Routing Framework for LEO Mega-constellation Based on Region Division

draft-hou-rtgwg-satellite-routing-framework-00

HOU Dongxu, XIAO Min, ZHOU Fenlin

San Francisco, California

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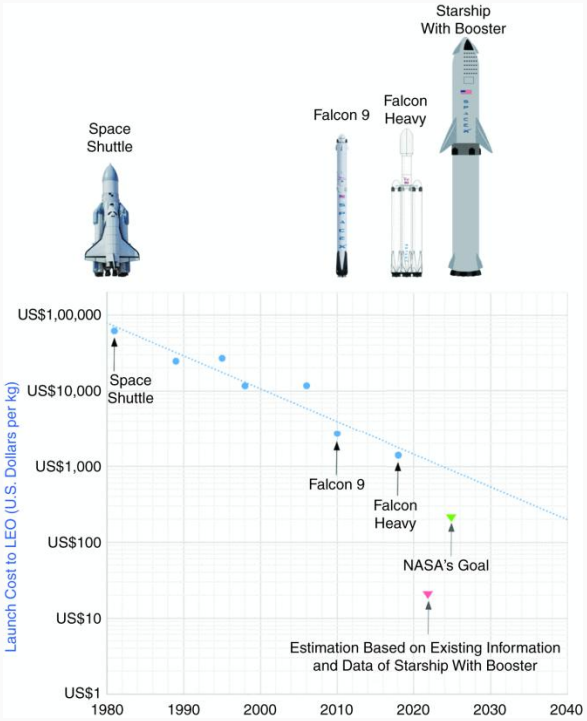
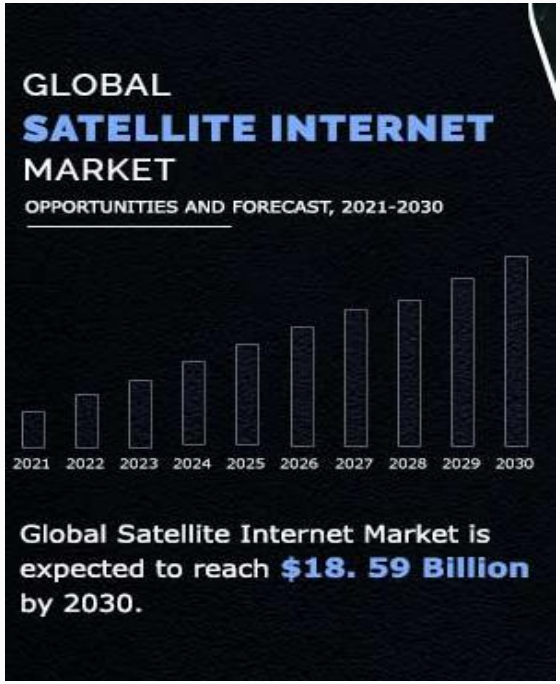
Background

