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Geosynchronous-Orbit-aided Low-Earth-Orbit Networking Management Mechanism for 6G Network Service Provisioning

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Objective

We propose a GEO-aided satellite-terrestrial integrating network (STIN) management architecture. By introducing geostationary orbit satellites, effective and reliable control of low orbit satellites can be achieved. We built a STIN simulation platform and show that the architecture can guarantee the timeliness and stability of network control under high-load cases.

Control model for GEO-LEO networking

We describe this LEO satellite network with a time-varying graphical model thus:

$$G = (V, E, T, \kappa)$$

where the V represents the set of all nodes (satellites), E denotes the ISL set, and T is the time sequences. We assume that the continuous time T is divided into a multi-discrete time sequence set (T).

We assume that each satellite is a switching node in the data plane. TCSs and direct-connected users can access each satellite directly. The satellite ISL propagation delay:

$$E\langle T_{prop}\rangle = E \times T$$

We define path parameters (κ) to characterize the impact of different routing algorithms on the delay of control messages. We use the shortest path-first routing approach. We represent the path between any two nodes in the node-set by the following formula:

$$\kappa = V \times V \times T$$

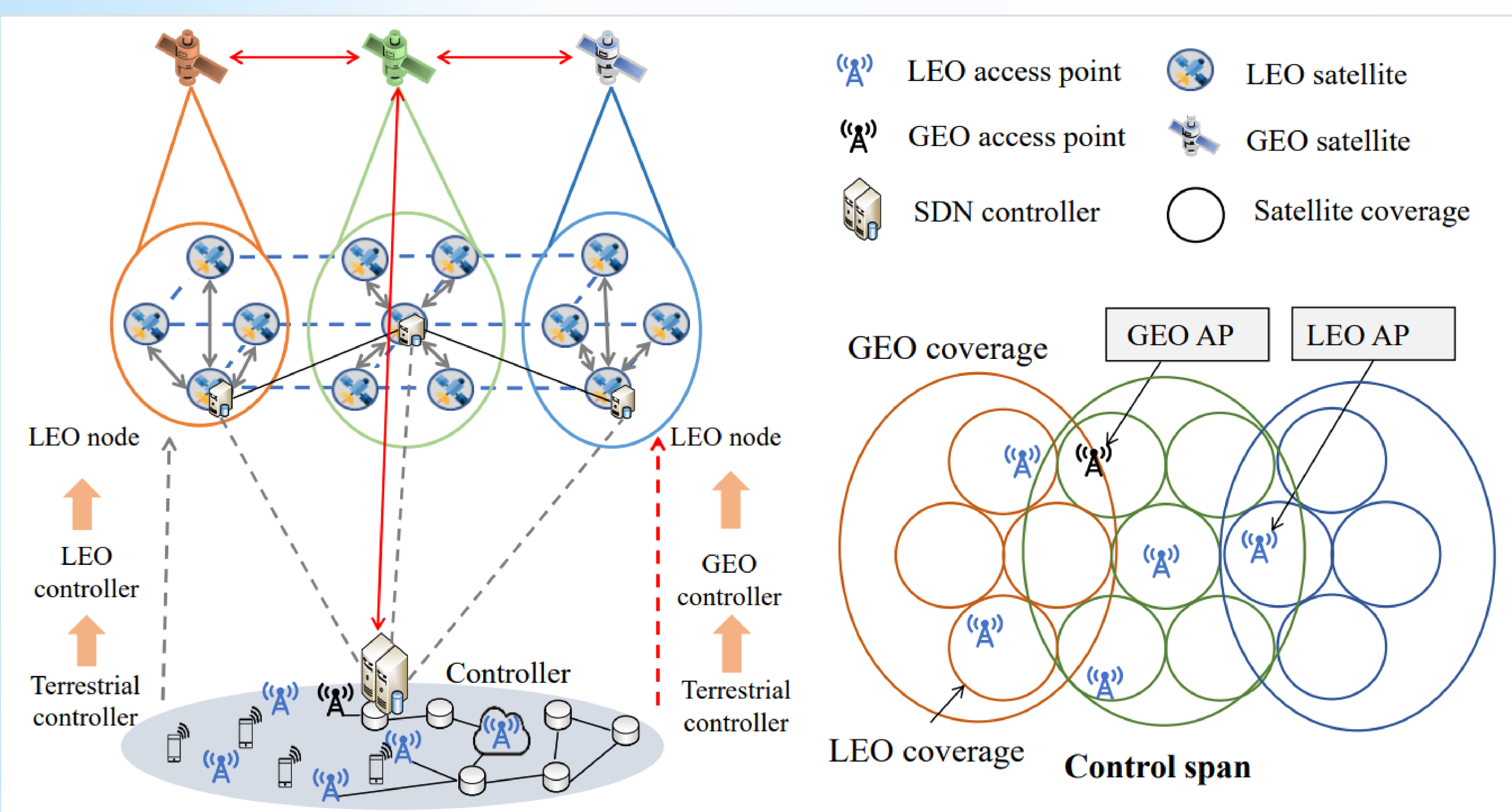

Figure 1: The GEO-addied STIN management architecture: management process and coverage range

In this model, GEO satellites only serve as control nodes and act as information bridges between ground stations and LEO satellites. It can avoid the control robustness problem caused by the sharing of bandwidth between the control channel and the data channel.

