



Applicability and Performance of NEMO in Satellite Networks

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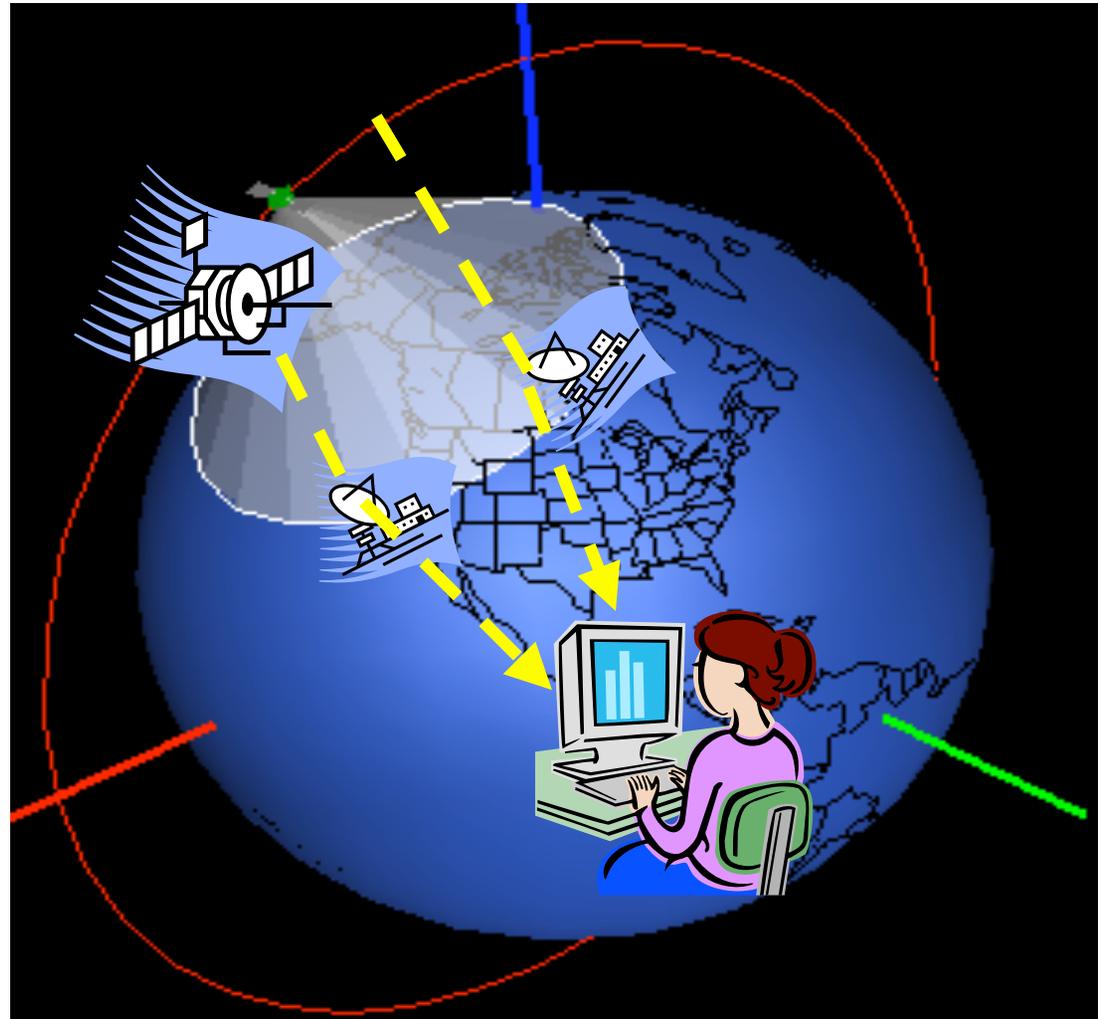


- Why Network MObility (NEMO)?
- NEMO Architecture
- NEMO BSP
- NEMO in Satellite networks
 - ÿ Basic NEMO
 - ÿ Nested NEMO
- Best MR selection for handoff
- Requirement for Performance evaluation
- Satellite network characteristics
- TCP for satellite network
- Saratoga: A file transfer protocol for satellite network
- Ongoing and Future work