- Rapid development of satellite technology



- Widespread attention of satellite network

- Broad market of satellite Internet

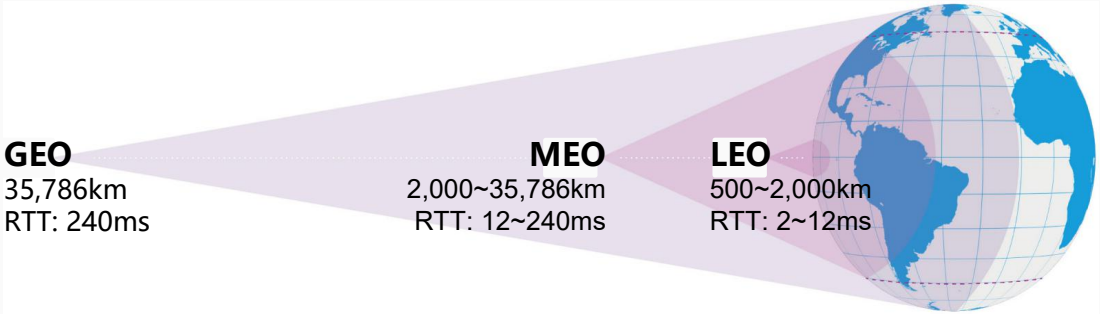


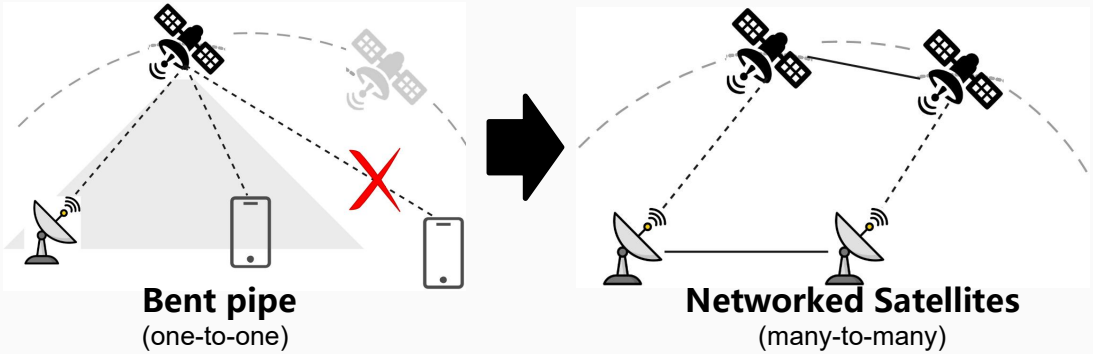
The satellite network is on the fast track.

Trends

NEW orbit: Evolving from GEO to LEO/VLEO.

Trends: Larger network scale, e.g. 42,000 satellites as planned in Starlink.



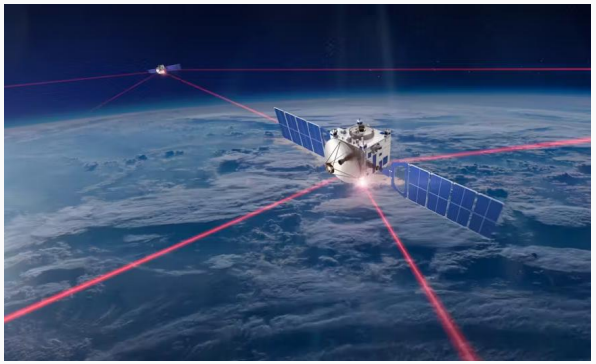


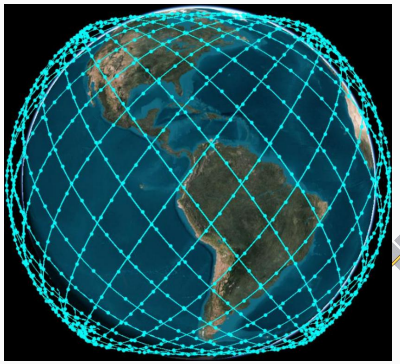
NEW infrastructure: Evolving from bent pipe to networked satellites.

Trends: More frequent link changes, e.g. satellite peering relationship changes roughly every 6~7 min.

NEW link: Evolving from Ground-to-Sat links to Inter-Sat links.

Trends: More complex route selection.





Problem Analysis

Trends

- larger network scale
- more frequent link changes
- more complex route selection

Impacts on the inter-satellite routing

- sharply increased network management cost
- massively increased routing message flooding
- dramatically increased routing computation

Problems when current routing methods are applied in LEO mega-constellation:

Traditional Terrestrial Network Routing Protocol (e.g. OSPF, IS-IS)

Due to highly dynamic nature of satellite networks, **the existing area division is hard to apply.**

