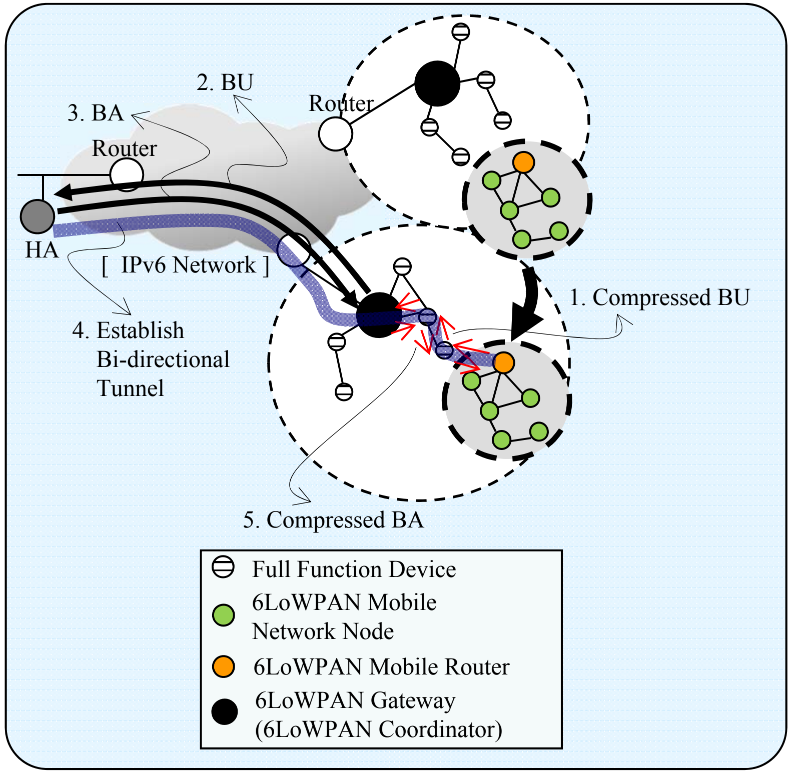
- **6LoWPAN with MIPv6 (Mobile IPv6)**
  - ✓ When a 6LoWPAN node moves to another PAN, it requires an exchange of signaling messages with its home agent.
  - ✓ This approach is unsuitable for energy-constrained sensor nodes.

    → All of the 6LoWPAN nodes should have a mobility stack.

→The host-based mobility approach is unsuitable for energy-constrained sensor nodes.

Mobility Management Protocols in 6LoWPAN

Network-based Mobility Approach

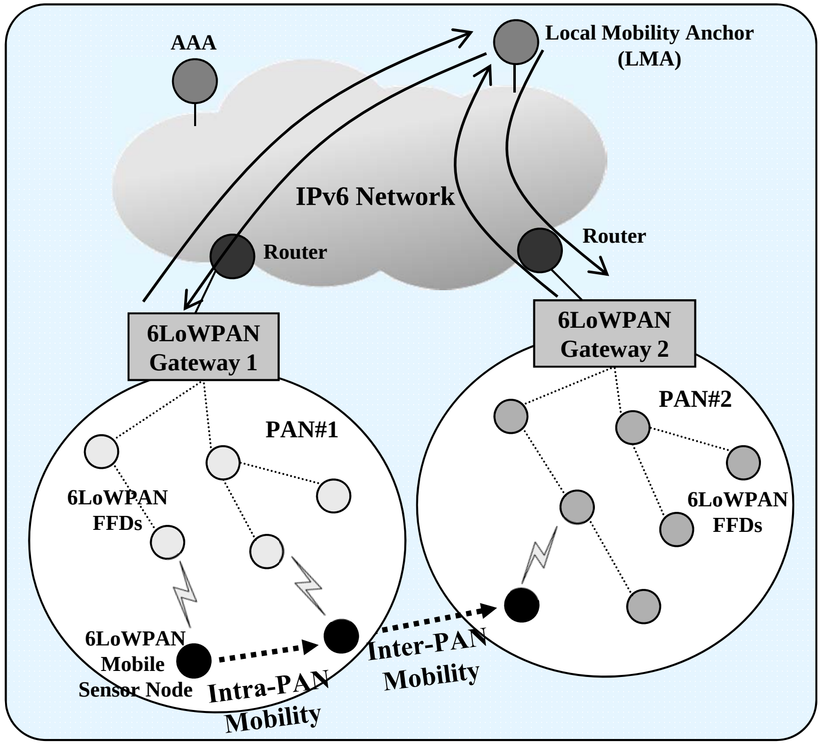


- **6LoWPAN with NEMO (Network Mobility)**
  - ✓ 6LoWPAN nodes can maintain connectivity with the Internet through the 6LoWPAN mobile router (MR) as a network unit.
  - ✓ Propose a new header compression scheme for mobility headers in 6LoWPAN networks
  - ✓ Propose a lightweight NEMO protocol to minimize the signaling overhead by using a compressed mobility header

→ **NEMO has been assumed that the sensor nodes will move together under mobile router.**

- The NEMO is unable to provide the solution for the individual or scattered mobility of the host.
- Nested NEMO & Route Optimization problem

Network-based Mobility Approach

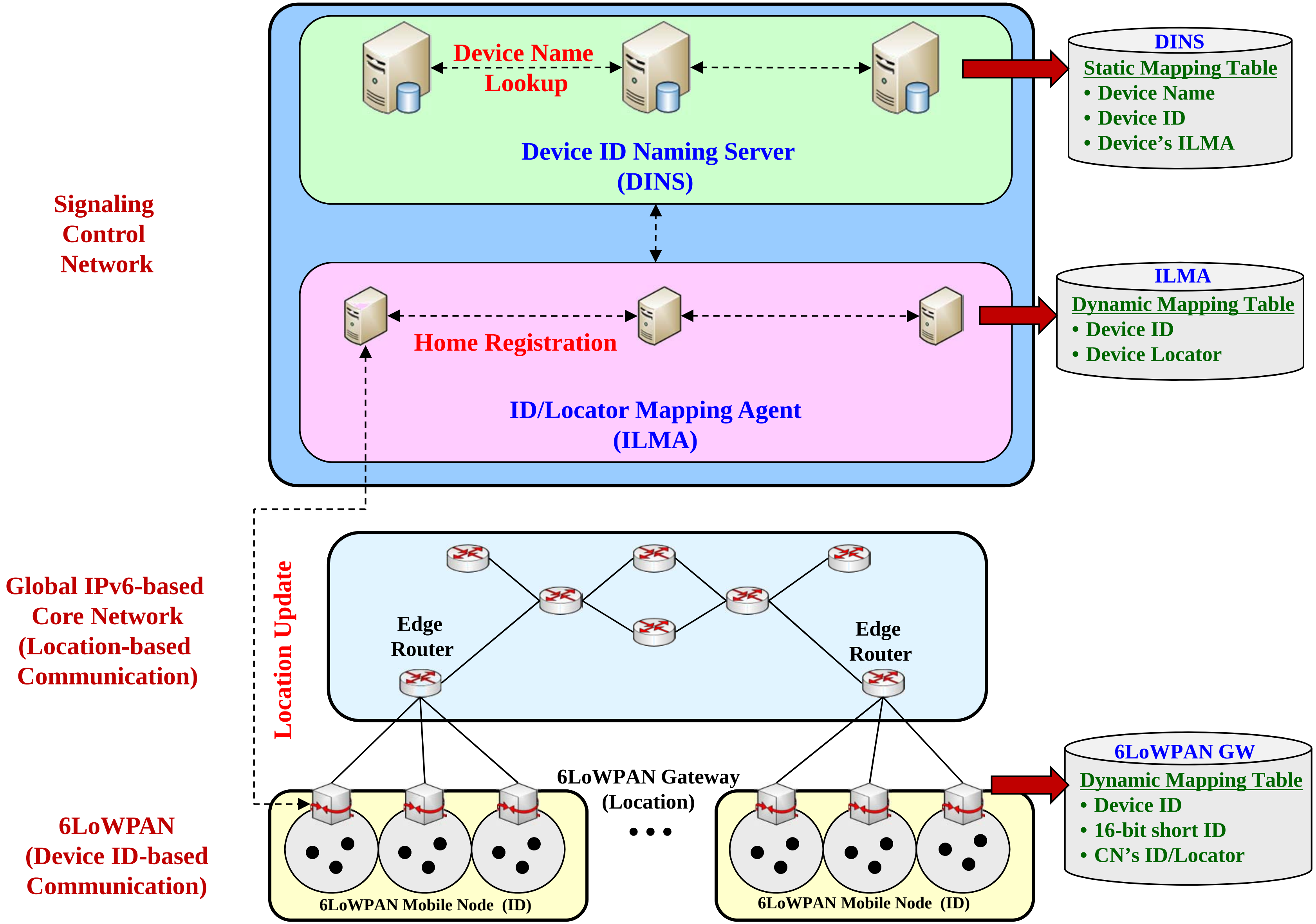


- **6LoWPAN with PMIPv6 (Proxy Mobile IPv6)**
  - ✓ The 6LoWPAN sensor node itself does not require any mobility related to the signal messages.
  - ✓ The conventional PMIPv6 protocol cannot be applied to multi-hop-based 6LoWPAN networks.
  - ✓ Propose a PAN attachment detection scheme for 6LoWPAN sensor nodes.

→ **PMIPv6 has been assumed that the sensor nodes will move within the PMIPv6 domain.**

- The PMIPv6 supports only localized mobility, and PMIPv6 is unable to provide the NEMO protocol.

Overview of Lightweight Mobility Management Architecture



Device Identifying Structure

- **Device Name**
  - Human readable character (ex. terminal1@myhome)
  - Identify devices for communication initialization

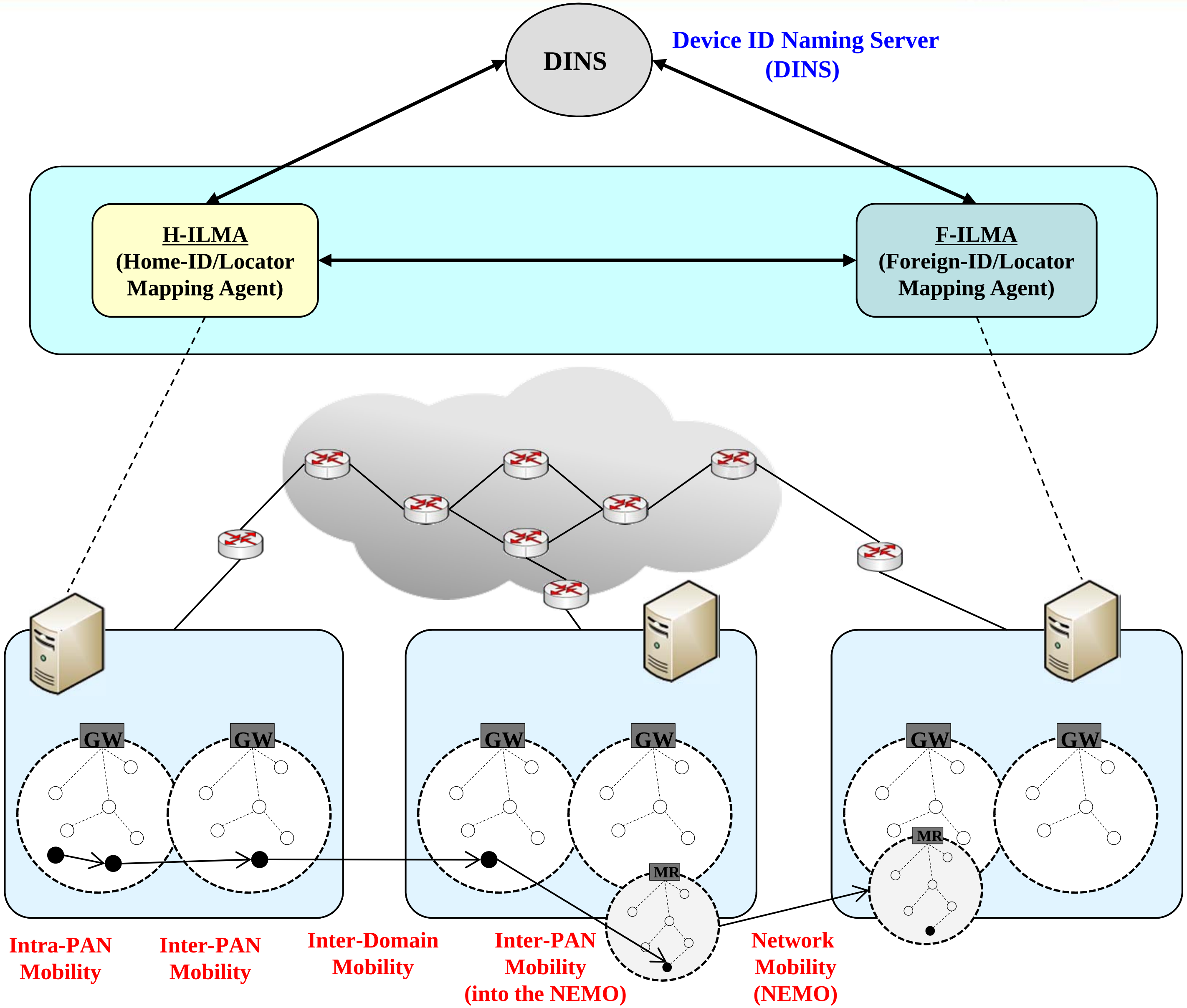
- **Device ID**
  - Location independent
  - Used as control information and headers
  - Globally unique device ID (128-bit) in the sensor network
  - All devices should be identified by Device ID.
  - CID (Corresponding ID), LID (Local Device ID)

Nation (16)	Region (16)	Network Type (16)	PAN ID (16)	IEEE 802.15.4 MAC address(64)

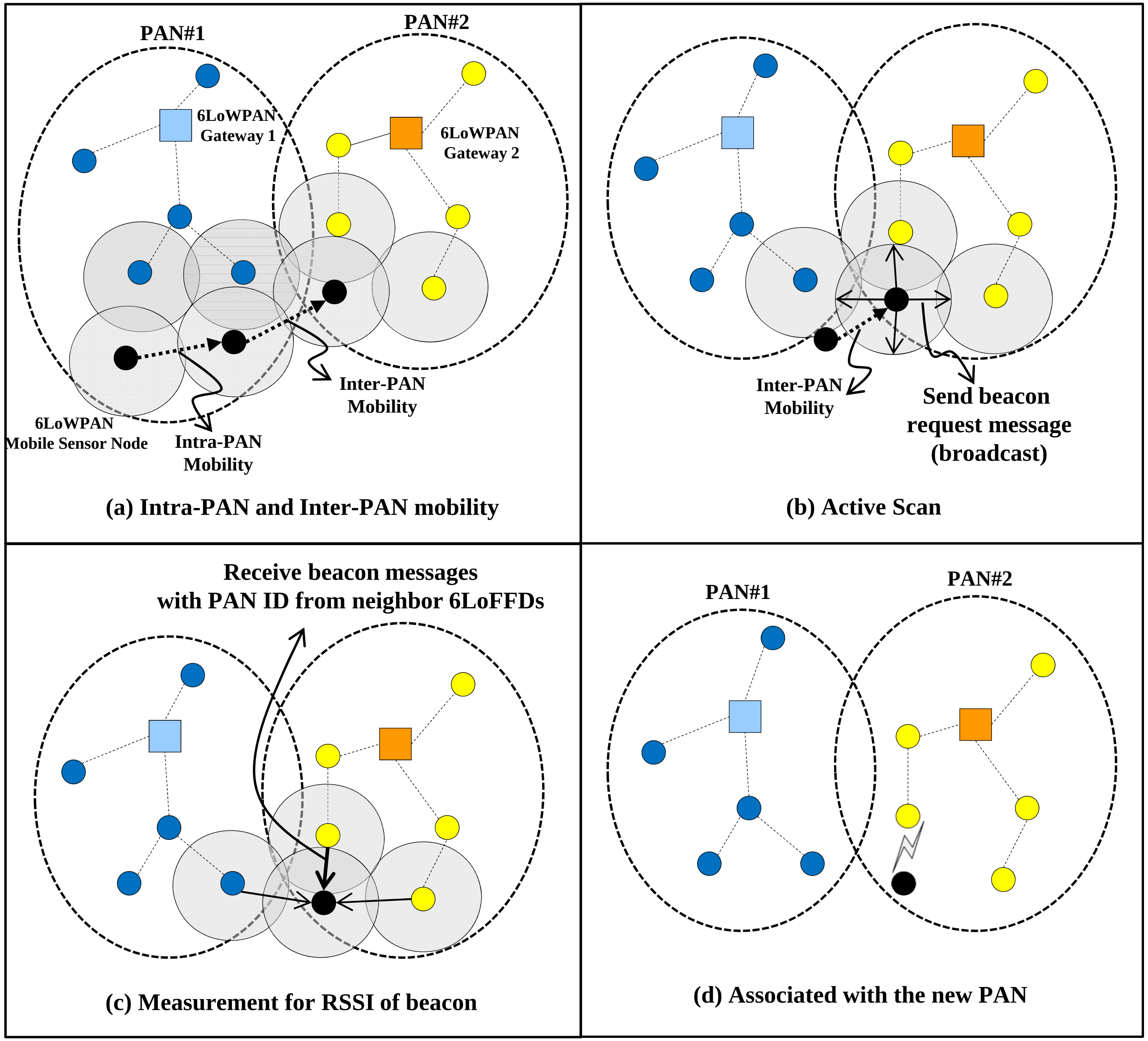
Device ID (128-bit)

- **Locator**
  - To represent locations of a device in the sensor network topology
  - Locators are temporal; change due to the device mobility
  - Re-use of IPv6 global address as Locator (128-bit)
  - Egress Interface address of the Gateway
  - RLOC (Remote Locator), LLOC (Local Locator)
  - 16-bit short address (temporary within the PAN area)

Mobility Scenario

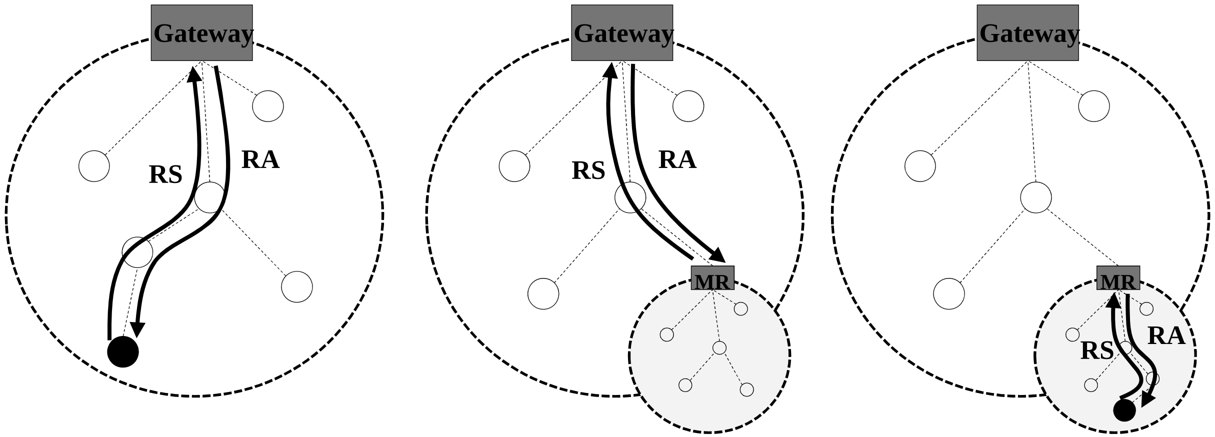


Movement Detection & Association



Default Gateway Discovery

- To discover the Default Gateway in the current PAN area
- Using modified Router Solicitation (RS) & Router Advertisement (RA) messages
  - RS and RA messages should contain the mesh header for multi-hop routing.
  - 6LoWPAN mobile node and mobile router's 16-bit short address option is included in the RA message.
  - 6LoWPAN Gateway assigns a 16-bit short ID, and it has a list of all the 6LoWPAN nodes.