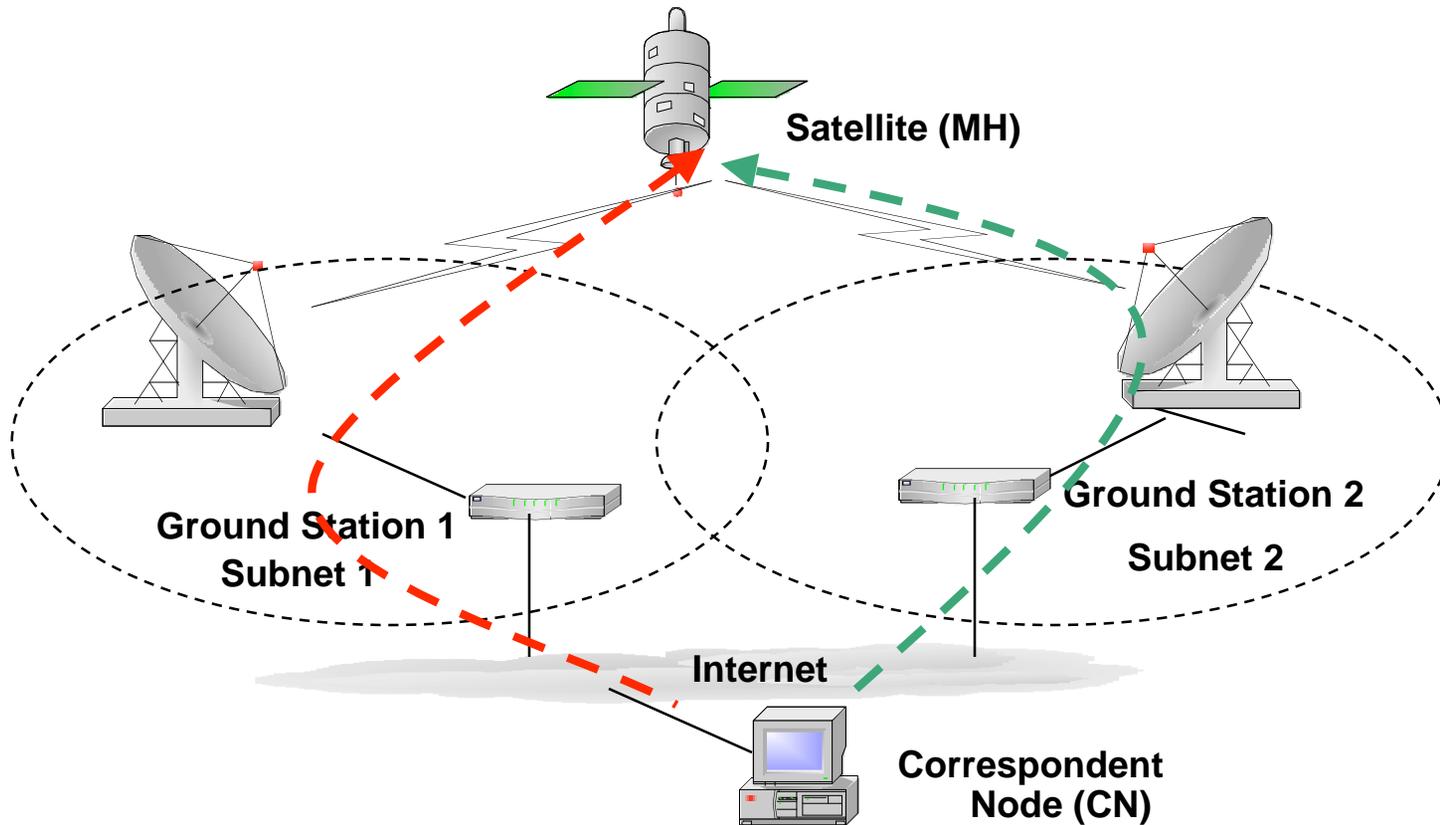
IP level handoffs in satellite networks

- 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.





Motivation: SIGMA for Mobility in Space



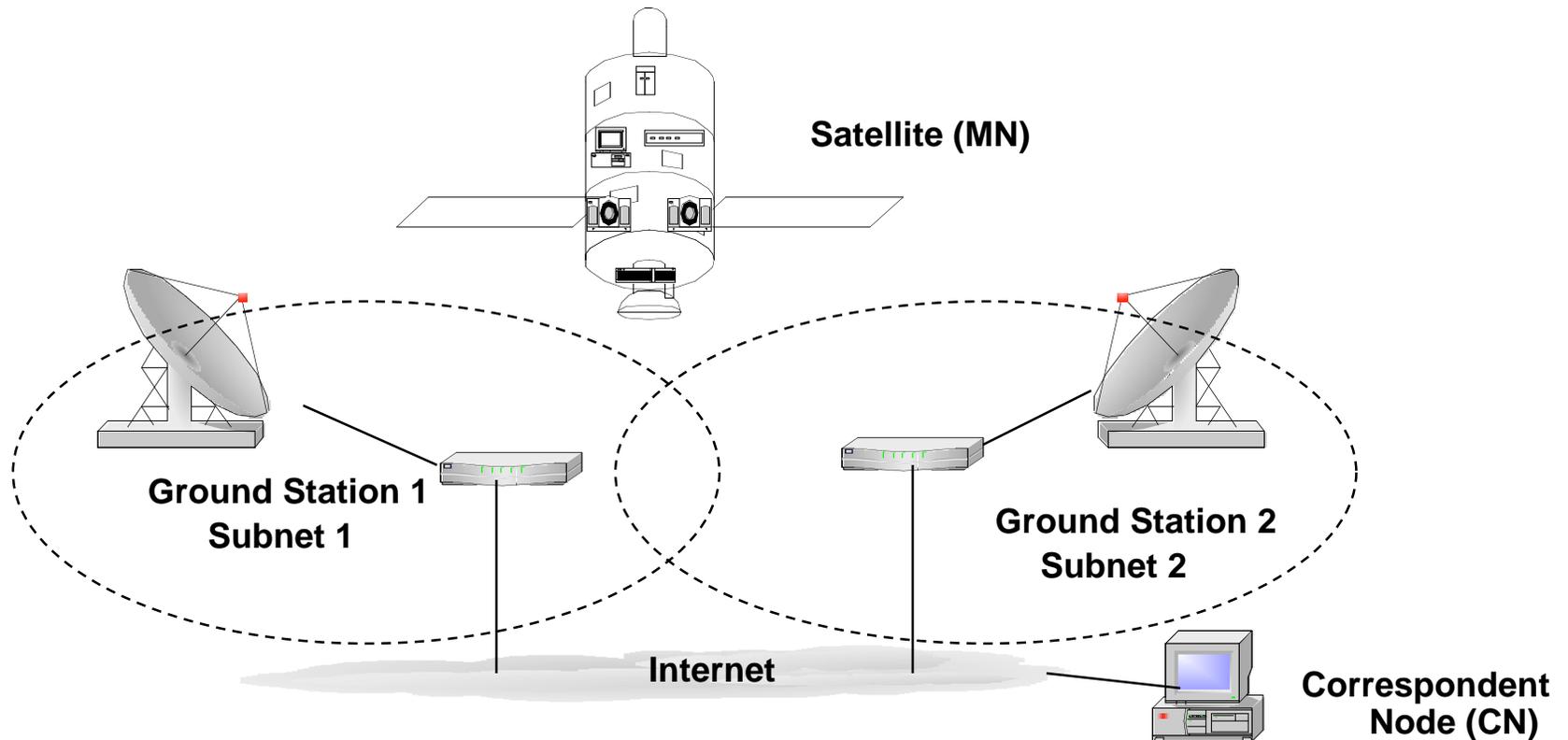
■ SIGMA

- IP diversity for seamless handover of a satellite between ground stations.
- considers satellite as a mobile host (only one IP address).





Motivation: Satellite as a Mobile Network



- **Satellite may be a Mobile Network (MN)**
 - onboard MR and other IP enabled devices.
- **SIGMA does not support the mobility of a MN.**



■ Earth Observing Satellites – TERRA

- ÿ Moderate Resolution Imaging Spectroradiometer (MODIS)
- ÿ Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
- ÿ Multi-angle Imaging Spectro-Radiometer (MISR)
- ÿ Measurement of Pollution in the Troposphere (MOPITT)