Latency analysis

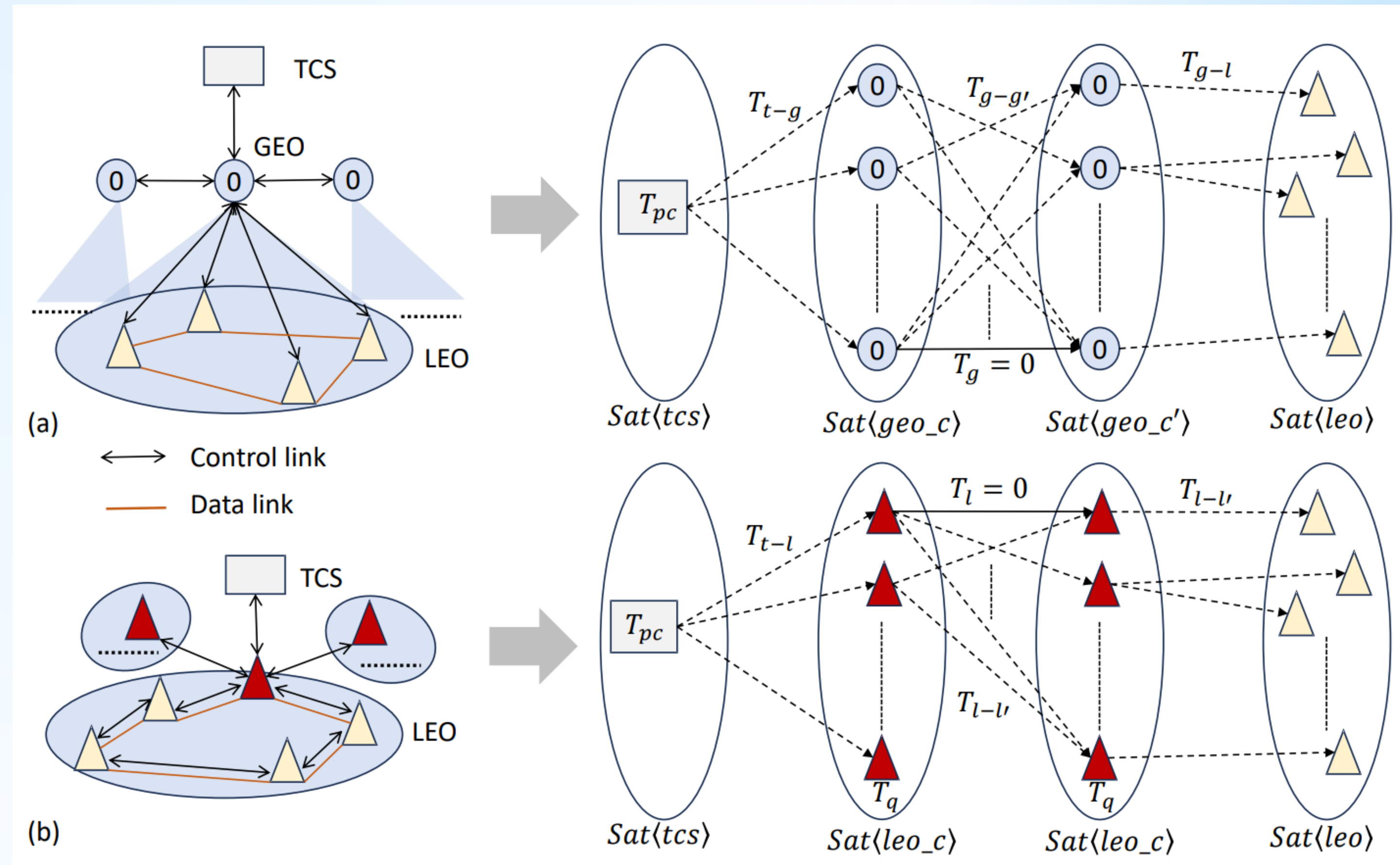

Figure 2: STIN management models: (a) GEO-aided management model (b) LEO-aided management model.

