Flexible and Reliable Access for the Future NASA Space Network

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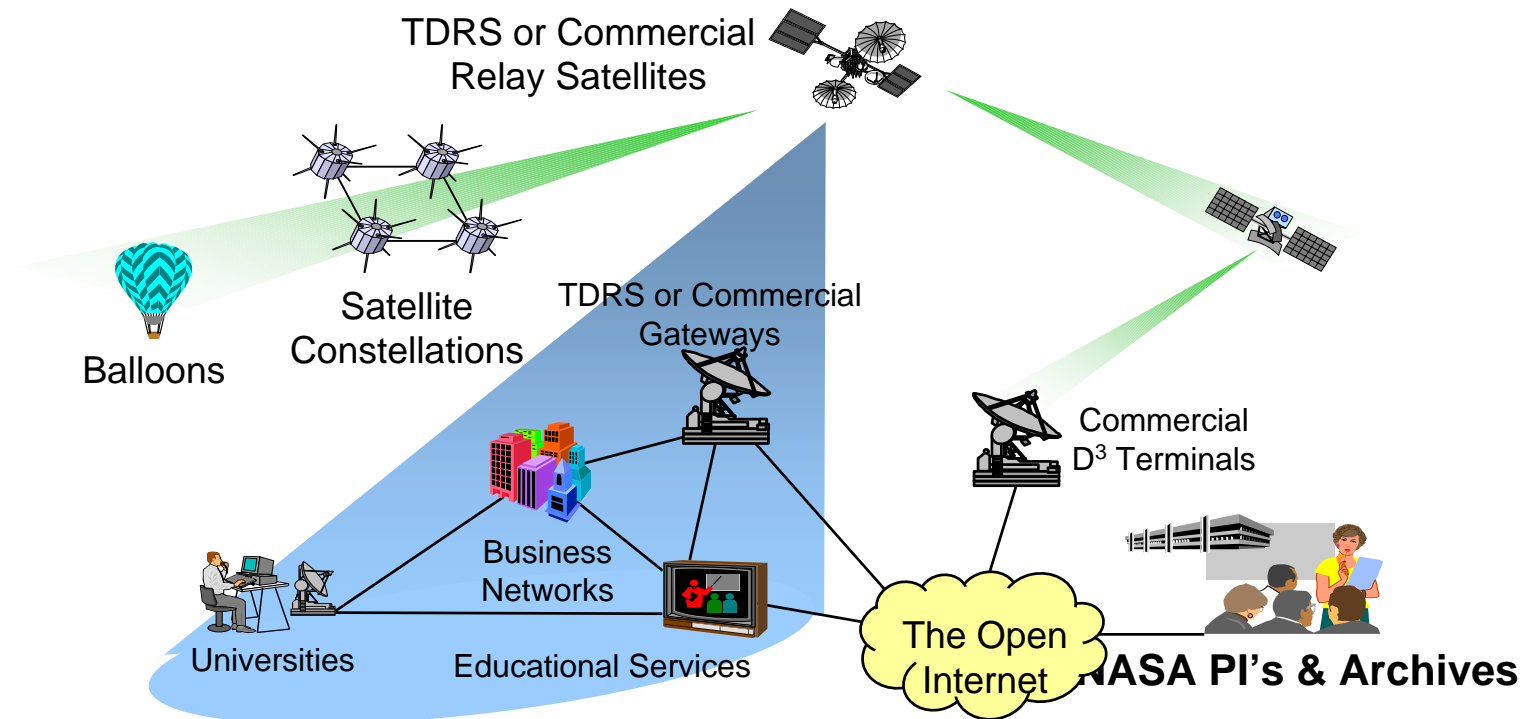*GSAW2004*

Session 8, Space and Ground Communications

NASA's New Vision

- **This project is in direct alignment with NASA's new vision to pursue breakthrough technologies, investigate planetary resources, and align ongoing programs to develop sustainable, affordable, and flexible exploration strategies.**

- **Focus is not about one-time events but in infrastructure development that will result in reduced costs to maintain the affordability of the vision to:**

  – **Pursue Compelling Questions**

  – **Across Multiple Worlds**

  – **Employ Human and Robotic Capabilities**
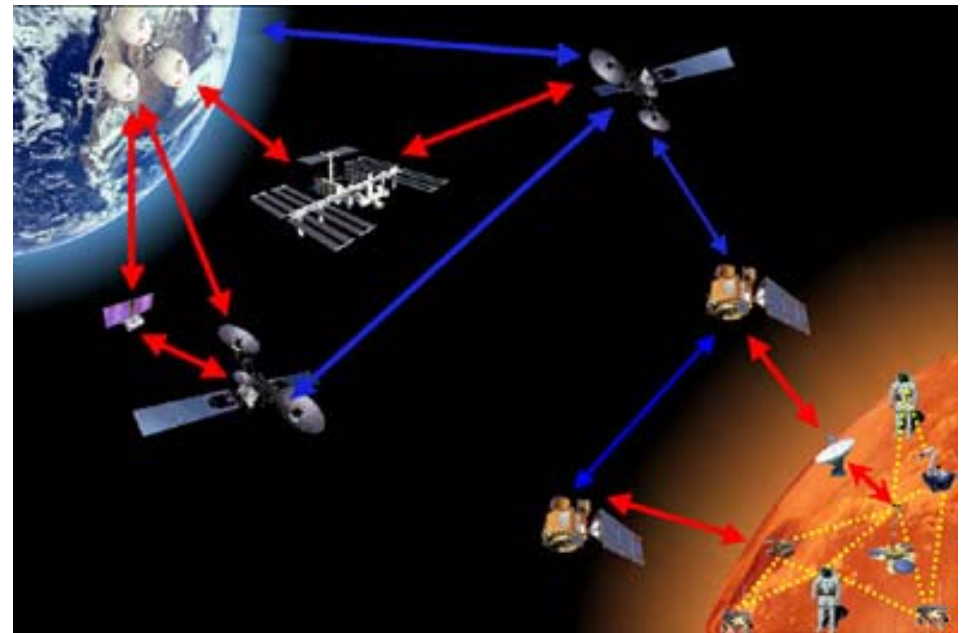
Future Mission Network Evolution

- NASA network supports large numbers of single or constellation spacecraft with IP-addressable instruments
- Mission Operation gradually evolves to a dynamic concept and uses a NASA & commercial assets for communication support; direct-to-ground as well as GEO relay solutions are employed.
- Commercial technology and standard communication protocols are employed (where possible).

TDRS or Commercial Relay Satellites

Balloons

Satellite Constellations

TDRS or Commercial Gateways

Commercial D^3 Terminals

Business Networks

Universities

Educational Services

The Open Internet

NASA PI's & Archives

What needs to be done to achieve this transition?