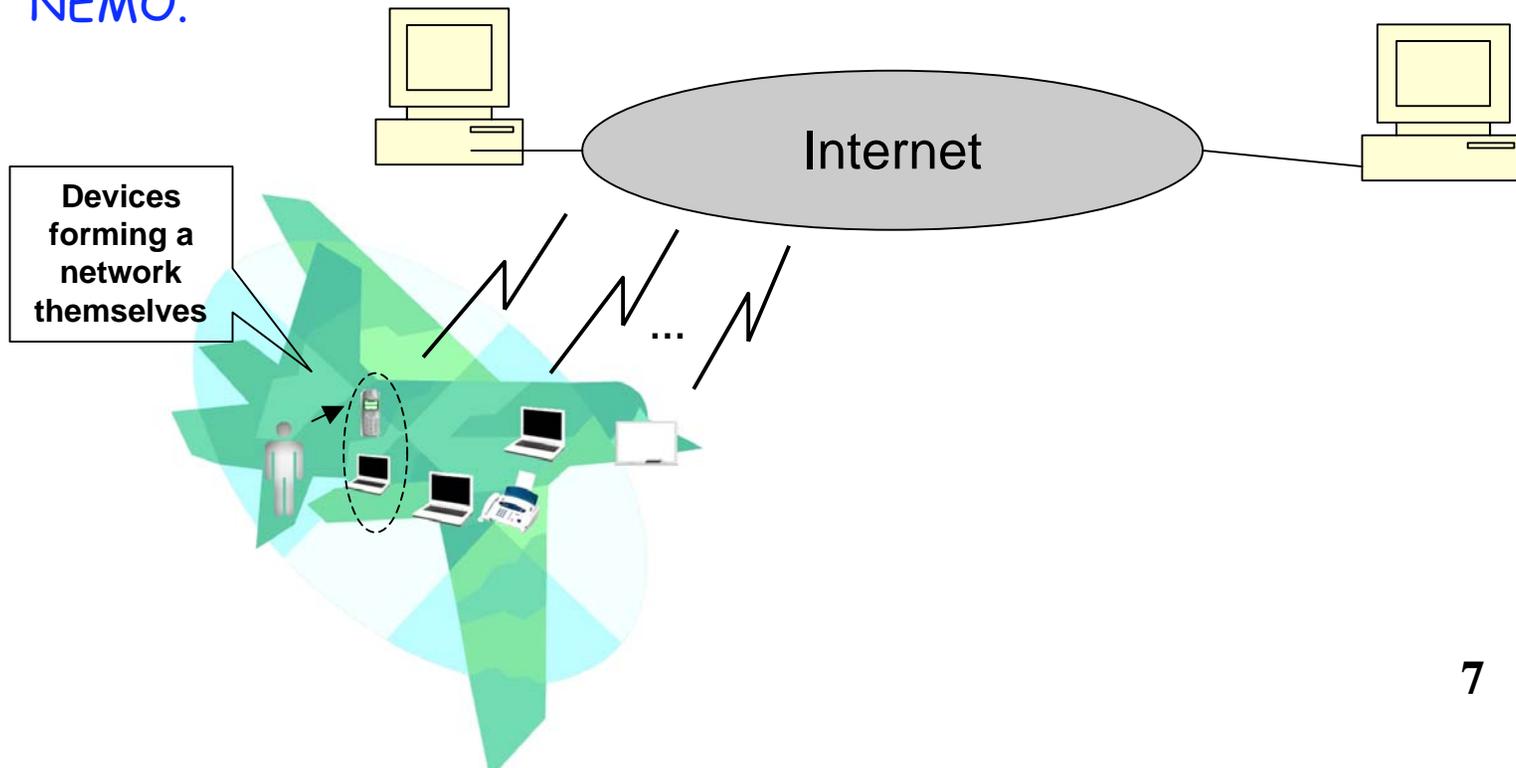
■ VMOC Satellite – UK-DMC

- ÿ CLEO Mobile Router – developed by CISCO
- ÿ Multispectral Imager
- ÿ IP-enabled Computers



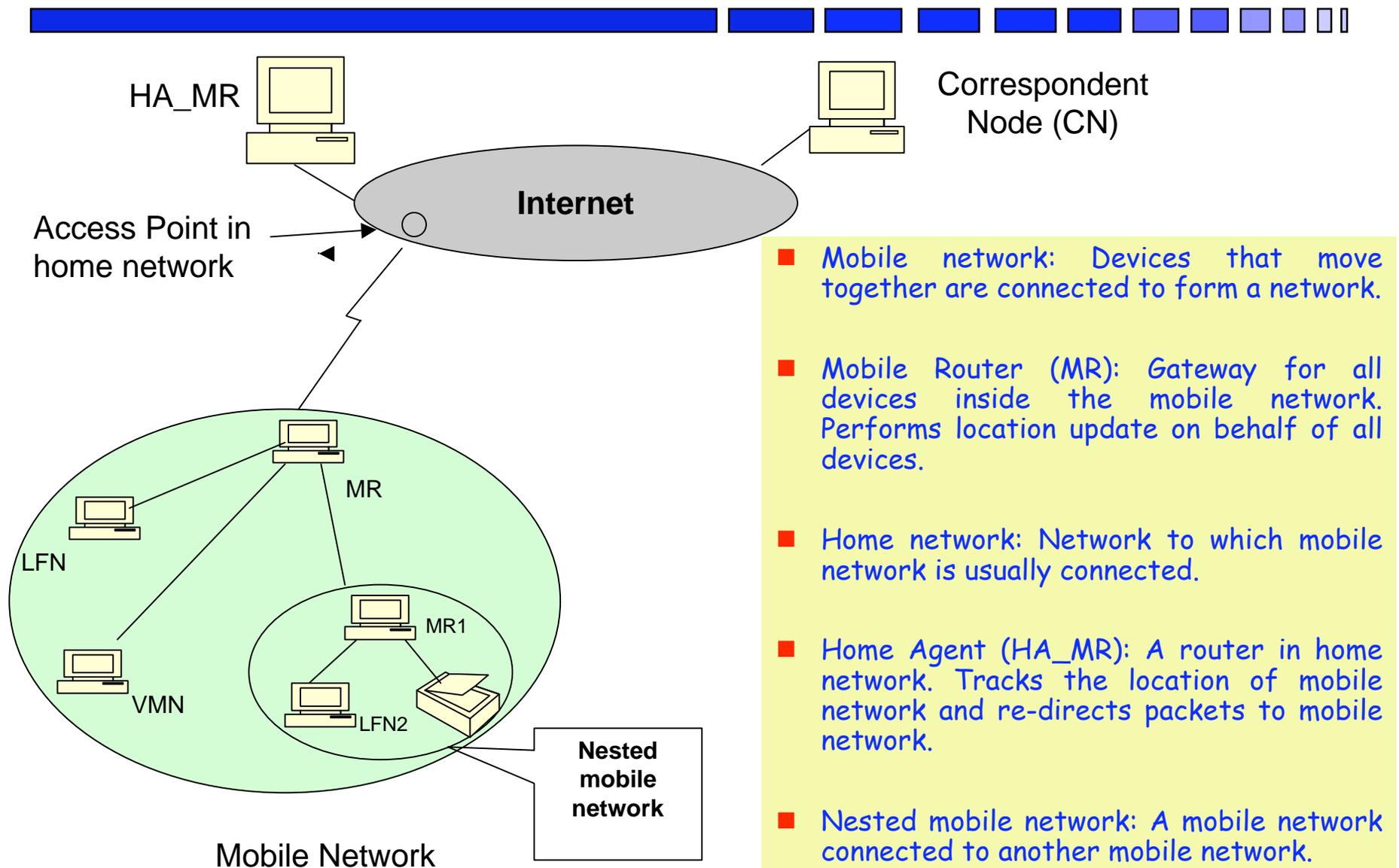
Why NETWORK MOBILITY (NEMO)?

