The Internet Is Blasting Off

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The Internet is everywhere, accessible in a heartbeat and at the swipe of a touch screen. In the office, at home, and even driving down the road at 60 MPH, a cellular device can access high speed Internet thanks to the hundreds of thousands of cell towers built by providers including AT&T and Verizon. Unfortunately, this vision of ubiquitous Internet access is a bit far from the everyday reality of dead zones caused by shifting terrain features and by a lack of towers in remote locations. To solve these access problems, the innovators of today are turning to new satellite and drone technologies to enable access to data around the world.

A world where the Internet is truly available everywhere is not far off. The average cellphone will be able to post status updates, whether from the moving deck of a cruise ship or in the high altitude deserts of Afghanistan through the use of new miniature satellite radio chips in addition to the standard LTE radio chips currently available in cellphones. Telephony and data providers will be able to enter new markets without building expensive cellular towers thanks to a network of low-orbit satellites which provide nearly as much bandwidth as a standard LTE tower, with nearly equivalent latency. Solar-powered drones which automatically avoid bad weather during their multi-year year autonomous flights will help create a seamlessly accessible worldwide network without complex terrestrial data transport mechanisms. Advanced network technologies such as software defined networks (SDNs), an emerging technology pioneered in Japan to control and manage intelligent data transmission pathways, and mesh networks, self-healing networks made of independent wireless nodes, are both capable of selecting the best way to transmit data when multiple pathways are available. Together, these evolving technologies will augment existing mobile data infrastructures to improve speed and quality of connections.

Global satellite Internet is going to be real within 4 years

Satellite Internet is poised to become the next major transport mechanism for Internet access. While voice and Internet data connectivity are not new, advances in both transmission technology and satellite technologies now enable low-latency / high-bandwidth satellites to literally blanket the earth with signal, including underdeveloped and hard to reach areas.
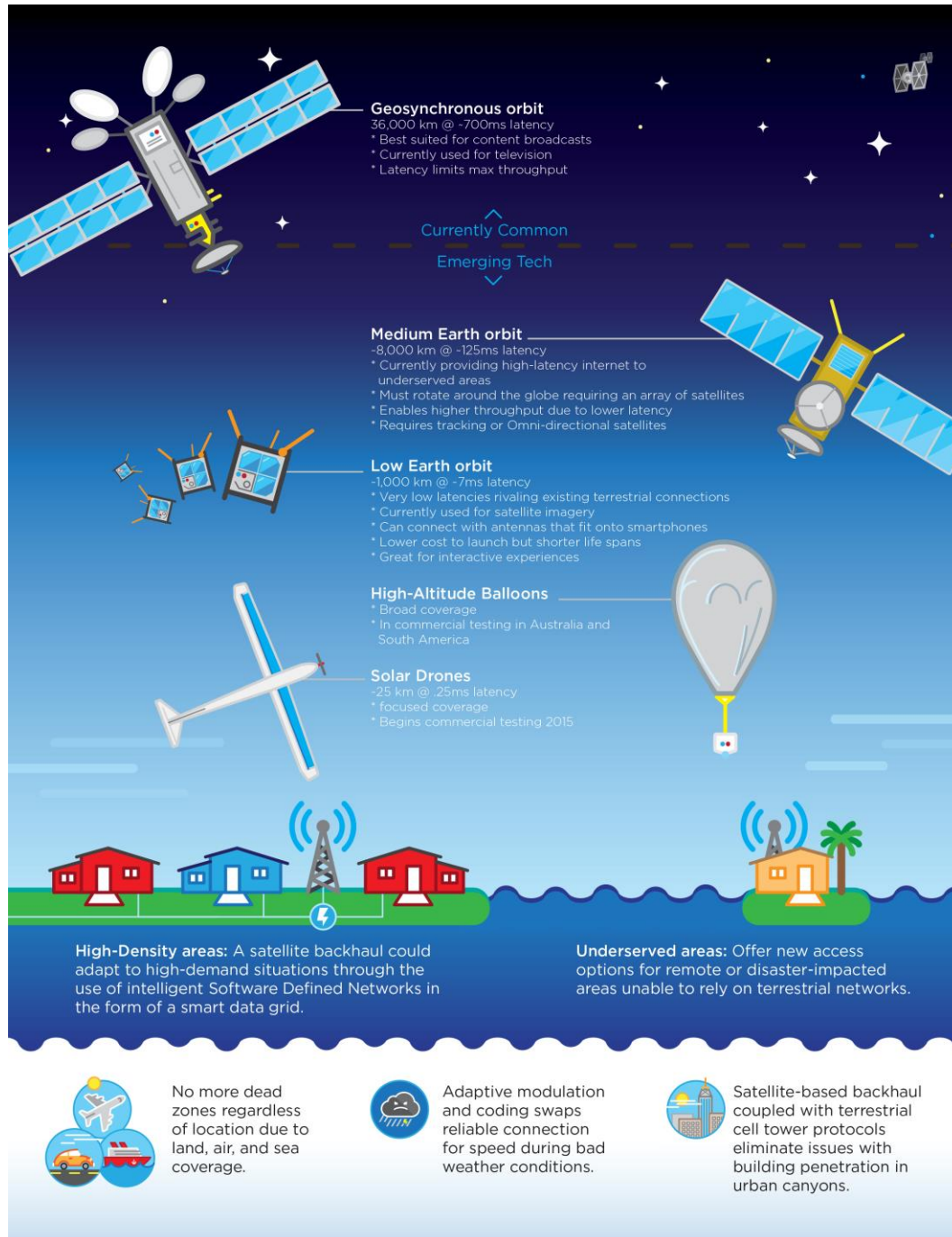
Satellites systems are moving to lower orbits

