



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

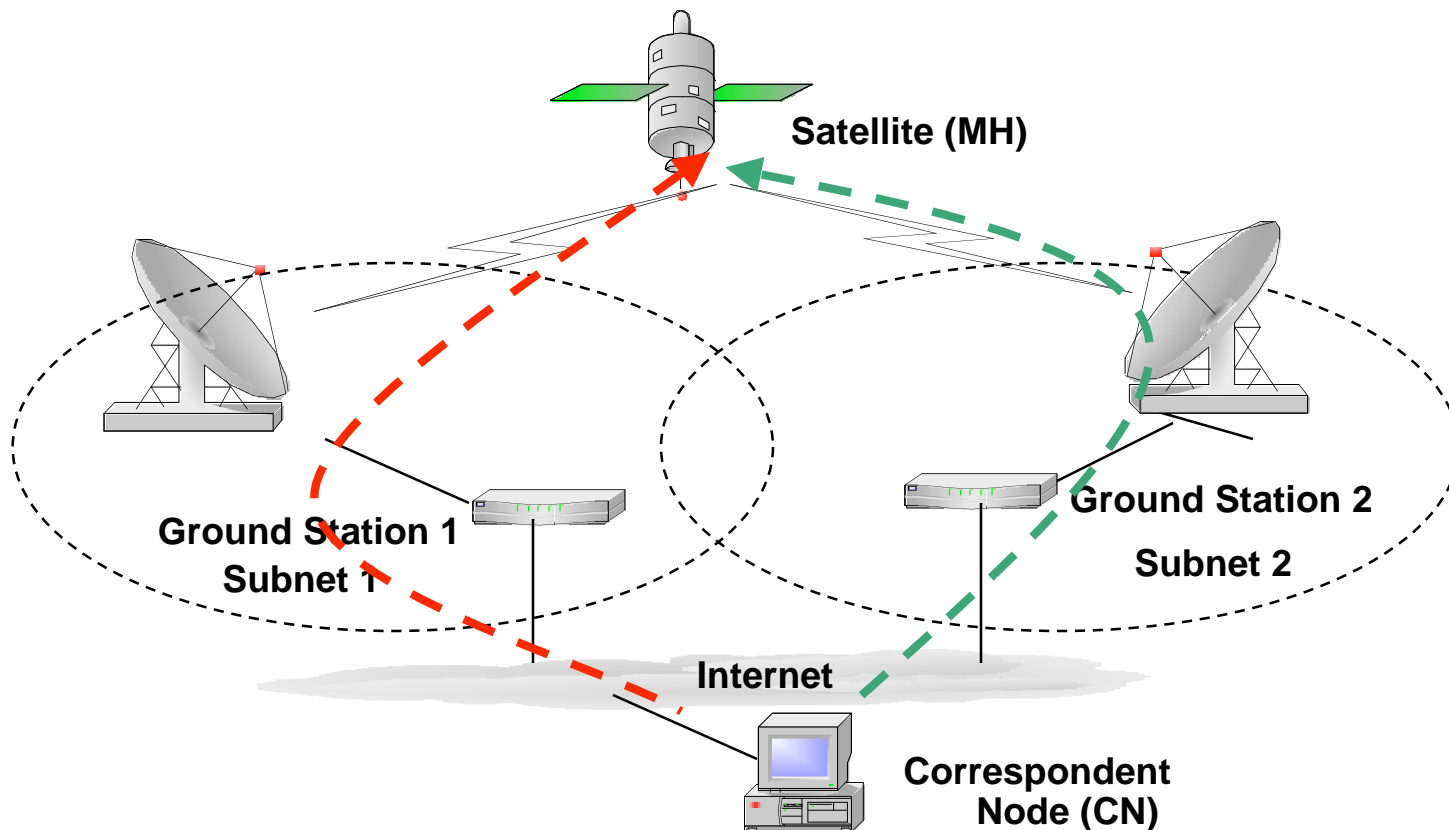


- Satellite onboard equipments act as the endpoint of the communication.
- Ground stations are allocated with different IP prefix.
- Satellite need to maintain continuous connection with remote computer.





