XONA PARTNERS

# Space Intersects Internet:
## Opportunities and Challenges

Dr. Riad Hartani

May 2019

Space has always been the last frontier for human kind. The Emergence of the Internet has probably been one of the most disruptive and exciting things of the last few decades. As we enter the 2020s, Space and Internet technologies are converging. Potentially. Global leading technology leaders that consider the Internet evolution, in terms of adoption, affordability, performance and reach, as fundamental to their continuous growth, are pouring 10s of billions into Space Internet technologies at the moment. Exciting, yet risky, times ahead.

Disruptions in the fundamentals of Internet infrastructure architecture and design, and the way it is deployed do not happen often. In fact, things have been mostly progressive and incremental over the last two to three decades, since the major shift from the use of circuit switching technologies to Internet packet switching at scale. This has seen a long but steady evolution from Time Division Multiplexing (TDM) based networks to a family of packet based technologies over time, including Frame Relay, Asynchronous Transfer Mode (ATM) and into Multi-protocol Label Switching (MPLS) and their various instantiations, as well as circuit based voice to IP based voice and other multimedia services. In parallel, various iterations of wireless technologies have been deployed, converging to the 5G cellular networks in early stages of deployment today. This has been complemented by the very rapid growth of the broader ecosystem supporting the Internet evolution, in the forms of large-scale data centers and clouds, software operating systems, and over the top applications. In fact, it is primarily this evolution of Internet connectivity models and underlying technologies that led to the growth of the Internet eco-system, as we know it today.

Few interesting paradigms have been emerging over the last few years, with a potential to impact the internet infrastructure design and deployment of Internet based services, with significant consequences on content delivery models, cloud networks, distributed computing and the economics of over the top applications rollouts. These include aspects such as blockchain and decentralized Internet technologies, quantum communications and low earth orbit (LEO) satellite communication networks. This paper focuses specifically on LEO networks, and mostly addresses the challenges to overcome to ensure their potential success. It provides a glimpse of how the technologies, protocols, standards and mechanisms developed for terrestrial and wireless Internet networks can be leveraged to speed up deployments of LEO based communication networks over the next few years.

Simply put, LEO networks are satellite-based constellations that orbit at altitudes below 1200 miles above the earth surface. These constellations have existed for a while, and numerous ones have been launched in the past, with the Iridium network being the most well known from the late 90s. The novelty is in the fact that these recent networks launches are very much focused on enabling global scale Internet connectivity, bringing in a new era of space based Internet technologies. Pretty much all the major Internet/Cloud providers are working on various aspects of such deployments, including Amazon, Google, and Facebook as well as large scale technology players such as Virgin, SpaceX and Softbank along with some of the existing satellite communication providers already present in the GEO (Geostationary Orbit) and MEO (Medium Earth Orbit), as well as venture capital backed startups, and government funded consortiums in China, Japan, Korea Europe and North America. Most constellations launches are being planned during

the 2020-2025 timeframe, with 10s of billions of dollars being invested. At the same time, this is still a high-risk initiative given the technical and business challenges that need to be solved. As such, this is a high-risk high-return equation, and only time will tell on how it will impact the Internet evolution, global competitiveness and Internet geo-politics matters over the next decade.

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 intent of leveraging the mechanisms designed for terrestrial networks such as those for routing, switching, Quality of Service (QoS), resources management, Software Defined Network control, Virtual Network Functions orchestration, Cyber-security, etc.. Yet, a lot of these mechanisms are far from optimal given the characteristics of LEO space networks, in terms of mobility, terrestrial to space wireless links management, and space-to-space wireless links connectivity. In some cases, these mechanisms need to be highly adapted, and in other cases fully redesigned. In fact, these LEO space networks are in early stages of taking advantage of the internet/wireless networking mechanisms that have been developed, deployed and in some cases abandoned over the last 20+ years.

There is an opportunity to leverage state of the art Internet designs and evolving it optimally to enable the deployment of this new generation of space networks. Below is a non-exhaustive review of some of the key aspects that need to be addressed, both in terms of services offering and technology development fronts. For each one of the dimensions considered, we list some of the aspects that require further work, and could take advantage of the various Internet mechanisms and standards out there, for the specific LEO networks context.