Proposed Router Solicitation (RS) Message Format

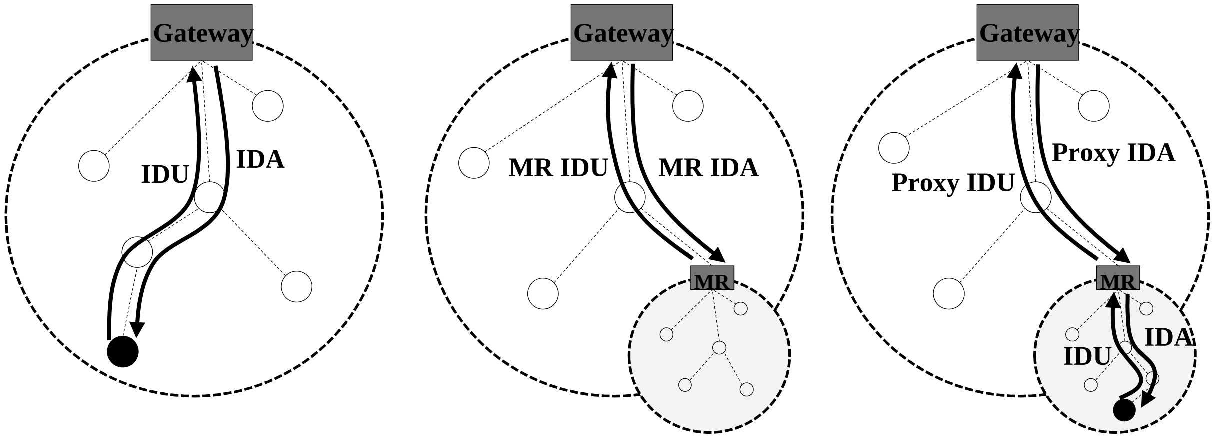
MN (64)	GW (16)	DSP	HC1	IPv6	RS header	RS option
6LoWPAN Mesh header		6LoWPAN IP (addressing) header			Router Solicitation	

Proposed Router Advertisement (RA) Message Format

GW (16)	MN (64)	DSP	HC1	IPv6	RA header	16-bit short ID option
6LoWPAN Mesh header		6LoWPAN IP (addressing) header			Router Advertisement	

ID Registration

- To register the 6LoWPAN device ID to the 6LoWPAN Gateway
- Using proposed <u>ID Update (IDU)</u> & <u>ID Acknowledgement (IDA)</u> messages
- Upon receipt of IDU message, the 6LoWPAN Gateway updates the mapping table .
  - (Device ID : 16-bit short ID)



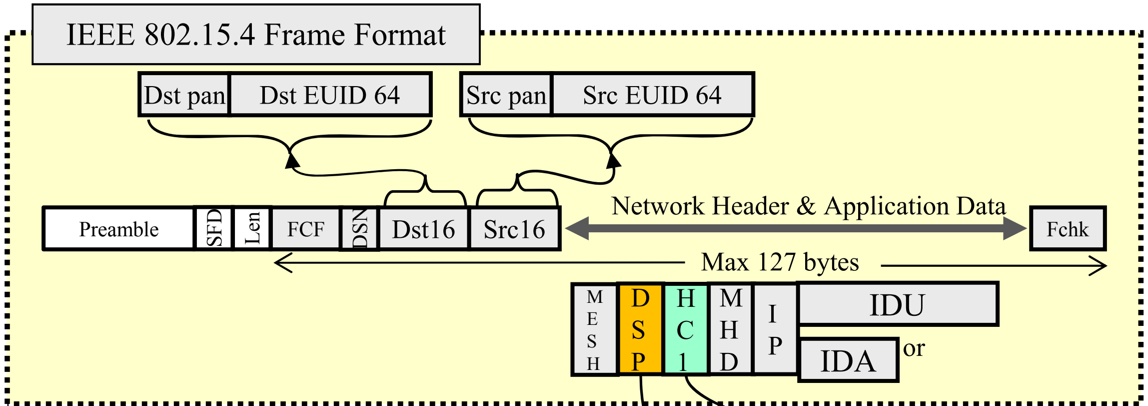
Proposed ID Update (IDU) Message Format

MN (16)	GW (16)	DSP	HC1	MHD	IPv6	IDU
6LoWPAN Mesh header		6LoWPAN IP (addressing) header				IDU, MR IDU, Proxy IDU

Proposed ID Acknowledgement (IDA) Message Format

GW (16)	MN (16)	DSP	HC1	MHD	IPv6	IDA
6LoWPAN Mesh header		6LoWPAN IP (addressing) header				IDA, MR IDA, Proxy IDA

ID Registration - New IDU & IDA Messages Format



MESH : Mesh Header
Dispatch (DSP) : LOWPAN_MH Mobility Header
HC1 : Src. & Dest: Link Local, Next header=Mobility Header
IP : Hop Limit
MHD : Mobility Header Dispatch
IDU: Sequence Number, Lifetime, Flags, Device ID
IDA: Sequence Number, Lifetime, Status

- Dispatch Header Patterns

Pattern	Pattern Name	Pattern Meaning
00 xxxxxx	NALP	Not a LoWPAN frame
01 000001	IPv6	uncompressed IPv6 Addresses
01 000010	LOWPAN_HC1	LOWPAN_HC1 compressed IPv6
01 000011	LOWPAN_MH	LOWPAN_MH Mobility Header Dispatch
01 000100	LOWPAN_LD	LOWPAN_LD Locator Discovery Dispatch
……	reserved	Reserved for future use
01 010000	LOWPAN_BC0	LOWPAN_BC0 broadcast
……	reserved	Reserved for future use
01 111111	ESC	Additional Dispatch byte follows

- Proposed LOWPAN_MH Dispatch Header Pattern (1 byte)

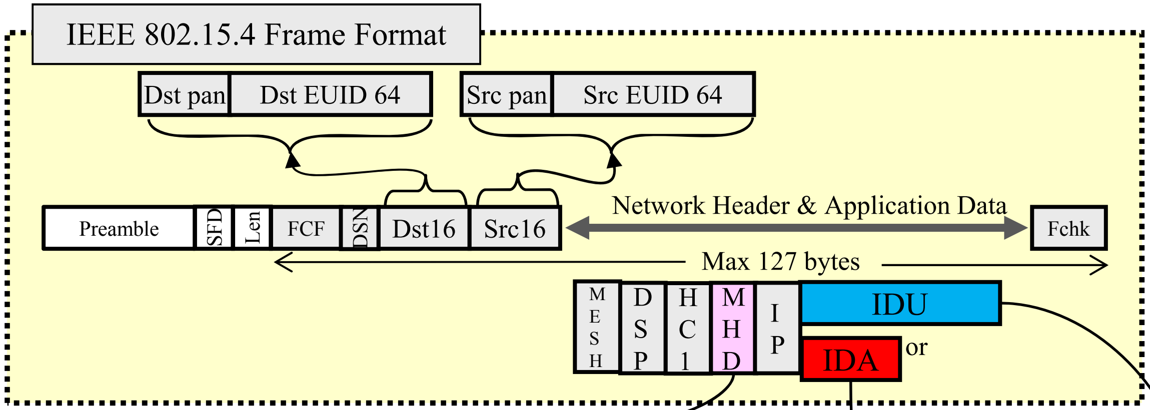
0	1	2	3	4	5	6	7
0	*1*	0	0	0	0	*1*	*1*

- Proposed Compressed IPv6 Header (HC1 header : 1byte)

0	1	2	3	4	5	6	7

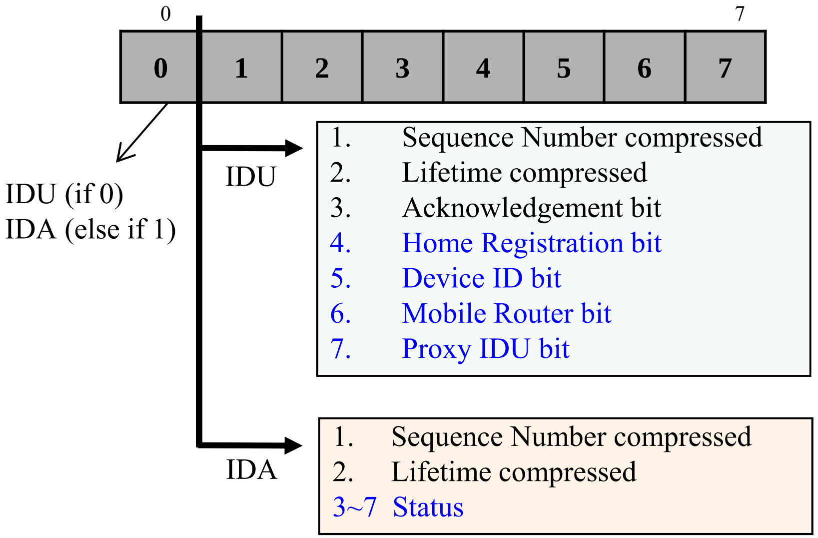
- Source prefix compressed
- Source interface identifier compressed
- Destination prefix compressed
- Destination interface identified compressed
- Traffic and Flow Label zero
- Next Header
  00:Mobility Header, 01:Locator Discovery, 10, 11:reserved
- Additional HC2 compression header follows

ID Registration - New IDU & IDA Messages Format



- MESH : Mesh Header
- Dispatch (DSP) : LOWPAN_MH Mobility Header
- HC1 : Src. & Dest: Link Local, Next header=Mobility Header
- IP : Hop Limit
- MHD : Mobility Header Dispatch
- IDU: Sequence Number, Lifetime, Flags, Device ID
- IDA: Sequence Number, Lifetime, Status

- Proposed LOWPAN_MH Dispatch (1 byte)



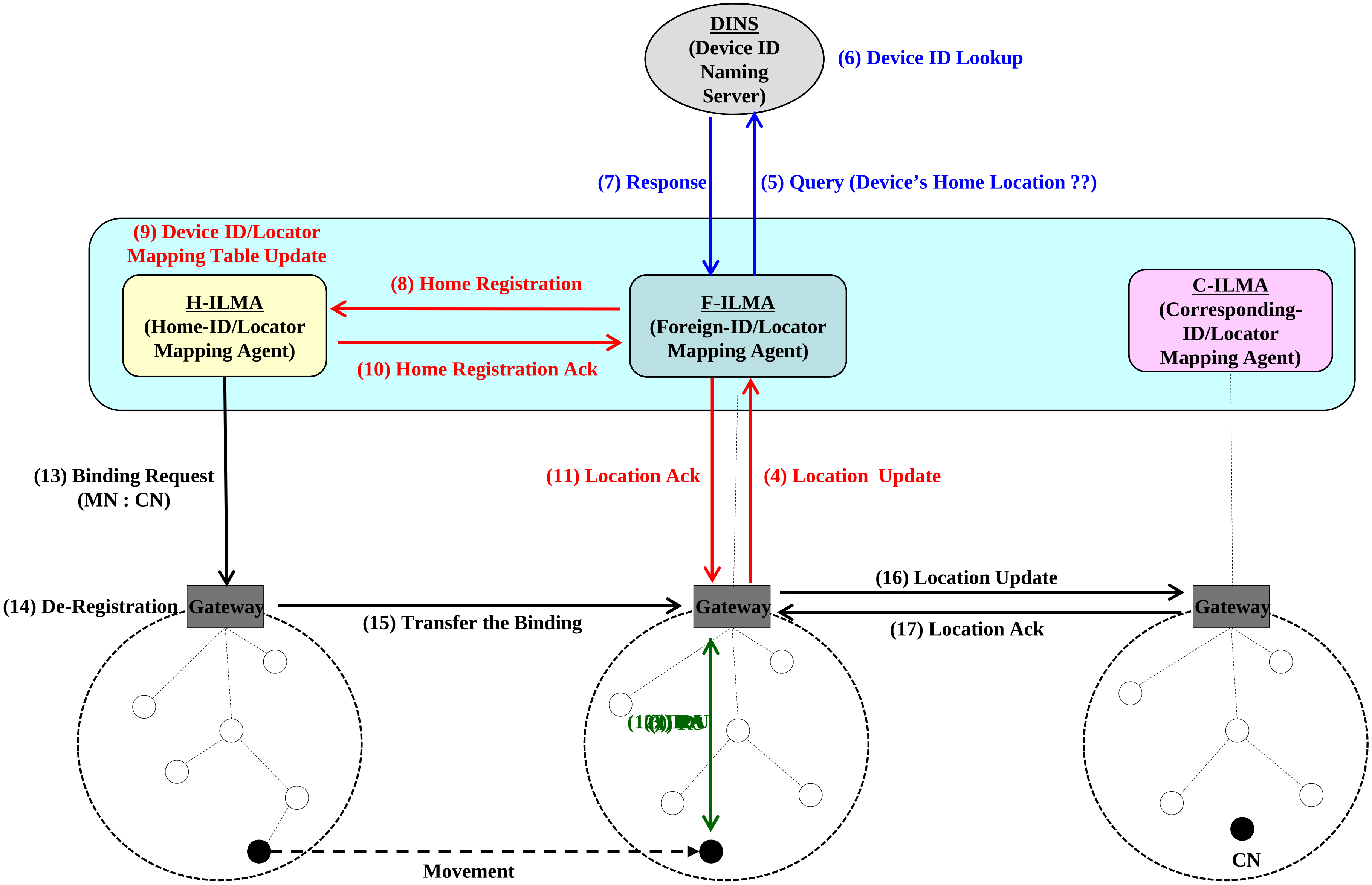
- ID Update (IDU) message

Sequence #	Lifetime	Device ID
1byte	1byte	16 bytes

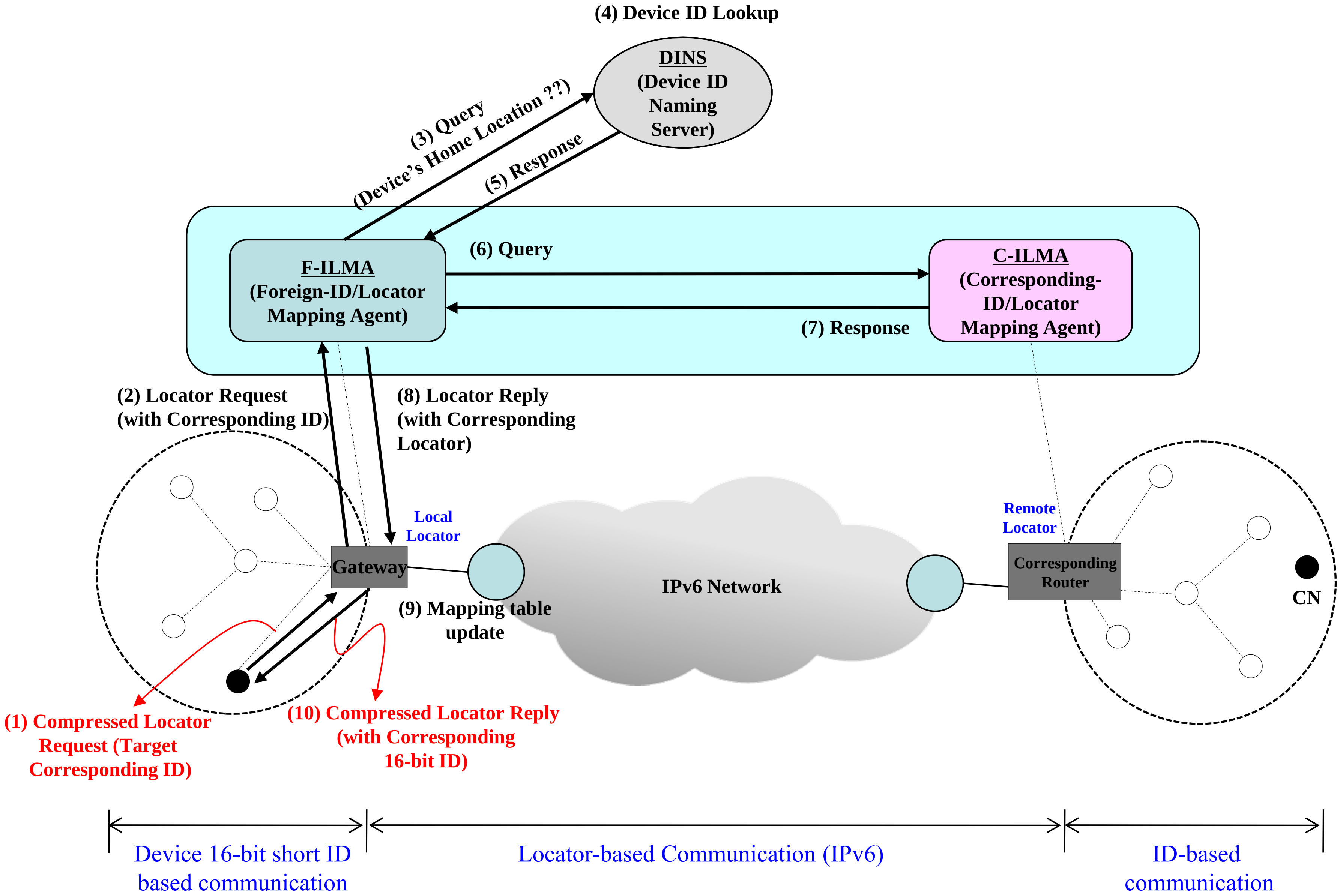
- ID Acknowledgement (IDA) message

Sequence #	Lifetime
1byte	1byte

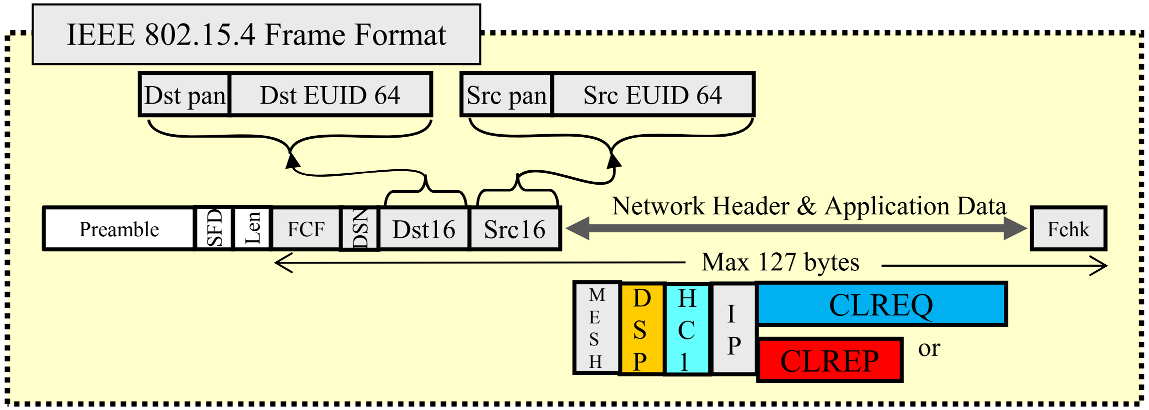
Location Update



Locator Discovery



Locator Discovery - New CLREQ & CLREP Messages Format

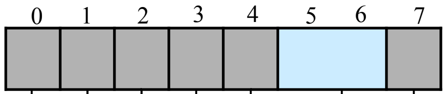


MESH : Mesh Header
Dispatch (DSP) : Locator Discovery
HC1 : Sour. & Dest: Link Local, Next header=Locator Discovery
IP : Hop Limit
LD : Locator Discovery Dispatch
CLREQ: Sequence Number, Lifetime, Target Corresponding Device ID
CLREP: Sequence Number, Lifetime, Corresponding 16-bit ID

- Proposed LOWPAN_LD Dispatch Header Pattern (1 byte)

0	1	2	3	4	5	6	7
0	*1*	0	0	0	*1*	*0*	*0*

- Proposed Compressed IPv6 Header (HC1 header : 1byte)



- Source prefix compressed
- Source interface identifier compressed
- Destination prefix compressed
- Destination interface identified compressed
- Traffic and Flow Label zero
- Next Header
  00:Mobility Header, 01:Locator Discovery, 10, 11:reserved
- Additional HC2 compression header follows