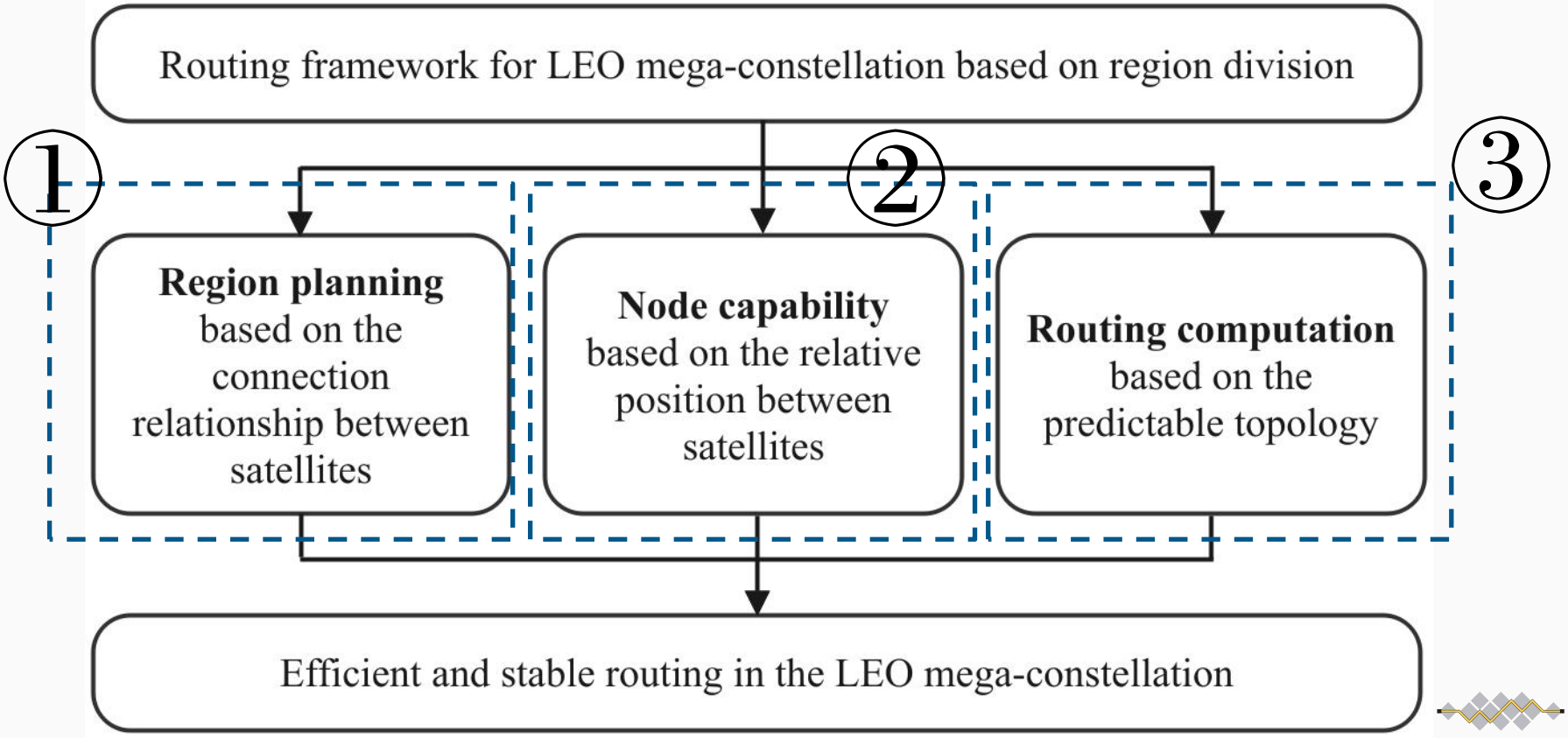
Existing Improved Terrestrial Network Routing Protocol

More frequent link changes in LEO mega-constellation **cause a lot of routing computation.**

