IoTBD 2016
International Conference on Internet of Things and Big Data

WEBIST 2016
12th International Conference on Web Information Systems and Technologies

CLOSER 2016
6TH INTERNATIONAL CONFERENCE ON CLOUD COMPUTING AND SERVICES SCIENCE

Extending the Internet of Things to Space

Keynote talk at

International Conference on Internet of Things and Big Data

12th International Conference on Web Information Systems and Technologies

6th International Conference on Cloud Computing and Services Science

Rome, Italy

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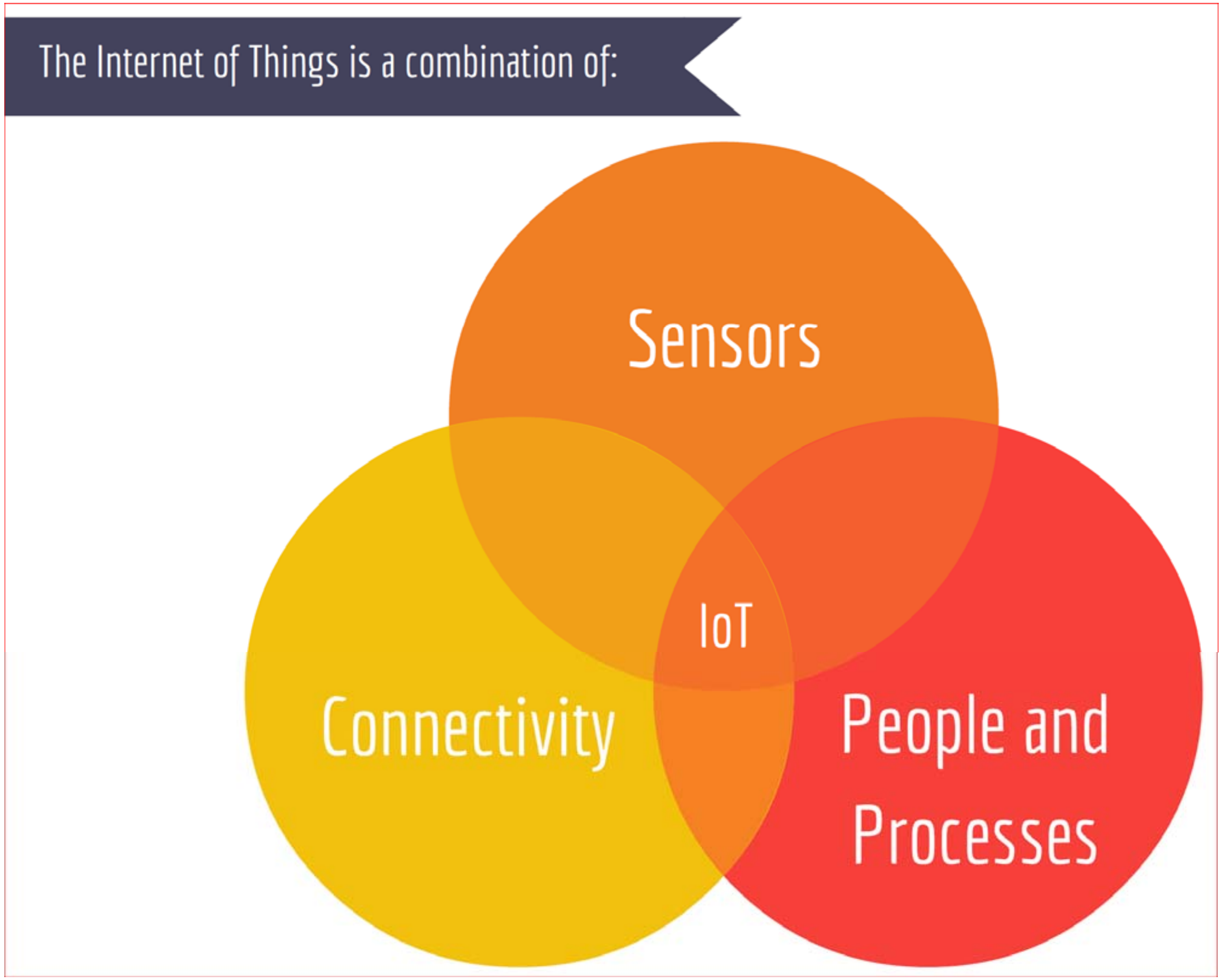
- Handoffs
- Mobile IP
- SIGMA
- Network in Motion – NEMO
- SINEMO – SIgma for NEMO

- Technologies that enable the Internet to reach out into the real world of physical objects
- A dynamic global network infrastructure with self configuring capabilities
- Physical and virtual 'things' have identities, physical attributes
- Seamlessly integrated into the information network
- 'Things' are expected to become active participants in business, information and social processes where they are enabled to interact and communicate among themselves and with the environment by exchanging data and information 'sensed' about the environment
- 'Things' react autonomously to the 'real/physical world' events
- Internet of Things (IoT) is an integrated part of Future Internet

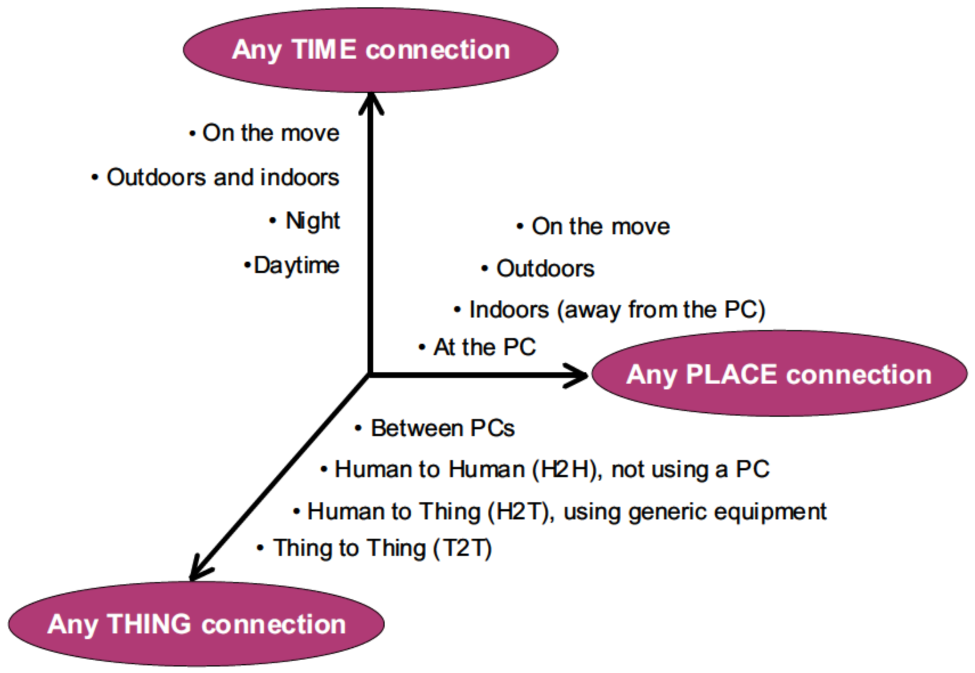
Source: Pasquale Puzio, "Internet of Things and its applications"


The Internet of Things is a combination of:
Sensors
IoT
Connectivity
People and Processes

From any time, any place connectivity for anyone, we will now have connectivity for anything!

- WiFi
- ZigBee
- 6LOPAN
- Bluetooth
- 4G/5G
- Broadband
- WiMax
- Satellites

Figure 1 – A new dimension

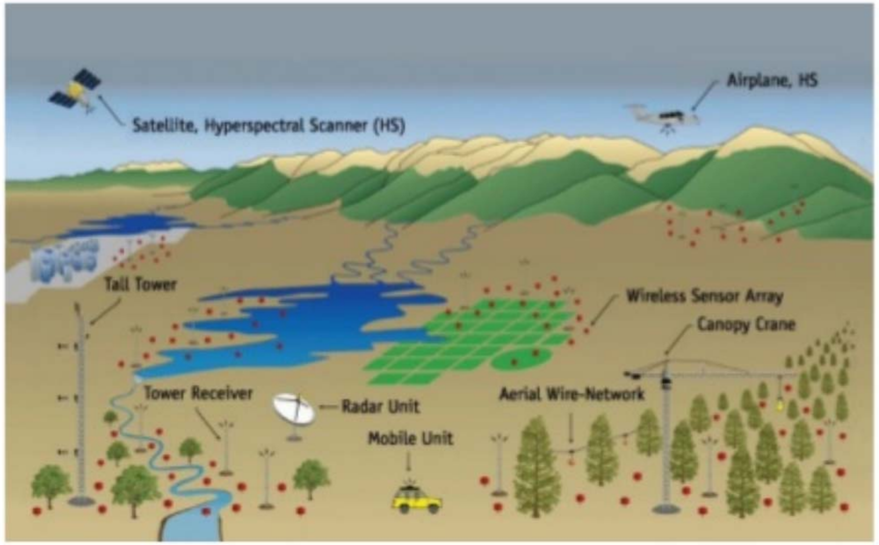


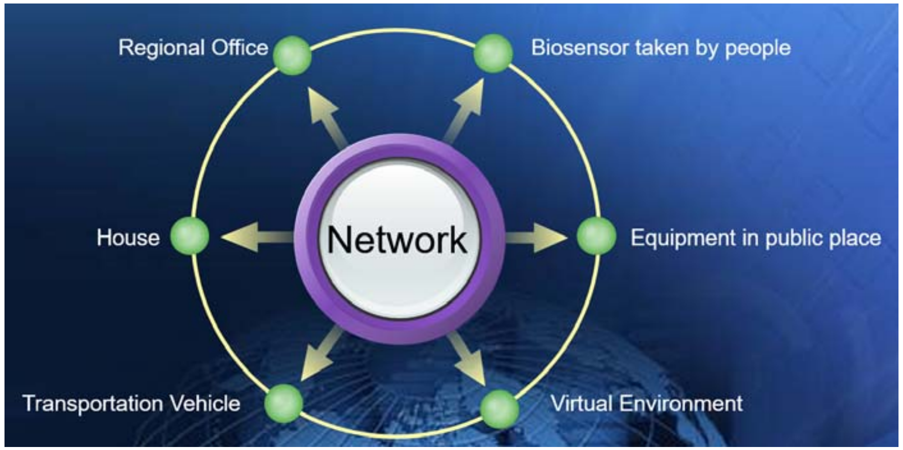
Source: ITU adapted from Nomura Research Institute

IoT Applications

Transport and Logistics

Environmental Monitoring





Source: Pasquale Puzio, “Internet of Things and its applications”

Connected Rail Operations

PASSENGER SECURITY

- In-station and onboard safety
- Visibility into key events

ROUTE OPTIMIZATION

- Enhanced Customer Service
- Increased efficiency
- Collision avoidance
- Fuel savings

CRITICAL SENSING

- Transform “data” to “actionable intelligence”
- Proactive maintenance
- Accident avoidance

Source: Mikhail Kader (Cisco), IoT (Internet of Things) and Security

The Connected Car

WIRELESS ROUTER

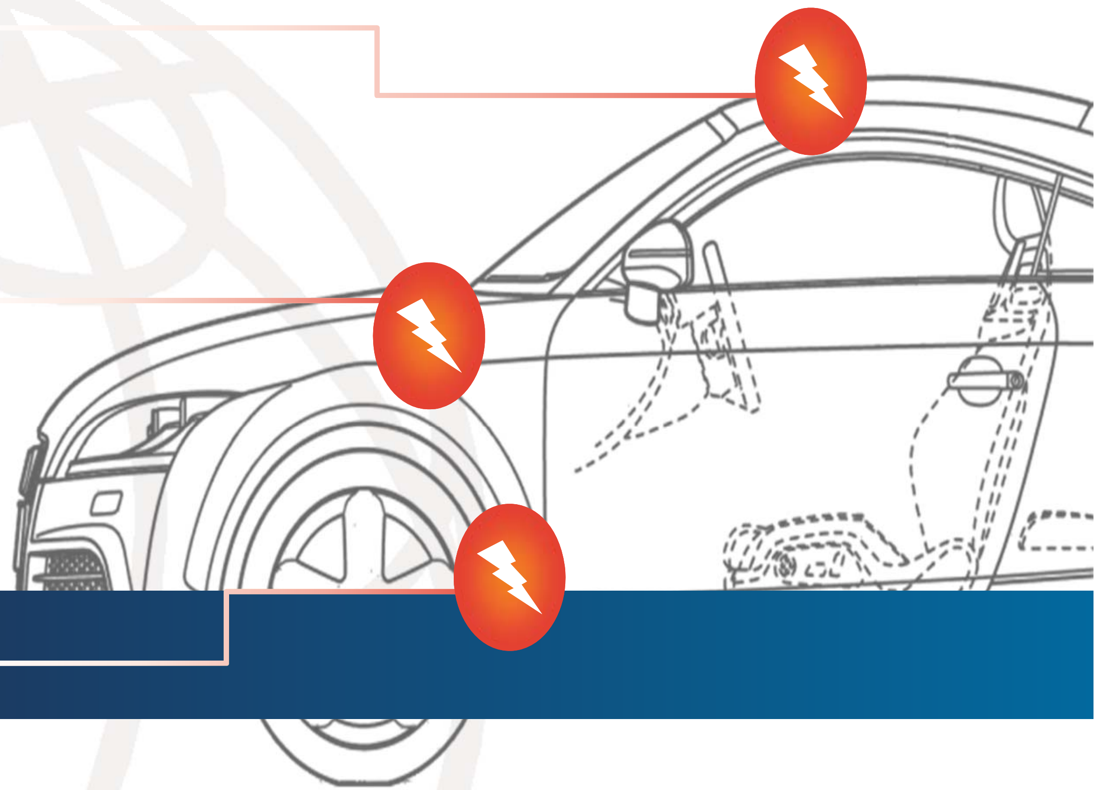
- Online entertainment
- Mapping, dynamic re-routing, safety and security

CONNECTED SENSORS

- Transform “data” to “actionable intelligence”
- Enable proactive maintenance
- Collision avoidance
- Fuel efficiency

URBAN CONNECTIVITY

- Reduced congestion
- Increased efficiency
- Safety (hazard avoidance)



Source: Mikhail Kader (Cisco), IoT (Internet of Things) and Security

Smart City

CONNECTED TRAFFIC SIGNALS

- Reduced congestion
- Improved emergency services response times
- Lower fuel usage

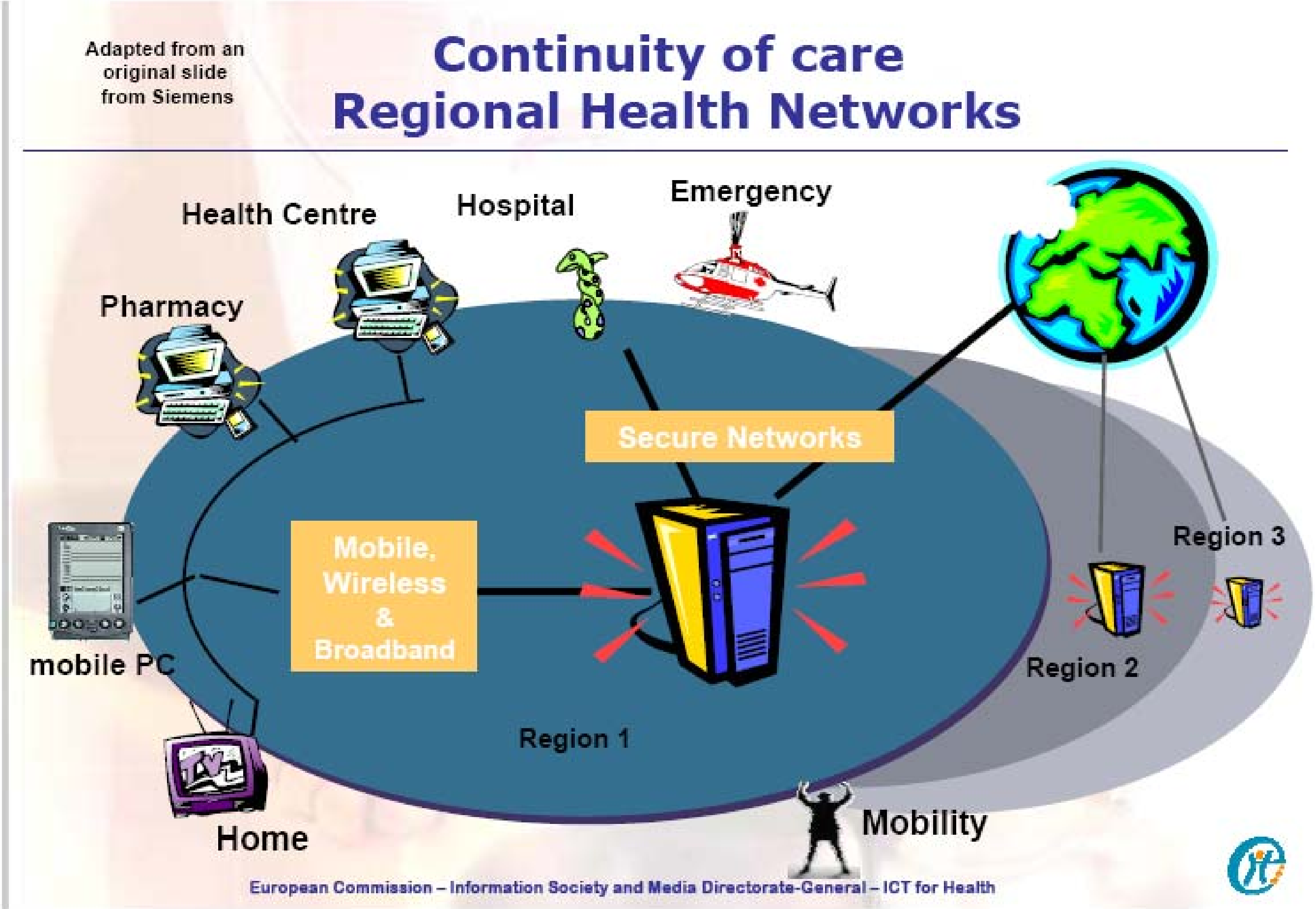
PARKING AND LIGHTING

- Increased efficiency
- Power and cost savings
- New revenue opportunities

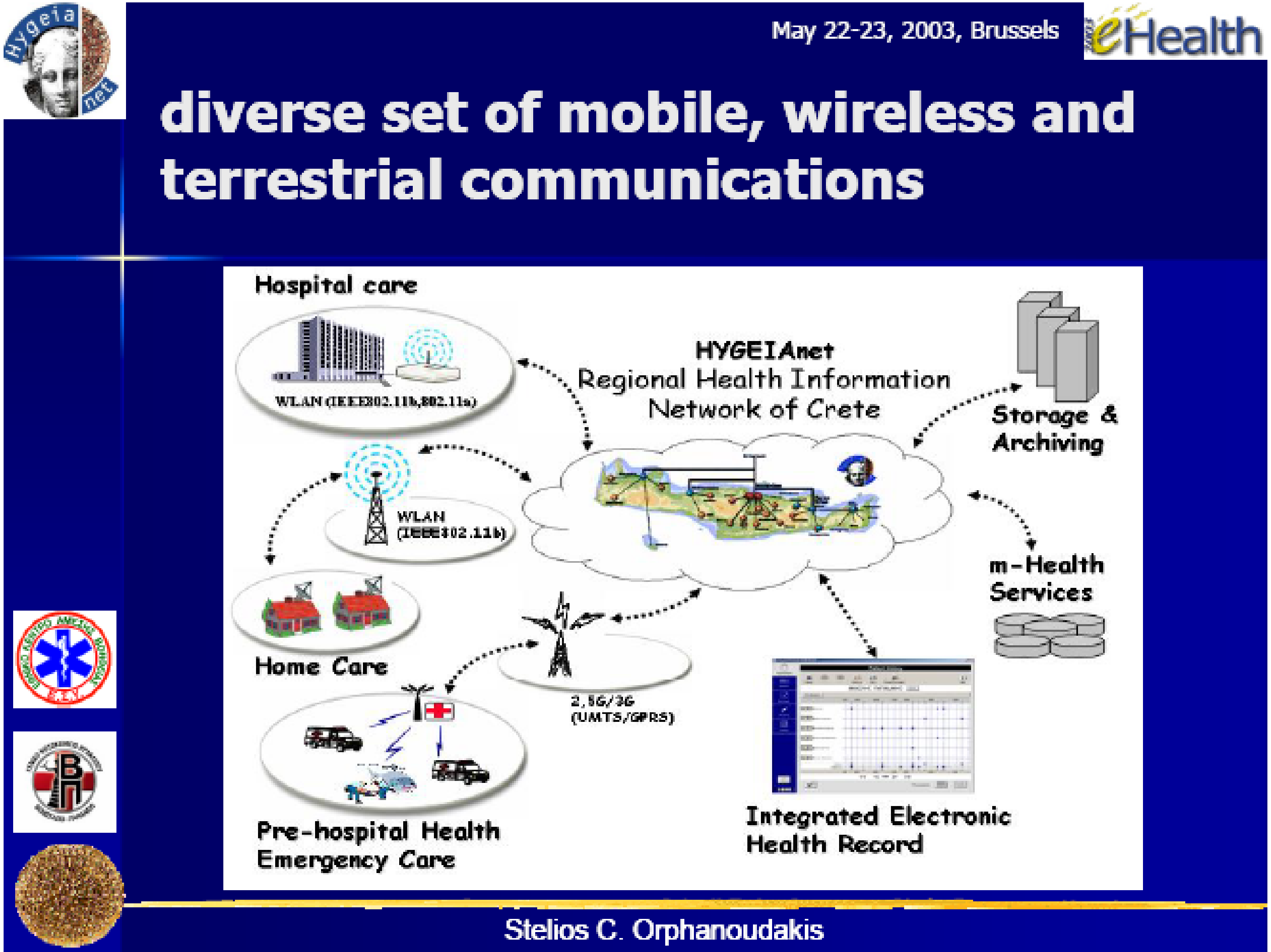
CITY SERVICES

- Efficient service delivery
- Increased revenues
- Enhanced environmental monitoring capabilities

Source: Mikhail Kader (Cisco), IoT (Internet of Things) and Security

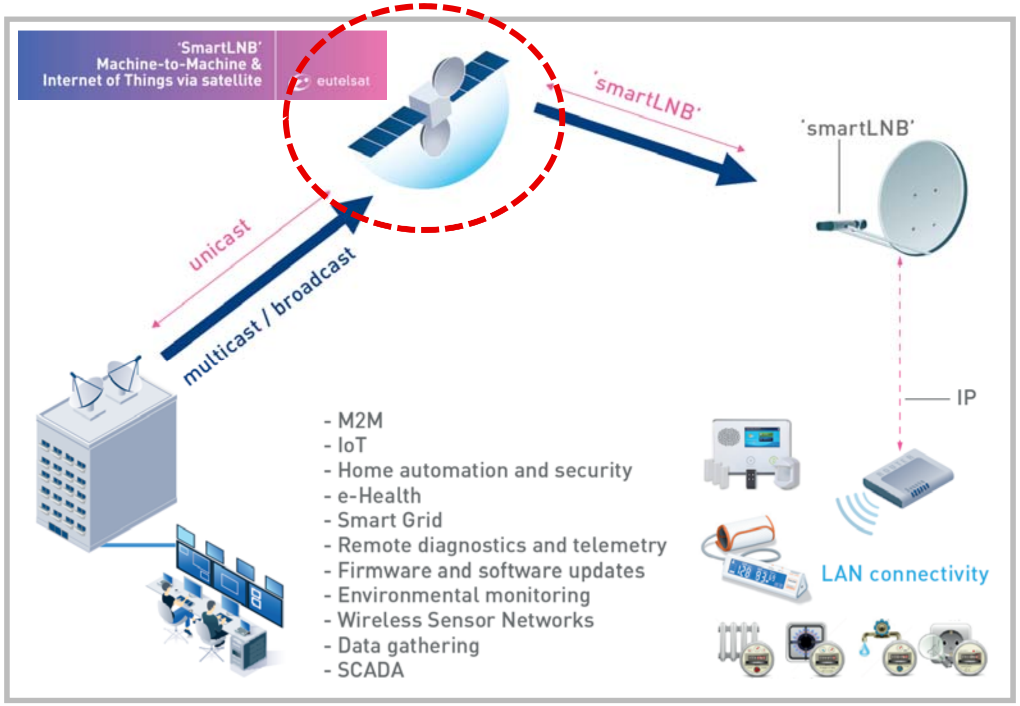

Adapted from an original slide from Siemens
Continuity of care
Regional Health Networks
Health Centre
Hospital
Emergency
Pharmacy
Secure Networks
Mobile, Wireless & Broadband
mobile PC
Region 1
Region 2
Region 3
Home
Mobility
European Commission – Information Society and Media Directorate-General – ICT for Health