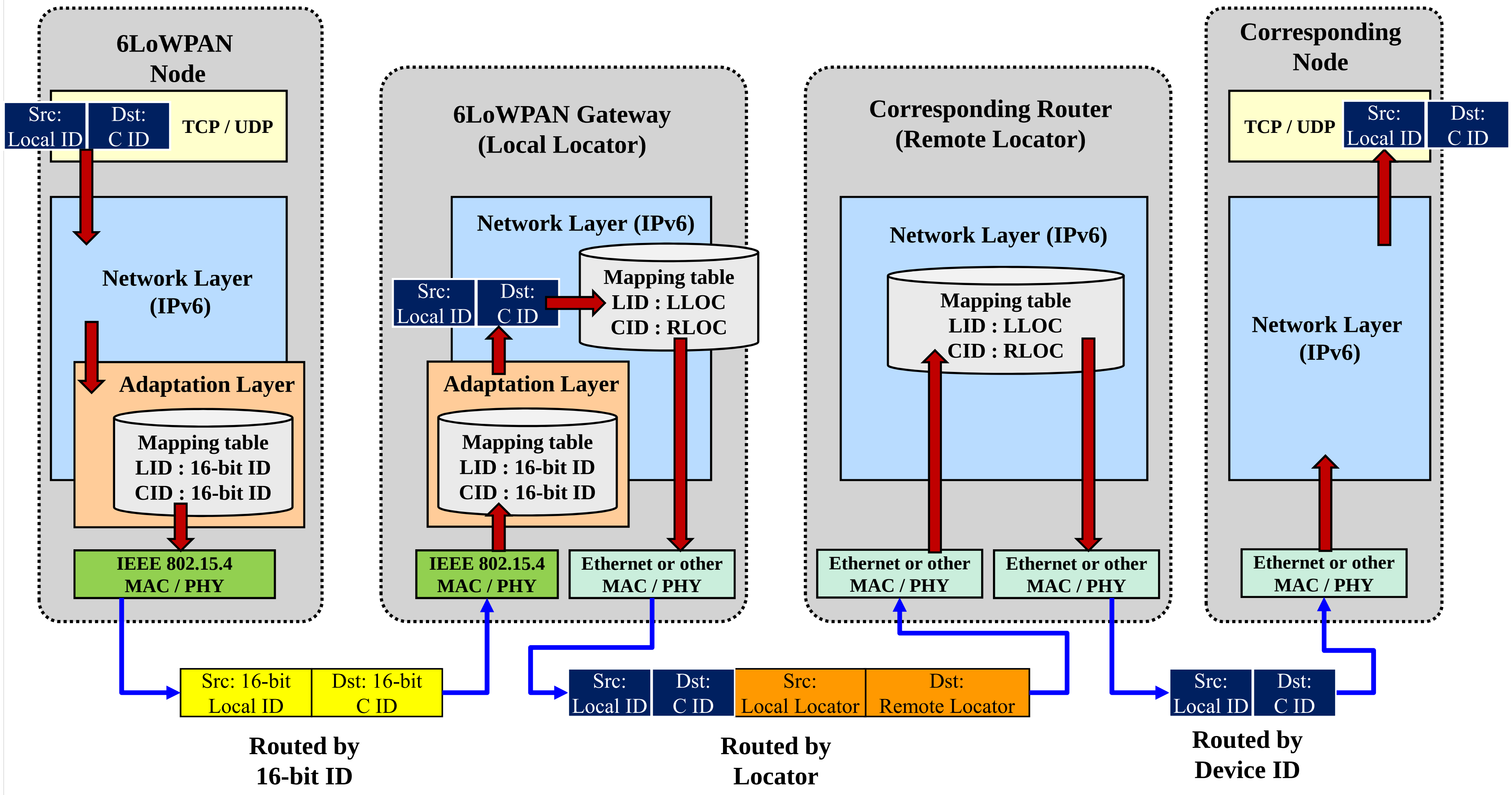
- Compressed Locator Request (CLREQ) message

Sequence #	Lifetime	Target Corresponding ID
1byte	1byte	16 bytes

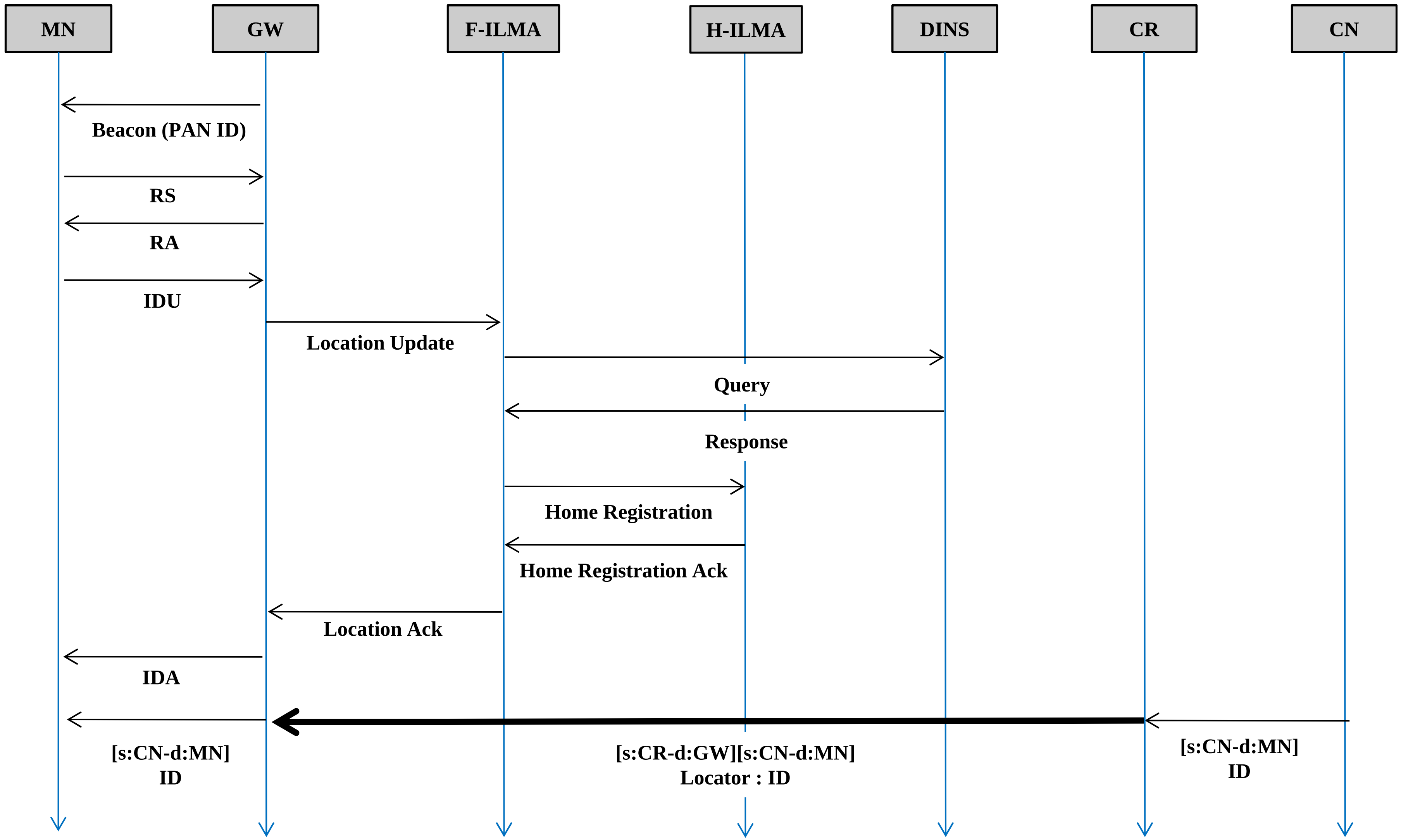
- Compressed Locator Reply (CLREP) message

Sequence #	Lifetime	Corresponding 16-bit ID
1byte	1byte	2bytes

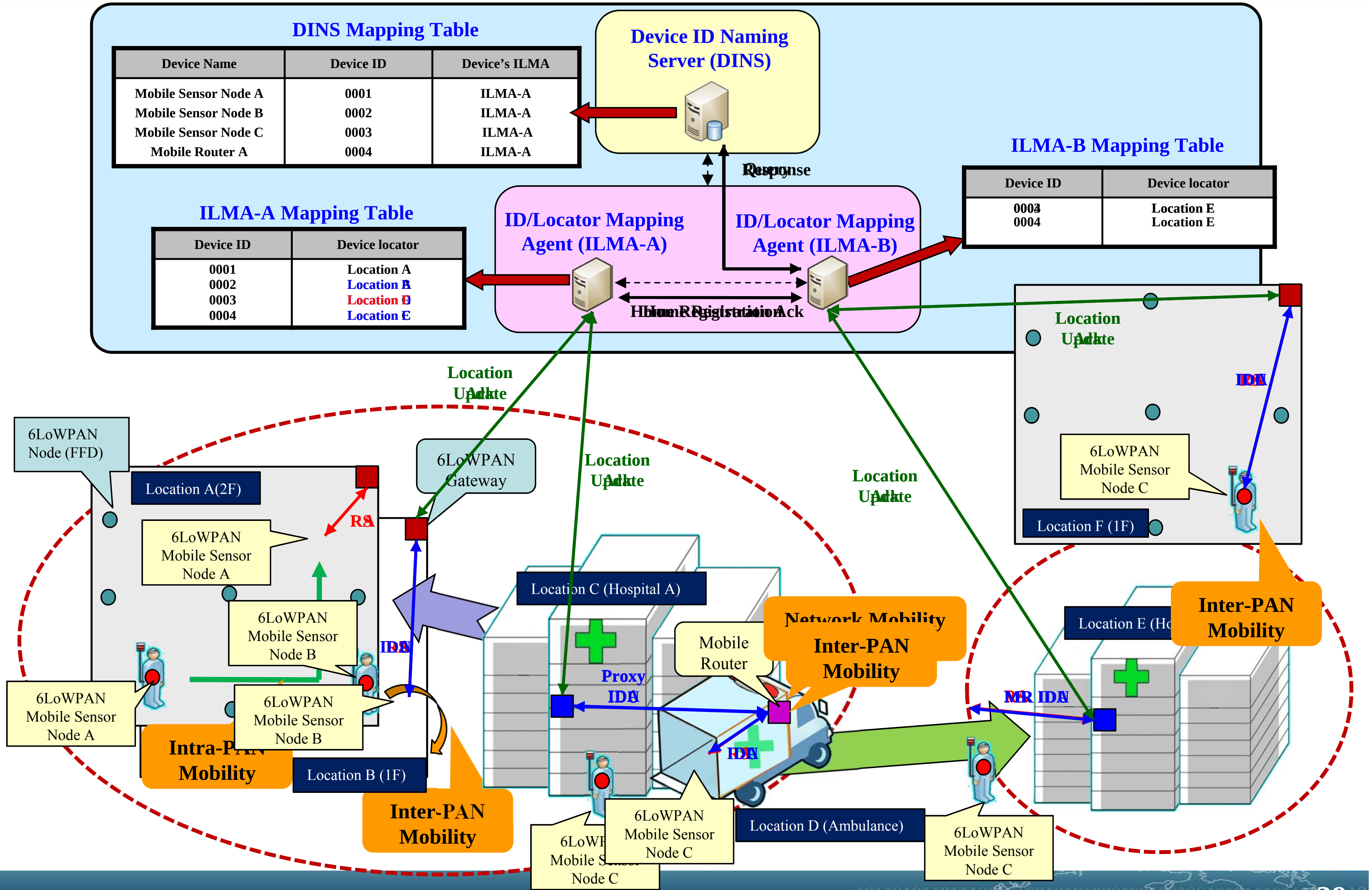
Communication Procedure after Location Discover



Signaling & Data Flow



Example of Application - healthcare scenario



DINS Mapping Table

Device Name	Device ID	Device's ILMA
Mobile Sensor Node A	0001	ILMA-A
Mobile Sensor Node B	0002	ILMA-A
Mobile Sensor Node C	0003	ILMA-A
Mobile Router A	0004	ILMA-A

ILMA-A Mapping Table

Device ID	Device locator
0001	Location A
0002	Location B
0003	Location D
0004	Location E

ILMA-B Mapping Table

Device ID	Device locator
0003	Location E
0004	Location E

Example of Application - logistics scenario

DINS Mapping Table

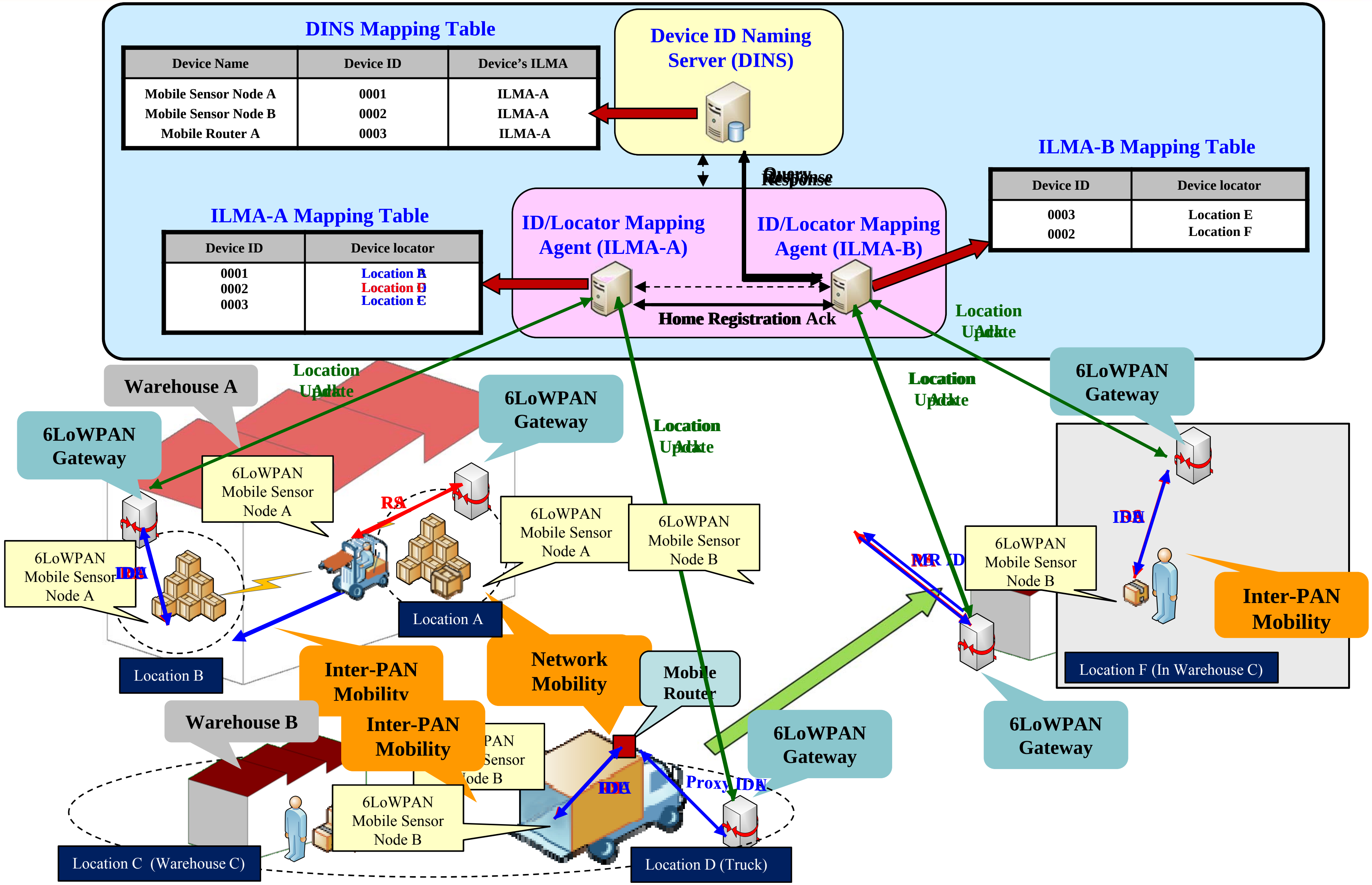
Device Name	Device ID	Device's ILMA
Mobile Sensor Node A	0001	ILMA-A
Mobile Sensor Node B	0002	ILMA-A
Mobile Router A	0003	ILMA-A

ILMA-B Mapping Table

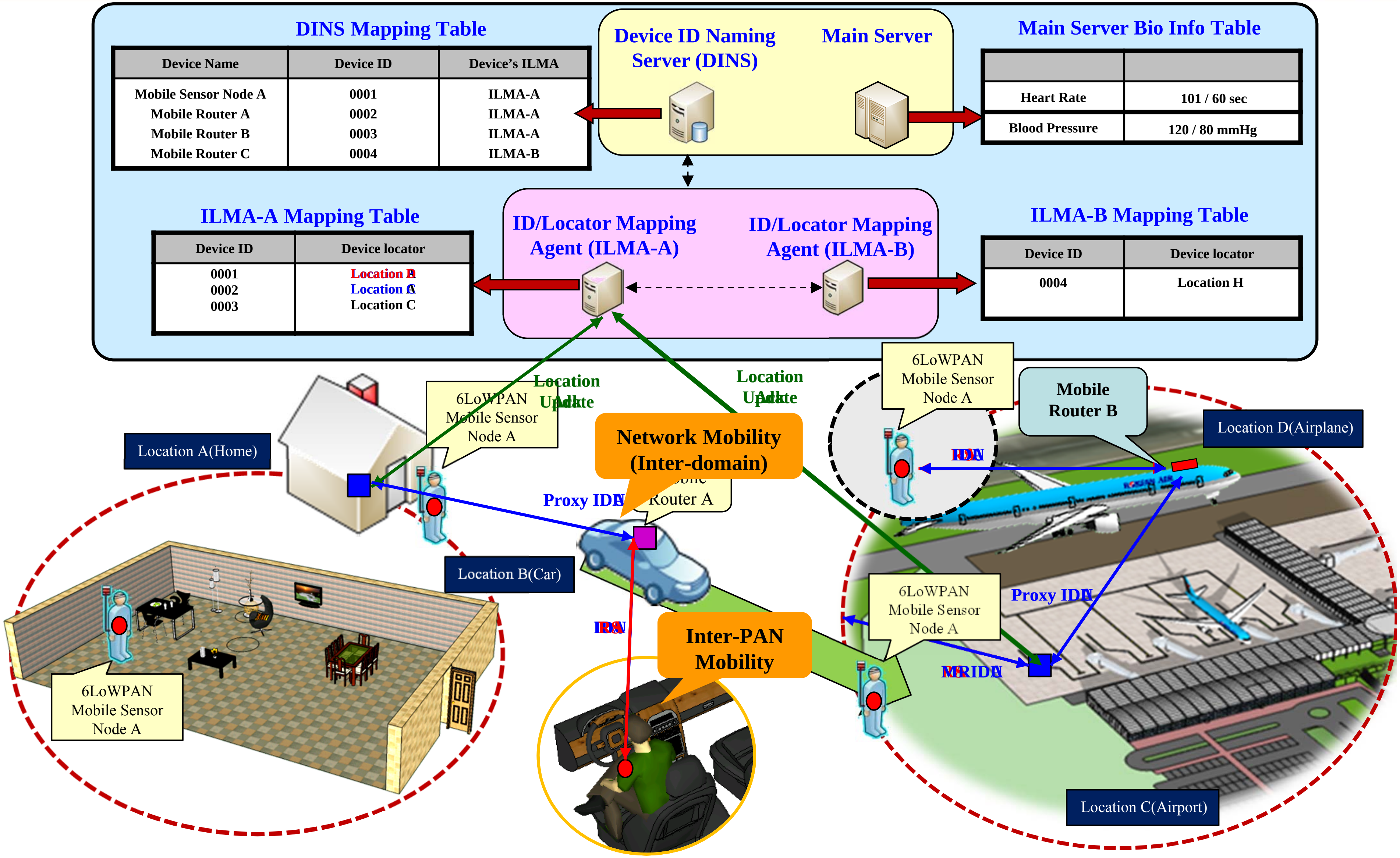
Device ID	Device locator
0003	Location E
0002	Location F

ILMA-A Mapping Table

Device ID	Device locator
0001	Location B
0002	Location F
0003	Location E



Example of Application - healthcare scenario



DINS Mapping Table

Device Name	Device ID	Device's ILMA
Mobile Sensor Node A	0001	ILMA-A
Mobile Router A	0002	ILMA-A
Mobile Router B	0003	ILMA-A
Mobile Router C	0004	ILMA-B

Main Server Bio Info Table

Heart Rate	101 / 60 sec
Blood Pressure	120 / 80 mmHg

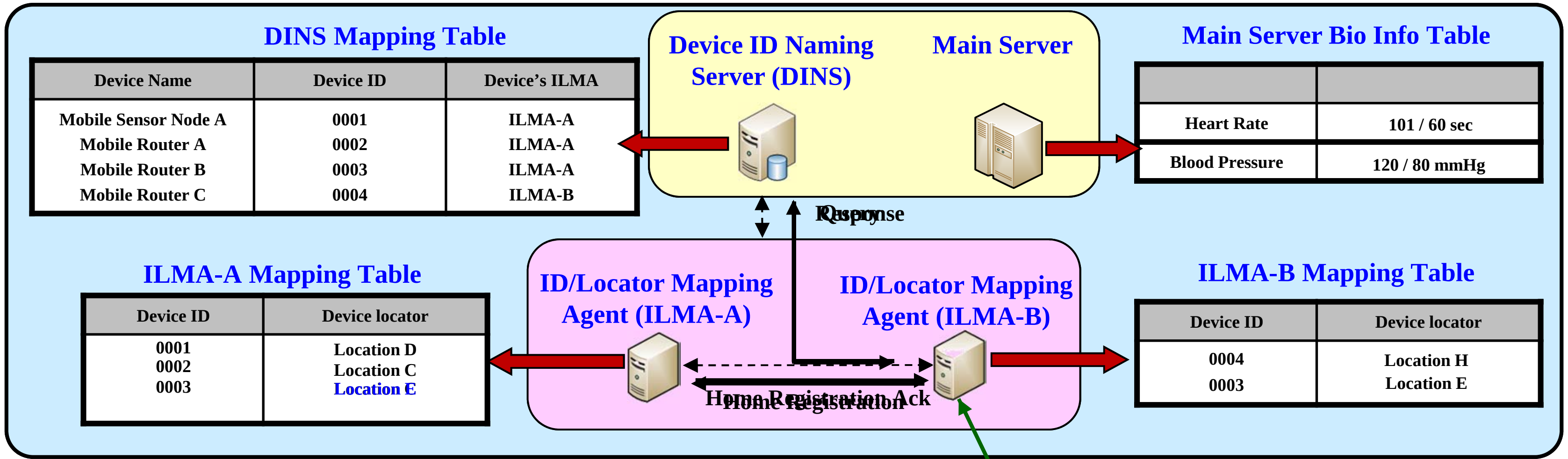
ILMA-A Mapping Table

Device ID	Device locator
0001	Location A
0002	Location A
0003	Location C

ILMA-B Mapping Table

Device ID	Device locator
0004	Location H

Example of Application



DINS Mapping Table

Device Name	Device ID	Device's ILMA
Mobile Sensor Node A	0001	ILMA-A
Mobile Router A	0002	ILMA-A
Mobile Router B	0003	ILMA-A
Mobile Router C	0004	ILMA-B

