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# Extending the Internet to Space

Dr. Mohammed Atiquzzaman
University of Oklahoma
Norman, OK 73019-6151, USA.
atiq@ou.edu
www.cs.ou.edu/~atiq

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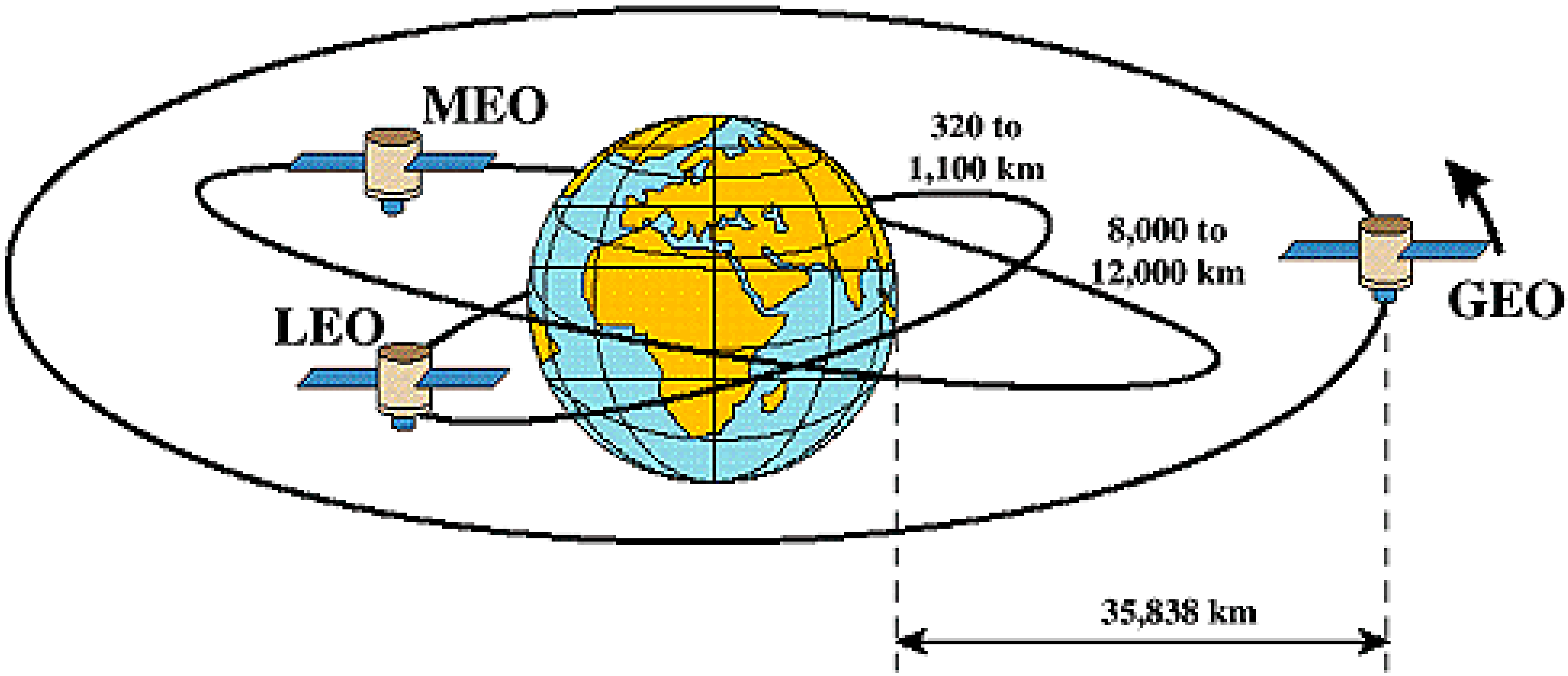
# Types of Satellites based on Alltitude

- Low Earth Orbit (LEO)
- Medium Earth Orbit (MEO)
- Geostationary (GEO)

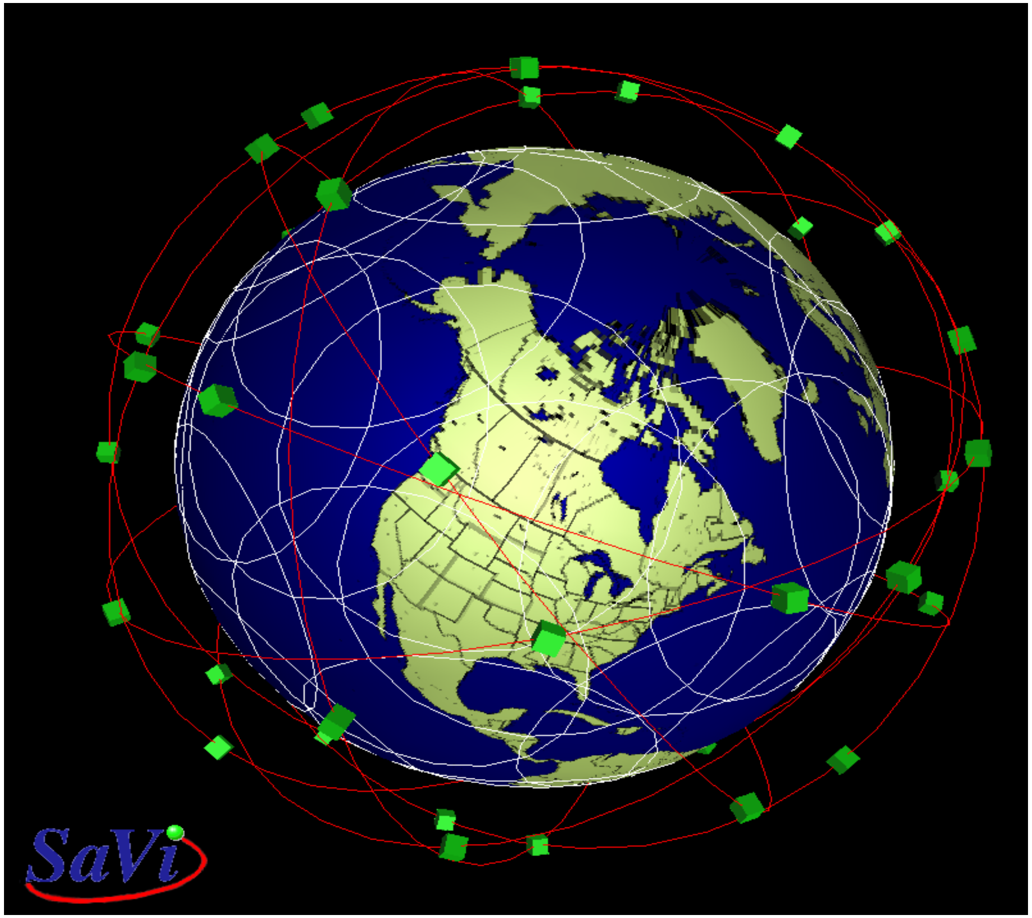


# Handoffs in LEO Satellite Constellations

# Handoffs in satellite IP networks

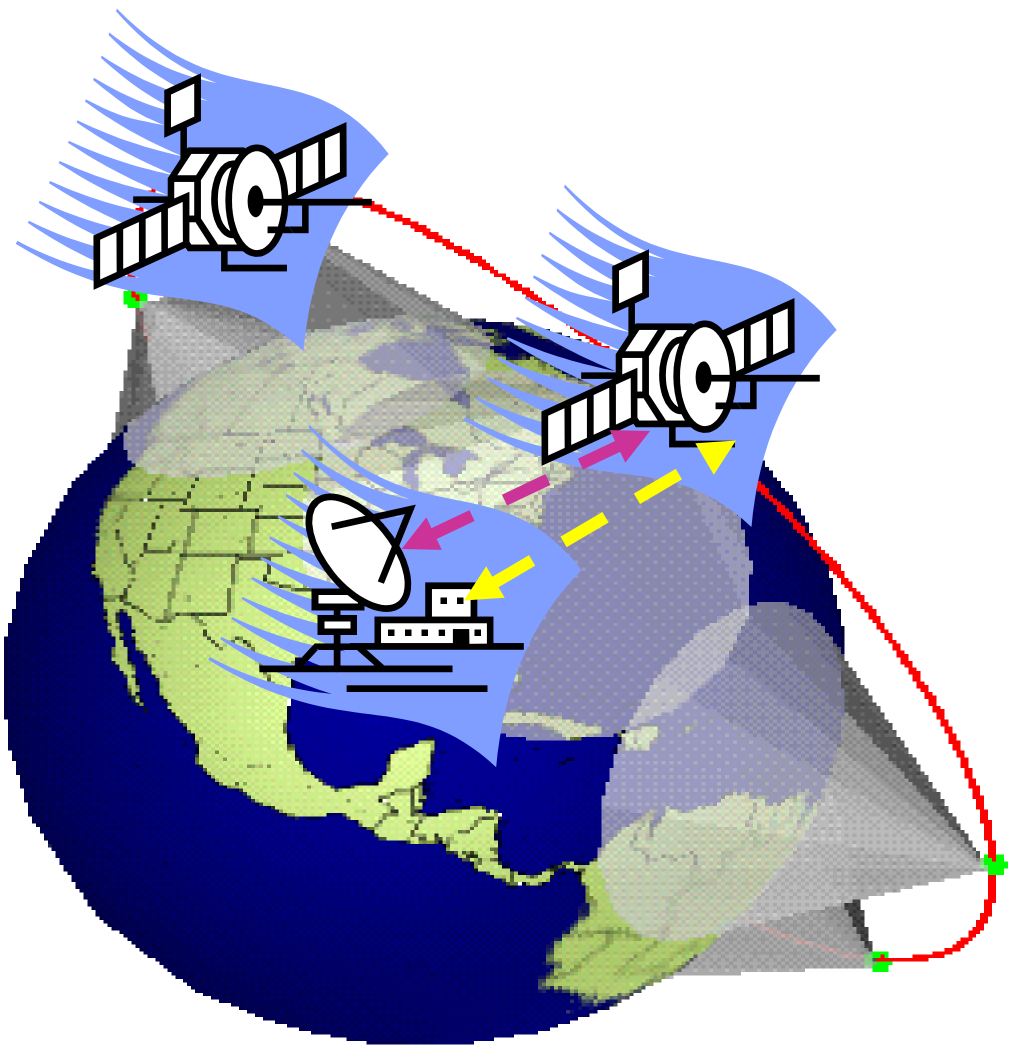
- **Link Layer Handoff**
  - Inter-satellite handoff
  - Link handoff
  - Spotbeam handoff