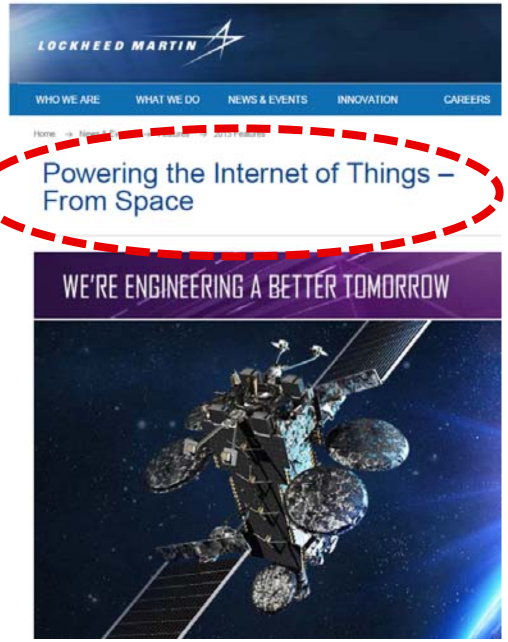
Communication Scenarios for IT-based healthcare



IoT via Satellite

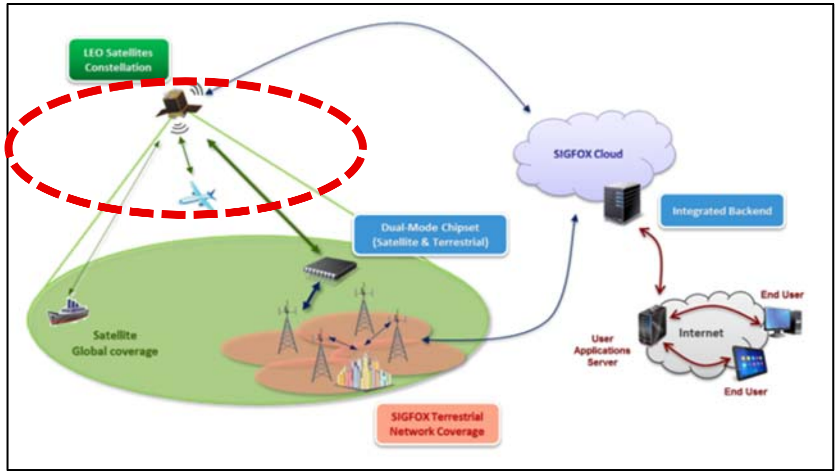
IoT via Satellite: Industry involvement





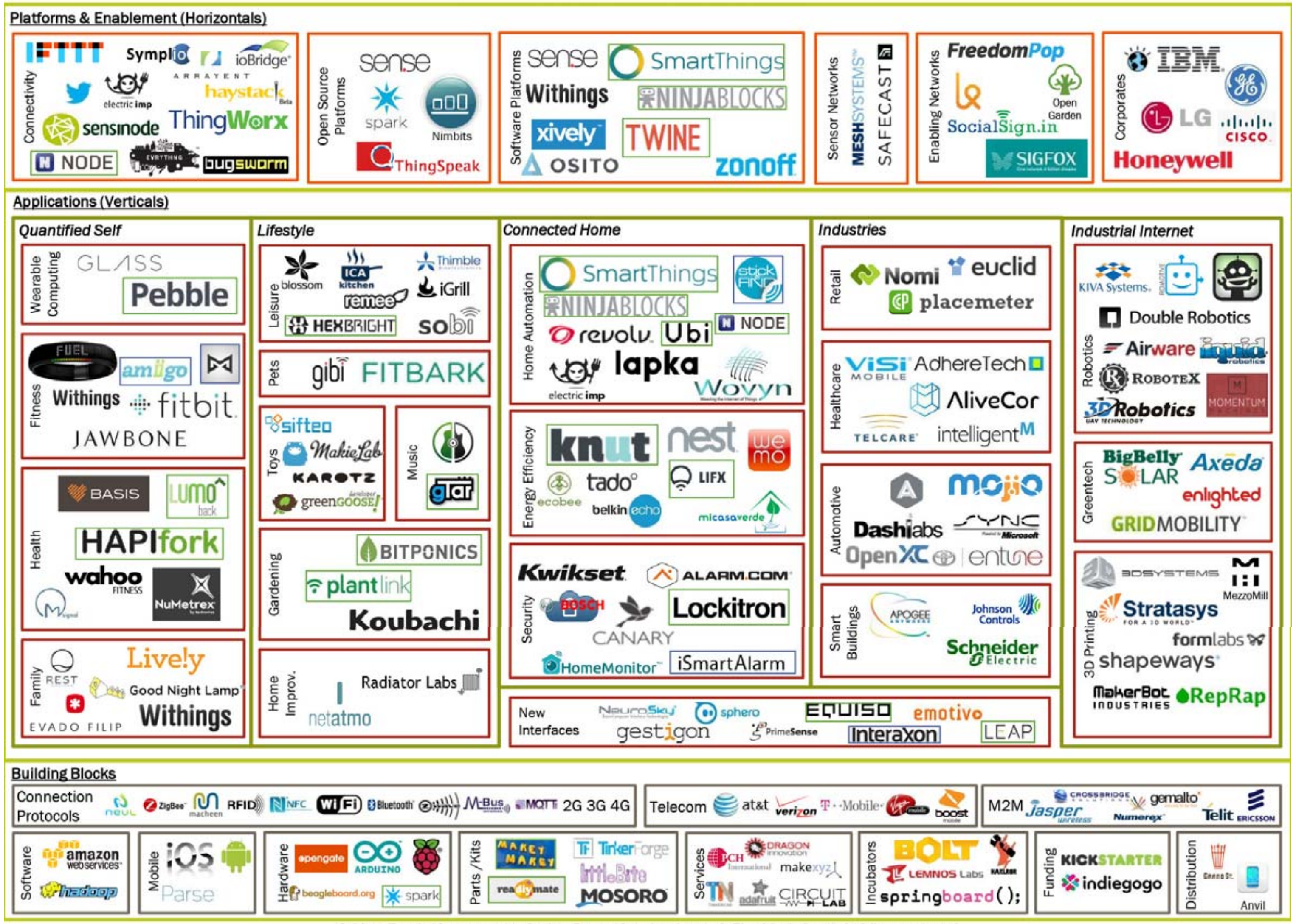
AIRBUS DEFENCE & SPACE

Airbus Defence and Space has started work on the MUSTANG project for machine to machine communications, in partnership with the SMEs SIGFOX and SYSMECA, and the CEA-Leti research centre. The project focuses on low-cost exchange of short messages in the fast-growing machine-to-machine (M2M) market, with the aim to develop an innovative hybrid terrestrial/satellite access solution for the Internet of Things (IoT) for seamless and ubiquitous communications across the



Mohammed Atiquzzaman, University of Oklahoma

IoT Landscape



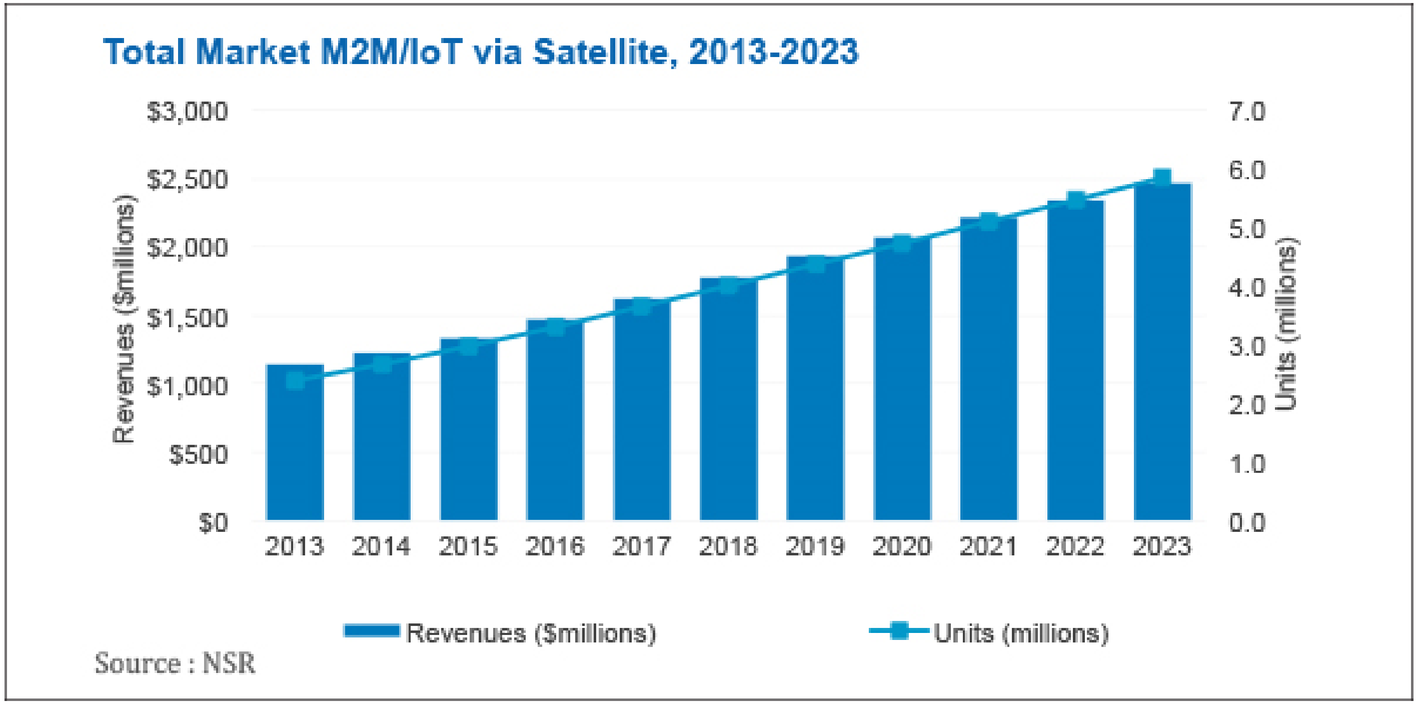
© Matt Turck (@mattturck), Sutian Dong (@sutiandong) & FirstMark Capital (@firstmarkcap)

Source: Sanctis, Cianca, Araniti, Bisio, and Prasad, "Satellite Communications Supporting Internet of Remote Things"

Advantages of Satellites over Terrestrial for IoT

- Ubiquitous coverage and is usually more reliable, especially in remote and underserved regions.
- "Things"/Smart objects are often
  - remote
  - dispersed over a wide geographical area
  - inaccessible
- Satellite-based IoT can offer truly global coverage for many applications
  - Trans-oceanic shipping (Connected Ship), Trains, Transportation (Connected Vehicles) → Network in Motion
  - Battlefield →Mobility
  - Aeronautical → Network in Motion
  - Energy and mining companies
- IoT/M2M via satellite permits the use of a single platform, as compared to a patchwork of terrestrial networks.
  - Example: mission-critical military and transportation

- Cisco expects more than 50 billion connected devices by 2020
- Higher numbers of sensors being implemented and monitored, with each requiring their own IoT connection.



- Terrestrial networks currently dominate, but IoT via satellite will experience strong growth over the next decade.

THURAYA

Can the Internet of Things (IoT) Survive without Satellite?

Satellite technology has a pivotal role in driving the growth momentum behind the Internet of Things (IoT) and unlocking the promise of interconnected devices.

The nascent IoT movement promises to drive the relentless shift towards the interconnected network of devices. According to research firm Gartner, the growth in IoT will far exceed that of other connected devices and will grow to 26 billion units by 2020, representing an almost 30-fold increase from 2009.

Besides the proliferation of connected devices, the continued adoption of machine-to-machine (M2M) technology will spur the development of a wide range of new consumer-centric services, or even facilitate new business models.

Transforming IoT connectivity via satellite

Satellite technology serves as a key enabler for these new services - across industries, across geographical borders - to transform IoT connectivity as we know it today. In highly varied applications that range from consumers, to oil and gas to the transportation sector, satellite operators can deliver strategic advantages over terrestrial deployments in the following aspects:

Connecting remote assets - Business operations that extend to geographically remote environments depend on satellites to provide the critical communication means to conduct remote facility monitoring and real-time asset management at unmanned sites and offshore platforms.

Driving the use of sensor networks - Energy and mining companies are starting to explore more extensive usage of satellite-based sensor networks to support their offshore exploration projects.

Transforming transportation infrastructure - Broadband connectivity on trains, cargo vehicles and maritime vessels is a burgeoning trend across the global transportation landscape, and satellite communications is key to enabling the next generation of mobility services.

Developing sustainable cities - City administrators around the world are harnessing the power of the IoT to drive energy efficiency and smarter resource allocation to help make cities more sustainable. Satellite services can facilitate the deployment of smart grids in remote regions where terrestrial networks fall short and act as a reliable backup network for critical services such as safety and security.

Connected Cars - Many car manufacturers are providing safety features in their vehicles including emergency calling and airbag deployment notifications. Guaranteeing the availability of these services can only be achieved with coverage in remote areas around the world.

Collecting fitness data - Athletes wear small sensors for location tracking purposes and to collect bio-data such as their heart rate, blood pressure and oxygen levels. The data collected can be used to track potential health risks, monitor progress in training, or identify the location of athletes in remote areas.

Facilitating mobile banking and retail - Satellite can serve as the main communications backbone that keeps wireless ATMs and mobile point-of-sales applications running smoothly across a broad geographical span.

Services Enabled by Satellites

Success of satellites for IoT
will depend of support
provide by satellites

Unlocking the future of the IoT

The basic requirements of the IoT are that all devices need to be connected wherever they happen to be.

While Wi-Fi deployments, Bluetooth and terrestrial GSM networks are able to support most applications, these network services simply cannot provide the ubiquitous and seamless coverage of satellites. The ultimate success of the IoT will depend on the active support of satellite networks, such as the L-band services provided by Thuraya, to address the following requirements:

- **Coverage** - A new breed of IoT applications will emerge from the connectivity of intelligent devices. Expected to encompass billions of devices around the world, the potential scale of the IoT demands ubiquitous network coverage even in remote locations, which are best served by satellite networks.
- **Reliability** - Maintaining a high level of service reliability is a key requirement for effective IoT deployments. The low latency of L-band services holds a distinct advantage in catering to applications such as remote asset monitoring that requires reliable, always-on connectivity.
- **Speed** - The future landscape of the IoT involves the exchange of data between interconnected objects to facilitate quicker decision making and enhance business processes. These developments have, in turn, driven up the demand for high data speeds to support bandwidth-intensive applications in real time.
- **Cost** - Satellite technology has the potential to be a versatile and cost-effective solution to address IoT connectivity needs. The costs associated with mobile satellite services, for instance, are highly competitive with terrestrial networks, and is considered a more affordable option relative to other satellite platforms.
- **Integration** - The IoT is expected to continue driving up market demand for the integration of satellite into the overall communications mix.

IoT and Mobility

The Internet of Things

- Represents the first true evolution of the Internet
- Why?
  - More mobile than fixed
  - New architecture models
  - New protocol (IPv6)
  - Sensor-laden
  - More machines than people

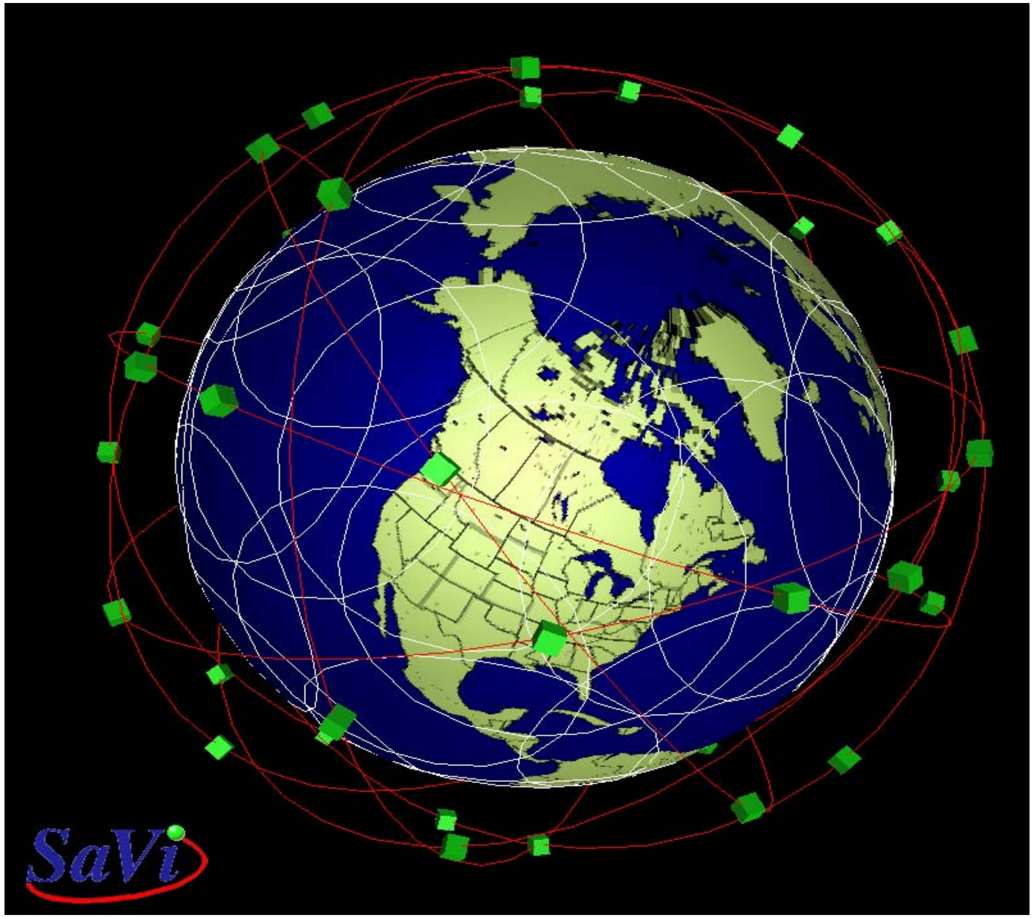
 Cisco Public Internet Business Solutions Group 5

- Spacecrafts can have IP-addressable devices ('things')
  - Sensor
  - Radars
  - Telescopes
  - Weather observation equipment
  - Forest fire detection
- The space 'things' need to be connected to the Internet.
- These space 'things' are
  - Mobile
  - Connected together in a LAN on a spacecraft
- Connecting mobile space 'things' to the Internet requires mobility management.


0.000

- Link Layer Handoff
  - Inter-satellite handoff
  - Link handoff
  - Spotbeam handoff

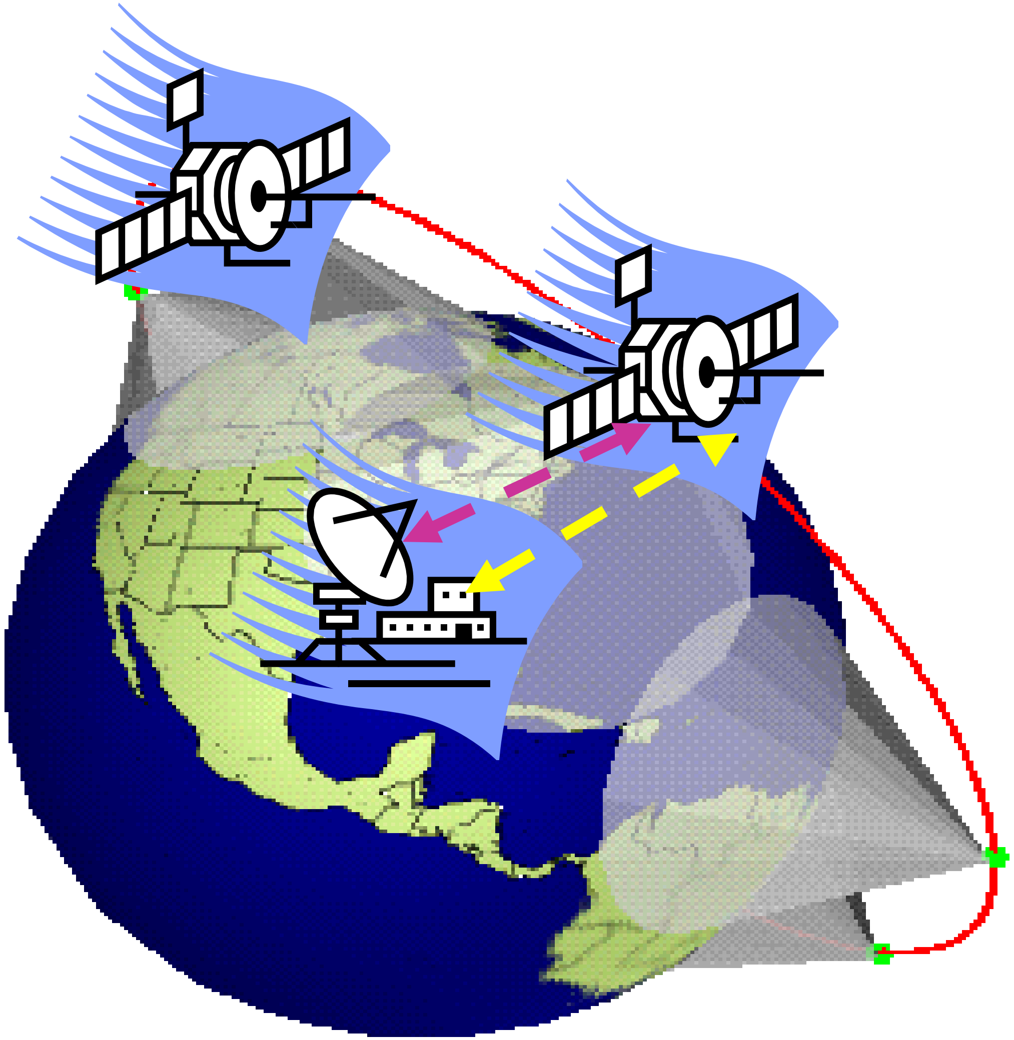
- Network Layer Handoff
  - Satellite as a router
  - Satellite as a mobile host



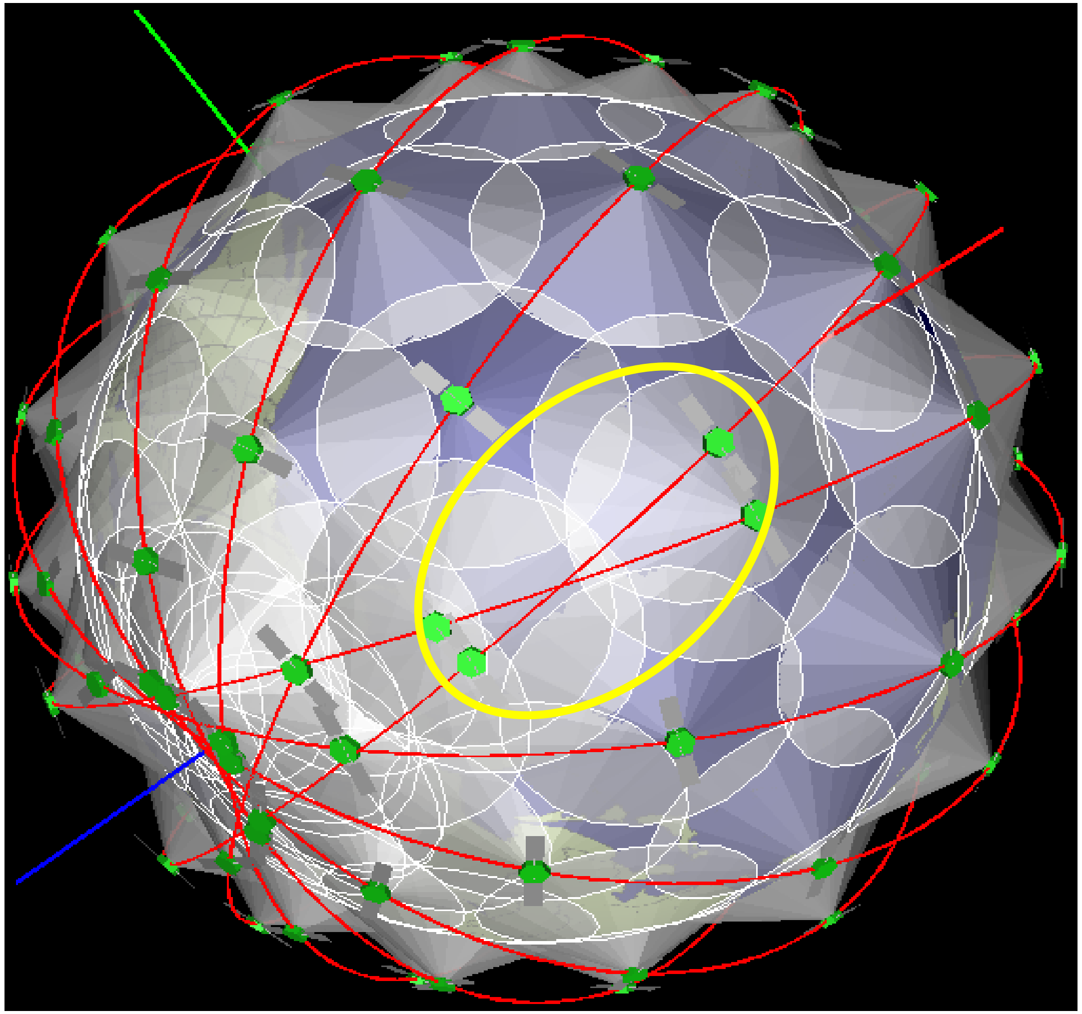
A Globalstar design, with 48 active satellites in 8 planes of 6.

