Software Defined DTN-Based Satellite Networks
draft-li-dtn-sd-dtn-sat-net

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Outline

- Introduction
- Key Points of the Design
- Model Description
- Implementation
- Use cases

Introduction

- Main parts of the draft

1. Introduction
2. Key points of the design
   - 2.1. Separated control plane and forwarding plane
   - 2.2. Bundle tunnel
   - 2.3. Satellite gateway
3. Use case
4. Conclusions

Introduction

Contributions to DTNwg

- This draft is a use case of DTN. We apply DTN in the space networks.
- The research in the draft is an implementation of DTN, which is supported by a national project.
- This draft focus on the control and management of disrupted networks.
- We have focused on DTN since 2015.

Introduction

- Characteristics in the space networks
  - The transmission delay is very long and varies rapidly in a big range.
  - The satellite links interrupt frequently and the interrupt time is long.
  - The bit error rate is high and the path loss is big.
  - The bandwidth of uplink and downlink is Asymmetric.
  - The onboard satellite resource is limited.

Introduction

Comparison

Protocol	Advantages	Disadvantages
TCP/IP	Mature technology Low cost Integrated with ground networks	Cannot be used in satellite links directly Not suitable for deep space
CCSDS	Perfect protocol system	Protocol conversion is needed
DTN	Designed for space networks	Still in the experimental stage

Introduction

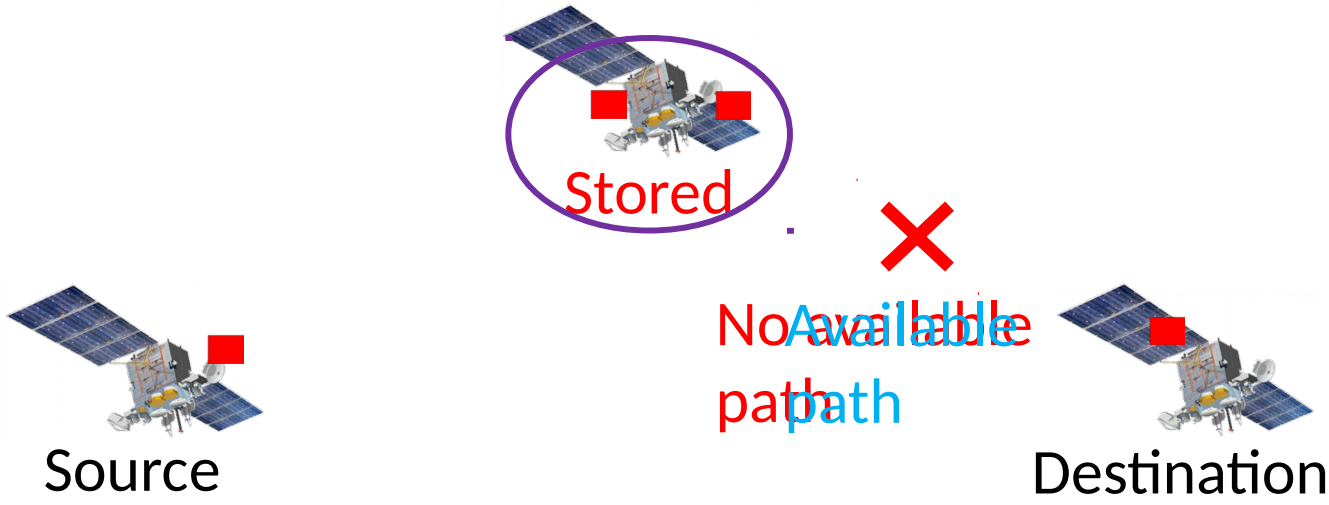
DTN in the space network

Time	Experiments	Results
2008.01	Disaster Monitoring Constellation (Surrey Satellite Technology Ltd)	The first use of DTN from orbit.
2008.10	Deep Impact Network Experiment (NASA)	Verify that DTN can be used in space network.
2010.03	DTN in TDRSS Experiment (NASA)	Verify the ability of file transmission and custody of DTN (BP/LTP)
2010.12	Earth Observation-1 satellite Experiment (NASA)	Verify a DTN-based satellite node
2011.04	Internet Protocol Routing in Space (IRIS) (Cisco)	Store-and-forward automatically on IRIS.
2012.11	LEGO Space Robot Experiment (NASA &ESA)	Control the LEGO space robot in the international space station based on DTN.

Introduction

DTN in the space network

DTN is typically applied in the scenes where there are no guaranteed end-to-end paths between the source and destination. The original design is very suitable for satellite network links.



Introduction

- Problems in traditional satellite networks

- Slow configuration
- Inflexible traffic scheduling
- Inefficient service delivery

Traditional satellite networks are inefficient and inflexible in providing fine-grained management and configuration

We need a new design!

Introduction

In the past years, a lot of projects that focus on new satellite network have been proposed.