Main Server Bio Info Table

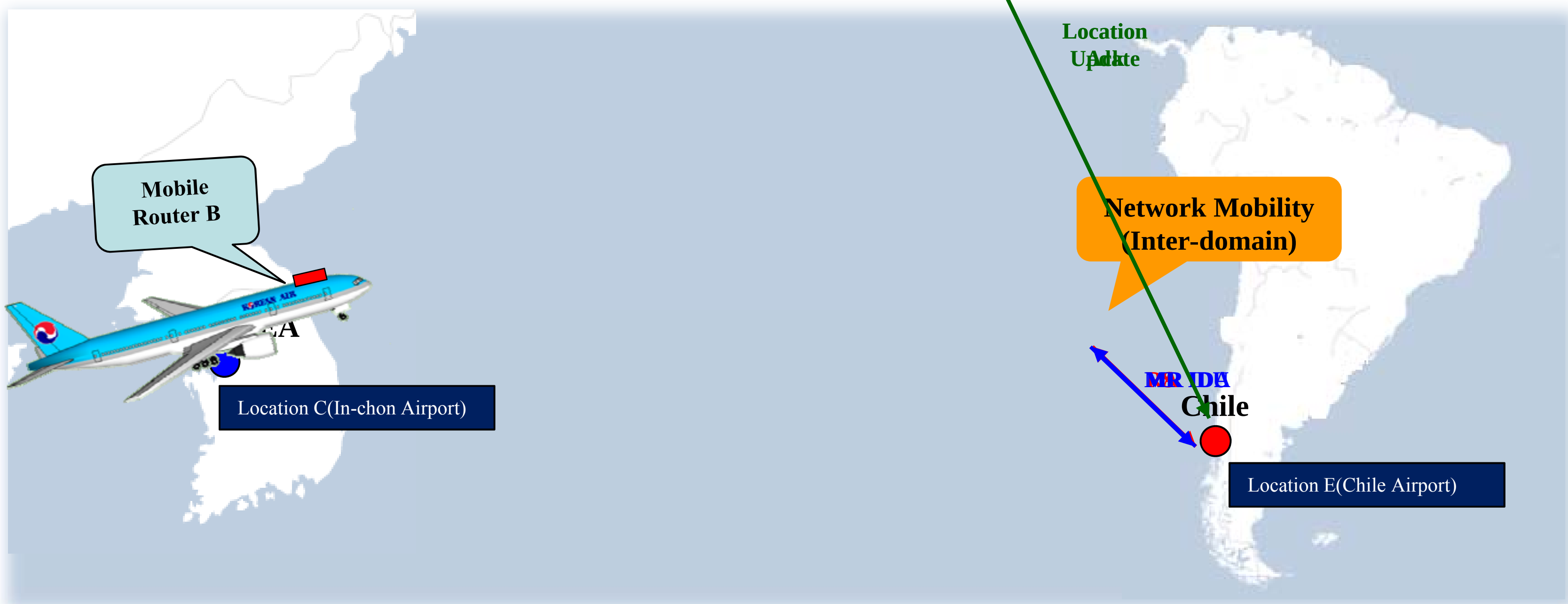
Heart Rate	101 / 60 sec
Blood Pressure	120 / 80 mmHg

ILMA-A Mapping Table

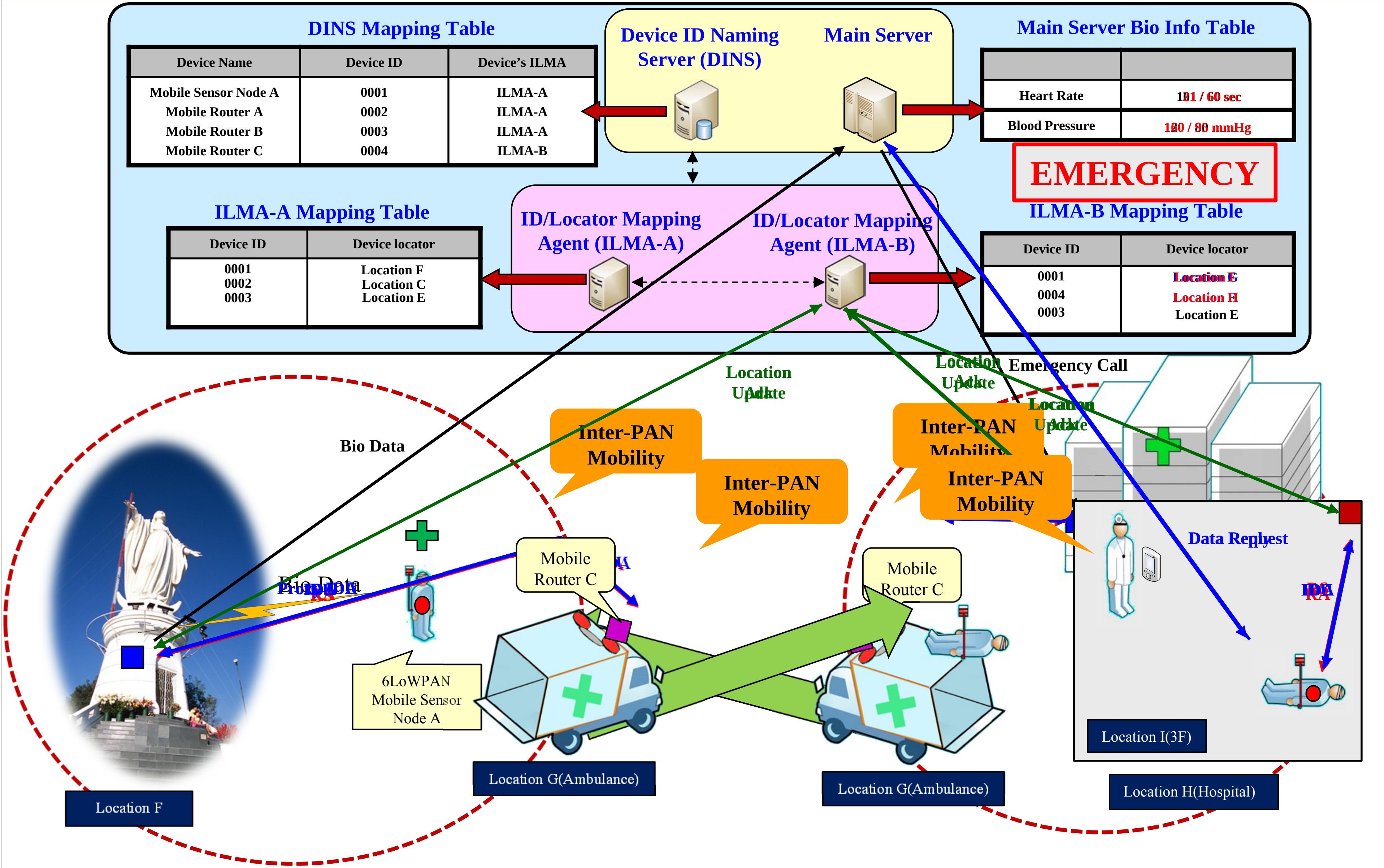
Device ID	Device locator
0001	Location D
0002	Location C
0003	Location E

ILMA-B Mapping Table

Device ID	Device locator
0004	Location H
0003	Location E



Example of Application - healthcare scenario



Conclusion

- ID/Locator separation architecture can be instrumental for future Internet to efficiently support mobility, multi-homing, scalable routing.
- We proposed a new ID/Locator separation architecture for supporting the lightweight mobility to both sensor node mobility & network mobility.
  - It is applicable in a sensor network mobility where many sensor nodes support only lightweight communication.
- The proposed scheme supports data/signaling split, energy-efficient mobility, and packet route optimization.
- Also, the proposed approach supports minimum signaling within the PAN, and multi-hop communication between 6LoWPAN node and gateway.

MobilityFirst: A Robust and Trustworthy Mobility-Centric Architecture for the Future Internet

Introduction: NSF Future Internet Architecture (FIA) Program

- **FIA program started in Oct 2010, with 4 teams funded:**
  - XIA (led by CMU) – project aims to develop very flexible architecture which can evolve to meet new requirements
  - NEBULA (led by UPenn) – project aims to design fast/managed flows to cloud services at the core of the Internet
  - NDN (led by UCLA/PARC) – project aims to re-design Internet to handle named content efficiently
  - MobilityFirst (led by Rutgers) – project aims to develop efficient and scalable architecture for emerging mobility services
- Scope of all these FIA projects includes architecture/design, protocol validation and comprehensive evaluation of usability and performance (using real-world applications in later stages)

MobilityFirst Project: Collaborating Institutions

RUTGERS (LEAD)

D. Raychaudhuri, M. Gruteser, W. Trappe, R, Martin, Y. Zhang, I. Seskar, K. Nagaraja

THE UNIVERSITY OF MASSACHUSETTS AMHERST 1863

A. Venkataramani, J. Kurose,
B. D. Towsley

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

M. Reiter

THE UNIVERSITY of WISCONSIN MADISON

S. Bannerjee

Massachusetts Institute of Technology

W. Lehr

MICHIGAN

Z. Morley Mao

Duke UNIVERSITY

X. Yang, R. RoyChowdhury

UMASS LOWELL

G. Chen

UNIVERSITY OF Nebraska Lincoln

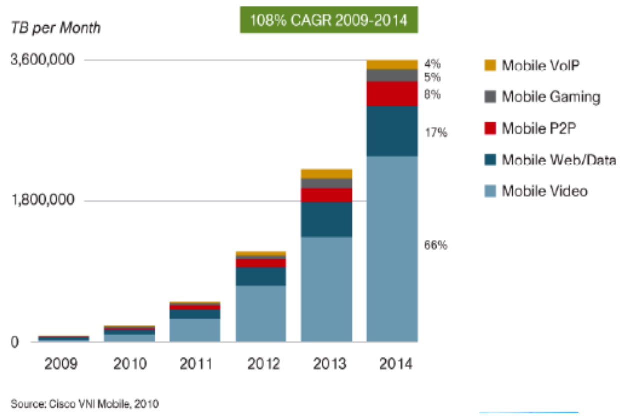
B. Ramamurthy

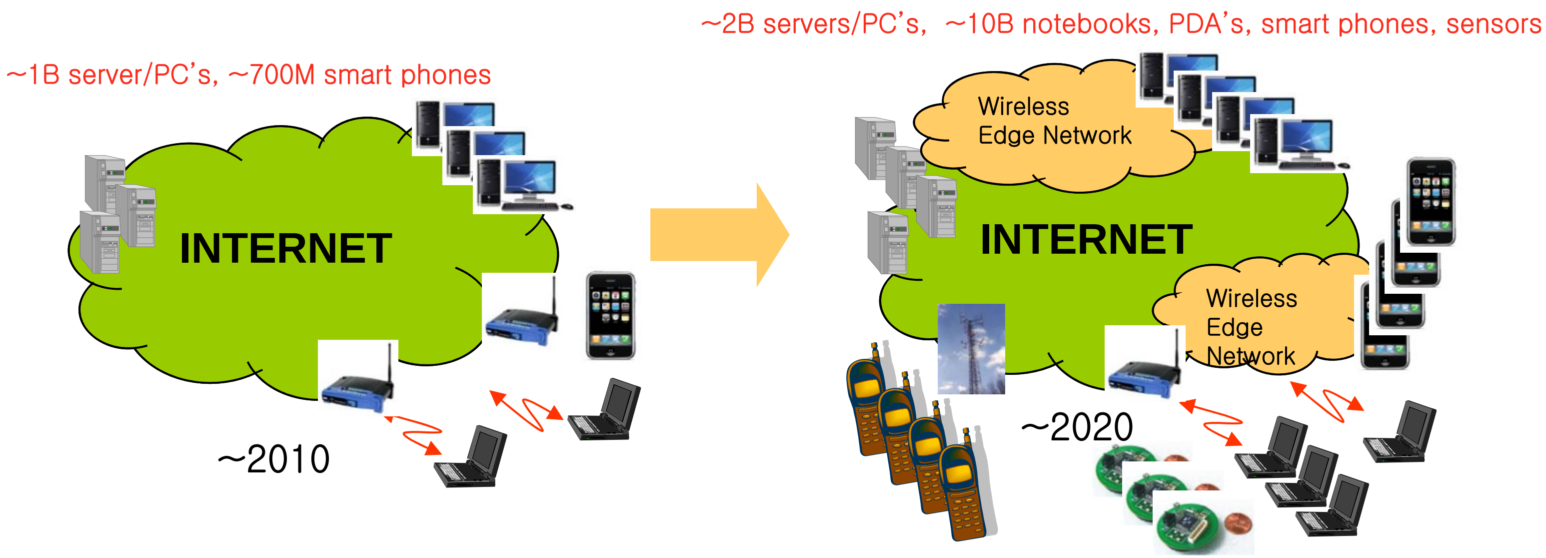
+ Also industrial R&D collaborations with AT&T Labs, Bell Labs, NTT DoCoMo, Toyota ITC, NEC, Ericsson and others

Project Funded by the US National Science Foundation (NSF) Under the Future Internet Architecture (FIA) Program, CISE

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

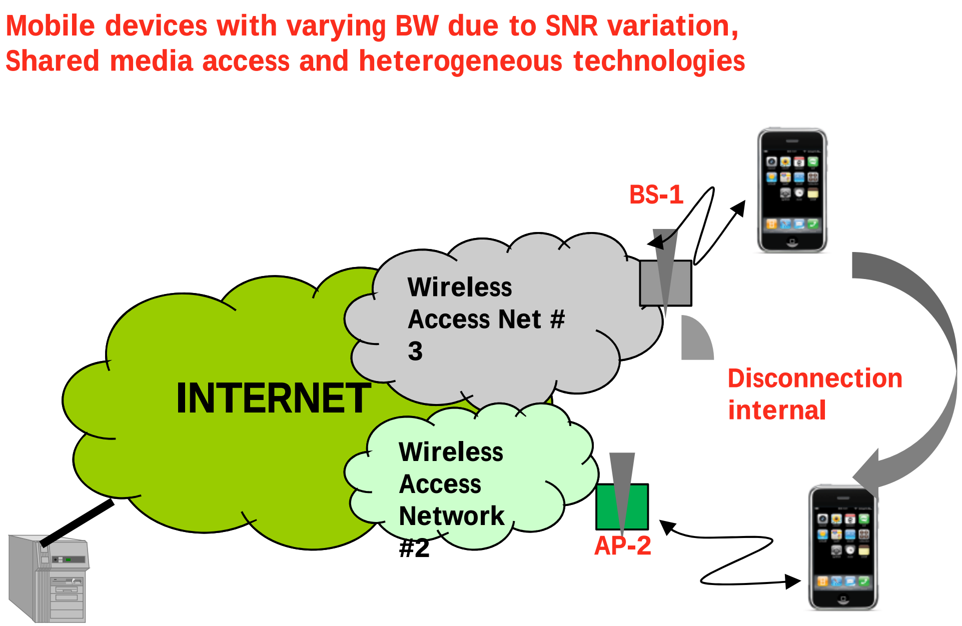
- Historic shift from PC's to mobile computing and embedded devices…
  - ~4 B cell phones vs. ~1B PC's in 2010
  - Mobile data growing exponentially – Cisco white paper predicts 3.6 Exabytes by 2014, significantly exceeding wired Internet traffic
  - Sensor/IoT/V2V just starting, ~5-10B units by 2020

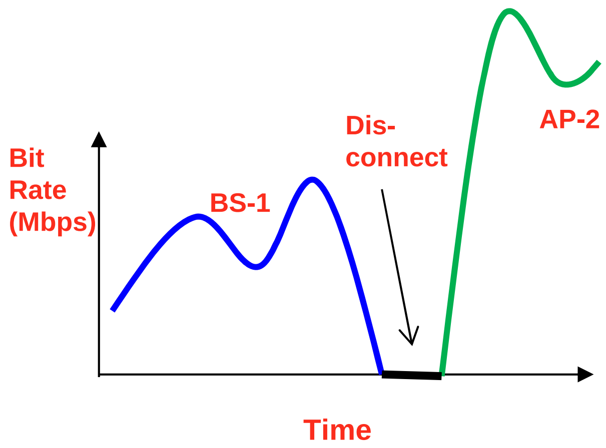




Introduction: Why Are Mobile Networks Different? - BW Variation & Disconnection

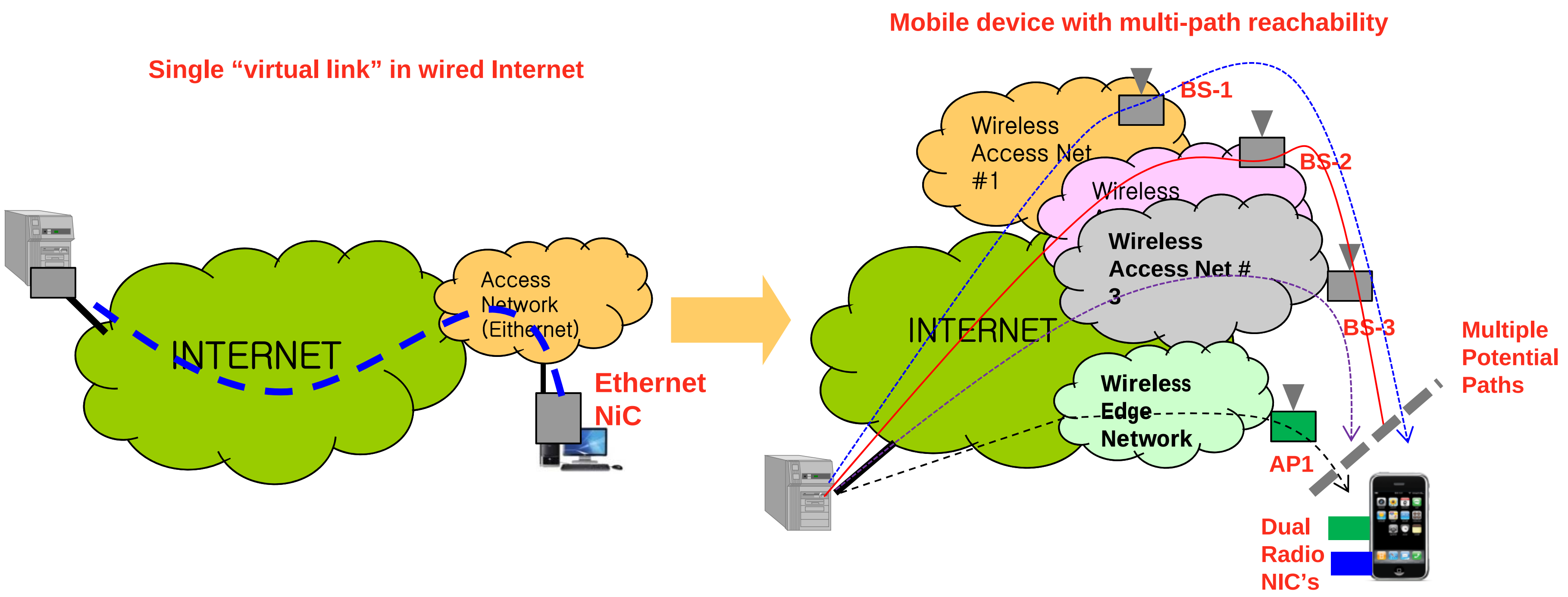
- The wireless medium has inherent fluctuations in bit-rate (by as much as 10:1 in 3G/4G access, heterogeneity and disconnection → fundamental protocol design challenge
- Motivates in-network storage and hop-by-hop transport (solutions such as CNF, DTN, ..)





