The Analysis of Network Throughput of LEO Communication Satellite System for Priority Coverage of Russian Federation

A.V. Kuzovnikov1, A.M. Badertdinov2, V.M. Golovkov3, M.P. Ivanova4 and V.G. Somov5

1Head of Department, 2Leading Manager, 3Engineer of 1 Category, 4Engineer of 1 Category, 5Professor, Reshetnev Siberian State University of Science and Technology.

1,2,3,4 Joint-Stock Company, Academician M.F. Reshetnev Information Satellite Systems, 52, Lenin Street, Zheleznogorsk, Krasnoyarsk region, Russia.

Orcid IDs: 1 0000-0002-5085-646X, 2 0000-0002-5549-0233, 3 0000-0003-2360-7916, 4 0000-0002-5219-8130, 5 0000-0001-6133-2592

Abstract
This system is a further advancement of geostationary personal communication systems providing increased network data transmission and global coverage. This paper is using the results obtained by the research conducted under the Agreement № 14.585.21.0003, the project identifier RFMEFI58514X0003.

The initial conditions for network throughput calculation
Four types of orbital constellations are considered:

Type 1:
– orbit height – not less than 1500 km;
– orbit plane inclination – 82.5°;
– number of spacecrafts (Nsat_syst) – 48;
– number of planes (n) – 6;
– number of spacecraft in-plane (m) – 8.

Type 2:
– orbit height – not less than 1000 km;
– orbit plane inclination – 82.5°;
– number of spacecrafts (Nsat_syst) – 128;
– number of planes (n) – 8;
– number of spacecraft in-plane (m) – 16.

For type 1 and type 2 two more subtypes (1.1, 1.2 and 2.1, 2.2 respectively) are considered with different longitude of the ascending node and mean anomaly.

Type 3 and type 4 of orbital constellations are considered without overlay over cover areas.

Type 3:
– orbit height – not less than 1500 km;
– orbit plane inclination – 82.5°;
– number of spacecrafts (Nsat_syst) – 360;
– number of planes (n) – 20;
– number of spacecraft in-plane (m) – 18.

Type 4:
– orbit height – not less than 750 km;
– orbit plane inclination – 82.5°;
– number of spacecrafts (Nsat_syst) – 720;
– number of planes (n) – 20;
– number of spacecraft in-plane (m) – 36.

Calculation of network throughput
The results of communications spacecraft orbital constellation simulation given in [1] have been used. Network throughput calculation results for subtypes 1.1, 1.2, 2.1 and 2.2 are shown in Table 1.

Note – The calculation of network throughput is based only on predicted spectrum/orbit resource calculation and it does not take into account system components energetics parameters. Further research is required to assess available spectrum/orbit resource and calculate radio link capacity to determine system components main energetics parameters [2].
Table 1: Network throughput calculations results for 1.1, 1.2 and 2.1, 2.2 types of constellation.

| Note – Uniformly distributed by component beam of 7/19/37 multi-beam antenna load has been assumed. Spectrum/orbit resource may be reallocated to increase bandwidth.

| Network throughput for 48 satellites constellation with 15° elevation (with overlay of cover areas – Type 1.1) is lower (36 Gb/s) than network throughput for 48 satellites constellation with 20° elevation (Type 1.2, 72 Gb/s) because of lower utilization of spectrum/orbit resource.

| Network throughput for 128 satellites constellation with 25° elevation (with overlay of cover areas – Type 2.1) is lower (72 Gb/s) than network throughput for 128 satellites constellation with 33° elevation (Type 2.2, 144 Gb/s) because of lower utilization of spectrum/orbit resource.

| Network throughput for 128 satellites constellation with 35° elevation (with overlay of cover areas – Type 2.2) is lower (72 Gb/s) than network throughput for 128 satellites constellation with 54° elevation (Type 2.3, 144 Gb/s) because of lower utilization of spectrum/orbit resource.

| Network throughput for 128 satellites constellation with 45° elevation (with overlay of cover areas – Type 2.3) is lower (72 Gb/s) than network throughput for 128 satellites constellation with 64° elevation (Type 2.4, 144 Gb/s) because of lower utilization of spectrum/orbit resource.

| Network throughput for 128 satellites constellation with 55° elevation (with overlay of cover areas – Type 2.4) is lower (72 Gb/s) than network throughput for 128 satellites constellation with 75° elevation (Type 2.5, 144 Gb/s) because of lower utilization of spectrum/orbit resource.

| Network throughput for 128 satellites constellation with 65° elevation (with overlay of cover areas – Type 2.5) is lower (72 Gb/s) than network throughput for 128 satellites constellation with 85° elevation (Type 2.6, 144 Gb/s) because of lower utilization of spectrum/orbit resource.

