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 launch 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 Plane and Satellite

Satellite Coverage and Speed

\[ \alpha = \cos^{-1}\left(\frac{R}{R + H} \cdot \cos \beta \right) - \beta \]

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

\[ V = \sqrt{\frac{GM}{R + H}} \]

\( \beta \) – 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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>VLE01</th>
<th>VLE02</th>
<th>LEO1</th>
<th>LEO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>As (km)</td>
<td>335.9</td>
<td>450</td>
<td>1100</td>
<td>1150</td>
</tr>
<tr>
<td>a (degree)</td>
<td>3.907</td>
<td>5.078</td>
<td>10.681</td>
<td>11.051</td>
</tr>
<tr>
<td>Rc (km)</td>
<td>435</td>
<td>565</td>
<td>1189</td>
<td>1230</td>
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<tr>
<td>Ns</td>
<td>54</td>
<td>41</td>
<td>20</td>
<td>19</td>
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<tr>
<td>No</td>
<td>62</td>
<td>48</td>
<td>23</td>
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</tr>
</tbody>
</table>

Table 1: Satellite coverage estimation for LEO and VLEO examples

<table>
<thead>
<tr>
<th>Parameters</th>
<th>VLE01</th>
<th>VLE02</th>
<th>LEO1</th>
<th>LEO2</th>
<th>LEO3</th>
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</thead>
<tbody>
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<td>As (km)</td>
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<td>a (degree)</td>
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<td>5.078</td>
<td>10.681</td>
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<td>12.293</td>
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<tr>
<td>AL (km)</td>
<td>793</td>
<td>1848</td>
<td>2415</td>
<td>2515</td>
<td>2863</td>
</tr>
<tr>
<td>SD (km)</td>
<td>792.5</td>
<td>1847.2</td>
<td>2404</td>
<td>2503.2</td>
<td>2846.1</td>
</tr>
<tr>
<td>V (km/s)</td>
<td>7.7</td>
<td>7.636</td>
<td>7.296</td>
<td>7.272</td>
<td>7.189</td>
</tr>
<tr>
<td>T (s)</td>
<td>103</td>
<td>137</td>
<td>331</td>
<td>346</td>
<td>398</td>
</tr>
</tbody>
</table>

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

<table>
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<tr>
<th>A (degree)</th>
<th>0</th>
<th>10</th>
<th>45</th>
<th>90</th>
<th>135</th>
<th>180</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.065</td>
<td>1.338</td>
<td>5.869</td>
<td>10.844</td>
<td>14.169</td>
<td>15.336</td>
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<td>T (s)</td>
<td>61810</td>
<td>2984</td>
<td>680</td>
<td>368</td>
<td>282</td>
<td>260</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>A (degree)</th>
<th>0</th>
<th>10</th>
<th>45</th>
<th>90</th>
<th>135</th>
<th>180</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.083</td>
<td>1.263</td>
<td>5.535</td>
<td>10.226</td>
<td>13.360</td>
<td>14.461</td>
</tr>
<tr>
<td>T (s)</td>
<td>47961</td>
<td>3155</td>
<td>720</td>
<td>390</td>
<td>298</td>
<td>276</td>
</tr>
</tbody>
</table>

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 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
- 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