IETF 114

Satellite-Integrated Community Networks

— Bridging the management gap with autonomous maintainability

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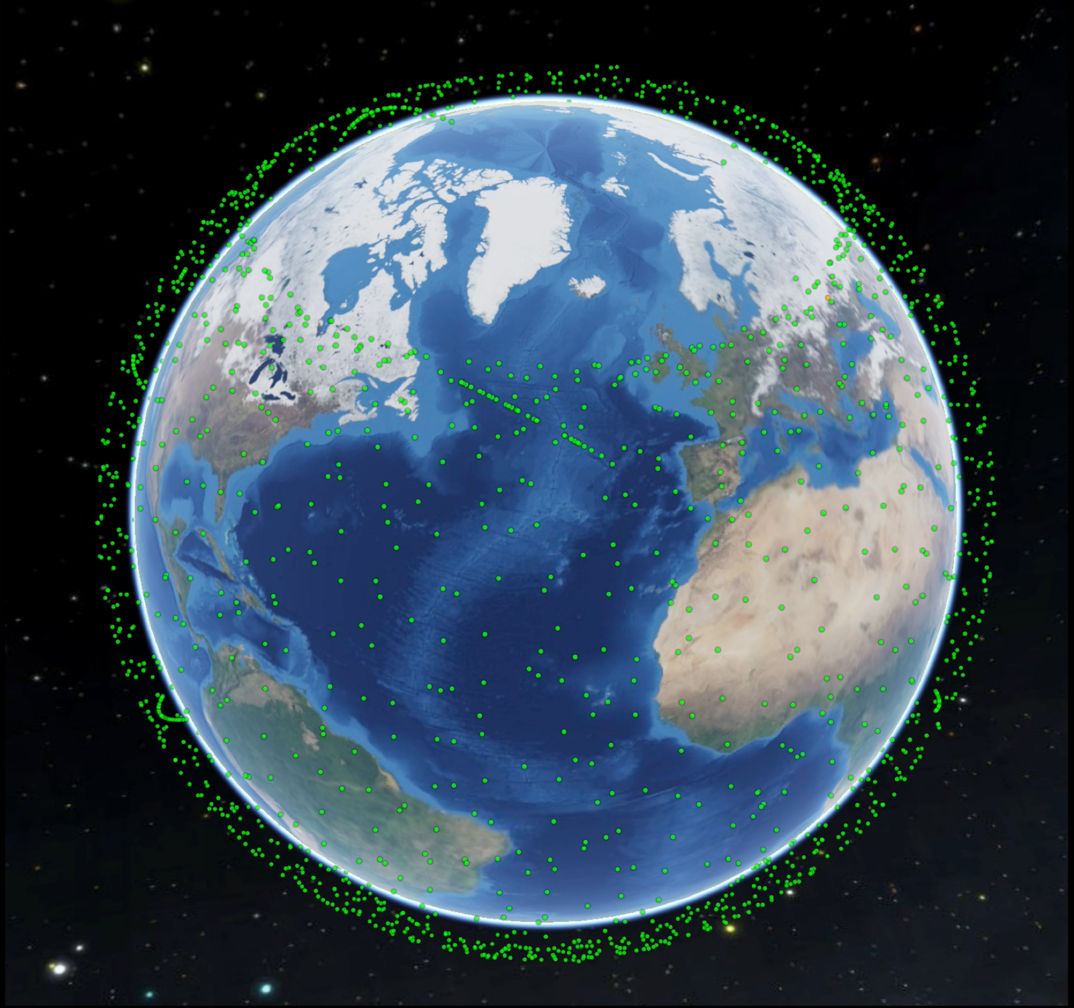
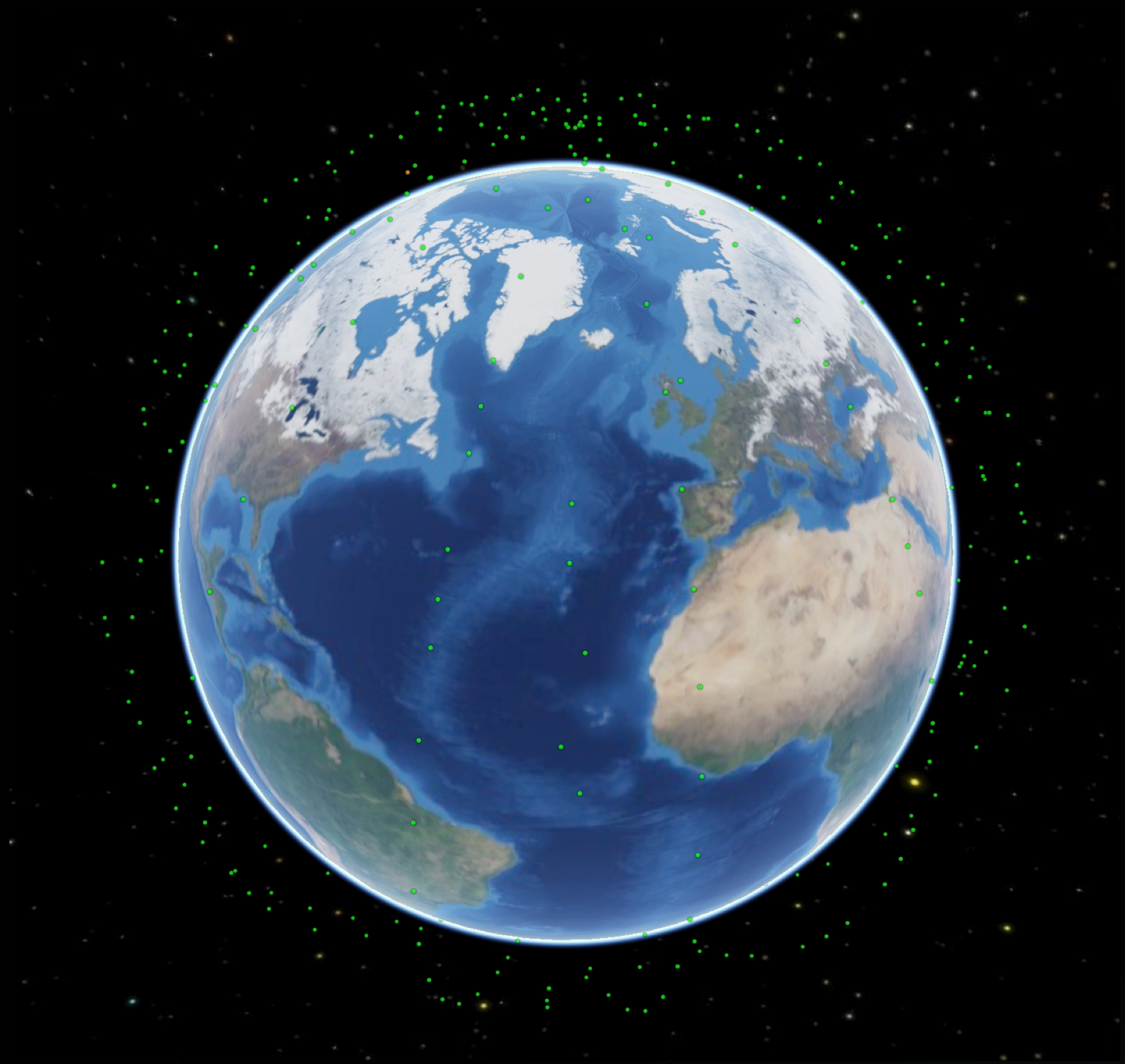
Outline