When a satellite is placed in orbit around the earth, the distance from the earth defines its orbit tier. The higher the orbit, the larger the area of the earth that single satellite can cover but the trade-off for that broad range of coverage is higher latency, the time it takes for data to cover the distance from the surface of the Earth to the satellite and back. Lower orbits allow for higher throughput due to lower latencies. Geosynchronous satellites, which have much higher orbits, stay in a fixed position along the equator which allows satellite dishes to only point to one place in the sky. The tradeoff for moving to a lower orbiter tier is the need to produce an array of satellites that circle the globe. Connecting to these satellites require mechanical or Omni-directional antennas but can provide 7ms - 125ms latency as opposed to approximately 700ms of latency in the highest orbits. Low latency is critical in providing quality interactive experiences.

Newly developed satellites offer data speeds and throughput which is competitive with existing terrestrial fiber networks. For example, OneWeb systems are actively building a medium earth orbit satellite system that will look to leverage its 2 Ghz of spectrum to provide 10 terabits per second of capacity to divvy up amongst consumers. They are also developing new antennas

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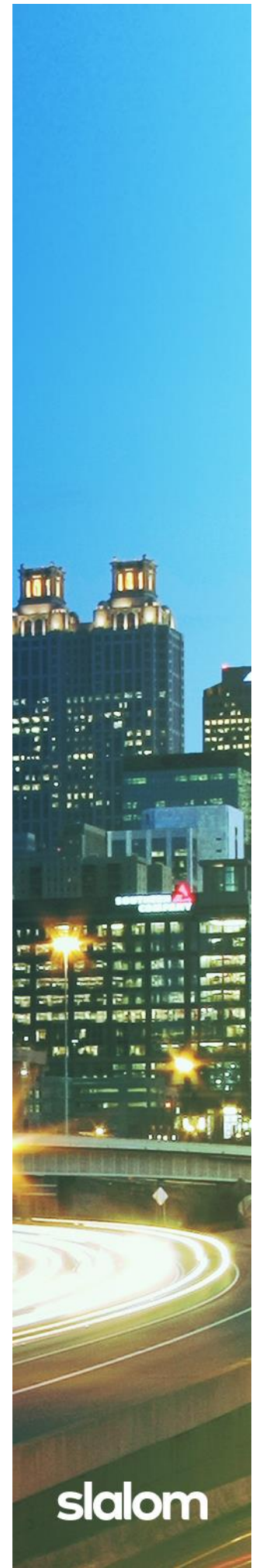
for airplanes that will provide 400 Mb/s to an aircraft with low latency. (Steel, 2015) Low earth orbit satellites not only offer lower latencies, they require less power on both transmission and recipient sides of communication. This lower power requirement enables a new category of satellites called nanosats which can weigh as little as 1-10 kilograms. These tiny satellites can be manufactured relatively cheaply and launched in clusters such as the recent launch of a "flock" of 28 nanosats called CubeSats launched in January 2014 by PlanetLabs to increase the frequency of imaging the Earth for agricultural monitoring.