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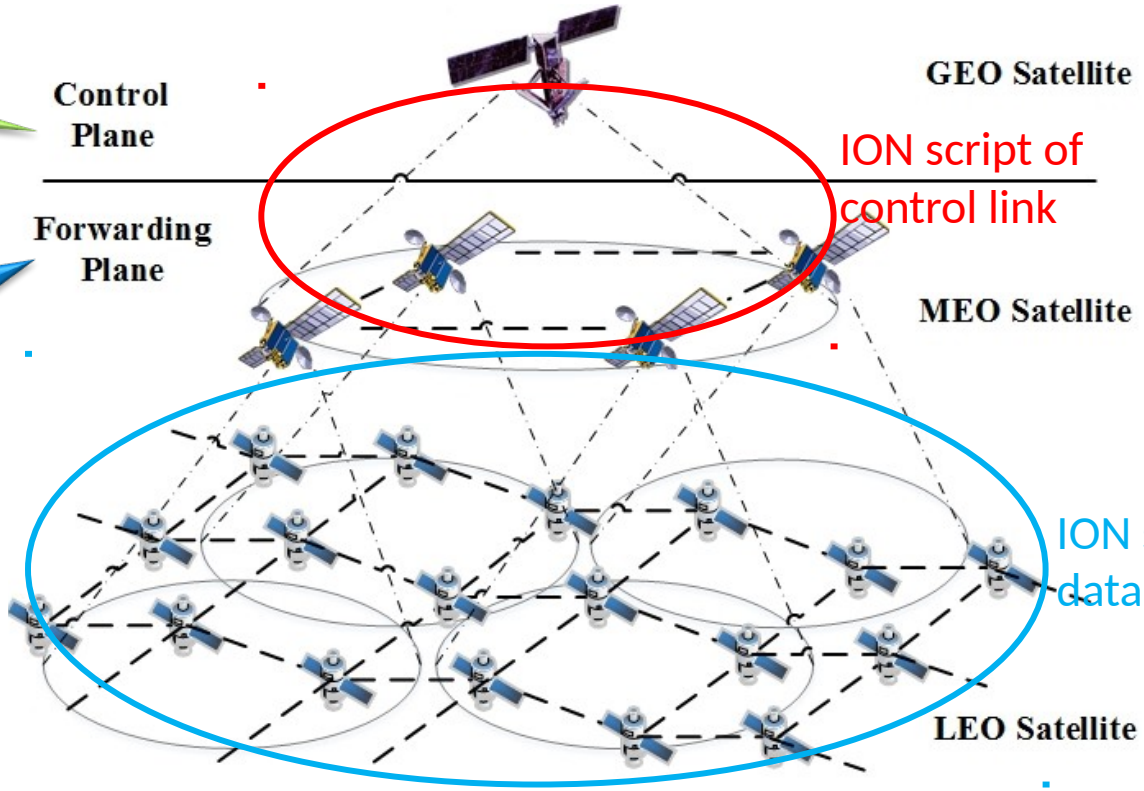
Key Points of the Design

- Separated Control Plane and Forwarding Plane

Control Plane
GEO satellites

Forwarding Plane
MEO satellites
/LEO satellites



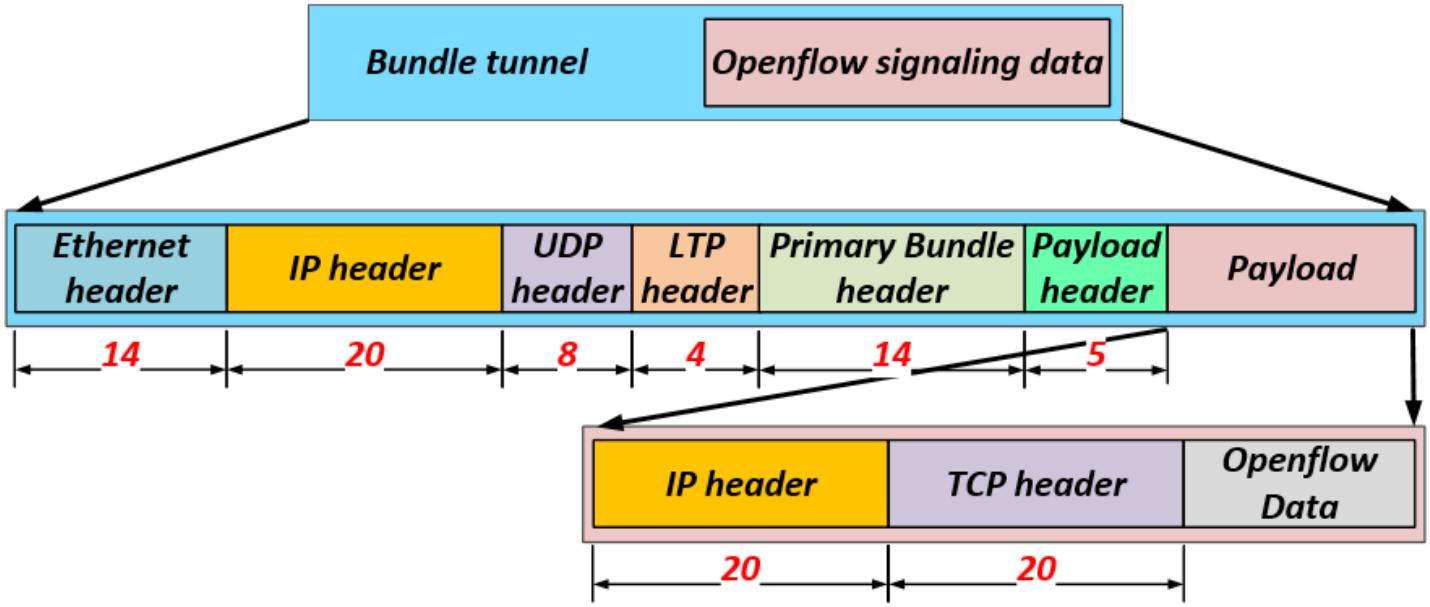
Software Defined Satellite Networks (SDSN)