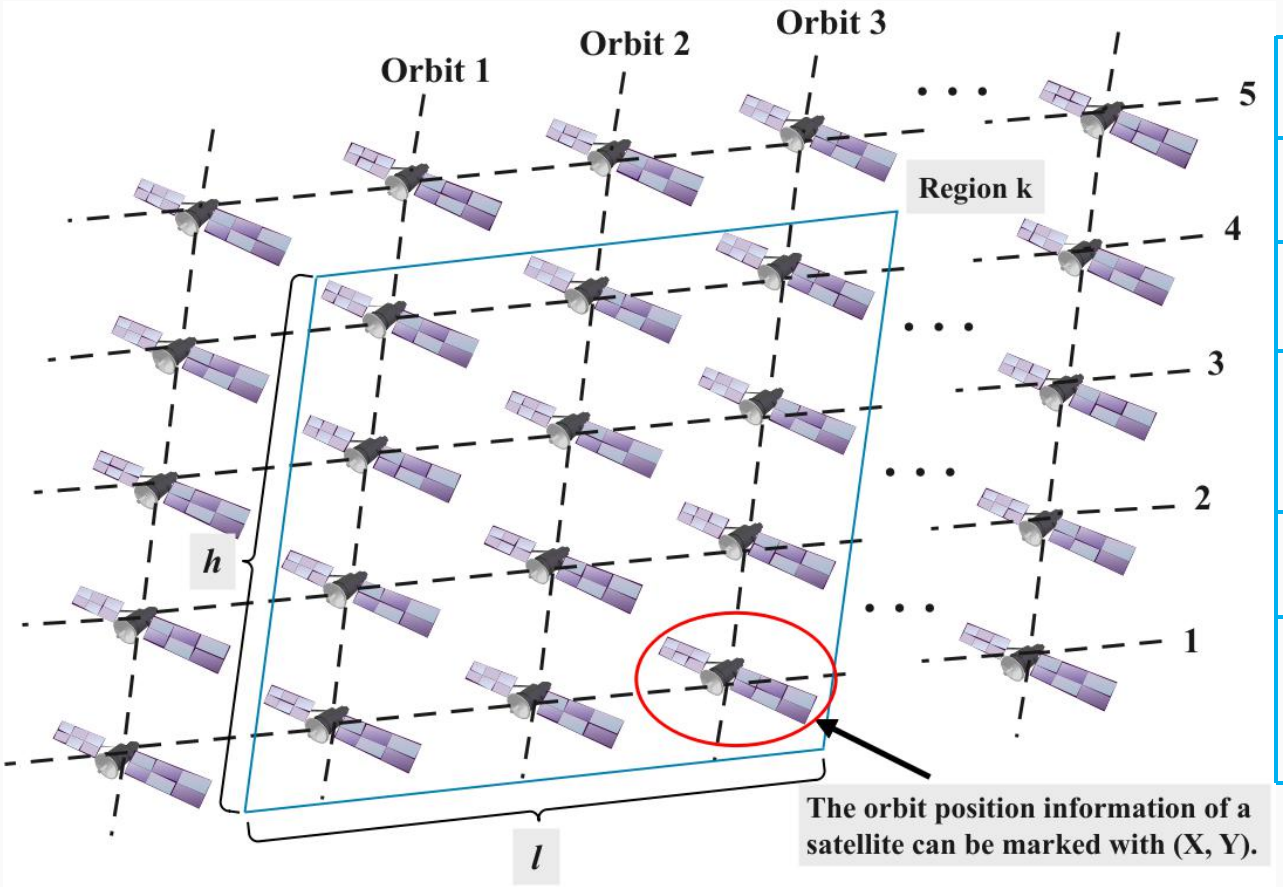
Current routing methods are hard to be applicable.

Routing Framework

Considering these problems, a routing framework is proposed.



Region Planning



Parameter	Meaning
X	The orbit plane of a satellite.
Y	The sequence in orbit plane of a satellite.
h	The number of satellites included in a region in a single orbit plane.
l	The number of orbits spanned by a region.
delta	An offset value when calculating the region number.