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

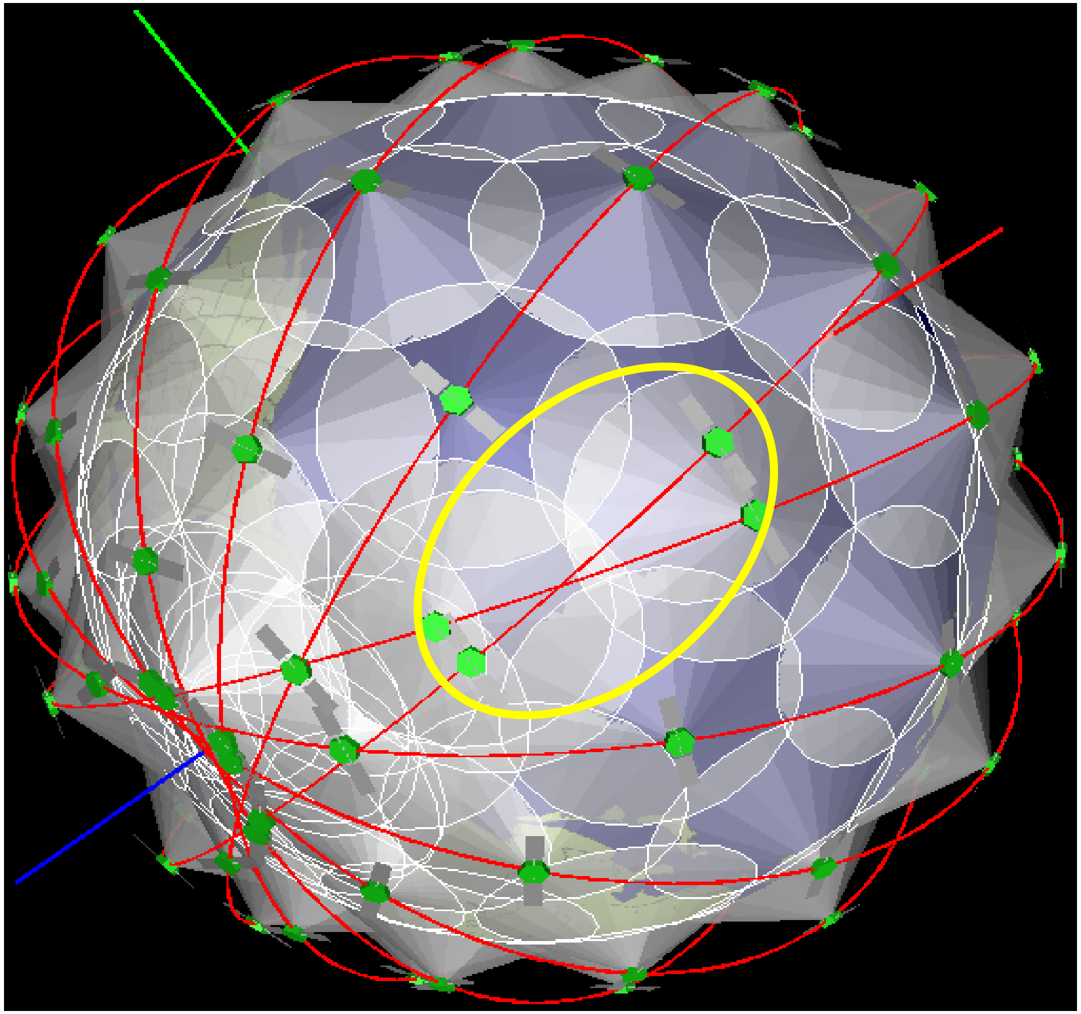



*A Globalstar design, with 48 active satellites in 8 planes of 6.*

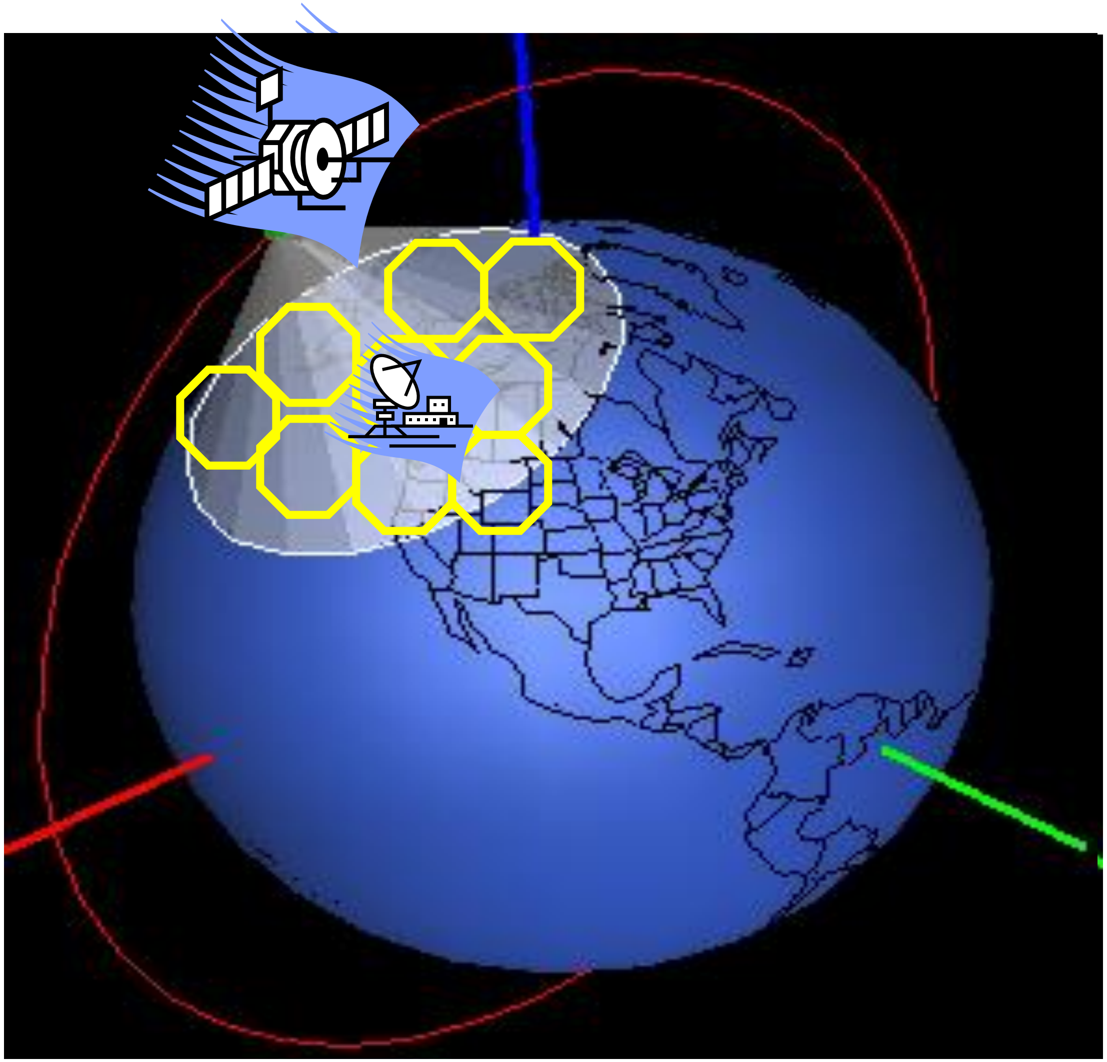
- The movement of satellite causes a Ground Station being handed off from one satellite to another.
- Similar to inter-switch handoff in the case of terrestrial mobile network.



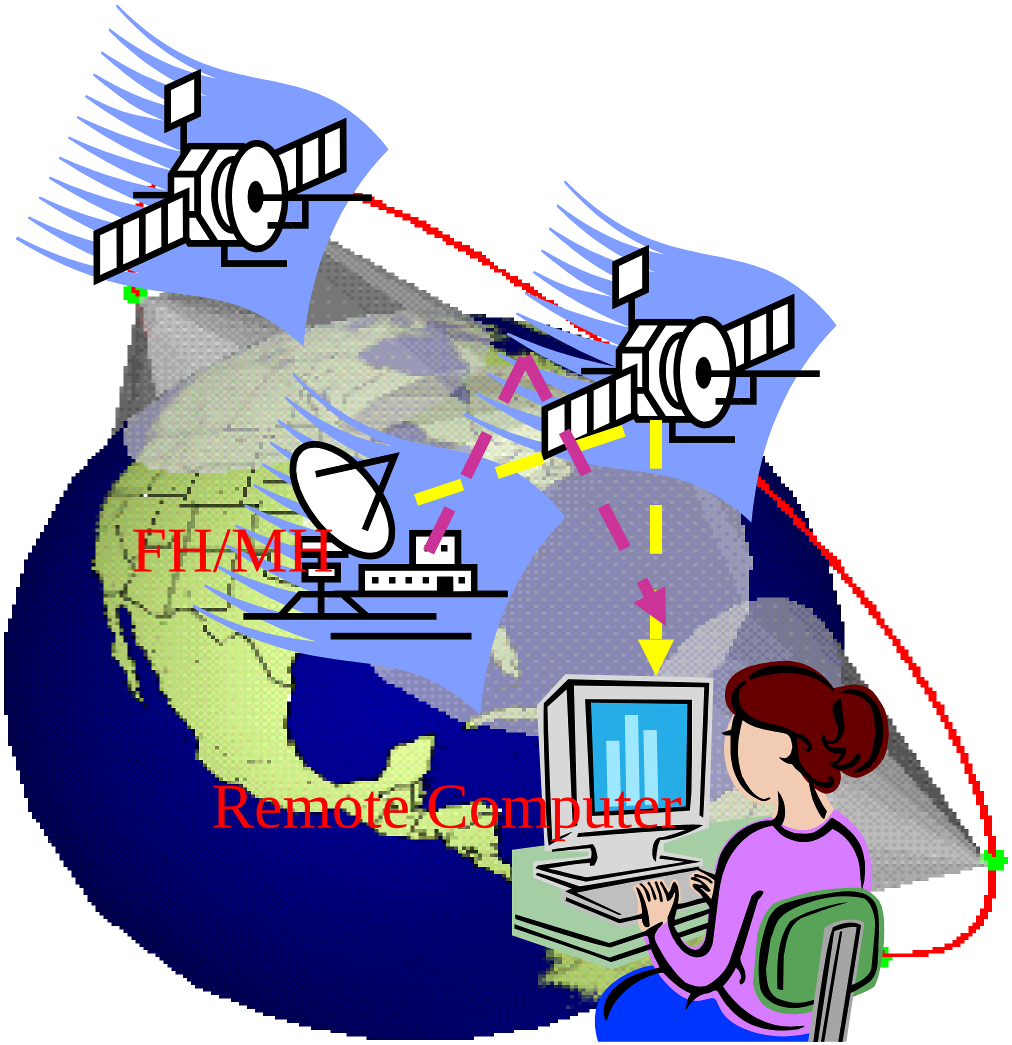
- Iridium design
  - 96 active satellites
  - 8 planes of 12.
- Satellite movement requires rerouting the on-going application to new Inter-satellite Links (ISL).