GEO: Geosynchronous Earth Orbit
MEO: Medium Earth Orbit
LEO: Low Earth Orbit

Key Points of the Design

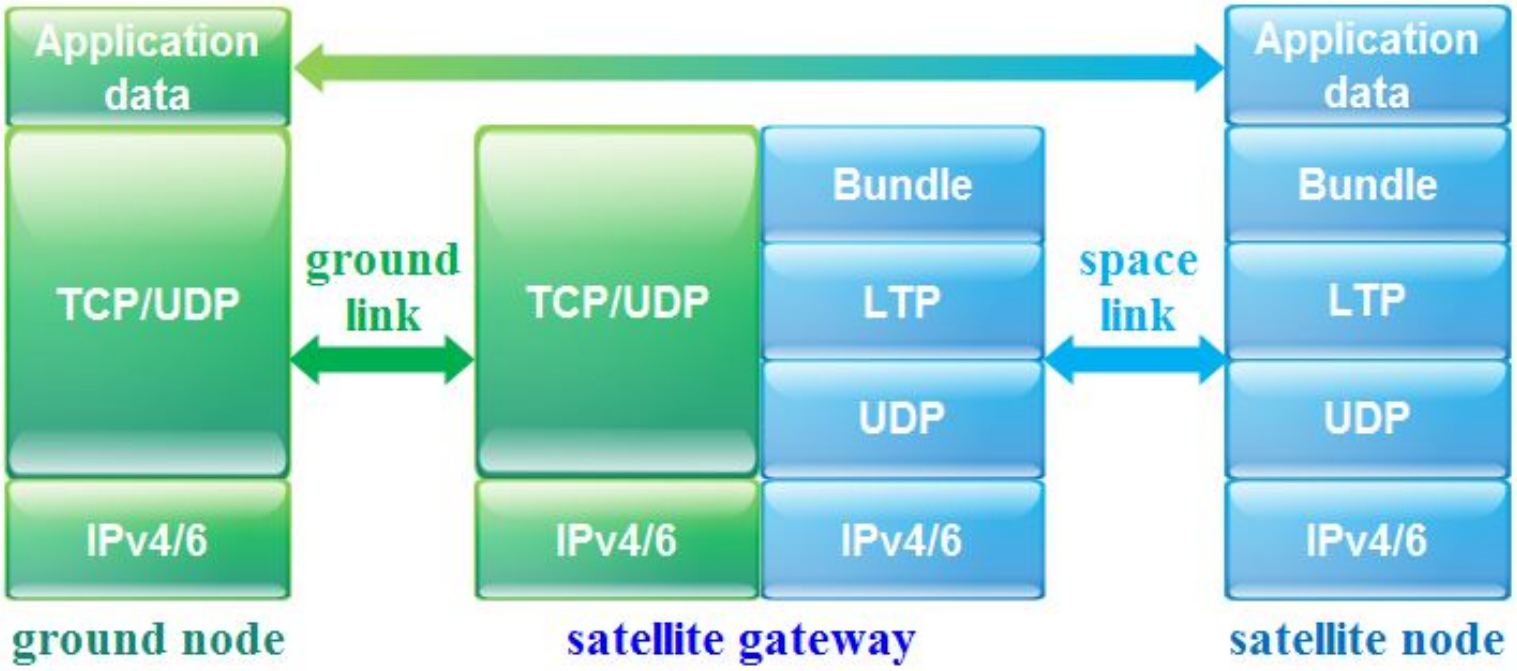
Bundle Tunnel

We deploy OpenFlow over DTN by a method of tunnel. That is, signaling packets are transmitted in bundle tunnel when controller (GEO satellite) communicates with the switches.