Geosynchronous orbit
36,000 km @ ~700ms latency
* Best suited for content broadcasts
* Currently used for television
* Latency limits max throughput

Currently Common

Emerging Tech

Medium Earth orbit
~8,000 km @ ~125ms latency
* Currently providing high-latency internet to underserved areas
* Must rotate around the globe requiring an array of satellites
* Enables higher throughput due to lower latency
* Requires tracking or Omni-directional satellites

Low Earth orbit
~1,000 km @ ~7ms latency
* Very low latencies rivaling existing terrestrial connections
* Currently used for satellite imagery
* Can connect with antennas that fit onto smartphones
* Lower cost to launch but shorter life spans
* Great for interactive experiences

High-Altitude Balloons
* Broad coverage
* In commercial testing in Australia and South America

Solar Drones
~25 km @ .25ms latency
* focused coverage
* Begins commercial testing 2015

High-Density areas: A satellite backhaul could adapt to high-demand situations through the use of intelligent Software Defined Networks in the form of a smart data grid.

Underserved areas: Offer new access options for remote or disaster-impacted areas unable to rely on terrestrial networks.

No more dead zones regardless of location due to land, air, and sea coverage.

Adaptive modulation and coding swaps reliable connection for speed during bad weather conditions.

Satellite-based backhaul coupled with terrestrial cell tower protocols eliminate issues with building penetration in urban canyons.

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Autonomous solar powered drones and high altitude balloons

Satellite based voice and data delivery capabilities point to a fascinating future of truly world-wide coverage, but the complete replacement of terrestrial cell towers is generations of technology away based on the capacity needs of the growing population of connected devices. More immediately, capacity needs are expected to explode as Internet of Things technologies grow in popularity. Considering the number of Internet connected devices, Gartner forecasts that over 4.9 billion devices will connect to the Internet in 2015 and that by 2020 the number will be above 25 billion (Rivera, 2014). Another mechanism to augment capacity is the use of solar powered autonomous drones and high altitude balloons to serve as cell towers. High altitude balloons are already in use in South America and Australia thanks to Google's Project Loon and solar powered autonomous drones from Titan Aerospace. A single Titan Solar drone can provide gigabit cellular service to an18 km2 area, enough to cover the 5 New York boroughs. The Titan solar drones are expected to provide gigabit download speeds with latency as low as 0.25ms, which compares to wired speeds. Drones and balloons cost much less than satellites to launch and are more nimble to deploy. In addition, drones have a similar deployment life to LOE satellites of 5 years, but drones are easily serviceable and upgradable, whereas LOE satellites are purposefully disposable and designed to burn up as they fall back into the atmosphere.

Advances in antenna technology

Satellite technology isn't the only technology following general computing trends of miniaturization. In their own version of Moore's law, satellite phones have also been experiencing ongoing R&D to make the technology smaller and more powerful. While we are still a few years away from embedding multiband cellular and satellite radios into the same SoC silicon chip for use in standard smart phones, it is now possible to purchase satellite connectivity for iPhone as a simple snap-on phone case and satellite phones are price competitive, if not feature competitive, with flagship smartphones.

Satellite-based telecommunications have historically dealt with challenges familiar to traditional cellular technology users, including problems with urban canyons and penetration into buildings. Advances in antenna technologies such as adaptive modulation and coding are making inroads against these issues by shifting to lower frequencies as interference makes connectivity problematic.

With the success of Multiple In Multiple Out (MIMO) radio antennas used in terrestrial communication standards such as LTE, the next generation satellite networks will look to adopt this technique to help further improve communication efficiencies. Advancements in this space may result in mobile phone manufacturers incorporating satellite connectivity in addition to the current cellular, Wi-Fi and Bluetooth options that are present in devices today.

An additional option available to carriers and providers of connectivity is to leverage aerial and space-based Internet connections to augment or even replace the backhaul, the connection from traditional cell towers to the Internet. Today the backhaul is typically a fiber-optic or Ethernet connection from each cell tower to the provider's backbone which in turn links into the Internet. One of the main reasons for internet access issues in remote areas is the backbone requires a hard wire connection at each cell tower. With a satellite-based backhaul, a cell tower is placed in a rural area without concern for how that rural cell tower will connect to the Internet. As a result, commercial consumers are able to leverage existing wireless cellular