- **We need to better understand the traffic profiles in this new Network**

$\Rightarrow$*Look into existing traffic at NASA collection nodes and develop a mathematical/statistical basis for analyzing the changes to the communication network architectures.*

- **We need to find ways to share bandwidth more efficiently**

$\Rightarrow$*Develop dynamic solution for sharing bandwidth based on demand, able to support new communication requirements and different QoS.*

- **We need to make sure this is done securely**

=>*Investigate and determine technologies, policies and procedures to ensure the security of this hybrid network*

Project Philosophy

- Project addresses the needs of NASA Enterprises directly.

- We focus on basic research that can raise NASA Technology Readiness Levels and try to design a new communication infrastructure that future missions can use for better science return.

- We try, where possible, to work with the aerospace industry, adopt commercial standards and solutions and use available commercial assets (in space or on the ground) so that costs are reduced and we can take advantage of recently deployed technologies and proven solutions from the Internet and wireless industry.
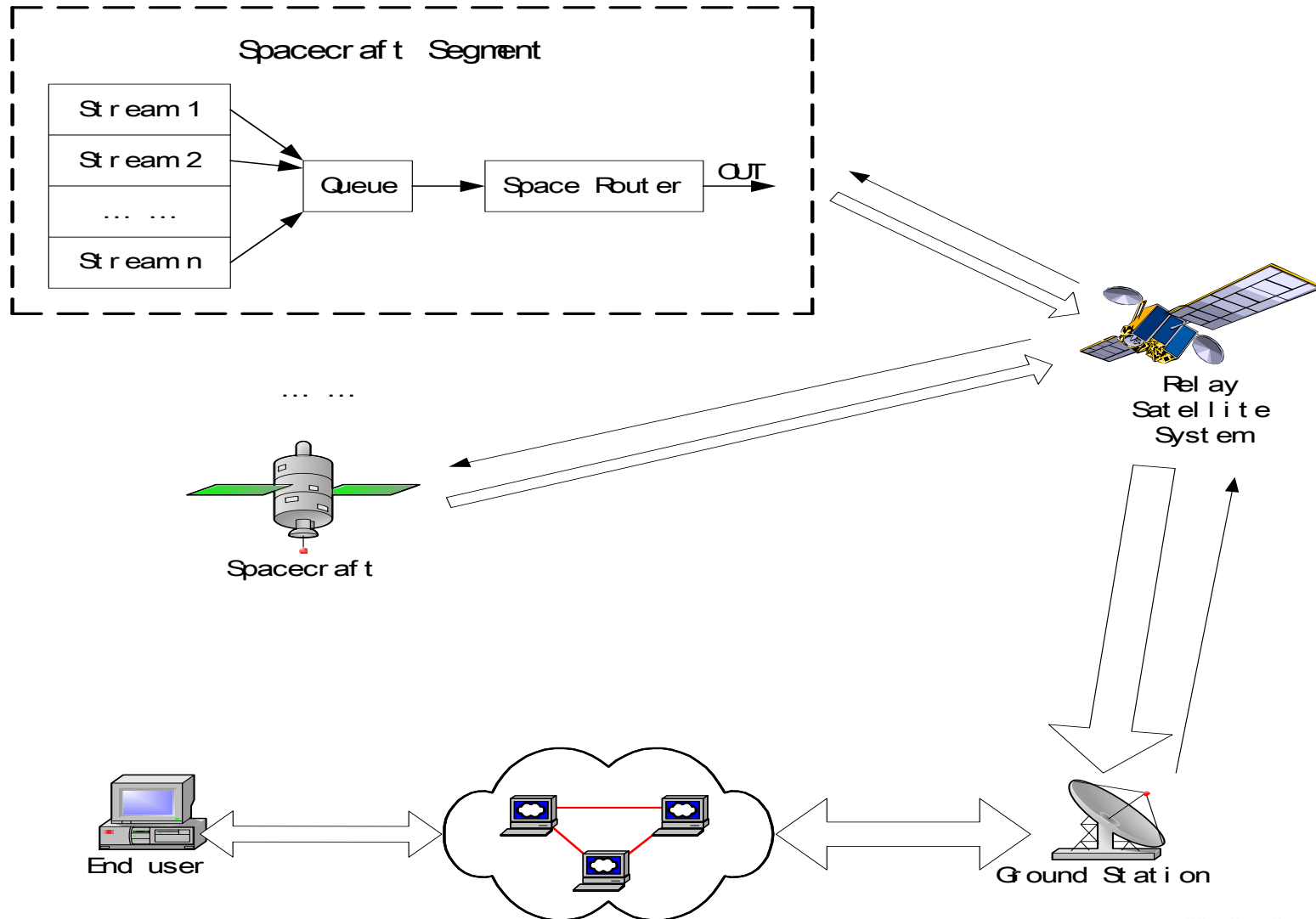
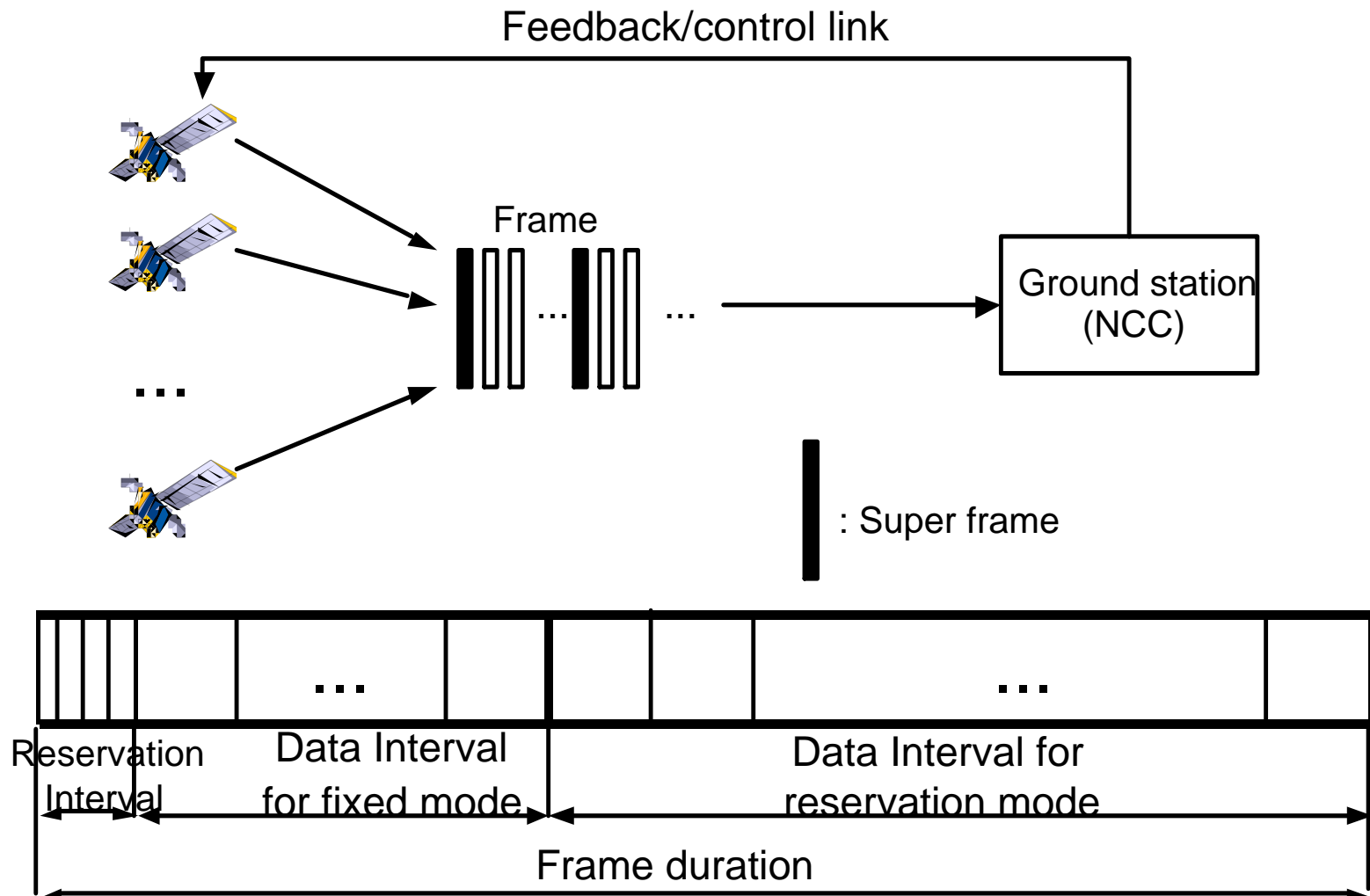# Methodology
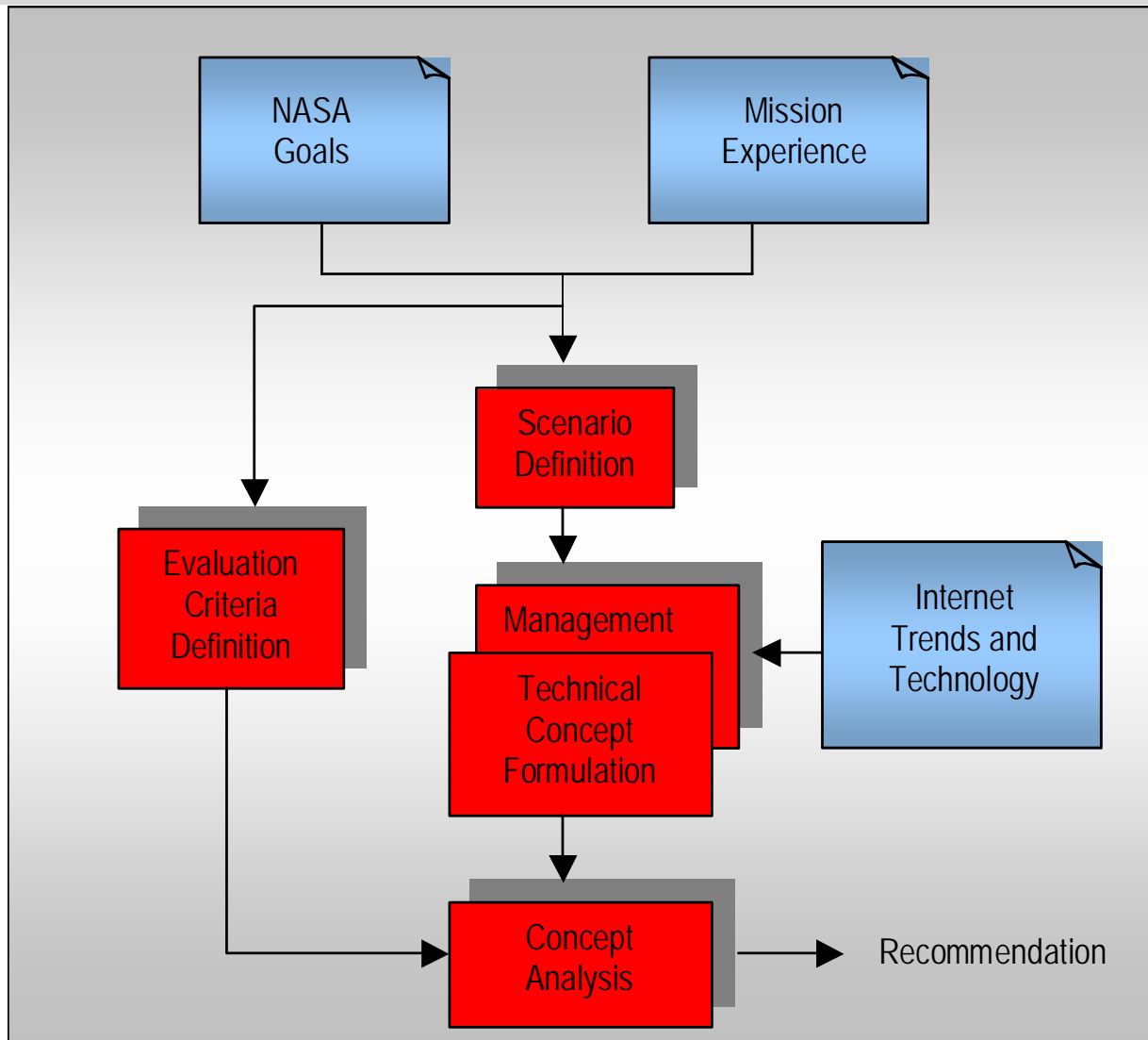
Progress so far

