IETF 111

Problems and Requirements of Satellite Constellation for Internet

draft-lhan-problems-requirements-satellite-net-00

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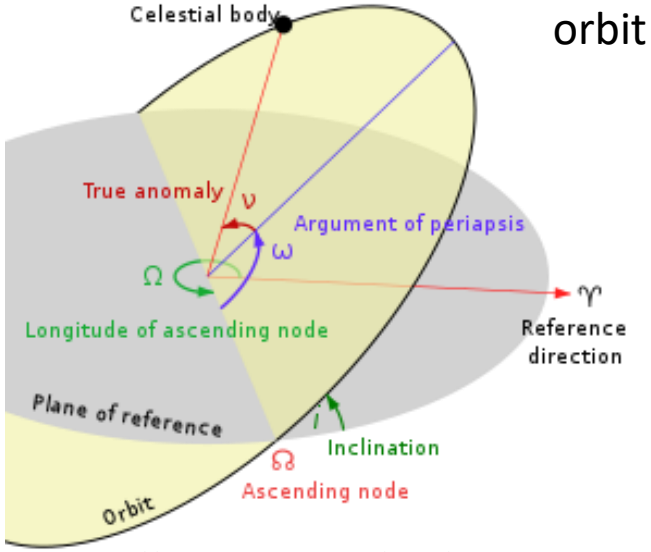
Background and Motivation

- Background
  - Satellite network is becoming a hot topic for 5G and beyond (6G?)
  - StarLink has provided the beta service
    - As of 5/2021, ~1500 satellites, ~10k subscribers in service, ~500k have ordered the service;
    - Has shown some competitive quality over traditional ISP
    - But the deployment and service are preliminary, limited areas, offline, long provisioning, etc
  - More companies/countries plan to launce LEO/VLEO satellites
- Motivation
  - Analyze the issues in satellite network and drive the better solution
    - Orbit, Coverage, Life time of Communication,
    - Operation Model
    - Problems of networking, only focus on mobility, routing and switching technology

Satellite Orbit elements and position

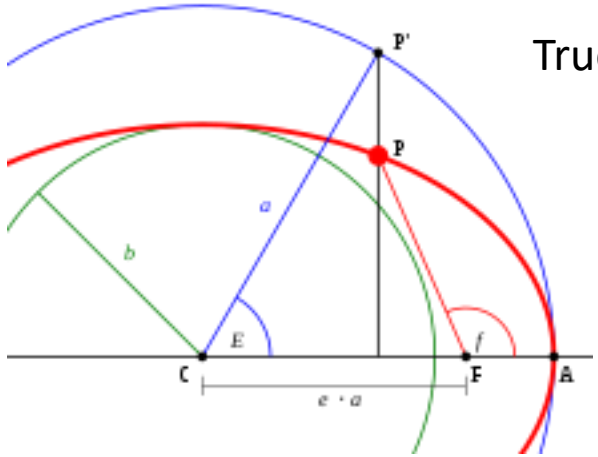
- Fully represent physical characters (position) of a satellite, it needs orbit elements.
- Orbit Elements:
  - Eccentricity (e)
  - Semimajor axis (a)
  - Inclination (i)
  - Longitude of the ascending node (Ω)
  - Argument of periapsis (ω)
  - True anomaly (ν).
  - Epoch (t0), the time above parameters are measured
- At any time t, the exact position of a satellite can be calculated by the law of ‘conservation of angular momentum’.