- The movement of satellite causes a Ground Station being handed off from one satellite to another.

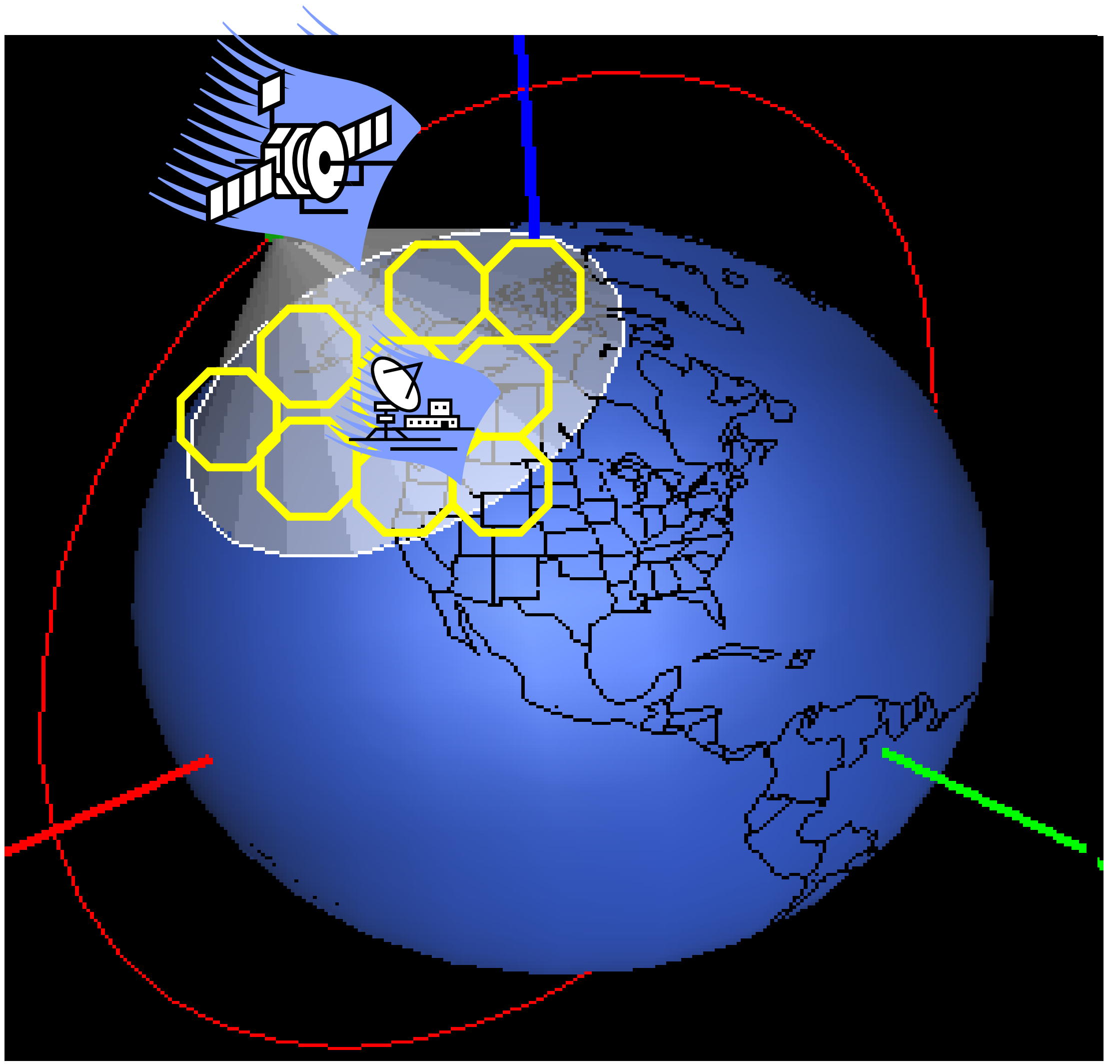
- Similar to inter-switch handoff in the case of terrestrial mobile network.



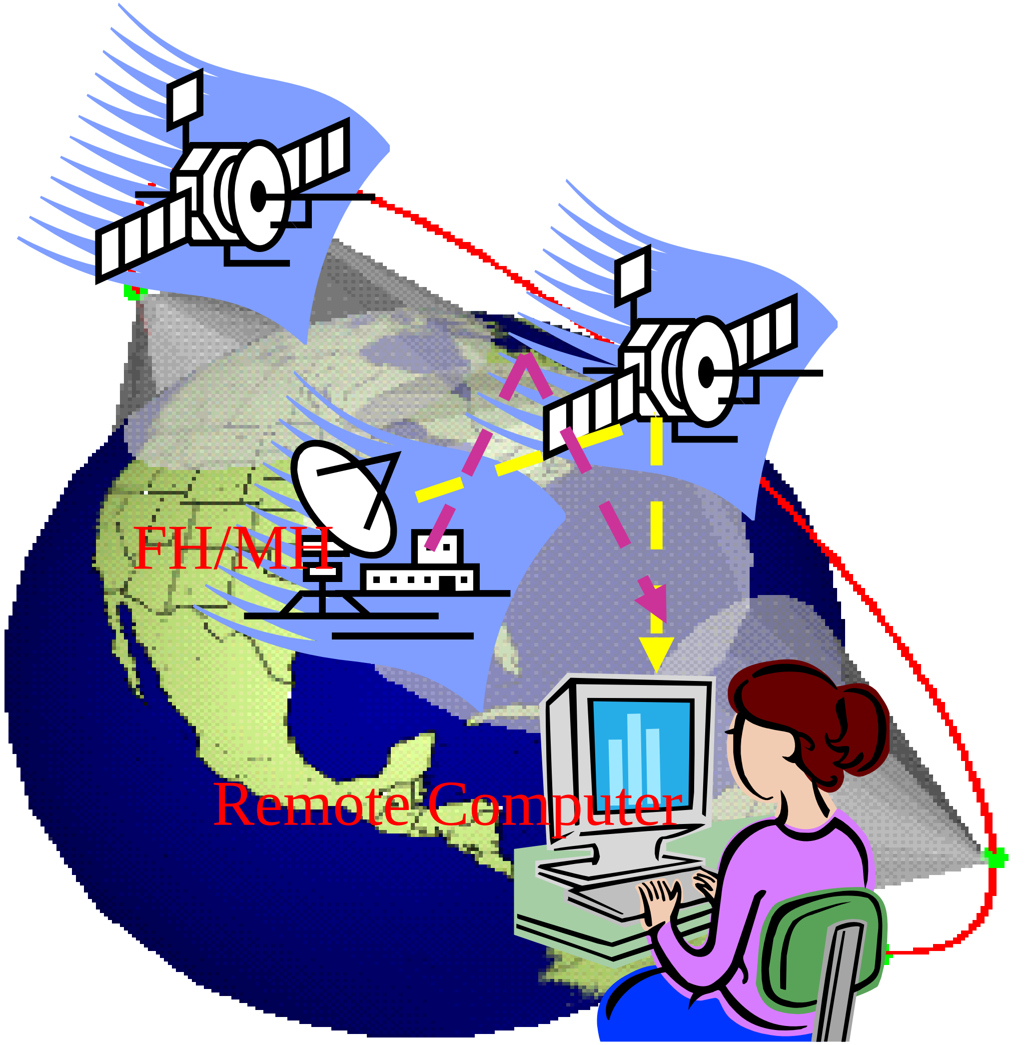
- Iridium design
  - 96 active satellites
  - 8 planes of 12.
- Satellite movement requires rerouting the on-going application to new Inter-satellite Links (ISL).



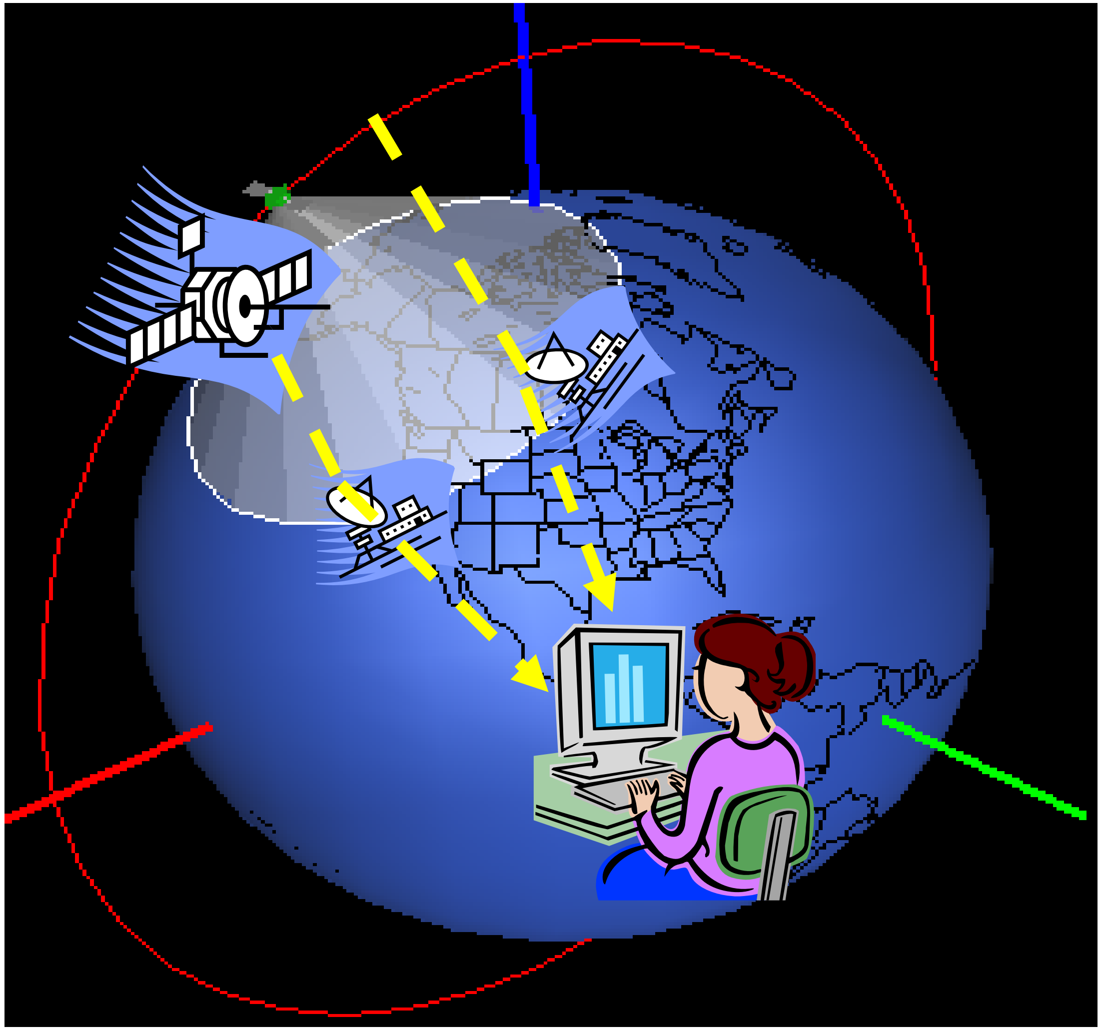
- Spotbeam handover occurs when the existing application is transferred to neighboring spotbeam.
- Similar to intra-switch handoff in the case of terrestrial mobile network.



- Satellites act as IP routing devices.
  - No on-board device generating or consuming data
- Satellites are allocated with different IP prefix.
- FH/MH need to maintain continuous connection with Remote Computer.



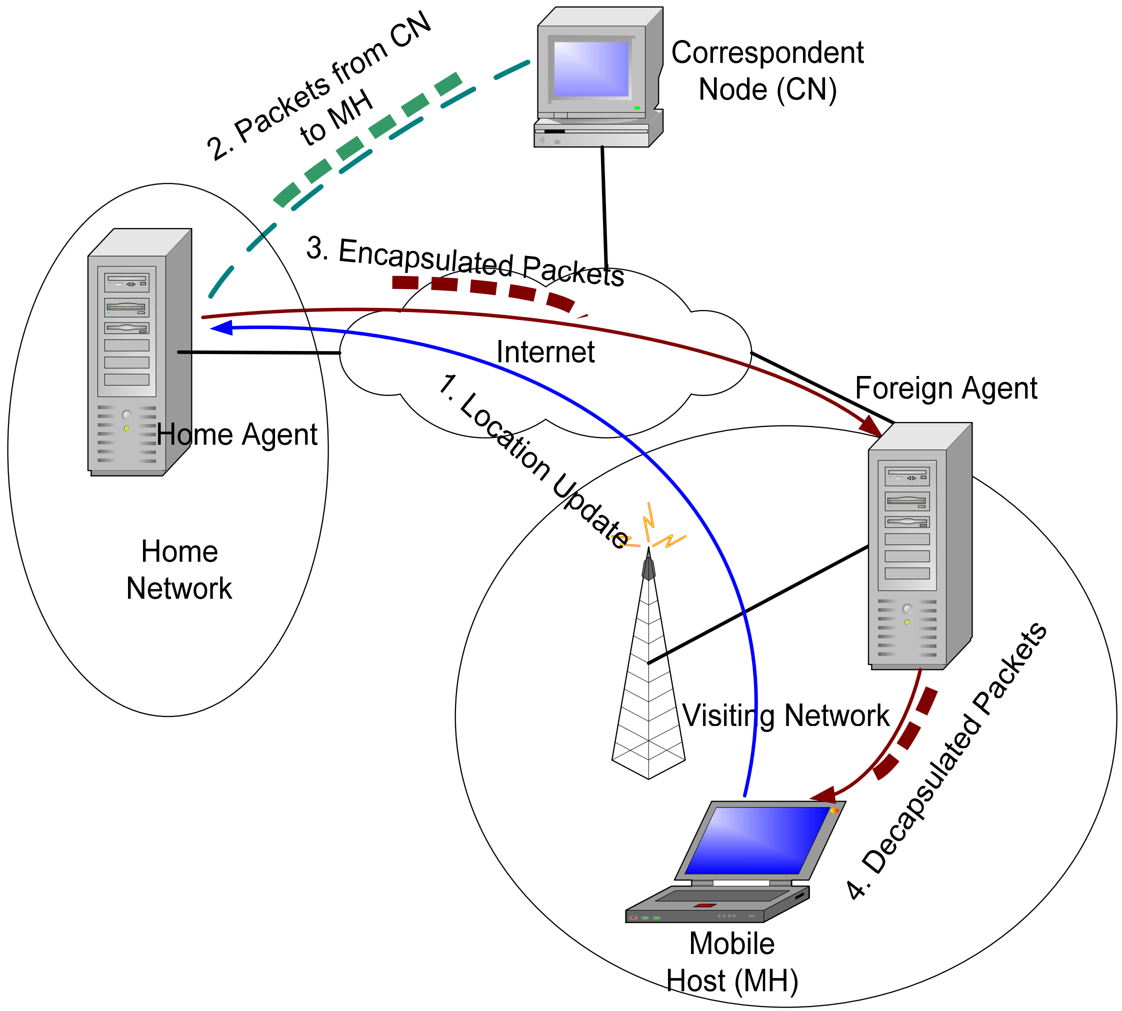
- Satellite onboard equipments act as the endpoint of the communication.
- Ground stations are allocated with different IP prefix.
- Satellite need to maintain continuous connection with remote computer.



Mobility Management

Mobile IP: Enabling IP host mobility

- When Mobile Host moves to a new domain, a location update is sent to Home Agent.
- Packets from CN to Mobile Host are encapsulated and forwarded to MH's current care-of address.
- Packets are decapsulated and delivered to upper layer protocol.



Main Drawbacks of base Mobile IP

- Need modification to Internet infrastructure.
- High handoff latency and packet loss rate.
- Inefficient routing path.
- Conflict with network security solutions such as Ingress Filtering and Firewalls.
- Home Agent must reside in MH's home network, making it hard to duplicate HA to various locations to increase survivability and manageability.

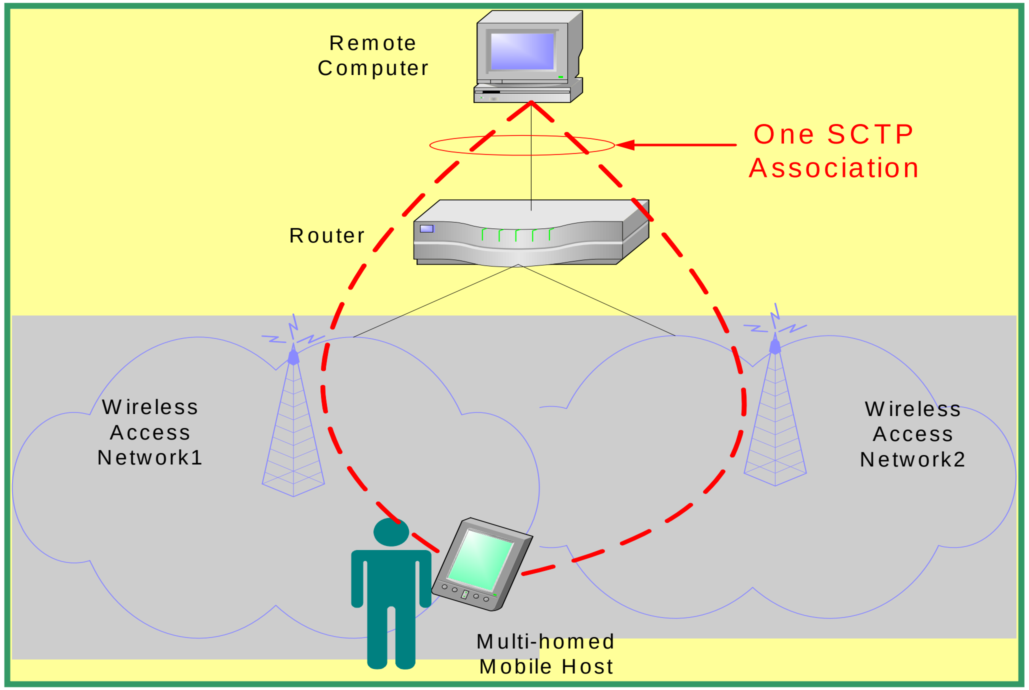
SIGMA: Seamless IP-diversity based Generalized Mobility Architecture

- Several NASA projects considering IP in space and Mobile IP
  - Global Precipitations Measurement (GPM)
  - Operating Missions as Nodes on the Internet (OMNI)
  - Communication and Navigation Demonstration on Shuttle (CANDOS)
  - NASA currently working with Cisco on developing a Mobile router
- Mobile IP may play a major role in various space related NASA projects
  - Advanced Aeronautics Transportation Technology (AATT)
  - Weather Information Communication (WINCOMM)
  - Small Aircraft Transportation Systems (SATS)
- Develop an efficient, secure and seamless handoff scheme which would be applicable to both the satellite and wireless/cellular environment.

- No need for install new hardware or software component in Internet infrastructure.
- Low handoff latency and packet loss rate.
- Efficient data path
  - Avoid triangular routing.
- Cooperate with existing network security mechanisms.
- Increased survivability, scalability and manageability.
- Suitable for satellite IP handoffs.

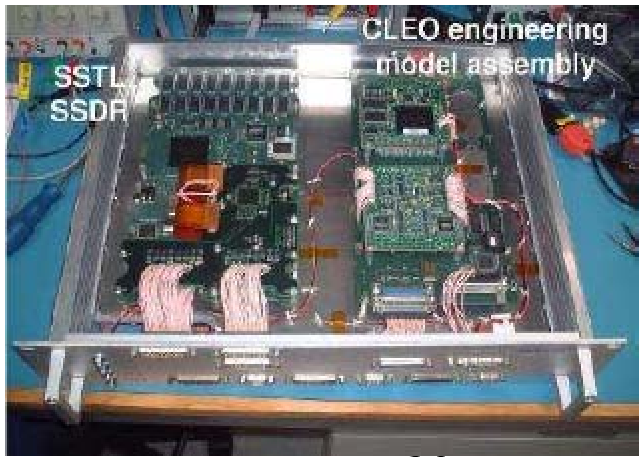
- Decouple location management from handoff
- Carry out location management and handoff in parallel to data transmission
- Allow the layer whose performance is to be optimized to take responsibility of the handoff
- Implementation:
  - Multihoming to achieve simultaneous communication with multiple access points.
  - Stream Control Transmission Protocol (RFC 2960).

- Mobile IP assumes the upper layer protocol use only one IP address to identify an logical connection. Some buffering or re-routing should be done at the router for seamless handover.
- SCTP support multiple IP addresses at transport layer naturally via multi-homing feature. When mobile host moving between cells, it can setup a new path to communicate with the remote computer while still maintaining the old path.



Advantages of SIGMA:

- Reduced packet loss and handover latency
- Increased throughput
- No special requirement on Router and Access networks.



What is SCTP?