- 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)



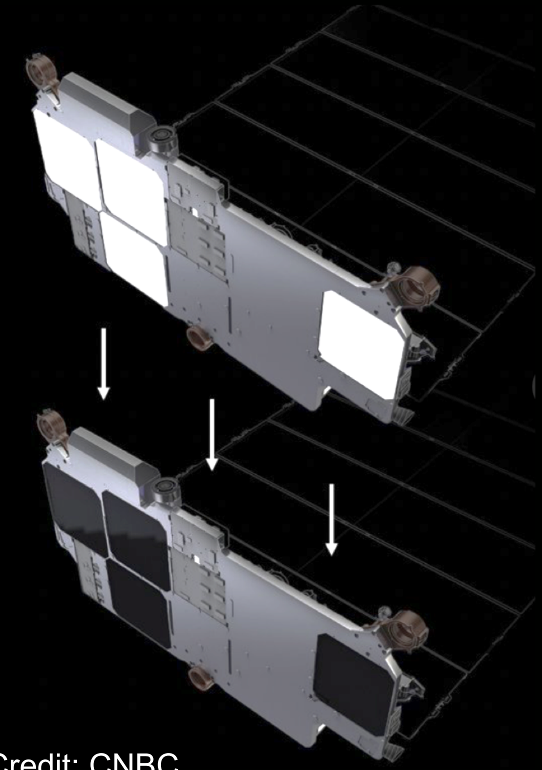
OneWeb Constellation (427 LEO Satellites)