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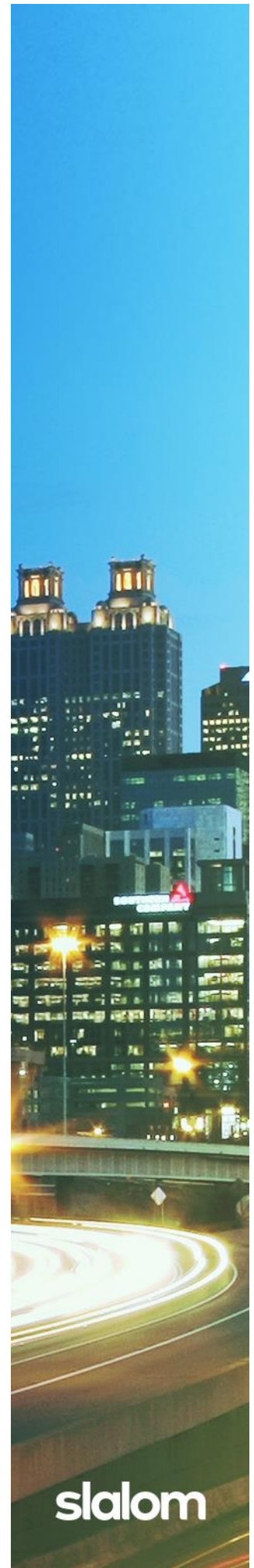
technology like LTE-enabled phones and hotspots to connect to the Internet, resulting in more users accessing the internet, even those traditionally hard to reach.

Software Defined Networks & Wireless Mesh Networks

As the number of connected devices explodes, thanks in large part to the coming "Internet of Things" (IOT), the ability for applications to communicate network needs so that the network can dynamically adapt to ensure a satisfactory level of connectivity quality, is crucial.

To meet this need, a traffic routing middleware component called a software defined network (SND) has been introduced to the world of networking. It separates the decisions about where the traffic goes from the underlying systems and enables greater control and adaptability for managing networks. It serves as a foundation that could eventually abstract specific connectivity details from consumers. An application that leverages SDN capabilities could communicate it's connectivity needs based on data types to the ISP's that could then use the information to provide the best data path to meet that need, while enabling them to better manage the network pipelines for congestion. In the world of satellites, there are a few different communication patterns that could then be leveraged in a more real time adaptable way, such as one-way broadcast, one-way receive with terrestrial transmit, or two-way send & receive. For example, in a world where the Internet of Things has been realized, web surfing and games would leverage low-latency/high-bandwidth connections for snappy user experiences while intelligent appliances would turn to high-latency/low-bandwidth connections for intermittent status updates.

In addition to the ability to segment traffic to the appropriate latency/bandwidth tier is the ever-present need to remain connected. A wireless mesh network uses commonly available wireless access points and hotspots to connect wireless devices to the Internet and to each other. The individual access points, called nodes, communicate with each other to automatically find the quickest and safest path from source to destination. This pathfinding technique, known as dynamic routing, enables the network to easily expand as new nodes are added. Even better, if a node goes offline for any reason, the network is able to detect the outage and quickly route traffic around the problem, healing the network automatically!

Leveraging the multitude of data pathways controlled by a mesh network and an SDN, both via terrestrial and via satellites, could be the foundation from which IOT grows and having connectivity everywhere, is where it will thrive.

Disruption among telco providers

Some combination of these technology advances is going to quickly become a disruptor in the traditional marketplace of telecommunications providers, much in the same way that Internet access has been a disruptor of cable television service providers.

Leveraging satellite technology for personal communications and data needs are not new, having been offered in the US by both GlobalStar and Iridium since the late 1990s. Early attempts at reliable voice and data services were not commercially successful but new technological advances allow for smaller and cheaper satellites, as well as cheaper satellite-connected cellphones. Companies like ViaSat are seeing success in Internet satellite services leveraging geosynchronous earth orbit (GEO) satellites which offer ~20 - 30mb download even

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in airplanes, but it still suffers from the high latency issue. Any low earth orbit (LEO) satellite system that offers comparable download speed but with low latency will win.

Mobile Satellite Service companies are actively pursuing the ability to add broadband data to their service offerings. The reduction in barriers to entry have seen a number of new, non-traditional players officially register interest in the satellite market. The International Telecommunication Union, the international agency that regulates satellite orbits and satellite broadcast frequencies, has seen an explosion in the number of registrations from companies including SpaceX, Google, Virgin Group, Qualcomm and others. These public registrations account for interest in the collective launch of over 13,253 satellites as of January 2015 (Selding, 2015). While details of these registrations are still developing at the time of this writing, several responsible organizations have declared their intentions of developing a space-based Internet service provider including SpaceX (backed by Google) and OneWeb (backed by Virgin and Qualcomm).

The potential for complete or partial replacement of traditional telecommunications players shouldn't be ignored by vendors nor by consumers. Already, signs are in place that organizations are shifting to learn additional parts of a traditional telecommunication service provider's business. For example, Google is learning to be a telecommunications provider today with their recent announcement of that they are forming a phone company - a mobile virtual network operator (MVNO) partnership with Sprint and T-Mobile. This is a learning experience for Google that will allow them to work on branding, selling, billing, service, and support without having to incur all of the network and IT infrastructure costs. It's not hard to imagine that once they learn these traditional telco skills they may choose to replace or supplement their MVNO network backbone (T-Mobile/Sprint) with a low orbit satellite network augmented with their drones (Project Titan) and balloons (Project Loon).

