Feeding the Beast

How Mobile Operators are Racing to Keep Up with Insatiable Demand for Mobile Broadband

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Operators Will Need to Use All Tools to Keep Up with Insatiable Traffic Demands

Abstract

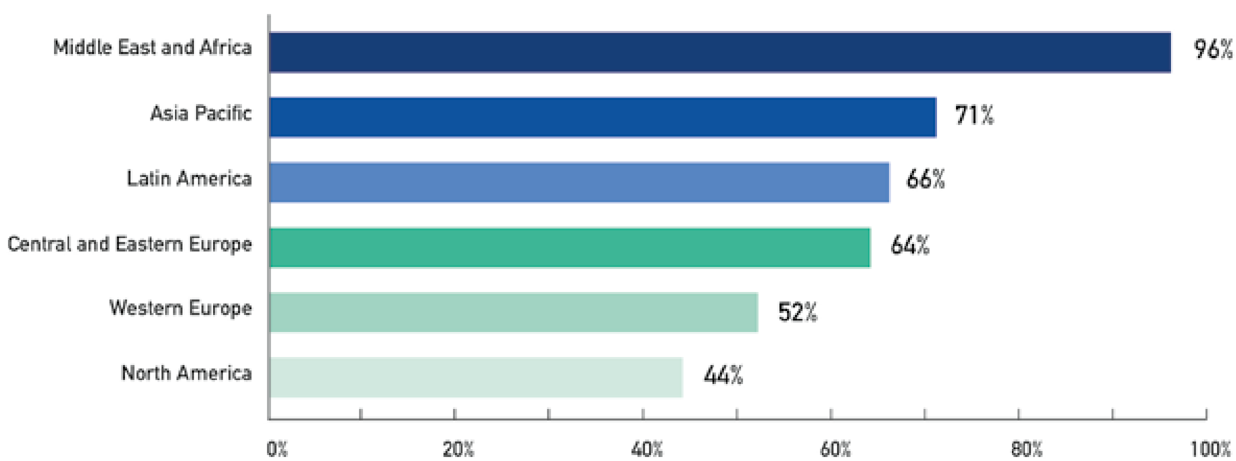
Traffic on mobile networks has grown every year and shows no sign of abating, as society has become mobile-first. This report will explore how the wireless ecosystem is addressing insatiable traffic demands borne from mobile data adoption through network optimization efforts, densification strategies, policy frameworks and new spectrum and technologies coming to market.

Introduction

The traffic growth and demand on U.S. operators' wireless broadband networks continues to explode without any sign of slowing down. Subscriber connections, smartphone penetration rates, and data consumption on fourth-generation LTE (4G) networks have set record highs each year. Just like too many automobiles on a highway leads to congestion, more traffic on a wireless network slows down the network. Even as major nationwide operators tried to keep up with this increased traffic through network optimization and efforts to speed up the network by bringing it closer to the end user, they also launched competing unlimited data plans, which encouraged customers to use more data. In turn, this placed increased demands on the availability of capacity, bandwidth and coverage, putting additional stress on the networks – a vicious but necessary cycle in the pursuit of customer loyalty.

Technology manufacturer Cisco estimated that global mobile data traffic grew 63 percent in 2016, according to Cisco's 2017 published report.[1] Cisco estimated that 69 percent of the mobile traffic in 2016 ran over 4G networks. Mobile network connection speeds grew from 2.0 Megabits per second (Mbps) in 2015 to 6.8 Mbps in 2016. Further, mobile video – which is among the most data-heavy applications on networks – accounted for 60 percent of the total mobile data traffic.