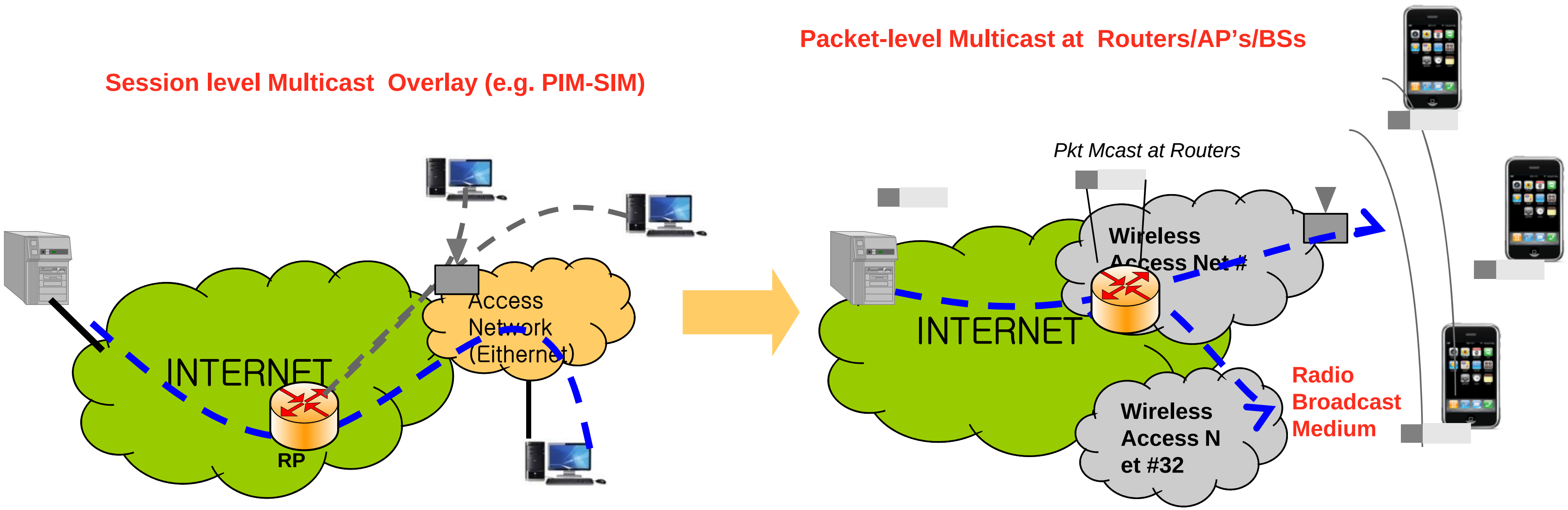
Introduction: Why Are Mobile Networks Different? – Multihoming, Multipath

- Wired Internet devices typically have a single Ethernet interface associated with a static network/AS
- In contrast, mobile devices typically have ~2-3 radios and can see ~5-10 distinct networks/AS's at any given location
- Basic property - multiple paths to a single destination → leads to fundamentally different routing, both intra and inter domain!



Introduction: Why Are Mobile Networks Different? - Multicast

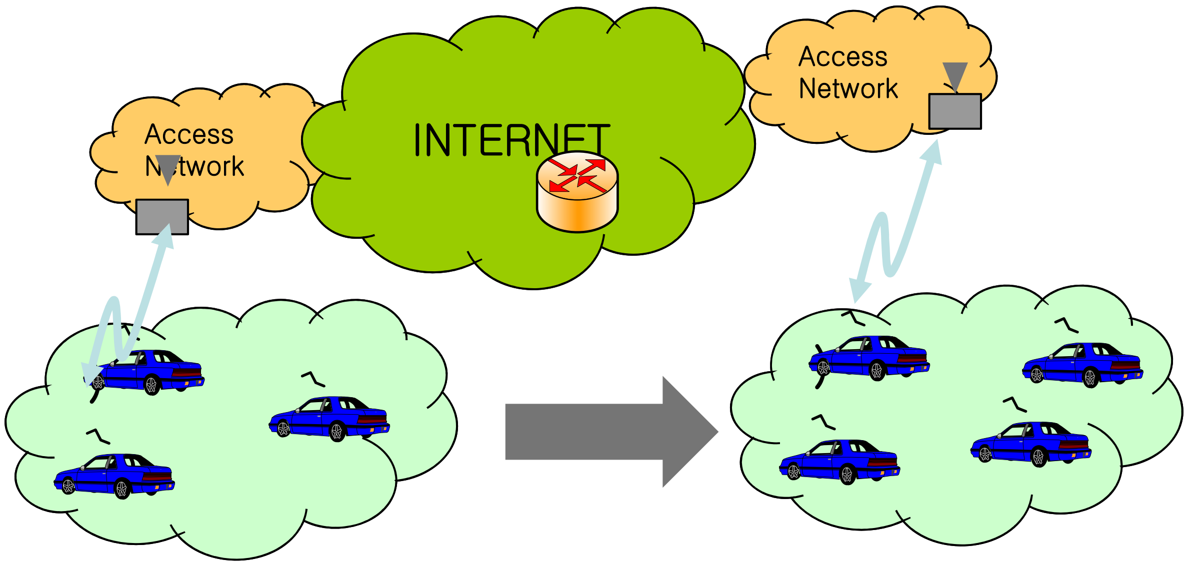
- Many mobility services (content, context) involve multicast
- The wireless medium is inherently multicast, making it possible to reach multiple end-user devices with a single transmission
- Fine-grain packet level multicast desirable at network routers



Introduction: Why Are Mobile Networks Different? – Ad Hoc & Network Mobility

- Wireless devices can form ad hoc networks with or without connectivity to the core Internet
- These ad hoc networks may also be mobile and may be capable of peering
- Requires rethinking of interdomain routing, trust model, etc.

Ad Hoc Network Formation, Intermittent Connection to Wired Internet & Network Mobility

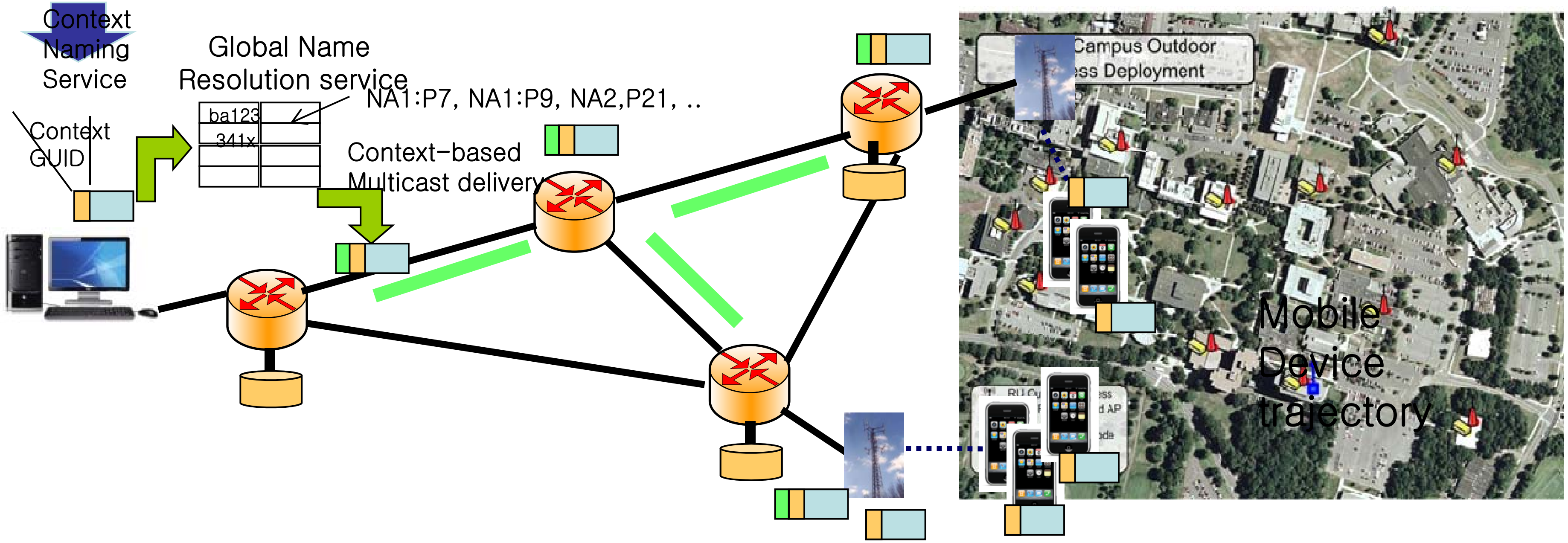


Introduction: Why Are Mobile Networks Different? – Content & Context

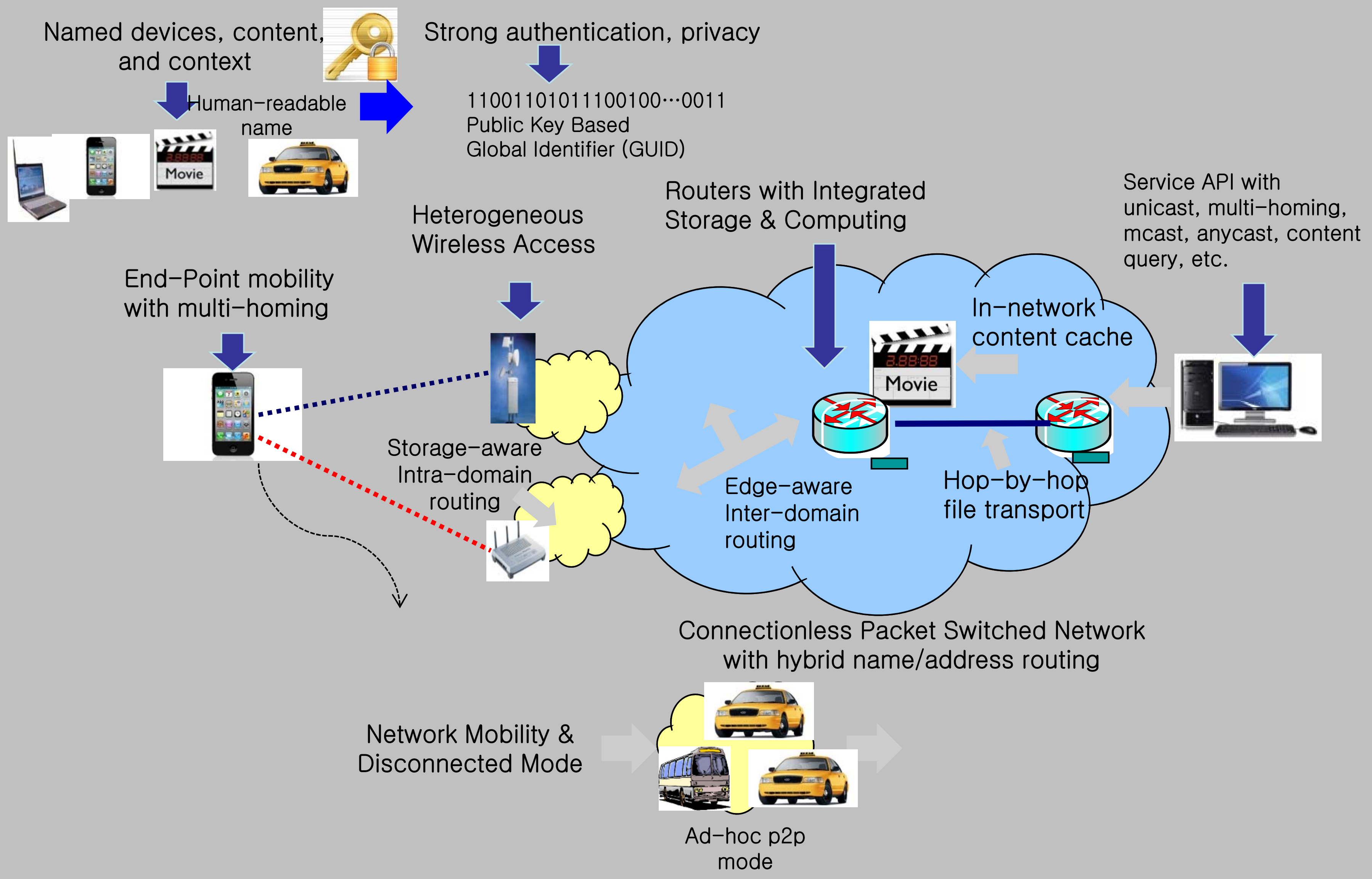
- Content and context aware message delivery often associated with mobile services
  - "Anycast" content retrieval from nearest storage location (cache)
  - Context based message delivery specific by group, area, time, etc.
  - Service typically involves dynamic binding of content or context to a specific set of network addresses along with multicast delivery

Context = geo-coordinates & first_responder

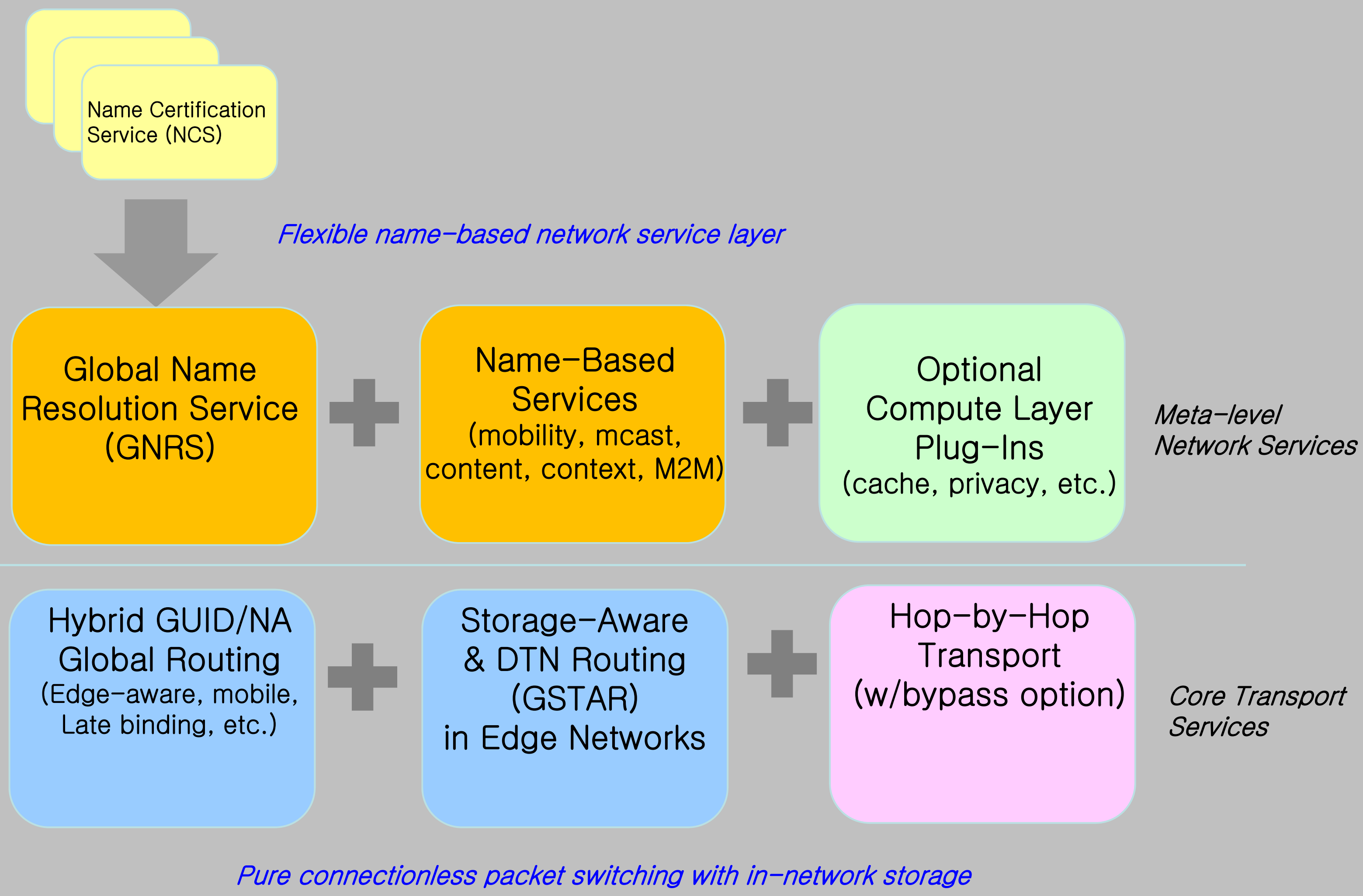
Send (context, data)



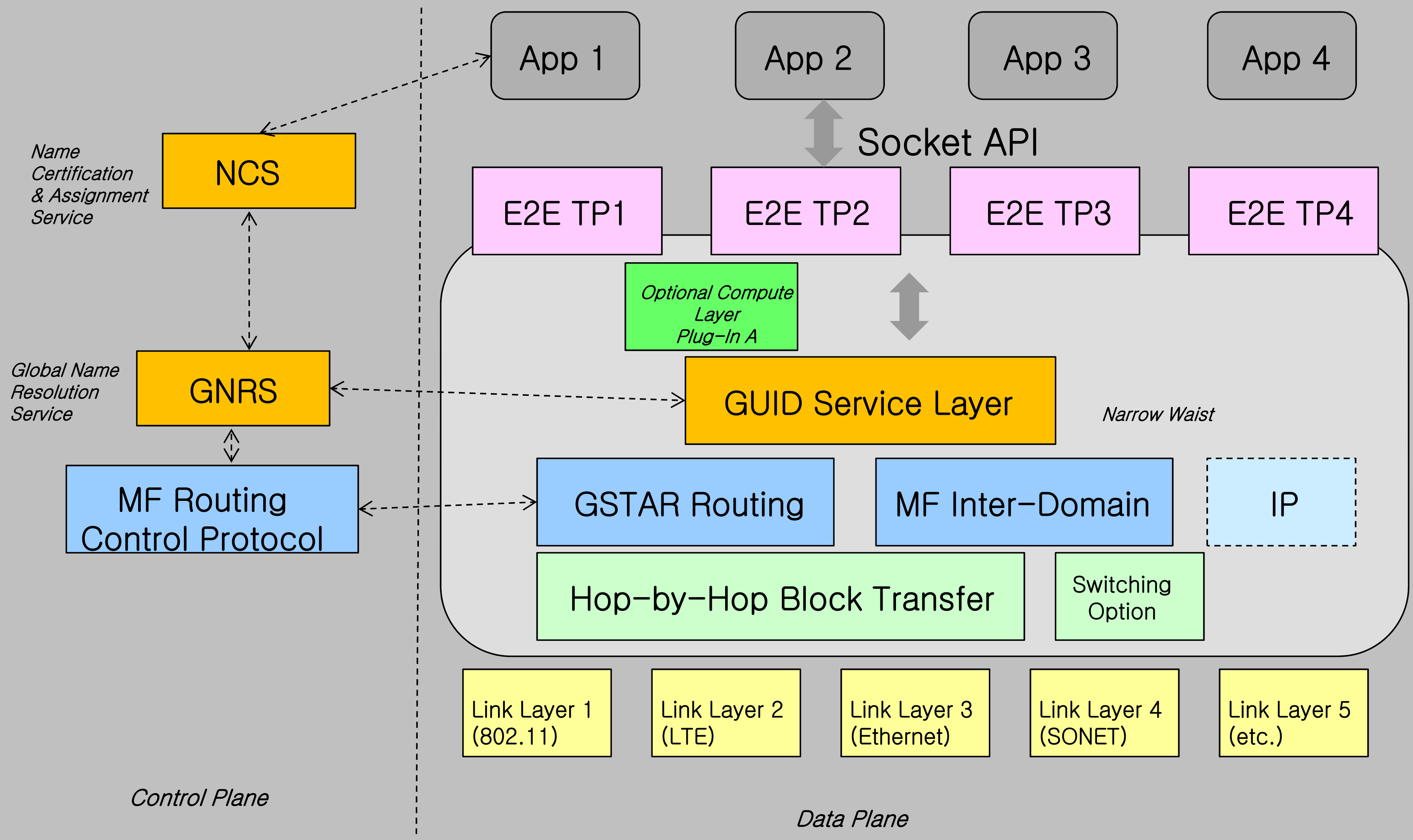
MobilityFirst Design: *Architecture Feature*