**Table 1:**

<table>
<thead>
<tr>
<th></th>
<th>Type 1.1</th>
<th>Type 1.2</th>
<th>Type 2.1</th>
<th>Type 2.2</th>
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<tbody>
<tr>
<td>Nobs</td>
<td>50000</td>
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<tr>
<td>Nspat</td>
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<td>Nregs</td>
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<tr>
<td>Nspatftware</td>
<td>40000</td>
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<td>40000</td>
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</table>

**Notes:**

1. Nobs – number of beam terminals.
2. Nspat – simultaneously active users percentage.
4. Nregs – single user mean calls per hour.
5. Nspatwaukee – mean time of one call, minutes.
7. Nspatftware – mean called traffic per user, miling.
8. Nspatoftware – total called traffic, miling.
9. Nspatftware – number of beams per satellite.
10. Nspatftware – number of beams per beam.
11. Nspatftware – channel capacity per beam.
13. Nspatoftware – number of beams per beam.
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Type 2.1) is the same (72 Gb/s) as for 48 satellites constellation with 20° elevation (without overlay of cover areas – Type 1.2), but the one day mean global coverage percentage is higher (98.25% vs 75.00%);

- payload for each Type 1 satellite is much more complex than for Type 2 satellite due to Type 1 satellite payload requiring a lot more number of channels per beam (by 2 or 3 times).

Network throughput calculation for 360 and 720 satellites constellations communication systems (Type 3 and Type 4) with uniformly distributed ground control stations is given in Table 2 (analysis of constellation must be performed on next stages of research).

Note – The calculation of network throughput is based only on predicted spectrum/orbit resource calculation and it does not take into account system components energetics parameters. Further research is required to assess available spectrum/orbit resource and calculate radio link capacity to determine system components main energetics parameters.

<table>
<thead>
<tr>
<th>Type</th>
<th>Payload</th>
<th>Channels</th>
<th>Number of beams</th>
<th>Number of spot beams</th>
<th>Number of gates</th>
<th>Number of beams per gate</th>
<th>Number of spot beams per gate</th>
<th>Number of satellites</th>
<th>Number of ground control stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>360</td>
<td>High</td>
<td>1000</td>
<td>20</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>720</td>
<td>High</td>
<td>2000</td>
<td>20</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>20</td>
<td>5</td>
</tr>
</tbody>
</table>

Note – Uniformly distributed by component beam of 7/19/37 multi-beam antennas load has been assumed. Spectrum/orbit resource may be reallocated to increase bandwidth.
As shown in Table 2:

- network throughput significantly increases if there isn’t coverage areas overlay:
  - 180 Gb/s for 360 satellites constellation;
  - 360 Gb/s for 720 satellites constellation.
- payload for each Type 3 or 4 satellite is much more simpler than for Type 1 or 2 satellite due to decrease in the number of channels per beam (by 2 to 6 times)

**CONCLUSION**

This paper shows that communication systems with more than 128 satellites in constellation at 500-1000 km LEO orbit must be designed in order to increase network throughput (assuming constant number of subscribers) and decrease satellite payload complexity.

It is also shown that 720-satellite constellation is the most efficient in terms of throughput.

Next stages of this topic research will require to evaluate:

- the demand for LEO mobile satellite communications;
- the necessary cover area for LEO orbital constellation;
- the minimal number of spacecraft to meet the demand for LEO mobile satellite communications;
- the complexity and costs of payload and a single spacecraft for every orbital constellation type;
- Launch costs and vehicle type for every orbital constellation type;
- Ground station design and build costs

**REFERENCES**