- **Region model**

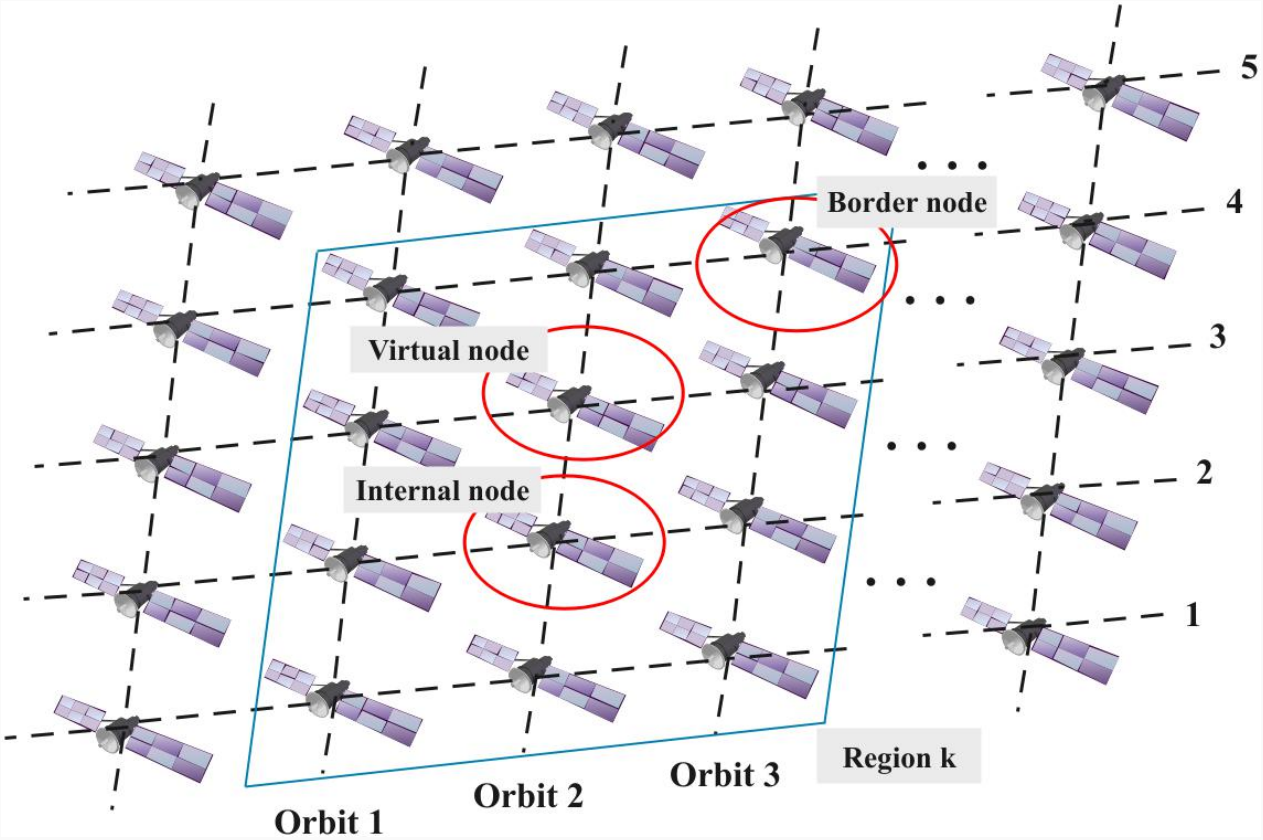
the quadrangle is adopted as the basic model of region division

- **Mapping Function**

$$k = ceil(\frac{X}{l}) \times \frac{M}{l} + ceil(\frac{Y}{h}) + delta$$

Node Capability

To realize the region division, the corresponding capability of satellite nodes should be defined.



- **Internal node capability**

(1) Maintain intra-region network information.
(2) Maintain cross-region connection relationships.
(3) Maintain inter-region network topology.

- **Border node capability**

(1) Establish connections with cross-region neighbor nodes.
(2) Maintain connections with cross-region neighbor nodes.
(3) Isolate network information advertisements.