- SCTP: "Stream Control Transmission Protocol"
- Originally designed to support SS7 signaling messages over IP networks. Currently supports most of the features of TCP
- Standardized by IETF RFC 2960
- Reliable transport protocol on top of IP

TCP and SCTP compared

- Both of them are reliable transport protocols;
- Similar Congestion Control algorithms (slow start, congestion avoidance);
- SCTP has two new features:
  - Multihoming
  - Multistreaming

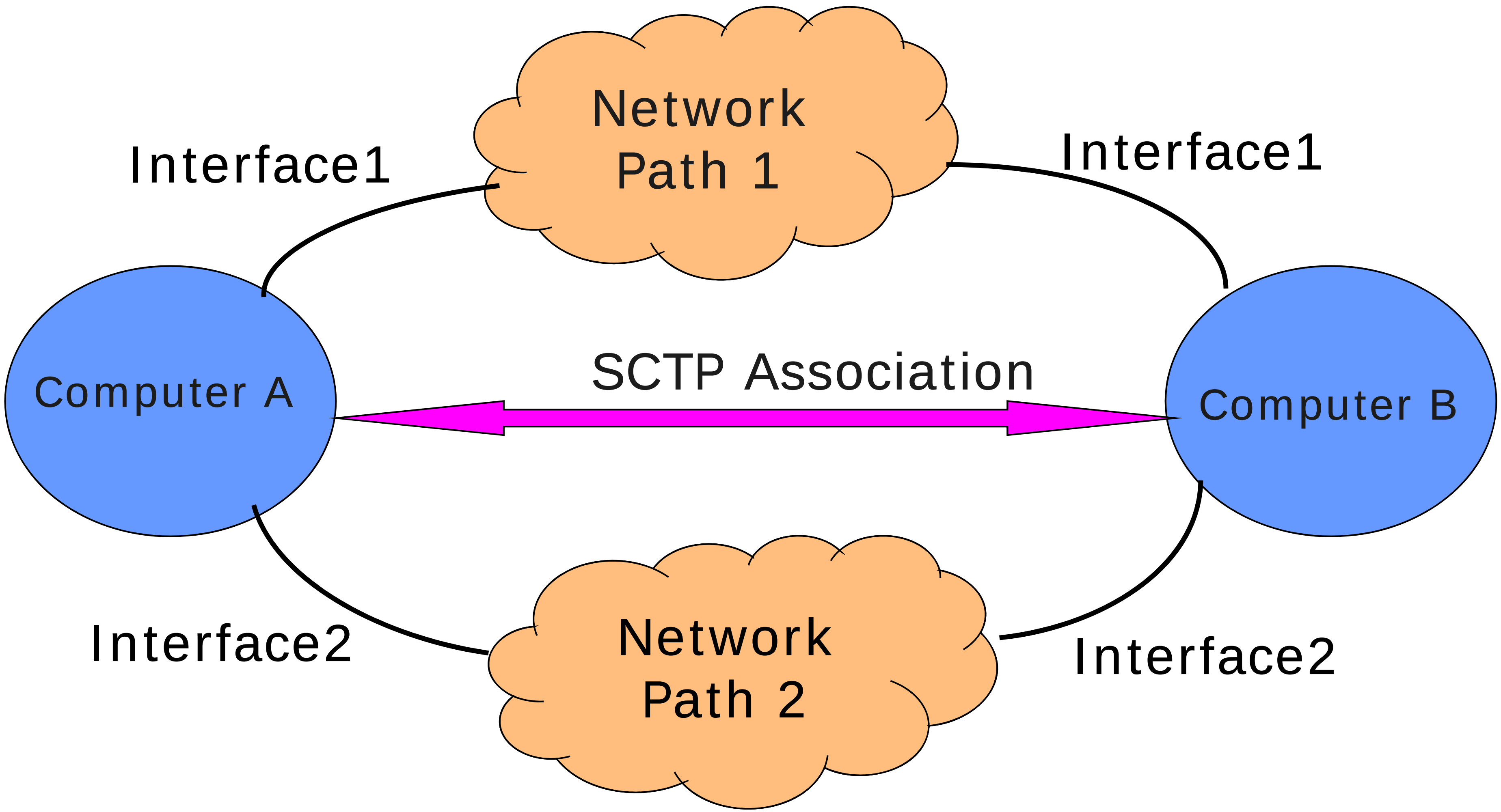
Upper layer applications

TCP, UDP, **SCTP**

IP

Link Layer

Physical Layer


Network
Path 1
Interface1
Interface1
SCTP Association
Computer A
Computer B
Interface2
Network
Path 2
Interface2

Signaling

1.Satellite obtains a new IP address in new domain.

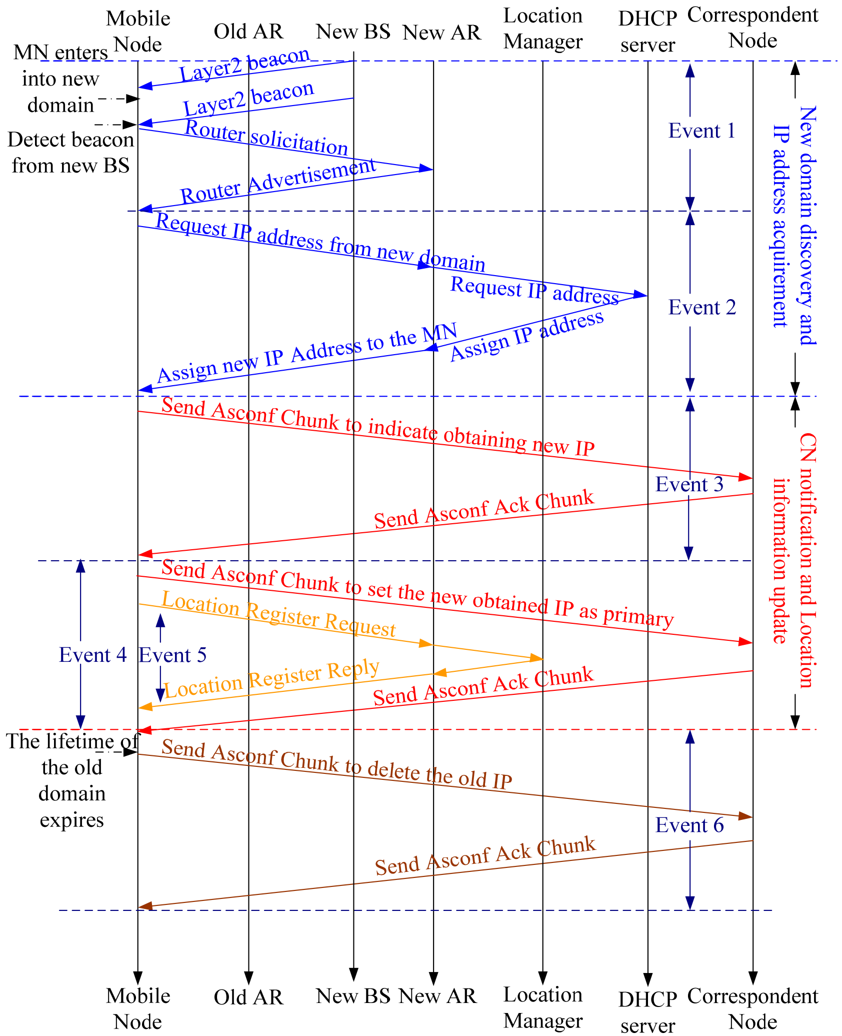
2. Satellite notify remote computer about the new IP address.

3. Satellite let remote computer set primary address to new IP address.

4.Update Location Manager.

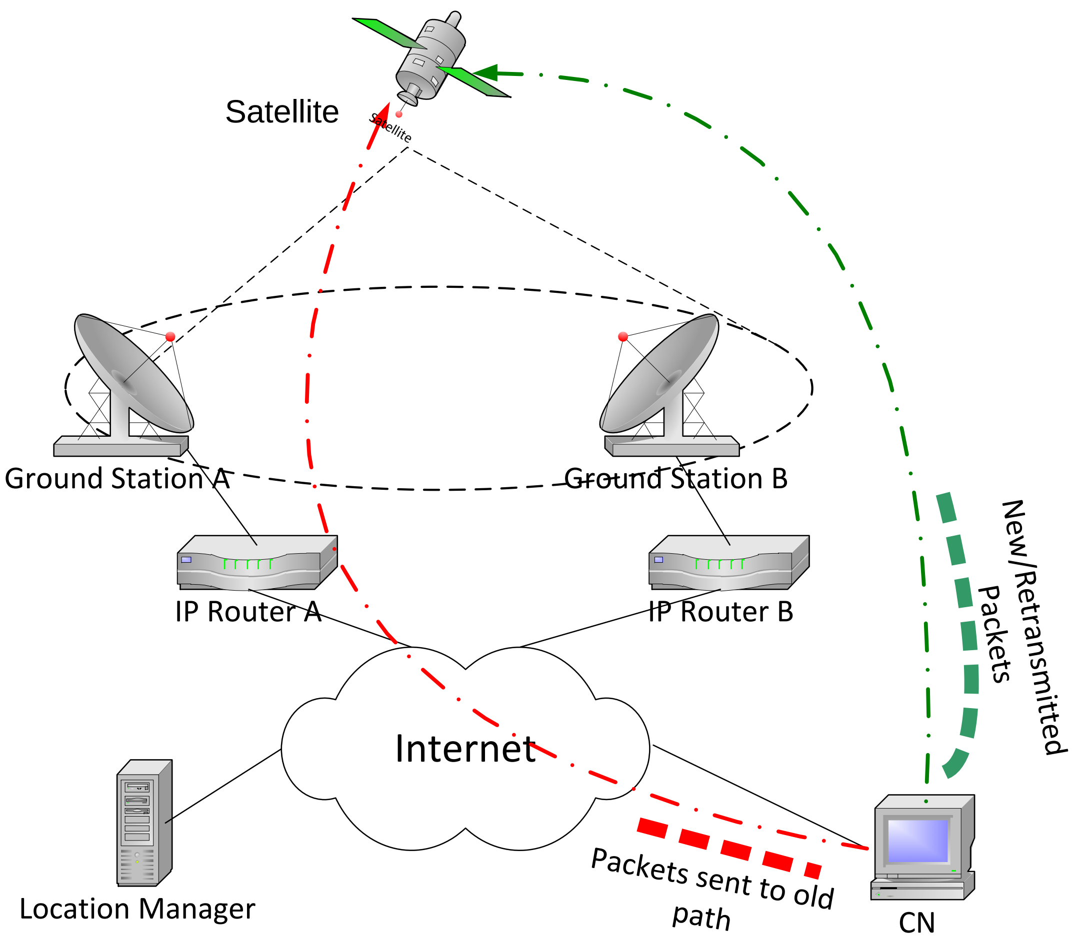
5. Delete or deactivate old IP address.

SIGMA: Timing Diagram



Timeline for SCTP based handover in concept

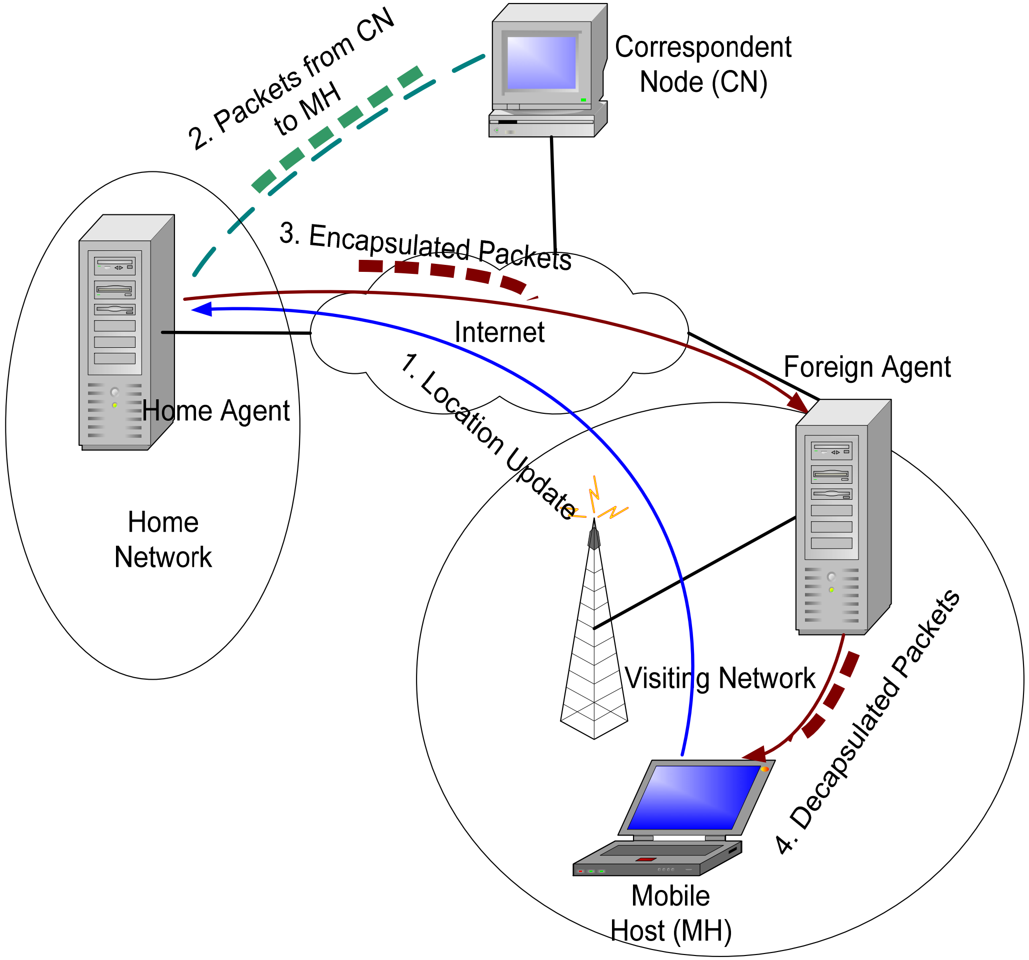
SIGMA: Data Transfer Path



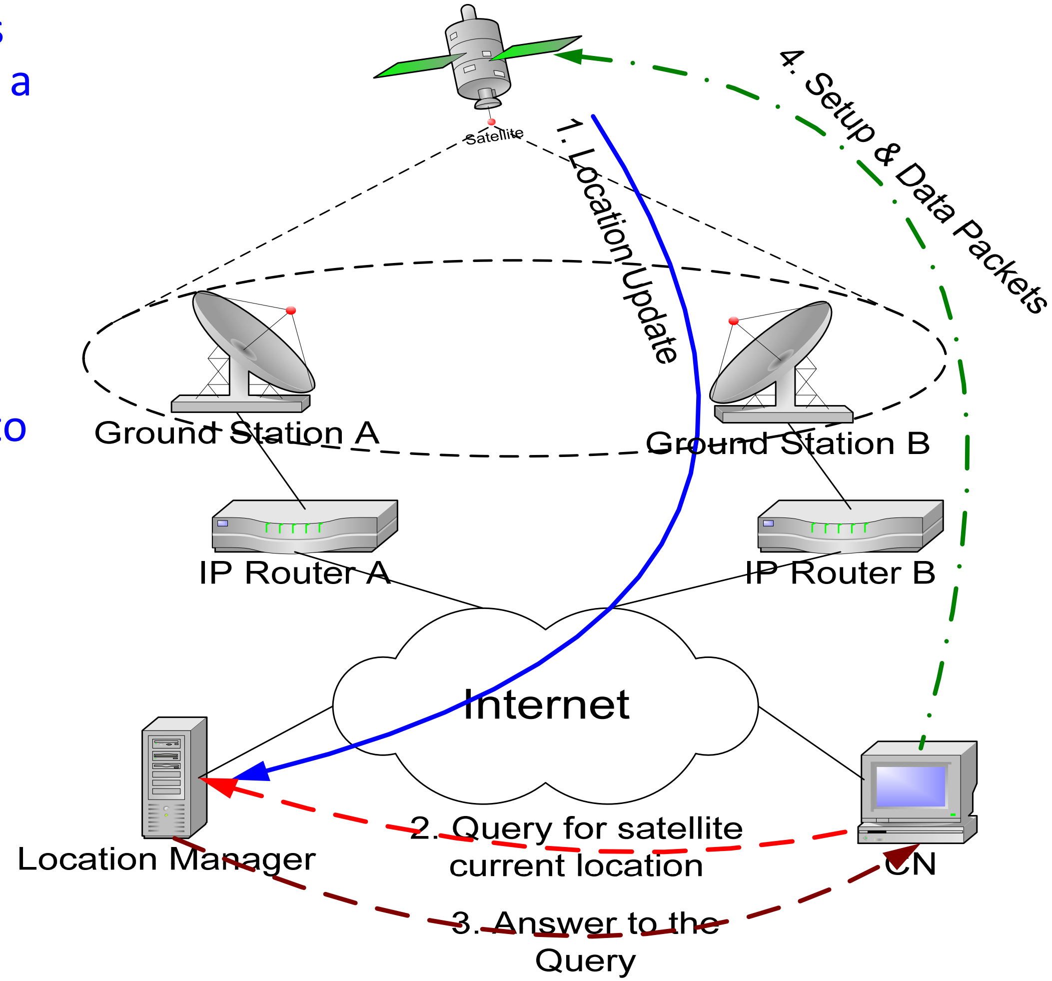
Survivability and Location Management

Mobile IP: Survivability due to location management

- In Mobile IP, Home Agent must reside in MH's home network to intercept packets sent from CN to MH.
- In situations where the home network is vulnerable to failure, this becomes a serious problem.
- It is difficult to replicate the Home Agent at various locations distributed throughout the network in order to achieve survivability.



- Only location update/query needs to be directed to Location Manager (LM). Thus LM need not to be located in a specific network to intercept data packets.
- It is easy to replicate the Location Manager at distributed secure locations to improve survivability.
- LM can further be integrated with DNS server to reduce system complexity.



More Benefits of Centralized Location Management

- Security: Storing user location information into a central secure databases is much more secure than scattering it in various Home Agents located at different sub-networks (in the case of Mobile IP).

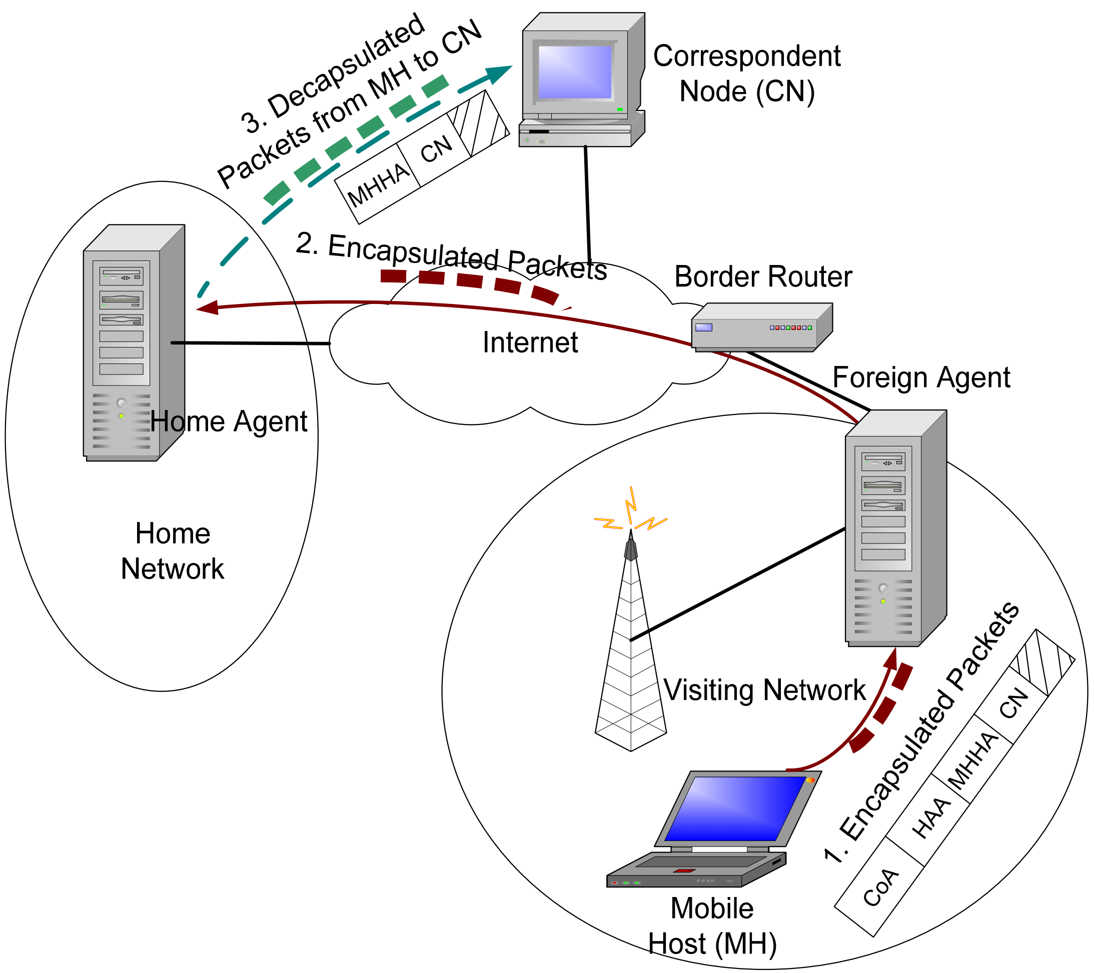
- Scalability: Location servers do not intervene into data forwarding task, which adapts to the growth in the number of mobile users gracefully.

- Manageability: Centralized location management provides a way for an organization/service provider to control user accesses from a single server.

