Resiliency in Low Earth Orbit Satellite Routing

Mission-Critical Computing
NSF CENTER FOR SPACE, HIGH-PERFORMANCE, AND RESILIENT COMPUTING (SHREC)

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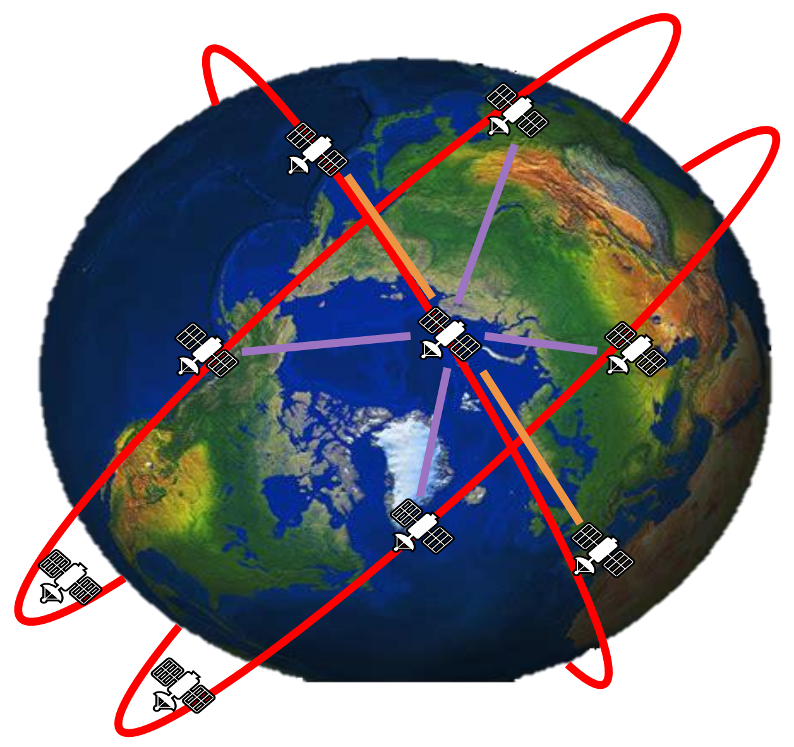
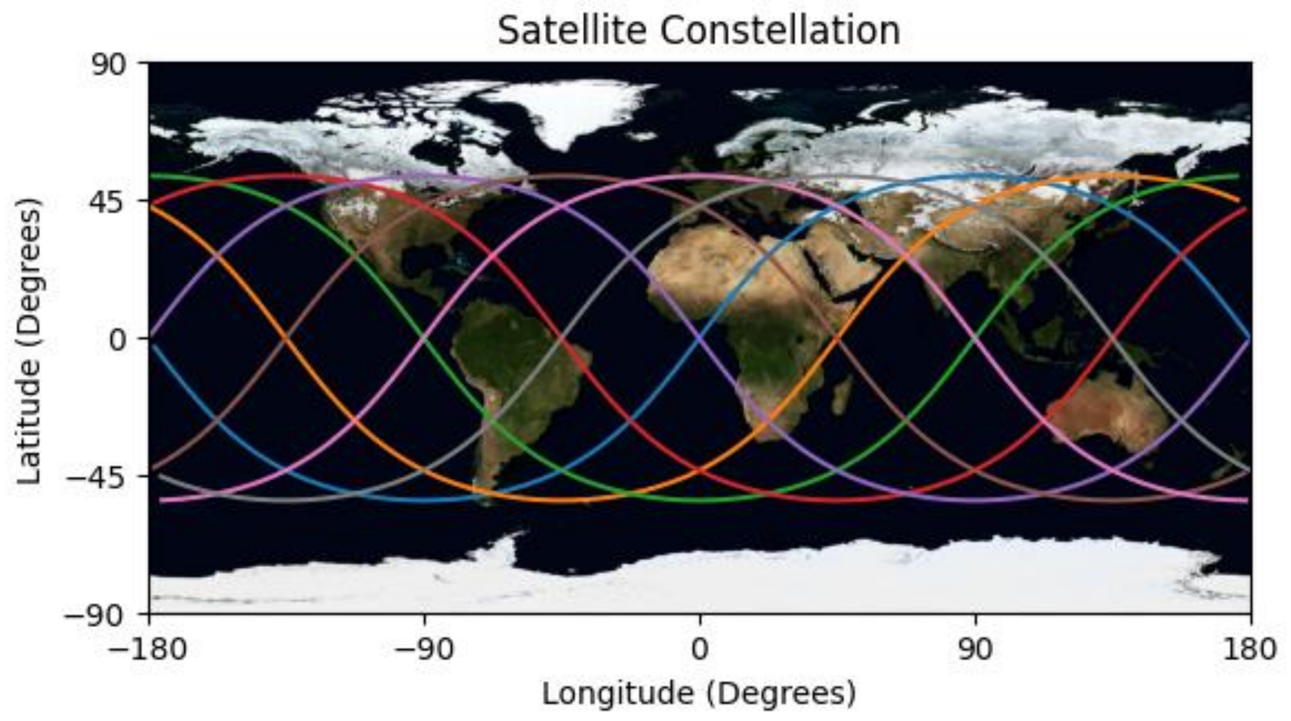
Satellite Constellations