- **Virtual node capability**

(1) Hide network information and topology change from external network.
(2) Represent the time-varying geographical location of a region.

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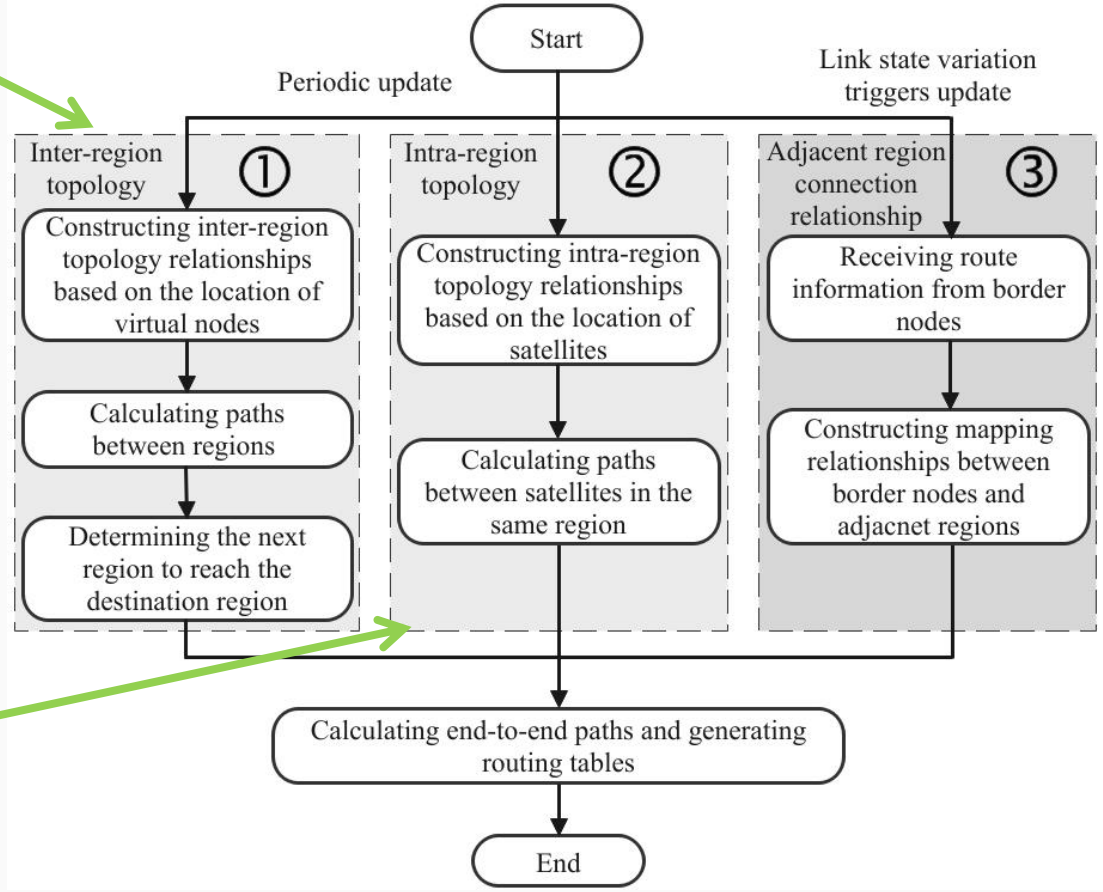
Routing Computation

