



Space Intersects Internet – Opportunities and Challenges

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Space has always been the final frontier for human kind. As we enter the 2020s, space and Internet technologies are converging. Global technology leaders that consider the Internet evolution, in terms of adoption, affordability, performance and reach, fundamental to their continuous growth, are pouring tens of billions into space Internet technologies at the moment. This makes for exciting, yet risky, times ahead!

Few interesting paradigms have been emerging over the last few years, with the potential to impact the Internet infrastructure and the design and deployment of Internet-based services. These paradigms low earth orbit (LEO) satellite communication networks. Simply put, LEO networks are satellite-based constellations that orbit the earth at altitudes of 1200 miles or less. These constellations have existed for a while, but a new generation of networks is being launched at the moment. The novelty is that these recent networks launches are focused on enabling global-scale Internet connectivity, bringing in a new era of space-based Internet technologies.

Indeed, all the major internet/cloud providers are working on various aspects of such deployments, including Amazon, Google, Facebook, Microsoft as well as large-scale space technology players such as Virgin and SpaceX and technology investors such as Softbank. Also active are some of the existing satellite communication providers already present in GEO (Geostationary Orbit) and MEO (Medium Earth Orbit), as well as venture capital-backed startups, and government funded consortiums in China, Japan, Korea, Europe, North America and the Middle East. Most constellations launches are being planned in the 2020-2025 timeframe, with tens of billions of dollars being invested.

The new LEO satellite networks being designed at the moment bring in a whole new set of opportunities, taking advantage of the potential low latency, broad reach and high capacity of such networks. The scale of investments going into such initiatives, primarily from the private sector, adds a significant advantage to their potential. These LEO space networks are being designed with the intention of leveraging the mechanisms designed for terrestrial networks such as those for routing, switching, Quality of Service (QoS), resources management, software-defined network (SDN) control, virtual network functions (VNF) orchestration, and cyber-security.

There is an opportunity to leverage LEO networks for various Internet service offering. These include:

- Offering services that would leverage the new cost structure of LEO network deployments in terms of coverage, bandwidth and latency, as well as the potential routing topologies that they bring such as global routing with a reduced number of autonomous systems and new peering/transit models.
- Piggyback on the deployment of distributed mobile edge computing solutions with highly distributed data centers and clouds, content delivery networks, and public safety networks.
- Revisit the technologies and deployment models of peer-to-peer (P2P) based networks, and to leverage the characteristics of LEO networks for bringing in new topology models for designing and hosting peers' hierarchies and topologies.

- Potential deploy global Mobile Virtual Network Operations (MVNOs) given the large-scale geographical nature of LEO networks and their underlying economics.
- The global nature of LEO networks, and the new interconnection models they provide to connect with terrestrial wireline, wireless, submarine and cloud networks, has the potential to significantly change the dynamics of rolling out high-speed broadband in rural regions, particularly in the developing world.

Yet various challenges need to be addressed over the coming years, including:

- Harmonizing Internet Routing and Signaling Protocol Design to fit the requirements of LEO networks, where intra and inter domain routing protocols would need to be adapted to fit the requirements of LEO networks
- Evolving QoS and Traffic Management Mechanisms for data path resources management and the design and dimensioning of oversubscription models over LEO space segments
- Reconciling NFV, SDN and Operational Systems given that LEO space networks are global, distributed and dynamic
- Tailoring State-of-the-Art Cyber-Security Mechanisms, where Cyber-security for data and control paths would require rethinking to accommodate the characteristics of space segments given the constrained functionalities on the satellites.
- Growing Next-Generation IoT Networks Leveraging LEO Connectivity given that The IoT gateways and backend architectures in use today would benefit from interfacing with the control and management plane of LEO networks
- Fashioning Technology Standards and Regulations for LEO Networks, taking into account that Standards bodies have already been addressing the various regulations required for the deployment of large-scale LEO networks.

Major technology and financial investments are going into the deployment of LEO networks at present. Yet, major challenges remain to be overcome. These include both technical and business challenges. The intersection of space and Internet technologies is still in its early phases, with lot of learnings from both sides aiming to enhance the joint value proposition.

The next few years will likely witness a rapid evolution of these technologies, with a possible significant impact on how Internet services evolve. A potentially high-risk high-return equation, where there will likely be few winners and lots of losers. These are certainly exhilarating times for Internet evolution, in a world where the Internet is, and will continue to be, the cornerstone of the development of nations.