# IEEE DISTINGUISHED LECTURER PROGRAM

IEEE ComSoc
IEEE Communications Society

# Connecting Space Assets to the Internet: Challenges and Solutions

IEEE Distinguished Lecturer talk at
IEEE Comsoc Oregon Section


**Dr. Mohammed Atiquzzaman**
Presidential Professor
School of Computer Science
University of Oklahoma, Norman, OK 73019-6151, USA.
atiq@ou.edu, www.cs.ou.edu/~atiq


Dec 10, 2020

SCAN ME

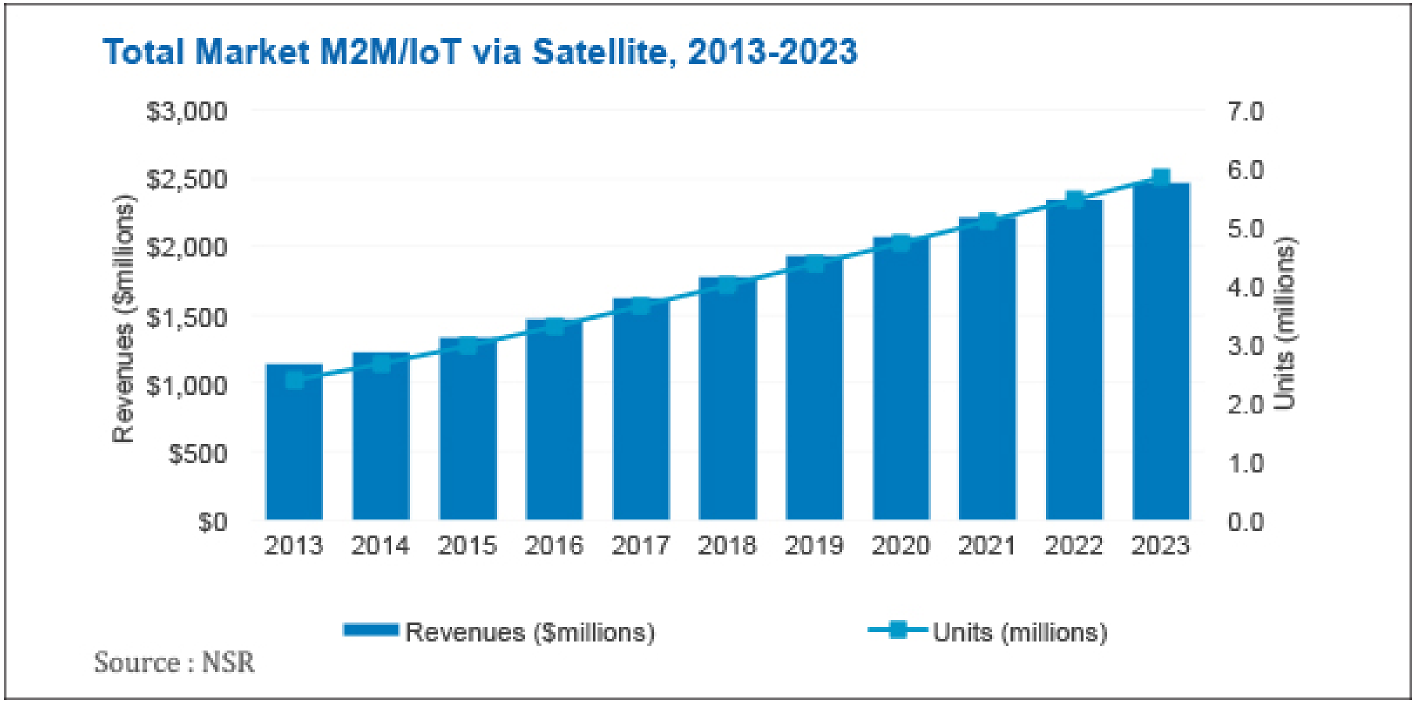
# Advantages of Satellites over Terrestrial Networks

- Ubiquitous coverage and is usually more reliable, especially in remote and underserved regions.
  - Communicating enitites/IoT/Smart objects are often
    - remote
    - dispersed over a wide geographical area
    - inaccessible
- Satellite-based applications for global coverage.

- Satellite permits the use of a single platform, as compared to a patchwork of terrestrial networks.

# IoT over Satellite Growth

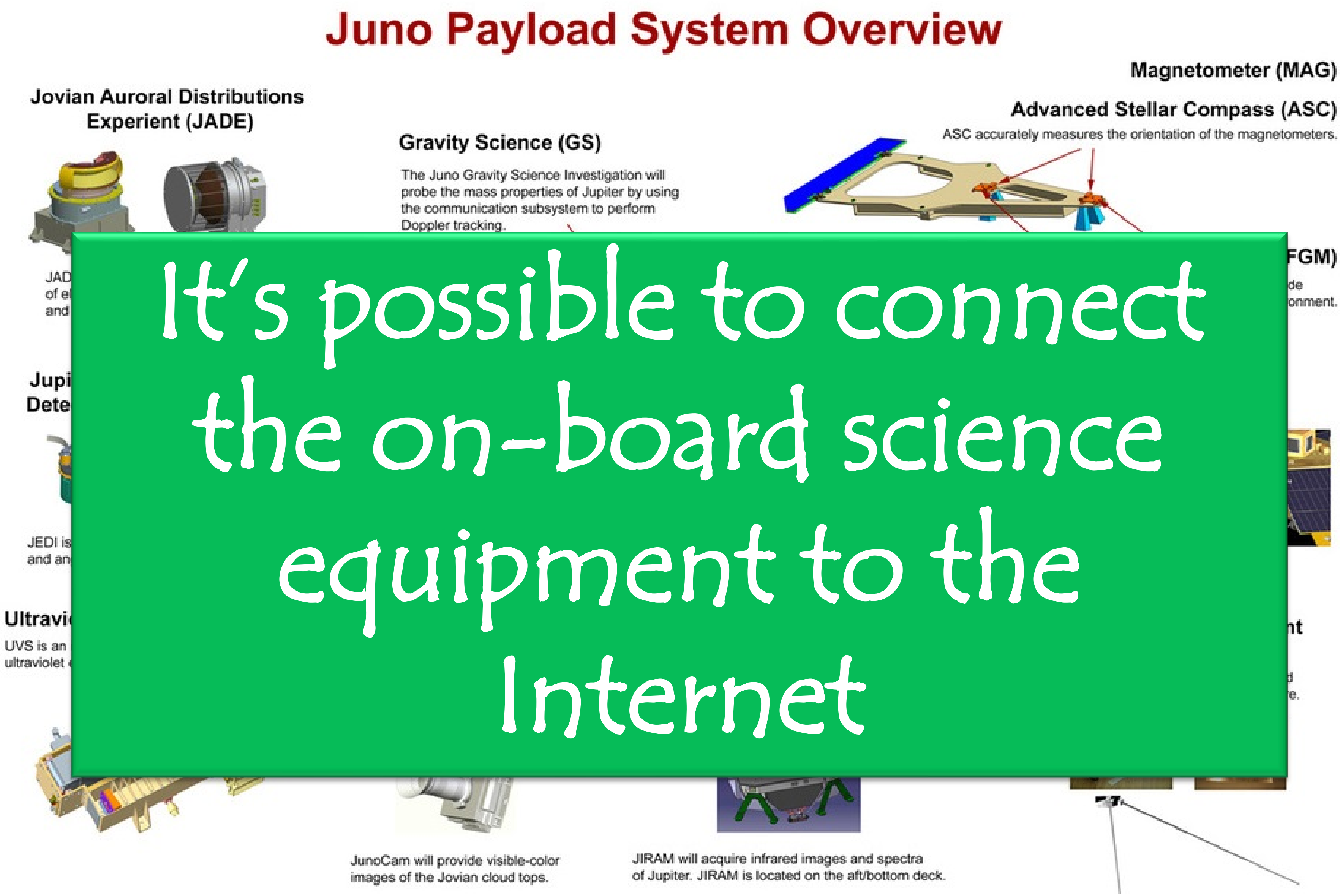
- Cisco expects more than 50 billion connected devices by 2020
- Higher numbers of sensors being implemented and monitored, with each requiring their own IoT connection.