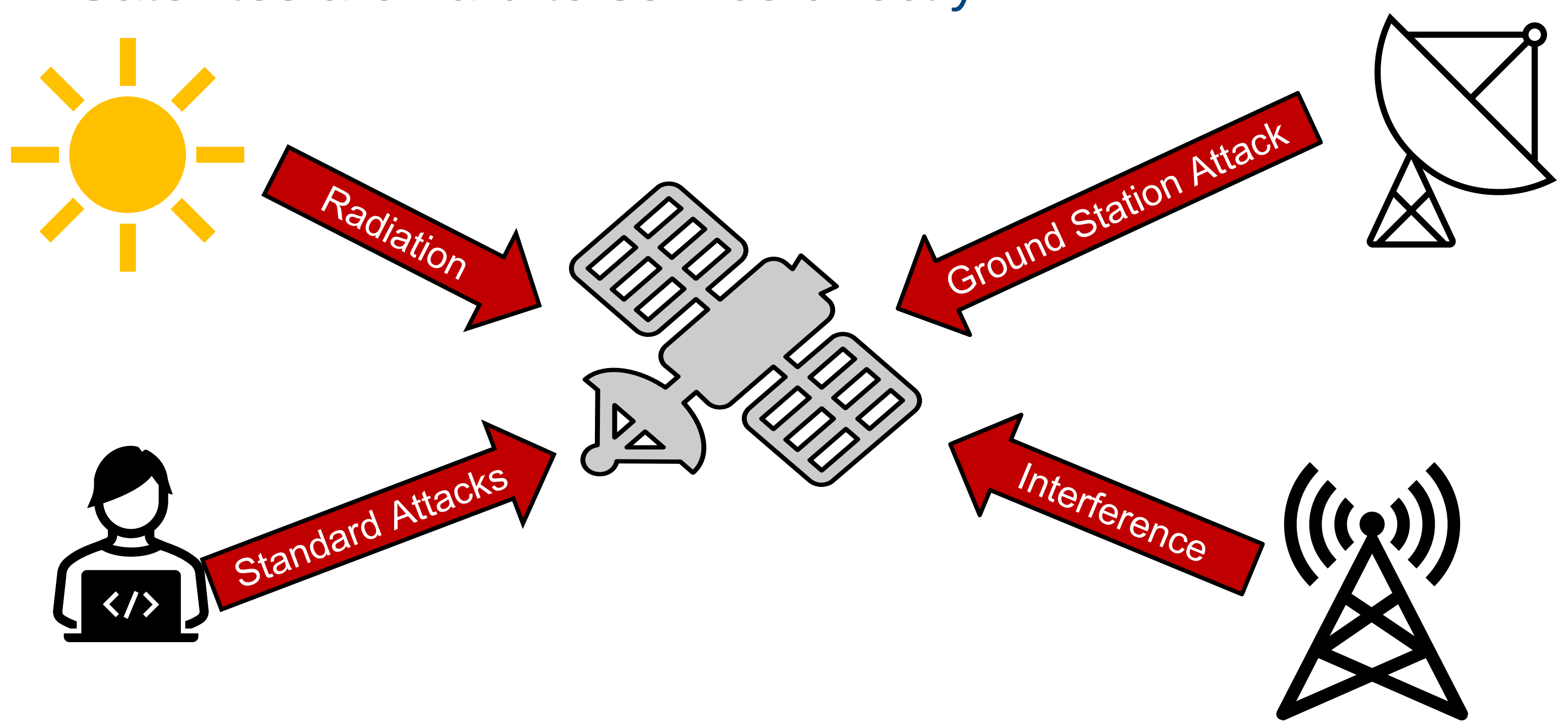
- LEO constellations are of growing interest and used for essential services, necessitating security
- Applications include earth observation, communication, and computation, all of which require coordination
- Commercial satellite constellations, such as Starlink and OneWeb, have hundreds of satellites
- How do we ensure availability and security of the constellation?