- 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.



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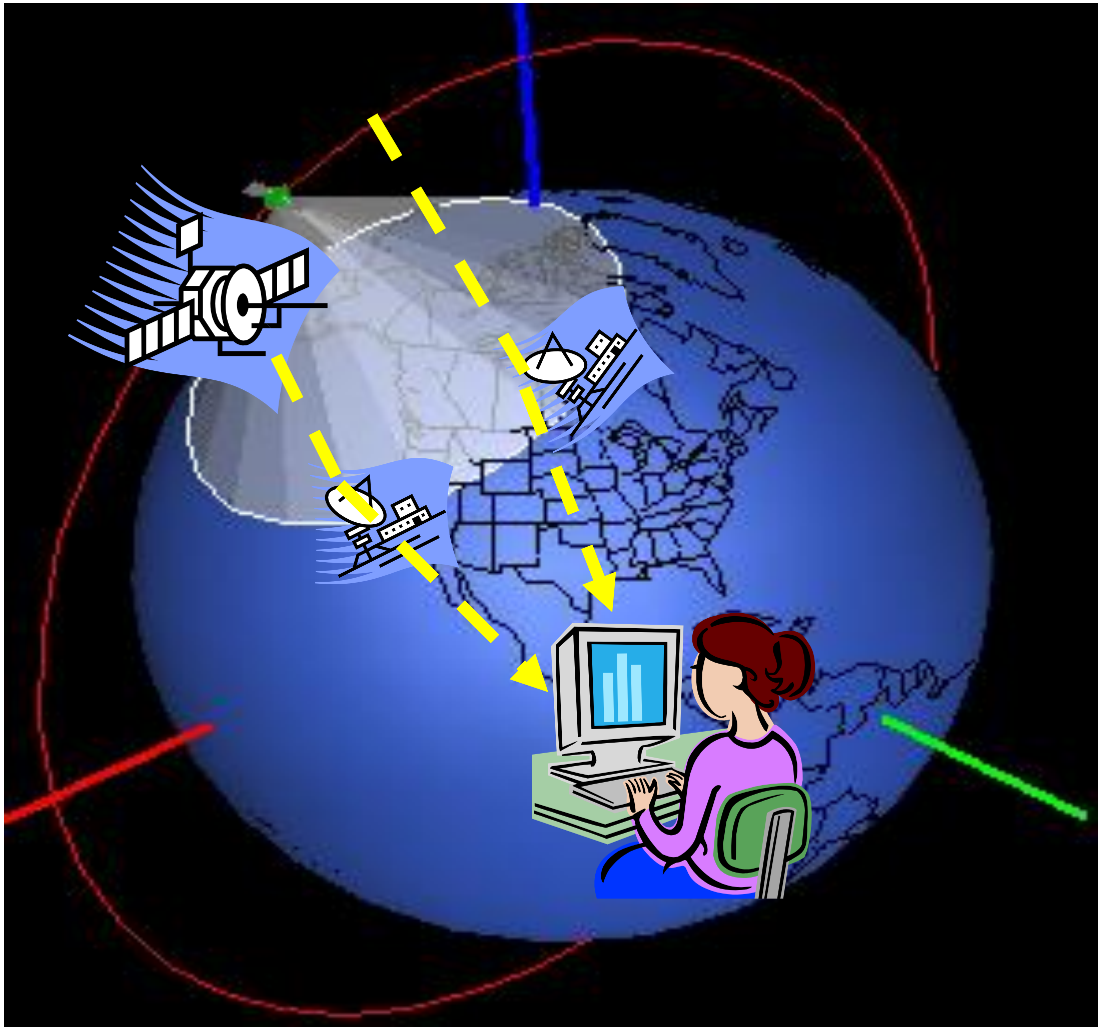
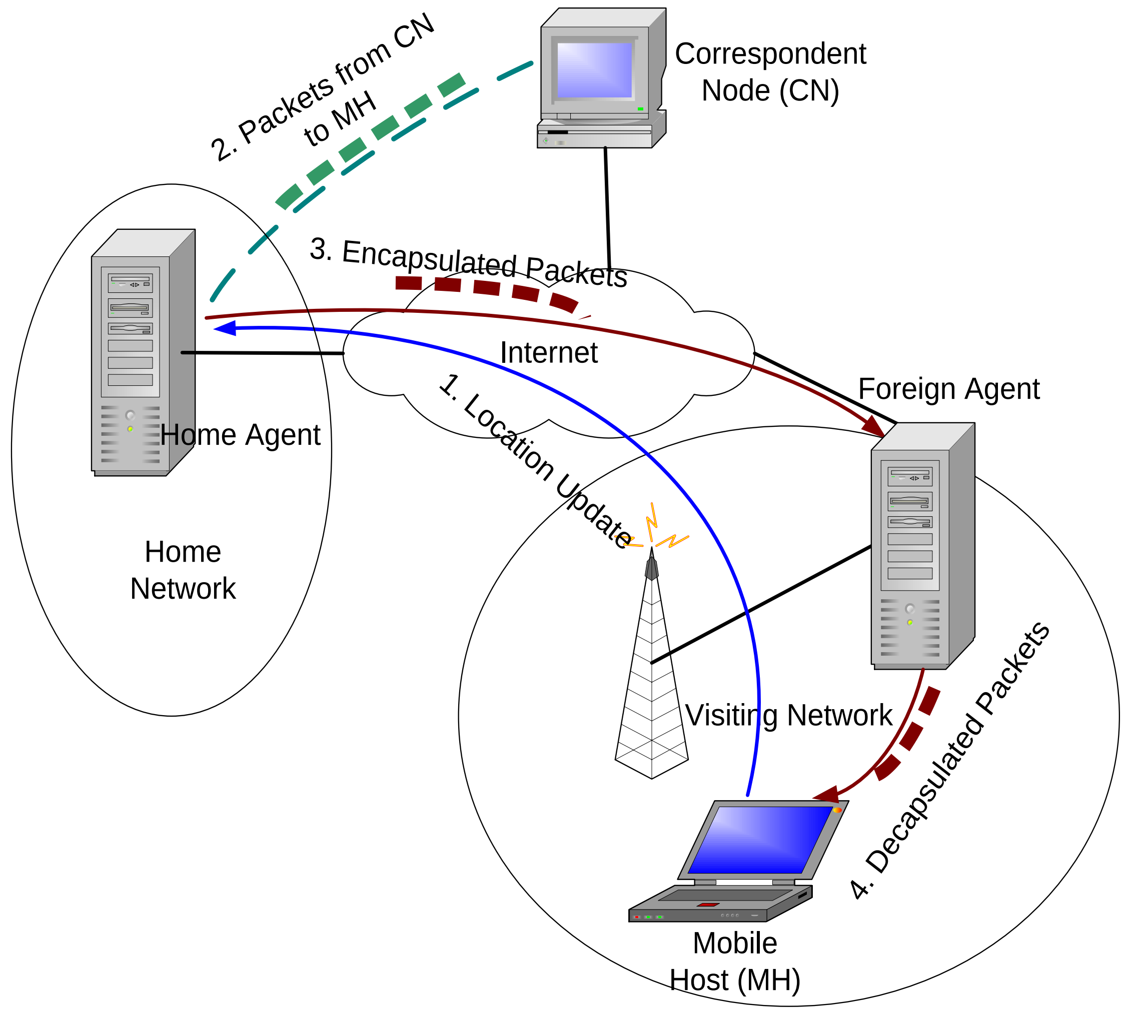
# Network Layer Handoff
# Case 2: satellite as a mobile host

- Equipment on board a satellite act as the *endpoint* of the communication.
- Ground stations are allocated with different IP prefix.
- Satellite need to maintain continuous connection with remote computer.



# 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

# SIGMA: Motivation

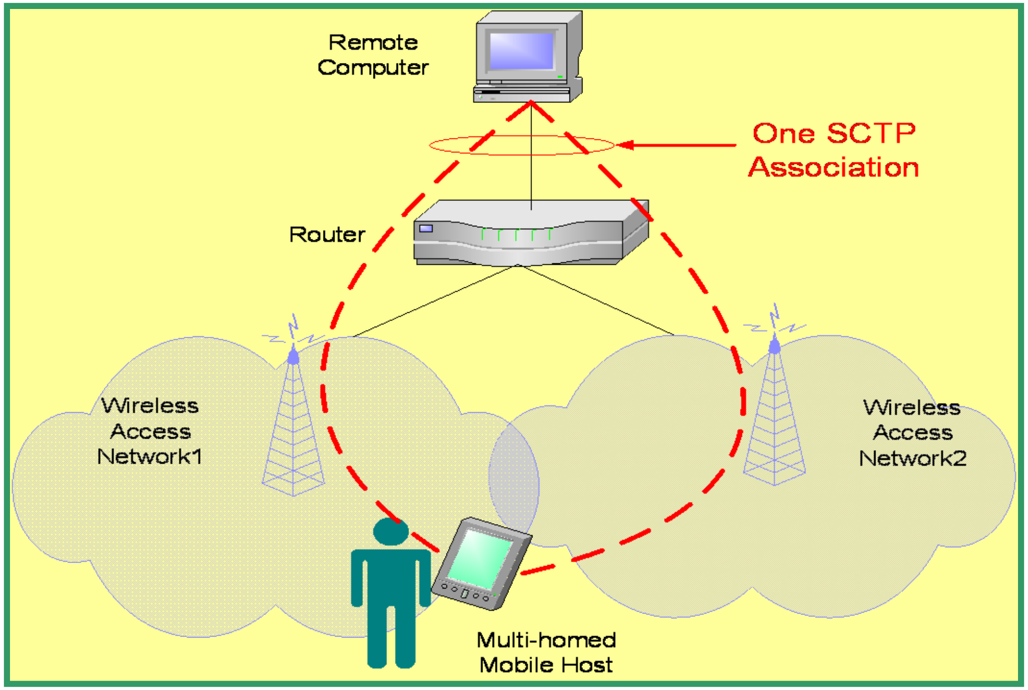
- Several NASA projects considering IP in space and Mobile IP
  - Global Precipitations Measurement (GPM)
  - Operating Missions as Nodes on the Internet (OMNI)
  - Communication and Navigation Demonstration on Shuttle (CANDOS)
  - NASA currently working with Cisco on developing a Mobile router
- Mobile 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).