MobilityFirst Design: *Technology Solution*

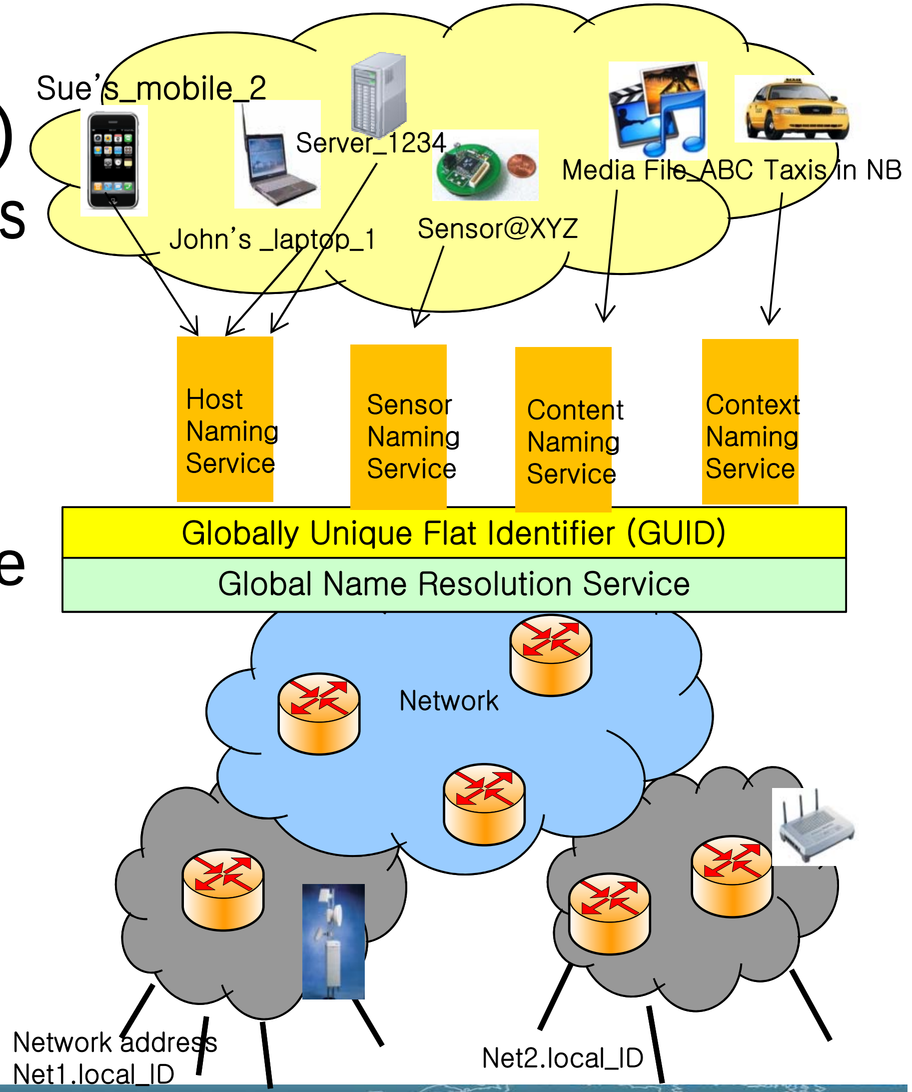


MobilityFirst Design: *Protocol Stack*



MobilityFirst Design: 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

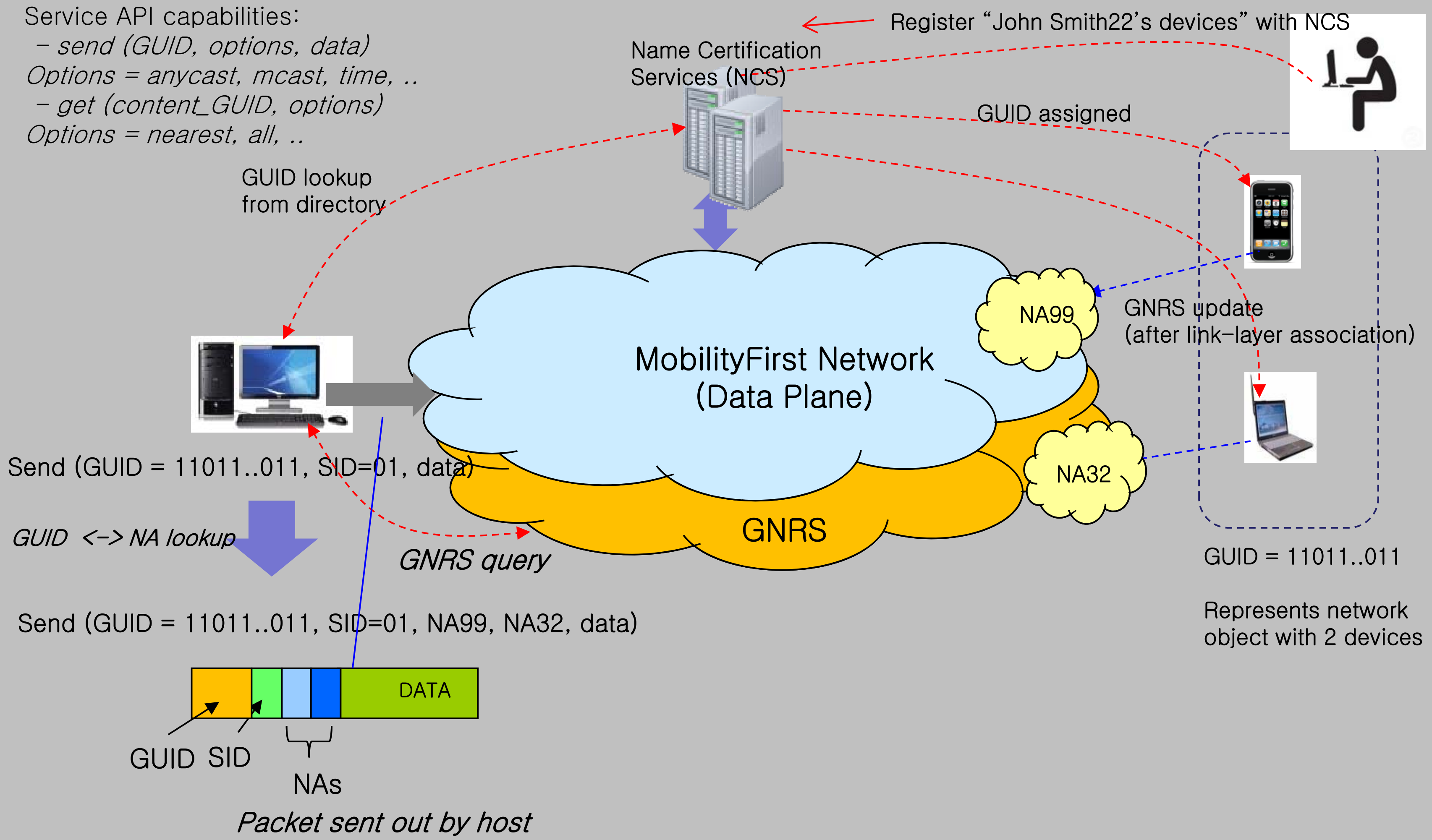


MobilityFirst Design: Protocol Example - Name Resolution at Device End-Points

Service API capabilities:
- *send (GUID, options, data)*

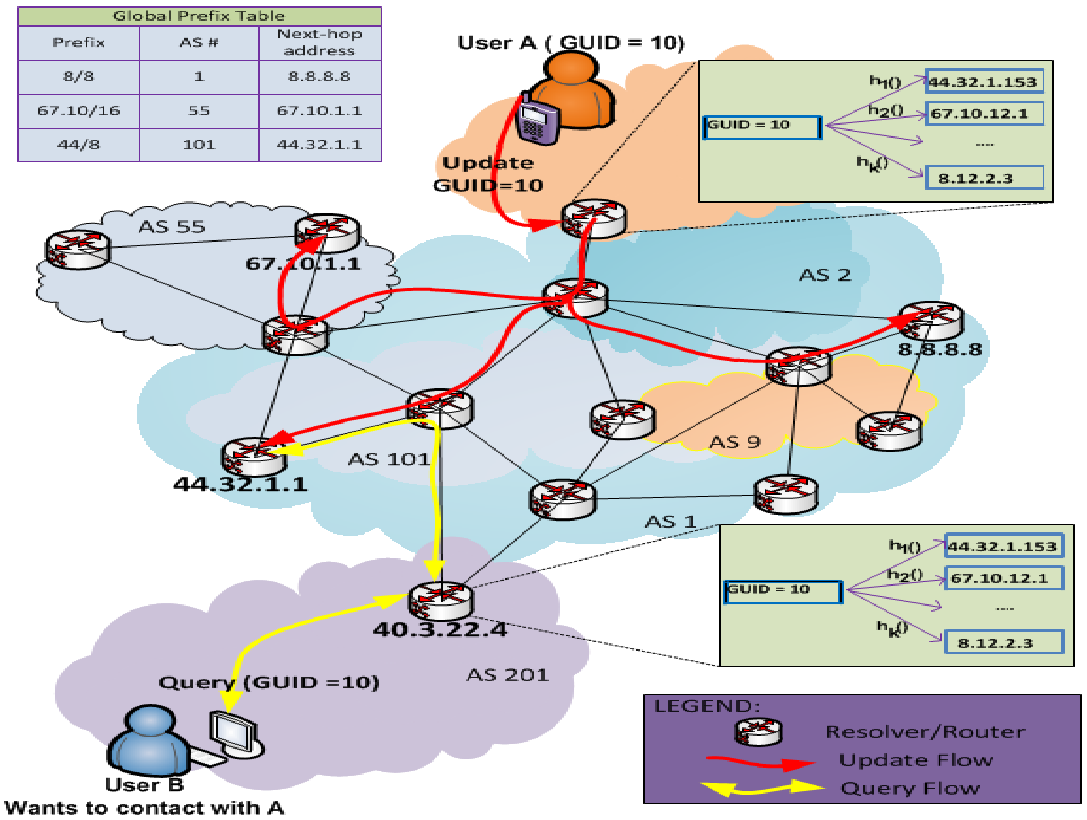
Options = anycast, mcast, time, ..
- *get (content_GUID, options)*

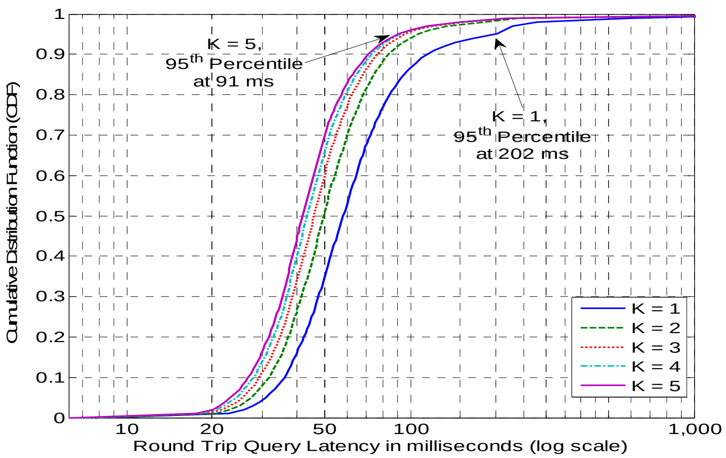
Options = nearest, all, ..



MobilityFirst Design: Realizing the 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)

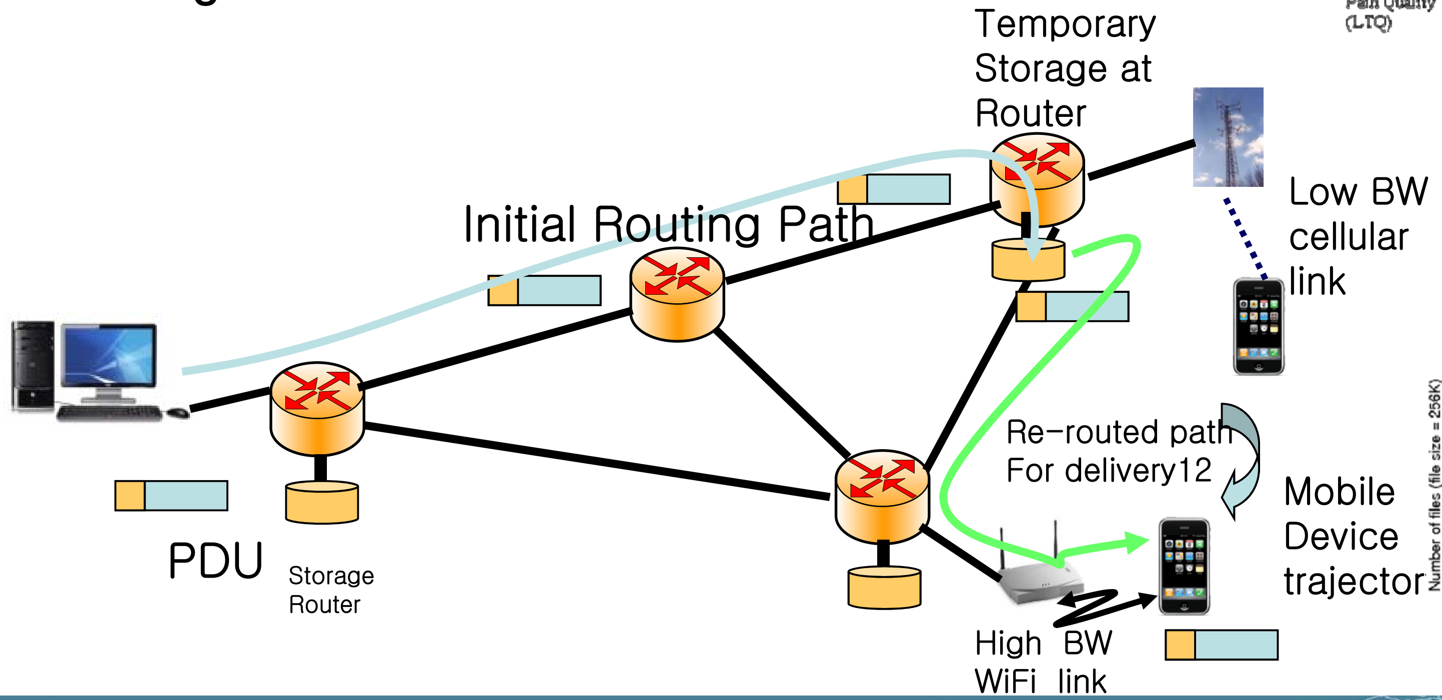


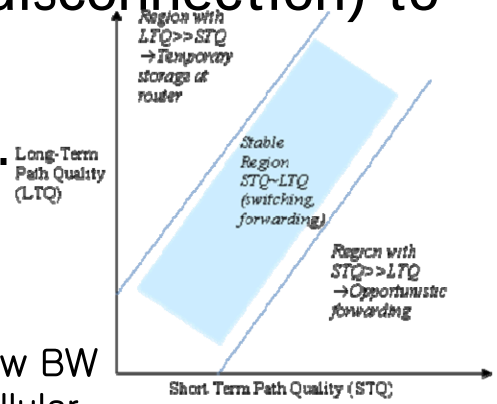


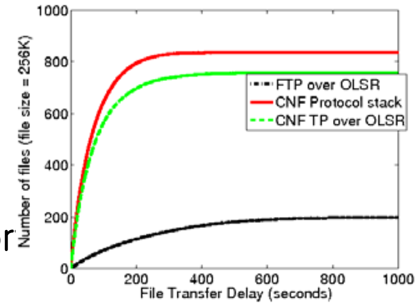
Internet Scale Simulation Results
Using DIMES database

MobilityFirst 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 seamlessly 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…



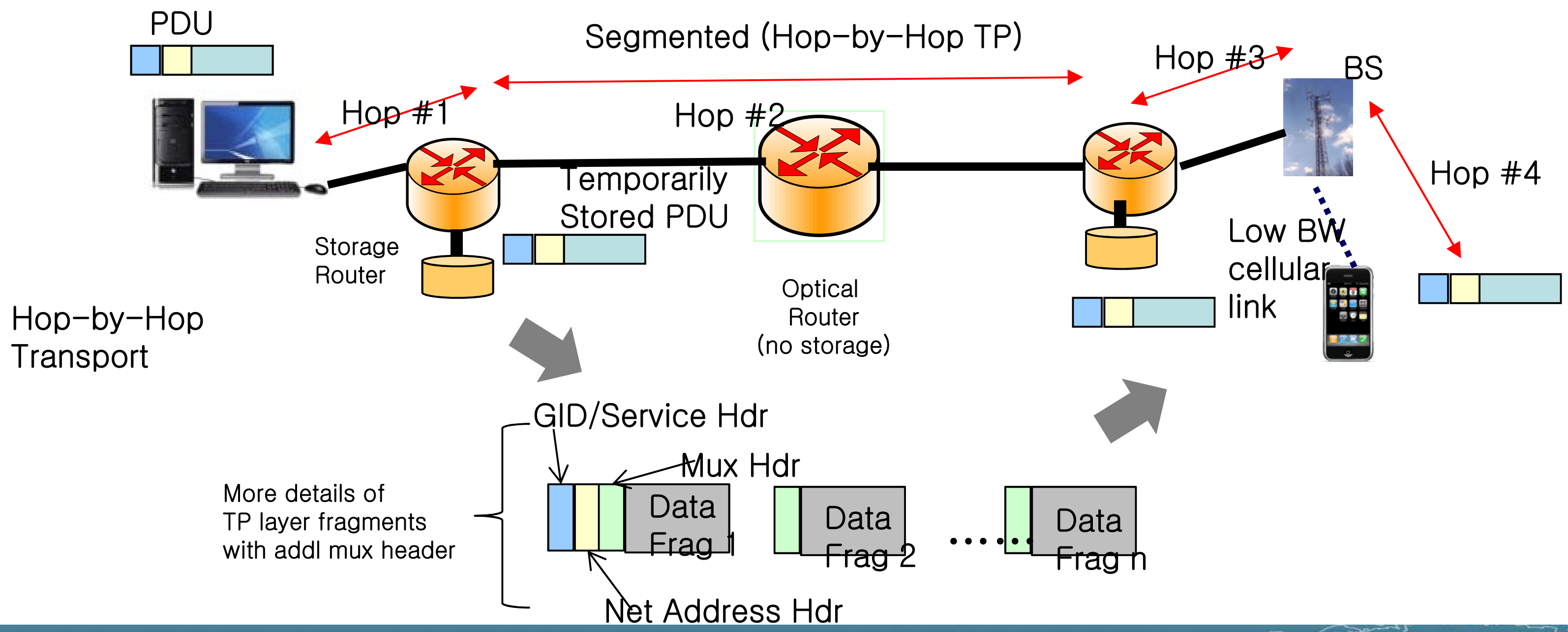




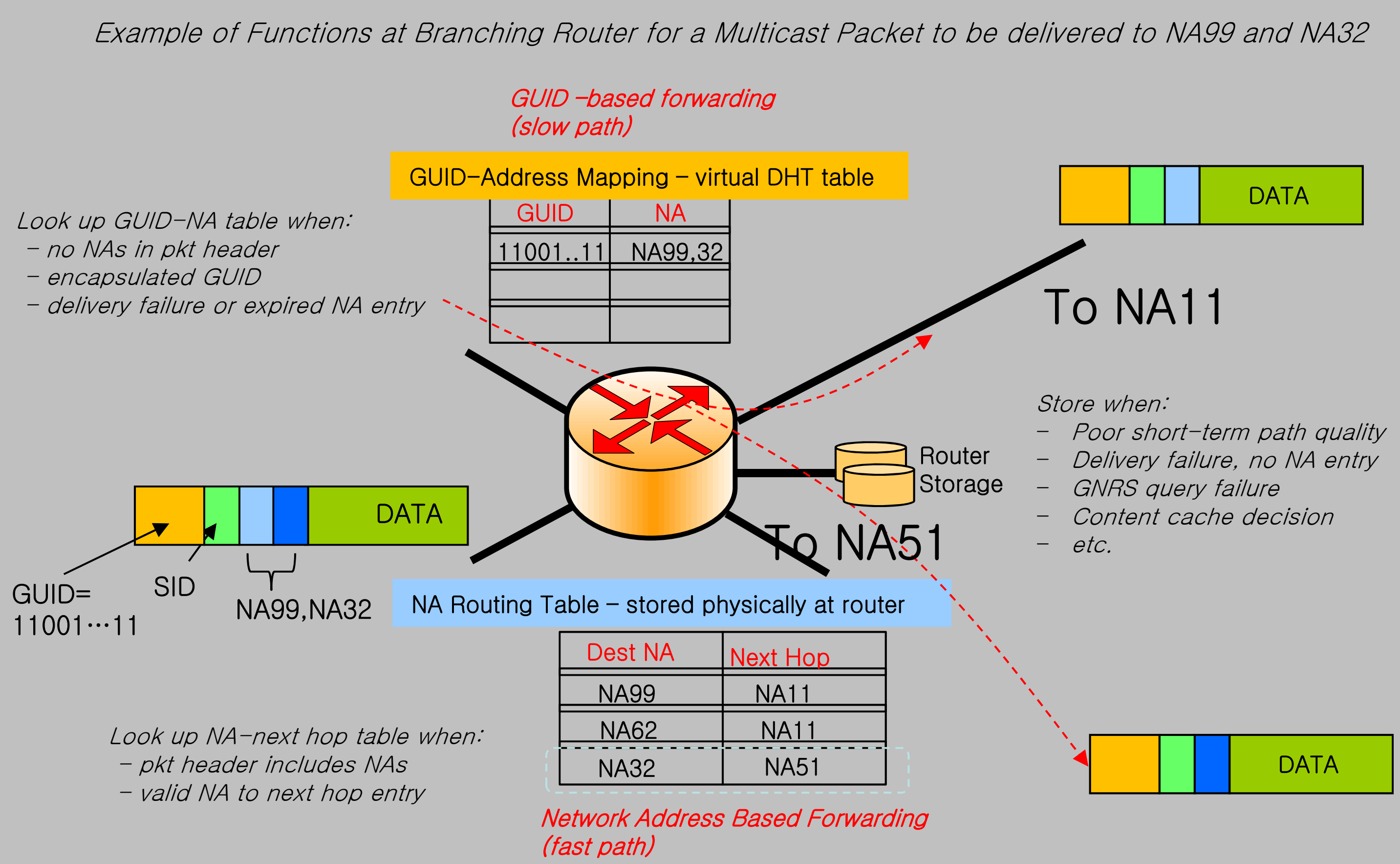
Sample CNF routing result

MobilityFirst Design: Segmented Transport

- Segment-by-segment transport between routers with storage, in contrast to end-to-end TCP used today
- Unit of transport (PDU) is a content file or max size fragment
- Hop TP provides improved throughput for time-varying wireless links, and also helps deal with disconnections
- Also supports content caching, location services, etc.