- Defined a sample mission scenario, using the ESE TERRA mission, determined the details of the data generation of the instruments and packetization and queuing on-board.
- Formulated conventional access scheme and scheduling policy for traffic relay through TDRSS supporting several similar spacecraft.
- Developed OPNET Model consisting of spacecraft, TDRSS and NASA Ground Network.
- Investigated packet-based scheduling algorithms for data multiplexing and traffic priority assignment on board a spacecraft.
- Started formulating a dynamic access scheme capable of *efficiently* sharing transmission bandwidth with other spacecraft, leading to a more dynamic mission operation scenario.
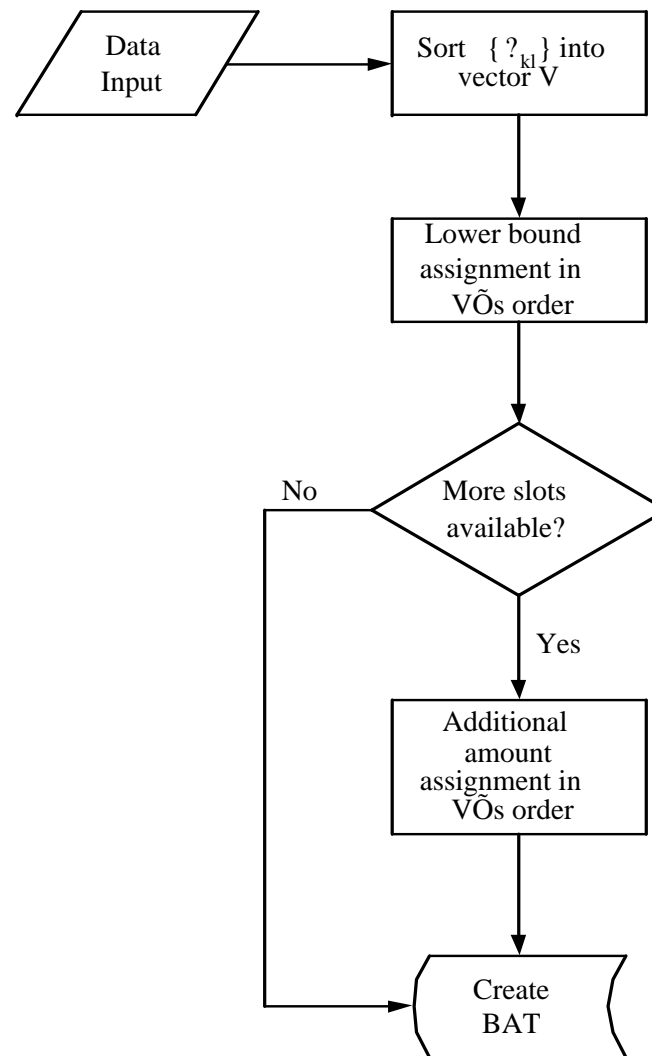
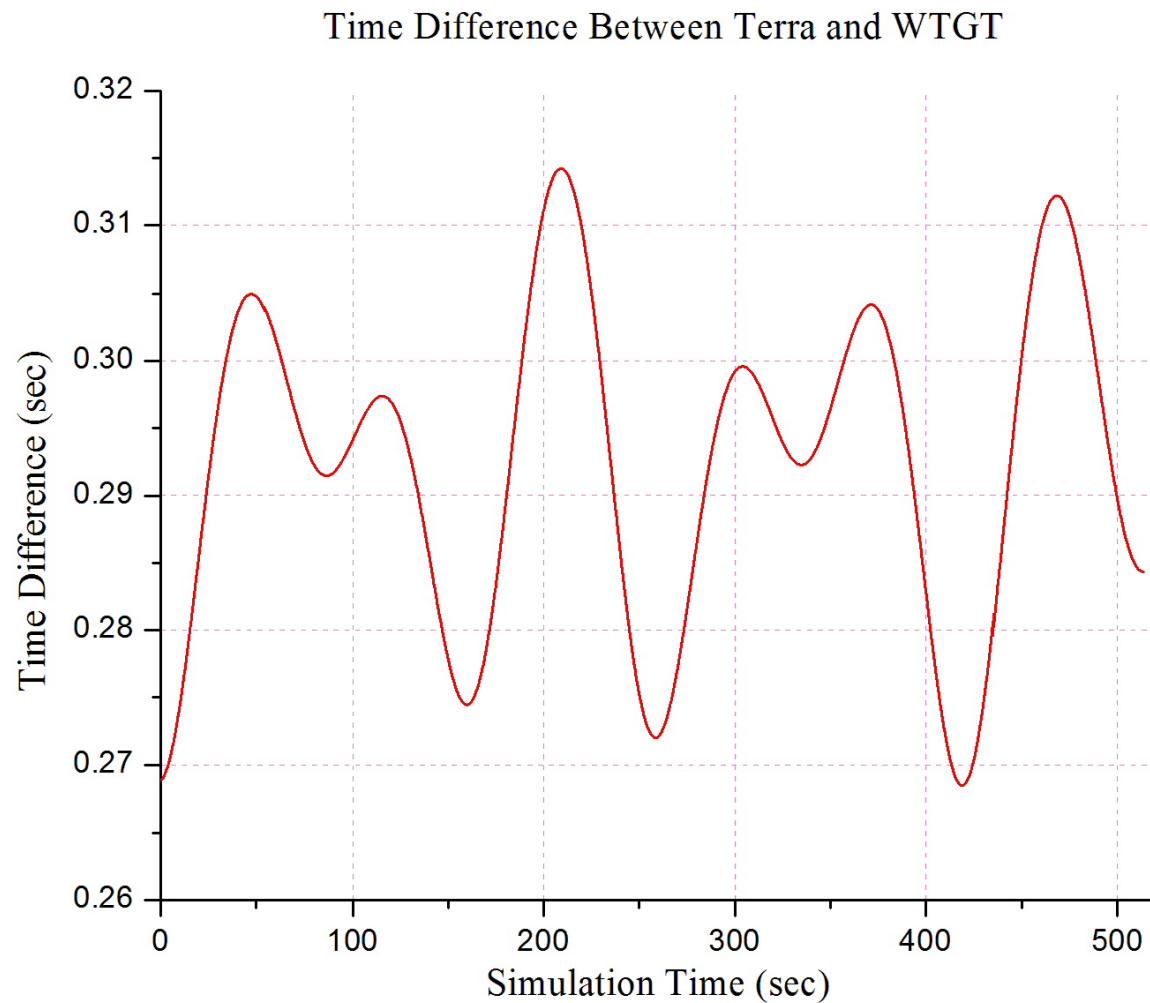# Architecture of multi-access for the downlink channel
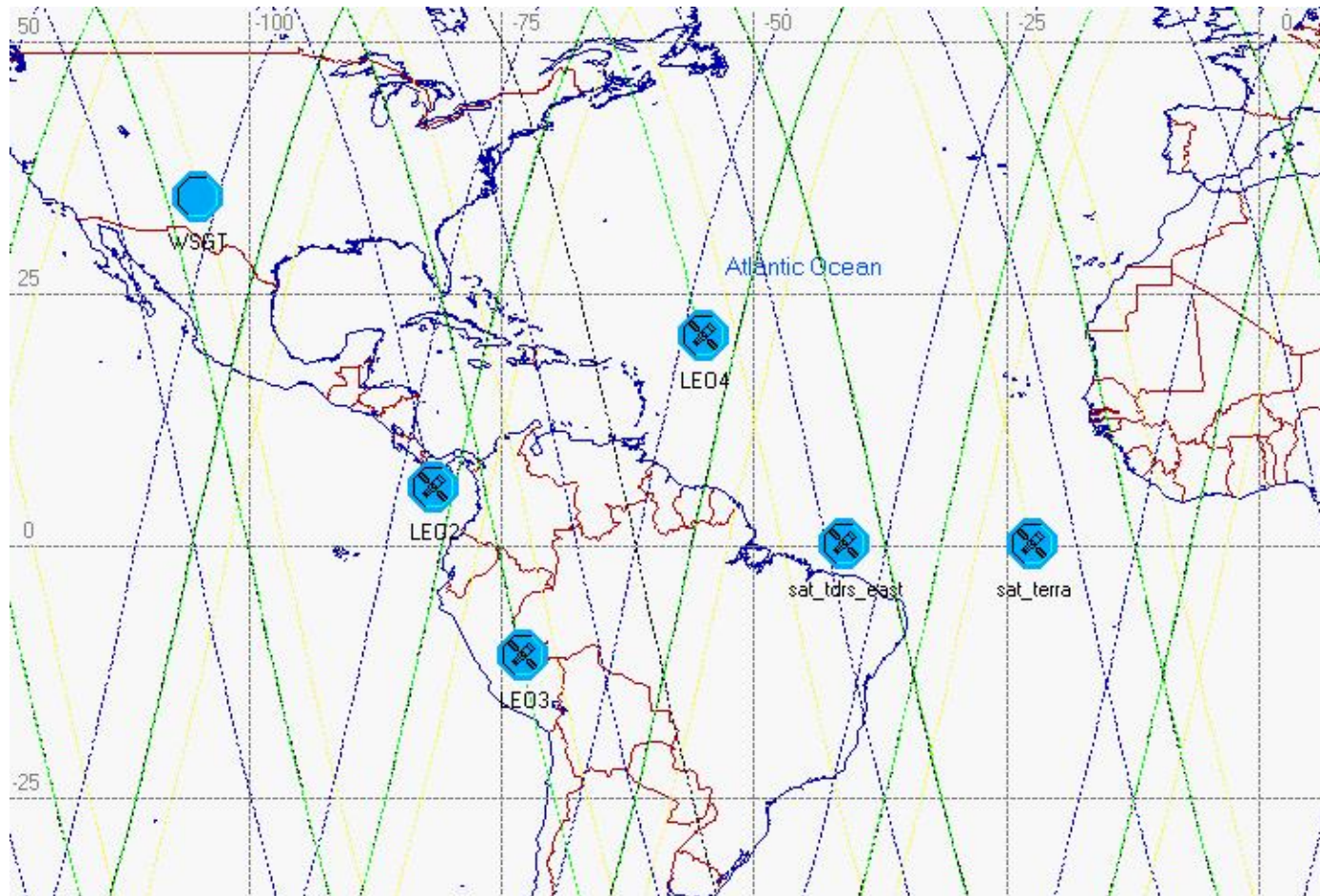
Hybrid Mode Access Protocol