Security

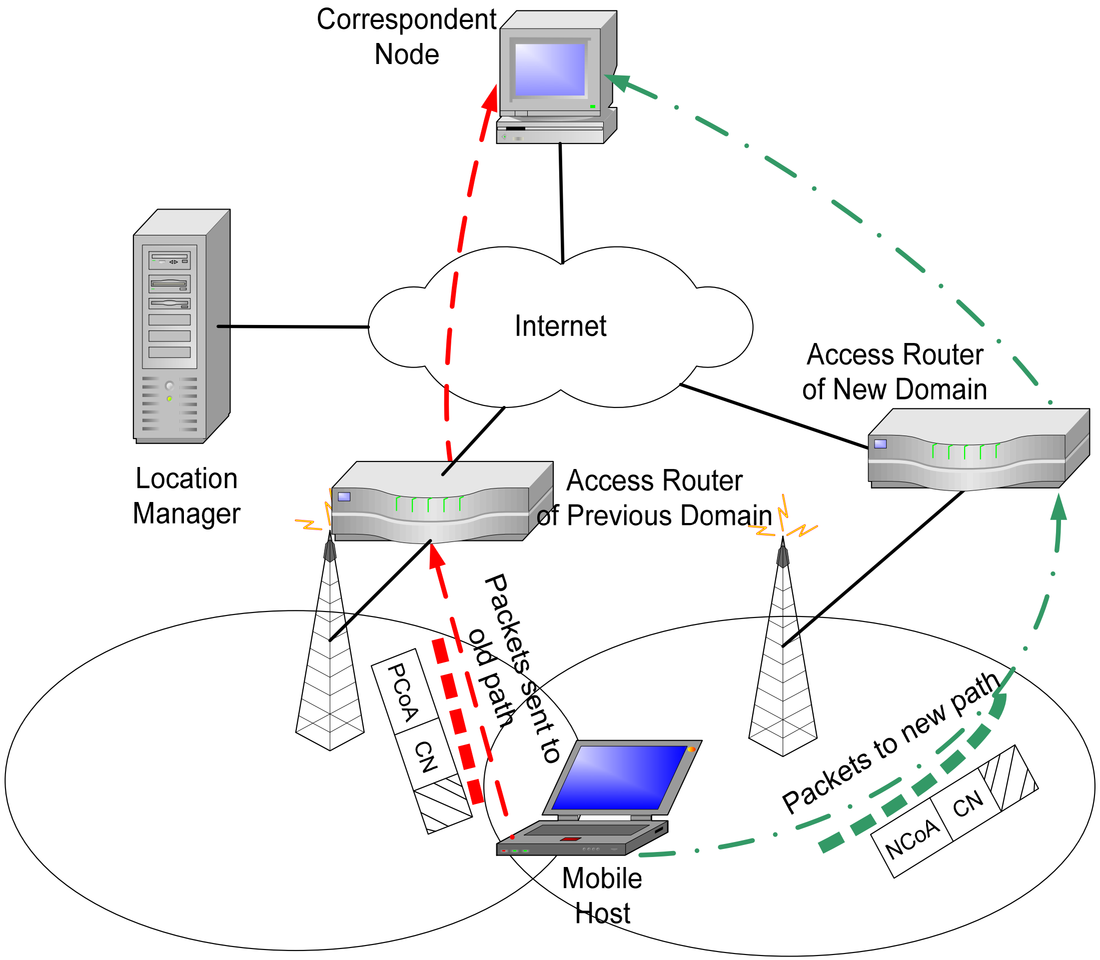
Mobile IP: Interoperability with Ingress Filtering

- Ingress filtering is heavily used in current Internet to prevent IP spoofing and DoS attack.
- Ingress filtering border routers enforce topologically correct source IP address.
- Topological correctness requires MH using COA as the source IP address.
- Applications built over TCP/UDP requires MH always using its home address as source address.
- **Solution: reverse tunneling**

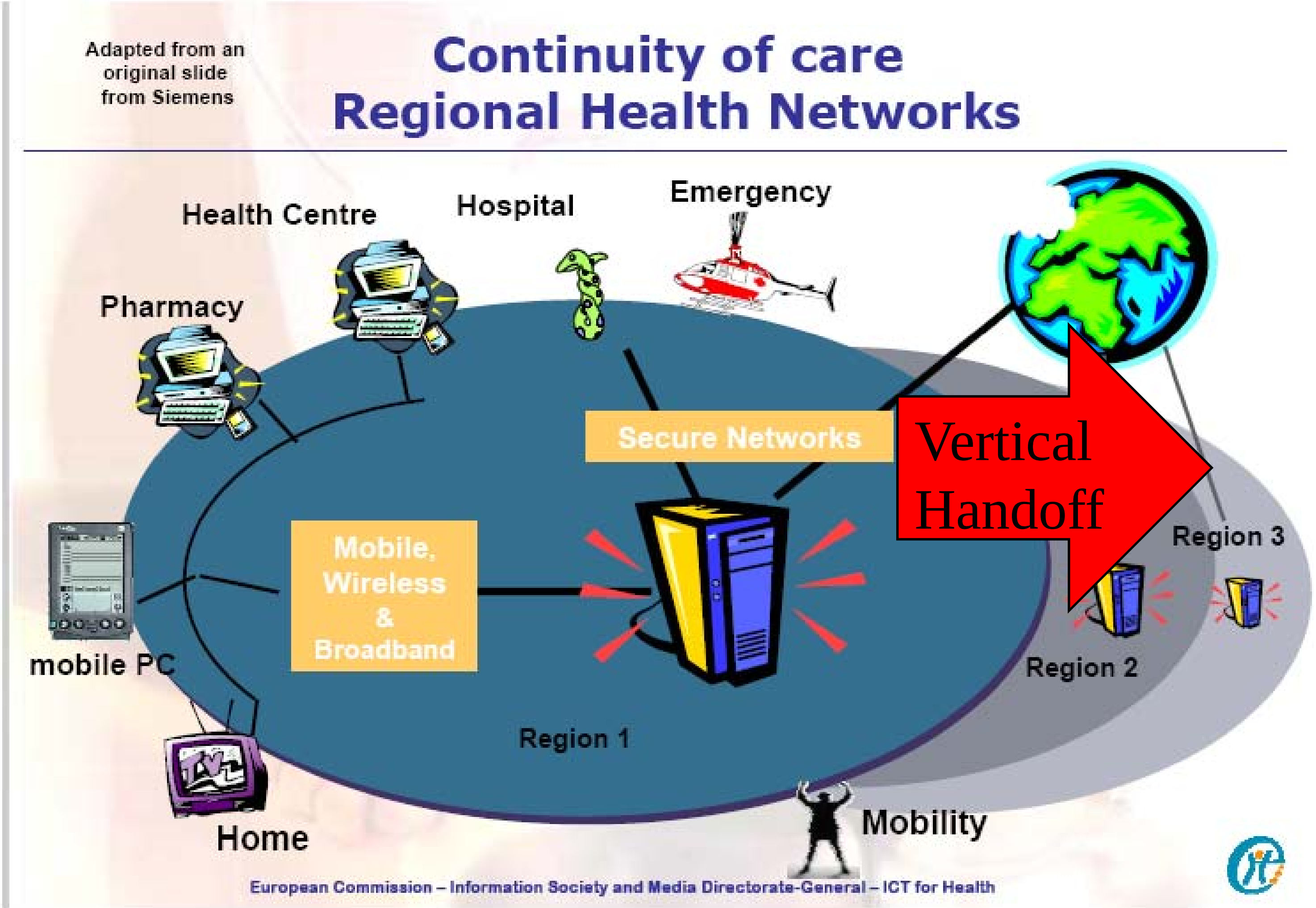


SIGMA: Interoperability with Ingress Filtering

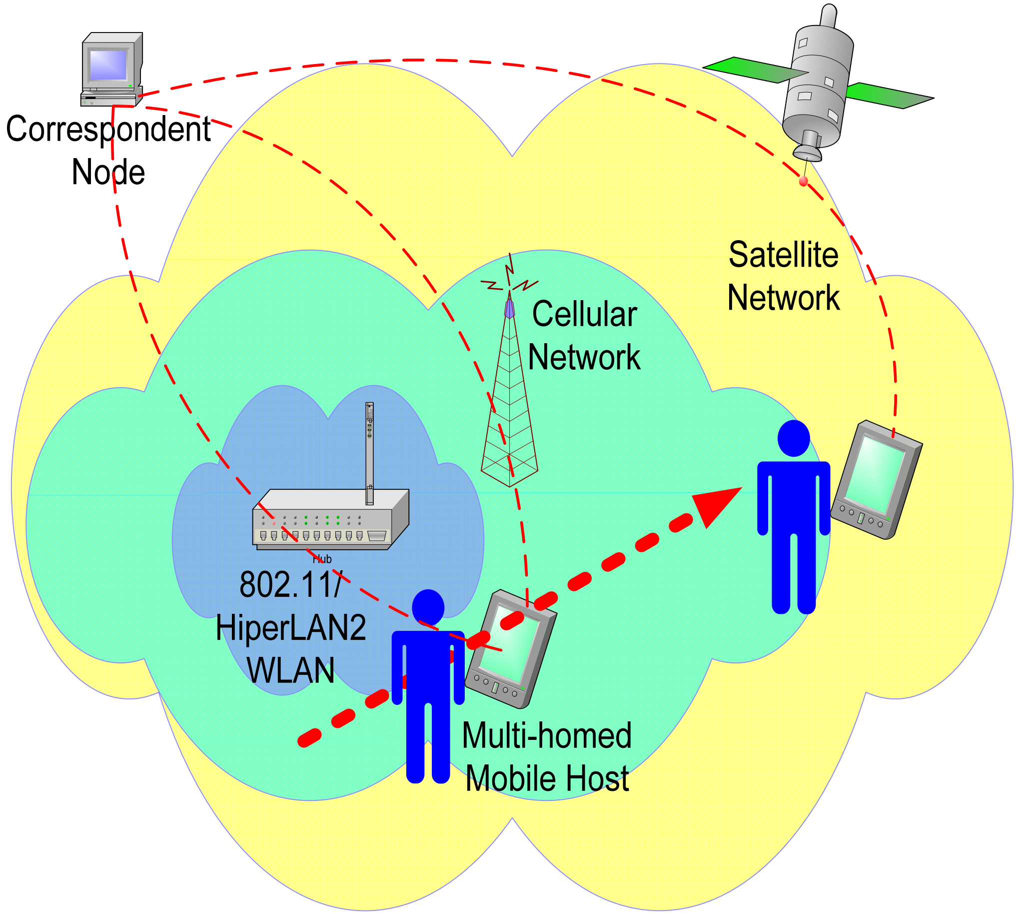
- In SIGMA, MH uses new CoA address directly to communicate with CN, it is already topologically correct.
- SIGMA can incorporate well with ingress filtering, no need for tunneling.



Vertical Handoff


Adapted from an original slide from Siemens
Continuity of care
Regional Health Networks
Health Centre
Hospital
Emergency
Pharmacy
Secure Networks
Vertical Handoff
Mobile, Wireless & Broadband
mobile PC
Region 1
Region 2
Region 3
Home
Mobility
European Commission – Information Society and Media Directorate-General – ICT for Health

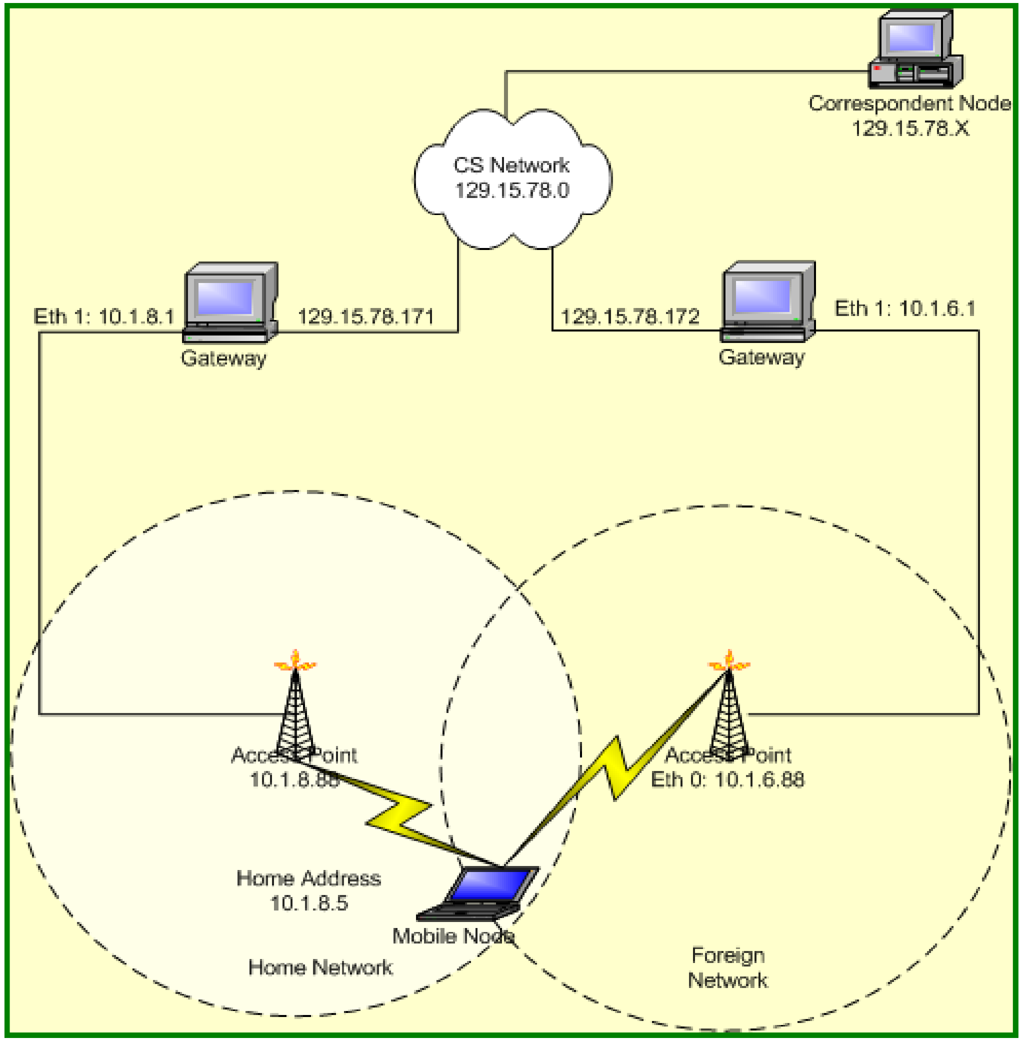
- Different access network technologies are integrating with each other to give mobile user a transparent view of Internet.
- Handover is no longer only limited to between two subnets in WLAN or between two cells in cellular network (horizontal handover).
- Mobile users are expecting seamless handover between different access networks (vertical handover).
- The mobility based on SCTP multi-homing is a feasible approach to meet the requirement of vertical handover.



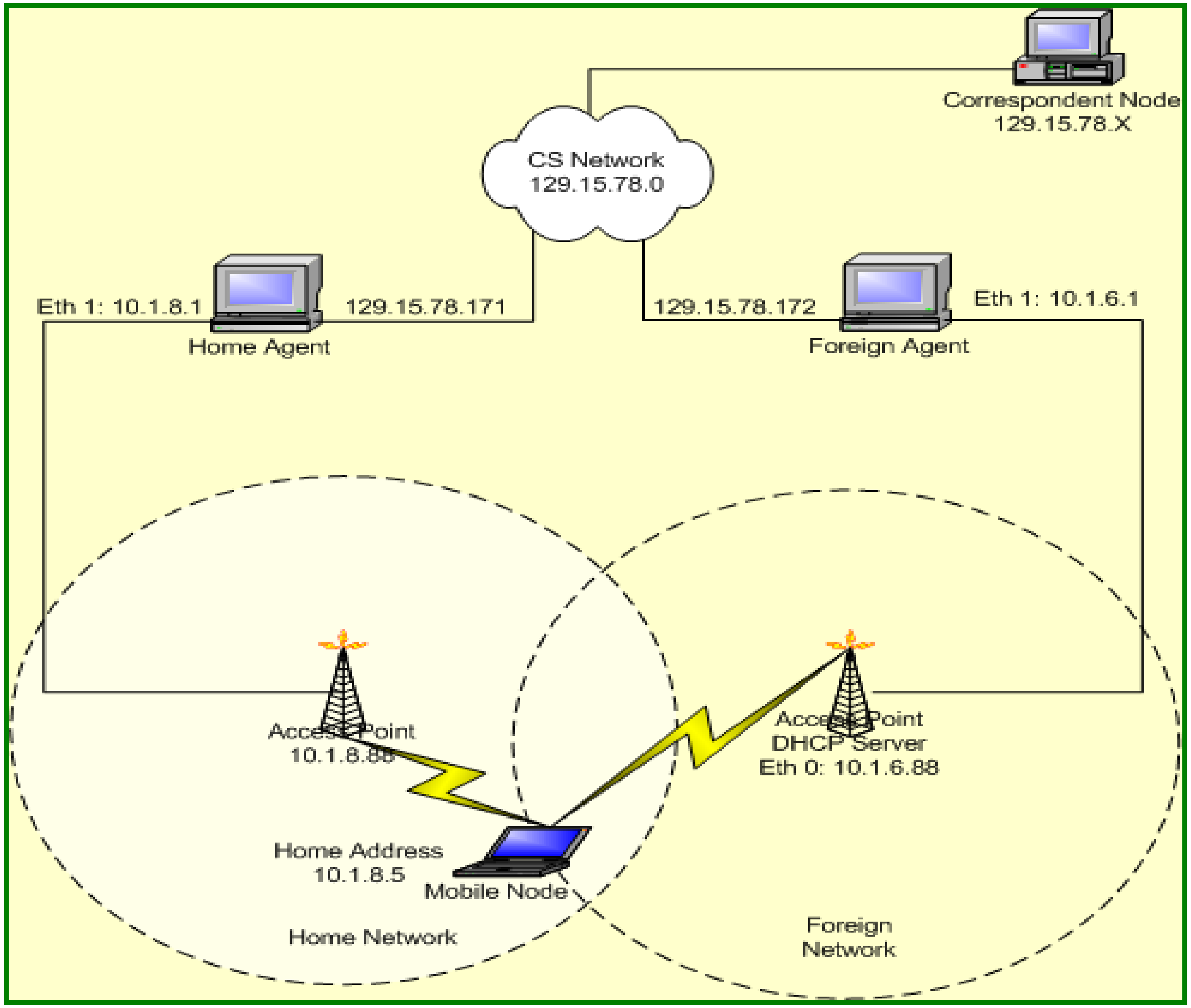
Experimental Testbed

Operation of SIGMA Testbed

- Link Layer is monitored to detect new AP signal strength.
- When a new AP is detected a new IP address is added to the association.
- When the new AP signal becomes stronger than the old AP signal, the Mobile Node notifies the Correspondent Node to make the new address the primary.



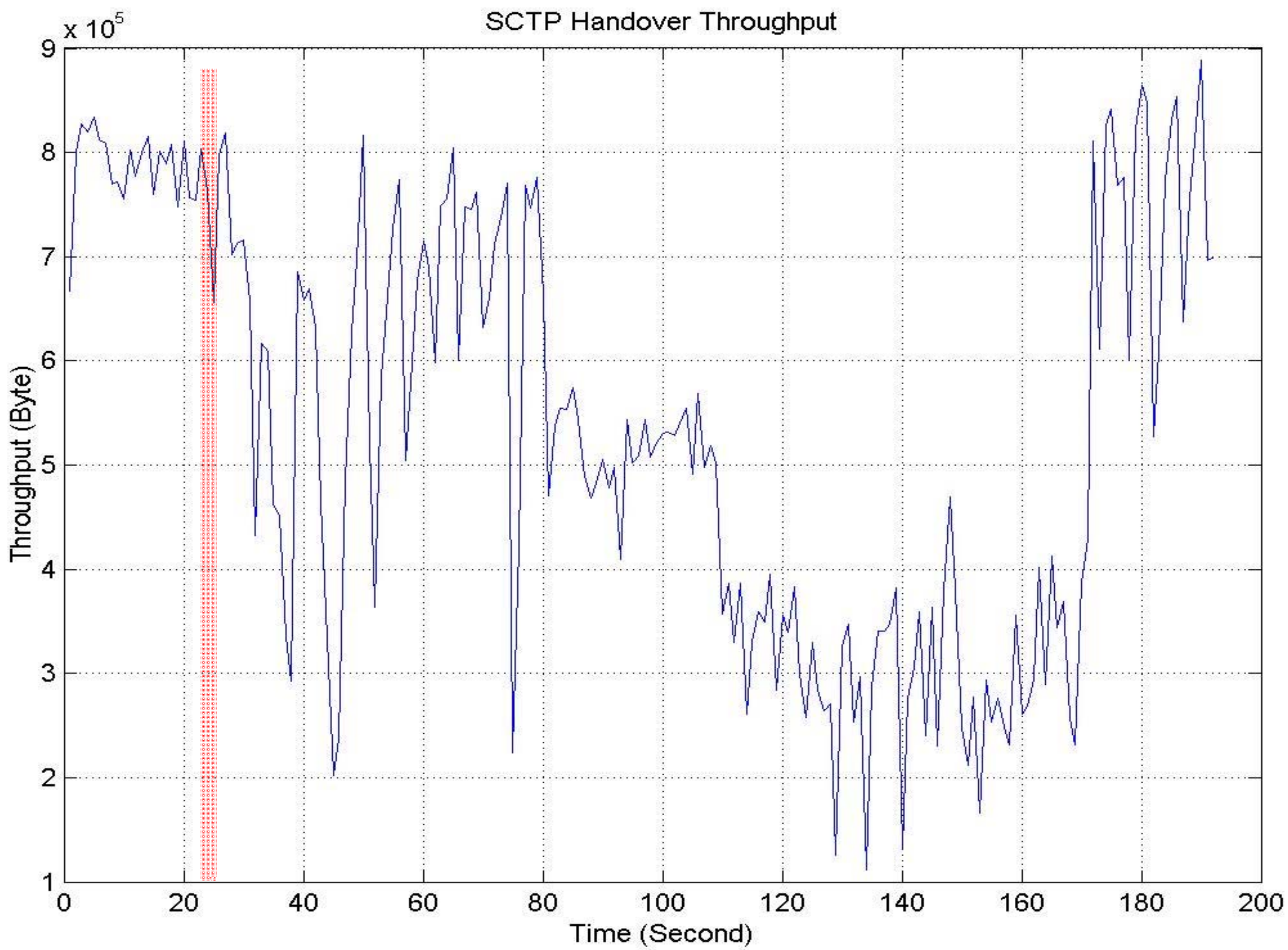
- lksctp reference implementation.
- Linux OS – Kernel 2.6.2.
- Network adapters
    - Avaya PCMCIA wireless network card and a NETGEAR USB wireless network card.



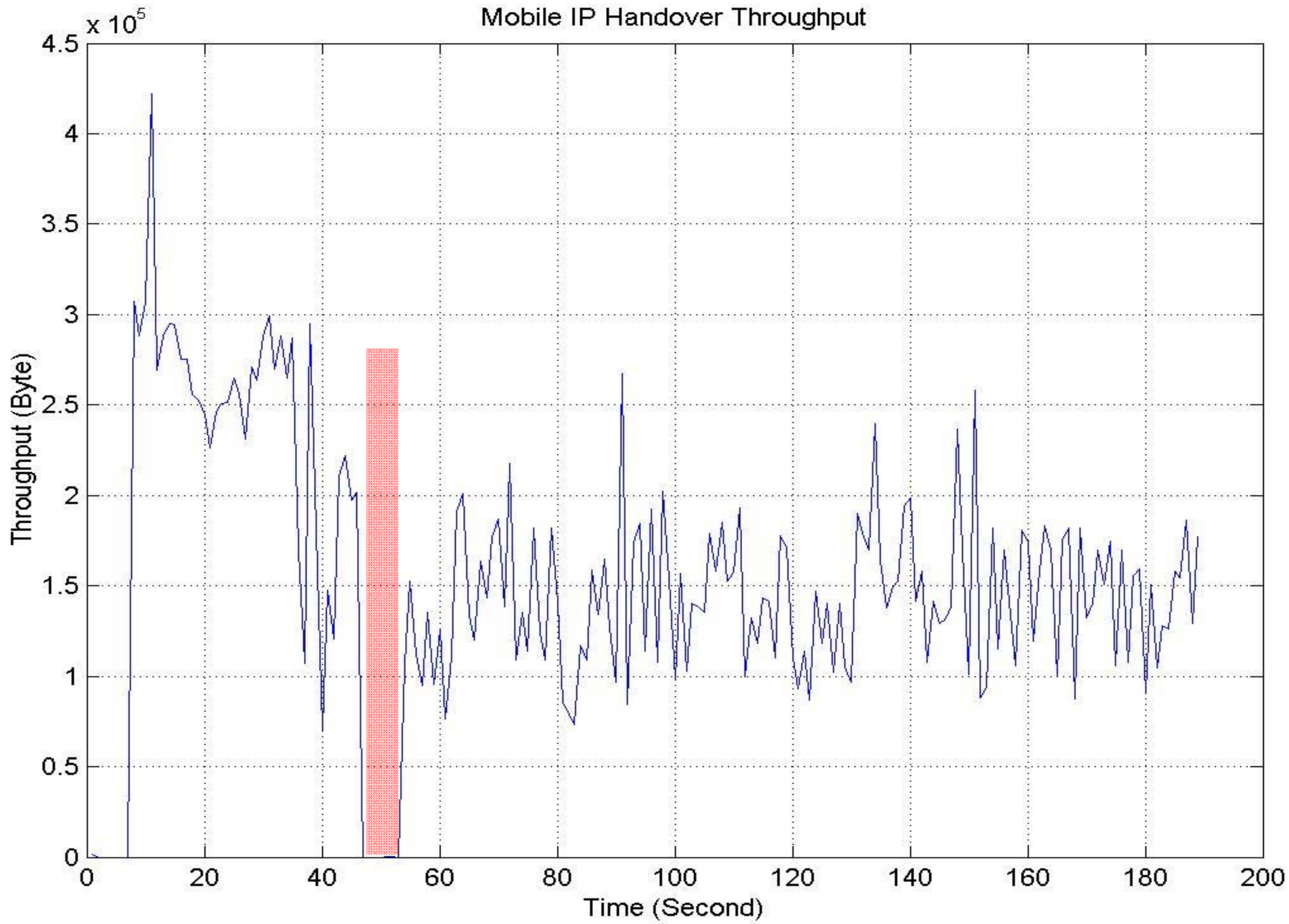
Correspondent Node
129.15.78.X
CS Network
129.15.78.0
Eth 1: 10.1.8.1
129.15.78.171
Home Agent
129.15.78.172
Eth 1: 10.1.6.1
Foreign Agent
Access Point
10.1.8.88
Access Point
DHCP Server
Eth 0: 10.1.6.88
Home Address
10.1.8.5
Mobile Node
Home Network
Foreign
Network