- Vehicles (airplanes, trains, ships) may contain several IP enabled devices, e.g. computers, PDA, data collecting equipment, etc. which move together.
- Each device can individually manage its mobility using host mobility protocols.
 - ÿ Requires lot of signaling messages over the bandwidth-limited wireless link
- Devices may not be able to communicate because of limited communication power.
- Could this mobility be managed in an aggregated way? Yes that is why NEMO.



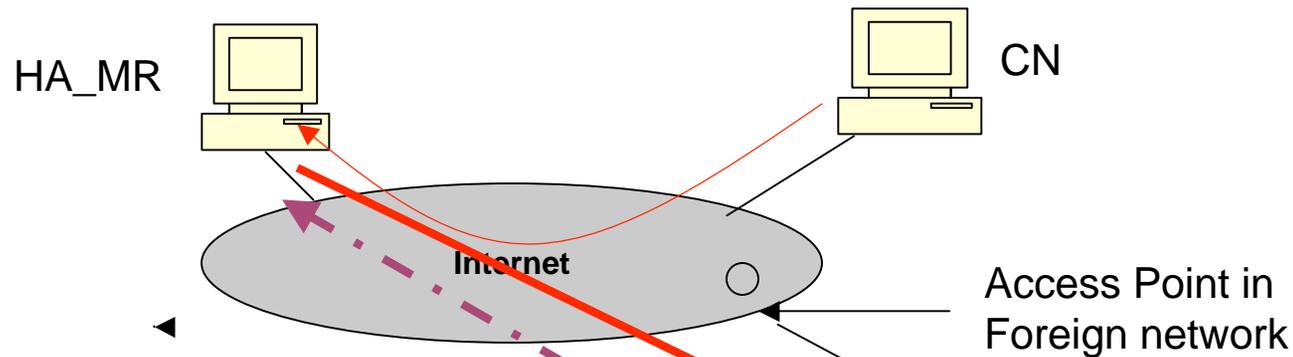


NEMO: Architecture



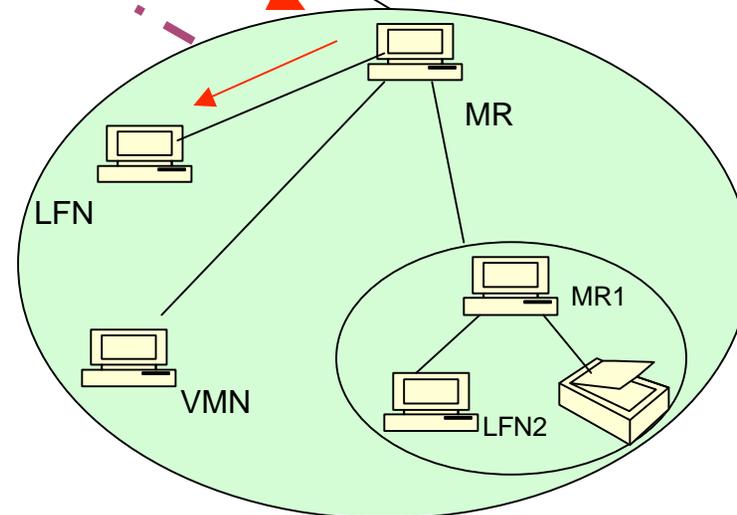


NEMO Basic Support Protocol (BSP)



Operation

- New address and prefix of the mobile network is sent to Home Agent by sending Binding Update (BU)
- Packets sent to mobile network are intercepted by Home Agent
- Home Agent encapsulates and forwards packets to mobile router
- Mobile router forwards the packet inside the mobile network
- Advantages over host mobility protocols
- Increased manageability and reduced complexity
- Reduced transmission power
- Reduced handoff signaling

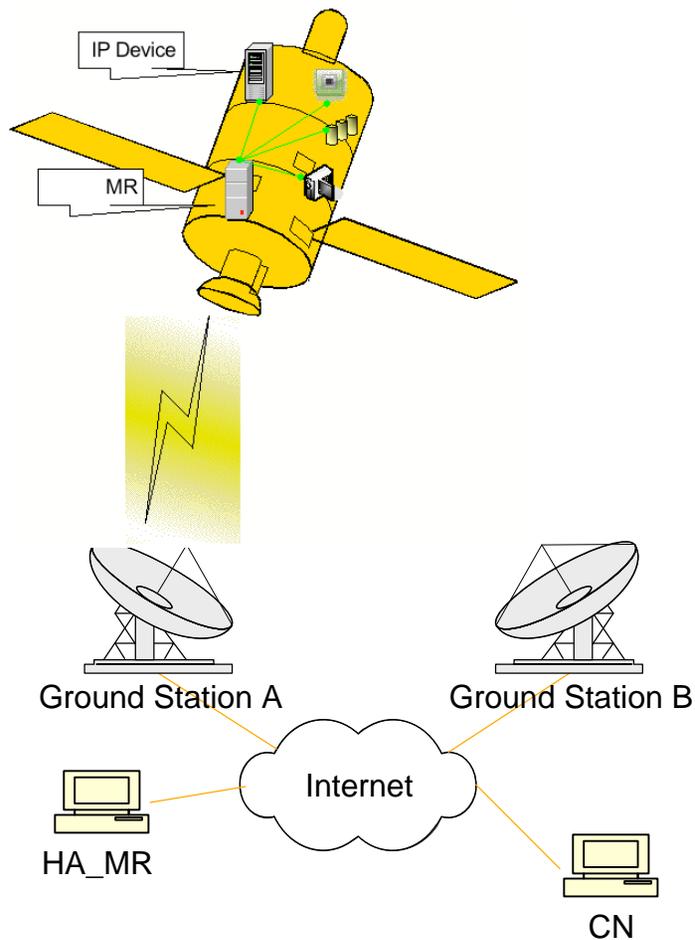


Mobile Network



NEMO in satellite networks

- Satellites containing many IP-enabled devices → network in motion.
- On-board network hands off between ground stations.