orbit

Vernal equinox

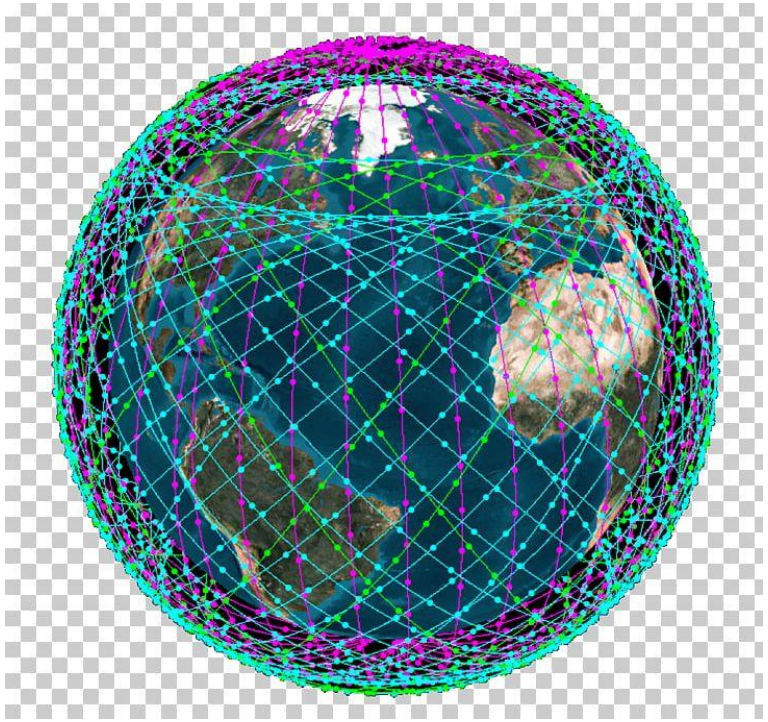
https://en.wikipedia.org/wiki/Orbital_elements



True anomaly

https://en.wikipedia.org/wiki/True_anomaly

Orbit Plane and Satellite



https://favpng.com/png_view/politifact-low-earth-orbit-satellite-internet-access-starlink-oneweb-satellite-constellation-png/TMgy2qS4

Satellite Coverage and Speed

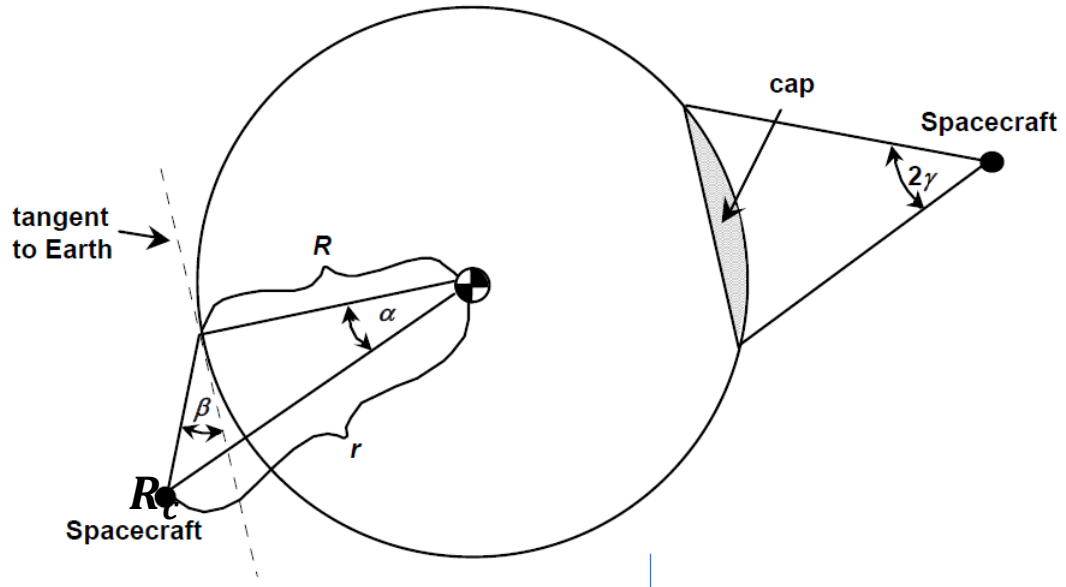
$$\alpha = \cos^{-1}\left(\frac{R}{R+H} * \cos\beta\right) - \beta$$