Inter-region topology relationship

Region 1	Region 2	Cost
R1	R2	10

Intra-region topology relationship

Node 1	Node 2	Cost
N1	N2	6



Mapping relationship

Border node	Nig region
N1	6
N2	INF

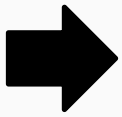
Inter-region routing table

Dst region	Nxt region	Pri	Cost	Inf	Nxt Hop Adr
8	4	1	6	ethx	x.x.x.x

Data Forwarding

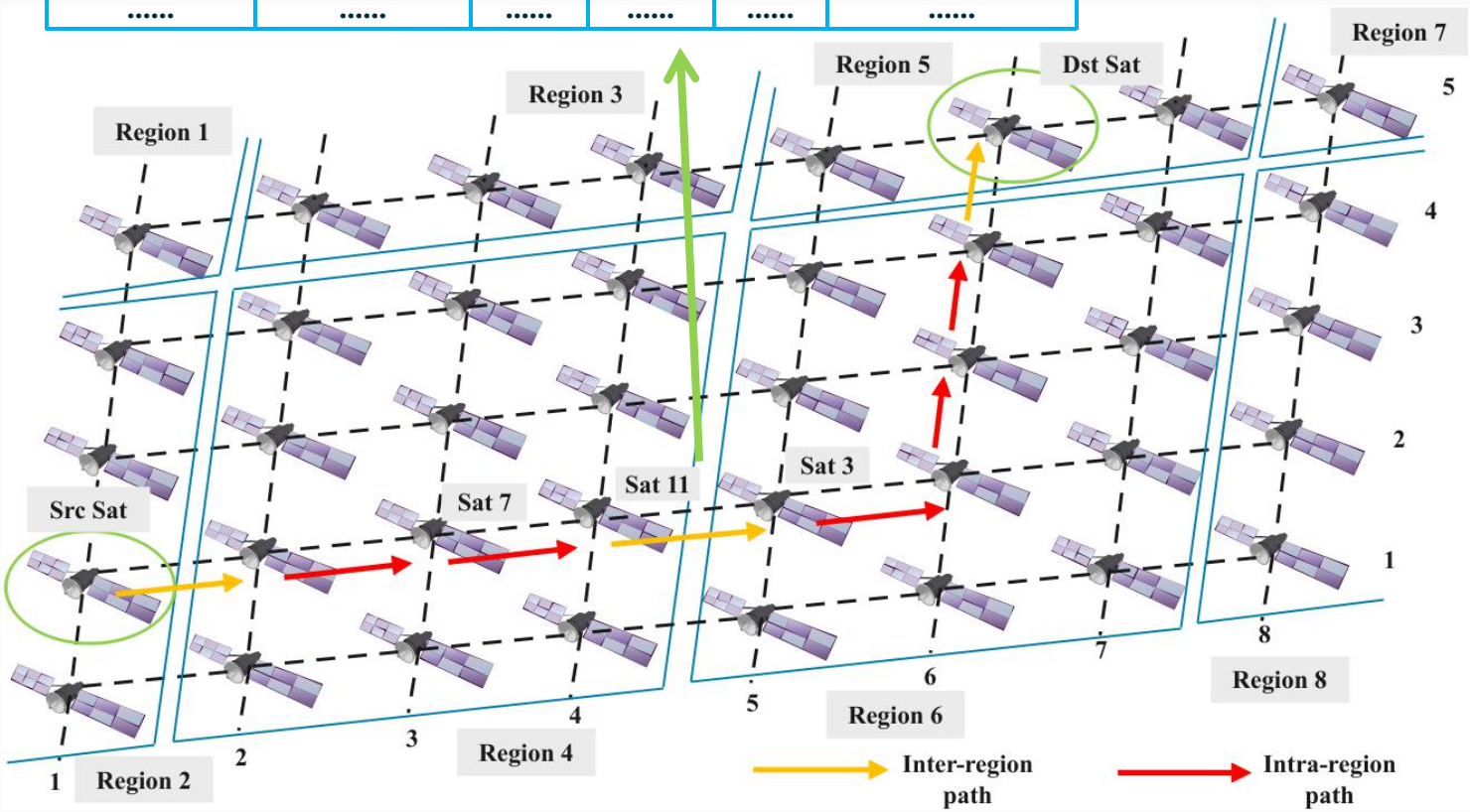
- **Inter-region Path**

Src Sat is located in R2 and Dst Sat is located in R5.