Recorded with CelesTrak.org on July 20, 2022

Advanced Satellite Platforms

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

A CubeSat



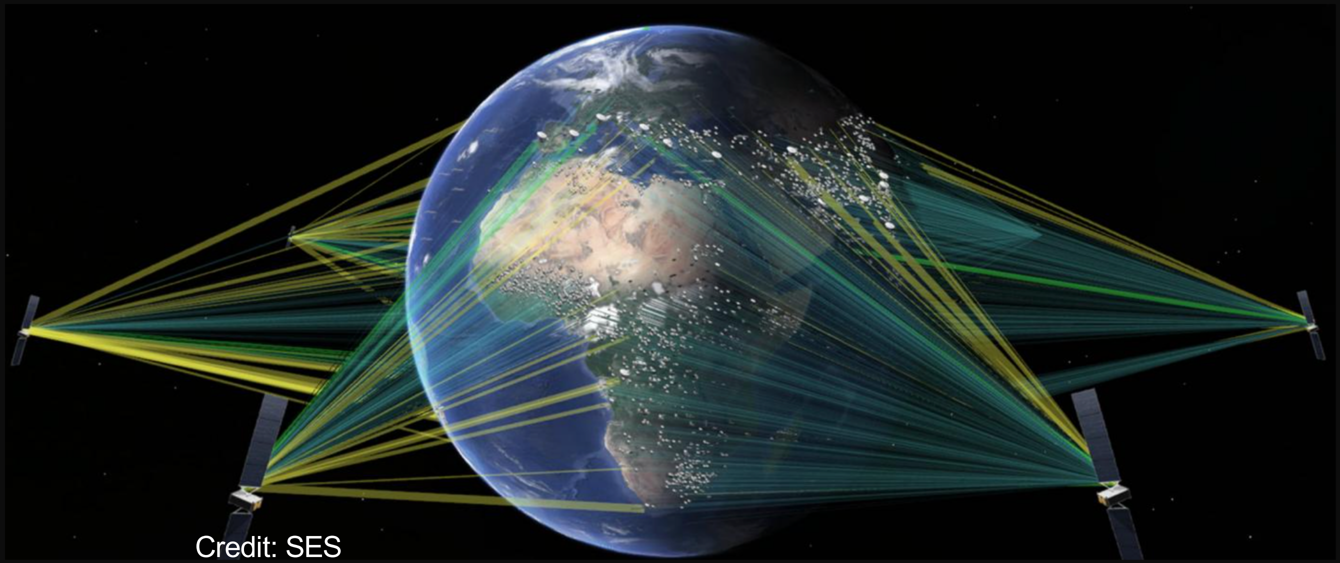
Credit: CNBC
https://www.cnbc.com/2020/04/29/elon-musks-spacex-reducing-starlink-brightness-after-astronomy-complaints.html

Starlink LEO Satellites
(42,000 satellites constellation)