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



Mohammed Atiquzzaman, University of Oklahoma



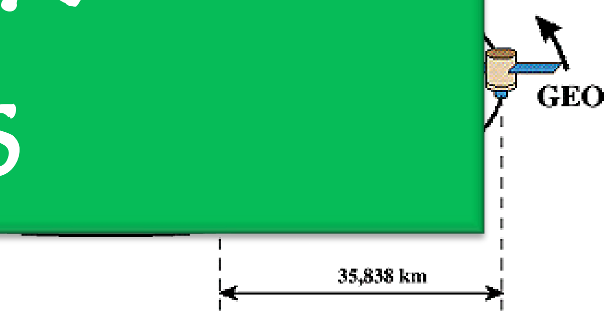

# It's possible to connect the on-board science equipment to the Internet

- Spacecrafts can have IP-addressable payload/devices/'things'
  - Sensor
  - Radars
  - Telescopes

We consider Low Earth Orbiting

- T
  c
- T
  spacecraft

# Mobility Management In Satellites

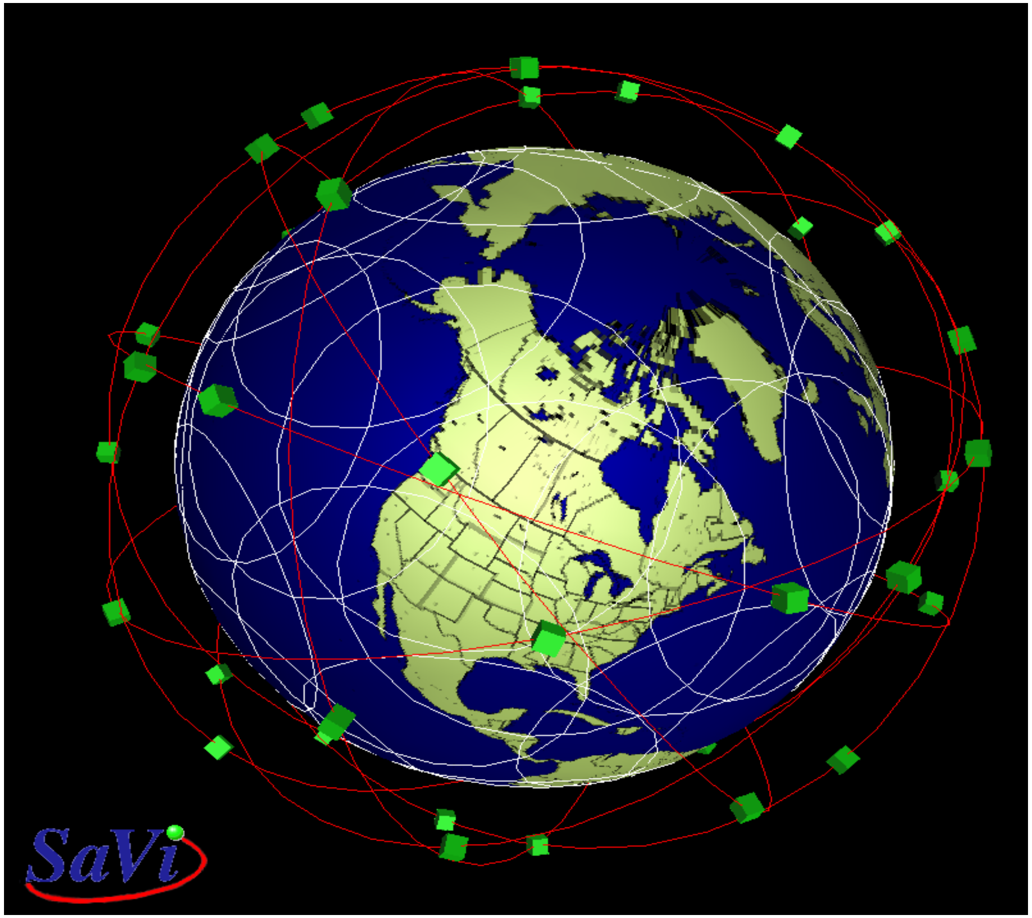



- Connecting mobile space devices to the Internet requires mobility management.

# Handoffs in satellite IP networks

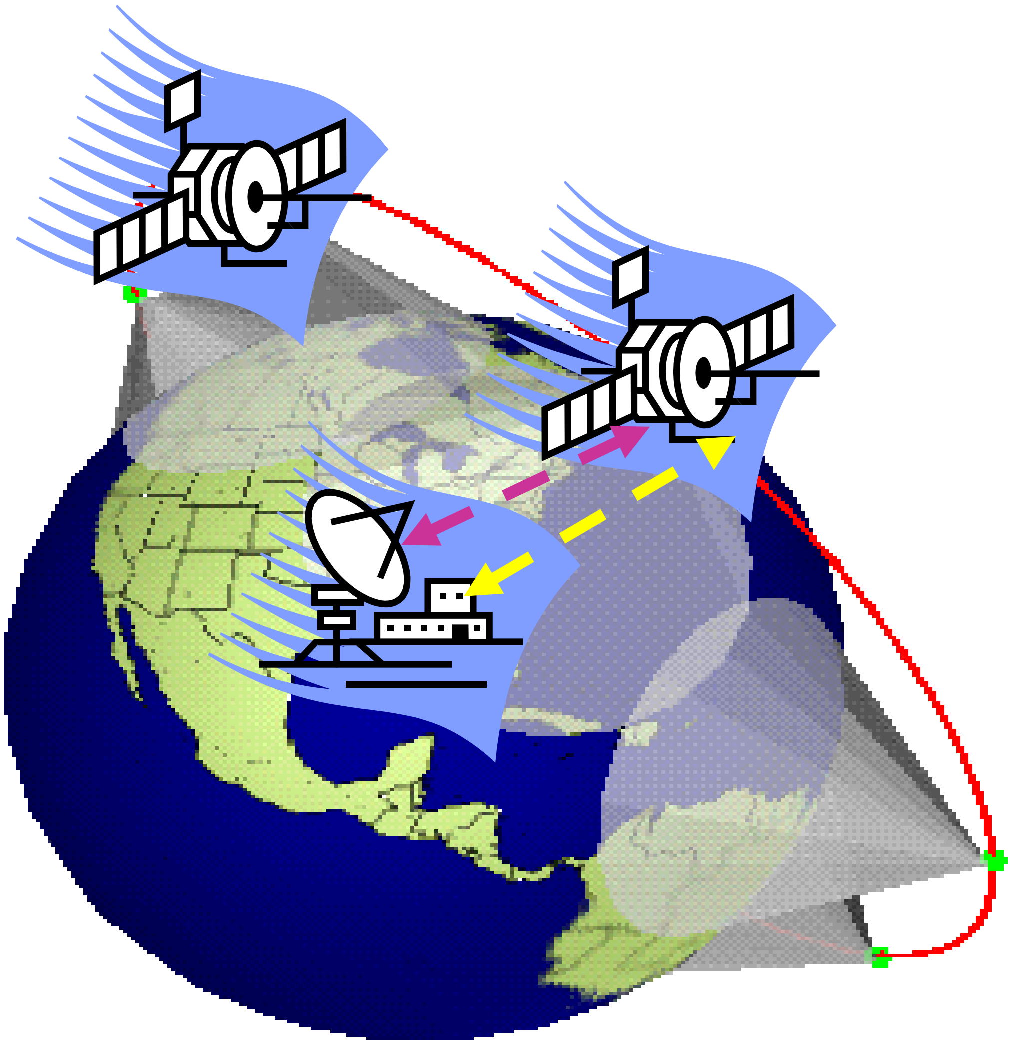
- **Link Layer Handoff**
  - Inter-satellite handoff
  - Link handoff
  - Spotbeam handoff