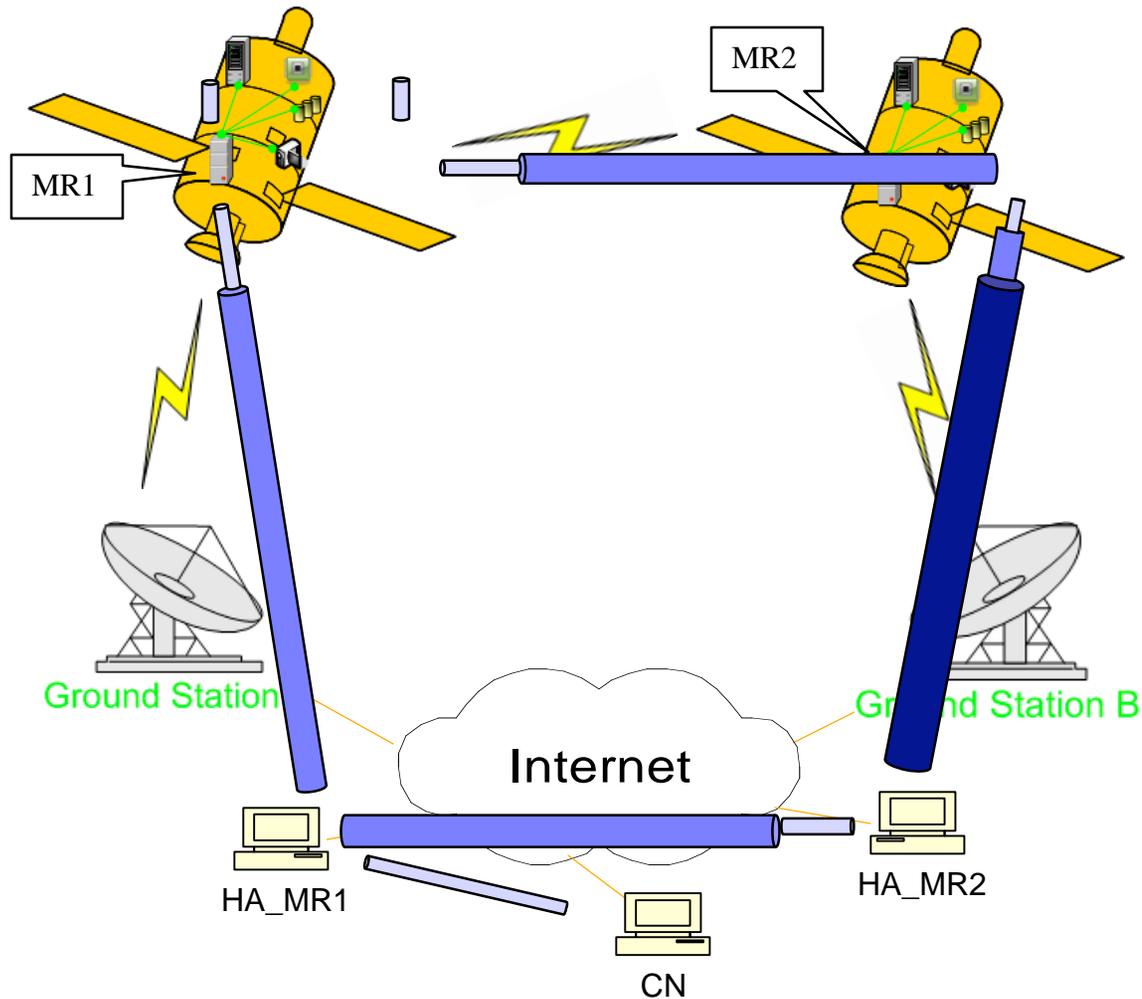




Nested NEMO in satellite networks



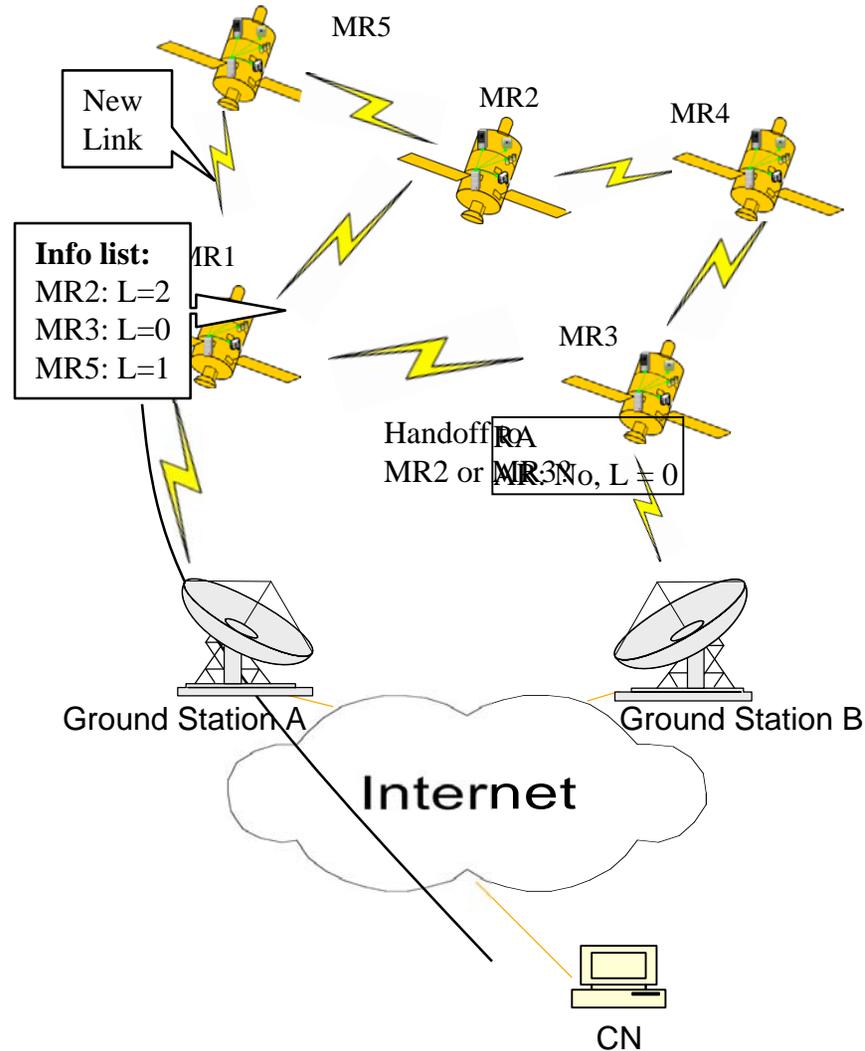
- Nested NEMO can be used to continue IP connectivity.