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

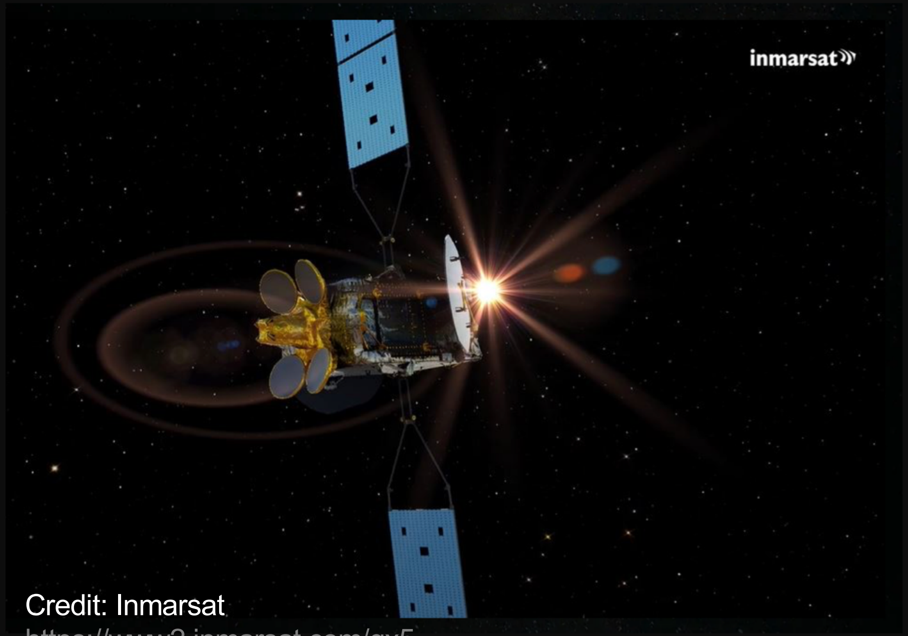
Telesat LEO Satellite
(298 satellites constellation)