FIGURE 1. MOBILE DATA TRAFFIC GROWTH IN 2016

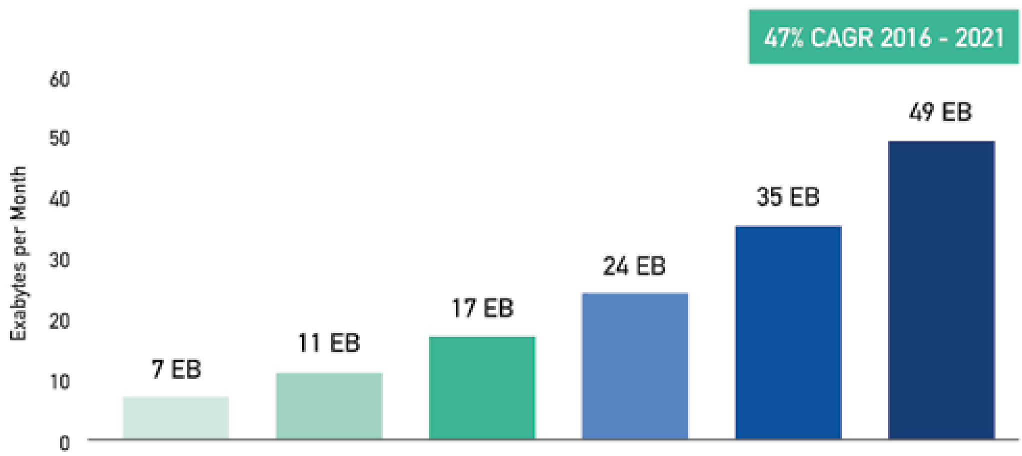


Source: Cisco VNI Mobile, 2017

Furthermore, according to the same report, global mobile data traffic is expected to increase sevenfold between 2016 and 2021, with a compound annual growth rate (CAGR) of 47% in the same period, reaching 49 exabytes per month by 2021.

4G networks will carry 53 percent of connections and 79 percent of total network traffic by 2021. That same year, industry will be at the early stages of deploying 5G-based networks and services. In 2021, Cisco expects 5G to account for 25 million connections and 1.5% of total traffic.

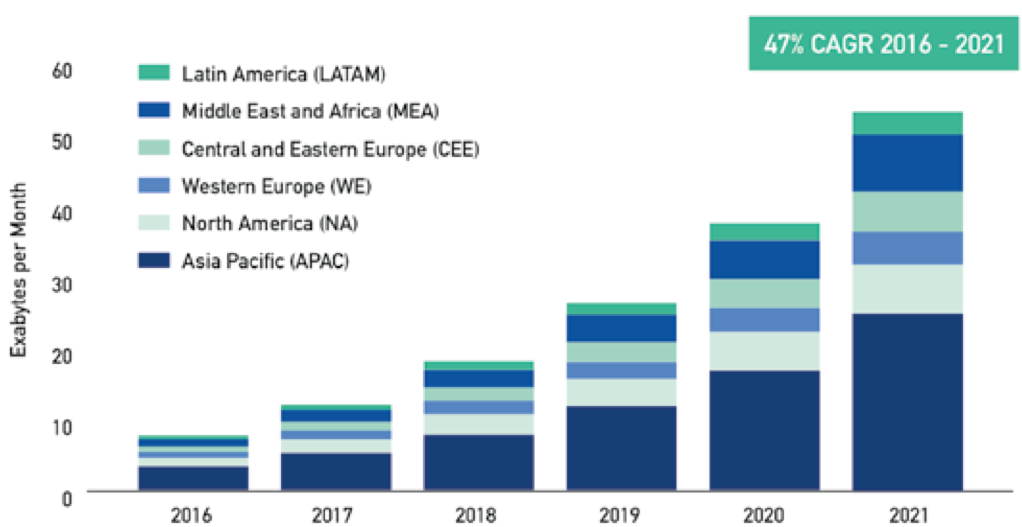
FIGURE 2. CISCO FORECASTS 49 EXABYTES PER MONTH OF MOBILE DATA TRAFFIC BY 2021



Source: Cisco VNI Mobile, 2017

Forecasted growth will occur in all global regions by 2021, with North America expected to experience 13 percent growth.