Key Points of the Design

- Satellite Gateway



DTN-TCP/IP bidirectional protocol translation

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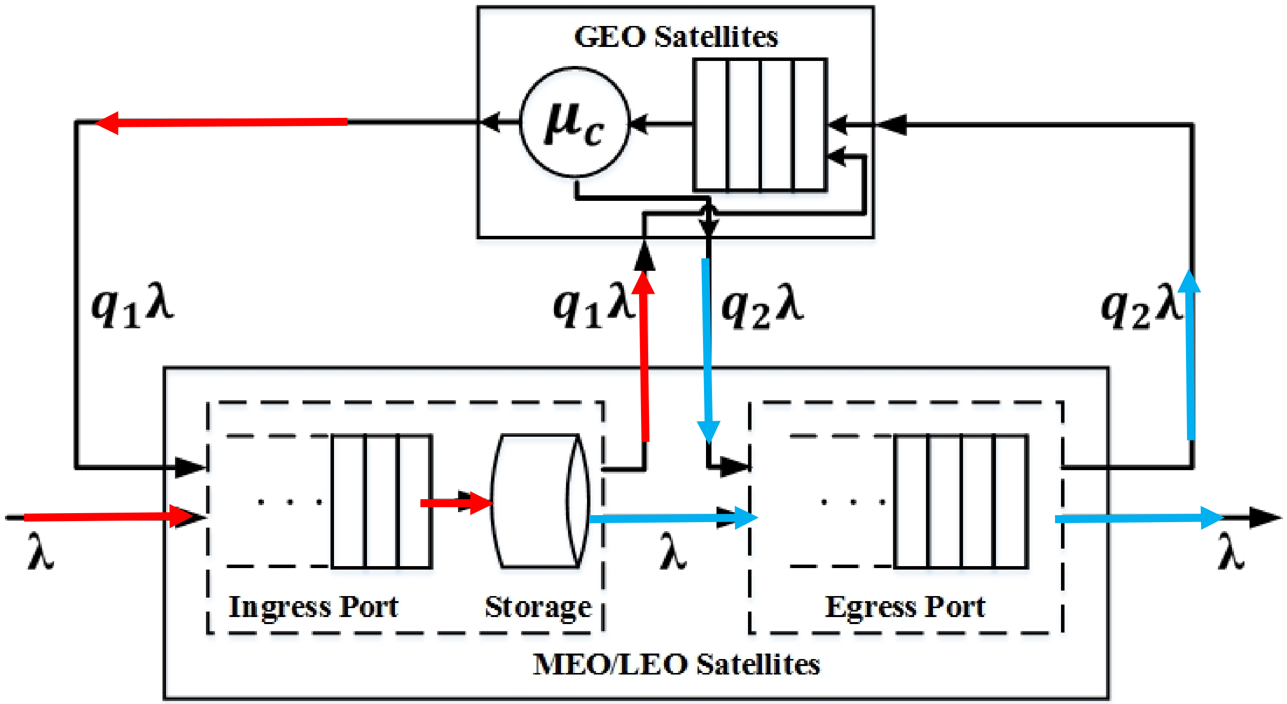
Model Description

In SDSN, the transmission of a packet is divided into two stages.

et-in message is sent.

back.

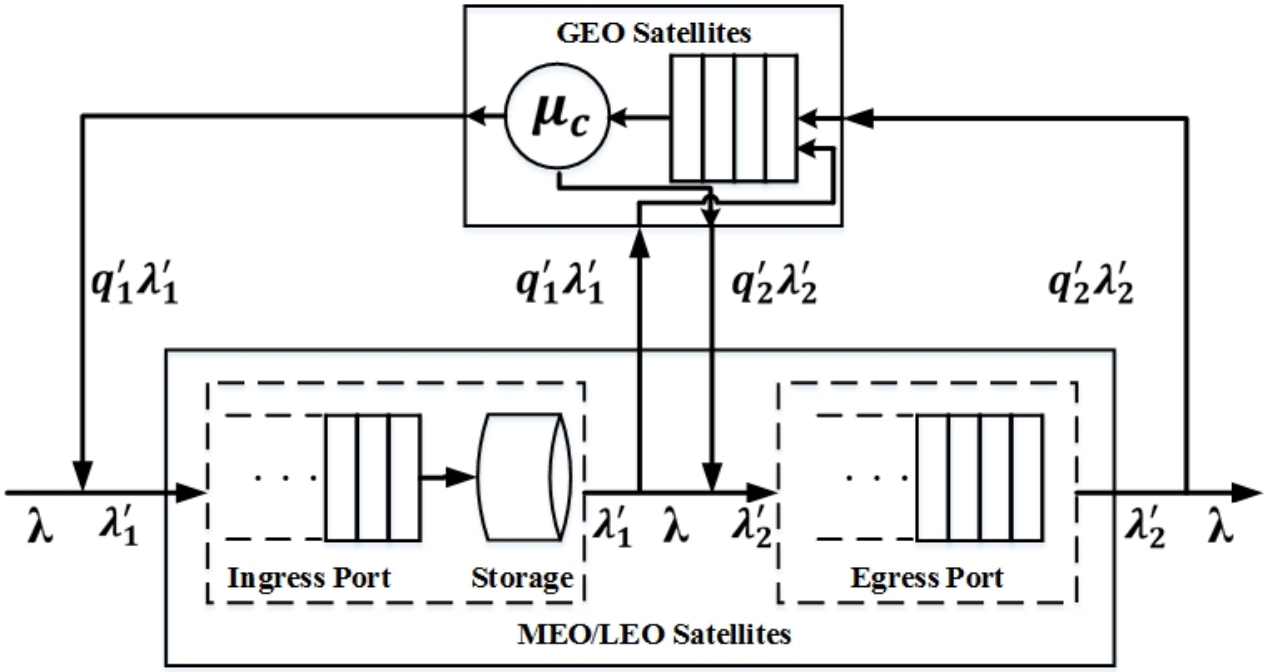


OpenFlow model of satellite nodes

Both of the two stages can be modeled as M/M/1 queues.

Model Description

To model the OpenFlow network with queueing theory, we make some modification.