The story of non-traditional competition gets even more complex when one considers the growing ubiquity of publically available wireless connectivity. No longer confined to the home or office, municipalities and businesses offering free wireless access points could combine their connections into a true wireless mesh network which offers broad areas of wireless coverage without relying on traditional cellular data providers.

What's stopping an avalanche?

Technology changes themselves don't precipitate an avalanche of change in an established marketplace. Organizations have to commit money and effort to effecting change. Even given the will and financial commitment from numerous corporations, several hurdles must be overcome before ubiquitous world-wide Internet access becomes a reality.

 The first and foremost of these hurdles is the availability of broadcast spectrum in the appropriate radio frequencies. To successfully deploy a nationwide, much less globally accessible mobile network, the providers must have access to contiguous blocks of spectrum. Management of spectrum in the US is managed by the FCC and the latest round of spectrum auctions saw $44.9 billion collected by the FCC in exchange for frequencies formerly used by the now defunct Wireless Cable service. Big winners in this auction were AT&T and Dish Network, together accounting for more than 70% of the released spectrum. Management and release of wireless spectrum is complex enough in the US alone, but with the coming advent of global wireless networks provided by satellites, the complexity of coordination among governing bodies and participant organizations is going to increase dramatically.

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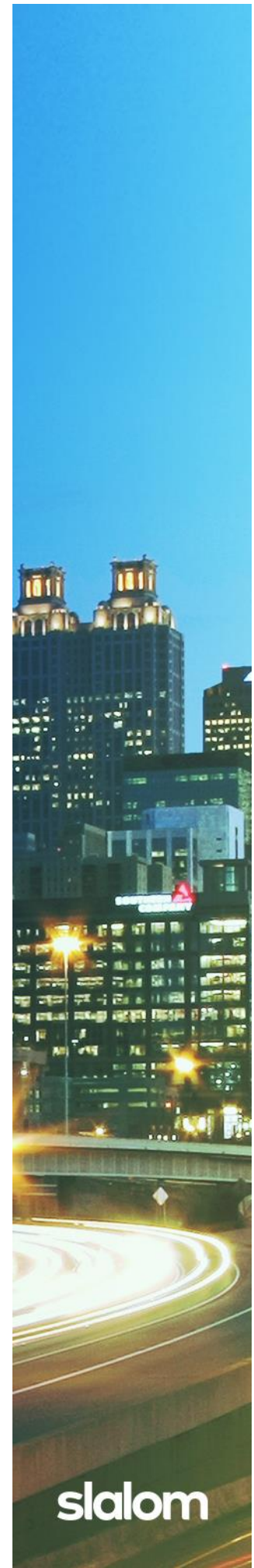
The second hurdle delaying a space-based "land rush" is the alignment of partners and manufacturers. In the past, device and protocol standards have made new technology launch slow and inconsistent. Having the major players align on these items have proven very difficult in the similar cases. Just think about Blu-Ray vs HD DVDs or NFC vs iBeacon. This generally gets battled until a major player dominates or open stand regulation is put into place.

There's gold in them thar hills!

Space-based Internet is interesting for a number of reasons beyond the simple introduction of access capabilities to regions which have been historically underserved. The same way satellite and drone based Internet delivery channels allow distribution of communication and data services to rural and hard to reach areas, they enable reliable communication mechanisms for areas hit by disaster where traditional terrestrial communication mechanisms typically fail. Imagine a provider such as Vodafone deploying a few drones in the aftermath of a coastal hurricane to quickly return cell service to the impacted area.

Rural America and disaster zones aren't the only areas without modern terrestrial infrastructure. As regulations change and new international markets are made more attractive, telecommunications companies would be easily able to open service offerings to new markets with minimal infrastructure investments. Imagine opening the Cuban market to US telcos with a small fleet of autonomous drones that can be easily reconfigured based on local market demand. These drones are potentially ready for launch this year while space-based Internet access is only a few years behind.

Another opportunity in front of wireless internet providers is the delivery of on-demand bandwidth to organizations whose current infrastructure is either maxed out or too expensive to expand upon. Consider the example of a regional bank which has wired each of 600+ branches with a T1. The T1 used to be a high speed connection, but in today's world of graphically intensive applications and high definition video on the intranet, a T1 is no longer sufficient. Replacement of that physical T1 infrastructure is an extremely expensive scenario when an alternative wireless networking solution could be introduced as a redundant high-speed network. Coupled with a SDN that makes intelligent routing and multiplexing decisions based on the type of traffic and network saturation, the resulting network would allow high-quality lower-cost options for bandwidth that provides business customers with options to prioritize traffic on their network relieving network congestion.