Advanced Satellite Platforms



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

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



Credit: Inmarsat
https://www2.inmarsat.com/gx5

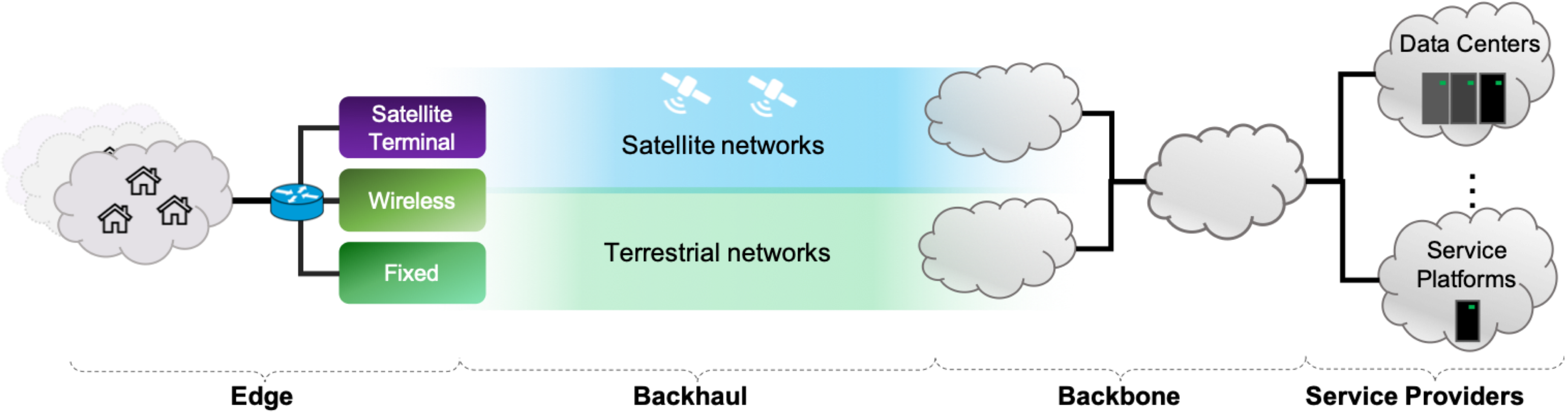
Inmarsat GX5 GEO V-HTS

Bridging the Broadband Gap for CNs with Advanced Satellite Networks

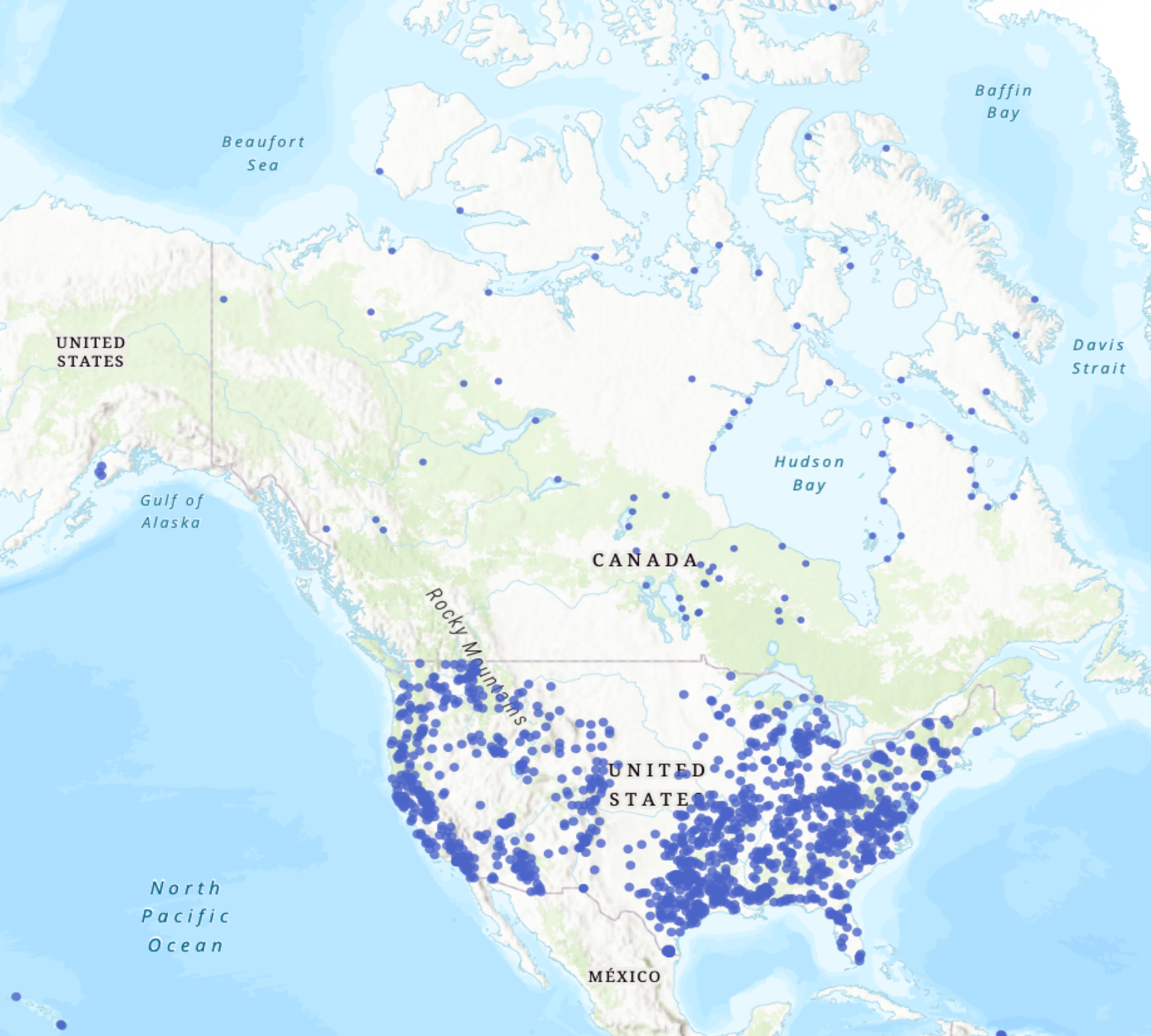
- The concept of CNs emerged in the late 90s and then evolved in different paths and forms for bringing Internet access to unserved and underserved areas.
- Satellite networks have long become a key connectivity option for CNs on a global scale. For example, in the Broadband Coverage in Europe 2017 report, 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.

From Satellite-Dependent CNs to Satellite-Integrated 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



Source: P. Hu, "Closing the Management Gap for Satellite-Integrated Community Networks: A Hierarchical Approach to Self-Maintenance," in IEEE Communications Magazine, vol. 59, no. 12, pp. 43-49, December 2021, doi: 10.1109/MCOM.001.2100479.

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.