R1	R3	R5	R7
R2	R4	R6	R8

Dst Region	Nxt Region	Pri	Cost	Inf	Nxt Hop Adr
5	6	1	4	inf_4	Sat3_Adr
.....	.....	.....	.....	.....	.....



- **Forwarding Process**

The data is forwarded from Sat 11 in R4 to Sat 3 in R6.

Step1: Sat 11 resolves the Dst Sat identifier from the destination address.

Step2: Sat 11 queries the inter-region routing table.

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Performance Verification

- **Time complexity of routing calculation**

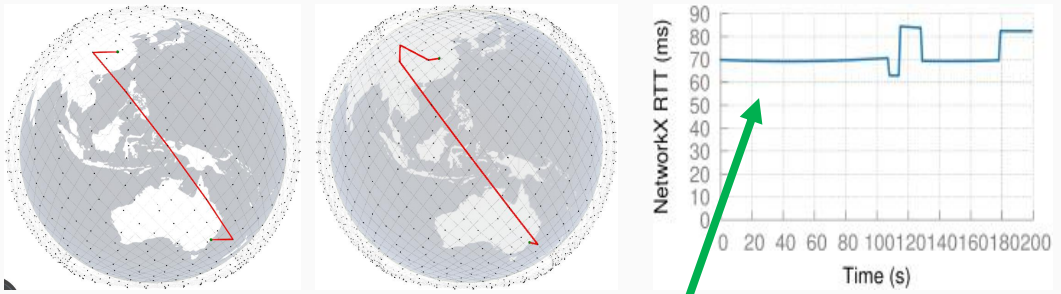
Scenario	Time complexity		Improved ratio
	Without region division (times)	Region division (times)	
Case 1 (8,50,2,5)	8000000	21000	381.0
Case 2 (72,20,4,5)	41472000	28736	1443.2
Case 3 (32,50,4,5)	128000000	84000	1523.8

➢ Computation cost is tremendously reduced.

The routing framework based on region division could effectively address routing challenges in the LEO mega-constellation.

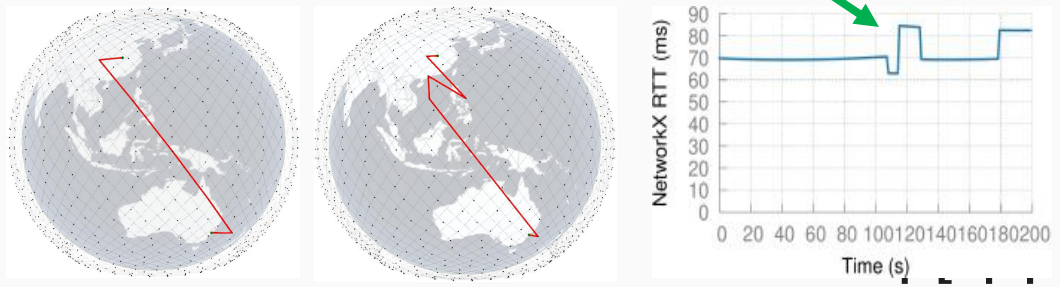
- **Comparison of path selection (from Wuhan to Sydney)**

(a) Without region division



➢ Path selection has no significant difference.

(b) Region division, h=4, l=4



Our Works

- What we have done in IETF:

(1) Routing Framework for LEO Mega-constellation Based on Region Division
https://datatracker.ietf.org/doc/draft-hou-rtgwg-satellite-routing-framework/

(2) Satellite Network Routing Use Cases
https://datatracker.ietf.org/doc/draft-hou-tvr-satellite-network-usecases/

(3) Lightweight Route Information Advertisement for LEO Mega-constellation
https://datatracker.ietf.org/doc/draft-hou-lsr-satellite-route-advertisement/

(4) An Emulation System Architecture for Space Network
https://datatracker.ietf.org/doc/draft-zh-sn-emulation-arch/

- Considerations for the future:

(1) Extension of the current routing protocol to support the framework described in this document.
(2) Improvement of the routing algorithm presented in this document to consider more network metrics and obtain the optimal path.

Thanks