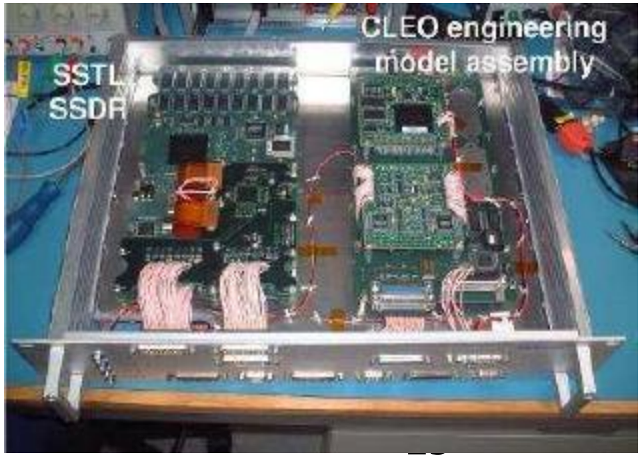
## SIGMA: Basic concepts

- 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 |

# Signaling

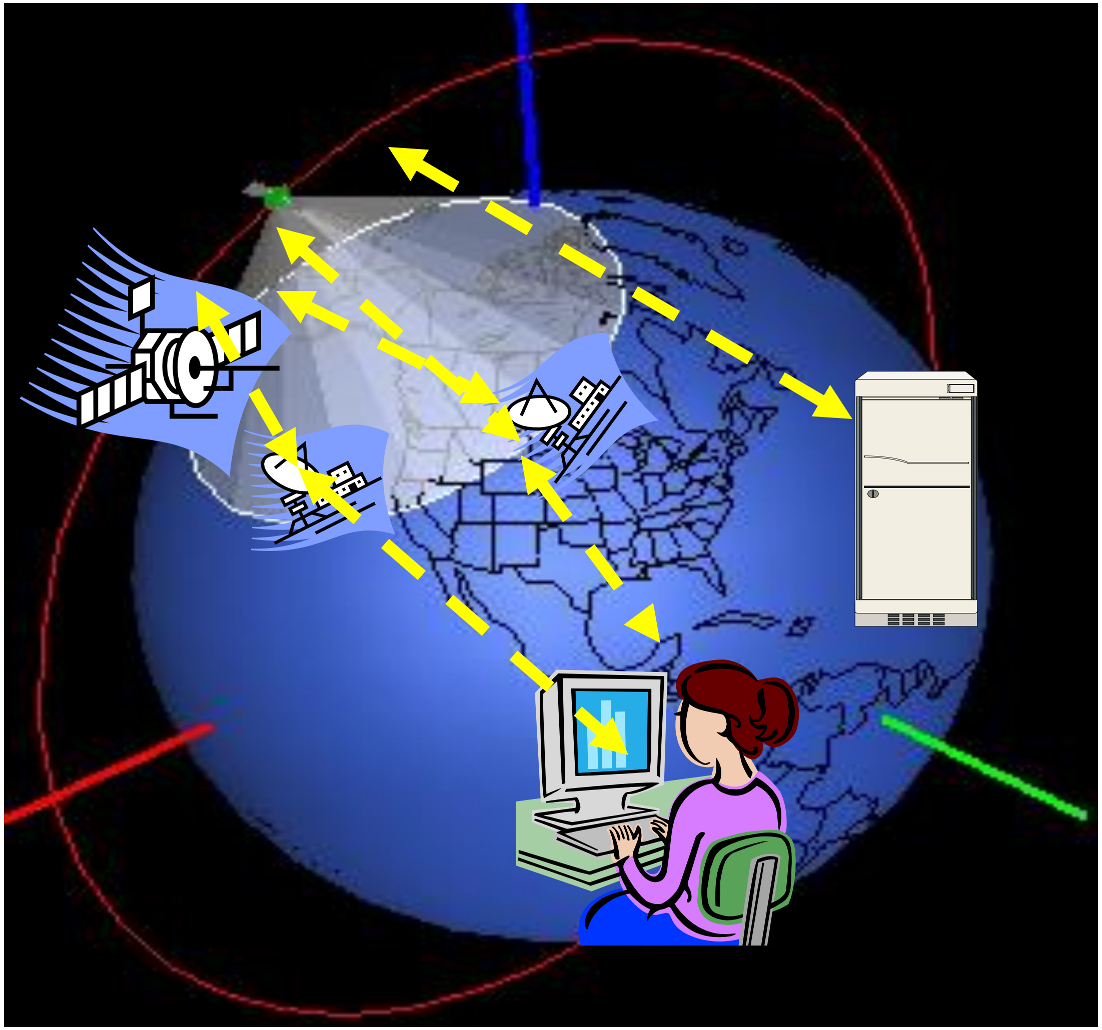
1.Satellite obtains a *new IP* address in new domain.

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

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

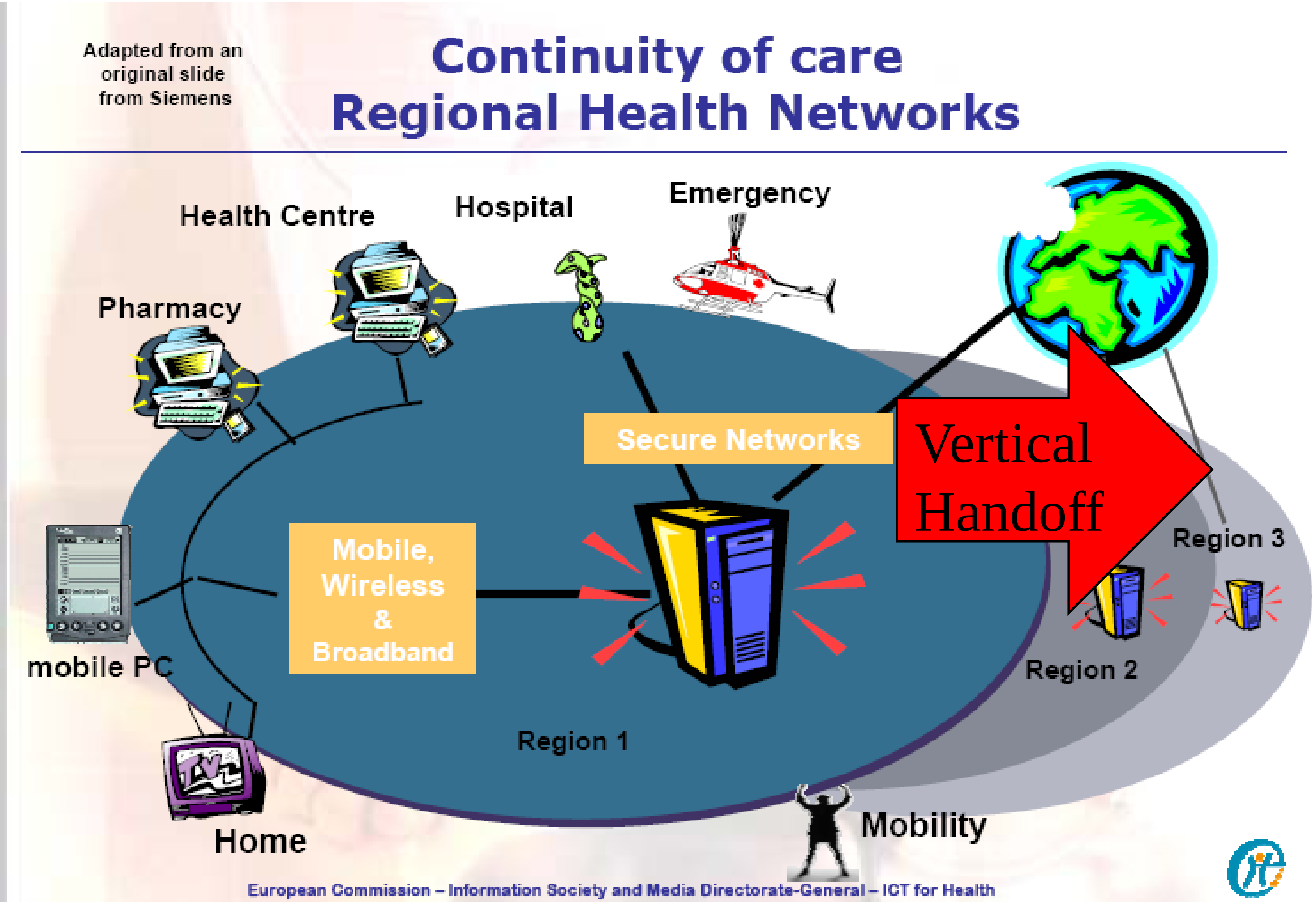
4.Update *Location Manager*.