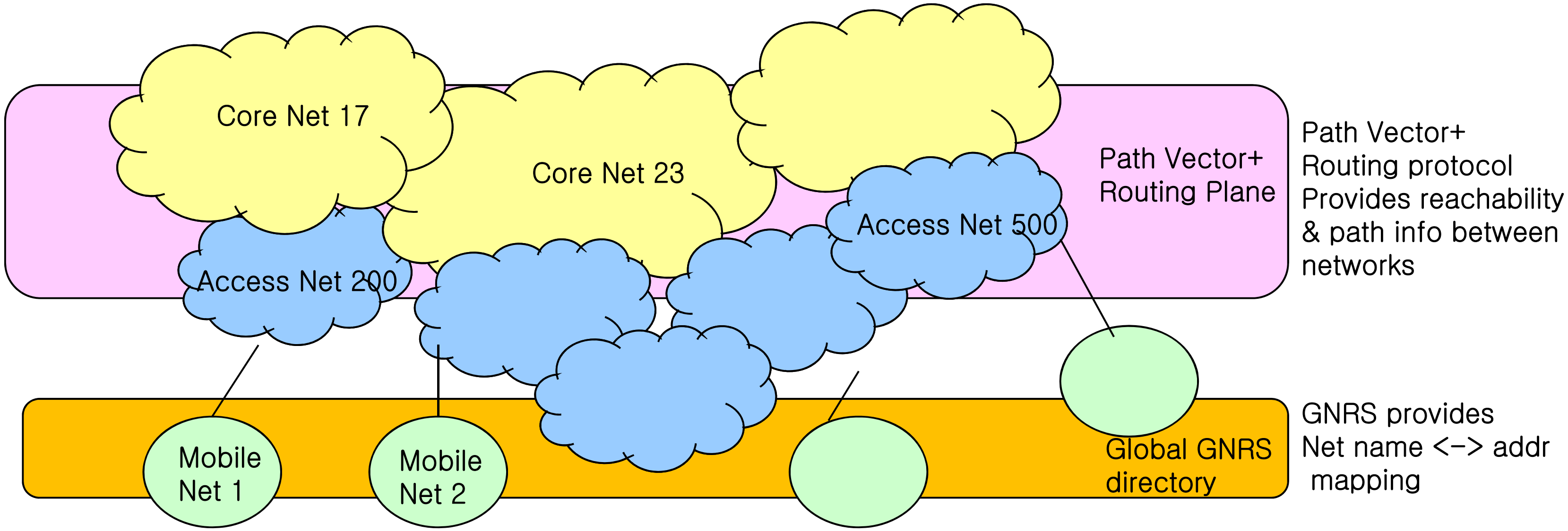


MobilityFirst Design: MF Router Operation



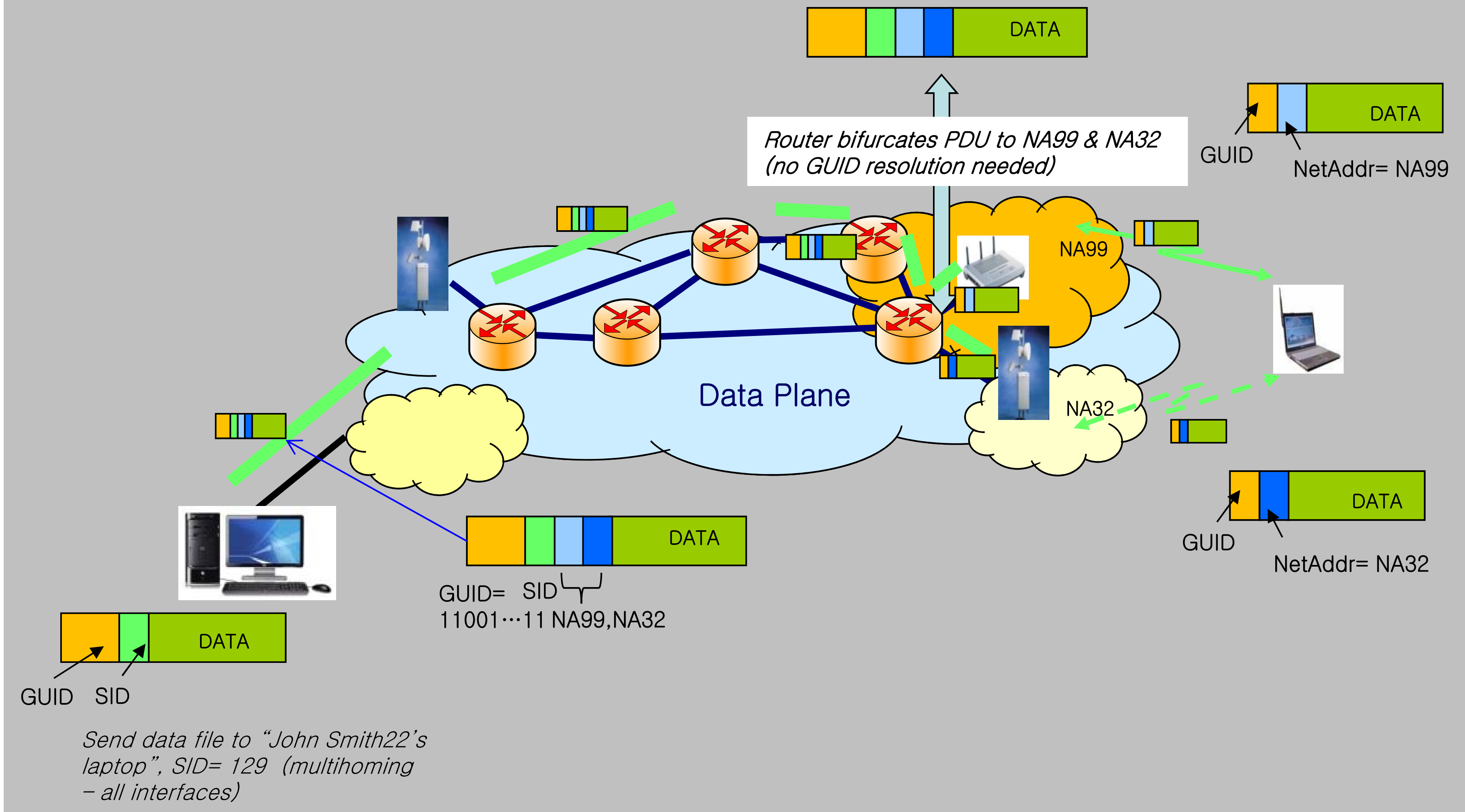
MobilityFirst Design: Interdomain Routing

- Requirements include: edge awareness, flexible network boundaries, dynamic AS formation, virtual nets, network mobility, DTN mode, path selection, multipath, multi-homing, etc.
- Motivates rethinking of today's 2-tier IP/BGP architecture (inter-AS, intranet)
- MobilityFirst interdomain approach uses GNRS service + enhanced global routing protocol (path vector, telescopic flooding) to achieve design goals – still evaluating multiple design options….



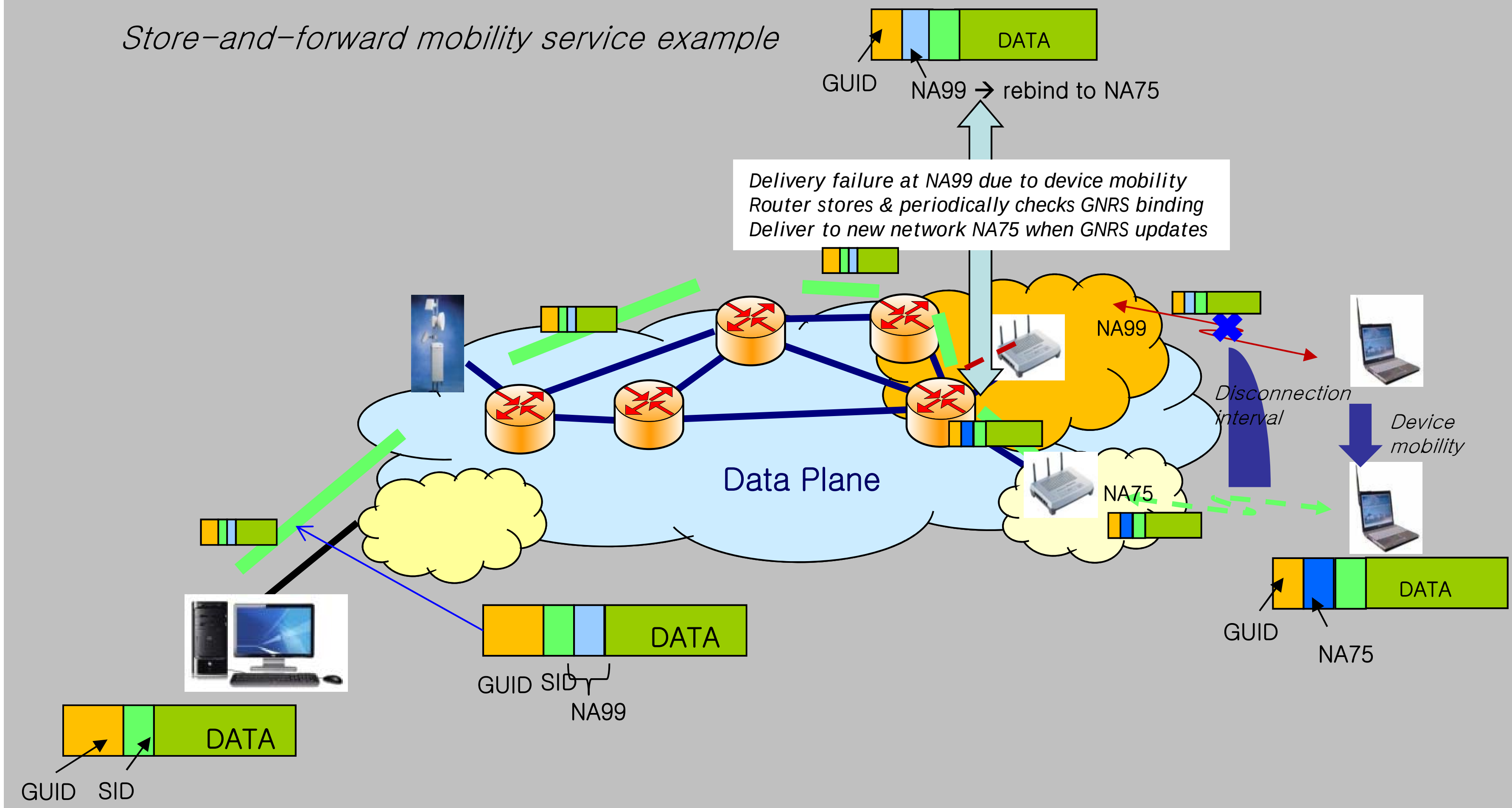
MobilityFirst Design: Protocol Example - Dual Homing Service

Multihoming service example



MobilityFirst Design: Protocol Example - Handling Disconnection

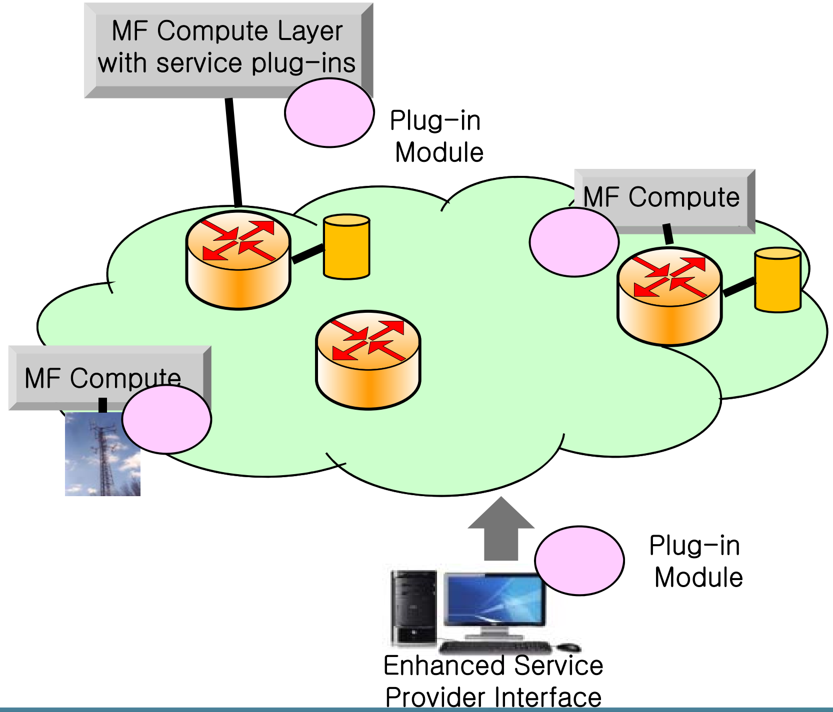
Store-and-forward mobility service example



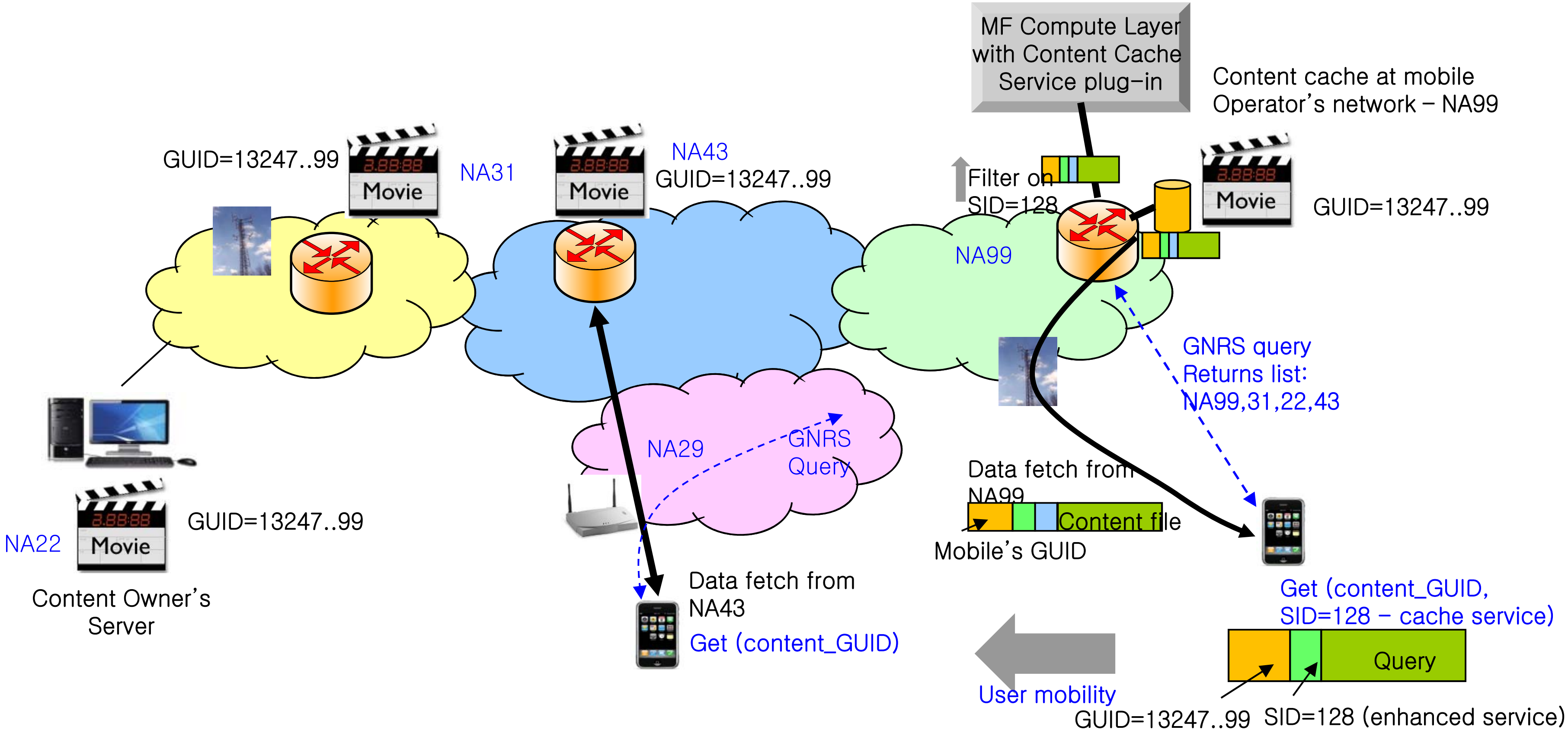
Send data file to "John Smith22's laptop", SID= 11 (unicast, mobile delivery)

MobilityFirst Design: Computing Layer

- Programmable computing layer provides service flexibility and evolution/growth path
  - Routers include a virtual computing layer to support new network services
  - Packets carry service tags and are directed to optional services where applicable
  - Programming API for service creation provided as integral part of architecture
  - Computing load can be reasonable with per-file (PDU) operations (vs. per packet)

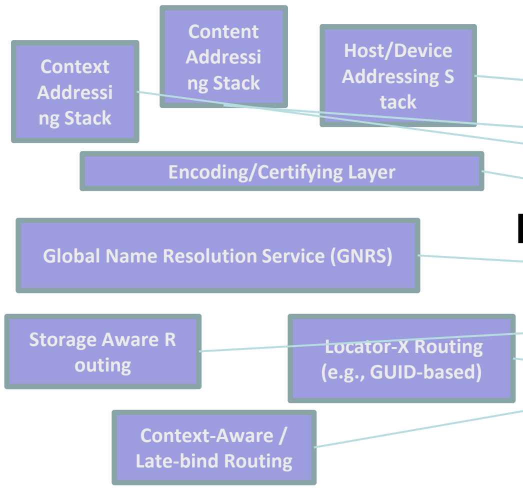


Enhanced service example – content delivery with in-network storage

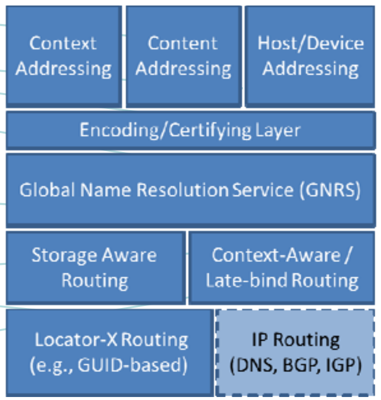


MobilityFirst Prototyping: Phased Strategy

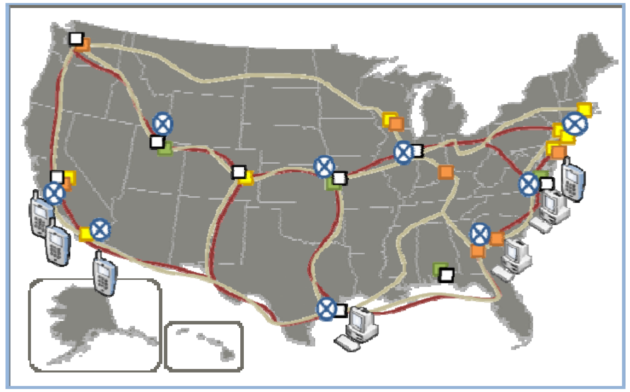
Phase 1



Phase 2



Phase 3



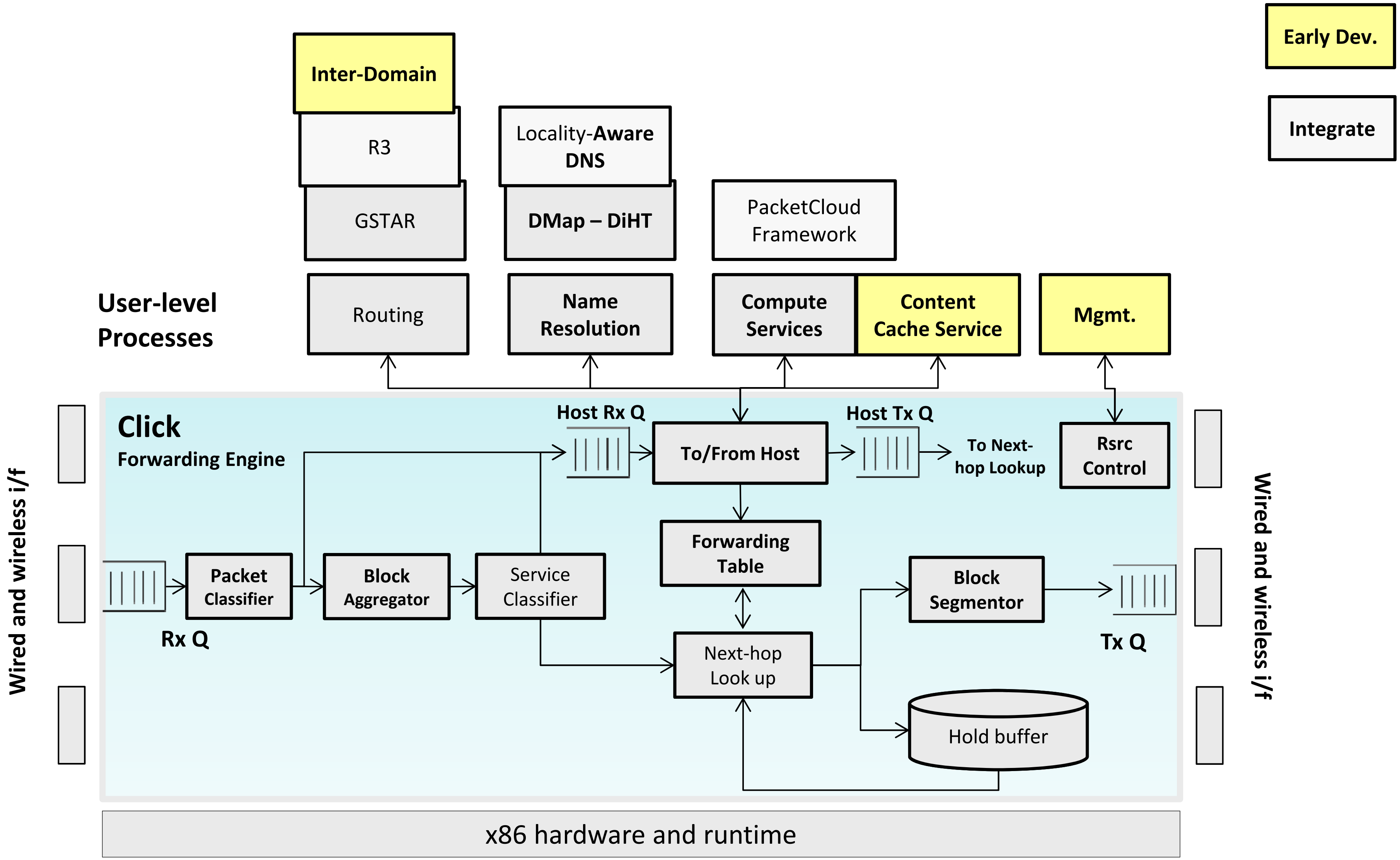
Prototype

Standalone Modules → Integrated MF Protocol Stack and Services → Deployable s/w pkg., box