Motivation: SIGMA for Mobility in Space



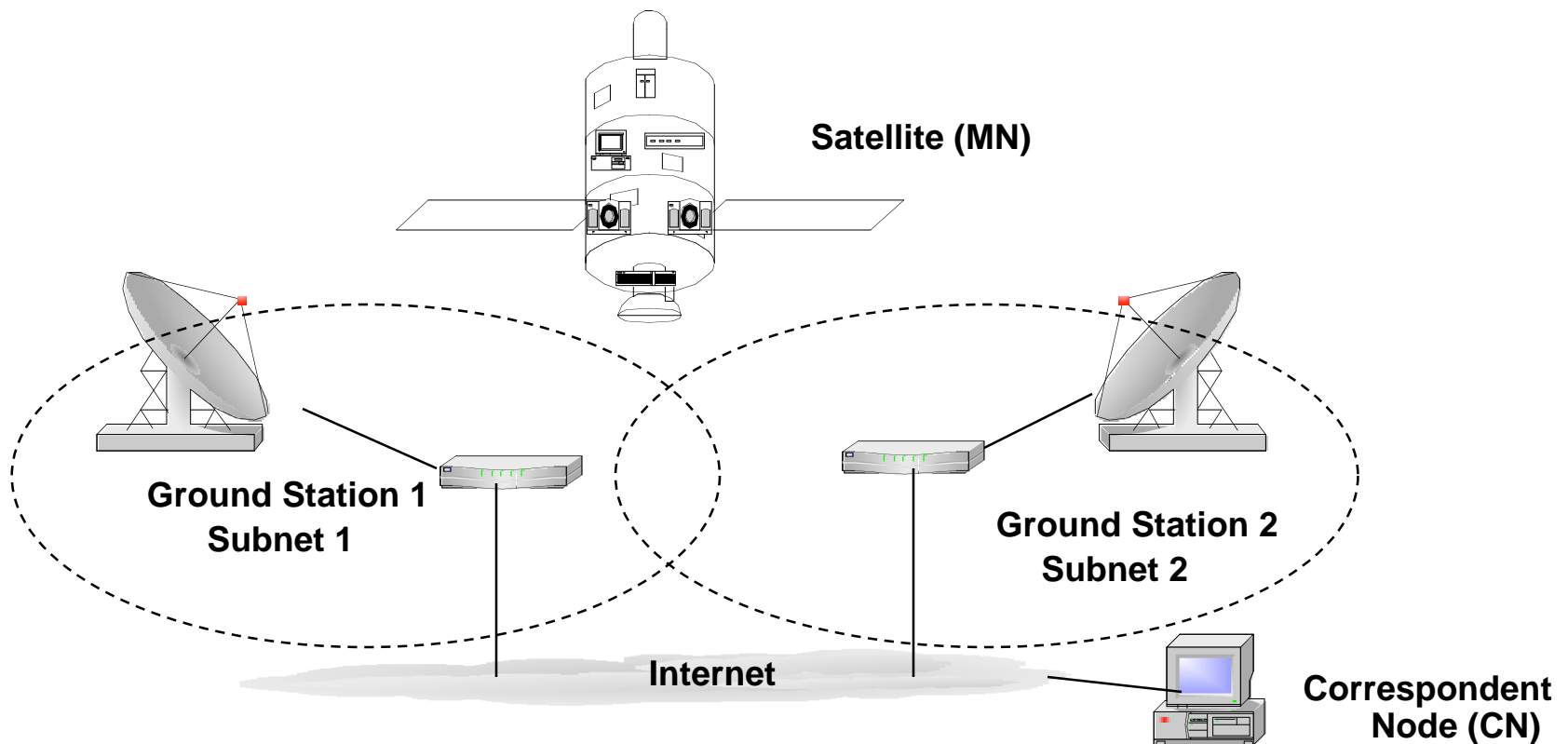
■ SIGMA

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

T



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.



Satellite as an MN (Example)



■ 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)