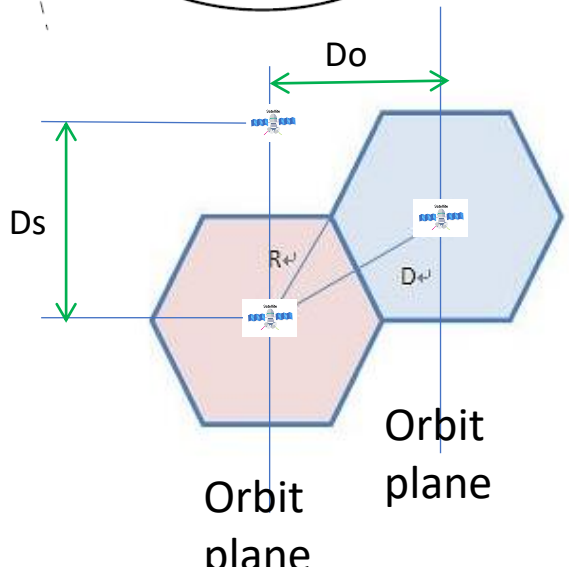
$$R_c = R\left(\frac{\alpha\pi}{180}\right)$$

$$V = sqrt\left(\frac{GM}{R+H}\right)$$

β – Elevation Angle.
R_c - Radius of coverage area
D_s - Distance of satellite
D_o - Distance of orbit
N_s - Minimum number of satellite per orbit
N_o - Minimum number of orbit
R- Radius of Earth
H- Altitude of satellite
V – The velocity of the satellite
G- Gravitational constant
M- Mass of Earth

https://faculty.nps.edu/awashburn/Files/Notes/EARTHCOV.pdf





Some data for coverage and life-of-communication

Parameters	VLEO1	VLEO2	LEO1	LEO2
As(km)	335.9	450	1100	1150
a(degree)	3.907	5.078	10.681	11.051
Rc(km)	435	565	1189	1230
Ns	54	41	20	19
No	62	48	23	22

Table 1: Satellite coverage estimation for LEO and VLEO examples

Parameters	VLEO1	VLEO2	LEO1	LEO2	LEO3
As(km)	335.9	450	1100	1150	1325
a(degree)	3.907	5.078	10.681	11.051	12.293
AL(km)	793	1048	2415	2515	2863
SD(km)	792.5	1047.2	2404	2503.2	2846.1
V(km/s)	7.7	7.636	7.296	7.272	7.189
T(s)	103	137	331	346	398

Table 2: The time for the ground-station-satellite communication

A (degree)	0	10	45	90	135	180
|V| (km/s)	0.065	1.338	5.869	10.844	14.169	15.336
T(s)	61810	2984	680	368	282	260

Table 4: Two VLEO intersects with different angle and the life of communication

A (degree)	0	10	45	90	135	180
|V| (km/s)	0.083	1.263	5.535	10.226	13.360	14.461
T(s)	47961	3155	720	390	298	276

Table 6: Two LEO intersects with different angle and the life of communication

LEO/VLEO satellite network

- Two Operational Mode
  - Satellite Relay
    - One satellite relay
    - Multiple satellite-ground-station relay
  - Satellite network
    - Inter-satellite Link (ISL) is mandatory, not mature
- Limited communication time:
  - Satellite to ground station communication: 100 ~ 500s
  - Inter-Satellite (different altitude) communication: <24Hr.
- Dynamic topology, Frequent Hands over