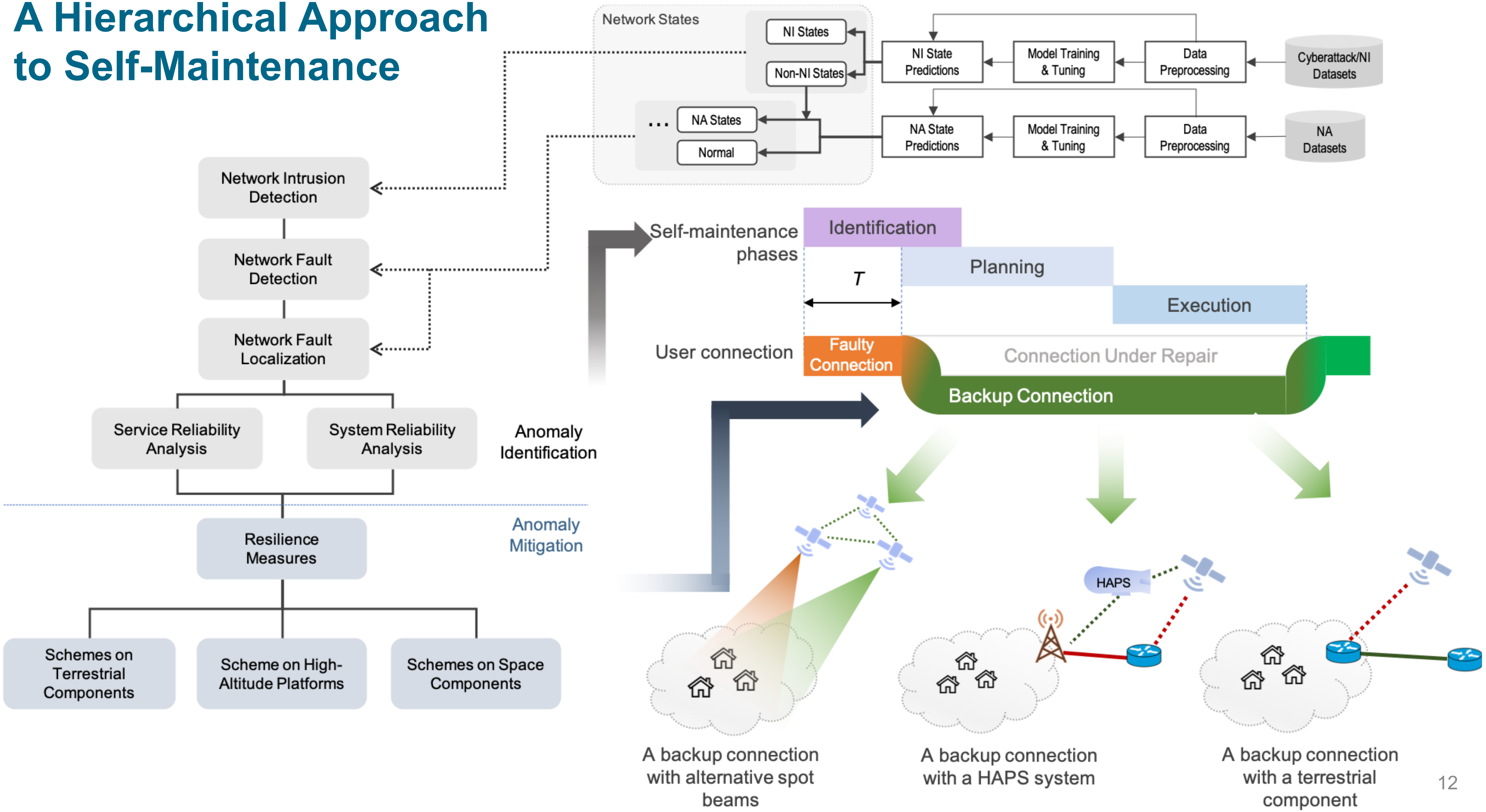
Challenges

- **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

