Satellite-Integrated Community Networks

— Bridging the management gap with autonomous maintainability

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Outline

• Bridging the Broadband Gap for Community Networks (CNs) with Advanced Satellite Networks
• From Satellite Dependent CNs to Satellite-Integrated CNs (SICNs)
• Bridging the Management Gap for SICNs with Autonomous Maintainability
• A Hierarchical Approach to Self-Maintenance
• A Case Study
• Conclusion
Starlink Constellation (2550 LEO satellites)

OneWeb Constellation (427 LEO Satellites)
Advanced Satellite Platforms

A CubeSat

Credit: NASA
https://www.nasa.gov/sites/default/files/phonesat_-_image.jpg

Starlink LEO Satellites
(42,000 satellites constellation)

Credit: CNBC

Telesat LEO Satellite
(298 satellites constellation)

Credit: Telesat
https://www.telesat.com/leo-satellites/
Advanced Satellite Platforms

SES o3b mPower
(12 MEO HTS constellation, scheduled to be launched in Q2 2022)

Inmarsat GX5 GEO V-HTS

Credit: SES
https://www.ses.com/o3b-mpower

Credit: Inmarsat
https://www2.inmarsat.com/gx5
Bridging the Broadband Gap for CNs with Advanced Satellite Networks

• The concept of CNs emerged in the late 90s and then evolved in different paths and forms for bringing Internet access to unserved and underserved areas.

• Satellite networks have long become a key connectivity option for CNs on a global scale. For example, in the Broadband Coverage in Europe 2017 report, satellite broadband is considered “the most pervasive technology in Europe in terms of overall coverage”.

• The recent development in high-throughput and non-geostationary (NGSO) satellites in large constellations enable high-quality Internet access for global CNs. 3GPP has been exploring the integration of LEO satellites into the 5G and beyond infrastructure. The Internet Society recently has started exploring the opportunities regarding LEO satellites for CNs.
A satellite-dependent CN (SDCN) is envisioned to be transforming into a satellite-integrated CN (SICN)\[1\], featuring an integration of heterogeneous networks and segments to provide broadband, resilient, and agile end-to-end connections.
A geographical view of SDCNs in Canada and the US

Challenges in SICNs

- **Performance**: latency, data rate, reliability, fairness, etc.

- **Complexity in communications**: dynamics in velocity/access states/routes, link diversity, handover, payloads, platforms, atmospheric conditions, etc.

- **Complexity in computation**: new architectures for various computing scenarios, data availability, etc.

- **Integration with terrestrial networks**[^2]: cross-satellite-terrestrial radio resource coordination, cross-platform handover, performance modeling, validation, and optimization.

- **Security**: vulnerabilities in space and terrestrial segments, protocols and algorithms, etc.
Challenges

• **Network management**: maintenance, resource management & orchestration, etc.
• **Multi-stakeholder governance**
Bridging the Management Gap for SICNs with Autonomous Maintainability

• There is a “management gap” in CNs that needs to be addressed, where autonomous maintainability is an essential step to achieving this goal.

• Autonomous maintainability (or self-maintainability) can be viewed as a capability to monitor and diagnose itself and maintain its functions in case of failures or performance degradation.

• The related discussions have recently been seen from the standards development organizations:
  • ITU-T Focus Group for Network 2030
  • ETSI White Paper No. 40 about self-healing and self-monitoring capabilities of autonomous networks (ANs); ETSI Zero-touch network & Service Management (ZSM) Group exploring automation challenges operators and vertical industries.
  • Autonomic networking related discussions at IETF
A Hierarchical Approach to Self-Maintenance

Network Intrusion Detection

Network Fault Detection

Network Fault Localization

Service Reliability Analysis

System Reliability Analysis

Resilience Measures

Schemes on Terrestrial Components

Scheme on High-Altitude Platforms

Schemes on Space Components

Network States

NI States

Non-NI States

NA States

Normal

NI State Predictions

Model Training & Tuning

Data Preprocessing

Cyberattack/NI Datasets

NA Datasets

Self-maintenance phases

T

Identification

Planning

Execution

User connection

Faulty Connection

Connection Under Repair

Backup Connection

A backup connection with alternative spot beams

A backup connection with a HAPS system

A backup connection with a terrestrial component
A Case Study

• An SICN is set up with Mininet VMs where the FRRouting stack is used for BGP. Zebra dump parser is used to parse data dump files and extract features as reported in [3].

• Common network intrusion (NI) data in [4] is considered, and link outage is considered for anomalous network (NA) events.
Experimental Results

- The results indicate the RNN methods (GRU and LSTM) and ensemble methods (XGBoost and RF) perform anomaly identification effectively.

<table>
<thead>
<tr>
<th>Model</th>
<th>Step 1 Accuracy</th>
<th>Step 1 F1-Score</th>
<th>Step 2 Accuracy</th>
<th>Step 2 F1-Score</th>
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</table>
Conclusion

• CNs are expected to have increasing integration with space and terrestrial components brought by the advanced satellite networks in the form of SICNs.

• SICN provides a promising setup for leveraging space, air, and ground network setups.

• The proposed ML-based hierarchical approach to autonomous maintenance for SICN management shows promising results, while there is much room for contribution.
References


Thank You!

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