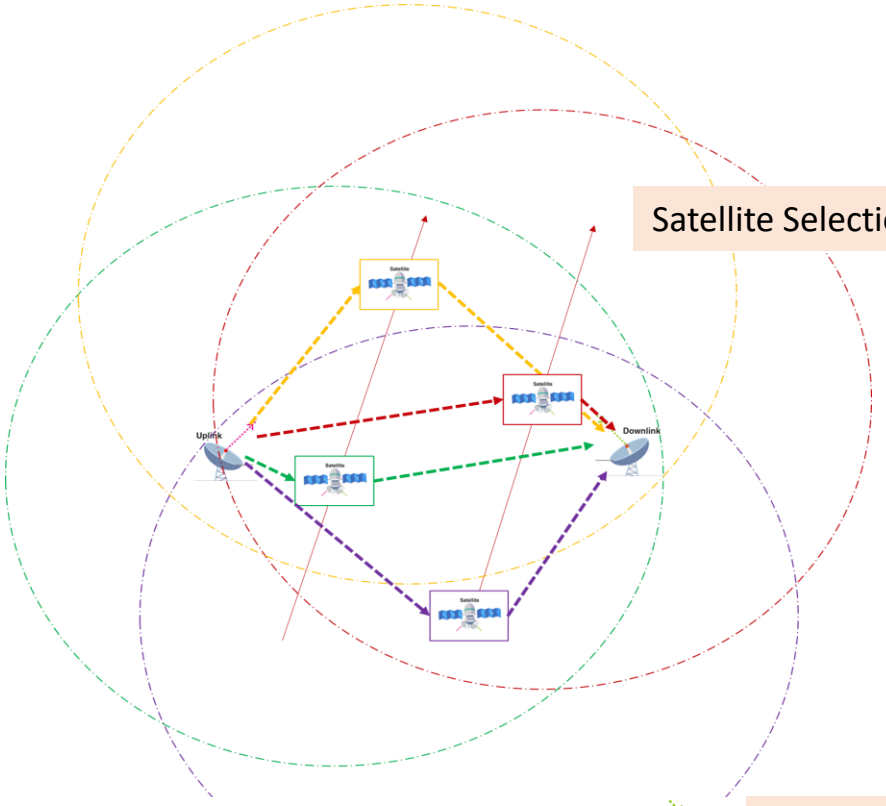
Common issues

- Mobility
  - Current Mobility not Helpful
    - Mobile end-communication-node + Static base station and provider network
    - Protocols:
      - 3GPP: inter and intra hands over
      - IETF: MIPv4, MIPv6/PMIPv6, LISP
  - Satellite Mobility
    - End-communication-node static + Provider network is moving
    - Moving speed is fast
- Power supply constraint
  - Packet process, forwarding should consider the power consumption
  - Link speed is limited (ISL ~10G for laser)