Feedback/control link

Frame

Ground station (NCC)

...

: Super frame

Reservation Interval

Data Interval for fixed mode

Data Interval for reservation mode

Frame duration

Job flow diagram of Bandwidth Allocation

Propagation Delay Variation

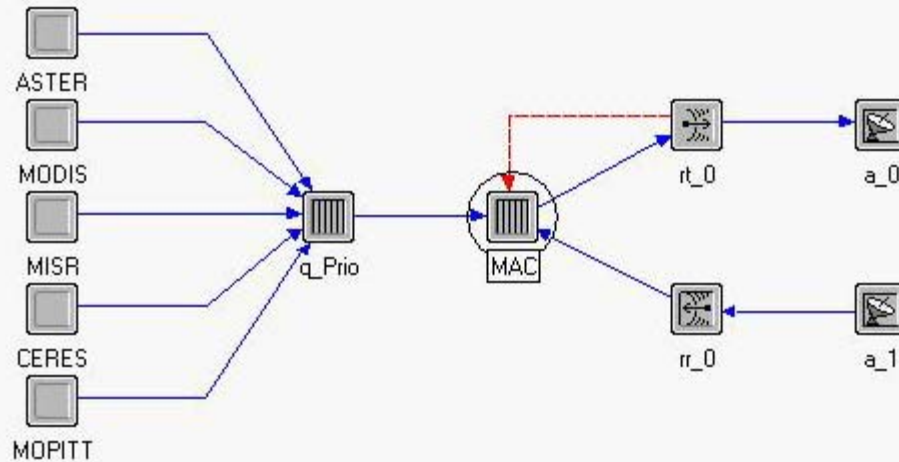Time Difference Between Terra and WTGT
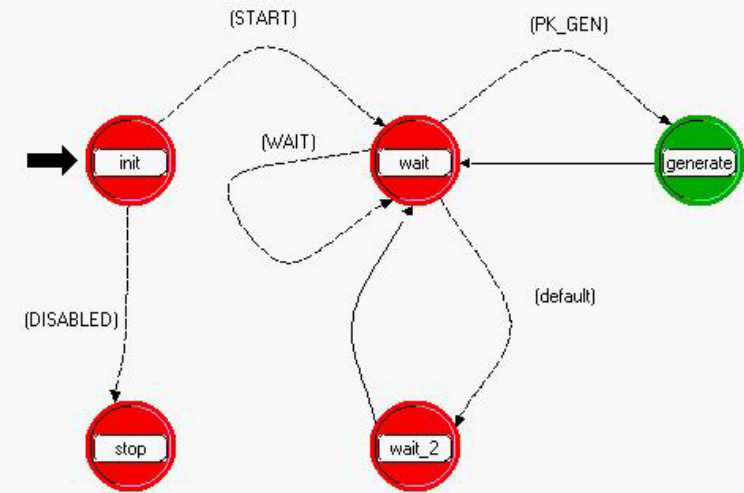
Simulation Components
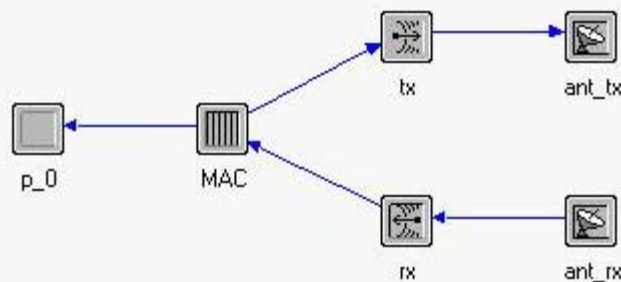