Results

SIGMA: Results



Mobile IP: Results

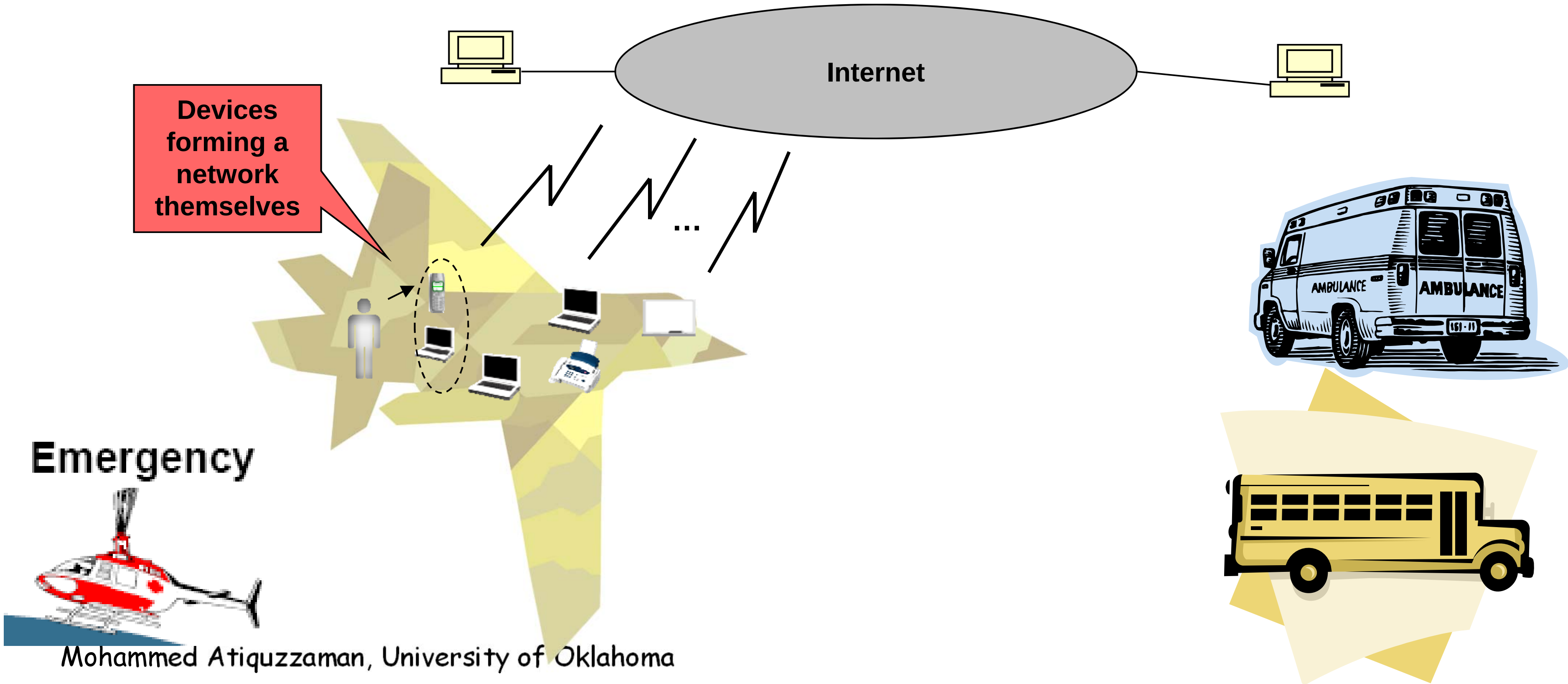


Network Mobility

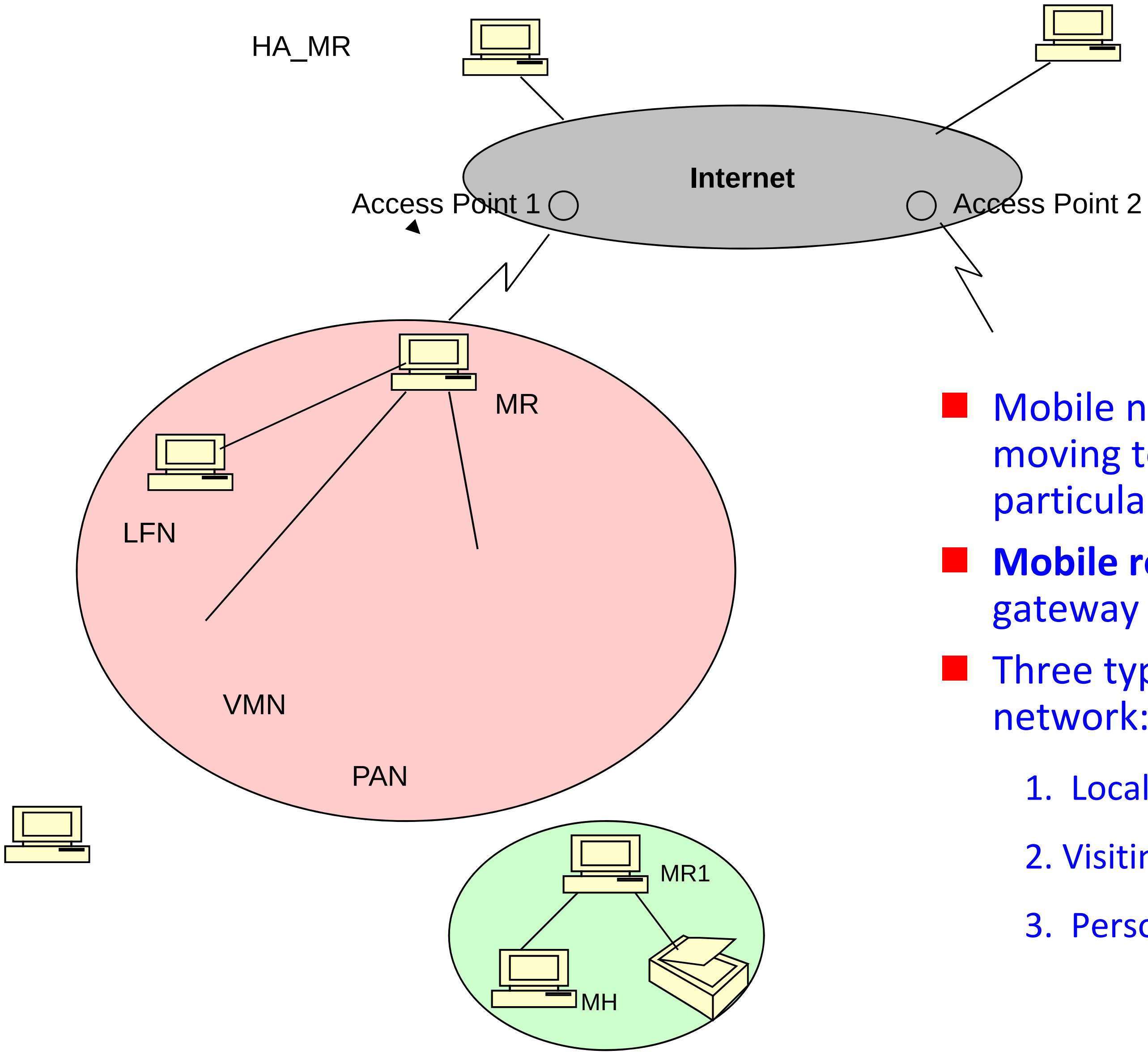
Topics to be discussed

- Why NEMO
- What is NEMO
- Location management in NEMO BSP
- Routing in NEMO BSP
  - Local Fixed Node
  - Visiting Mobile Node
- Signaling Diagram of NEMO BSP
- Limitations of NEMO BSP

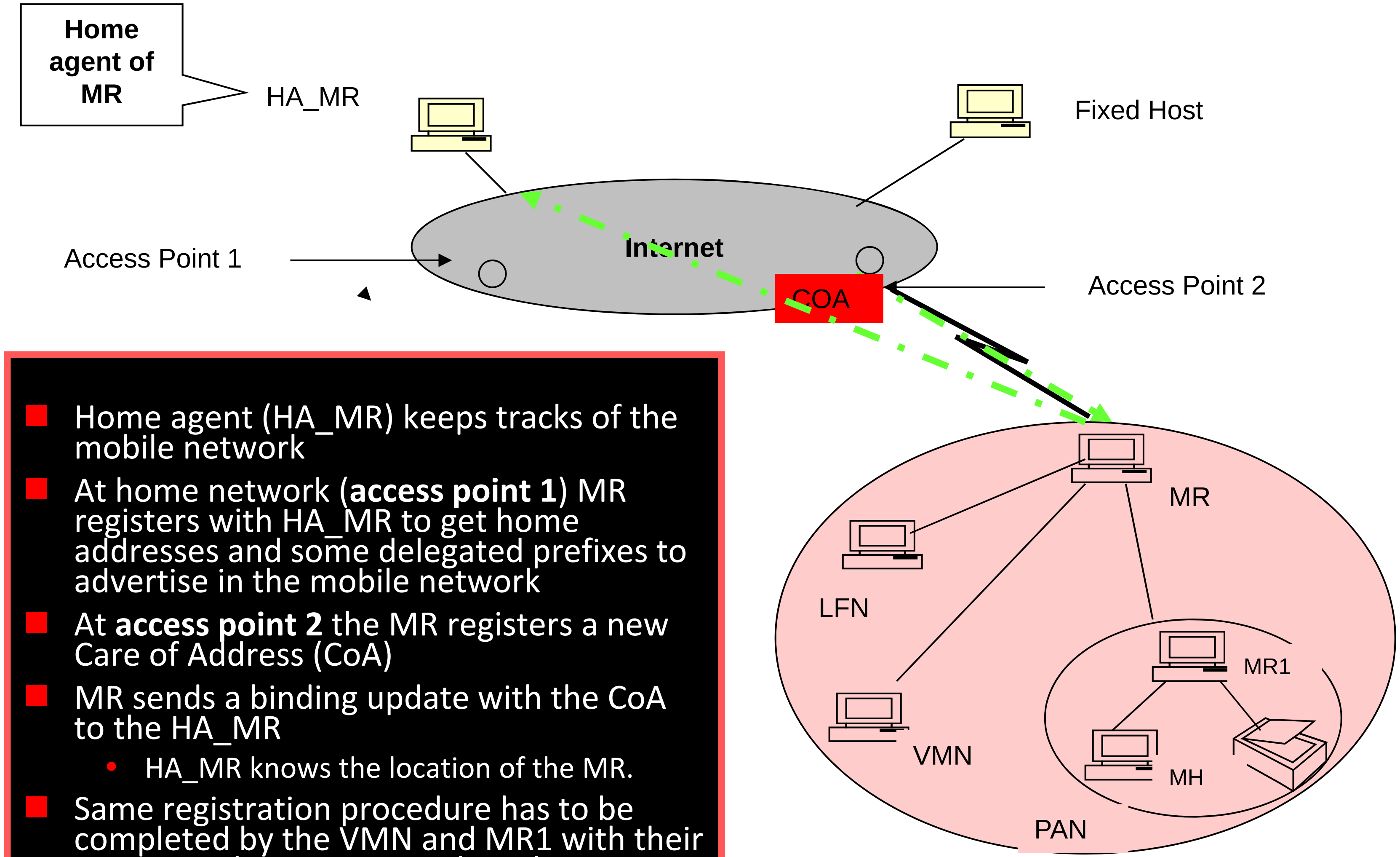
- Moving vehicles, ambulances, helicopters, and satellites may contain several IP enabled devices
  - Ex: computers, data collecting equipments, PDAs, observing equipment
- Each mobile device can individually manage its mobility using MIPv6
  - Requires lot of signaling messages over the precious wireless link
- Could this mobility be managed in an aggregated way?



NEtwork MObility (NEMO)



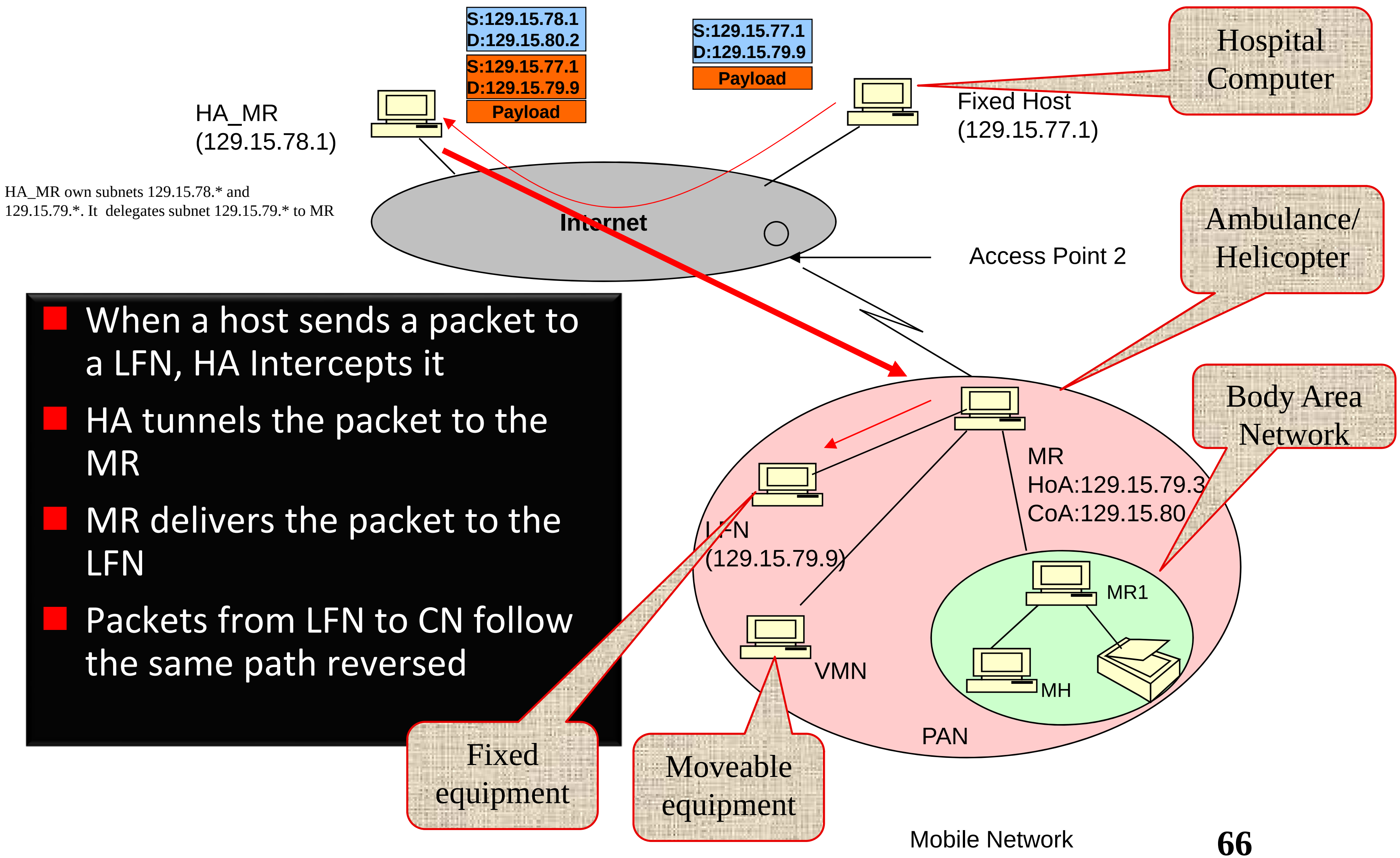
- Mobile network: A group of nodes moving together as a unit under a particular network.
- **Mobile router (MR)** provides gateway to the mobile network.
- Three types of nodes in the network:
  1. Local Fixed Node (LFN)
  2. Visiting Mobile Node (VMN)
  3. Personal Area Network (PAN)



- Home agent (HA_MR) keeps tracks of the mobile network
- At home network (**access point 1**) MR registers with HA_MR to get home addresses and some delegated prefixes to advertise in the mobile network
- At **access point 2** the MR registers a new Care of Address (CoA)
- MR sends a binding update with the CoA to the HA_MR
  - HA_MR knows the location of the MR.
- Same registration procedure has to be completed by the VMN and MR1 with their respective home agents when they move into the mobile network

NEMO: Routing for Local Fixed Node (LFN)

- When a host sends a packet to a LFN, HA Intercepts it
- HA tunnels the packet to the MR
- MR delivers the packet to the LFN
- Packets from LFN to CN follow the same path reversed



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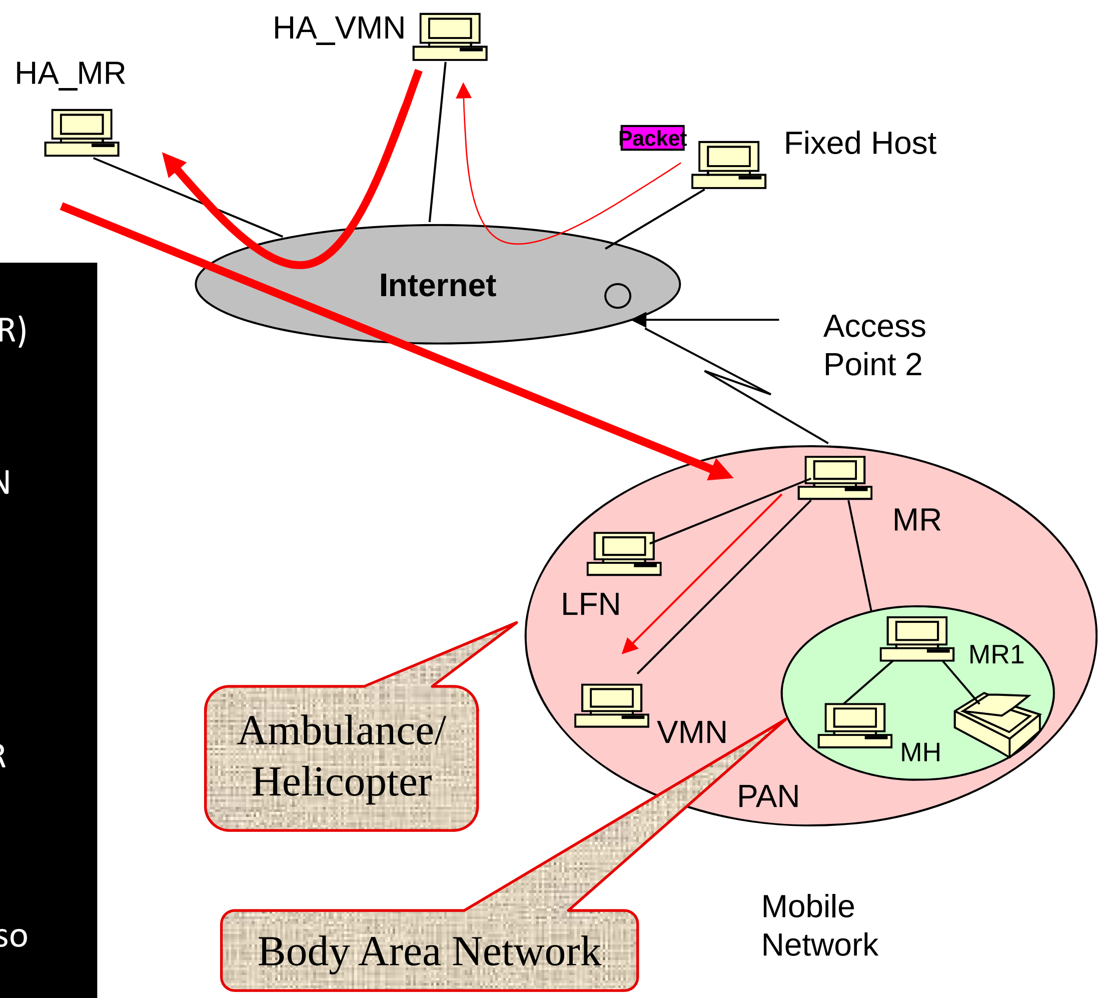
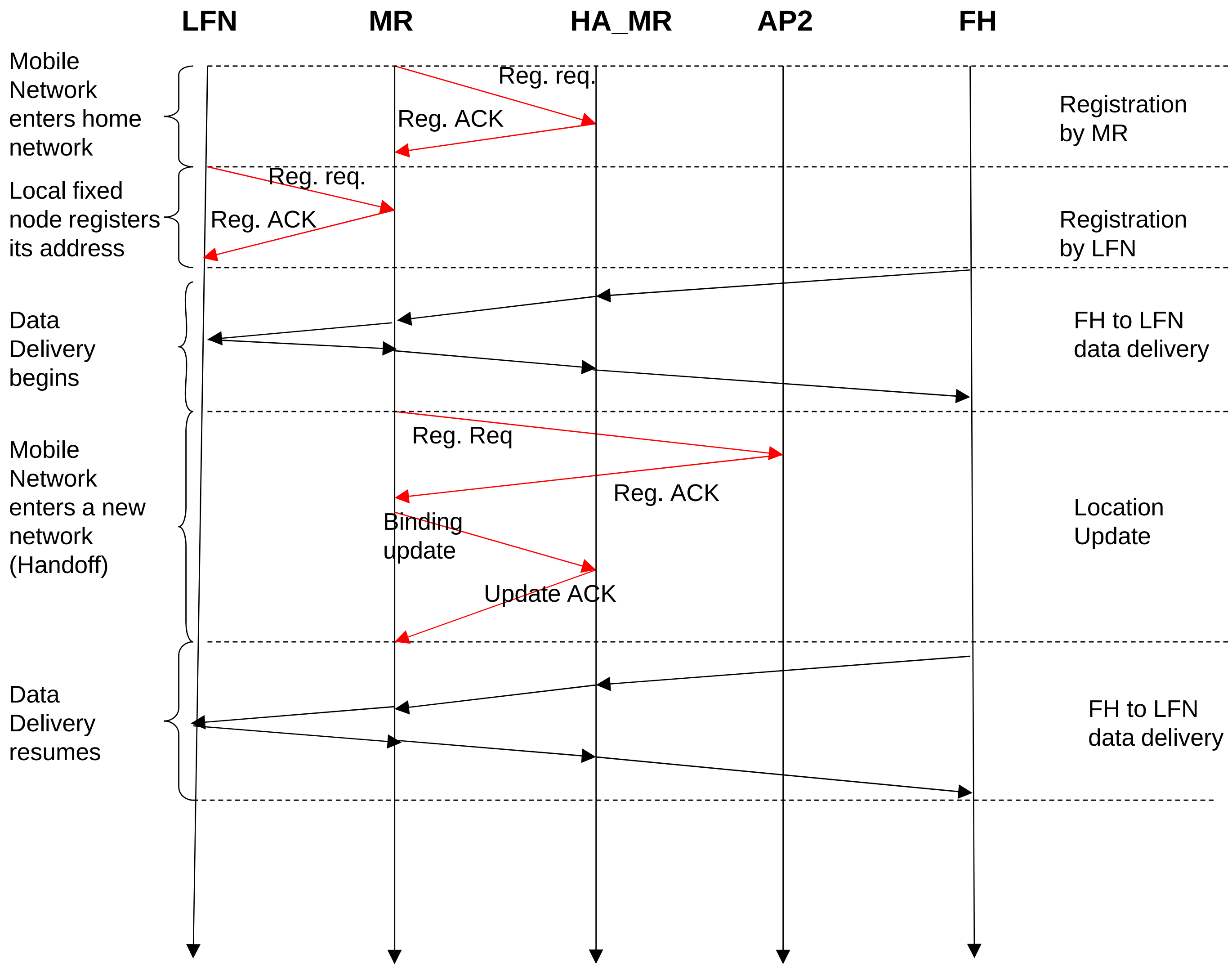
NEMO: Routing for Visiting Mobile Node