## Adapting Internet services and customer application offering over LEO networks

- Adaptation of the Services Level Agreements (SLAs) and Key Performance Indicators (KPIs) definition is required. The IP based services SLAs have primarily been defined with terrestrial networks in mind. Adapting them to LEO satellite networks is a must, as it has a direct impact on traffic management/engineering solutions that need to be put in place on the satellites, coordination between terrestrial and satellites networks, load balancing across space segments, among other things, and this on both data and control planes
- Various services targeted by LEO networks at are focused on well known internet services offered by existing terrestrial/wireless networks, such as business centric layer 2 and 3 services, Virtual Private Network Services (VPNs) etc. There are new opportunities for services that would leverage the new cost structure of LEO networks deployments in terms of coverage, bandwidth and latency, as well as the potential

new layer 3 routing topologies that they bring such as global Routing with a reduced number of Autonomous Systems, new peering/transit models, among other things.

- The analysis of new services includes aspects that would piggyback on the deployment of distribute mobile edge computing solutions with highly distributed data centers and clouds, content delivery networks, public safety networks, etc.
- There is an opportunity to revisit the technologies and deployment models of peer to peer (P2P) based networks, and leveraging the characteristics of LEO networks in brining in new topology models for designing and hosting peers' hierarchies and topologies. It would also be interesting analyze how this would complement the ongoing blockchain lead initiatives for incenting the use of P2P networks at scale and the evolution of file systems distributions.
- The emergence of LEO networks opens up new opportunities for the deployment of global Mobile Virtual Network Operations (MVNO) given the large-scale geographical nature of LEO networks and their underlying economics.
- Multi-media services, including voice and video services delivered directly over LEO networks, call for a rethink of the various mechanisms designed for LTE networks, such as those in the IP Multi-media Systems (IMS), roaming models, and inter-connection architectures.
- The global nature of LEO networks, and the new interconnection models it provides 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, and in particular in the developing world. It is as such, a clear opportunity for a lot of countries to explore ways of speeding up the implementation of their digital infrastructure strategies.

## Adapting Internet Routing and Signaling Protocols Design to LEO networks

- Adaptation of the Internet Gateway Protocols (IGP) and potentially Border Gateways protocols (BGP) for global routing to accommodate wireless links with very specific characteristics (this includes satellite to satellite links, ground to space fixed wireless links, mobile users to space wireless links, etc.), and direct impacts on layer 2 and 3 topology information dissemination, path computation, mapping of demand to paths and load balancing over paths.
- Bringing in the consideration of wireless link characteristics in the measure of QoS metrics and their usage for traffic routing, for the earth to satellite links as well as satellite-to-satellite links.
- As LEO networks get progressively deployed, and given the challenges in addressing their specific predictability, reliability and availability characteristics (weather, capacity limitations, etc.), there is a clear need to build network control models that leverage the potential complementarity of other technologies, including 4G/5G,

Microwave backhaul, submarine networks etc. to ensure end to end SLAs are satisfied with the right economics.

- The Handover models typically deployed in 3GPP 4G/5G networks would need to be adapted for the cases of mobile and high velocity satellites, as they call for different mechanisms to ensure data continuity with the appropriate quality of experience requirements. This is even more the case when dealing with dual network elements mobility scenarios, which includes mobile user terminals and mobile satellites.
- The data-path connectivity protocols, centered around the various layer 2/3 IP/MPLS mechanisms, as well as their corresponding control planes, would benefit from potential adaptations that would make them more optimal when carrying payloads over multi-hop space segments.
- The global reach of LEO networks potentially enables a more rapid adoption of internet based services by a larger number of users in the developing world, of IoT services globally and of peer to peer services. All of them requiring a larger Internet addressing space, and in turn, potentially speeding up the adoption of IPv6 addressing. Benefits could go beyond the expanded addressing space itself, and would include opportunities for evolved routing, QoS and security schemes.

## Adapting QoS and Traffic Management Mechanisms to LEO networks

- Data path resources management building on top of existing Transmission Control Protocol (TCP) and User Datagram Protocol (UDP), including their various alternatives developed for existing GEO satellite networks, taking into account aspects of high latency, high loss wireless links, compression, QoS signaling, etc., need to be adapted to LEO networks, as their characteristics are very different than standard GEO space networks.
- The design and dimensioning of oversubscription models over LEO space segments have to be fundamentally adapted compared to the models in use in terrestrial networks, given the specificity of traffic models in terms of network capacity demands the variability of the physical/logical space and ground to space topologies, along with the mechanisms available on the data and control paths for short/mid term traffic/resources management
- For a good number of LEO based services applications, the mechanisms in use in 4G/5G packet core networks, to optimize performance and efficiency, in terms of data-path adaptive and reactive optimization would benefit from adaptations taking into account multi-hop space networks characteristics.