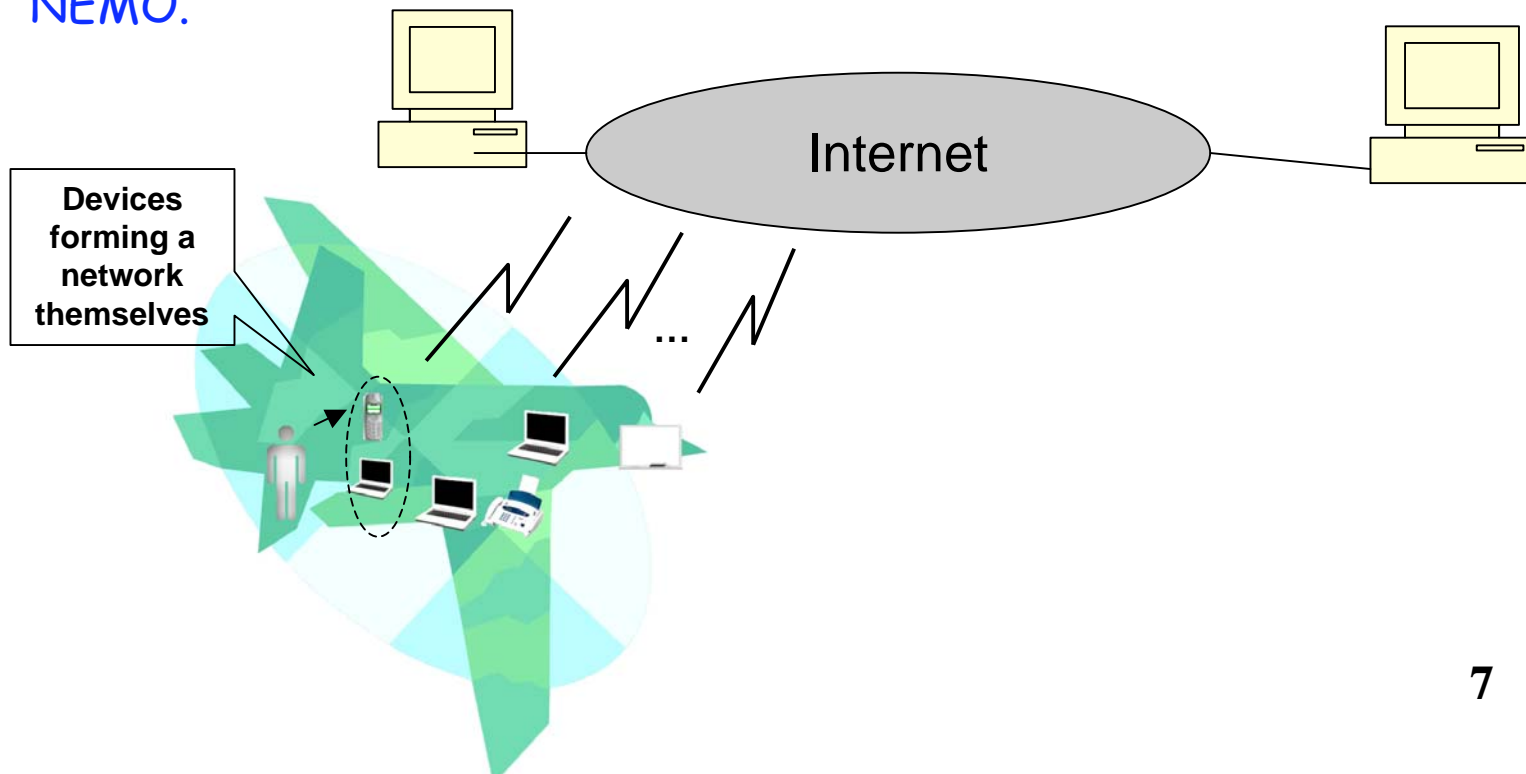
■ VMOC Satellite – UK-DMC

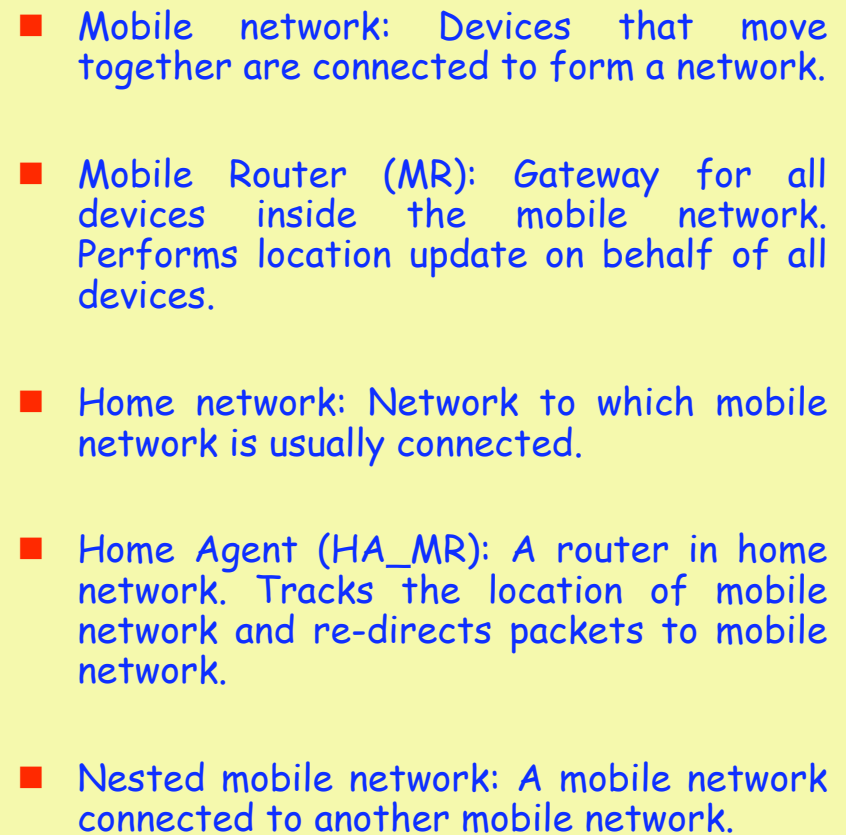
- ÿ CLEO Mobile Router – developed by CISCO
- ÿ Multispectral Imager
- ÿ IP-enabled Computers



Why NETwork MObility (NEMO)?

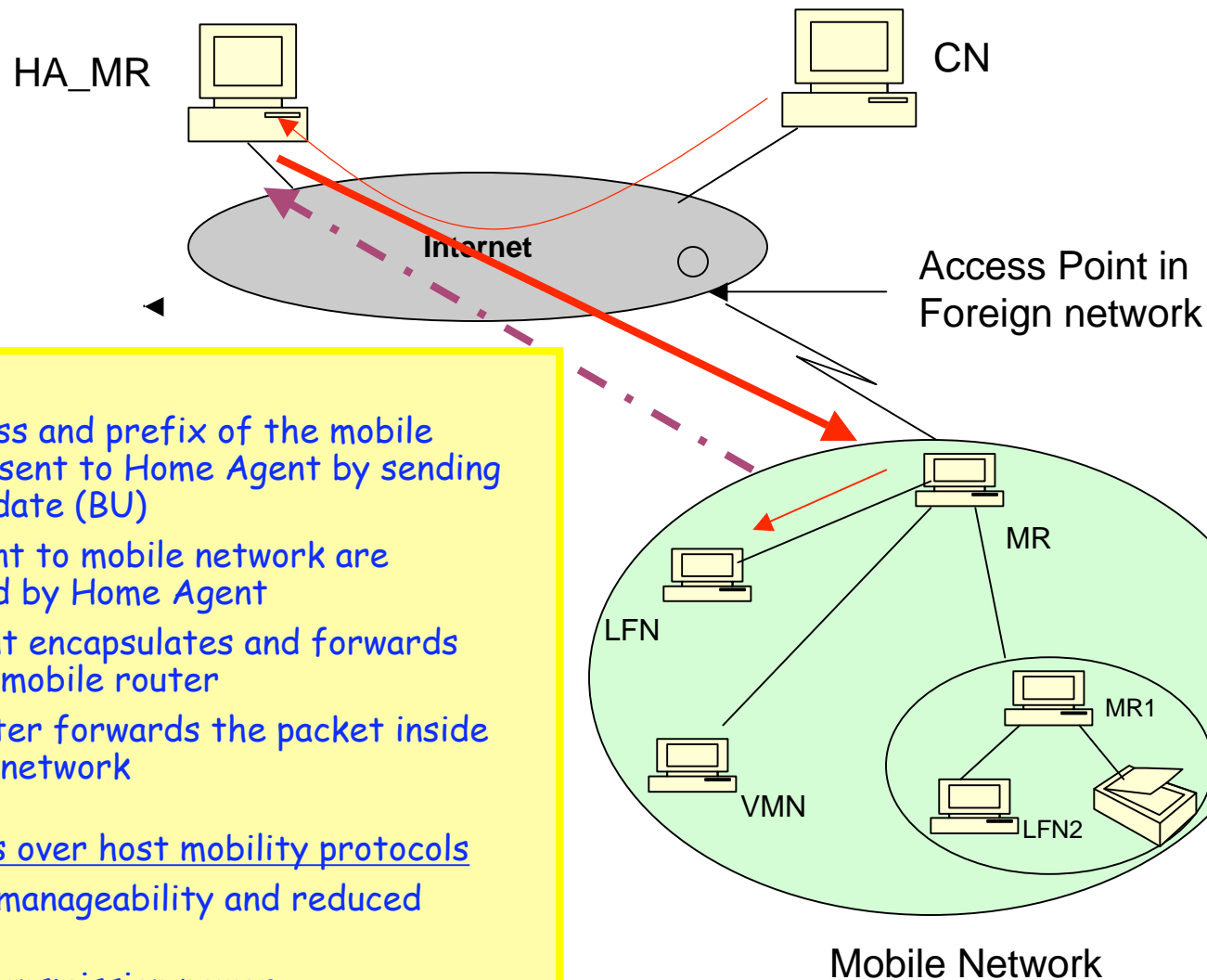
- Vehicles (airplanes, trains, ships) may contain several IP enabled devices, e.g. computers, PDA, data collecting equipment, etc. which move together.
- Each device can individually manage its mobility using host mobility protocols.
 - ÿ Requires lot of signaling messages over the bandwidth-limited 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 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