5. Delete or *deactivate old IP* address.



# Vertical Handoff

# Handoff Between Different Technologies



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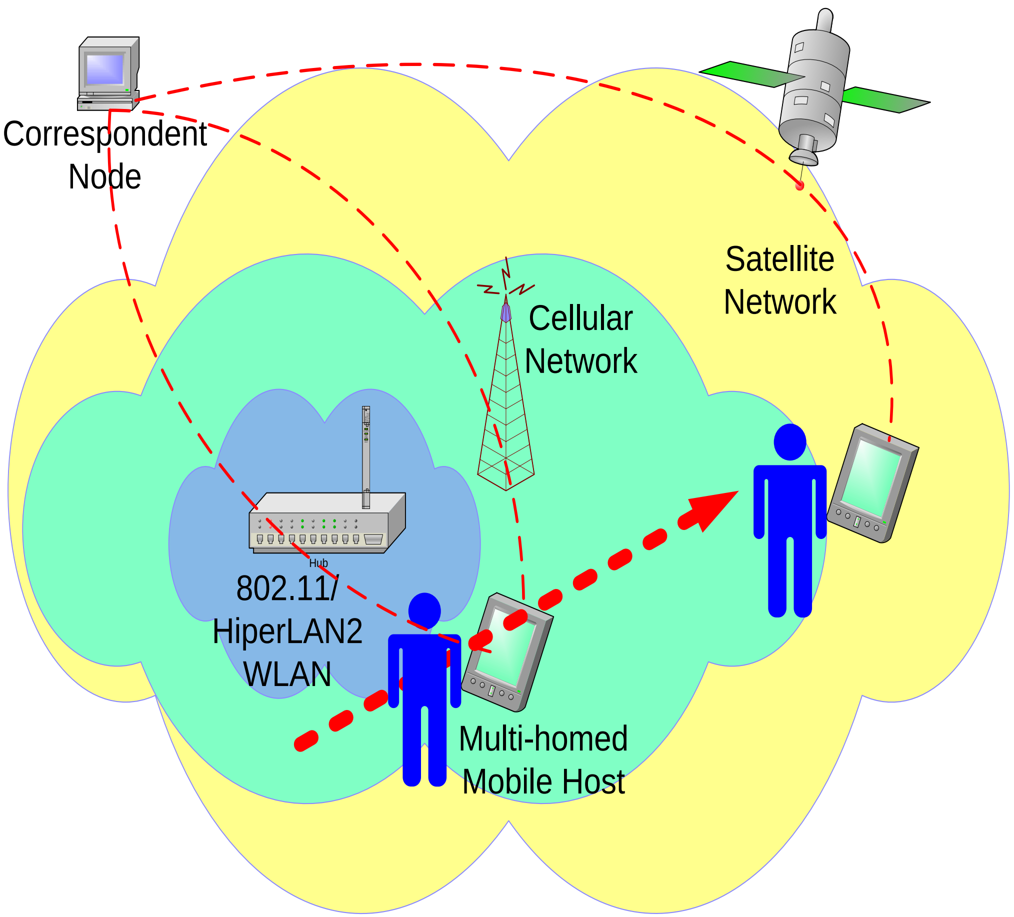
# SIGMA: Application to Vertical Handoff

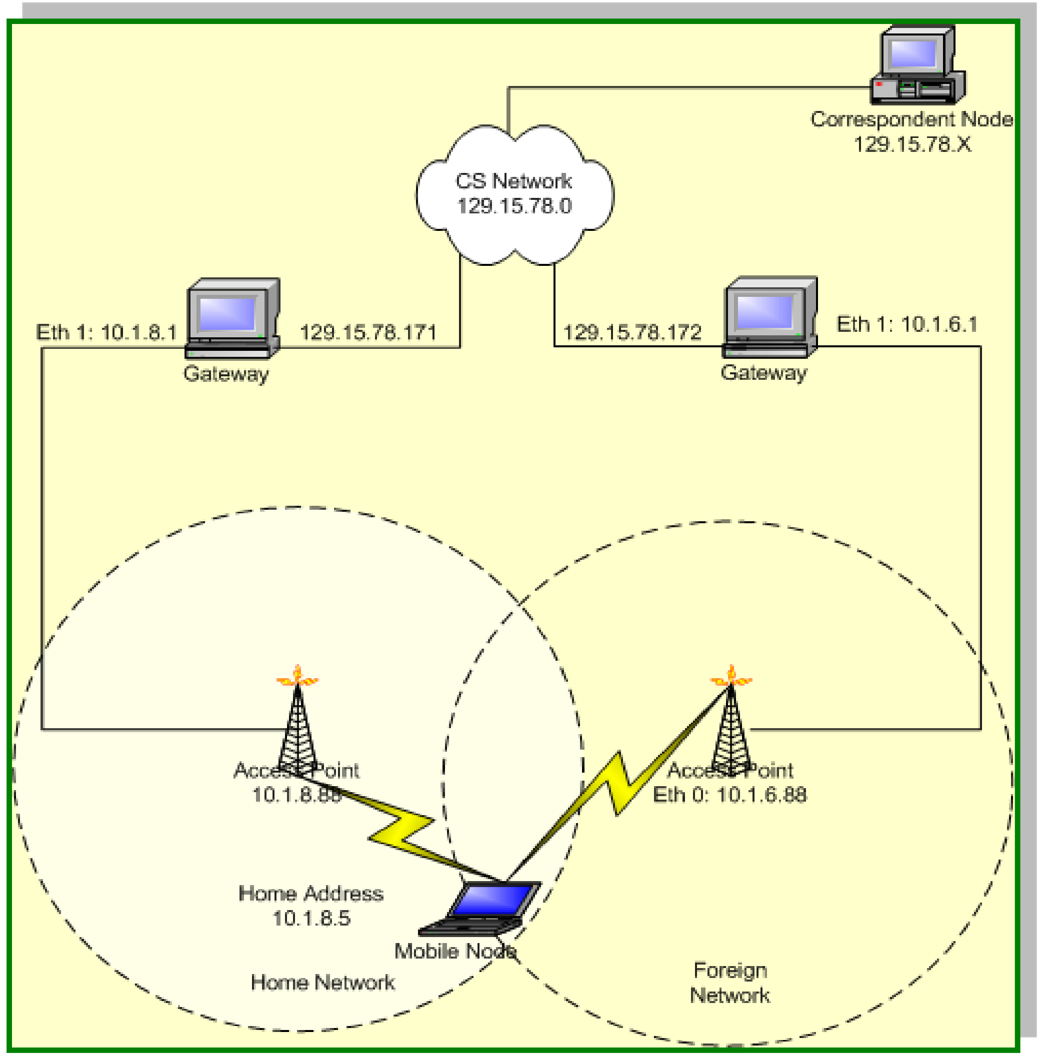
- *Different access network* technologies are integrating with each other to give mobile user a *transparent view of Internet*.
- Handover is no longer only limited to between two subnets in WLAN or between two cells in cellular network (horizontal handover).
- Mobile users are expecting seamless handover 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

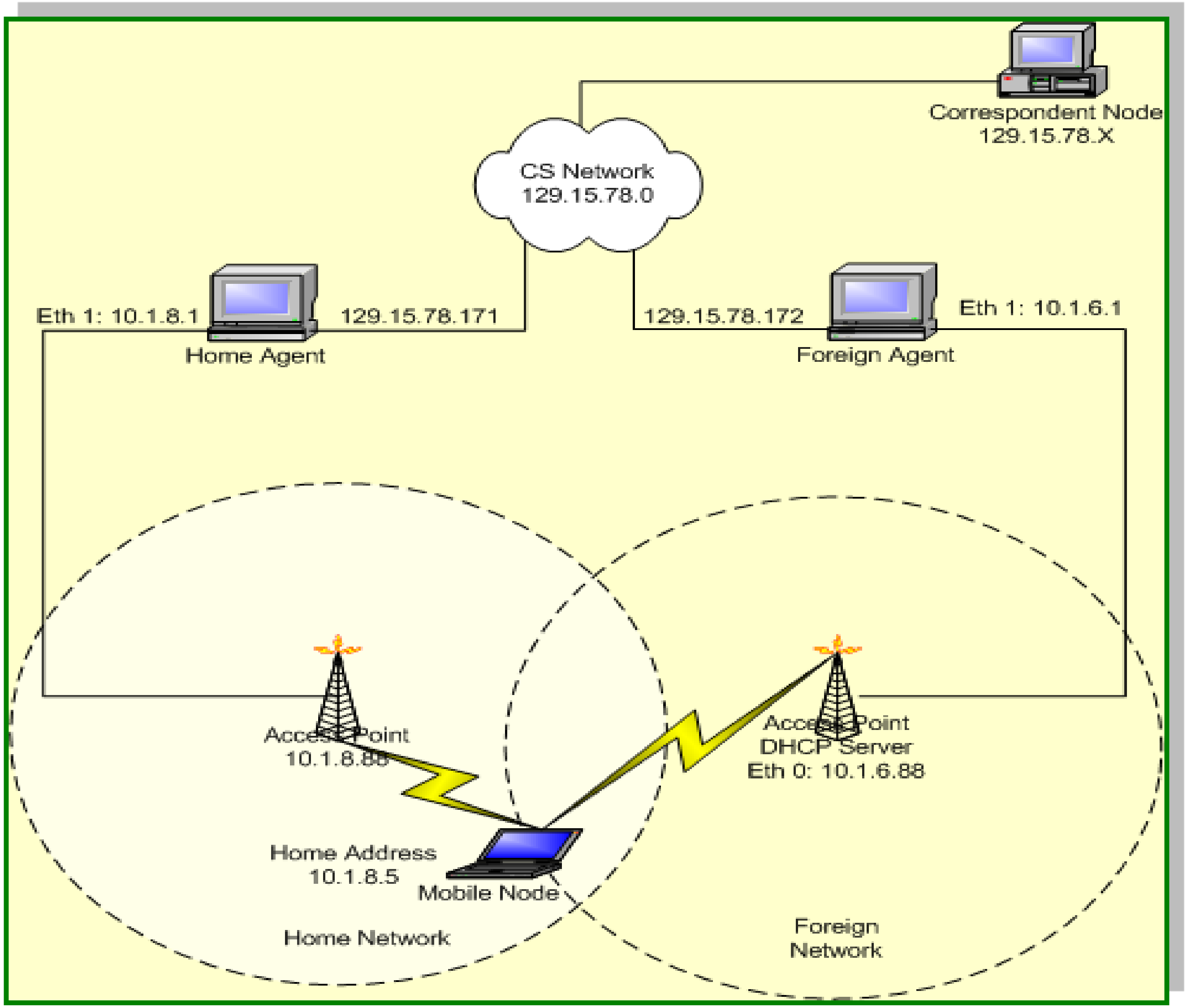
## Operation of SIGMA Testbed

- 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*.