Space Network Model
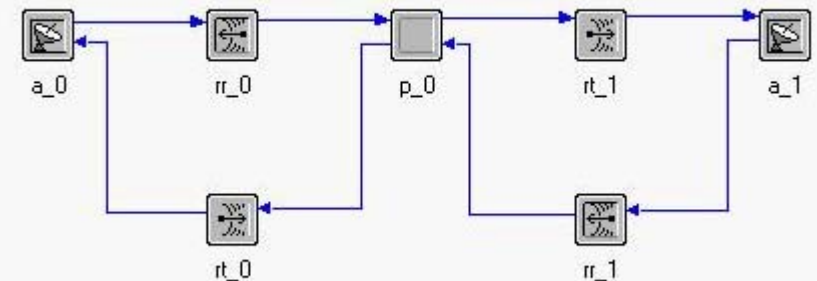
Simulation Components

Spacecraft Node Model (Terra)

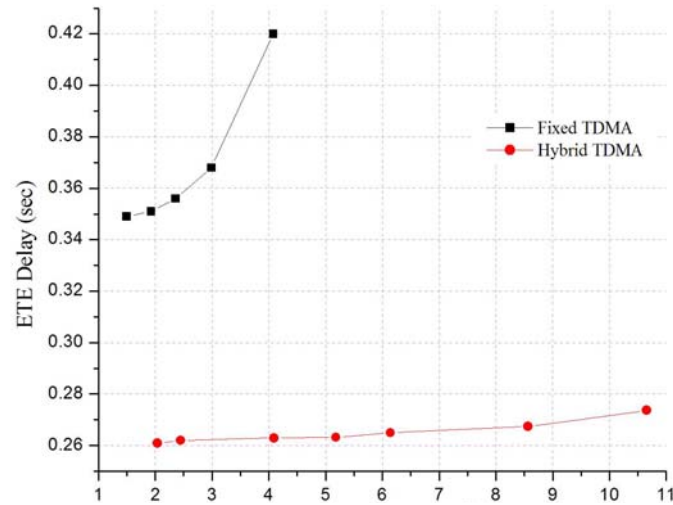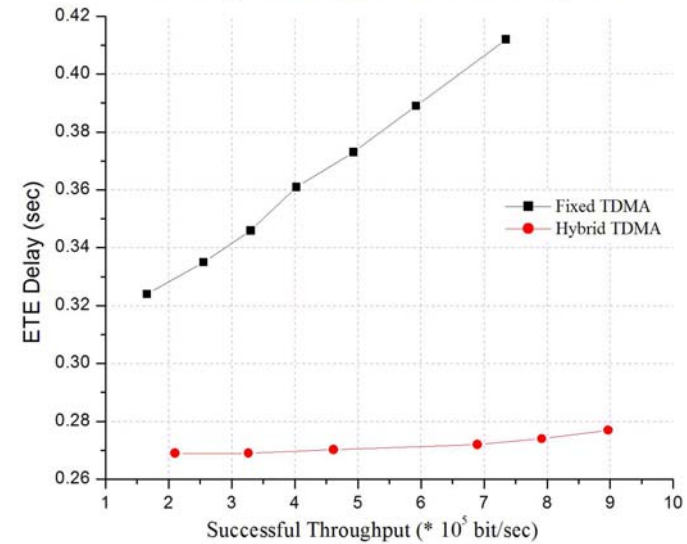Process Model (ASTER) of the Terra Model

Ground Terminal Node Model

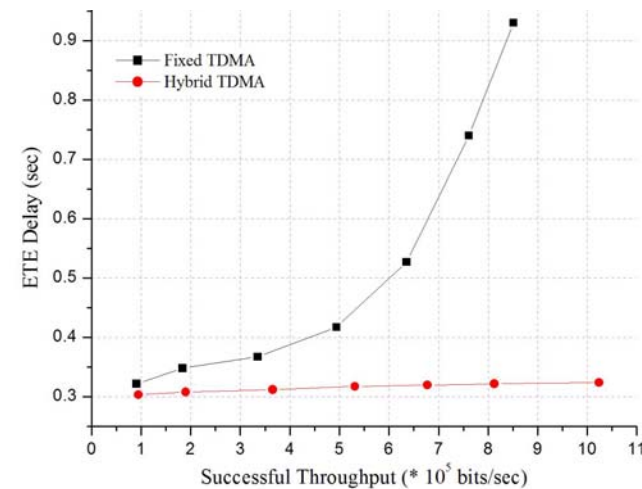Node Model (TDRS Spacecraft)