Jackson model of satellite nodes

$$q_1\lambda = q_1'\lambda_1' \qquad \lambda_1' = (1+q_1)\,\lambda = \lambda^f\lambda^p + \lambda^f q_1^f$$

$$q_2\lambda = q_2'\lambda_2' \qquad \lambda_2' = (1+q_2)\,\lambda = \lambda^f\lambda^p + \lambda^f q_2^f$$

equivalent transformation

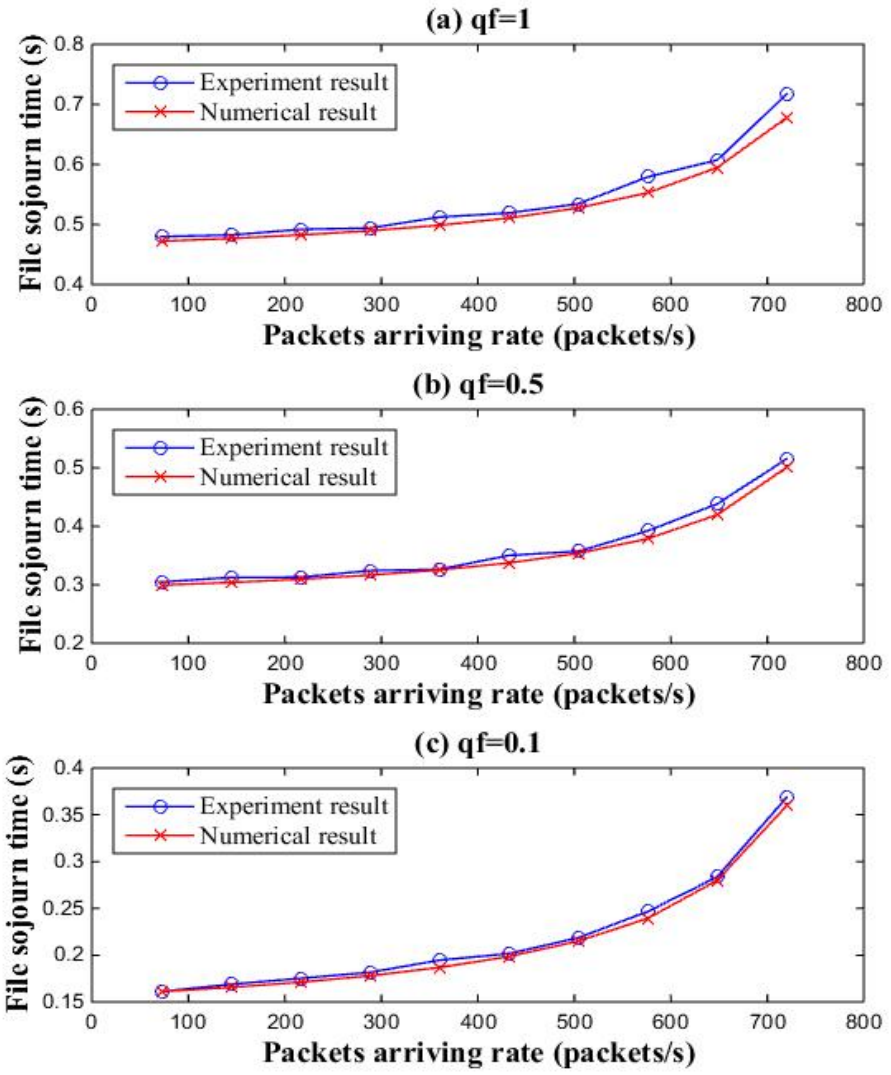
Model Description

- Verification:

POX controller, ION3.3.1, OvS2.5.0.

Comparison between the numerical results and the experimental results

The numerical results and the experimental results are very closed.