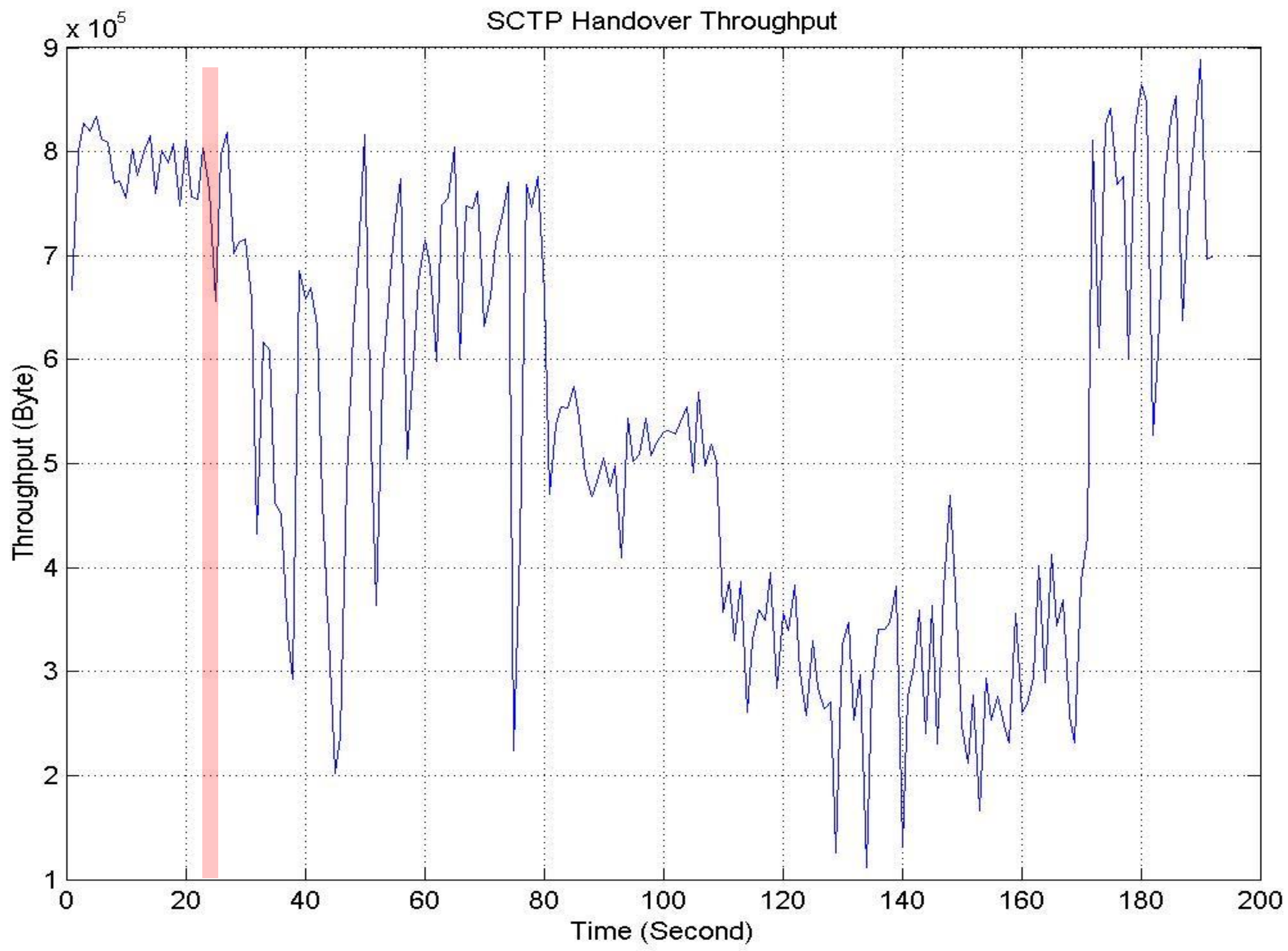

- lksctp reference implementation.
- Linux OS – Kernel 2.6.2.
- Network adapters
    - Avaya PCMCIA wireless network card and a NETGEAR USB wireless network card.