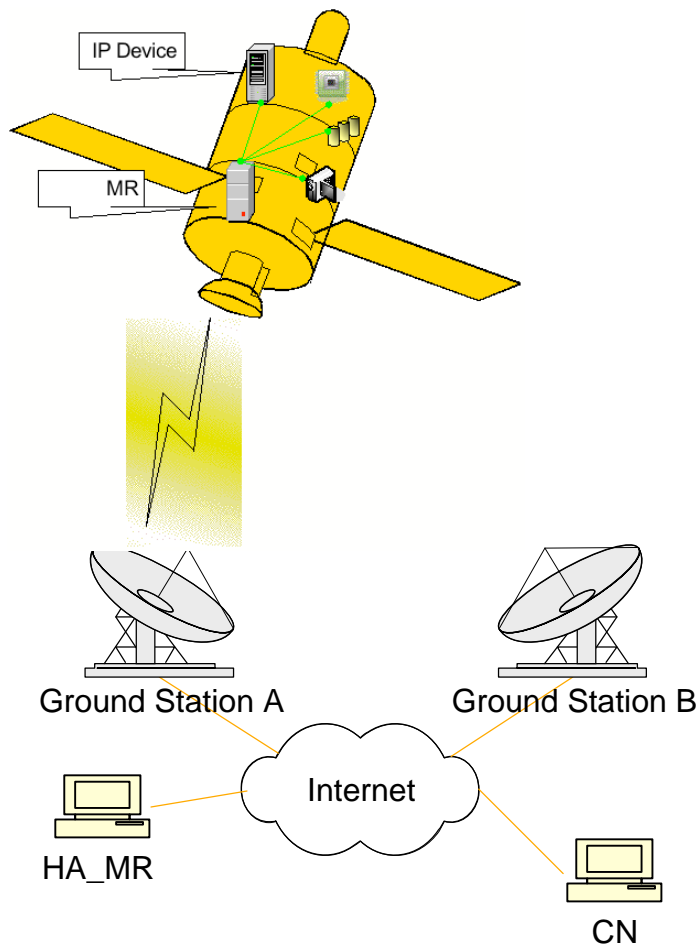
■ Advantages over host mobility protocols

- Increased manageability and reduced complexity
- Reduced transmission power
- Reduced handoff signaling