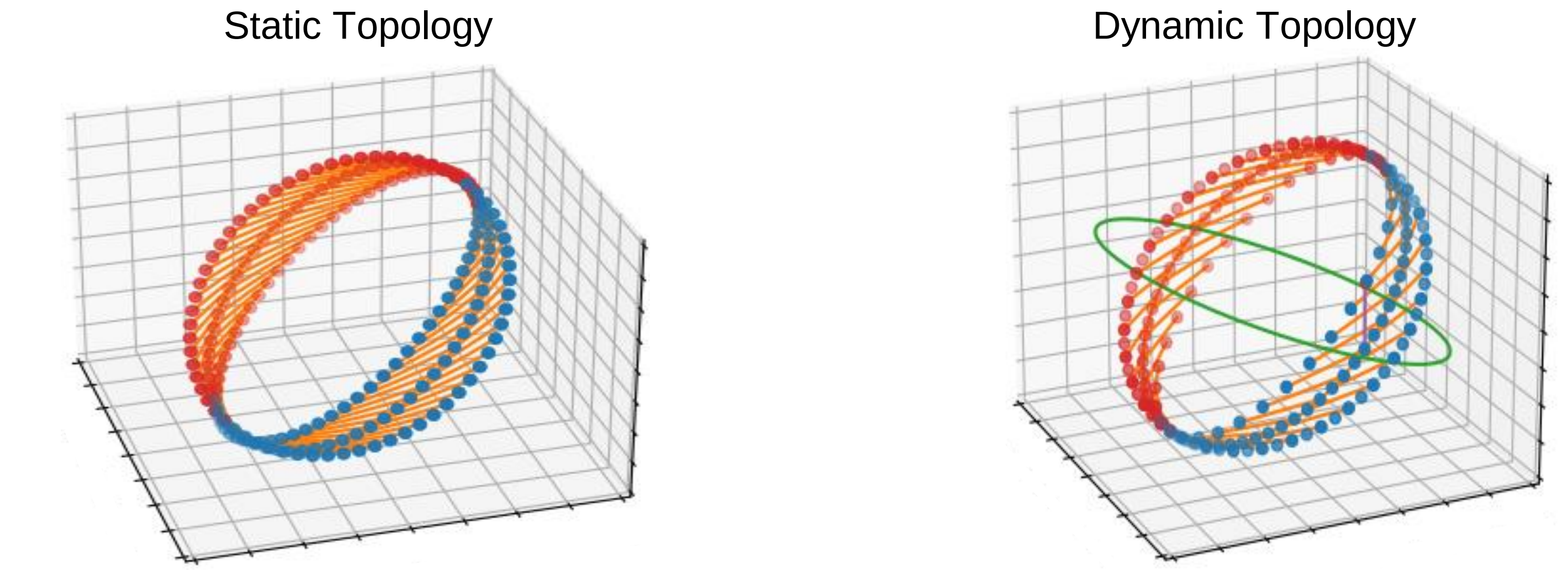
Satellite Failures and Attacks

- Solar radiation can cause memory errors
- Satellites are also vulnerable to attacks
  - Commodity components have known problems
  - Communication mediums can be attacked (e.g., interference, interception)
  - Ground stations can be physically attacked
- Satellites are hard to service directly