# Mobile IP Testbed

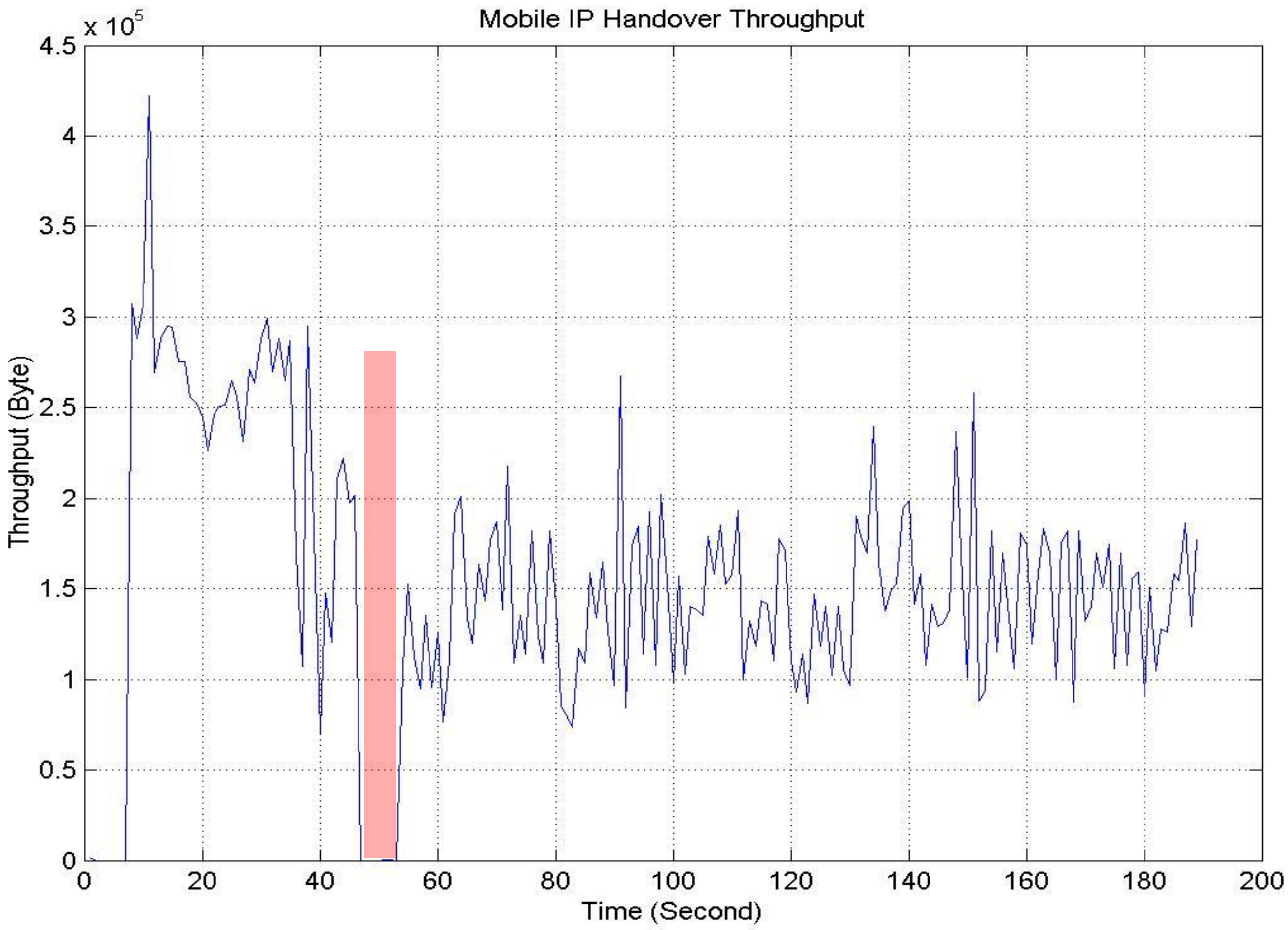


# Results

# SIGMA: Results



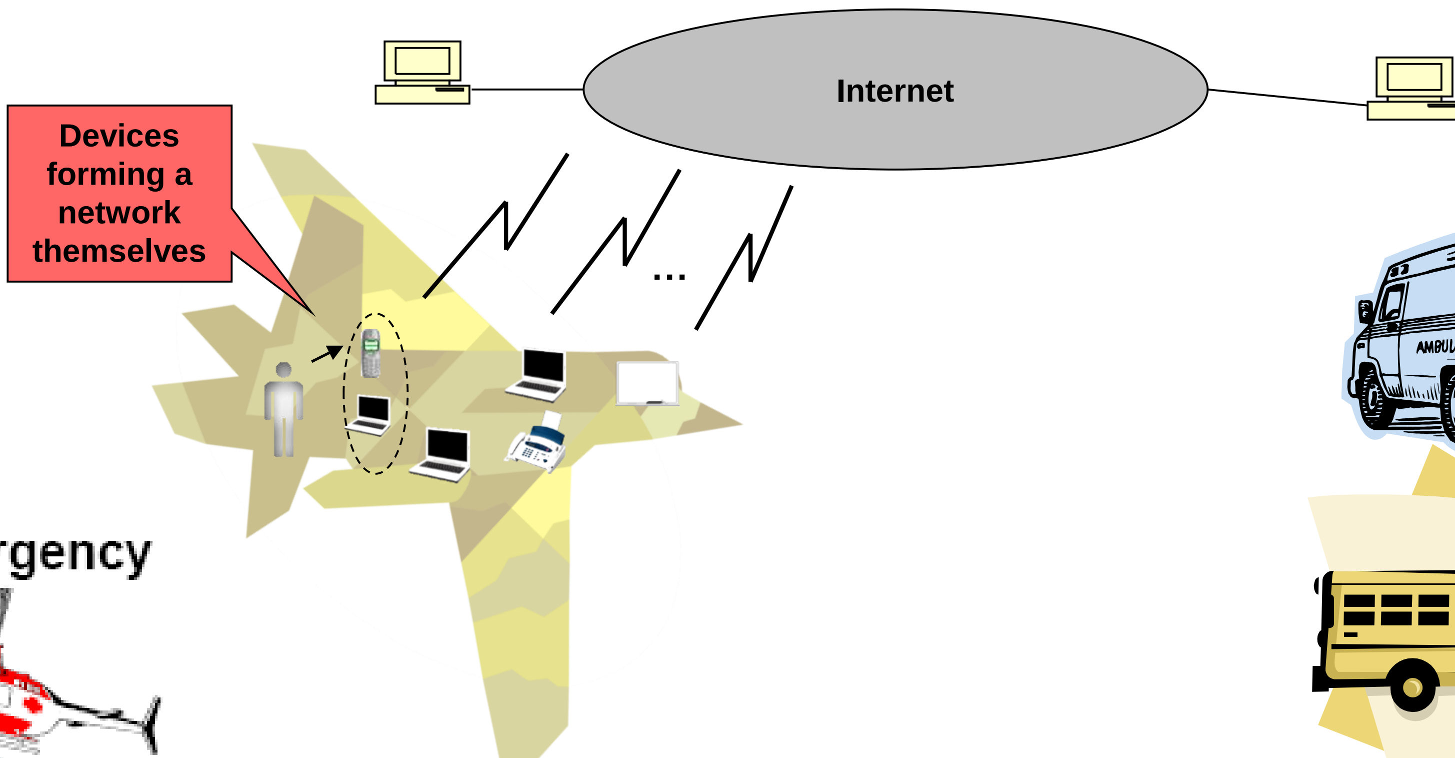
# Mobile IP: Results



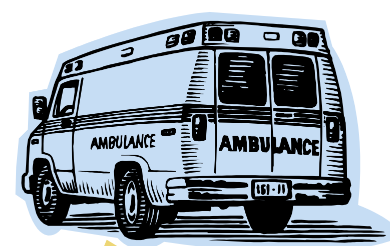
# Network Mobility

# Why NEMO?

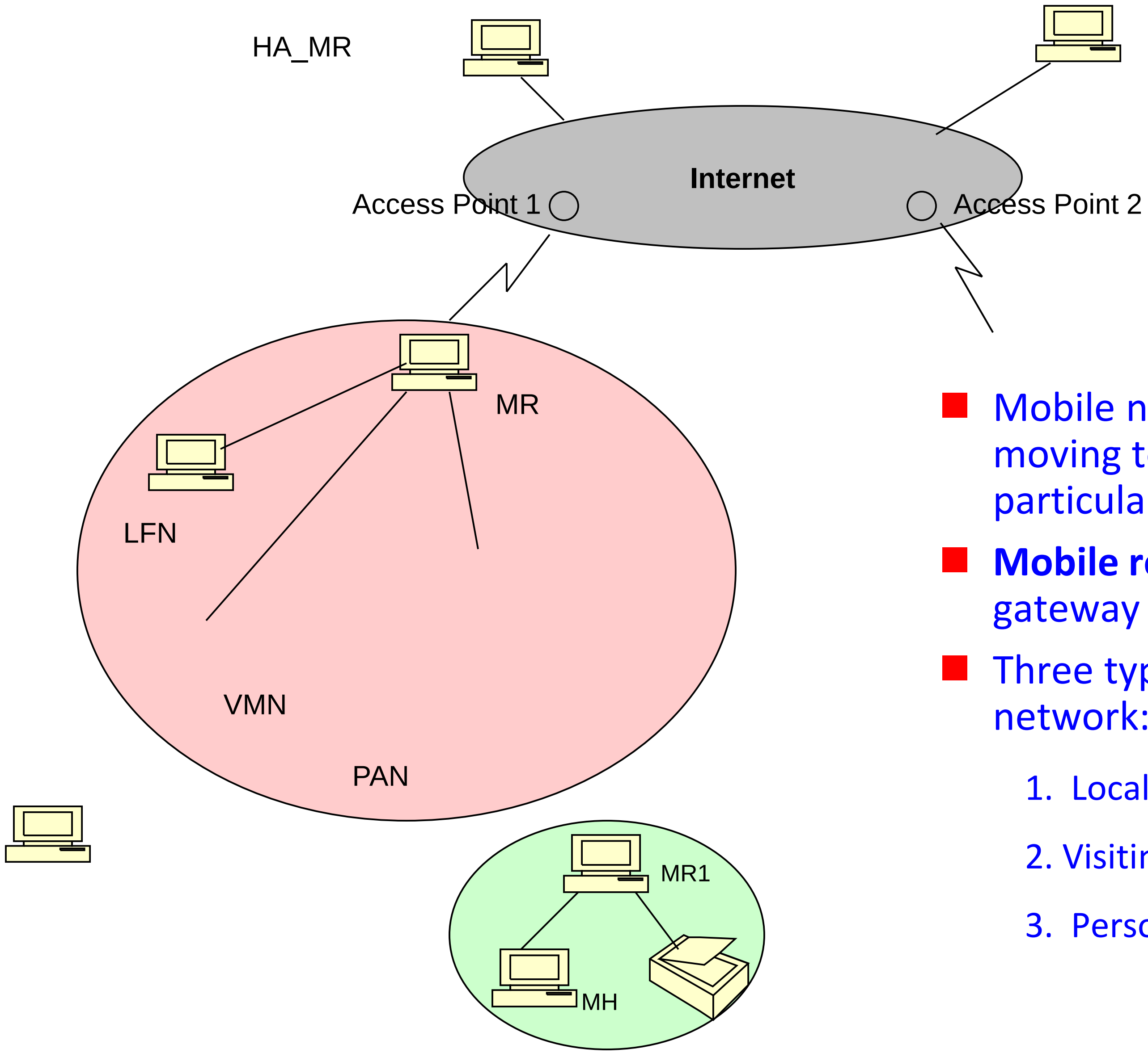
- Moving vehicles, ambulances, helicopters, and satellites may contain several IP enabled devices
  - Ex: computers, data collecting equipments, PDAs, observing equipment
- Each mobile device can *individually manage its mobility* using MIPv6
  - Requires lot of signaling messages over the precious wireless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





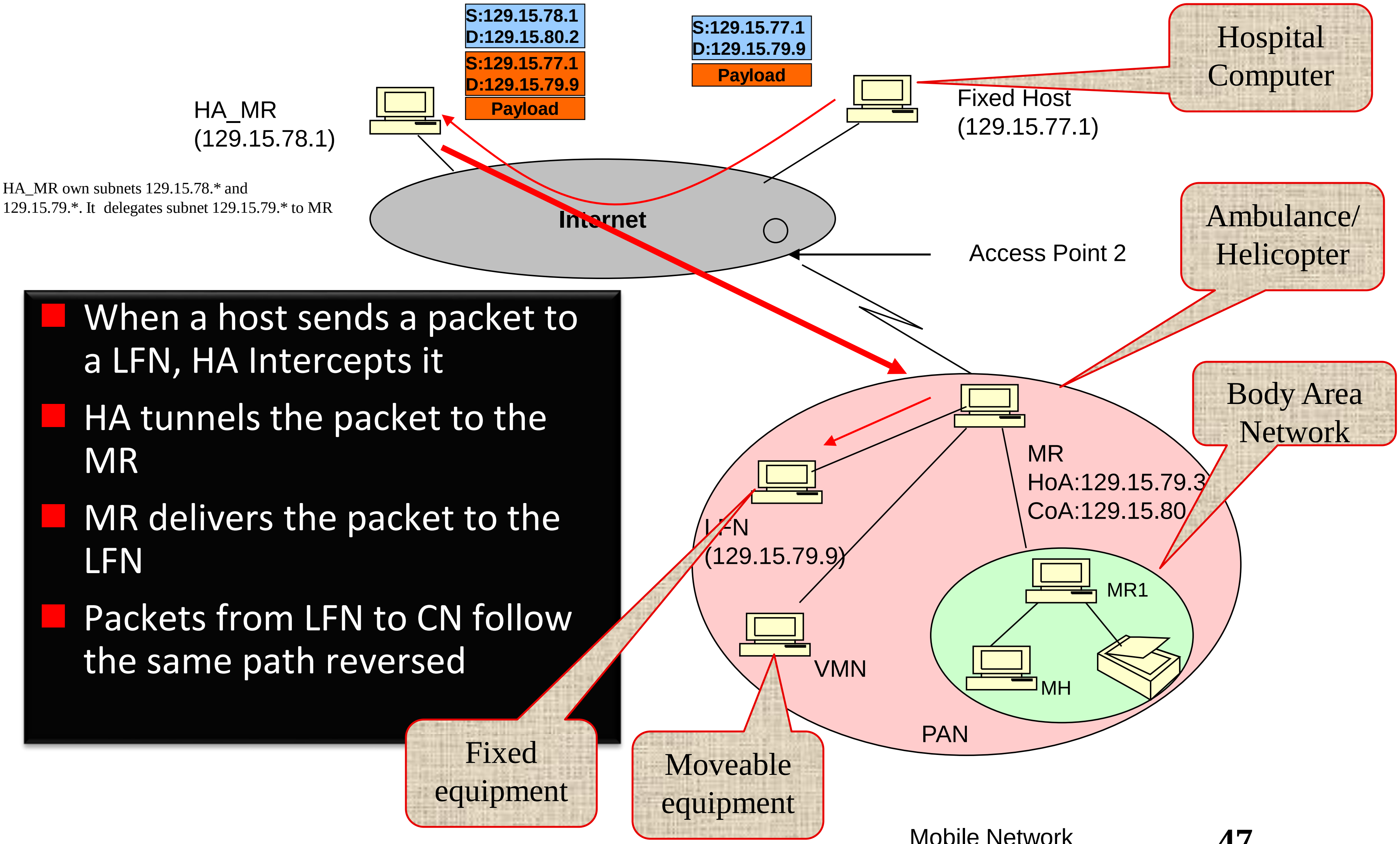



# NEtwork MObility (NEMO)




- 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)

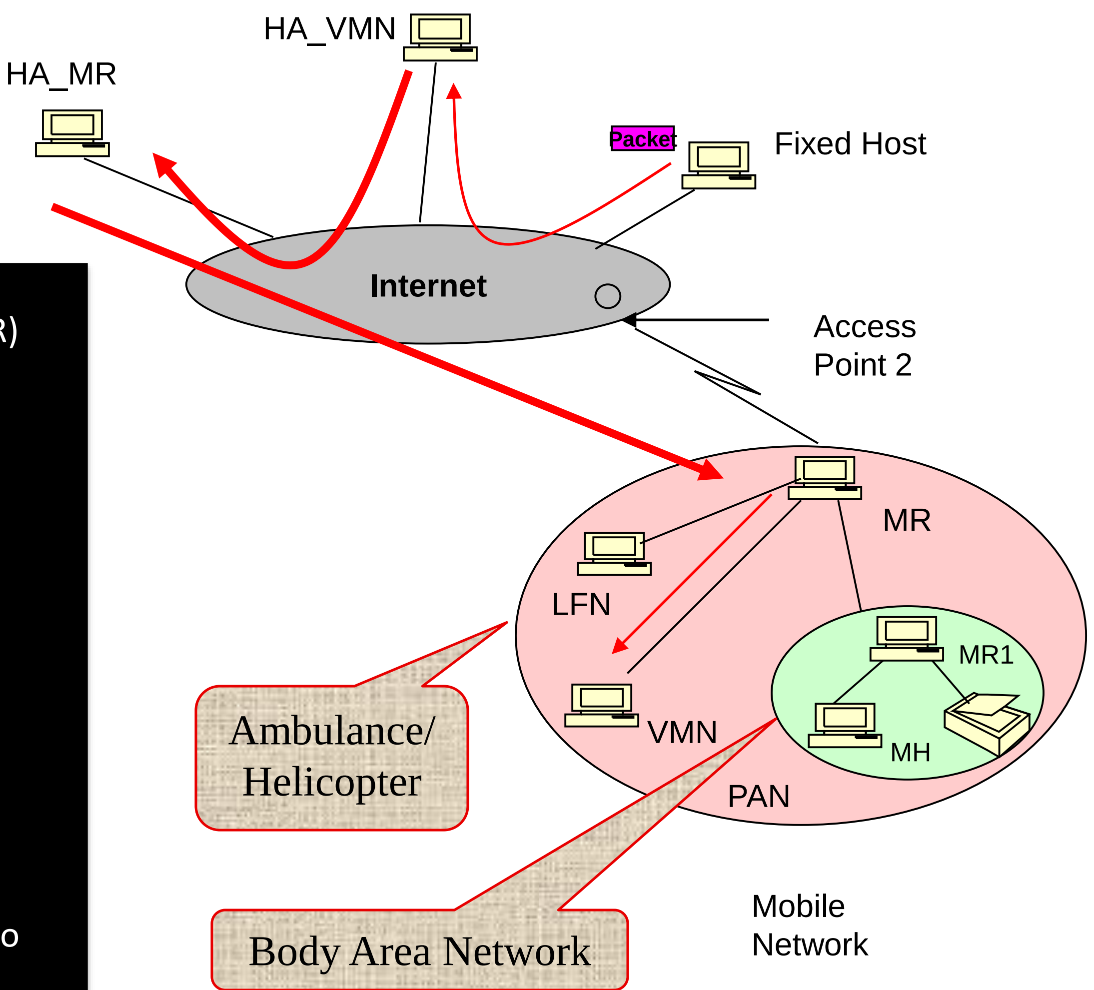
# NEMO: Routing for Local Fixed Node (LFN)