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

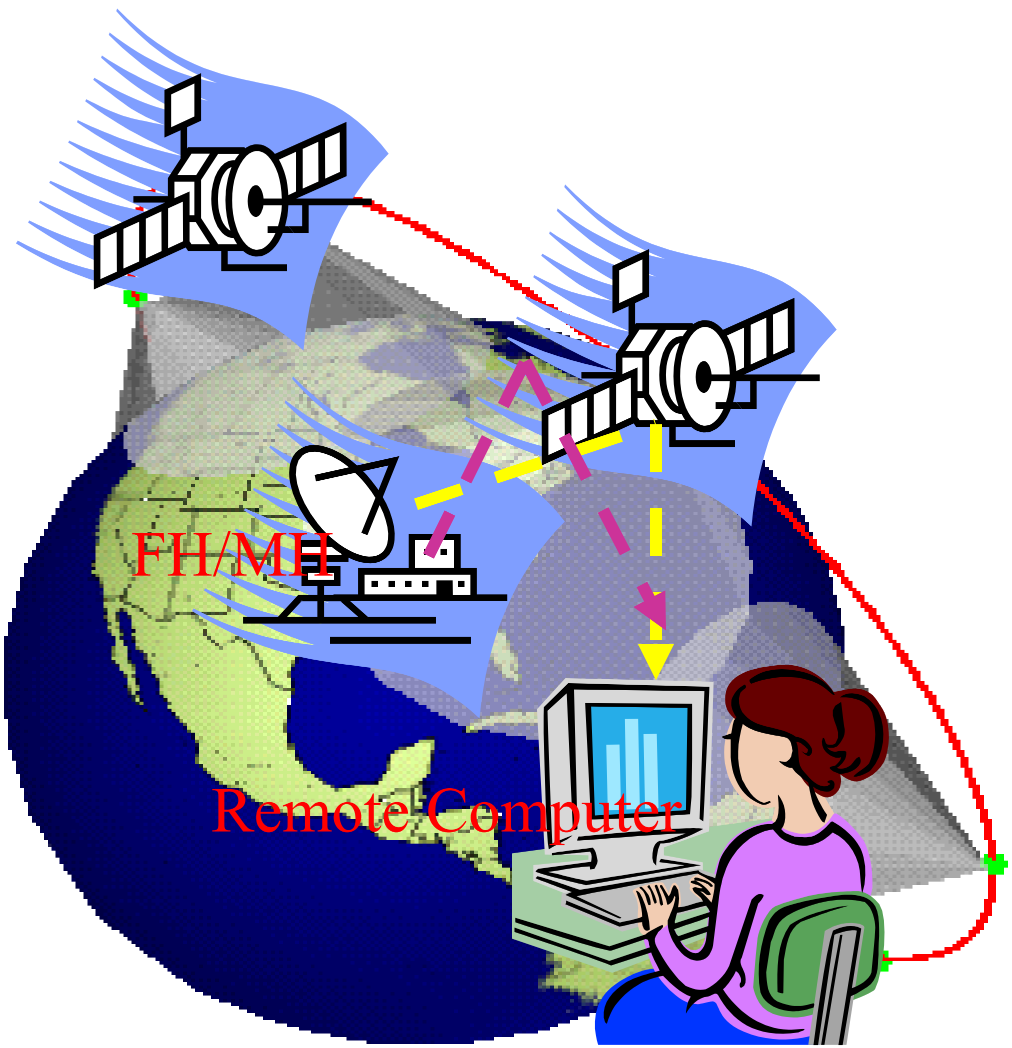



*A Globalstar design, with 48 active satellites in 8 planes of 6.*

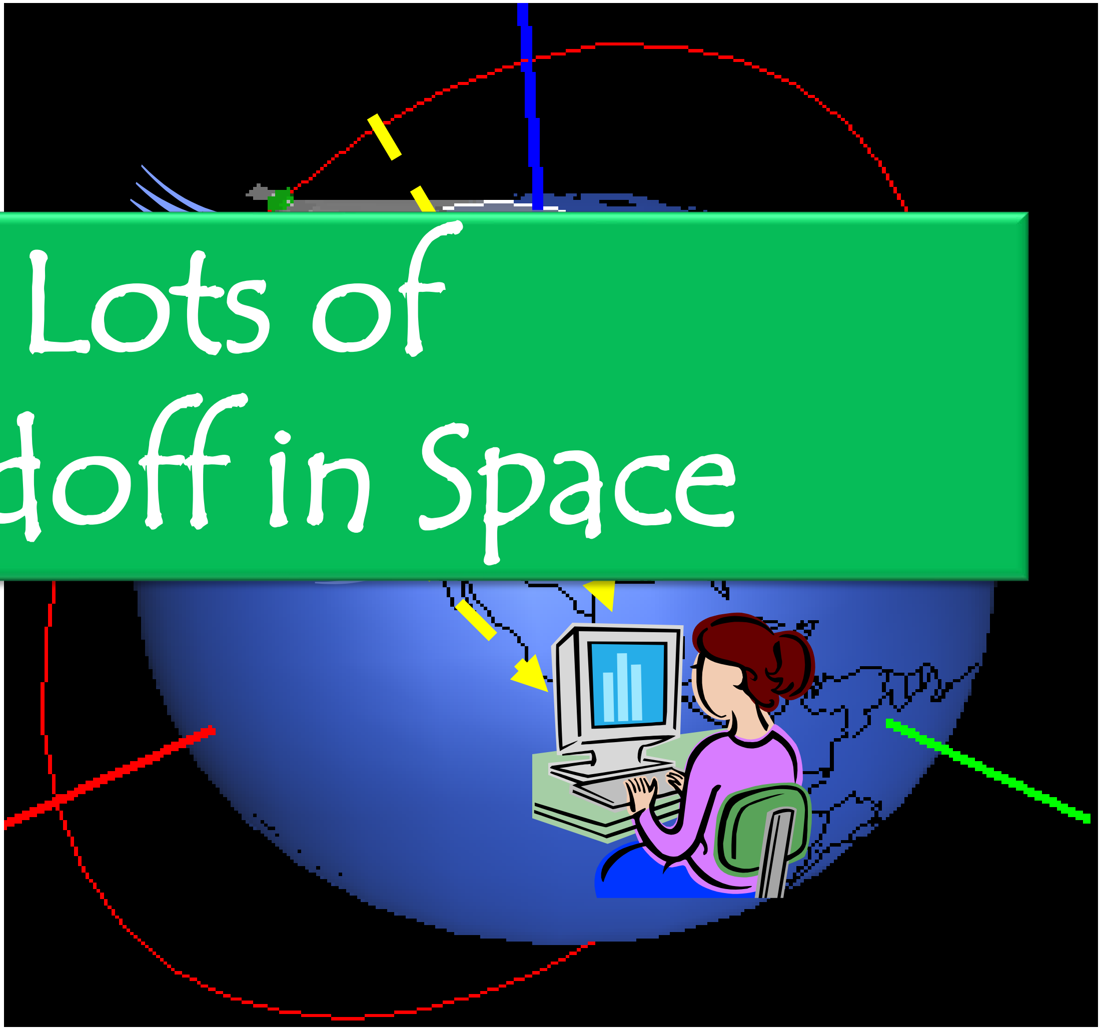
- Satellite movement causes handoff between ground stations.
- Similar to inter-switch handoff in the case of terrestrial mobile network.



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



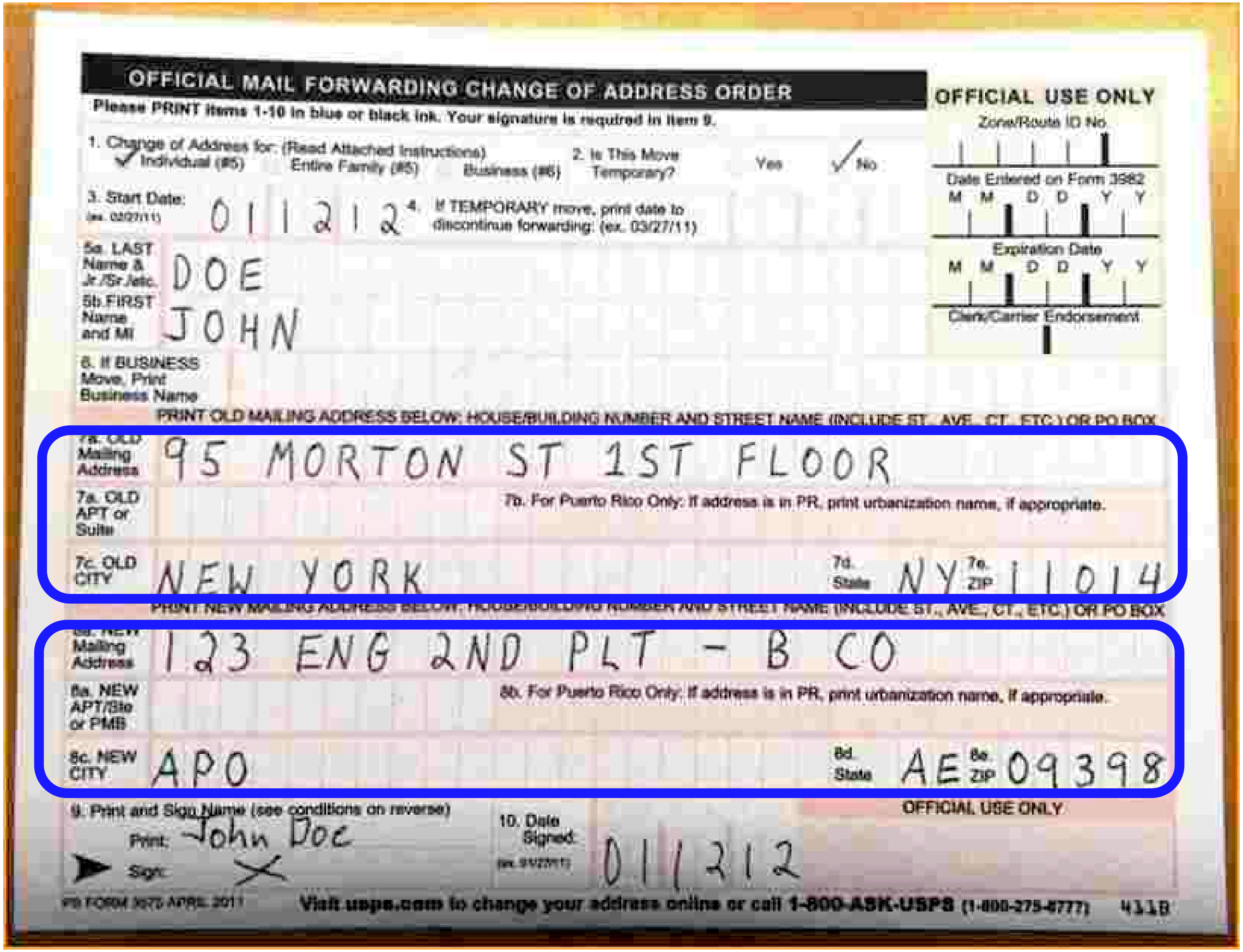
- Onboard equipment generate data and act as the endpoint of the communication.
- I
  g
- C
  allocated different IP prefix.
- Satellite need to maintain continuous connection with remote computer.