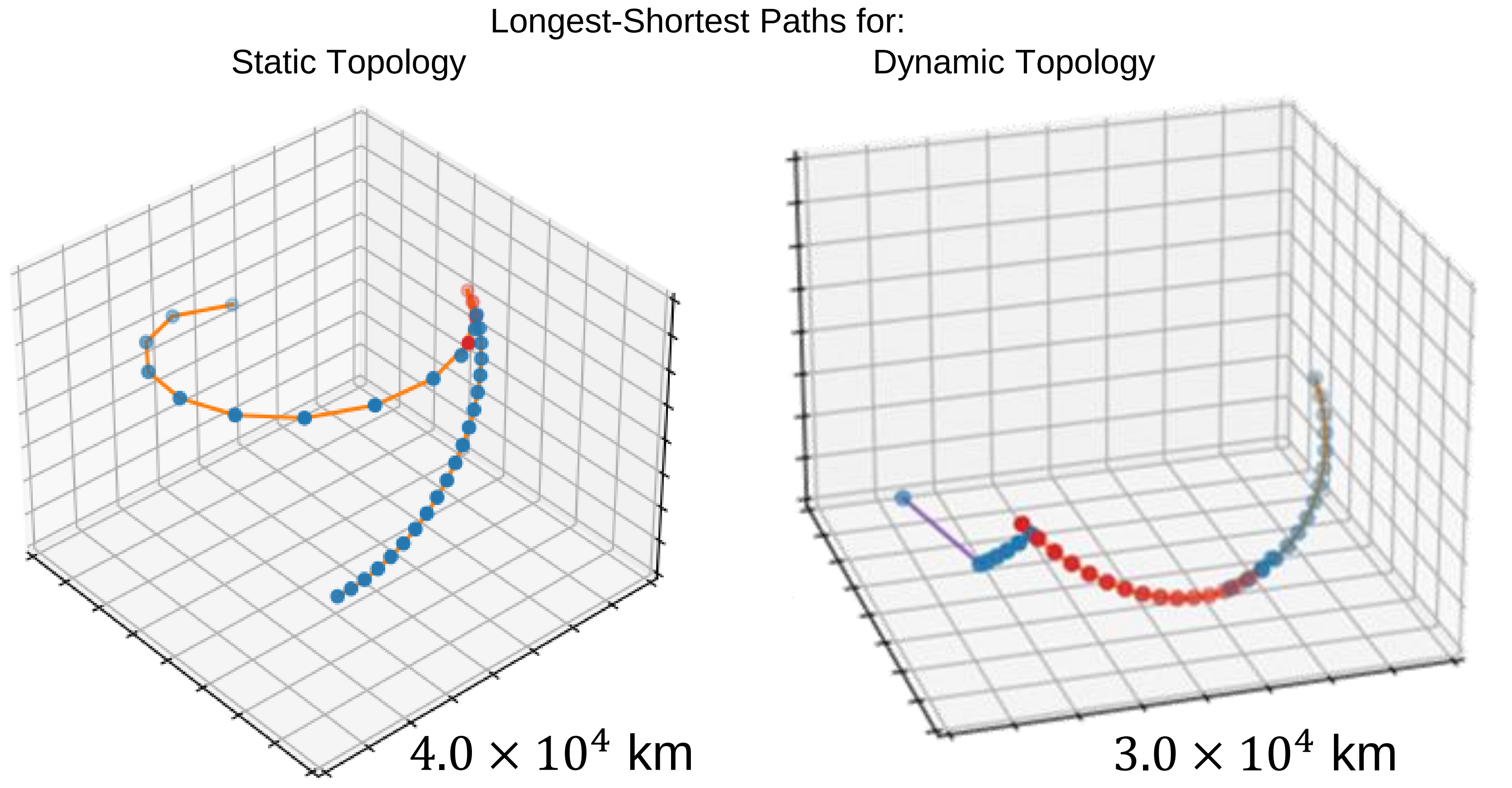
Constellation Topology

- LEO constellations have P orbital planes, with S satellites in each
- Each satellite has four laser transceivers
- At any given point, satellites could connect to many nearby satellites, some of which are in an intersecting orbital plane
- Static topology: satellites connect to their neighbors within their orbital plane and in neighboring orbital planes (constant neighbors throughout the entire orbital period)
- Dynamic topology: same as static except one ephemeral connection to a satellite in an intersecting orbital plane