Another business opportunity (and business threat to be wary of) is that telcos and cable companies will now be able to compete with new wave competitors who don't have the huge infrastructure overhead allowing them to be completive in the current market. New distribution models will also be unlocked, including a host of new Mobile virtual network operators/Mobile virtual network enablers (MVNE) service models while at the same time threatening the livelihood of the current operators. Low cost Wi-Fi dialing plans are beginning to emerge as additional completion in the market with companies like Republic Wireless or Frances's Iliad's mobile Wi-Fi call plans. Traditional ISP could look to cheaply expose and extend their footprint through the use of a mess network, this will allow them to provide Wi-Fi calling as a services as well as offload wireless traffic.

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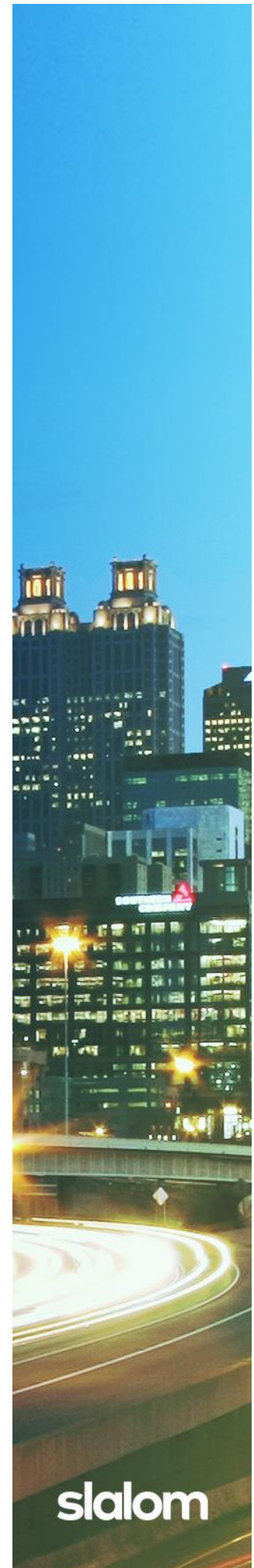
Calls to action

If this paper has convinced you that the coming aerial and space-based internet race is worth your attention and interest, the following calls to action may help get you more involved.

Prepare for new unlikely competition

Internet service providers will need to be ready for direct last mile competition from new providers with access to low latency satellite broadband. Imagine British Telecom competing with AT&T by offering to connect consumer homes and potentially mobile devices directly to their constellation of satellites. If mobile satellite connectivity services mature to a point where a company can offer broadband data service everywhere, the buying of home and mobile data separately will be a the thing of the past, as will traditional barriers to marketplace entry such as national boundaries and terrestrial investment.

ISP's need to expand to provide connectivity everywhere to remain dominant

In the near future, consumers of Internet data will look to consolidate their home and mobile services to a single provider. A mesh of connectivity options will need to be leveraged to ensure the appropriate quality of experience levels. Software defined networks powering a data smart grid, could form to intelligently handle traffic based on the known context of a request, such as varying levels of signal strength, population density or connectivity options.

Similar to how technology today seamlessly switches between 4g and Wi-Fi, satellite connections could be a part of that as well. In addition, imagine if the intelligent software defined network evolves in a way that it could adjust the connectivity paths to help increase efficiency and better manage traffic based on the type of data request.

Additionally, an intelligent network could theoretically understand the different connectivity needs between high latency, non-interactive activities like broadcast TV and low latency interactive services such as web browsing. As a result, traffic could be routed to appropriately to GEO satellites for TV and a LEO satellite array where low latency is necessary. When congestion or bad weather is an issue and the consumer of the service has access to terrestrial options, fiber or wireless could be used to ensure quality of experience.

Through acquisitions, mergers, or shared networking agreements, companies strive to keep their consumers connected wherever they go. The ability to maintain an acceptable QoE (Quality of Experience) everywhere will be the key differentiator. Wireless providers today are familiar with this ongoing challenge as they used to compete with each other over dead zones and drop calls in the not to distance past. In the end, no single connectivity option will fully replace another, instead these network-layer details will slowly become abstracted from the consumer who expects to always be connected.