Lots of
Handoff in Space

# Mobility Management

# US Postal System Mail Forwarding



OFFICIAL MAIL FORWARDING CHANGE OF ADDRESS ORDER

Please PRINT items 1-10 in blue or black ink. Your signature is required in item 9.

1. Change of Address for: (Read Attached Instructions) ✓ Individual (#5) Entire Family (#5) Business (#6)

2. Is This Move Temporary? Yes ✓ No

3. Start Date: (ex. 03/27/11) 01 12 12

4. If TEMPORARY move, print date to discontinue forwarding: (ex. 03/27/11)

5a. LAST Name & Jr./Sr./etc. DOE

5b. FIRST Name and MI JOHN

6. If BUSINESS Move, Print Business Name

PRINT OLD MAILING ADDRESS BELOW: HOUSE/BUILDING NUMBER AND STREET NAME (INCLUDE ST., AVE., CT., ETC.) OR PO BOX

7a. OLD Mailing Address 95 MORTON ST 1ST FLOOR

7a. OLD APT or Suite

7b. For Puerto Rico Only: If address is in PR, print urbanization name, if appropriate.

7c. OLD CITY NEW YORK 7d. State NY 7e. ZIP 11014

PRINT NEW MAILING ADDRESS BELOW: HOUSE/BUILDING NUMBER AND STREET NAME (INCLUDE ST., AVE., CT., ETC.) OR PO BOX

8a. NEW Mailing Address 123 ENG 2ND PLT - B CO

8a. NEW APT/Ste or PMB

8b. For Puerto Rico Only: If address is in PR, print urbanization name, if appropriate.

8c. NEW CITY APO 8d. State AE 8e. ZIP 09398

9. Print and Sign Name (see conditions on reverse)

Print: John Doe

Sign: X

10. Date Signed: (ex. 03/27/11) 01 12 12

OFFICIAL USE ONLY

Zone/Route ID No.

Date Entered on Form 3982 M M D D Y Y

Expiration Date M M D D Y Y

Clerk/Carrier Endorsement

OFFICIAL USE ONLY

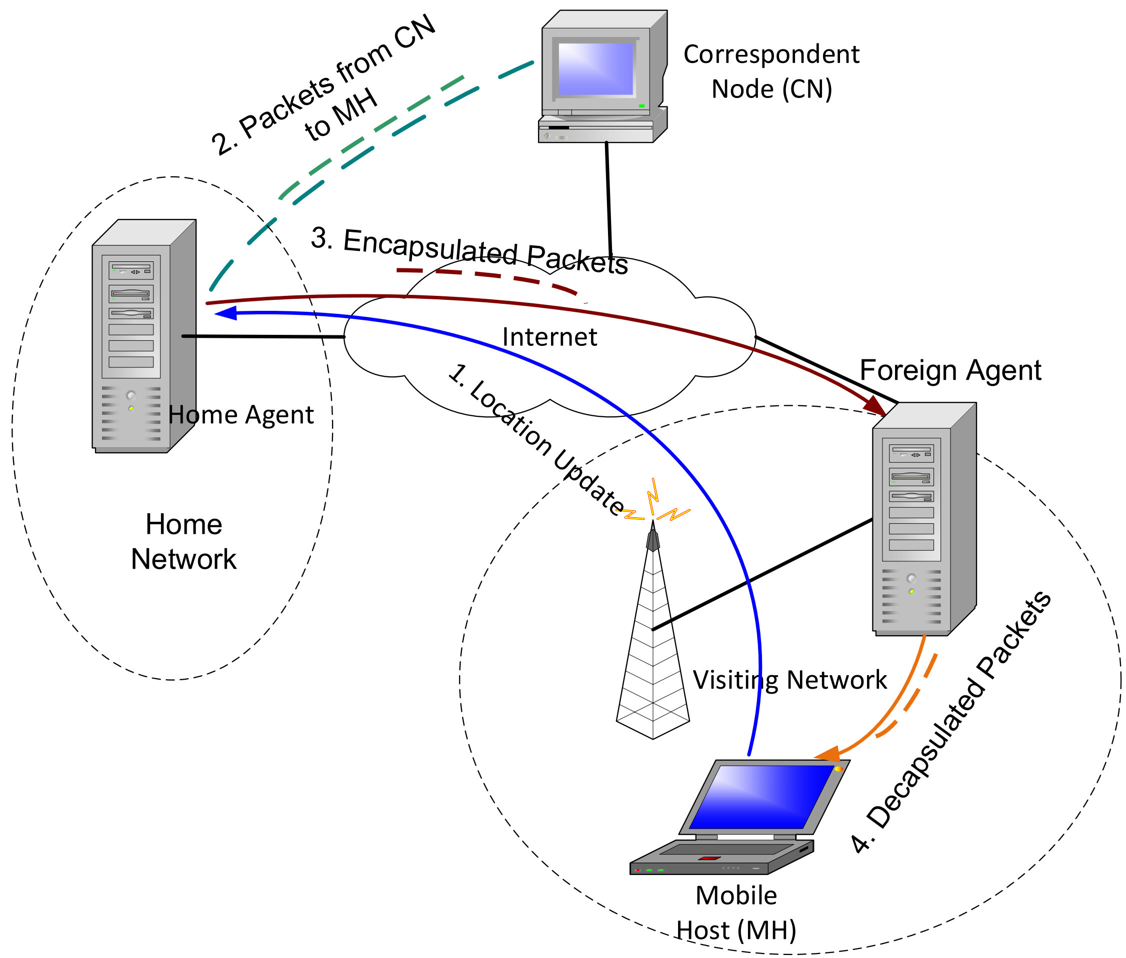
PS FORM 3575 APRIL 2011

Visit usps.com to change your address online or call 1-800-ASK-USPS (1-800-275-8777)

1. When Mobile Host moves to a new domain, a location update is sent to Home Agent.

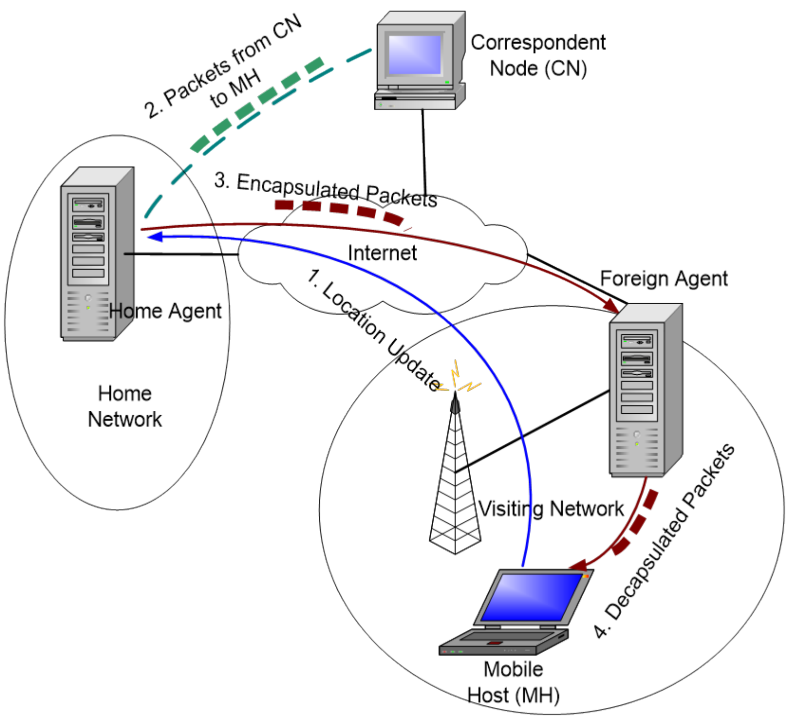
2 & 3. Packets from CN to Mobile Host are encapsulated and forwarded to MH's current care-of address.