Static Vs Dynamic TDMA

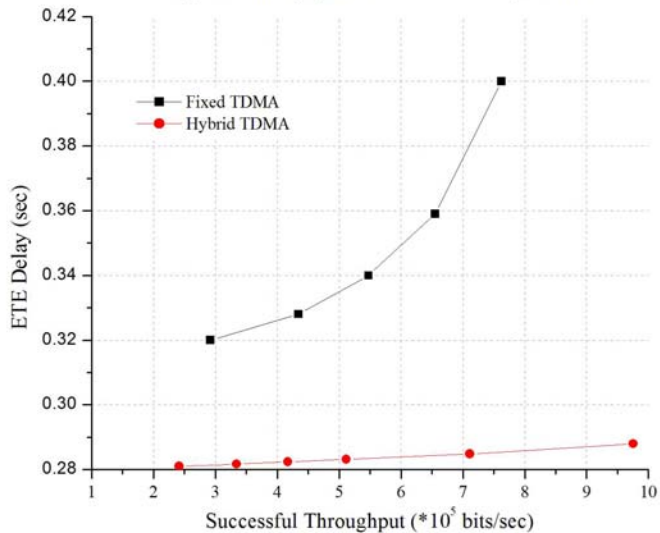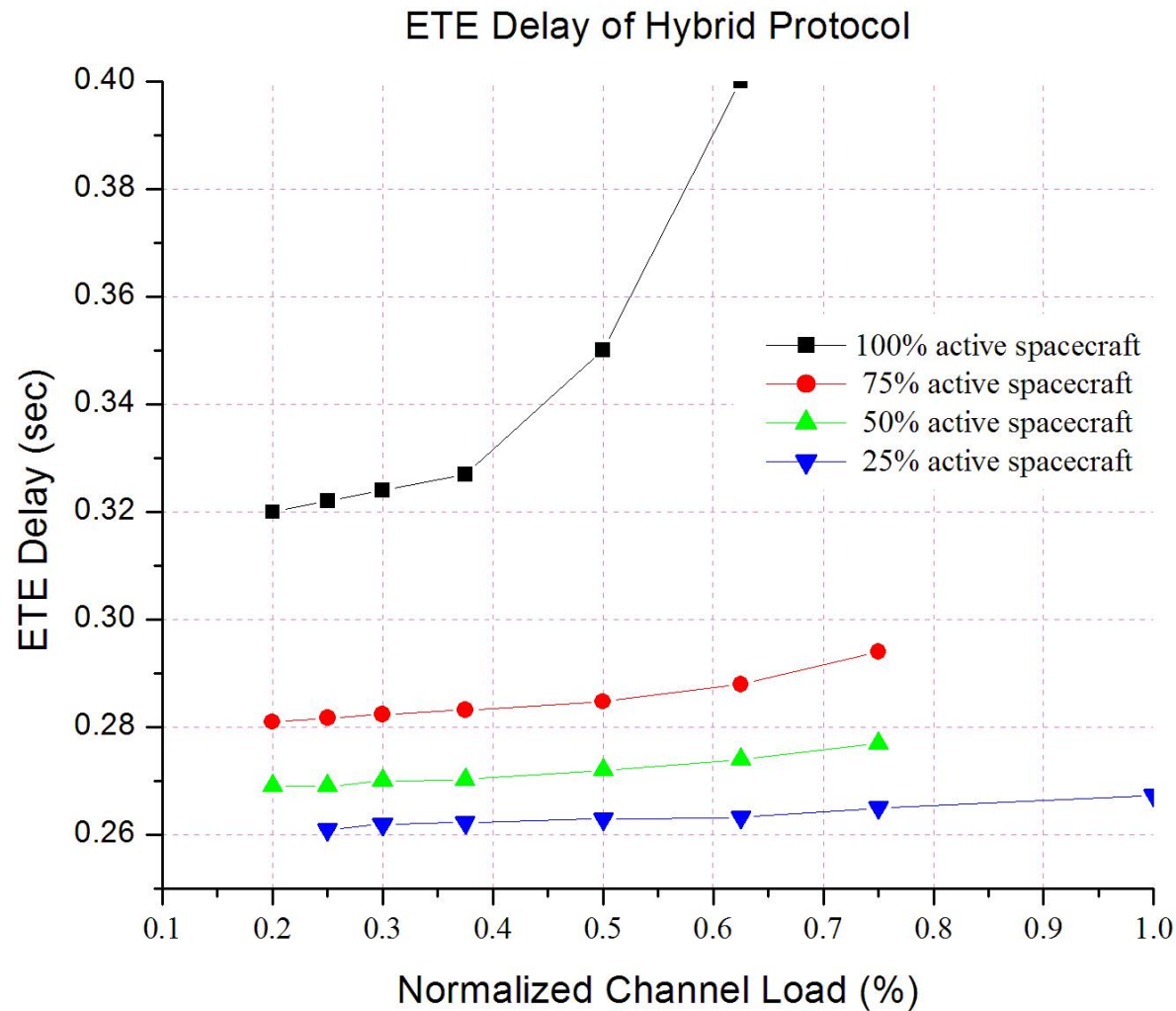ETE Delay v.s. Throughput with 25% Active Spacecraft

ETE Delay v.s. Throughput with 50% Active Spacecraft

ETE Delay v.s. Throughput with 75% Active Spacecraft
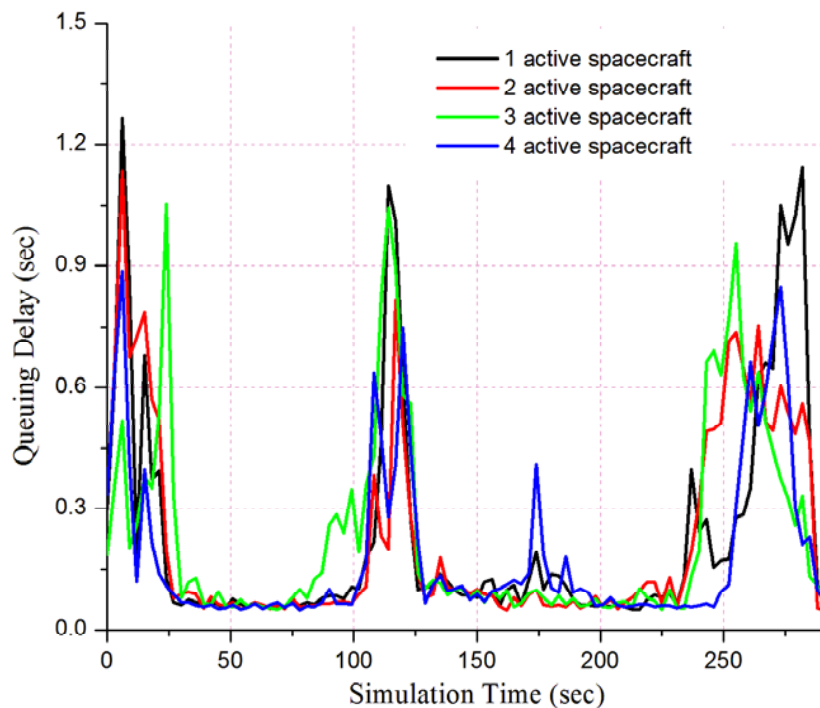
Performance of Hybrid MAC
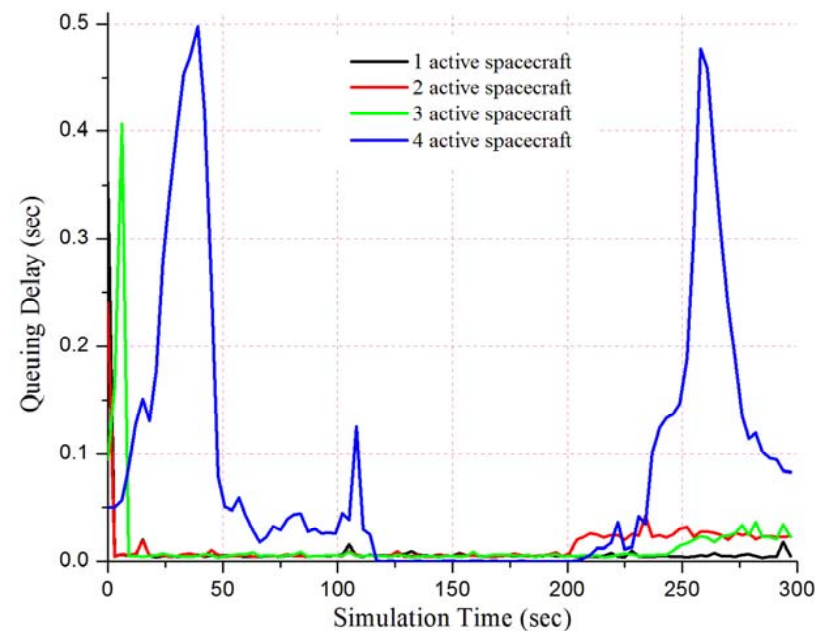