Best MR/AR selection for handoff

- MR having link level connection to multiple neighboring MRs.
- New links can appear over time.
- Best MR/AR selection required-
 - Ÿ When connection with Internet is lost.
 - Ÿ Router Advertisement (RA) is received.
- Information required for selection :
 - Ÿ In RA:
 - Ÿ MR/ AR indicator.
 - Ÿ Nesting level of neighboring MR
 - Ÿ Handoff frequency in recent times.
- Neighboring MRs' information can be maintained and updated to assist in selection.





Best MR/AR selection continued...

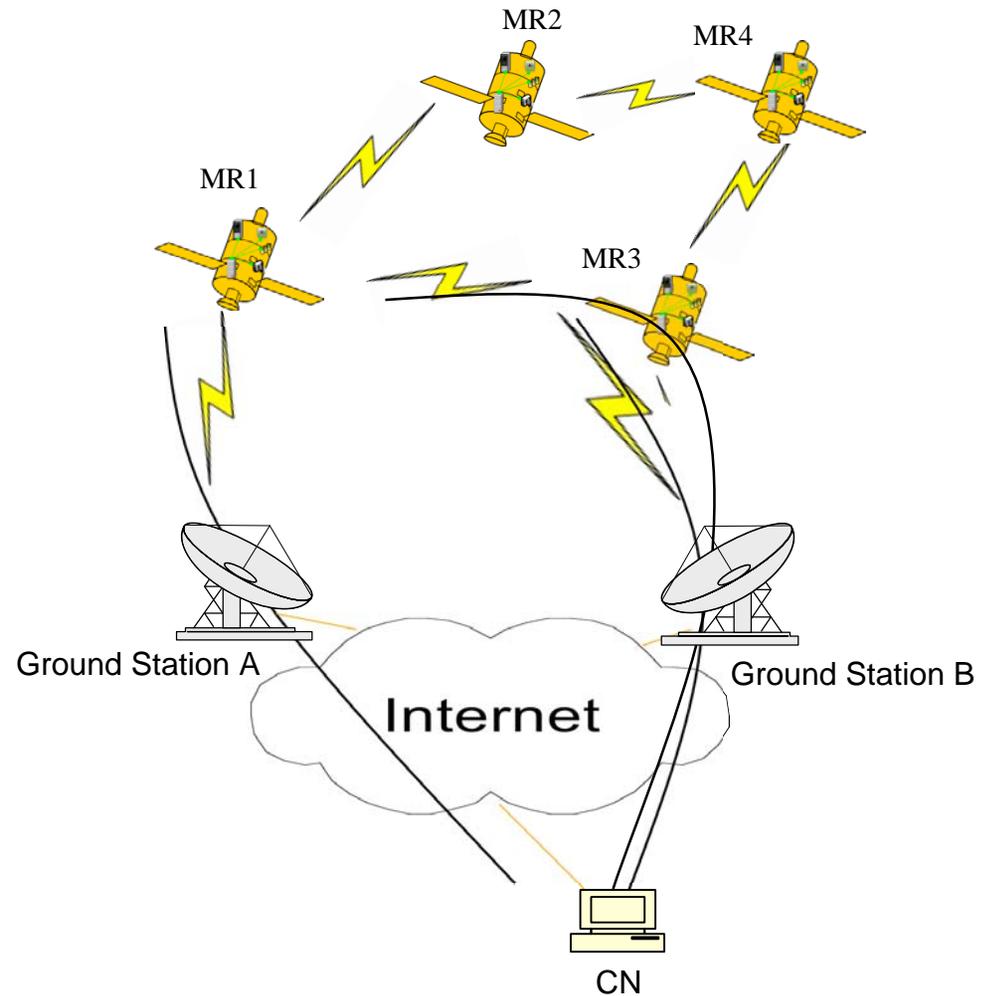


- Select an MR with lower nesting level.

- Ÿ Might consider handoff frequency in recent time (past).

- Ÿ Use MR's information.

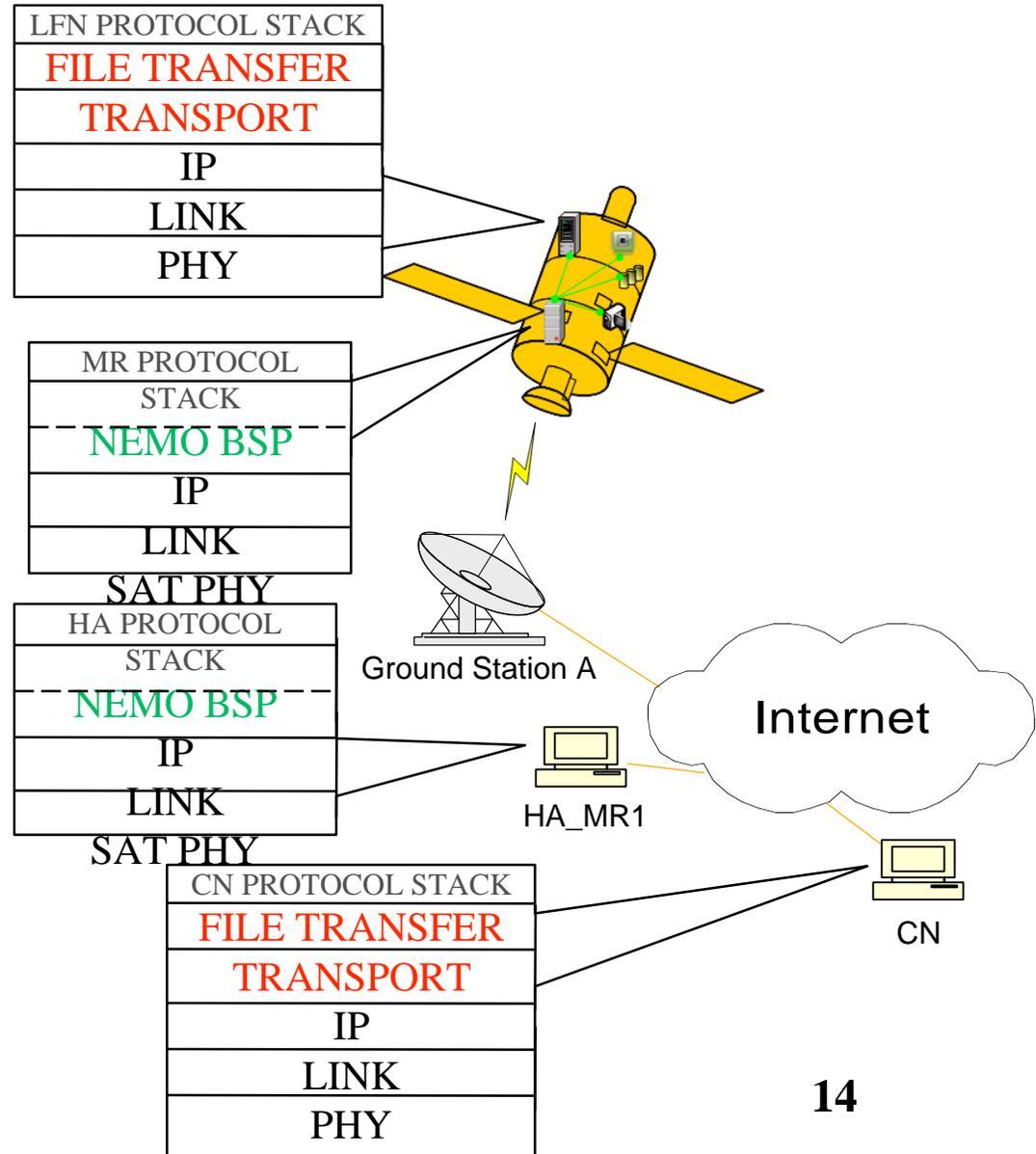
- Select a ground station whenever reachable.





