Development of an inter-satellite data transmission network for space debris evasion systems

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Introduction

Artificial Earth Satellites (AES) are among the most powerful tools across a wide range of fields, such as science, telecommunication, radio navigation, and many others. They are extremely important; therefore, all space nations strive to improve their operational reliability and efficiency. However, modern spaceflight must contend with space debris, which is a threat to both AES and manned spacecraft. However, under the conditions of accumulating space debris in low Earth orbit (LEO), the safety of space missions is becoming one of the key challenges nowadays.

A complex solution is required, consisting of specialized AES carrying equipment to detect potentially dangerous trajectories of small space debris and the creation of inter-satellite networks for exchanging operational information needed to adjust the orbital parameters of the threatened spacecraft.

Materials and methods

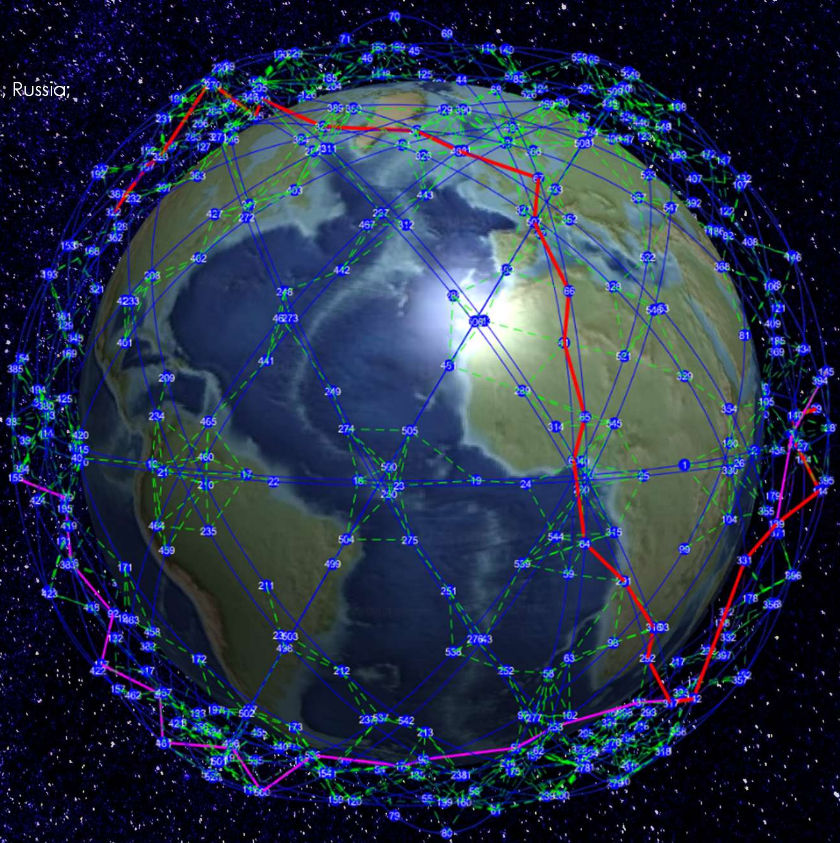
Technologies of the Internet of Things (IoT) were considered as the main devices for organizing network because of their low power consumption which is necessary for implementation on AES.

Simulation in MATLAB software was used to calculate main parameters of the network such as latencies for different signal paths, the dependence of error growth on the increase in the number of nodes.

Results and discussion

A mesh network meets all the requirements regarding architecture and scalability. It allows many nodes to be integrated, which will connect all satellites around the Earth so each individual device can send and receive data with any other node in the network thanks to signal routing. Therefore, the transmitter and receiver do not require direct radio contact, unlike in peer-to-peer networks. Moreover, this architecture is supported by many modern variants of technologies.

Also, IoT devices and protocols can achieve unbelievable efficiency in space because of low signal path loss, low transmission power and small sizes of the telecommunication devices.



Example of 3D mesh network topology model for LEO satellites

Capabilities of the network

For LoRa 32 device

- Global coverage for whole LEO range
- Calculated max link distance: 1945.27 km
- Mean link distance for 0 to 5 dB noise: 1458.26 km
- Time delay for 30 byte packet (15256 km): 21.7 s (purple)
- Time delay for longest link in the network: 28.9 s (red)
- Mean SNR for purple path: 1.82 dB
- Mean SNR for red path: 1.56 dB
- Relative transmission rate: 11.07 bps (purple)
- Relative transmission rate: 8.31 bps (red)

Conclusion

Model for intersatellite mesh network was developed. It contains mechanism for different satellite orbits creation including true anomaly calculation, so that model is basically discrete time-event simulator, Tx/Rx parameters setting, active routing vector protocol simulation and delay and SNR estimations for chosen links.

It should be noted that a network like this will significantly reduce the threat of collisions with space debris for satellites of various types, as well as make manned space expeditions much safer.