FIGURE 3. GLOBAL MOBILE DATA TRAFFIC FORECAST BY REGION

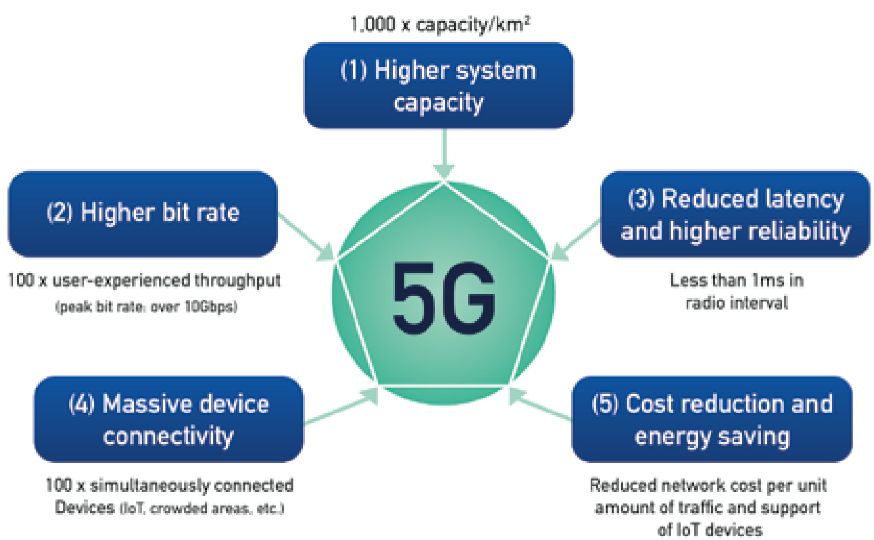


Source: Cisco VNI Mobile, 2017

The wireless ecosystem is planning to deploy fifth-generation (5G) technology in part to try to keep up with demand for more data but also to create new revenue opportunities. This report will explore available technologies, technical and regulatory solutions, and infrastructure options that mobile operators can use to continue to keep up and sufficiently stay ahead of the forecasted traffic demands on their respective networks as they ready their networks for coming 5G services and requirements.

New Standards: the 5G Promise

FIGURE 4: 5G OBJECTIVES



Source: Nokia

In order to keep up with increasing consumer demand for mobile data, the wireless ecosystem set ambitious requirements for next-generation 5G technology. In 2017, the International Telecommunications Union – the United Nations agency that sets standards so global telecom systems can talk with each other – outlined the minimum technical performance requirements for a 5G radio technology.[2]

Key requirements include:

- 1 Gigabit per-second speeds in the field
- 1 Millisecond or less end-to-end latency
- Support for 1,000 times increase in bandwidth per unit area

- Support for up to 100 times as many connected devices
- The perception of 100% coverage
- 90% reduction in network energy usage, which could be done in part using C-RAN technology
- Up to 10-year battery life for low-power, machine-type devices

The Gigabit-per-second speeds and low latency will enable high-bandwidth applications to run across the network, while the energy-use savings and long battery life will enable more Internet of Things (IoT) applications.

To achieve these requirements, changes will need to be made to the radio access and backhaul networks, along with greater network densification and more spectrum brought to market. Communications equipment manufacturer Ericsson, for example, believes the network needs to become more flexible and efficiently deal with traffic moving across the mobile platform and the core. "Future Cloud RAN architectures will therefore exploit a combination of virtualization, centralization and coordination techniques, all of which interact with each other in a variety of ways within the network. Cloud RAN will be composed of a mix of Distributed RAN, Centralized RAN and Virtualized RAN architectures, allowing for spectral efficient solutions over the transport infrastructure available," according to a joint Telefonica/Ericsson report.[3]

Options Available to Keep Up with Traffic Demands

As 5G standards are finalized and networks begin to be deployed, operators are using densification techniques within the heterogeneous (HetNet) architecture to cope with the amount of traffic on their networks. Wireless operators and their partners are testing pre-protocol solutions. AT&T and Verizon have fixed-wireless 5G trials underway in the United States, while T-Mobile USA announced plans to build its own 5G network by 2020, in part using its newly acquired 600 MHz spectrum.[4]

Offloading Options

To relieve their networks of congestion, wireless operators offload their traffic to Wi-Fi networks. Some operators have embraced this model more than others, but all do it to some extent. Indeed, all smartphones today have chips that can connect the signal to an operator's cellular network and Wi-Fi networks. Wi-Fi networks use RF spectrum in the 2.4 GHz and 5 GHz bands. Unlike cellular spectrum, Wi-Fi spectrum is unlicensed and shared among users. Wi-Fi signals only travel a few hundred feet. Because it is shared spectrum, it can be prone to interference from other devices. Also, a Wi-Fi network will slow down if there are too many users simultaneously on the network.

New Spectrum Coming to Market

Realizing that Wi-Fi alone cannot handle all the offloaded traffic that will be required in a mobile-first society, the Federal Communications Commission (FCC) announced plans to bring new spectrum to market using Citizens Band Radio Service (CBRS) spectrum at 3.5 GHz and millimeter-wave spectrum.