4. Packets are decapsulated and delivered to upper layer protocol.

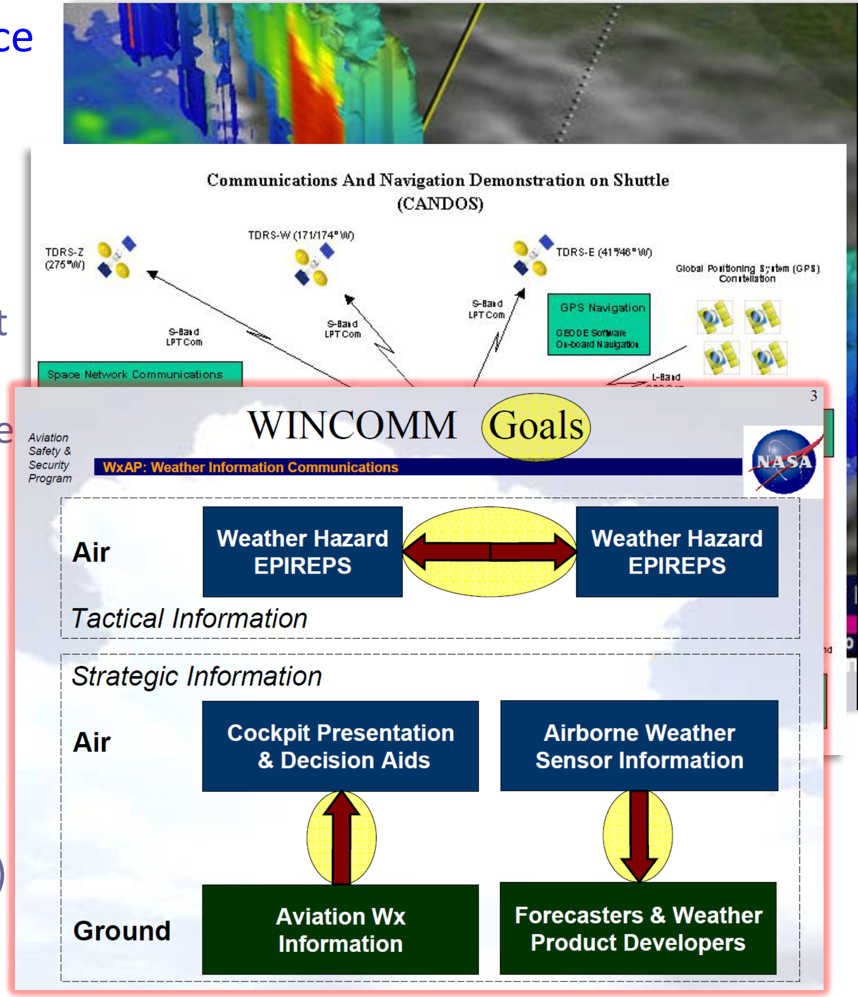


# Main Drawbacks of base Mobile IP

- 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.



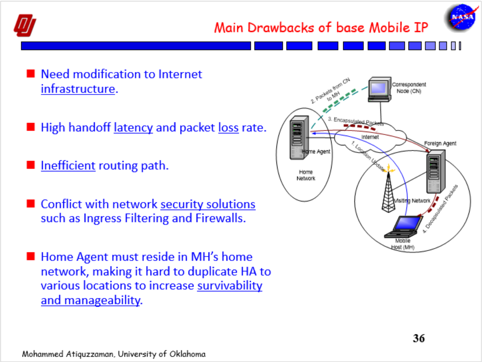
- Several NASA projects considering IP in space and Mobile IP
  - *Global Precipitations Measurement (GPM)*
  - *Communication and Navigation Demonstration on Shuttle (CANDOS)*
  - Operating Missions as Nodes on the Internet (OMNI)
  - NASA worked with Cisco to develop a Mobile router
- Mobile IP is promising for major role in various space related NASA projects
  - Advanced Aeronautics Transportation Technology (AATT)
  - *Weather Information Communication (WINCOMM)*
  - Small Aircraft Transportation Systems (SATS)




Develop an <u>efficient, secure and seamless handoff scheme</u> which would be applicable to both the <u>satellite and wireless/cellular environment</u>.

# Motivation for a New Mobility Management Protocol in Space

- No need to 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.

# SIGMA: Seamless IP-diversity based Generalized Mobility Architecture

# SIGMA: Basic concepts

Decouple location management from handoff

Carry out location management and handoff in parallel to data transmission

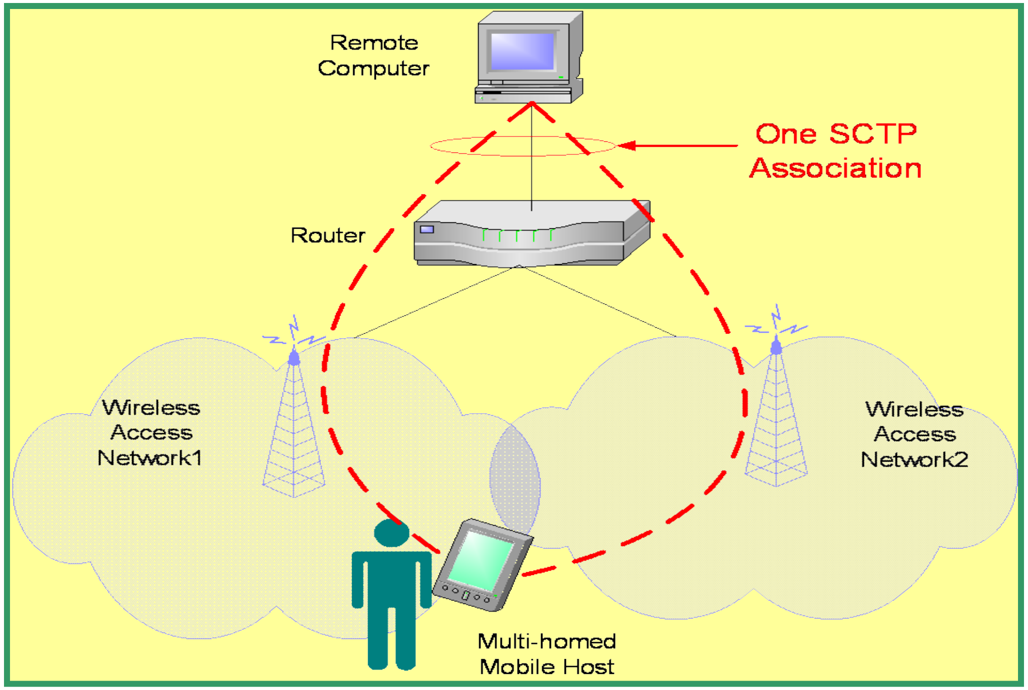
Allow the layer whose performance is to be optimized to take responsibility of the handoff

Implementation:

Multihoming for simultaneous communication with multiple access points.

Stream Control Transmission Protocol (RFC 2960).

- Mobile IP assumes the upper layer protocol uses only one IP address to identify a 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.
- When a mobile host moves 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