- 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

# 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



# Limitations of NEMO BSP

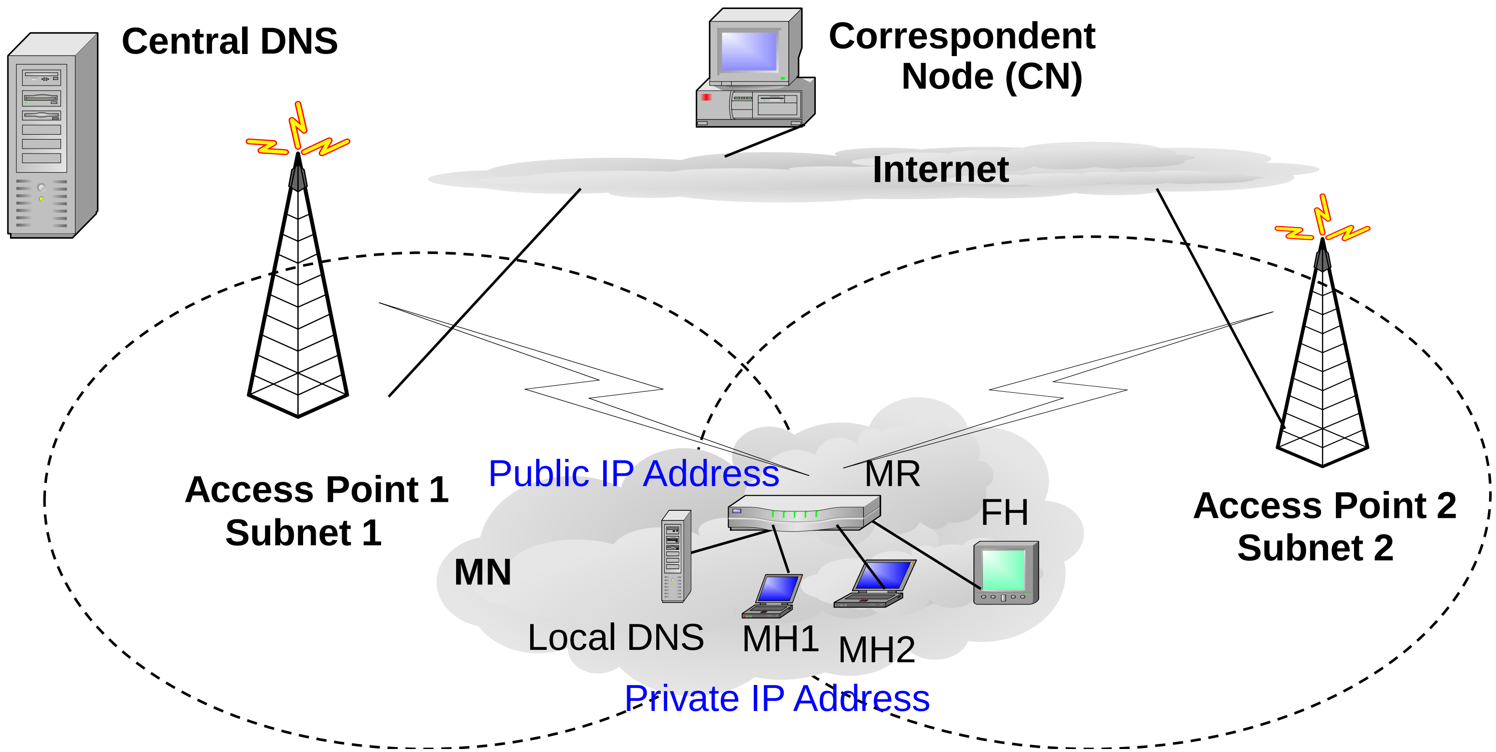
- *Inefficient routing* specially in case of nesting and visiting mobile nodes
- Header *overhead* due to *tunneling* encapsulation
- Other drawbacks of MIPv6 are *inherited* by NEMO BSP

# SINEMO – SIGMA for NEMO

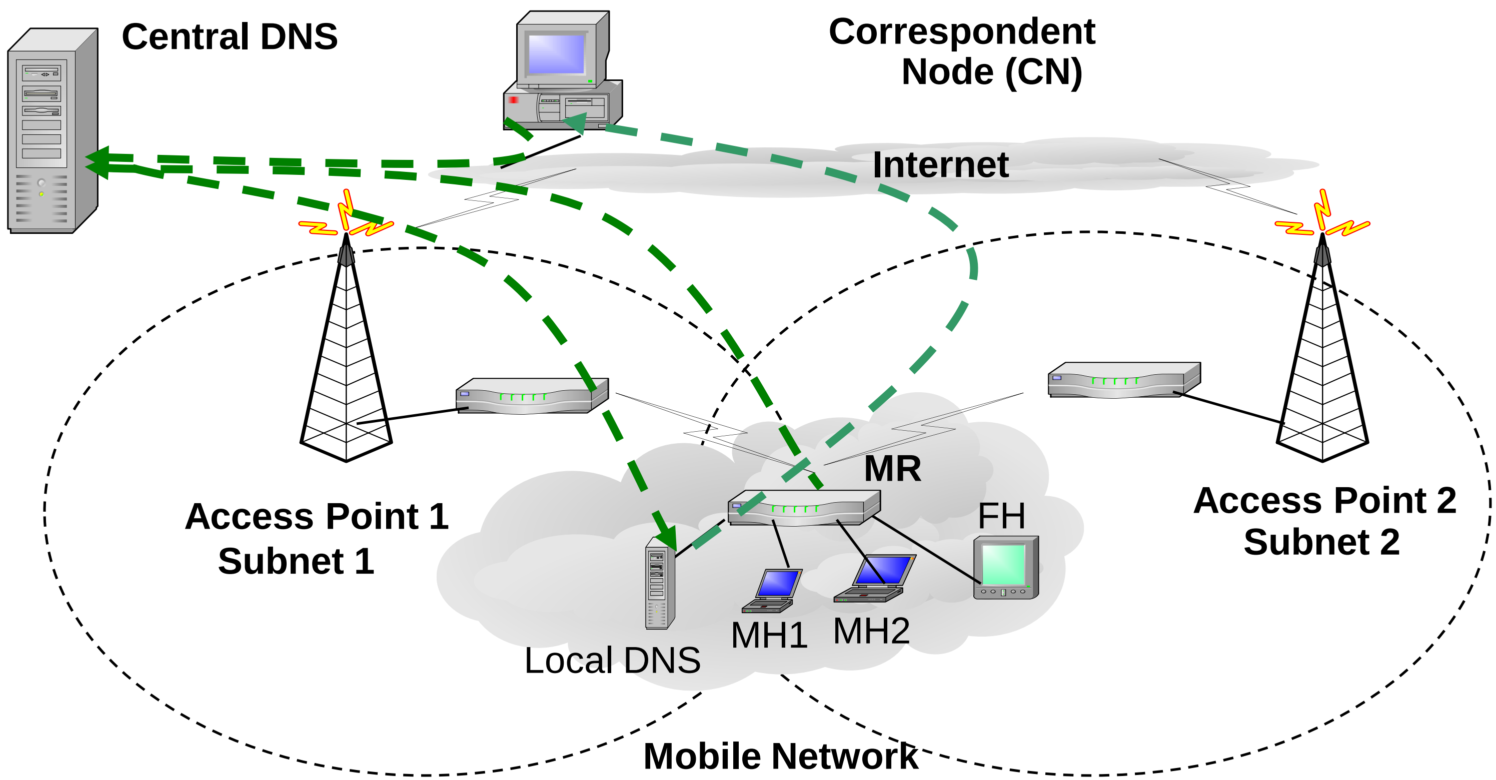
- Seamless IP-diversity based NEtwork MObility.
  - Uses IP-diversity to hand over between subnets.

- 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.




- 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.

# 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 |

- 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

- National Aeronautics and Space Administration (NASA) and Cisco for funding of this project
- The following people are participating/participated in the design, development and testing of SIGMA and SINEMO
  - Shaojian Fu (Opnet)
  - Yong-Jin Lee (Korea National University of Education)
  - Justin Jones (Riskmetrics)
  - Suren Sivagurunathan (Yousendit)
  - Abu Sayeem Reaz (Univ. of California, Davis)
  - Abu Shahriar (Univ. of Oklahoma)
  - Md. Shohrab Hossain (Univ. of Oklahoma)
  - William Ivancic (NASA)
  - Wesley Eddy (NASA)
  - David Stewart (NASA)
  - Lloyd Wood (Cisco)


Further information: atiq@ou.edu

www.cs.ou.edu/~atiq

# Thank you

Contact info


Mohammed Atiquzzaman

atiq@ou.edu

(405) 325 8077

www.cs.ou.edu/~atiq