NEMO in satellite networks

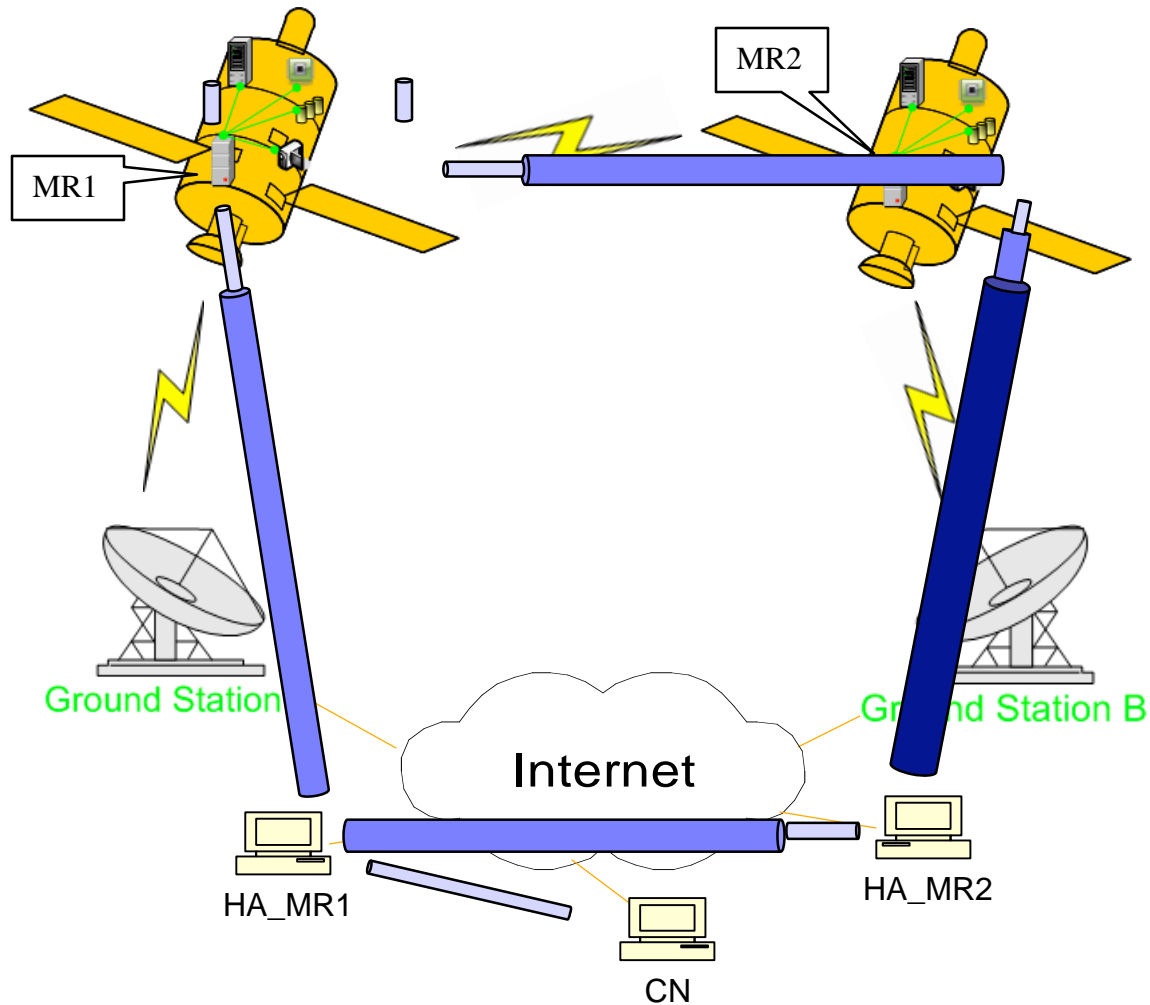
- Satellites containing many IP-enabled devices → network in motion.
- On-board network hands off between ground stations.





Nested NEMO in satellite networks

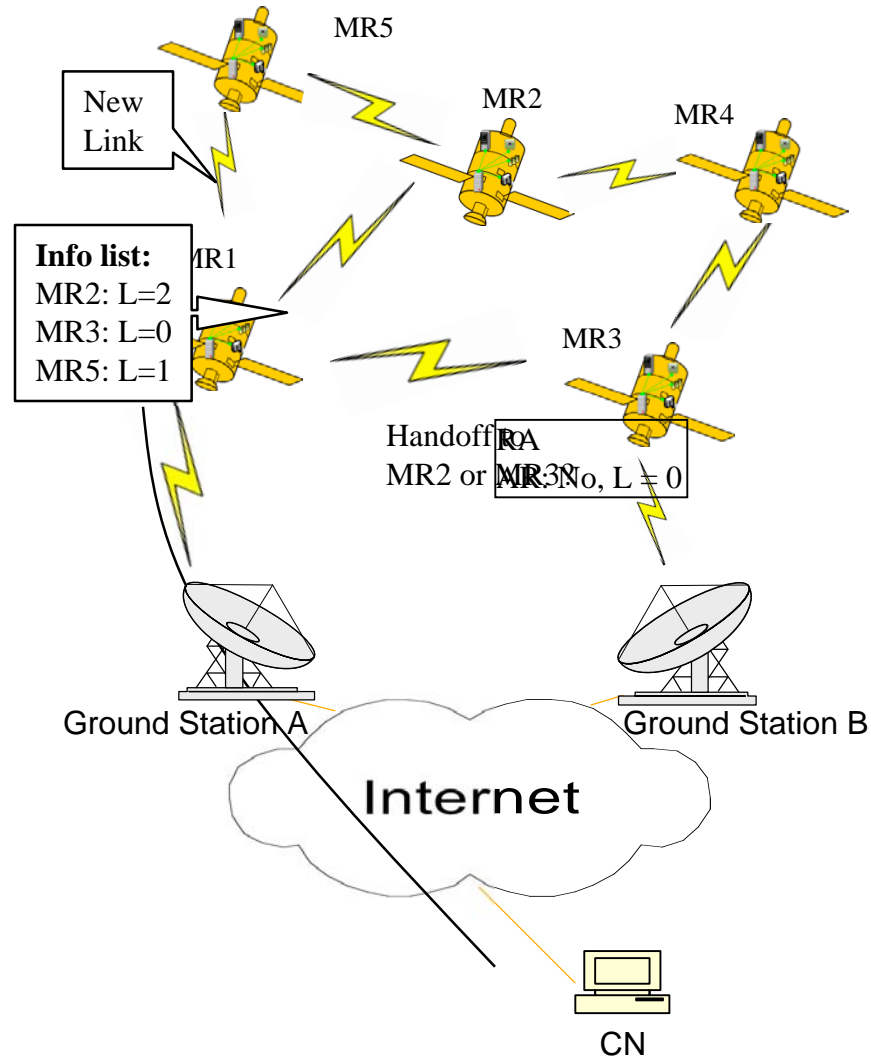
- Nested NEMO can be used to continue IP connectivity.