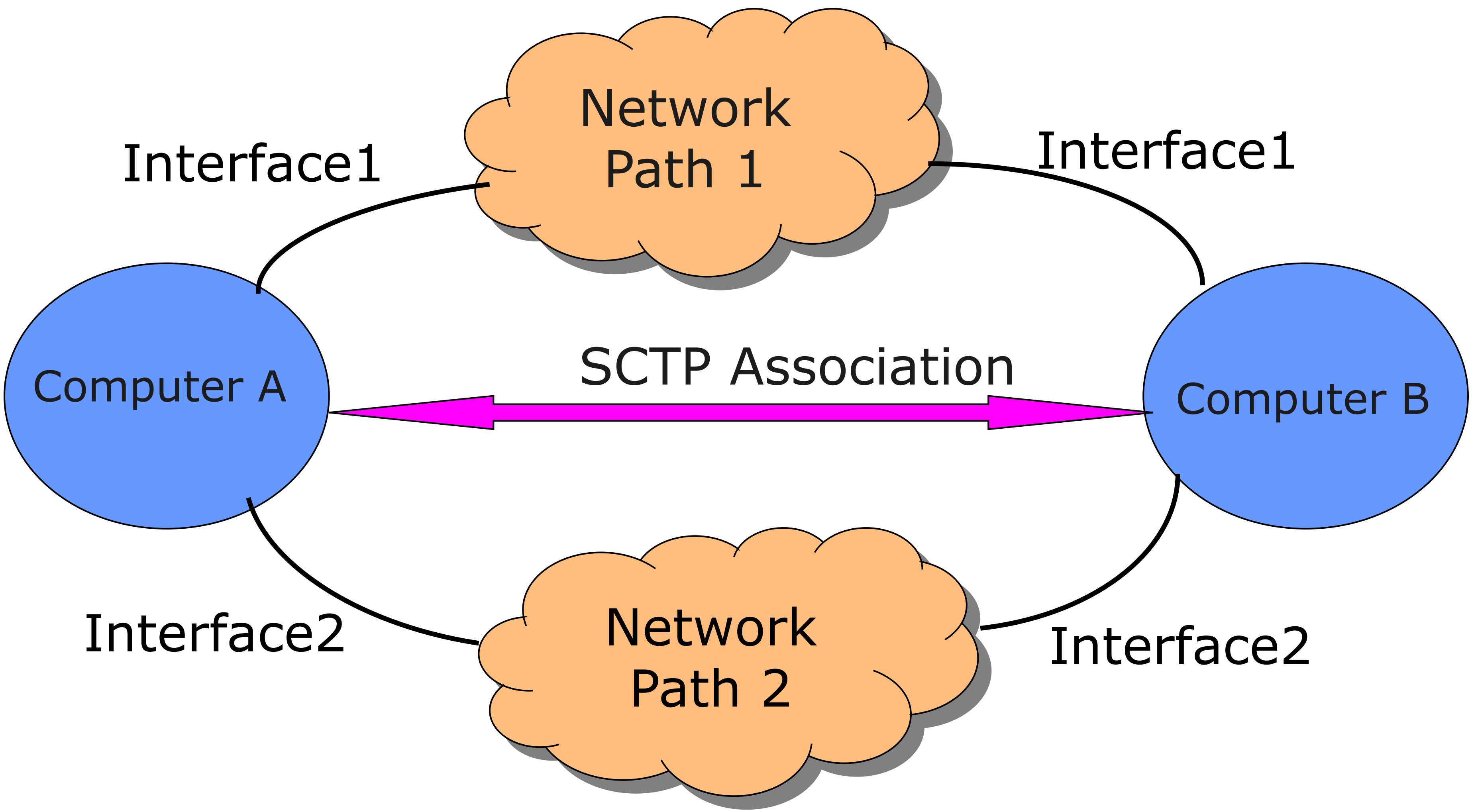
TCP, UDP, **SCTP**

IP

Link Layer

Physical Layer

# SCTP Multi-homing: Supporting Multiple IP Addresses in an Association.



# 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.

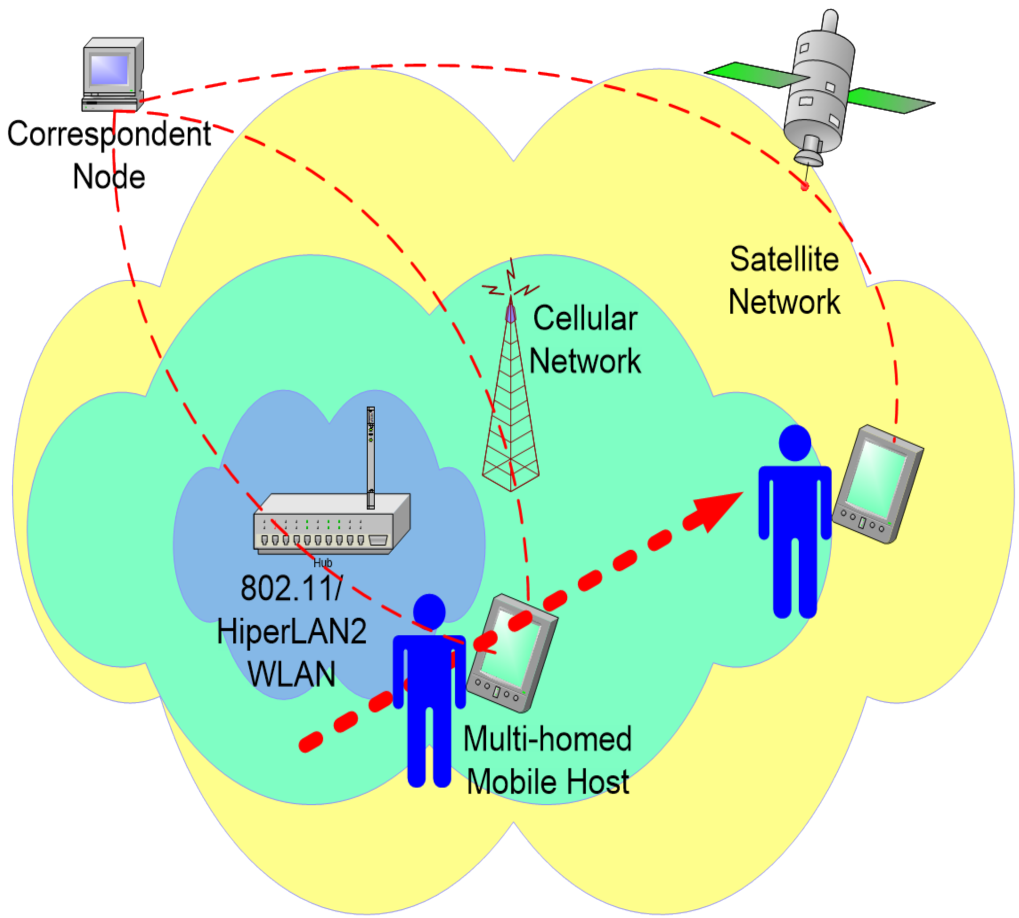
4.Update Location Manager.

5. Delete or deactivate old IP address.

# Vertical Handoff

# SIGMA: Application to Vertical Handoff

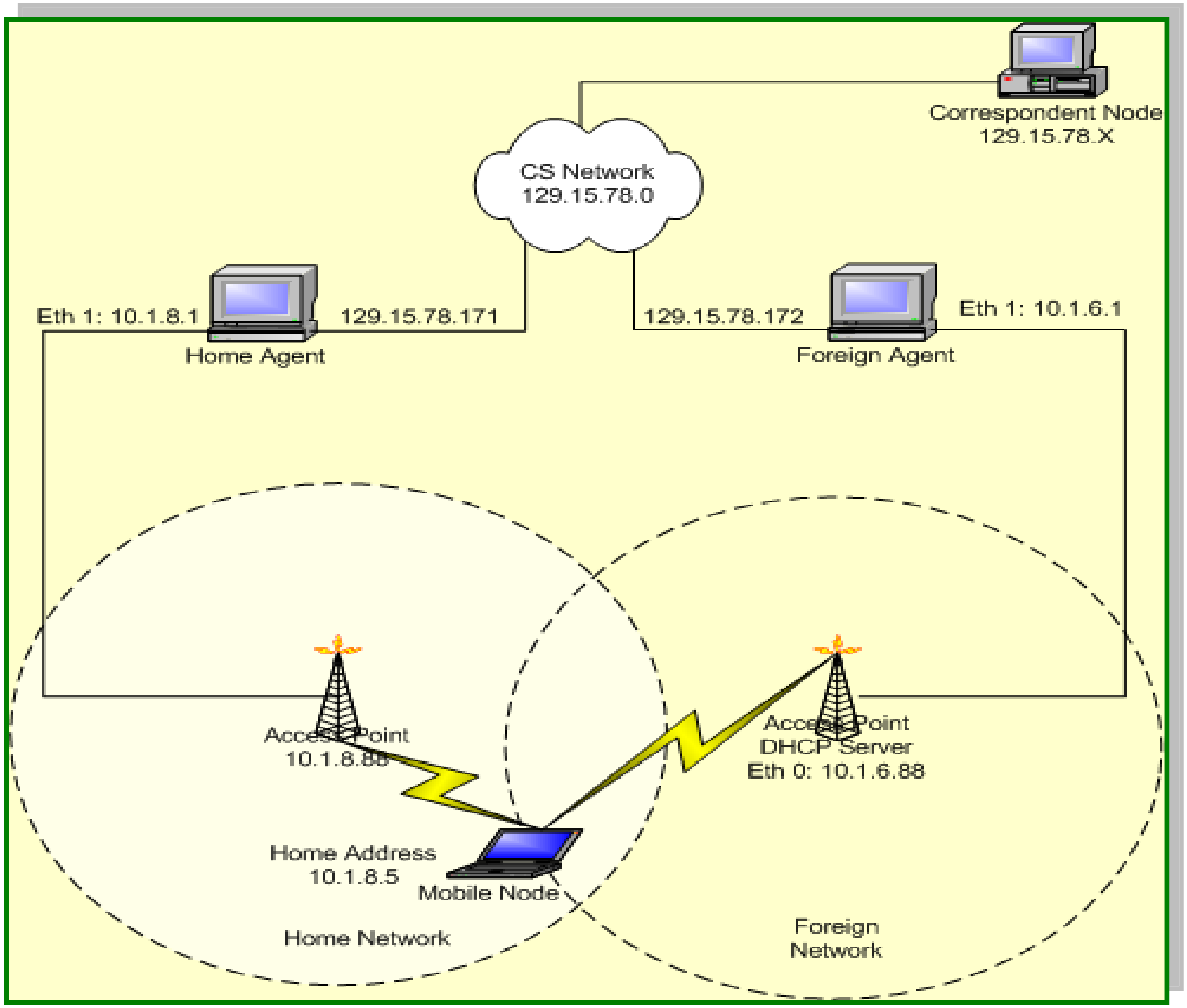
- Handover is no longer only limited to between two subnets in WLAN or between two cells in cellular network (horizontal handover).
- Mobile users are expecting seamless handover between different access networks (vertical handover).
- The mobility based on SCTP multi-homing is a feasible approach to meet the requirement of  vertical handover.