## Leveraging NFV, SDN and Operational Systems for the deployment of LEO networks

- LEO Space networks are global and hence there is a need to consider ways of deploying SDN and centralized/distributed network controllers and orchestrators in a way that satisfies latency QoS and security requirements and optimizes the cost of deployment and operations.
- This is also the case for the deployment of Operations Support Systems (OSS) and Business Support Systems (BSS) data models, for data ingest, processing and corresponding actions for the management in the network and orchestration of services.
- As terrestrial networks evolve towards NFV models, there is a clear need to leverage these concepts for the design of LEO satellites, for some of the data path functionalities (e.g. routing, QoS, services adaptations, etc.), while considering the constraints of satellites design (Operating Systems, link/data layers, Power, Upgradability, etc.).
- The interaction between the VNFs and the SDN controllers and orchestrators would have to be revisited to take into account the management requirements of satellites as far as dynamic configurability over global topologies
- Interaction of high OSS/BSS layers with the network layer via orchestrators across domains that have been developed for primarily terrestrial networks need to be adapted to LEO networks, as the various messaging / API models would need to include different set of information models and messaging to map the requirements of the data and control paths

## Leveraging state of the art cyber-security mechanisms in LEO networks

- Cyber-security for data and control paths would require a new rethinking to accommodate the characteristics of space segments given the constrained functionalities on the satellites, in terms of ability to process, detect and protect their compute and network resources (versus standard routers in terrestrial networks, with way more powerful capabilities), due to the design constraints being considered on space satellites (power, space, cost, upgradability, support, etc.).
- The aspects that relate to data residency for all aspects of network control and management including aspects such as fault management, performance management, billing, etc. would need to be architected very differently given the global nature of LEO networks, and the increasingly local nature of data residency on a per country/region basis
- Opportunity to leverage new key distribution models, including those of quantum keys distribution (QKD) from satellites in space to enhance end-to-end encryption.

## Evolving next generation IoT networks leveraging LEO connectivity

- The recent evolution of IoT connectivity services defined in 3GPP, Low Power Area Networks (LPWA) and others could take advantage of LEO connectivity characteristics as far as enhancing the business cases of deployments, as well as the possibility of offering different type of IoT services in rural/remote areas.
- Complementarity between terrestrial IoT networks and space based connectivity networks, provides a new framework for global service providers to deploy retail/wholesale IoT services at scale
- The IoT gateways and backend architectures in use today would benefit from interfacing with the control and management plane of LEO networks to provide an end to end IoT services deployment and cost/functionalities optimization.

## Adapting and evolving technology standards and regulations for LEO networks

- Standard bodies have already been addressing the various regulations required for the deployment of large scale LEO networks. However, various open areas remain under consideration given the global nature of LEO networks, the impact on local regulations on a per-country basis, and the various licensing schemes that need to be adapted
- Standards have also been addressing the aspects that relate to the management of interferences risks with GEO/MEO network as well as the various terrestrial networks. This is likely to be an active area of work as the deployments progress.

Major technology and financial investments are going into the deployment of LEO networks at the moment. There has rarely been so much of a push to experiment, design and launch breakthrough highly complex Internet technologies at scale. It is a race between lead technology players, governments, policy makers that is likely to accentuate over the next few years, given how strategic is the Internet infrastructure for the development of nations and technology corporations competitiveness. Yet, major challenges remain to overcome. This includes both technical and business challenges. The intersection of space and Internet technologies is still in its first phases, with lots of learnings from both sides aiming to enhance the joint value proposition.

In this paper, and building on our own work in the design of space Internet networks, we primarily leveraged our own experiences developing Internet based protocols and deploying Internet based services at scale over the last two decades, with specific views on how they can be leveraged for addressing the challenges of LEO based satellite constellations.

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

Xona Partners (Xona) is a boutique advisory services firm specialized in technology, media and telecommunications. Xona was founded in 2012 by a team of seasoned technologists and startup founders, managing directors in global ventures, and investment advisors. Drawing on its founders' cross-functional expertise, Xona offers a unique multidisciplinary integrative technology and investment advisory service to private equity and venture funds, technology corporations, as well as regulators and public sector organizations. We help our clients in pre-investment due diligence, post investment lifecycle management, and strategic technology management to develop new sources of revenue. The firm operates out of various regional hubs which include San Francisco, Tokyo, Vancouver, Dubai and Singapore.

www.xonapartners.com advisors@xonapartners.com @xonapartners