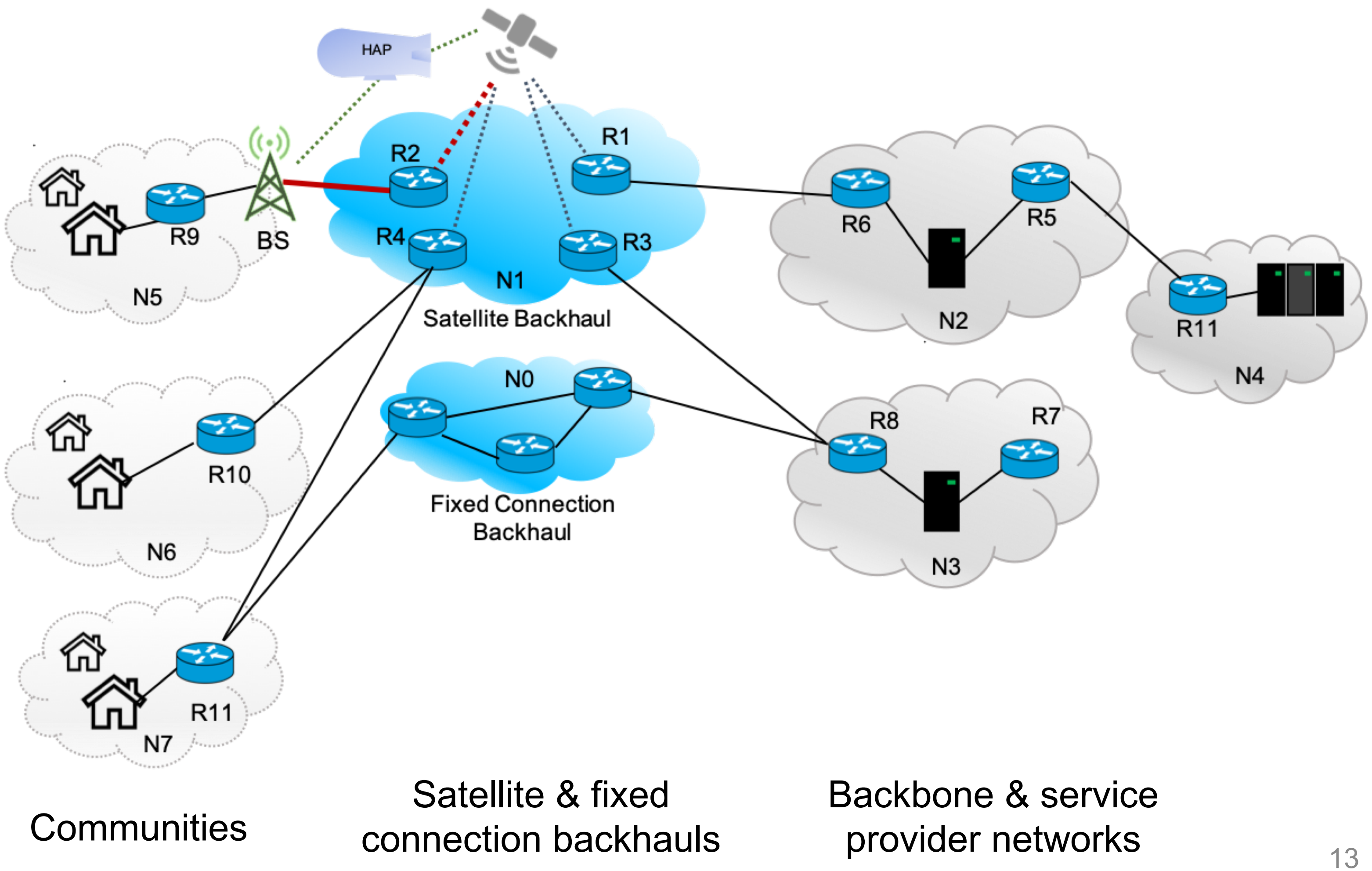
A Hierarchical Approach to Self-Maintenance



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.