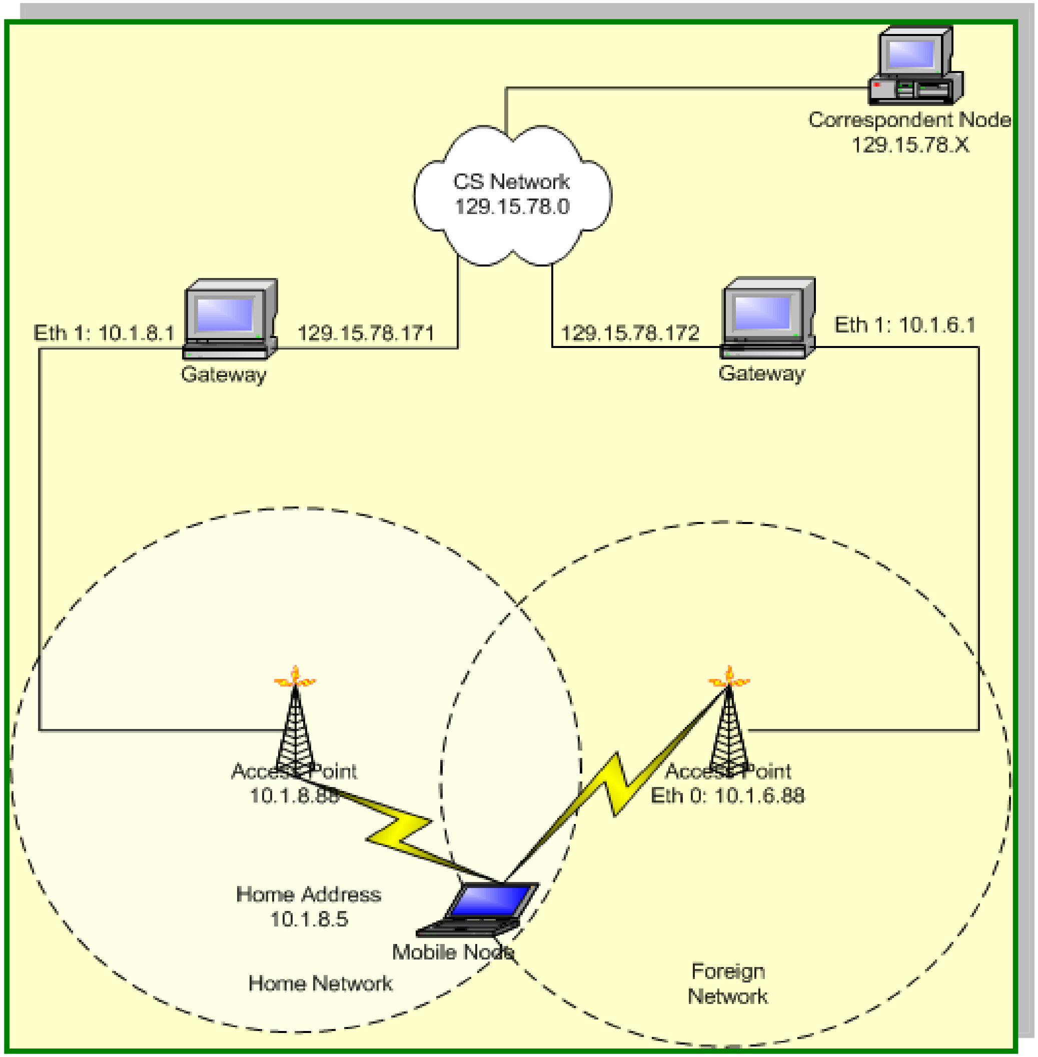

Mohammed Atiquzzaman, University of Oklahoma

# Experimental Testbed


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

Operation of SIGMA Testbed

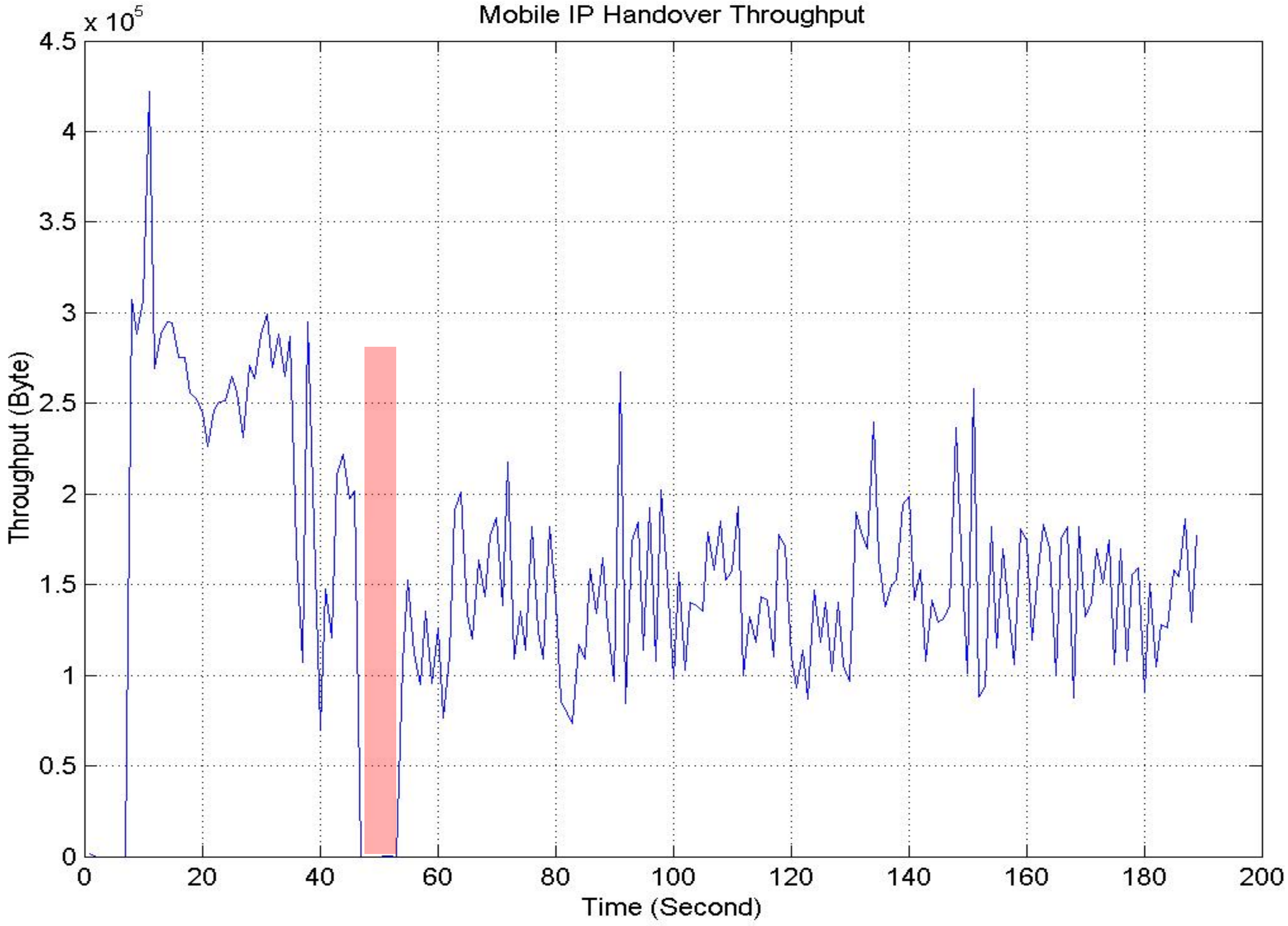
- Link Layer is monitored to detect new AP signal strength.
- When a new AP is detected a new IP address is added to the association.
- When the new AP signal becomes stronger than the old AP signal, the Mobile Node notifies the Correspondent Node to make the new address the primary.