ETE Delay of Hybrid Protocol

Data Queuing Delay on-board a Spacecraft

Queuing Delay On-board a Specific Spacecraft in Fixed TDMA

Queuing Delay On-board a Specific Spacecraft in Hybrid TDMA mode

Security Issues for IP-in-Space

- **As spacecraft become accessible network nodes, communication security becomes an issue.**

- **There is obviously a need to protect space missions from threads that have the potential to disturb normal communication.**

- **Possible attacks for the traffic traveling from space to ground include:**

  - **Data confidentiality violation and traffic flow confidentiality violation**
  - **Modification of messages**
  - **Masquerade (mimic behavior-IP spoofing)**
  - **A replay attack**
  - **A denial of service attack**
  - **Password sniffing**
  - **Session hijacking**
  - **Jamming**

Security Measures

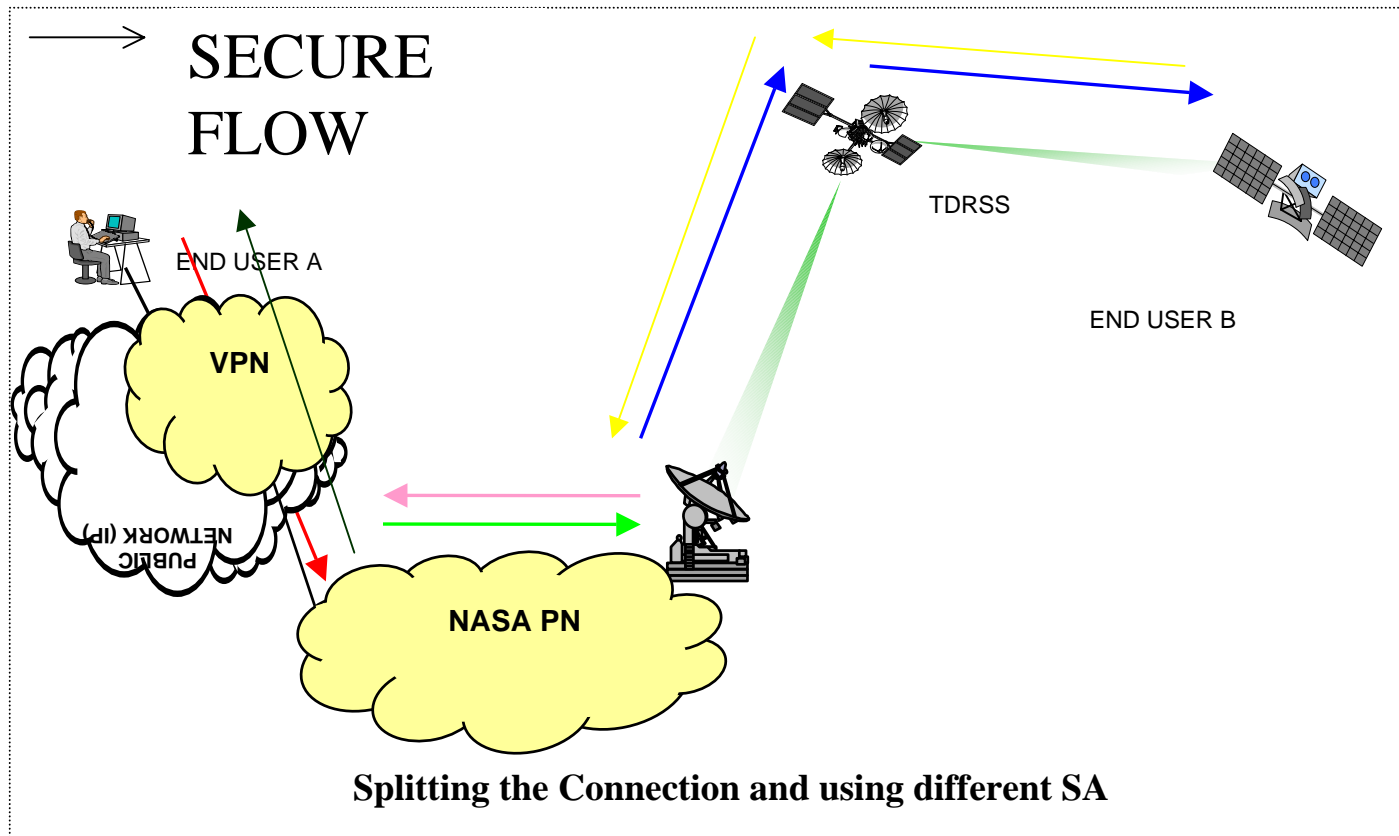Try to eliminate threads by enhancing the system with the following measures:

- **Prevention**
  - **Confidentiality:** Encryption forbids unauthorized users to disclose information
  - **Availability:** Resources must not be denied from authorized users- Access Control prevents unauthorized use of a resource, including the prevention of use of a resource in an unauthorized manner.

- **Detection-Response**
  - **Integrity:** Information cannot be altered and processed by the receiving communicating party-a hash function is applied on the packet and the result is sent for verification to the receiver. Violation results to discard the packet.
  - **Authentication:** Service requesters are the original ones-a secret shared key, an encrypted IP address or a private key can proof requester identity. When the system discovers unauthorized the connection is ended.
  - **Anti replay:** Avoid processing duplicate packets- the use of counters like sequence number field can identify and discard duplicate packets.

Topology Example

SECURE FLOW

END USER A

VPN

PUBLIC NETWORK (IP)

NASA PN

TDRSS

END USER B

Splitting the Connection and using different SA

Conclusions

- **Started an innovative study in evaluating alternatives for more efficient and dynamic ways to communicate with future space missions.**

- **Focus is on an IP-compliant network that consists of several spacecraft missions in near-Earth orbit.**

- **Modeled traffic scenario and network topology for space-to-ground relay.**

- **Proposed a dynamic TDMA approach , with early results showing a capability of more efficiently supporting dynamic access and potential for careful performance optimization.**

- **Started investigating security issues that must be addressed to ensure safe and reliable operation.**

Future Work

- **Continue to develop and optimize a dynamic multi-access protocol that offers both guaranteed and on-demand sharing of the available bandwidth.**

- **Investigate traffic statistics (provided by NASA) to determine how we can adapt protocol operation to reflect realistic traffic scenarios.**

- **Investigate candidate designs for future space-to-ground relay solutions, including next TDRS design, direct-to-ground and possible feasibility of using commercial providers and assets.**

- **Investigate security issues and examine ways to integrate security into solutions during mission design.**