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





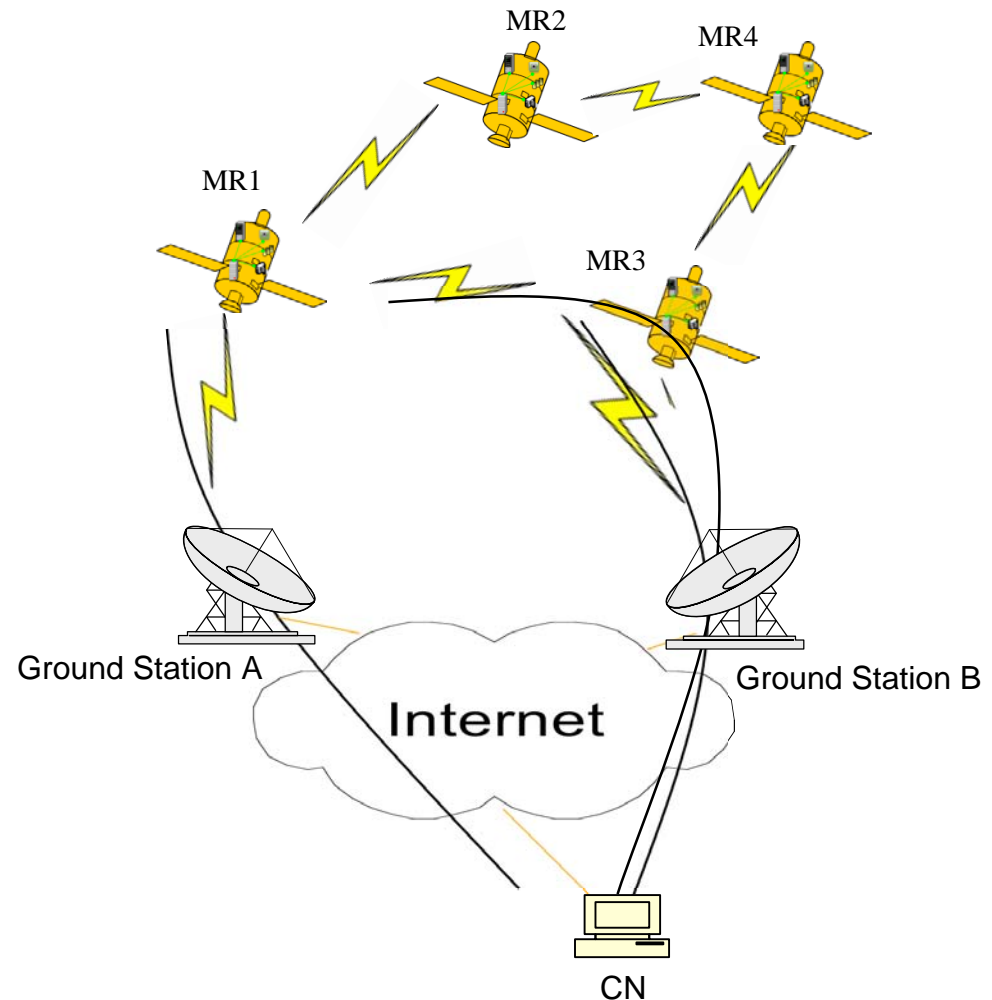
Best MR/AR selection continued...

- 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.