As shown in Fig. 2, we assume latency model include the following delay terms: processing latency (T_{pc}), the latency from ground to GEO orbit reaches 119ms (T_{t-g}), the latency between GEO and other GEO satellites ($T_{g-g'}$), the delay between GEO satellite and LEO satellite (T_{g-l}), the delay between adjacent LEO satellites ($T_{l-l'}$) and the delay between ground and LEO satellite. The control latency for GEO-aided and LEO-based architecture can be given by:

$$T_{max}^{geo} = 3 \cdot T_{pc} + T_{t-g} + T_{g-g'} + T_{g-l}$$

$$T_{min}^{geo} = 2 \cdot T_{pc} + T_{t-g} + T_{g-l}$$

$$T_{min}^{leo} = (1+p) \cdot T_{pc} + T_{t-l} + p \cdot \frac{Q \cdot load}{B}$$

$$T_{max}^{leo} = (1+p+q\cdot p) \cdot T_{pc} + T_{t-l} + (p+q\cdot p) \cdot (T_{l-l'} + \frac{Q\cdot load}{B})$$

where q is network domain number and p is the hops in each domain.

Performance Evaluation of GEO-aided LEO networking

TABLE I: Parameters of the constellation

Parameter	Value
The number of orbits	12
Orbit altitude	780 km
The number of satellites per orbit	12
The inclination of orbits	90 ∘
ISL bandwidth	100M
User bandwidth	2M
GEO number	3
Queue size of each output buffer	200-600 KB

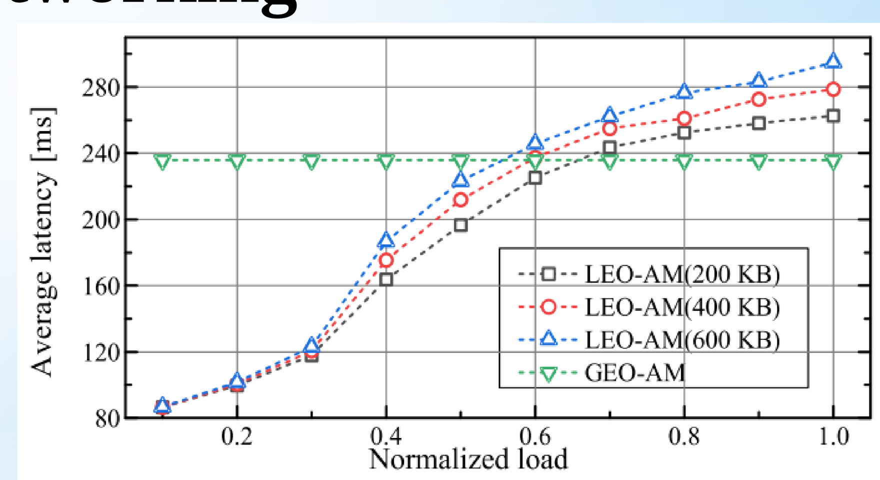

Figure 3: Average latency vs. different load cases

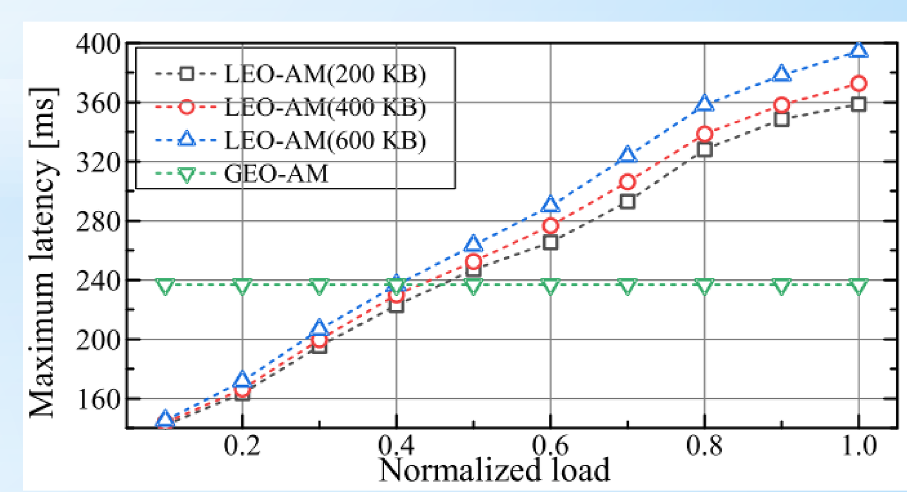

Figure 4: Maximum latency vs. different load cases

Conclusion

The paper proposes a GEO-aided management architecture and formulates a model for the proposed architecture. The architecture can utilize the large coverage area of GEO satellites to realize the management of LEO satellites. At the same time, we derive the maximum possible configuration latency for the architecture. We simulate the architecture and statistics of control messages' average transmission latency and maximum transmission delay. The proposed architecture can maintain the lowest configuration latency under high-load cases, and its performance is stable under different loads.

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