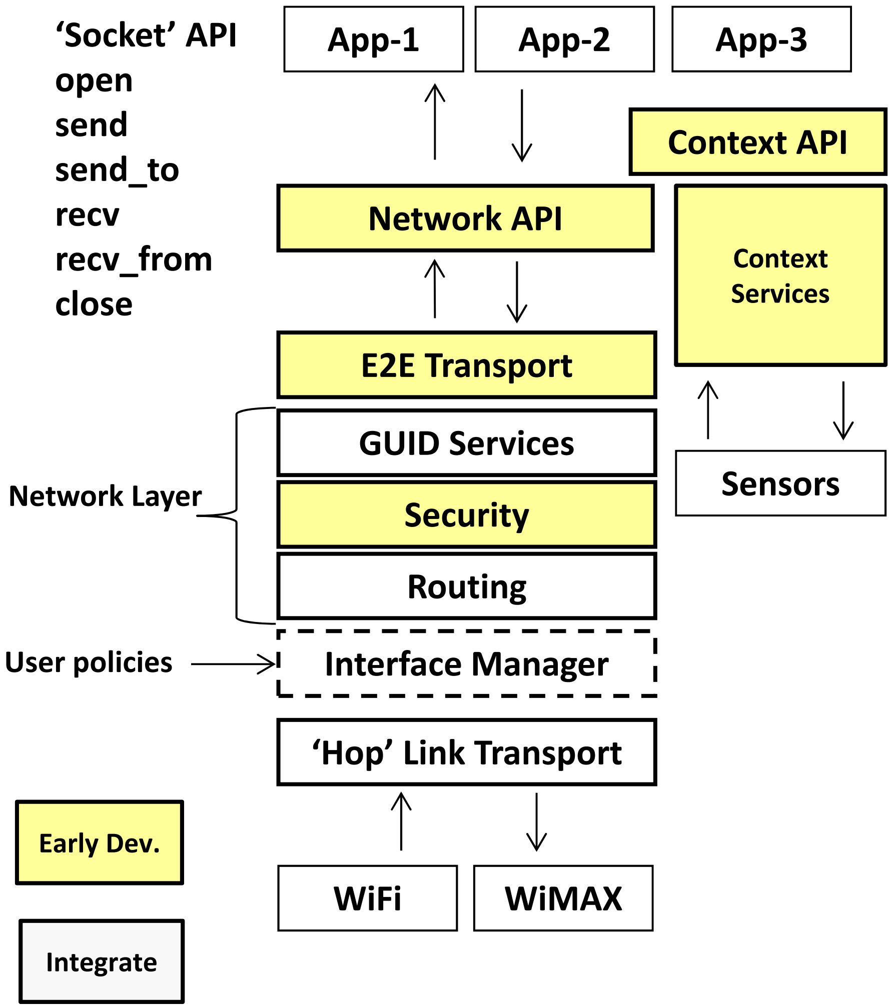
Evaluation

Simulation and Emulation → Smaller Scale Testbed → Distributed Testbed E.g. 'Live' on GENI

MobilityFirst Prototyping: Click-based Router Implementation



MobilityFirst Prototyping: Host Protocol Stack

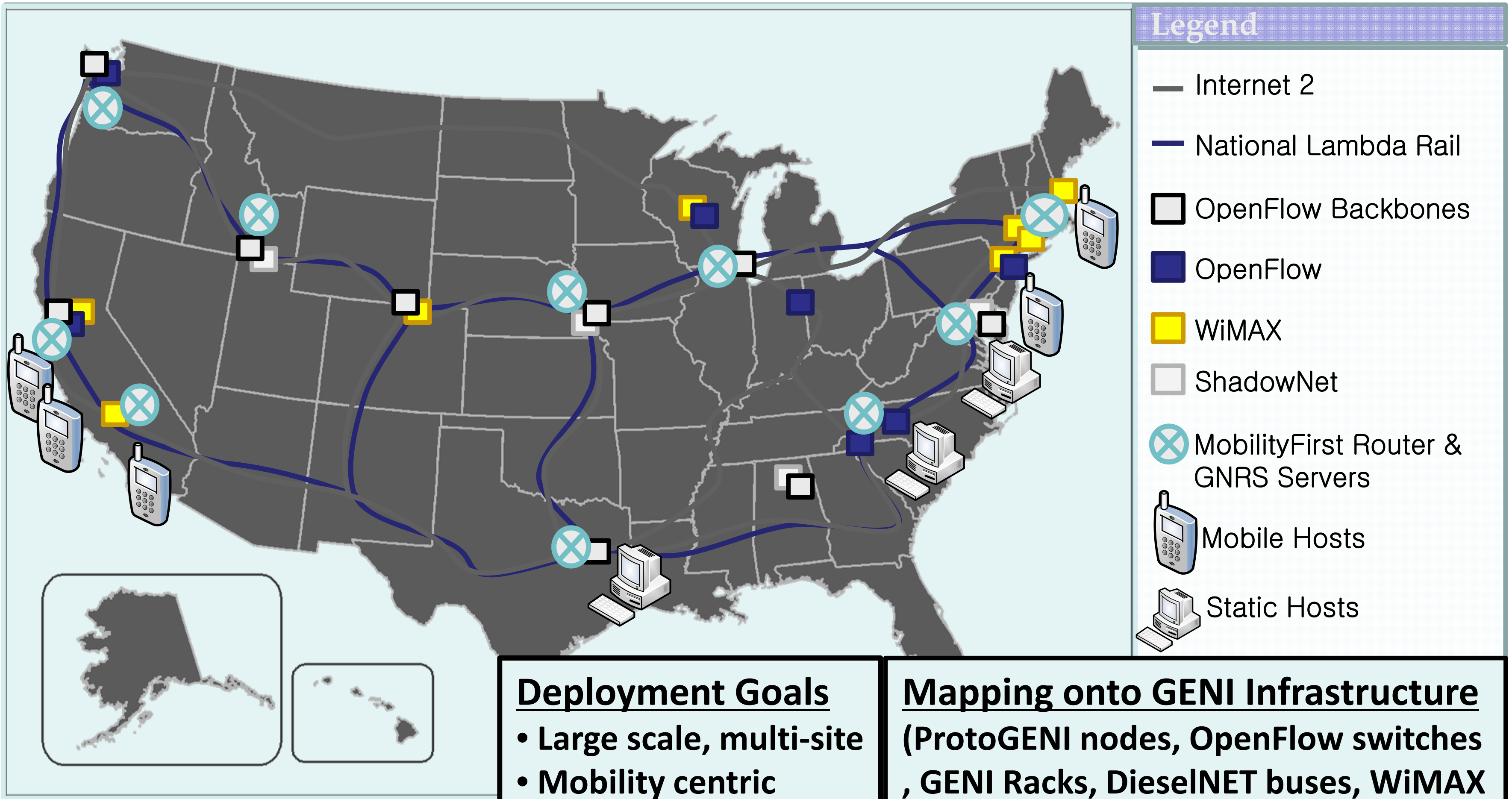


Linux PC/laptop with WiMAX & WiFi

Android device with WiMAX & WiFi

Device: HTC Evo 4G, Android v2.3 (rooted), NDK (C++ dev)

MobilityFirst Prototyping: GENI Deployment



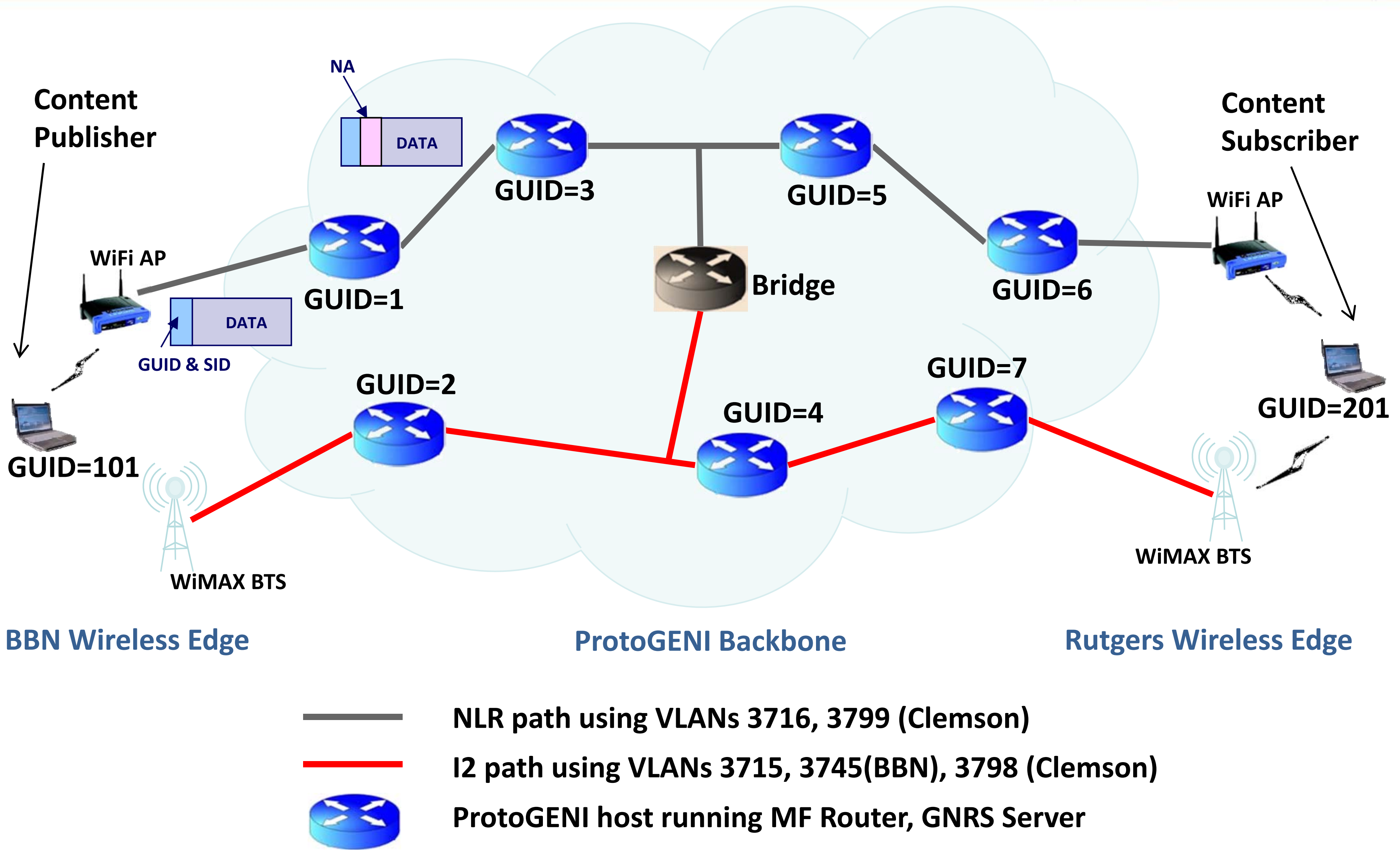
Deployment Goals

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

Mapping onto GENI Infrastructure

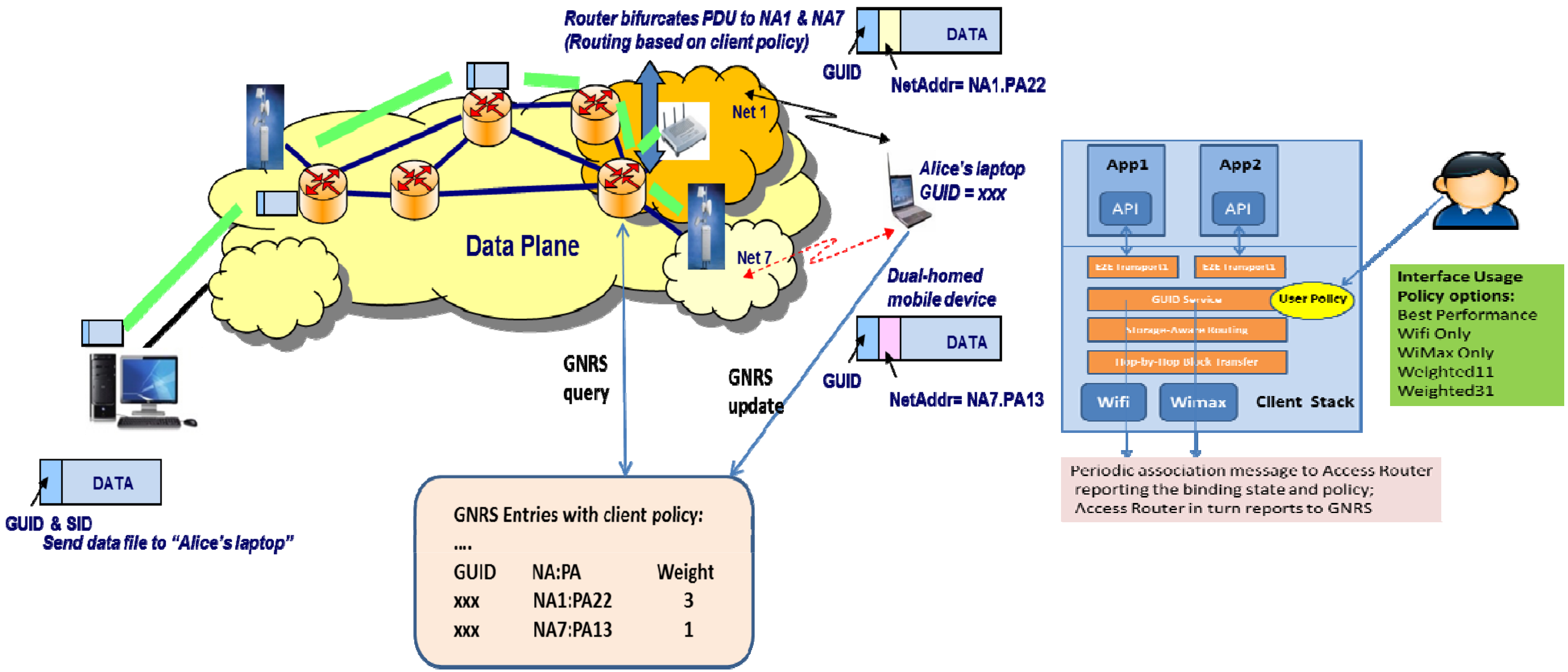
(ProtoGENI nodes, OpenFlow switches , GENI Racks, DieselNET buses, WiMAX /outdoor ORBIT nodes)

MobilityFirst Prototyping: GEC-12 Demo (Content Delivery)

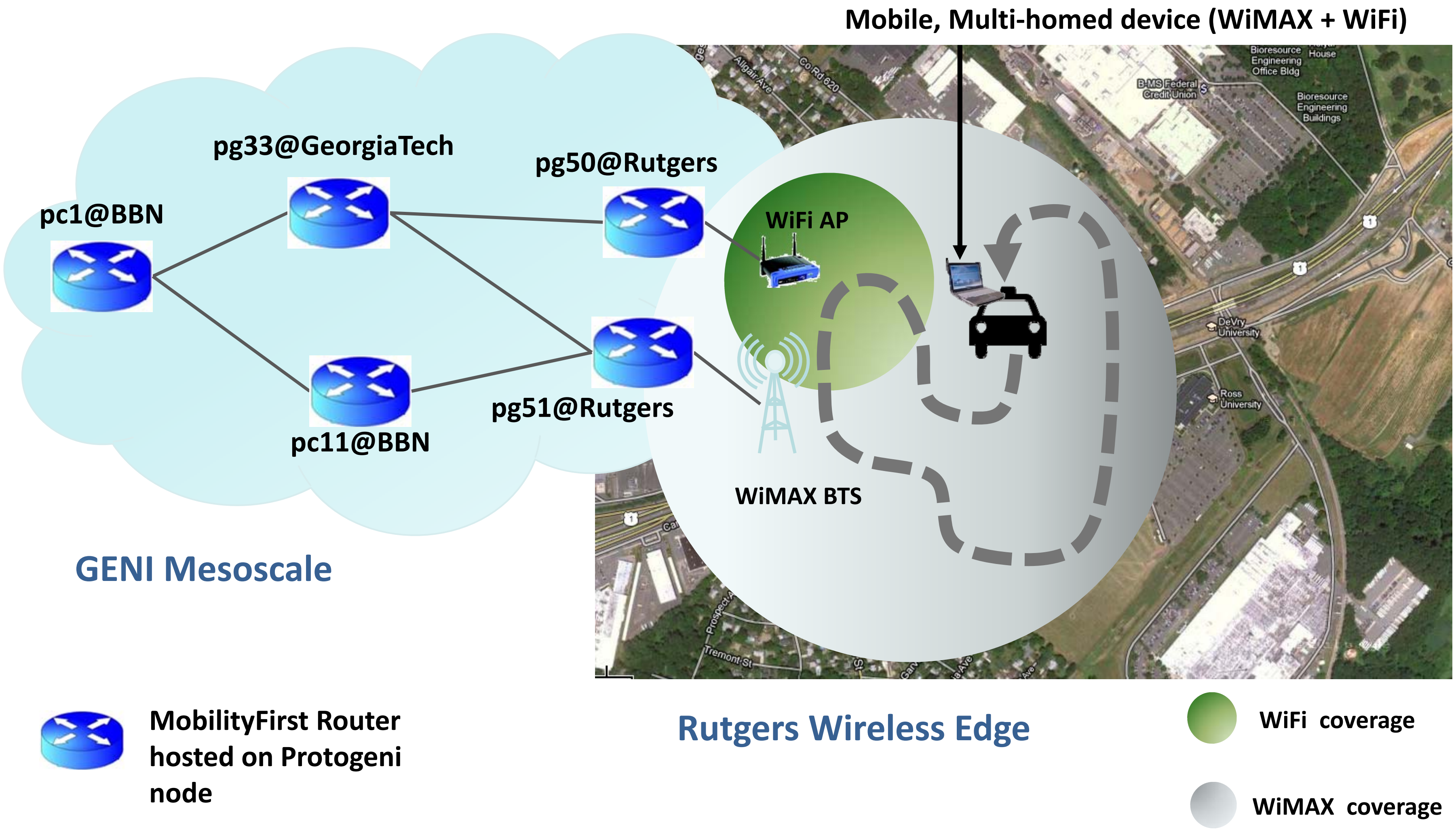


MobilityFirst Prototyping: Hot Mobile 2012

Delivery Services for Multi-Homed Devices with User preference of delivery interface



MobilityFirst Prototyping: GEC-13 Demo (Mobility, Multi-homing)



References

- GNAB presentation by CS Hong
- Project website: http://mobilityfirst.winlab.rutgers.edu

Thank you !
Q & A