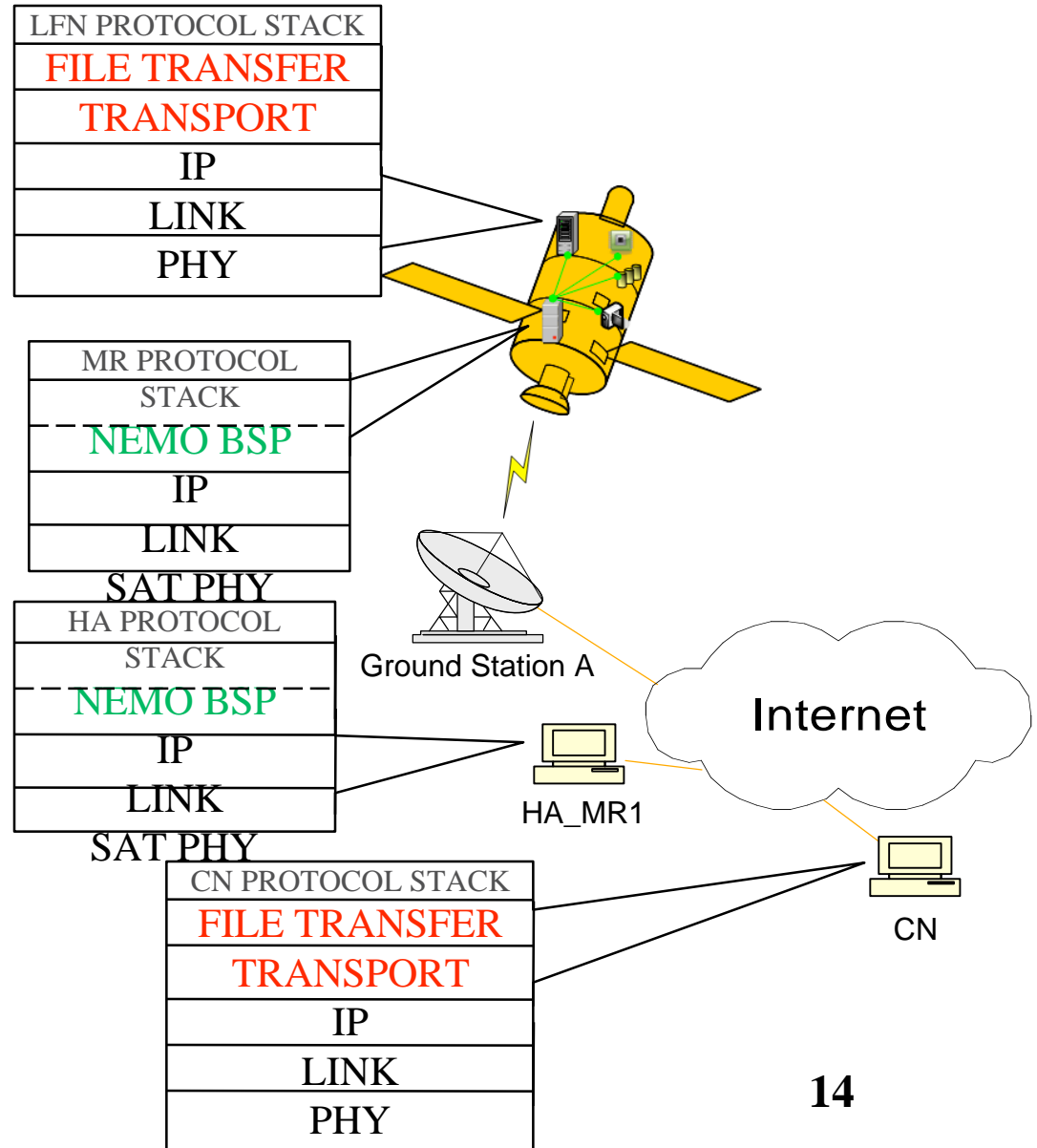




Requirement for performance evaluation

- Ns-2 simulation of NEMO BSP. Completed.
- Simulation of file transfer/transport protocol suitable for satellite network:

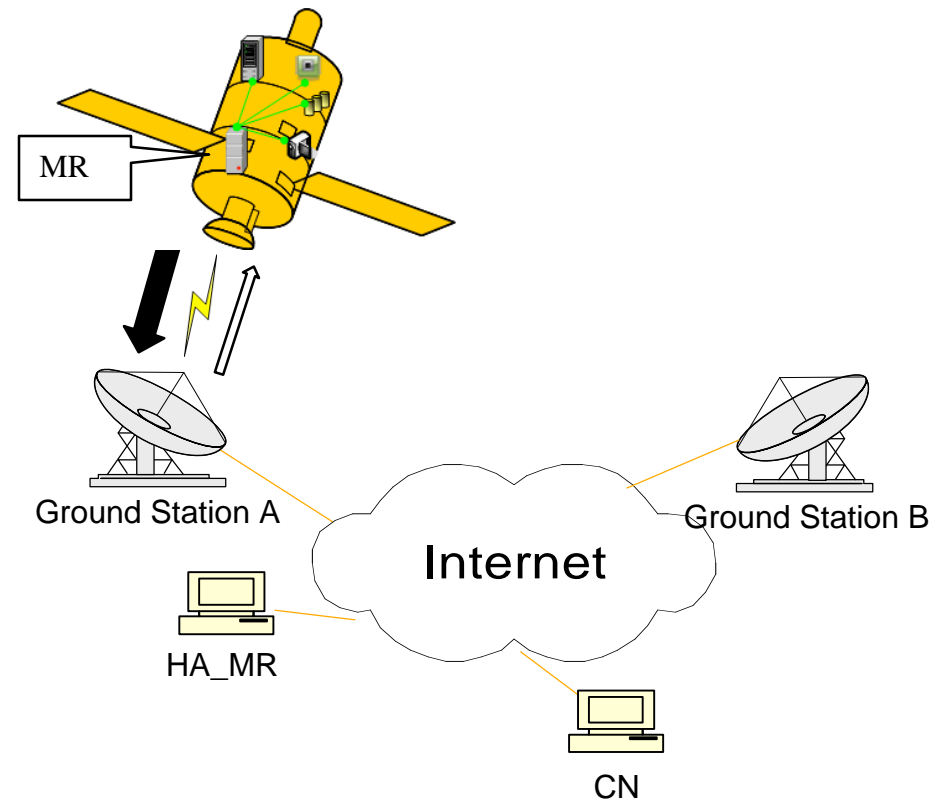
Ÿ Satellite network characteristics to be considered.