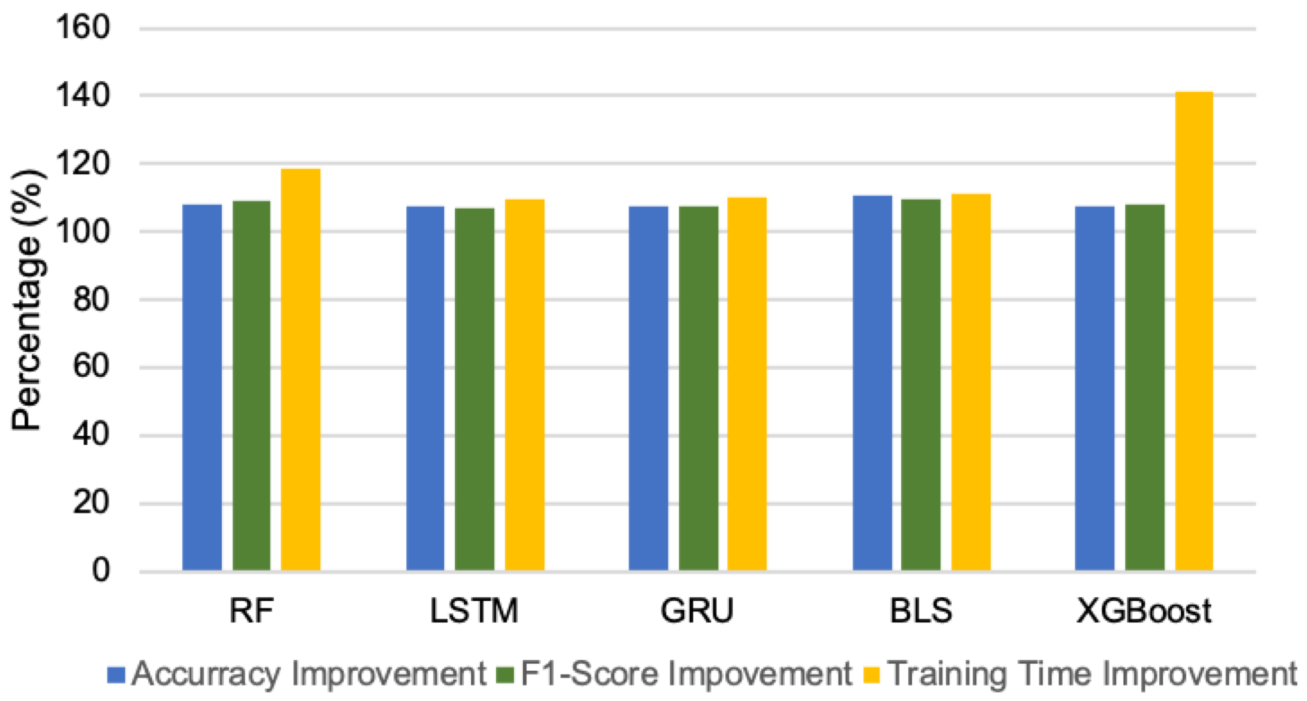
Experimental Results

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

Accuracy and F1-Score of ML Models

Model	Step 1		Step 2	
	Accuracy	F1-Score	Accuracy	F1-Score
NB	0.749	0.770	0.950	0.783
BN	0.801	0.775	0.904	0.847
LR	0.795	0.755	0.951	0.940
DT	0.771	0.774	**0.967**	**0.961**
RF	**0.839**	**0.821**	**0.970**	**0.961**
KNN	0.807	0.797	0.962	0.952
SVM	0.781	0.692	0.932	0.905
QDA	0.756	0.696	0.943	0.928
LSTM	**0.835**	**0.813**	0.959	0.956
GRU	**0.834**	**0.811**	**0.963**	**0.963**
BLS	0.825	0.799	0.959	0.937
XGBoost	**0.853**	**0.843**	**0.966**	**0.964**

Performance improvements in ensemble and RNN methods



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

1. P. Hu, "Closing the Management Gap for Satellite-Integrated Community Networks: A Hierarchical Approach to Self-Maintenance," in IEEE Communications Magazine, vol. 59, no. 12, pp. 43-49, December 2021, doi: 10.1109/MCOM.001.2100479.

2. B. Al Homssi, A. Al-Hourani, K. Wang *et al.*, "Next Generation Mega Satellite Networks for Access Equality: Opportunities, Challenges, and Performance," in IEEE Communications Magazine, vol. 60, no. 4, pp. 18-24, April 2022, doi: 10.1109/MCOM.001.2100802.

3. Z. Li, A. L. G. Rios, G. Xu *et al.*, “Machine Learning Techniques for Classifying Network Anomalies and Intrusions,” in 2019 IEEE International Symposium on Circuits and Systems (ISCAS), 2019, pp.1–5.

4. B. Al-Musawi, P. Branch, and G. Armitage, “BGP Anomaly Detection Techniques: A Survey,” IEEE Communications Surveys & Tutorials, vol. 19, no. 1, pp. 377–396, 2017.

Thank You!

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