- VMN registers its CoA (address of MR) with its own home agent (HA_VMN) when it enters the Mobile network
- Fixed host sends a packet to the VMN which is intercepted by the HA_VMN
- HA_VMN tunnels the packet to the address of the MR which in turn is intercepted by the HA_MR
- HA_MR tunnels the packet to the MR
- MR delivers the packet to the VMN
- Routing for the hosts in the PAN is also done in the same way



Signaling diagram of NEMO (LFN)



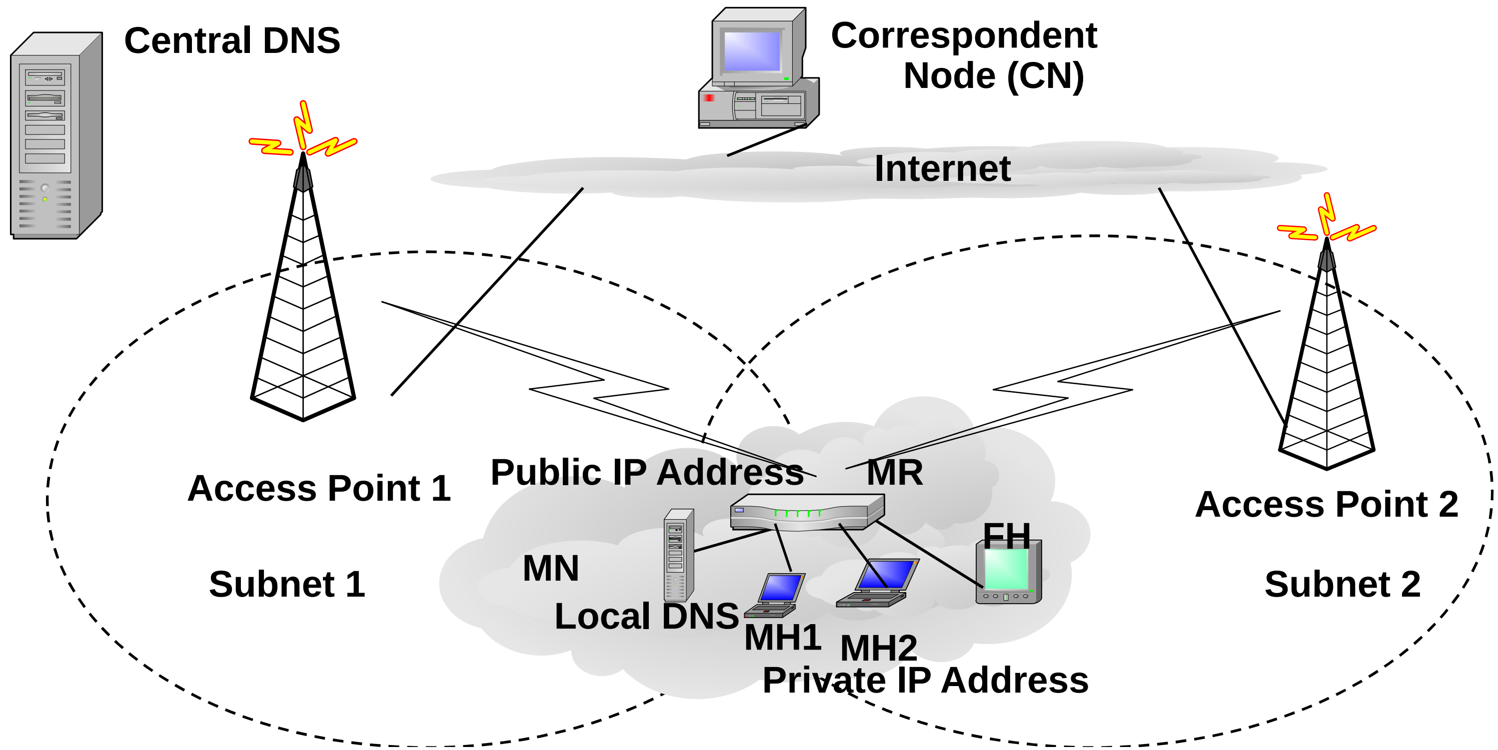
- Inefficient routing specially in case of nesting and visiting mobile nodes
- Header overhead due to tunneling encapsulation
- Other drawbacks of MIPv6 are inherited by NEMO BSP

SINEMO – SIGMA for NEMO

- Seamless IP-diversity based NEtwork MObility.
  - Uses IP-diversity to hand over between subnets.

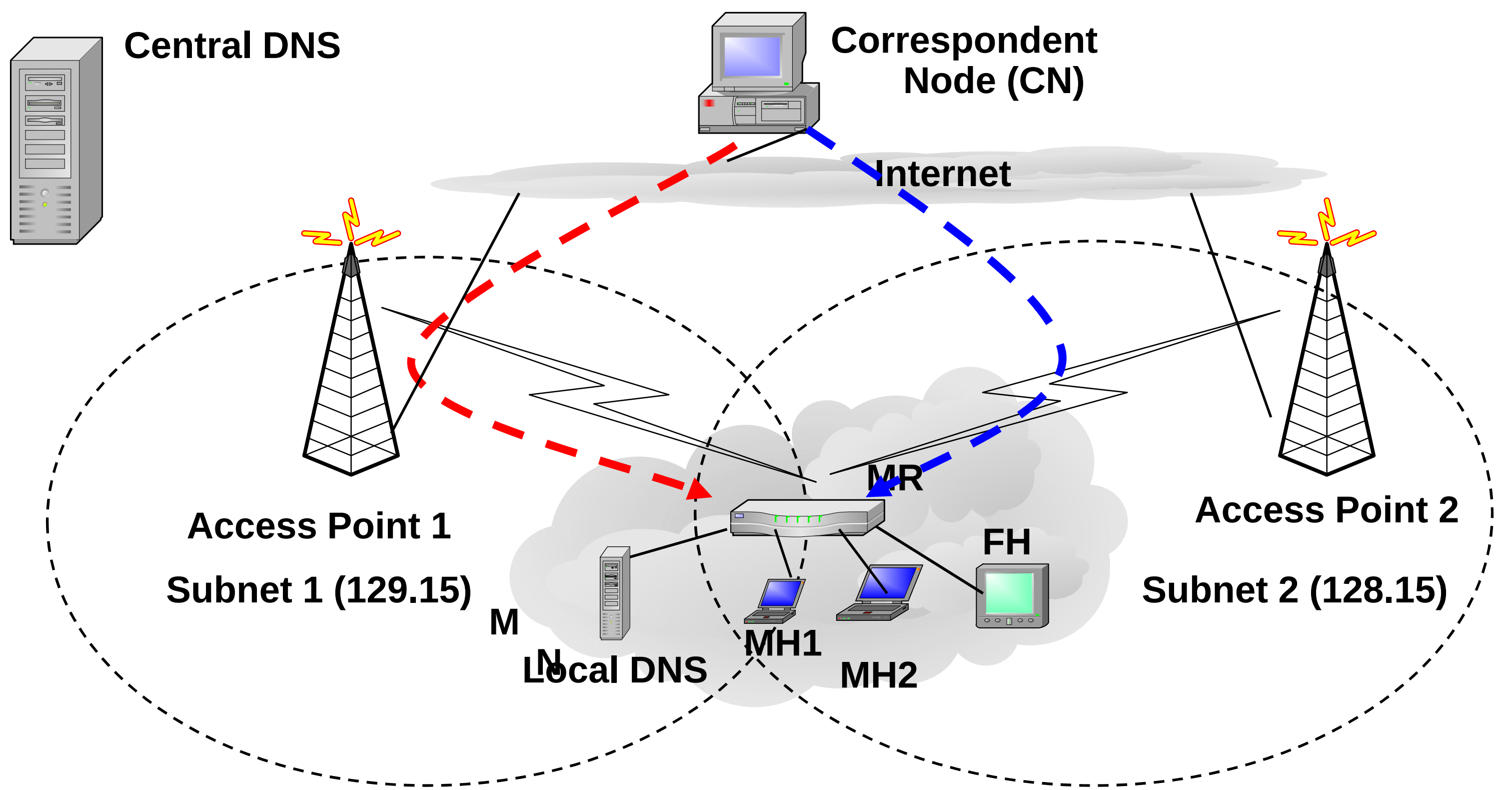
- SINEMO is an extension of SIGMA (Seamless IP-diversity based Generalized Mobility Architecture).
  - Underlying transport protocol has to support IP diversity.

SINEMO Architecture



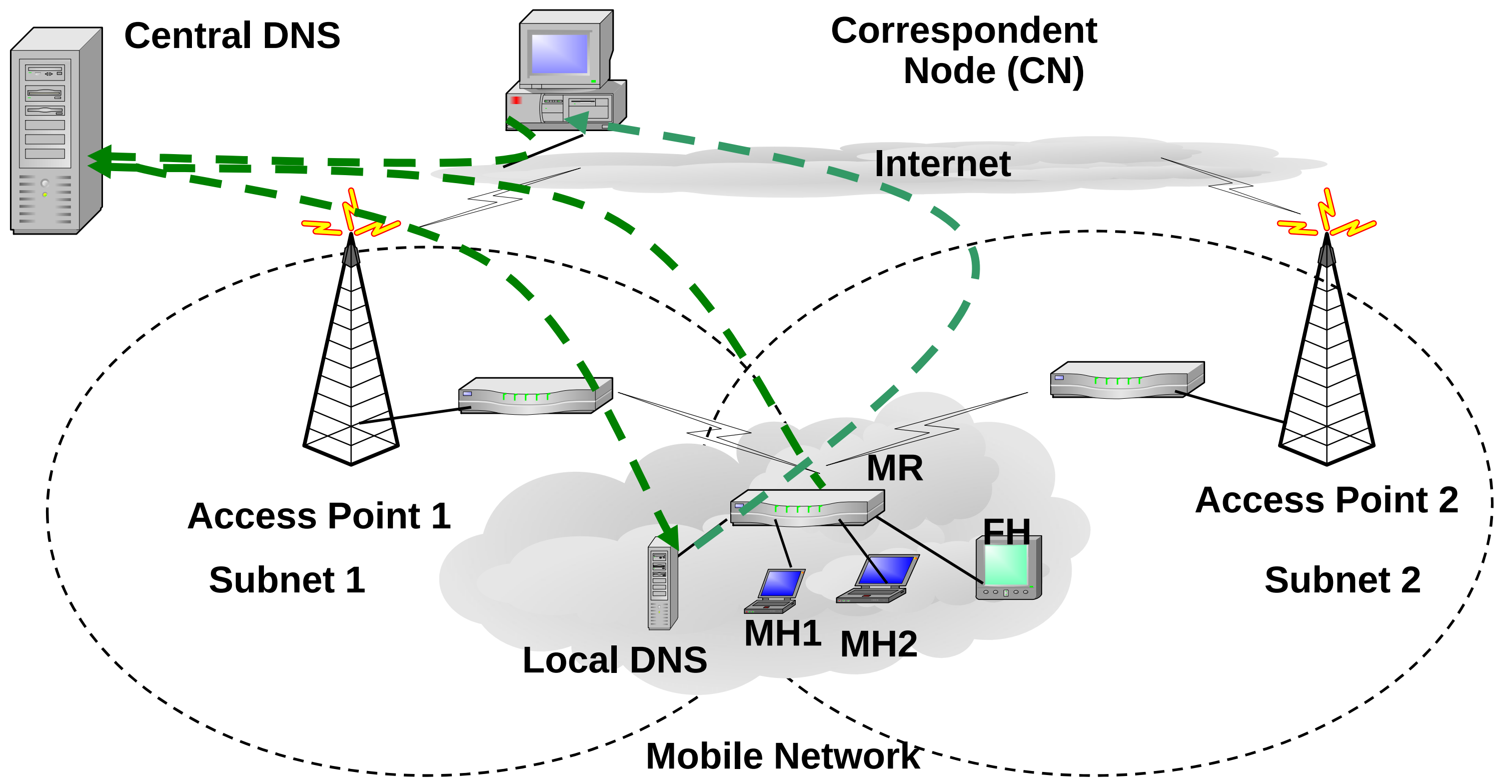
- MR acts a gateway, acquires IP prefix from the access points.
- Each host inside the MN has both public and private IP addresses. MR keeps a mapping between public and private IPs.
- Network Address Translation (NAT) at MR.
- Hierarchical Location Manager is used.

SINEMO Data Path

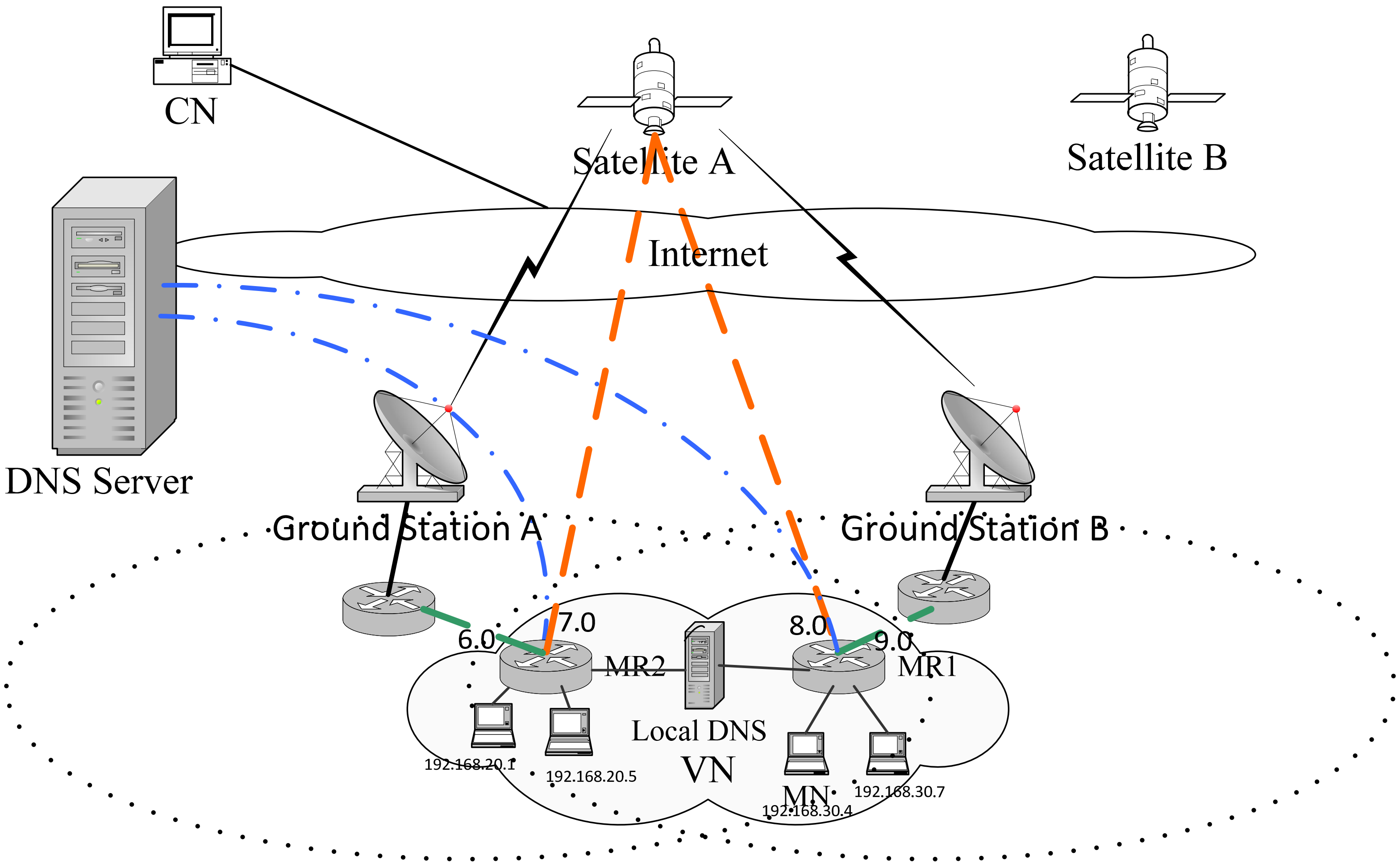


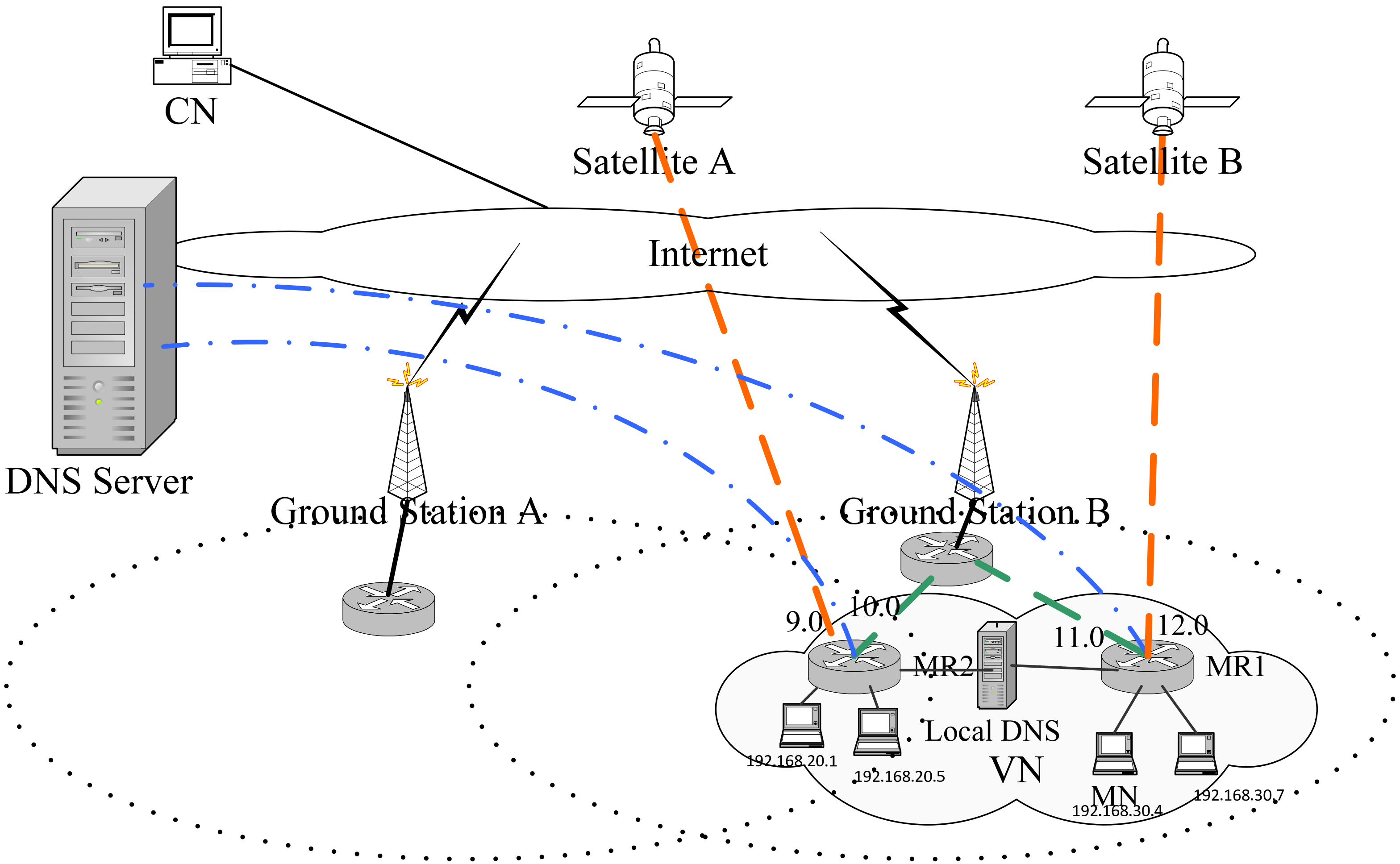
In Subnet 1		
Private IP	Public IP	Public Port
192.168.A	129.15.A	5000
192.168.B	129.15.B	6000

In Subnet 2 (after subnet change)		
Private IP	Public IP	Public Port
192.168.A	128.15.A	5000
192.168.B	128.15.B	6000



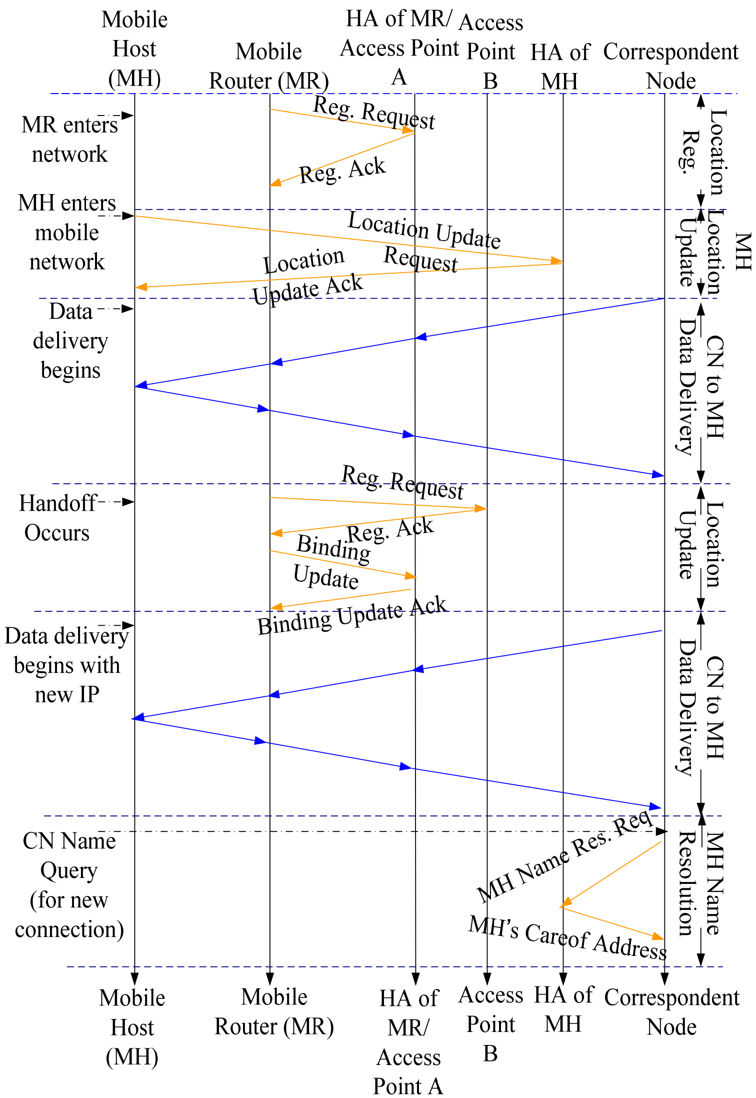
- MR only updates the Central DNS when subnet is changed.
- CN queries Central DNS to get the IP address of MH.
- Central DNS redirects the query to Local DNS and local DNS replies with the IP address of MH.