Requirement for performance evaluation

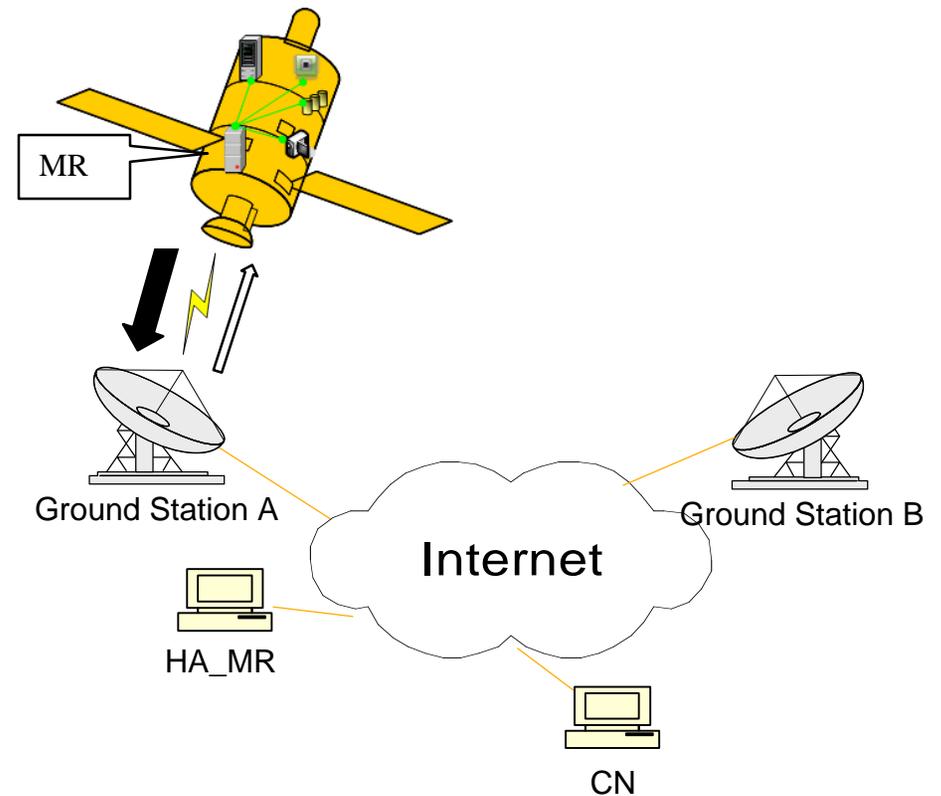
- Ns-2 simulation of NEMO BSP. Completed.
- Simulation of file transfer/transport protocol suitable for satellite network:
 - ÿ Satellite network characteristics to be considered.





Satellite network characteristics

- Asymmetry of uplink and downlink
- Brief period of connectivity with ground stations.
- Bursty errors in link; not due to congestion.