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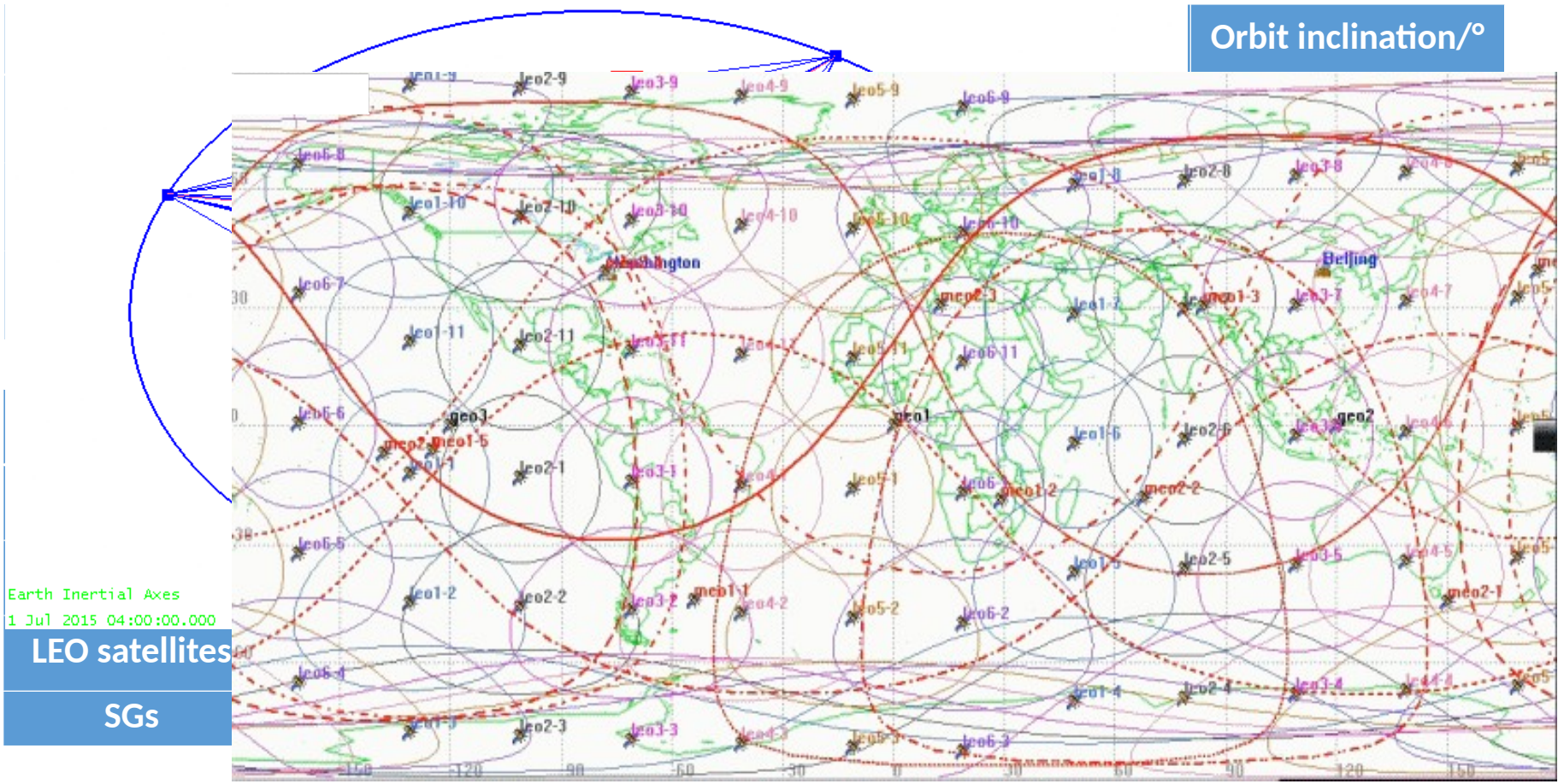
Implementation

- The Parameters of the Three-Layer Constellation



Implementation

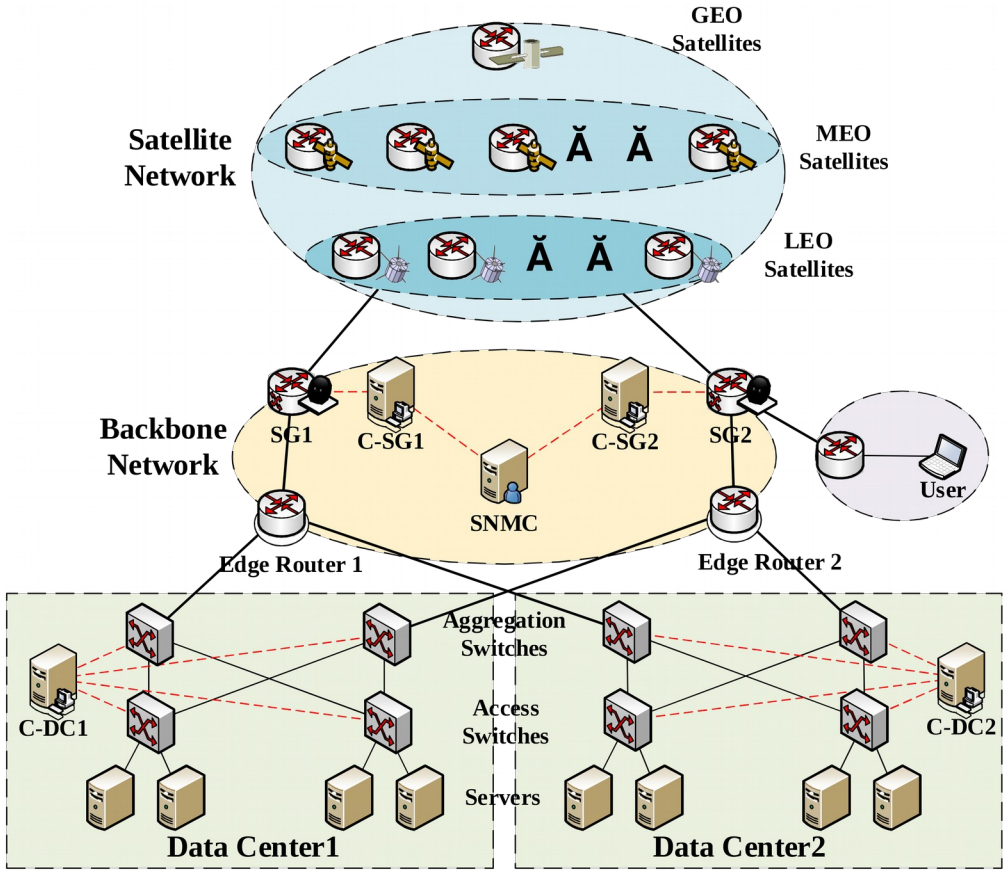
Integrated Space-Terrestrial Network Prototype

- The nodes are implemented in high-performance servers with the help of network virtualization.
- The links are configured by Linux Traffic Control.
- The connections and parameters of links are abstracted from STK.