Write a letter to your congressman (or call the FCC)

The FCC and Congress each play a role in the management of wireless spectrum. Get informed and active on the spectrum release process by following the FCC Spectrum Dashboard available online at http://www.fcc.gov/spectrum. By becoming an informed citizen, you can petition the government to consider the release of more spectrum and perhaps to

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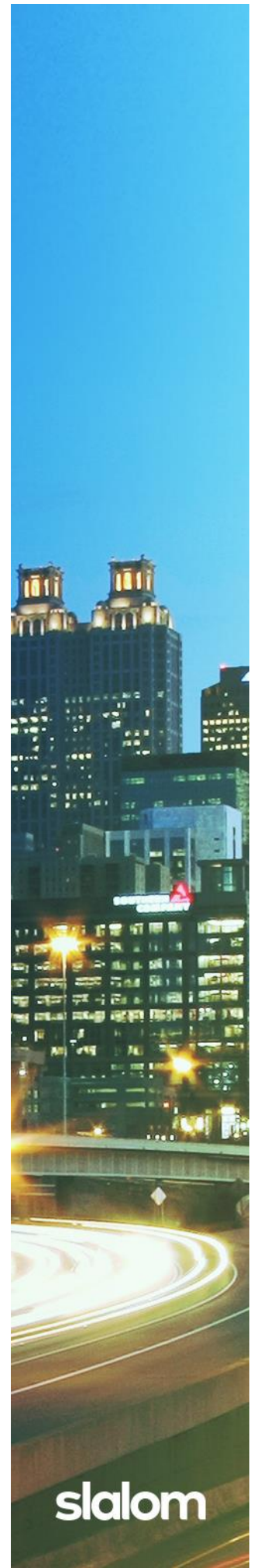
even consider the reorganization of spectrum to enable larger contiguous blocks of spectrum. While a bit utopian in vision, proposals have been made by PCAST (President's Council of Advisors on Science and Technology) that lays out a vision for managing the spectrum as if it's a super highway with large uninterrupted blocks of contiguous spectrum, shared by many different types of wireless services. If the proposed policies for new Federal spectrum architecture are adopted, it could lay the foundation that enables the high bandwidth connectivity everywhere and removes hurdles for high speed, low latency mobile satellite service.

In addition to the US spectrum oversight provided by the FCC, prospective satellite connectivity providers such as OneWeb and SpaceX must be concerned with the international regulatory body, the ITU. The International Telecommunication Union (ITU) of Geneva, a United Nations agency, is responsible for registering interest in satellite broadcast capabilities and in doling out spectrum in the Ka and Ku bands. These bands, similar to the wireless spectrum used by AT&T and Verizon in the US, are used by satellites to communicate with terrestrial stations and consumers. The Broadband Commission of the ITU publishes information and contact information online at http://www.itu.int.
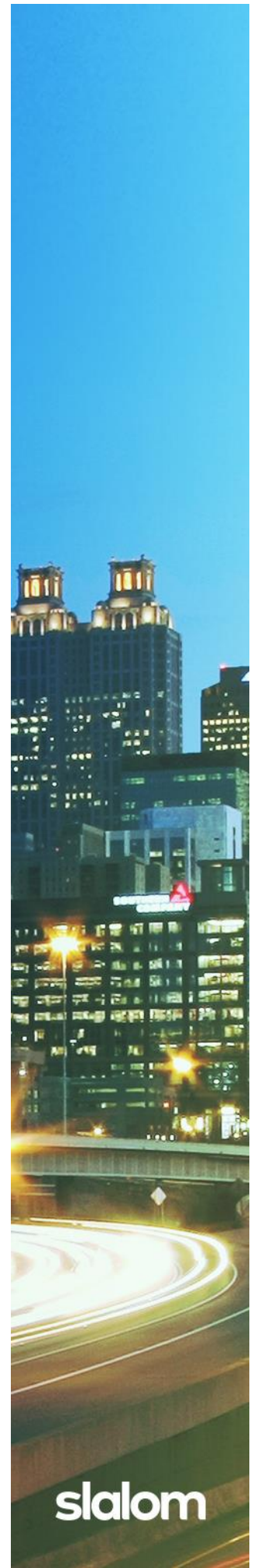
SIDEBAR: Don't count out the traditional players yet

While a lot of press has been devoted to potential new entrants into the broadband and telecommunications sector, don't count out the traditional players yet. Traditional carriers have a deep advantage in this sector, their home turf. Not only are telcos like AT&T in a unique position to integrate LOE satellites with their impressive suite of existing physical assets, the existing wireless carriers are the owners of spectrum frequencies blanketing the US.