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

# Results

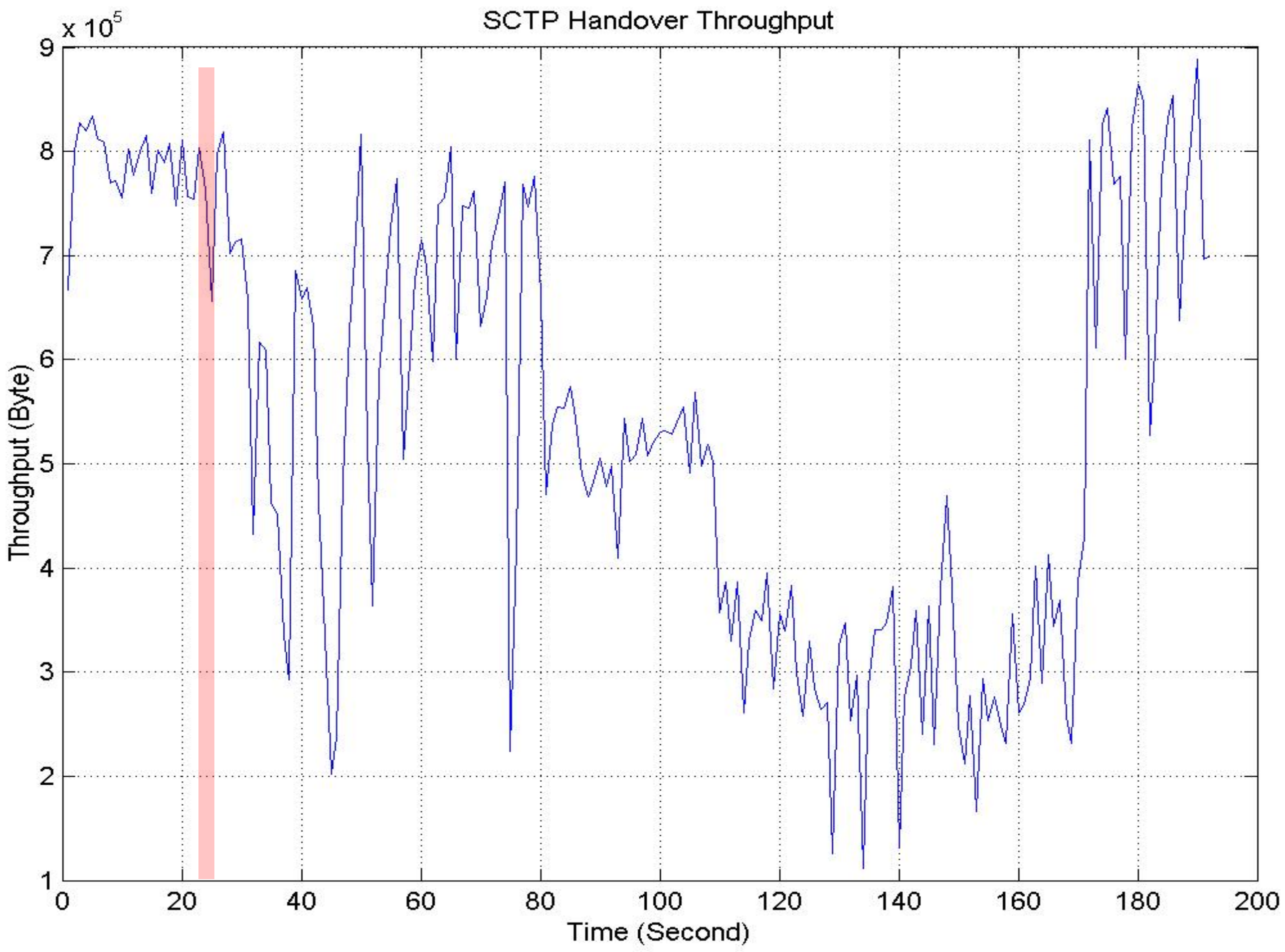
# Mobile IP: Results



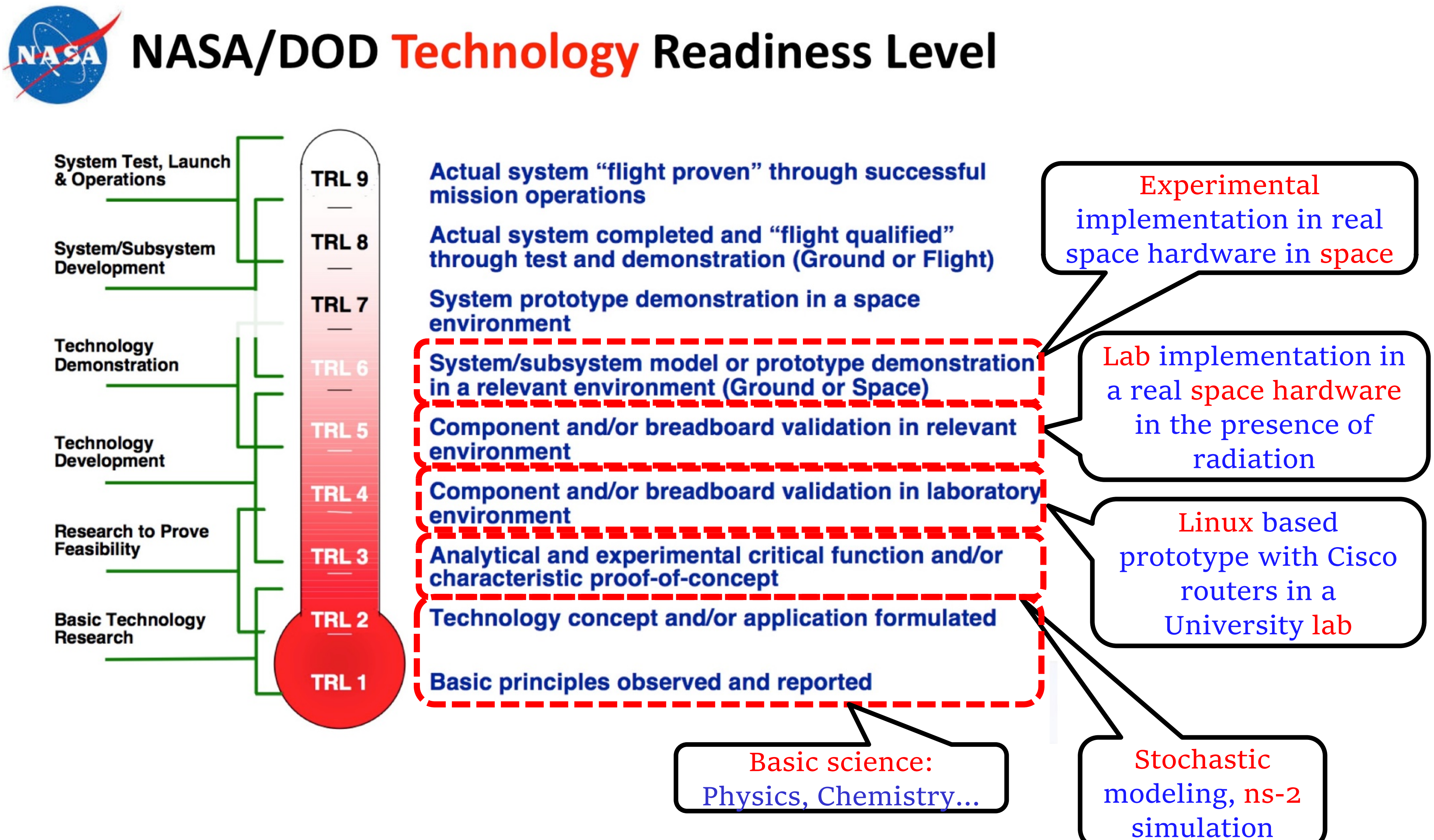



Mohammed Atiquzzaman, University of Oklahoma

# SIGMA: Results



# Technology Maturation - TRL




- Surrey Satellite Technologies Ltd.
- Disaster Monitoring constellation

**Very Limited on-board Computing Resources**

- PowerPC processor
- RTEMS Operating System
- Very limited memory

- Satellite is a critical component for GLOBAL COVERAGE
- Many mobility issues arise due to movement of "satellites".
  - Efficient mobility management schemes for satellites is an important topic for future research.
- Pay attention to TARGET SYSTEM before developing protocols for mission critical systems.

# Acknowledgements

- 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 (BUET, Bangladesh)
  - William Ivancic (NASA)
  - Wesley Eddy (NASA)
  - David Stewart (NASA)
  - Lloyd Wood (Cisco)



Further information: atiq@ou.edu

www.cs.ou.edu/~atiq

# Journals: Please submit high quality papers


2019 Impact Factors:

JNCA: 5.6
VehCom: 4.7


| Journal | Impact factor (2015) | Impact factor (2016) | Impact factor (2017) | Impact factor (2018) |
|---|---|---|---|---|
| IEEE Transactions Wireless Communications | 2.496 | 4.95 | 5.89 | 6.4 |
| IEEE Transactions Mobile Computing | 2.456 | 3.82 | 4.1 | 4.47 |
| **Journal of Network and Computer Applications** | **2.331** | **3.5** | **4.0** | **5.27** |
| Computer Communications | 2.099 | 3.38 | 2.61 | 2.76 |
| IEEE/ACM Transactions on Networking | 1.811 | 3.37 | 3.11 | 3.6 |
| Ad hoc networks | 1.66 | 3.05 | 3.15 | 3.5 |
| Pervasive Mobile Computing | 1.719 | 2.35 | 2.97 | 2.77 |
| IEEE Transactions Computers | [illegible] | [illegible] | [illegible] | [illegible] |
| Computer Networks | [illegible] | [illegible] | [illegible] | [illegible] |

| Index | Category | Rank | Total Journals | Quartile |
|---|---|---|---|---|
| SCIE | Computer Science, Hardware & Architecture | 6 | [illegible] | [illegible] |
| SCIE | Computer Science, Interdisciplinary Applications | 8 | 106 | Q1 |
| SCIE | Computer Science, Software Engineering | 6 | 107 | Q1 |

| Journal | Impact factor (2018) |
|---|---|
| **Vehicular Communications** | **3.53** |
| IEEE Transactions on Vehicular Technology | 5.34 |
| IEEE Vehicular Technology Magazine | 6.14 |
| IEEE Transactions on Intelligent Transportation Systems | 5.74 |

| Index | Category | Rank | Total Journals | Quartile |
|---|---|---|---|---|
| SCIE | Telecommunications | 25 | 88 | Q2 |
| SCIE | Transportation Science and Technology | 11 | 37 | Q2 |

PLEASE SUBMIT HIGH QUALITY PAPERS

# Thank you

Contact info

Mohammed Atiquzzaman

atiq@ou.edu

(405) 325 8077

www.cs.ou.edu/~atiq

SCAN ME