CN
Satellite A
Satellite B
Internet
DNS Server
Ground Station A
Ground Station B
6.0
7.0
8.0
9.0
MR2
MR1
Local DNS
VN
192.168.20.1
192.168.20.5
MN
192.168.30.4
192.168.30.7

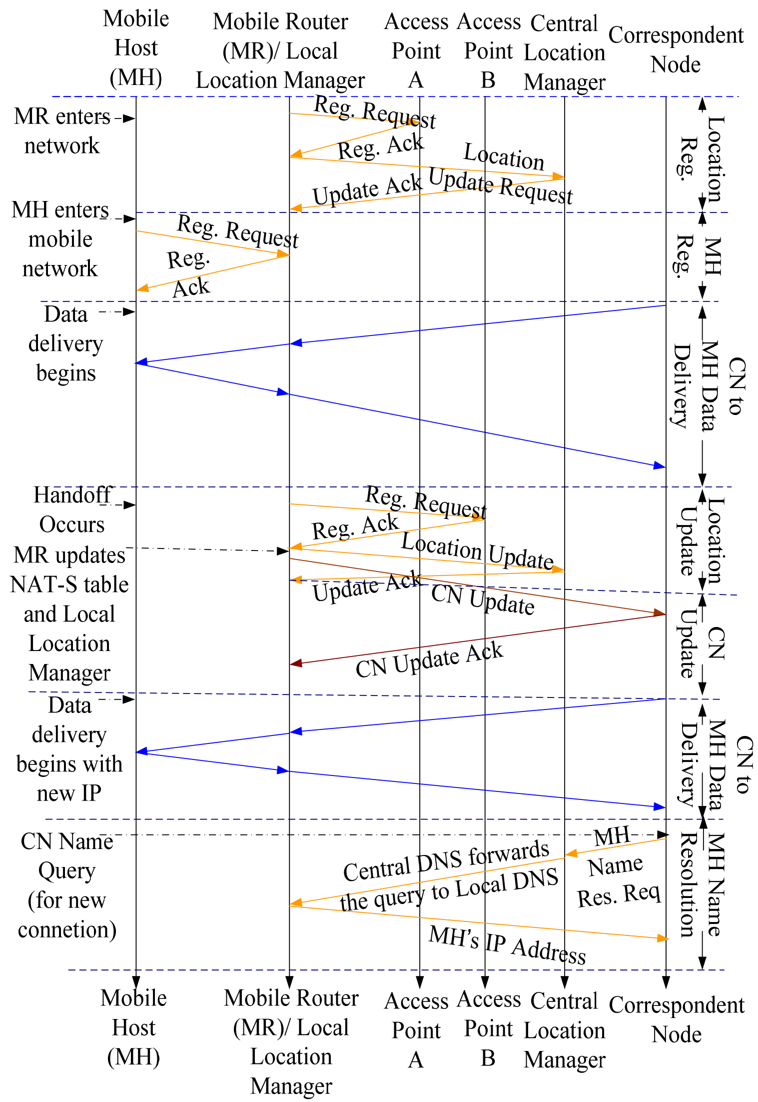

CN
Satellite A
Satellite B
Internet
DNS Server
Ground Station A
Ground Station B
9.0
10.0
11.0
12.0
MR2
MR1
Local DNS
VN
MN
192.168.20.1
192.168.20.5
192.168.30.4
192.168.30.7

Comparison between NEMO BSP and SINEMO

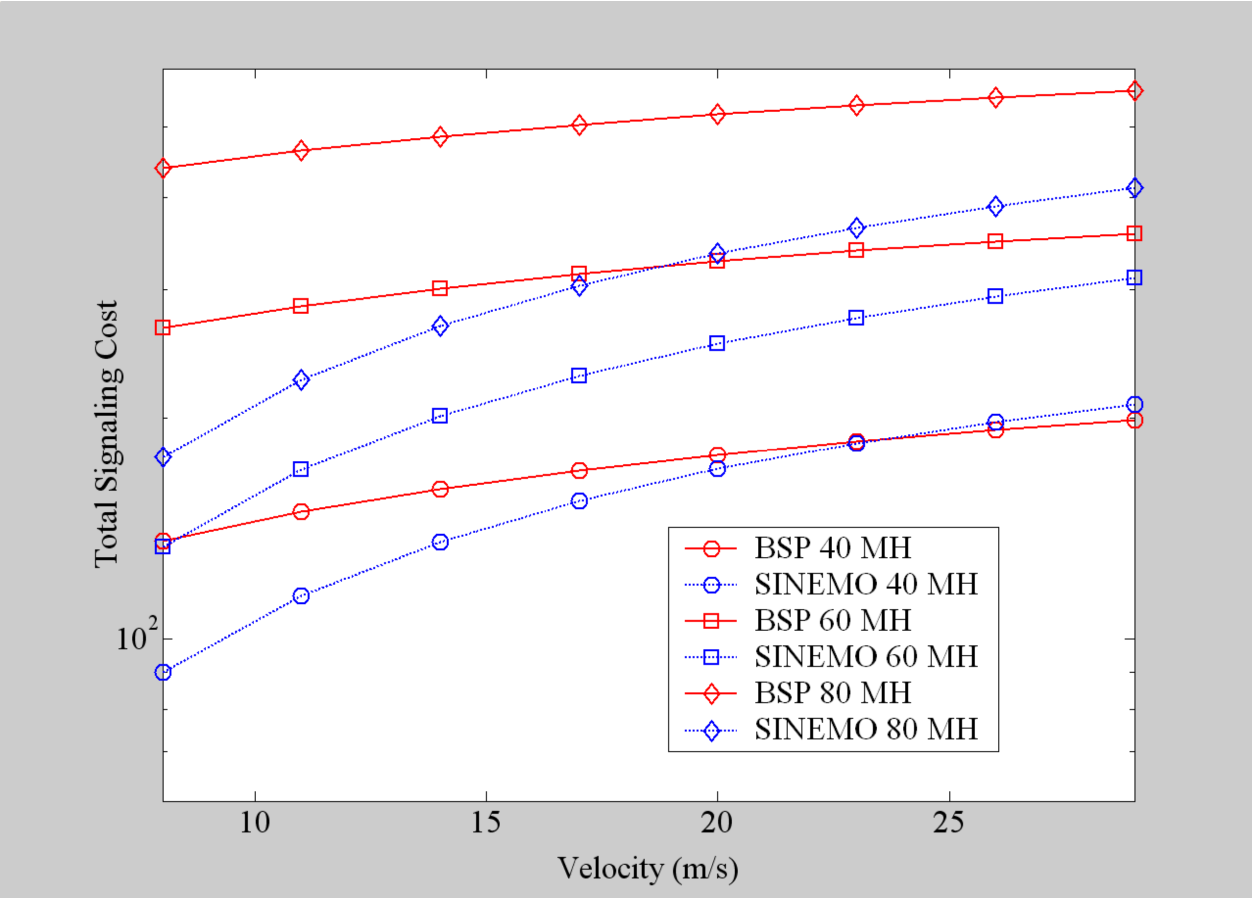
Features	NEMO BSP	SINEMO
Signaling	Low	Slightly higher than NEMO BSP
Routing	Not very efficient	Efficient
Handover Packet Loss	Higher	Lower
Deployment	Needs modification in Internet Infrastructure	Less modification is needed
Space Network Suitability	Suitable	Suitable


Mobile Host (MH)
Mobile Router (MR)
HA of MR/ Access Point A
Access Point B
HA of MH
Correspondent Node
MR enters network
Reg. Request
Reg. Ack
Location Reg.
MH enters mobile network
Location Update
Request
Location
Update Ack
MH Location Update
Data delivery begins
CN to MH Data Delivery
Handoff Occurs
Reg. Request
Reg. Ack
Binding
Update
Binding Update Ack
Location Update
Data delivery begins with new IP
CN Name Query (for new connection)
MH Name Res. Req
MH's Careof Address
MH Name Resolution
Mobile Host (MH)
Mobile Router (MR)
HA of MR/ Access Point A
Access Point B
HA of MH
Correspondent Node

NEMO

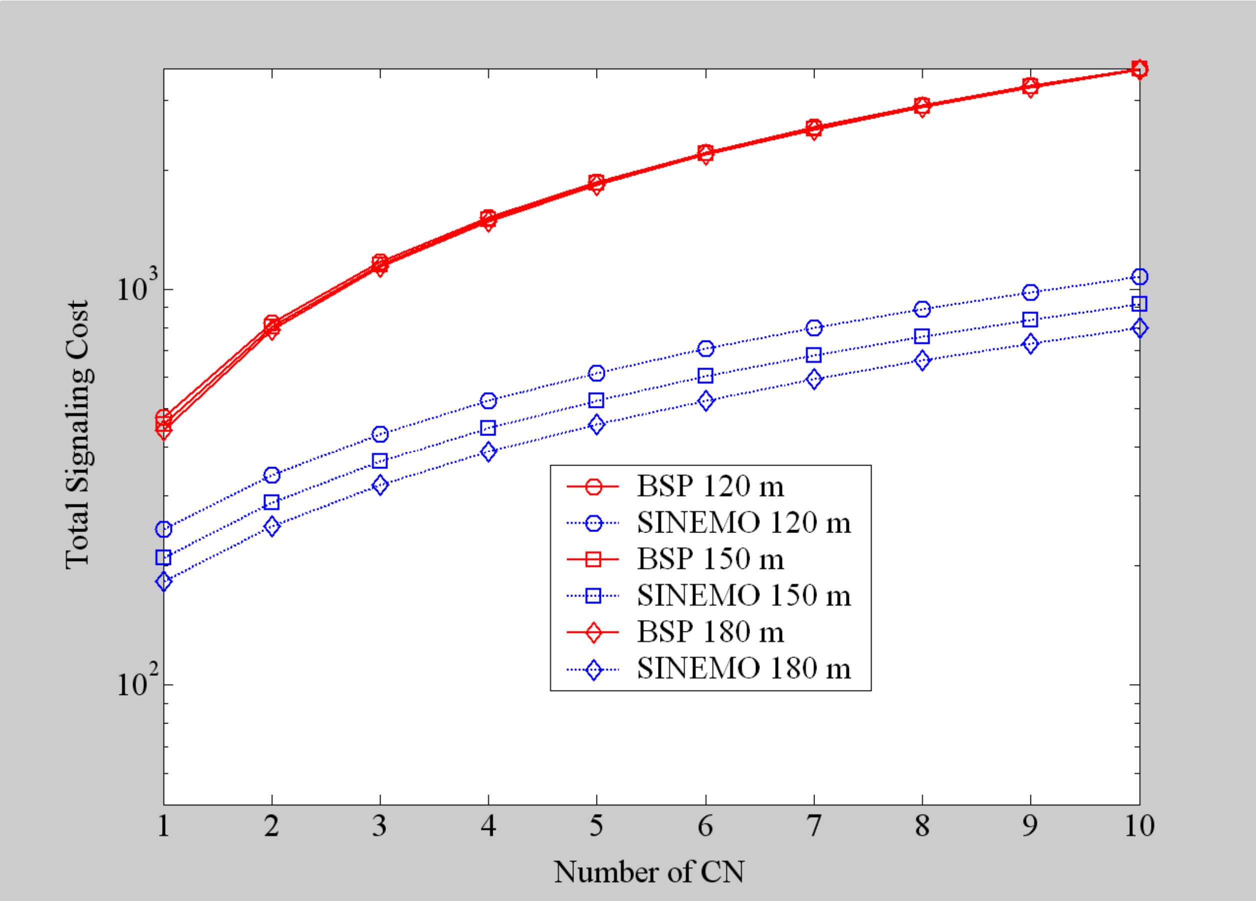

Mobile Host (MH)
Mobile Router (MR)/ Local Location Manager
Access Point A
Access Point B
Central Location Manager
Correspondent Node
MR enters network
Reg. Request
Reg. Ack
Location
Update Request
Update Ack
Location Reg.
MH enters mobile network
Reg. Request
Reg.
Ack
MH Reg.
Data delivery begins
CN to MH Data Delivery
Handoff Occurs
MR updates NAT-S table and Local Location Manager
Reg. Request
Reg. Ack
Location Update
Update Ack
CN Update
CN Update Ack
Location Update
CN Update
Data delivery begins with new IP
CN Name Query (for new conention)
MH Name Res. Req
Central DNS forwards the query to Local DNS
MH's IP Address
MH Name Resolution
Mobile Host (MH)
Mobile Router (MR)/ Local Location Manager
Access Point A
Access Point B
Central Location Manager
Correspondent Node

SINEMO



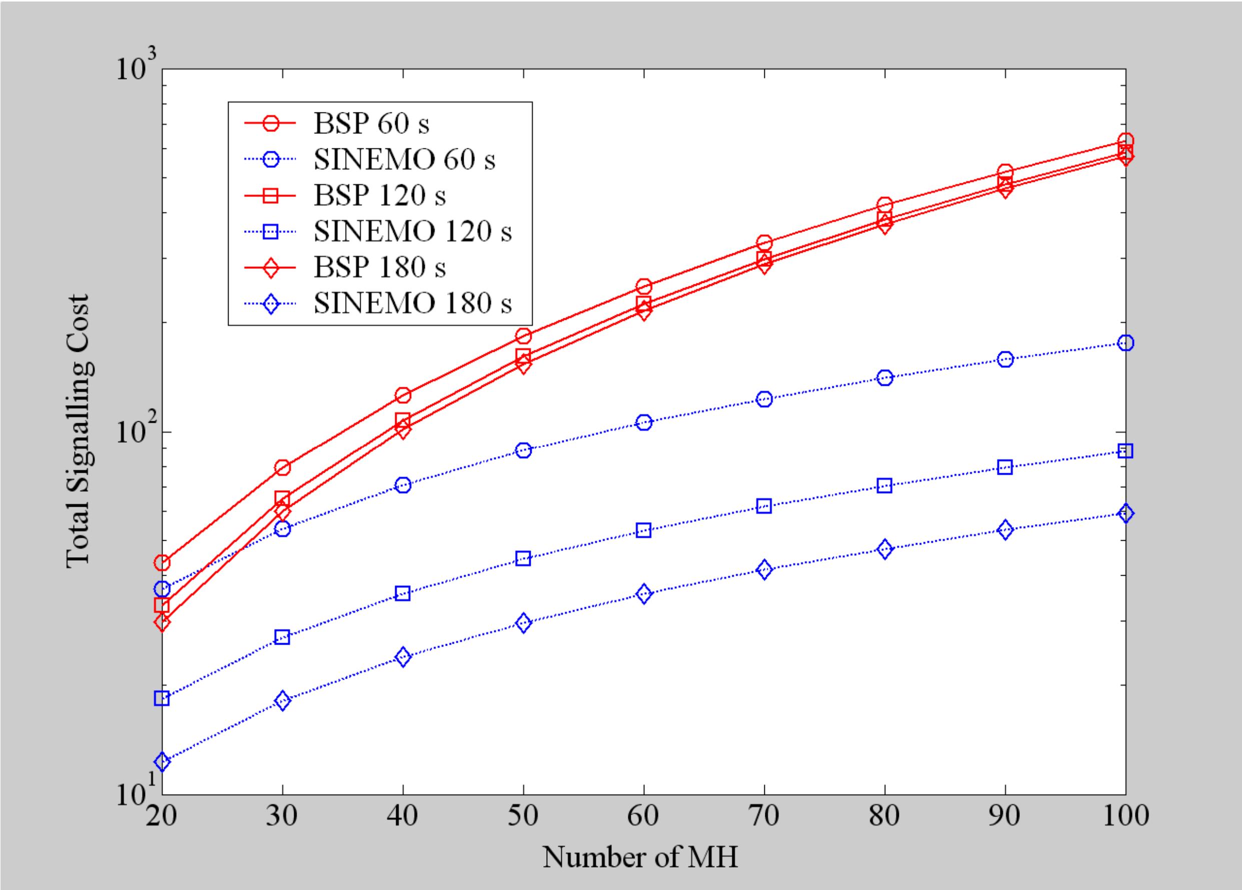
Signaling cost increases with velocity because higher velocity results in lower residence time and thus frequent handoffs

Signaling cost vs. MR velocity for number of MH.



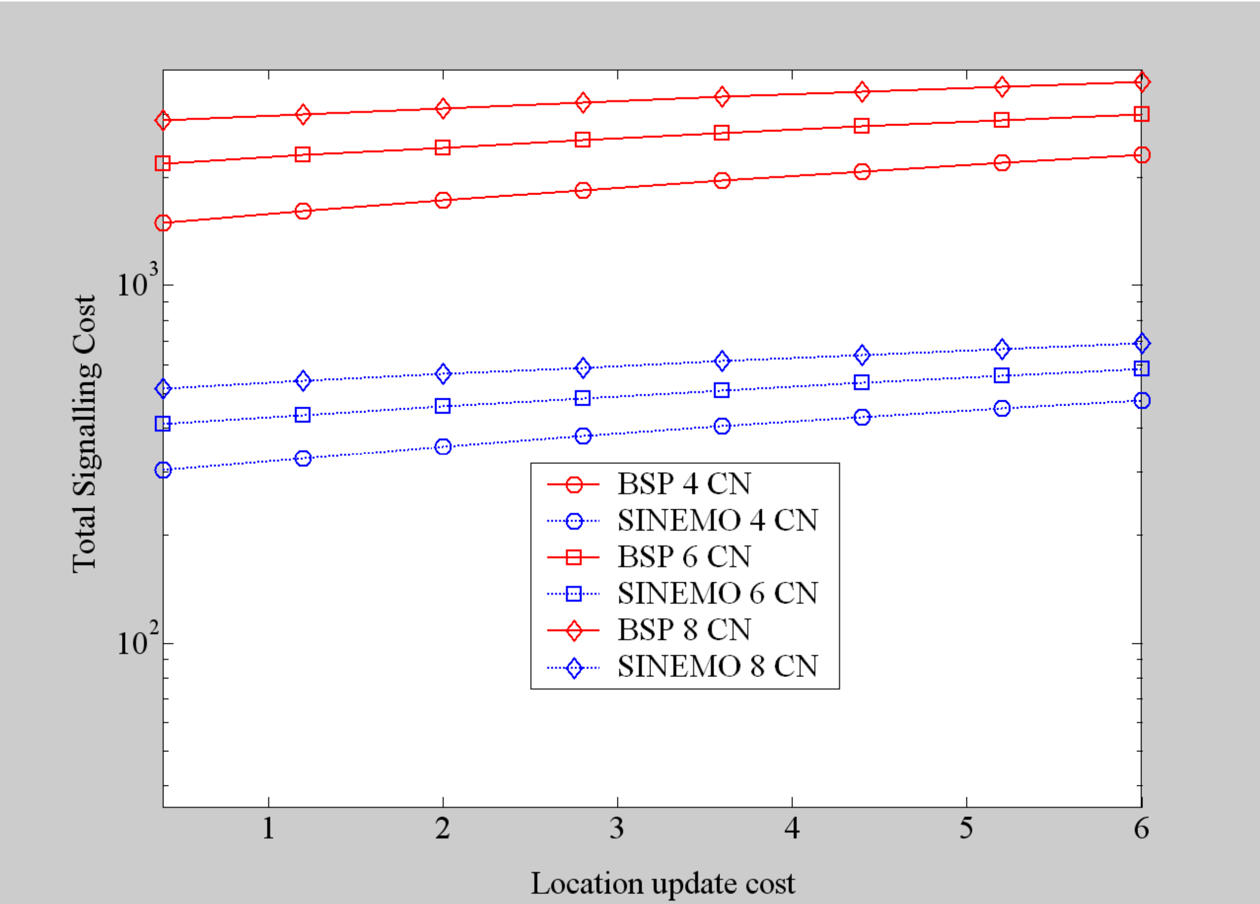
Signaling cost vs. number of CN for different epoch lengths.

Longer epoch time means higher residence time and thus less frequent handoffs and fewer signaling messages



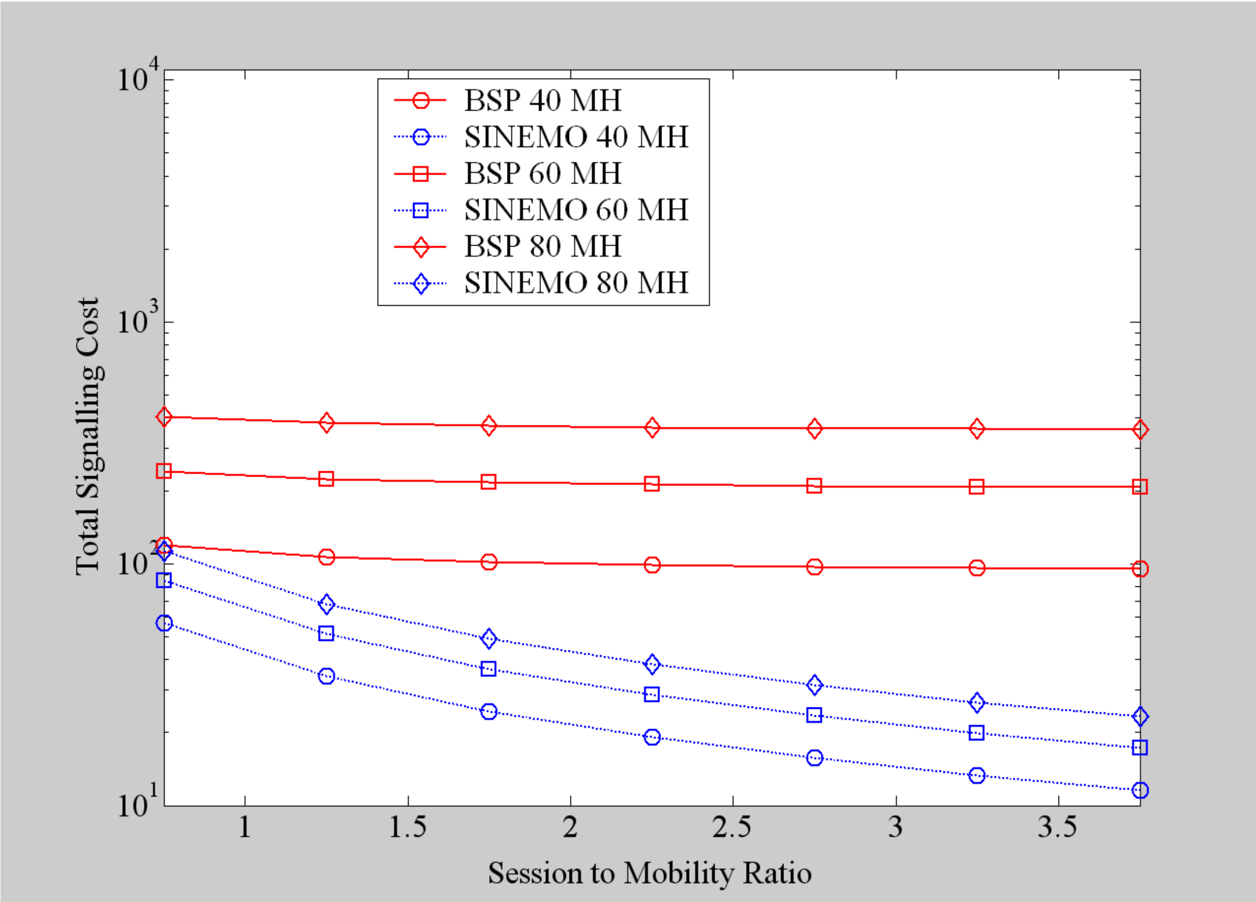
Signaling cost vs. number of MH for different residence time.

Signaling cost of SINEMO is lower than BSP due to the fact that the LLM update does not incur any data transmission cost



Signaling cost of SINEMO is lower than BSP because SINEMO does not update the CLM for MR handoffs

Signaling cost vs. number location update cost for different CN.



Higher value for *SMR* indicates low mobility, thus fewer number of updates and lower signaling cost

Signaling cost vs. session to mobility ratio for different number of MH

Conclusions

- Satellite is a critical component of future IoT.
- Many mobility issues arise due to movement of “things” and “satellites”.
- Efficient mobility management schemes involving satellites in IoT is an important topic for future research.
- Support of satellite services is an important component for its success in IoT.

- NEMO BSP → Lot of signaling for nested mobility
- SINEMO → IP diversity based end to end mobility management with local location management
- SINEMO avoids packet encapsulation and uses optimal route
- Signaling cost of SINEMO is lower than NEMO BSP

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  - Wesley Eddy (NASA)
  - David Stewart (NASA)
  - Lloyd Wood (Cisco)

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Thank you

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