Where new technologies will almost certainly benefit new competitors, these same new technologies will empower the incumbents in the market as well. New satellite technology will enable incumbent telcos to augment their network with a fully redundant network, as well as to offer additional capacity in markets currently pushing against capacity limits. By using software defined networks (SDN) to their full potential, SDNs would enable efficient auto-tuning data traffic transport, integrating landline connections, high speed mobile networks, GEO and LEO satellites into a single mesh network. The resultant mesh network would reduce disruptions and offer expanded speed and capacity offerings by routing data based on the desired class of service, which can come in handy when weather disasters or unforeseen circumstances take down a part of the network. Operators will simply be able to route traffic over un-impacted assets with an automated push of a few virtual buttons. Traditional providers could also look to cheaply expose and extend their footprint through the use of a mess network, this will allow them to provide Wi-Fi calling as a services as well as offload wireless traffic for more data-intensive activities.

Example: an integrated software defined network allows an operator to move VoIP traffic from a mobile network that gets damaged during a storm surge in the northeast to be retransmitted thru low orbit satellites, supporting first responder communications to those in need. Another use case is setting up emergency networks after a natural event similar to the quakes Haiti that took out the communications infrastructure.

Cloud computing applications could also be a big beneficiary of robust software-defined networking because these technologies make provisioning in a multi-service / multi-vendor virtual environment much simpler. A controller-based load balancing application could automate the movement of workloads among virtual machines by using the controller's library of data about the capacity of individual network devices. Much like virtualized network services appliances that are deployed on virtual machines, controller-based applications are more scalable, flexible, efficient and manageable than more conventional models that rely on physical devices to support functions. For example: Companies that start to reach their T1 capacity for their retail locations can start to segment their data traffic and route capacity traffic over the satellite or mobile networks or push non-time sensitive batch process jobs over the cheapest means available.

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Additional Recommended Reading

Overview of satellite Internet access

http://en.wikipedia.org/wiki/Satellite_Internet_acces

Why latency matters to the mobile backhaul

http://www.o3bnetworks.com/media/45606/o3b_latency_mobile%20backhaul_130417.pdf

Solar drones

http://www.theguardian.com/technology/2015/mar/03/googles-titan-drones-to-take-flight-within-months

Patent for shared satellite with cellular connectivity

http://www.google.com/patents/US8594682

Petition and comments to the FCC in LEO MSS space

http://www.globalstar.com/en/ir/docs/FCC12-Petition_for_Rule_Making_Nov_13th.pdf

http://www.globalstar.com/en/ir/docs/Globalstar_TLPS_Reply_Comments-FINAL_060414.pdf

Movers in the space

http://www.bloomberg.com/news/videos/2015-03-18/how-satellites-are-used-to-provide-global-internet

http://arstechnica.com/business/2015/01/google-might-pour-money-into-spacex-really-wants-satellite-internet/

http://www.theverge.com/2014/11/11/7192173/satellite-elon-musk-spacex

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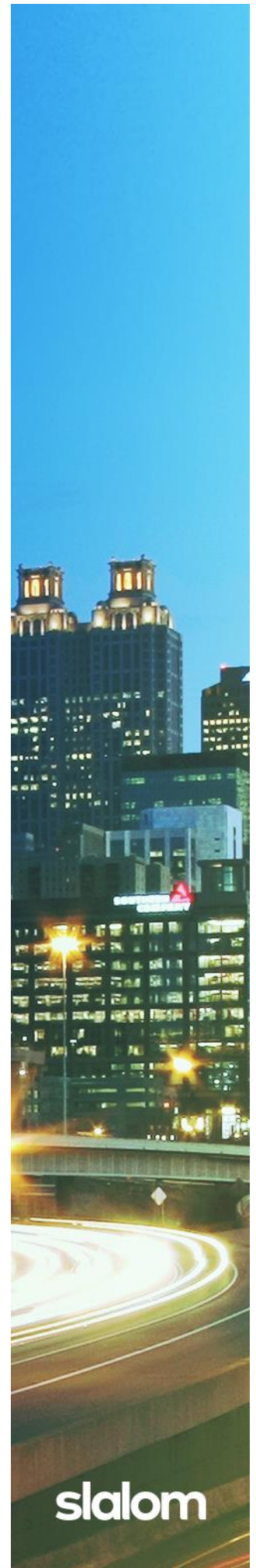
Map of wireless connectivity

http://opensignal.com

Current US spectrum allocation chart

http://www.ntia.doc.gov/page/2011/united-states-frequency-allocation-chart

PCAST Spectrum Report

https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf

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