✓ Easy to change the topology.

✓ Easy to migrate the VMs.

✓ Easy to extend experiments.



Implementation

- Integrated Space-Terrestrial Network Prototype

8 high-performance servers (DELL PowerEdge R720), 28 computers

Maritime satellite terminal

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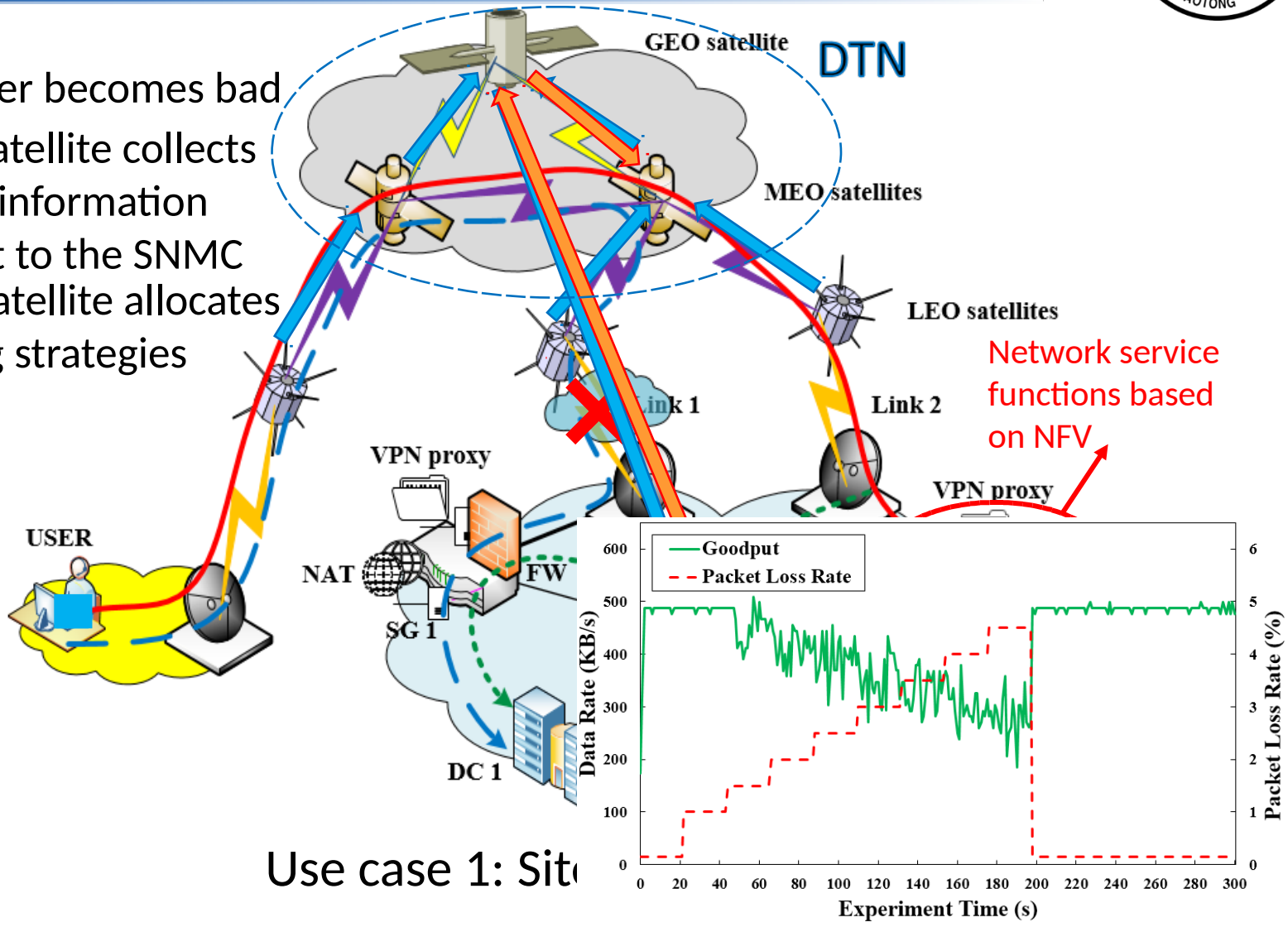
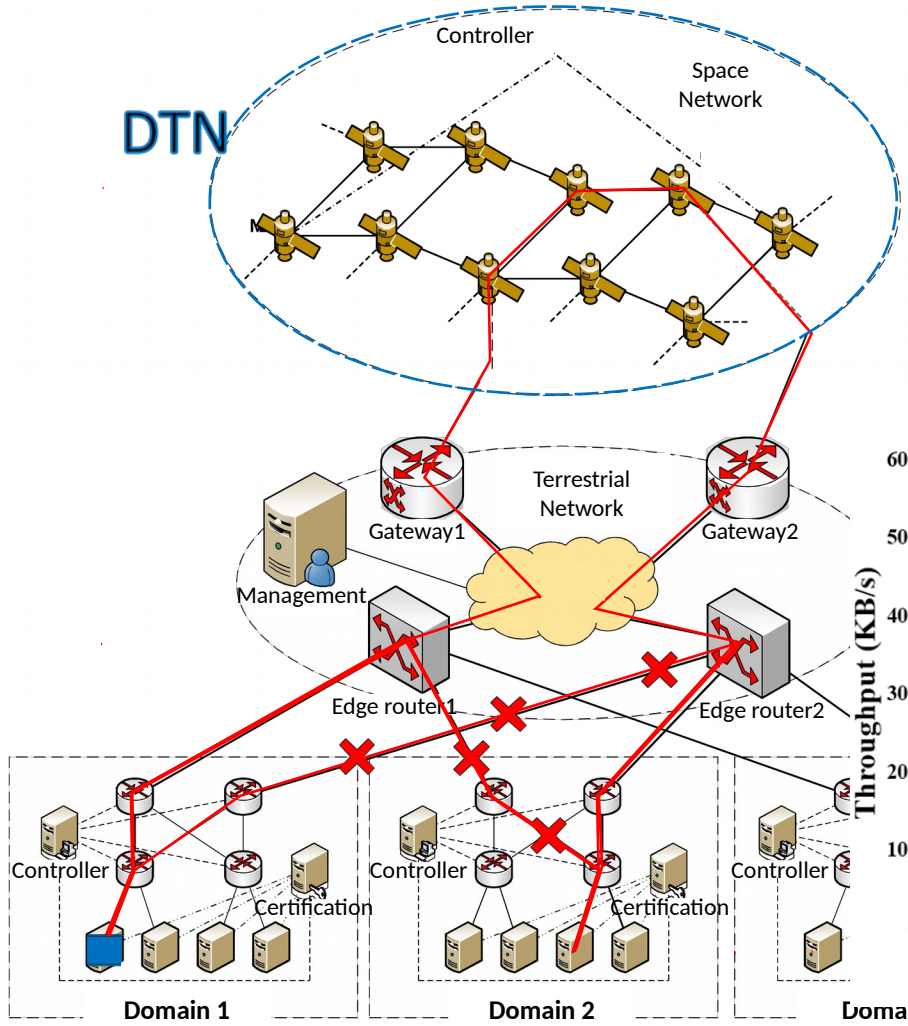
Use case 1

