Toward a Flexible and Reconfigurable Broadband Satellite Network: Resource Management Architecture and Strategies

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October 21, 2016
Outline

• Introduction

• Background Knowledge
  ✓ Existing Satellite Network Architecture
  ✓ Software Defined Networking and Network Virtualization
  ✓ FRBSN Architecture

• Resource Management Architecture
  ✓ Functional Architecture
  ✓ Multi-dimensional Resource Representation

• Resource Allocation Strategy and Performance Evaluation

• Conclusion
Introduction

• Applications of Broadband Satellite Networks (BSNs)
  ✓ Navigation, communication/relaying, Earth observation, emergency rescue, ...

• Drawbacks of traditional BSNs
  ✓ Lacks interactions and cooperation: Ocean and Resource satellite series are utilized separately
  ✓ Hard to reconfigure: Coupled control and data plane, customized legacy function
  ✓ Cannot adapt to traffic increase and new space mission

• Evolutions
  ✓ Single-satellite → Satellite constellations → Integrating multiple heterogeneous satellite networks → SDN, NFV and NV (use cases)
  ✓ Unified framework for efficient resource sharing and management for BSN ??
Background Knowledge

- Existing Satellite Network Architecture
  - A Network Operations Control Center (NOCC) mission planning, network control and resource management.
  - Multiple Ground Stations (GS) (1) different types of GS, communicate with satellites and perform tracking and upload operations; (2) a strong set of local control functions
  - Satellites in the space segment: bent-pipe or onboard processing.

Fig.1: An example BSN architecture.
Background Knowledge

• Main Design Principles
  ✓ Mission-dependent protocol
    - The standard protocol running on each satellite system is greatly coupled with a certain space mission, and may not be compatible with other protocols.
  ✓ Dedicated resource usage
    - The current satellite system is strictly customized. Certain GSs, despite being idle, cannot be shared with others
  ✓ Pre-planned mission
    - The missions, as well as the resource allocation strategies, executed by a system, e.g., data relay satellite system, are generally planned by several days in advance.
Background Knowledge

• Software Define Networking (SDN)
  ✓ Decoupling the control plane and data plane

• Network Virtualization (NV)
  ✓ Decoupling the roles of ISPs into infrastructure providers (InP) and service providers (SP)

• Combined together, SDN and NV can enhance the network openness, programmability and interoperability.
Background Knowledge

- **FRBSN architecture**
  - ✓ Infrastructure Layer (InL)
  - ✓ Virtual Network Layer (VNL)
  - ✓ Application Layer (AL)
  - ✓ Network Configuration Controller (NRC)

- **Open Issues regarding FRBSN**
  - ✓ Security
  - ✓ Fine-grained and reliable network control
  - ✓ Software defined payloads onboard
  - ✓ Resource management

Fig. 2: Logical view of FRBSN reference architecture.
Resource Management Architecture

- **Functional Architectures**: resource status collection

Fig. 3: (a) An example FRBSN architecture; (b) functions of each network device.
Resource Management Architecture

- **Challenges in Multidimensional Resource Representation**
  - ✓ Dynamic network topology
    - ☐ Due to orbit related network dynamics, resource availability varies continuously and periodically
  - ✓ Multi-dimensional resource space
    - ☐ Various resources, such as transmission resources, storage resources, observation resources, how to precisely represent them and dictate the relationship among them?
Resource Management Architecture

• Basic principles using TVRG
  ✓ A unified **two-dimensional time-space** basis, wherein vertices correspond to replicas of satellites, GSs, NOCC and observing targets in each time slot.
  ✓ **Edges**: corresponding resource availability, unify in terms of “bits” that can be transmitted, stored or observed.
  ✓ **Path**: reveal resource correlations: The number of bits that can be delivered by a possible resource combination.
Resource Management Architecture

- An example TVRG
  - Observing targets, LEO satellites, data relay satellites, NOCC

Fig. 4: An example Time-varying resource graph (TVRG).
Resource Management Strategy based on TVRG

- **Objective**
  - e.g., Network utility maximization
- **Multi-dimensional resource**
  - Flow conservation
  - Observation resource
  - Transmission resource
  - Storage resource
- **Solution**
  - MILP optimization problems on graph
  - Approximate online solutions

Fig.5: Modeling based on TVRG.
Performance Evaluation

• Optimal resource allocation
  ✓ Three different schemes: ORA, NCT-CO, NCT-NCO

Fig.5: (a) Throughput performance of different schemes with varying buffer size; (b) Resource utilization ratio.
Conclusion

• Addressed the issue of flexible and reconfigurable networking techniques for BSN. The resource management framework inside FRBSN was studied.

• We proposed a novel time-evolving resource graph to characterize the multi-dimensional resources in BSN. Furthermore, the optimal resource allocation mechanism was put forward to achieve an efficient utilization of network resources.

• In summary, we expect that this study could open up a new research direction for the design of next-generation BSN.
Reference


Reference


Thanks !!!

Q&A