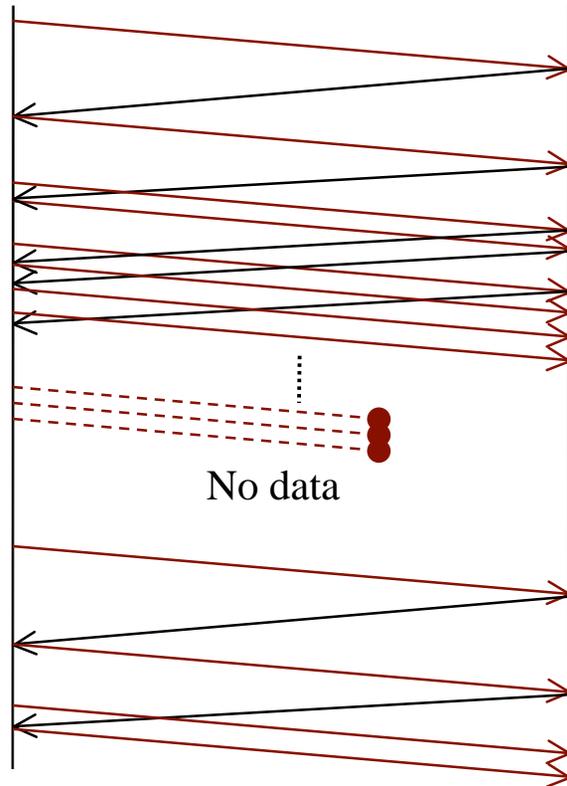




TCP for satellite network



Sender Receiver



→ Data
→ ACK
- - - ● Lost data

■ TCP not suitable for satellite network

Ÿ Uplink is bottleneck for ACK packets

Ÿ Loss at link misinterpreted as congestion

▫ Data sending rate reduced

■ Brief period of connectivity problem

Ÿ TCP connection break

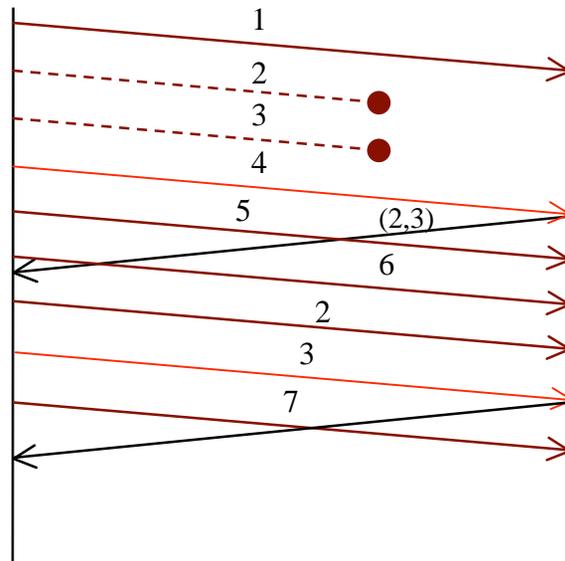
Ÿ Solved by NEMO BSP



Saratoga: A file transfer protocol for satellite network



Sender Receiver



- > Data
- > Data with ACK req
- > ACK
- - - ● Lost data

- Try to send as much data as possible based on link capacity

ÿ Not effected by loss

- ACK requested by sender periodically

ÿ Period determined based on reverse link capacity to avoid bottleneck

- Capable of resumption of data delivery

- Work over UDP

- Future version will have provision for congestion control

Saratoga at protocol stack

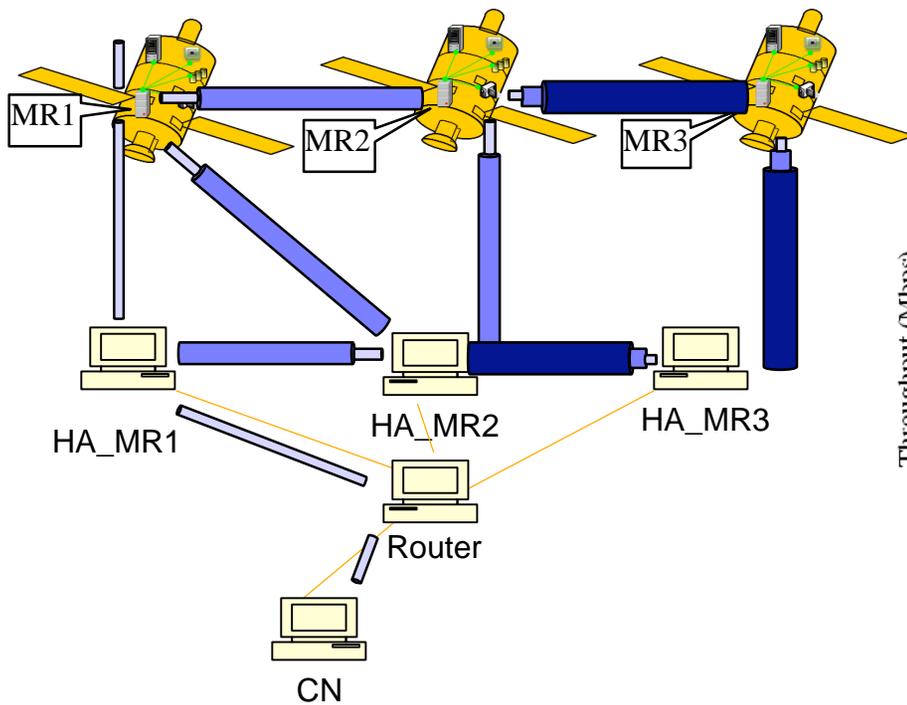
Saratoga
UDP
IP
LINK
PHY



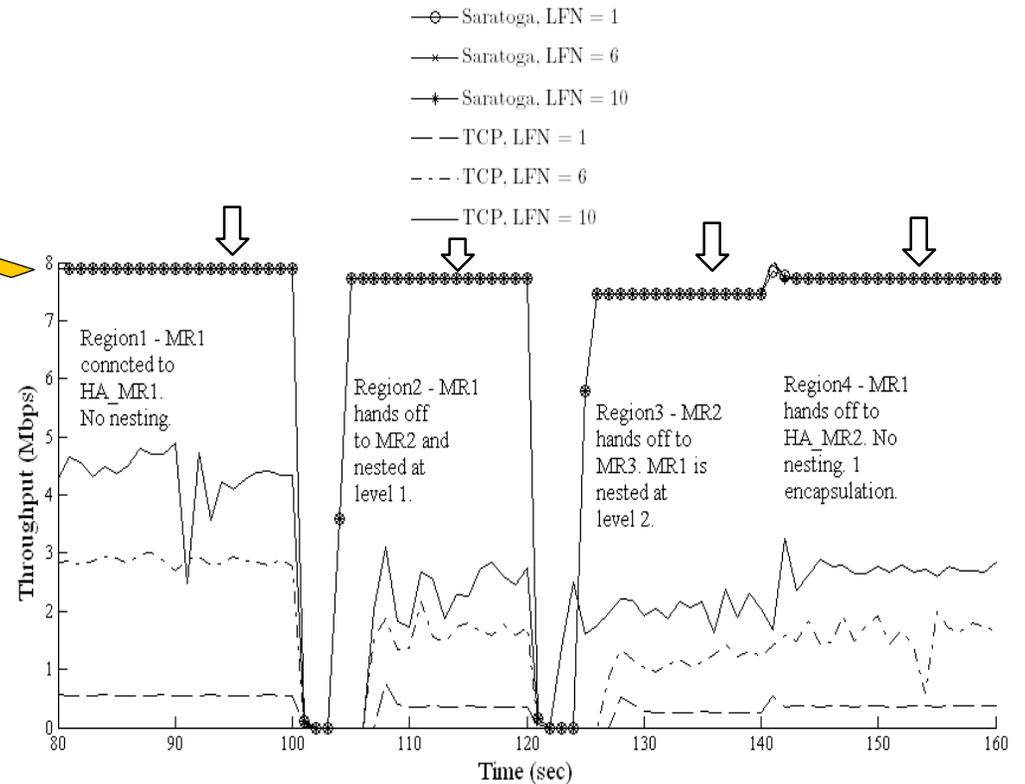
Performance : Saratoga vs TCP

■ Simulated features of Saratoga

- Sending data at a particular rate (8Mbps for current experiment)
- Loss recovery based on periodic acknowledgement (Period = 4 sec for current experiment)



Topology



Throughput



- **Simulation of Saratoga in ns-2.**
 - ÿ Mainly data sending and loss recovery part
 - ÿ Voluntary ACK sending from receiver
 - ÿ Resumption of data delivery not required because NEMO BSP provides continuous connectivity
 - ÿ Currently no congestion control.
 - ÿ Congestion control required when NEMO is used.
- **Simulation in a limited and controlled scenario (e.g. limited number of satellites, controlled handoff).**
 - ÿ Evaluate performance of Saratoga with NEMO BSP.
- **Experiment with handoff and evaluate performance**
 - ÿ Handoff only when existing connection is lost.
 - No neighboring MRs' list is maintained.
 - Neighboring MRs' list is maintained.
 - ÿ Handoff when a better MR is known from a new router advertisement.



- National Aeronautics and Space Administration (NASA) for funding this project.

- More information:

<http://www.cs.ou.edu/~netlab>

Thank You