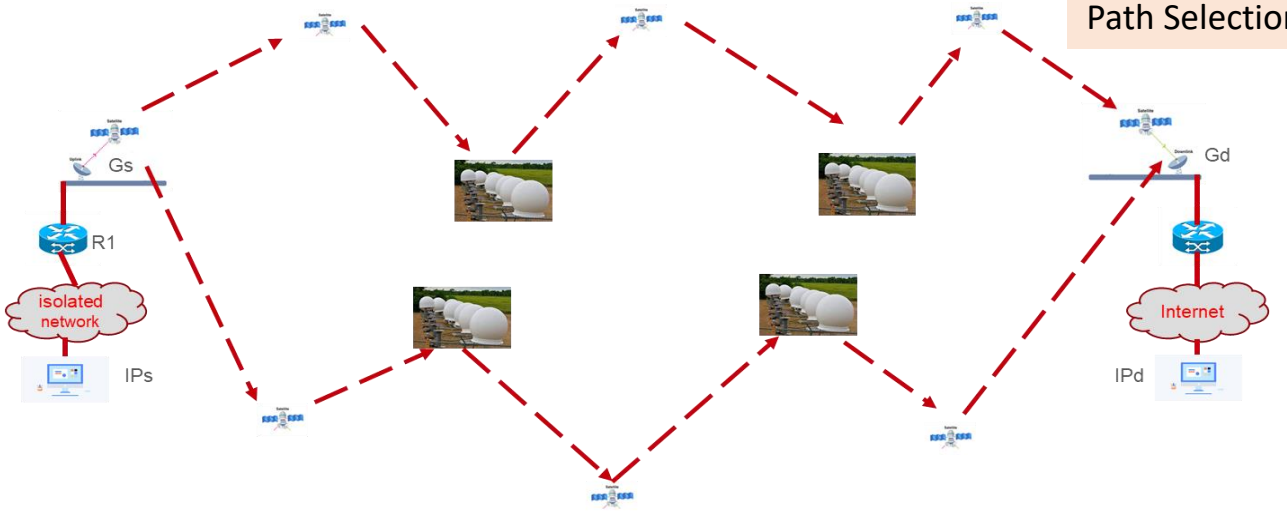
Satellite Relay

- One satellite relay is same as traditional GSO communication
- Multiple satellite Relay
  - Practical Solution for global coverage before Inter-Satellite Networking is available
- More complicated than One Satellite Relay
  - Networking
  - Satellite, Peer, Path selection
  - Protocols and Packet forwarding

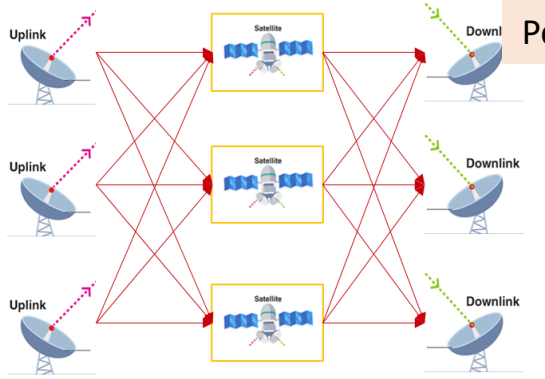
Satellite Selection



Path Selection



Peer GS Selection



M
SGS (Source Ground Station)

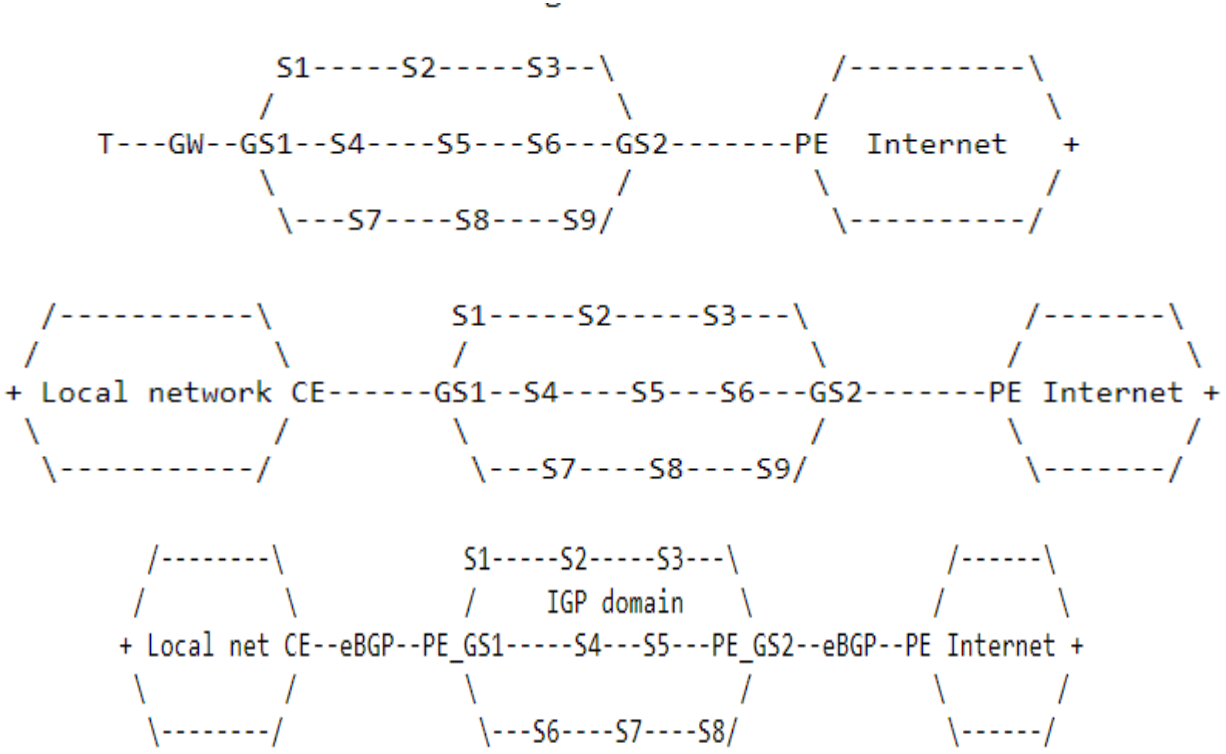
S
VSA (Via Satellite)