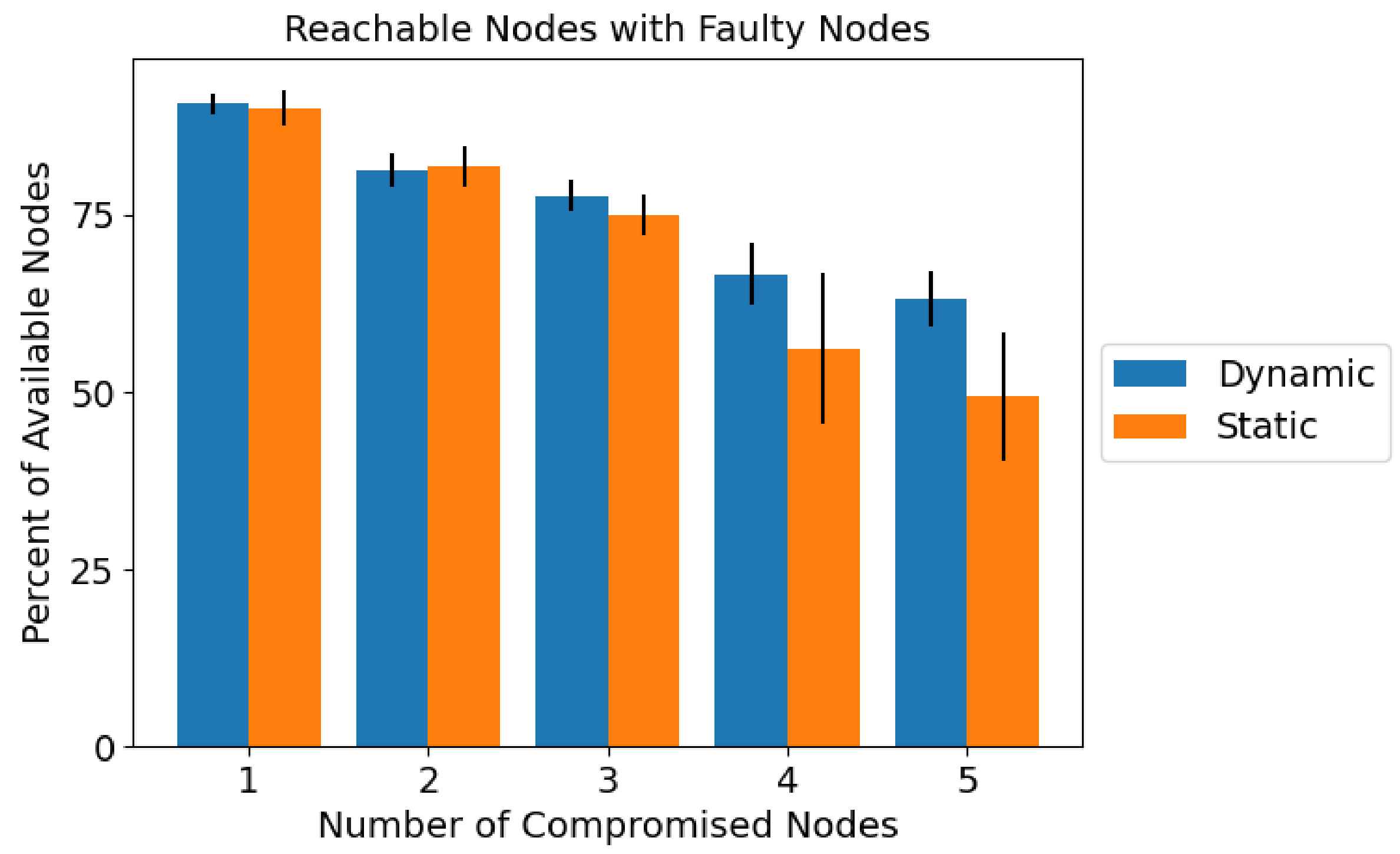
Constellation Routing

- Shortest-path routing algorithms are susceptible to single points of failure significantly degrading availability
- Walker-Delta satellite constellations have many redundant paths between any two nodes that can be leveraged



Simulated Effects of Attack

- Goal: Assess impact of routing attacks on a satellite constellation for both static and dynamic topologies
- Experiment: From a single source, send packets to all destinations in the presence of compromised nodes
  - Parameters: P=12, S=8, # compromised nodes=[1,2,3,4,5]
- Measure the average number of nodes that can be reached in the presence of individual faulty satellites



Conclusions and Future Work

- Preliminary results show the need for routing algorithms that address individual satellite failures
- As the number of faulty nodes increases, the dynamic topology exhibits less availability degradation than the static topology
- Future work
  - Develop a trust-based routing algorithm for constellations
  - Assess how the new protocol improves the constellation's ability to recover from compromised nodes

References & Acknowledgements

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