- The weather becomes bad
- The GEO satellite collects link status information and send it to the SNMC
- The GEO satellite allocates forwarding strategies
- Handoff



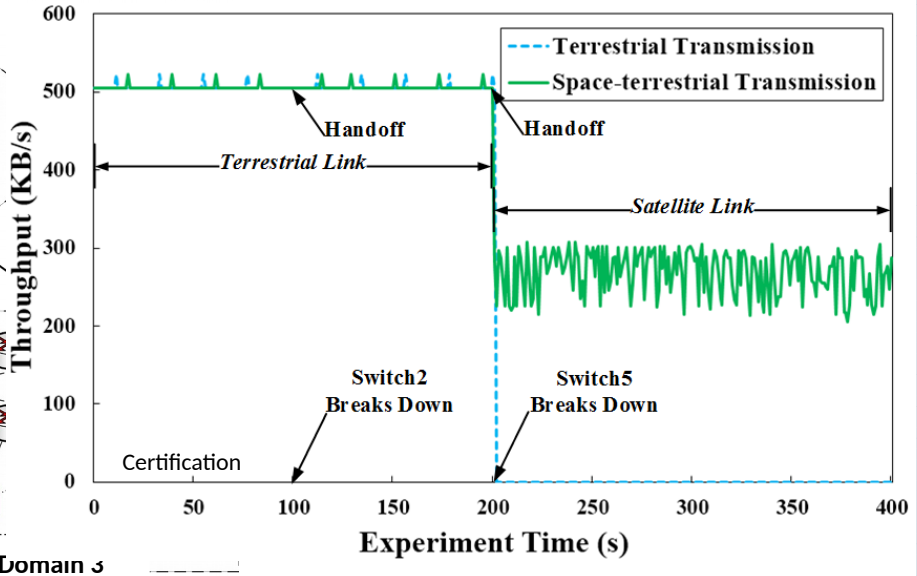
Use case 1: Sit

Use case 2



Use case 2: Resilience

- One switch breaks down
- Handoff!
- Another switch breaks down
- Handoff!



Related papers:

- **Taixin Li**, **Huachun Zhou**, et al. "SERvICE: A Software Defined Framework for Integrated Space-Terrestrial Satellite Communication." **IEEE Transactions on Mobile Computing**, **2017**.
- **Taixin Li**, **Huachun Zhou**, et al. "SAT-FLOW: Multi-Strategy Flow Table Management for Software Defined Satellite Networks." **IEEE Access**, **2017**.
- **Taixin Li**, **Huachun Zhou**, et al. “Modeling Software Defined Satellite Networks Using Queueing Theory.” **ICC 2017**.
- **Taixin Li**, **Huachun Zhou**, et al. “Timeout Strategy-based Mobility Management for Software Defined Satellite Networks.” **INFOCOM 2017 workshop**.
- **Bohao Feng**, **Huachun Zhou**, et al. HetNet: A Flexible Architecture for Heterogeneous Satellite-Terrestrial Networks. **IEEE Network**.
- **Bohao Feng**, **Huachun Zhou**, et al. SAT-GRD An ID-Loc Split Network Architecture Interconnecting Satellite and Ground Networks. **ICC 2016**.

Thank U!

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