N
DGS (Destination Ground Station)

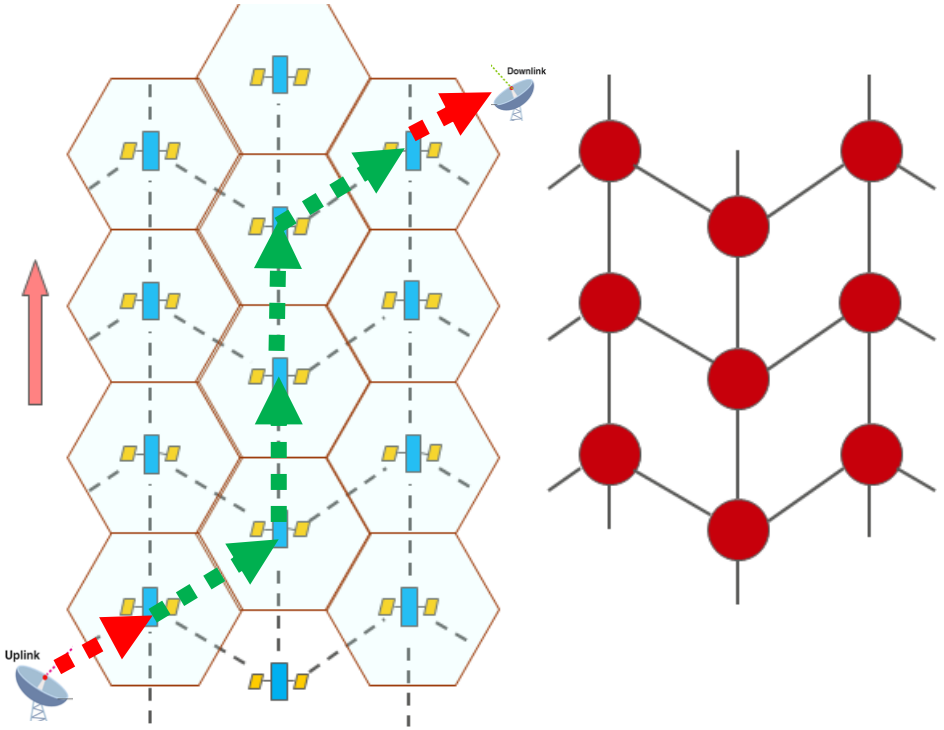
Satellite Networking by Inter-Satellite Communication

- Most complicated
  - Combination of satellite-to-satellite link and satellite-ground-station link
  - Ground station could be isolated or internet-connected
- Not mature
- Two key issues
  - Inter-satellite communication (out of scope of the draft)
  - Routing and switching

Satellite Networking – By Inter-satellite Link



- Huge amount of satellite
  - Satellite - >10k for one provider
- Huge amount of ground stations
  - Ground stations > 1m
    - ❑ StarLink has requested 1m ground station license
      - ❖ Each continent > 100 gateway ground stations
      - ❖ Others are terminal ground stations



Two routing issues

- Massive IGP flooding
- BGP convergency

Consequences

- Satellite routing device is costly and consume a lot power due to the heavy tasks for routing protocols
- ISL link consume bandwidth for control
- Network state is not steady
- Service is not steady

Comments & Feedback ?

Thanks