Satellite network characteristics

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

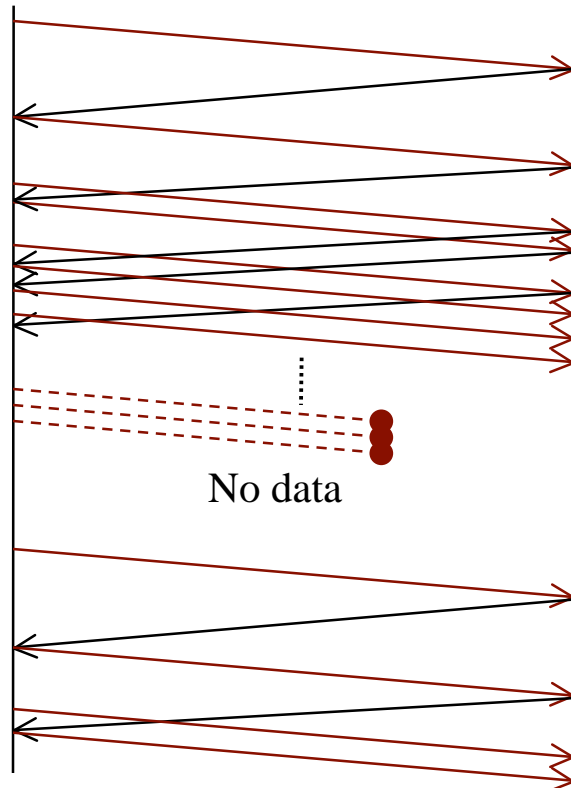




TCP for satellite network



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

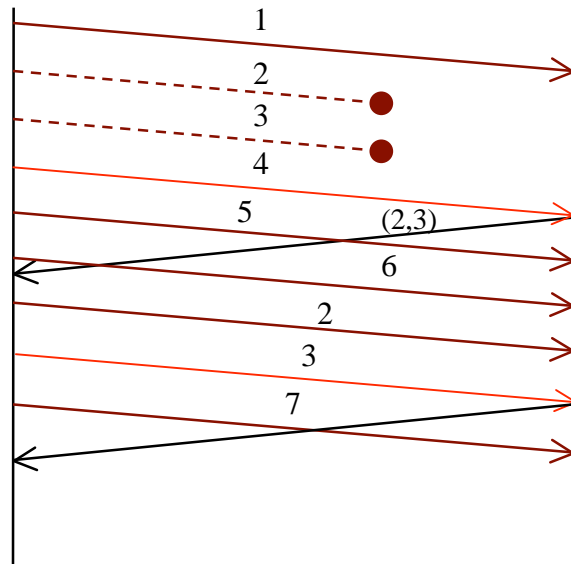
Ÿ TCP connection break

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

⚡ Not effected by loss

- ACK requested by sender periodically

⚡ 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

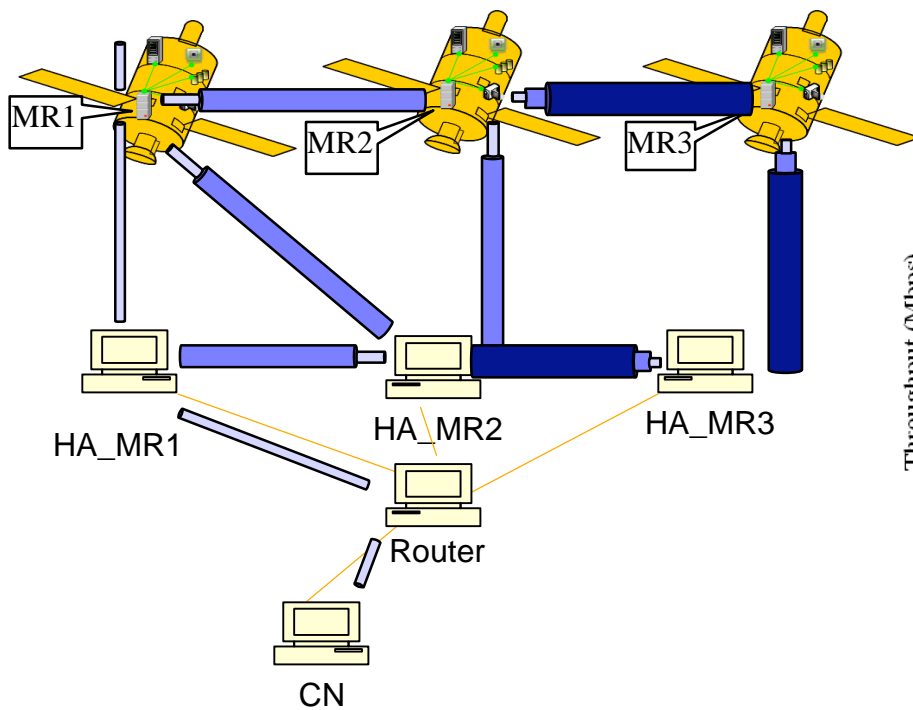
Saratoga
UDP
IP
LINK
PHY



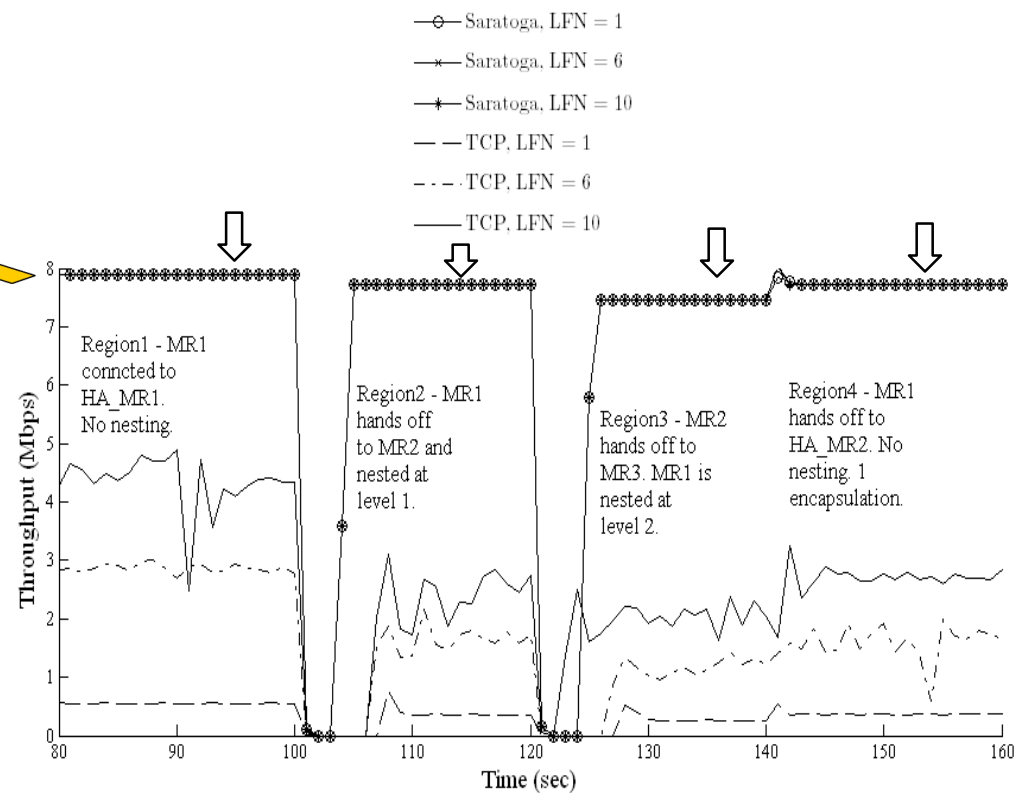
Performance : Saratoga vs TCP

■ 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.



Acknowledgements



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

- More information:

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

Thank You