CBRS Overview

The FCC set rules for using the CBRS frequencies in the 3.5 GHz band for shared use in 2015. CBRS is governed by a three-tiered spectrum authorization framework to ensure commercial uses can be shared with incumbent federal and non-federal users on the band. Incumbent users will be protected from interference from new Priority Access and General Authorized Access (GAA) users on the band. Priority Access Licenses (PAL) will be assigned via competitive bidding. Enterprises may use the GAA tier to deploy their private LTE networks.[5]

Enterprise Benefits

As enterprises begin to leverage greater amounts of data and deploy Internet of Things (IoT) communications throughout their operations to increase productivity and reduce costs, private LTE networks are more in demand. Enterprises often want to control their own wireless networks to ensure optimal security, availability and low latency necessary to provide seamless operations.

Previously, enterprises had the choice of using public LTE networks or attempting to obtain unlicensed spectrum individually or on a shared basis to build their own private networks. However, the planned availability of unlicensed spectrum in the United States in the CBRS band at 3.5 GHz, and advances such as MulteFire, which allow LTE to be deployed in unlicensed spectrum, may allow enterprises to more easily deploy their own dedicated, private LTE networks.

This is good news for several vertical markets that see value in deploying private LTE to streamline their operations, including healthcare, manufacturing, transportation, and oil and gas. Private LTE networks in these and other verticals can replace wired connections and integrate sensors that control everything from assembly-line robots to medical devices.

Operator Benefits

CBRS can benefit wireless operators in many ways. First, it opens the possibility of large amounts of shared spectrum becoming available for their use with little to no capital outlay. This is a major shift in their future cost model and a way for them to manage capacity and coverage costs effectively with a more uniform, LTE standard-based approach. Operators will no longer be required to buy and permanently own spectrum to densify their networks.

Secondly, CBRS will open the door for solving the problem of subscriber indoor coverage demand and capital allocation. It will also allow operators to match incremental cost to provide service with directly correlated customer usage.

According to Ericsson's 2017 Mobility Report, and many other concurring analyses, cellular usage is growing at rates of up to 50 percent per year.[6] About 80 percent of usage is indoors. Indoor coverage is the last priority for operators and is quickly becoming the most important priority for subscribers. In-building coverage falls to the bottom of operators' capital allocation plans and the subscriber problem only grows larger.

Potential Operator Benefits of CBRS Include:

- Improved quality of service compared to Wi-Fi because of LTE standards-based deployment
- Traffic stays on the operator's network rather than migrating to Wi-Fi, which opens revenue and retention possibilities
- Faster time to market due to elimination of spectrum auctions and the time and expense spent clearing the spectrum
- Lowest possible cost to provide coverage associated with a true neutral-host, handset-based solution
- Potential for less congestion and faster speeds for the in-building subscribers compared to Wi-Fi
- Last-mile options for backhaul
- Tower companies, building owners and investors could deploy systems
- A competitive advantage for operators that embrace CBRS

Millimeter-Wave Spectrum

The FCC also opened millimeter-wave spectrum to mobile and fixed-wireless broadband specifically aimed at next-generation 5G network development. The FCC created a new Upper Microwave Flexible Use service in the 28 GHz (27.5-28.35 GHz), 37 GHz (37-38.6 GHz), and 39 GHz (38.6-40 GHz) bands, and a new unlicensed band at 64-71 GHz. The FCC is planning to begin the auction for 28 GHz spectrum in November 2018.

While millimeter-wave spectrum is predominantly used for fixed-wireless applications, some are looking at whether it can be used in a mobile broadband environment. With the network performance opportunities that new spectrum provides, a full host of new challenges emerge that can fundamentally change the way wireless networks and hardware are implemented. The behavior of signals at these high frequencies is vastly different than at the frequencies deployed today. Smaller wavelengths will dictate smaller but more numerous antenna elements with narrower beams. Signal blockage will be a major consideration that current networks are essentially immune to, but which are severe at the millimeter-wave wavelength. For example, millimeter-wave signals may be blocked by someone walking between a mobile device and the transmitter, raindrops and even hand placement on the handset. These and other factors will necessitate an extremely high density of network transmitters with true line-of-sight coverage and even more sophisticated mobile devices with large arrays of small antennas.

There is a bright side, however, to the fragile nature of the millimeter-wave signals, most notably interference mitigation. Signals generated between two antennas several hundred feet apart will be completely absent from coverage areas as they encounter buildings and other obstructions. This will permit extremely tight frequency reuse while maintaining excellent signal-to-noise ratio.

The International Telecommunication Union (ITU) and the 3rd Generation Partnership Project (3GPP) have begun research plans — scheduled to conclude in September 2018 — on 5G standards specifically for frequencies lower than 40 GHz, providing the wireless industry a better understanding of what the future looks like. The millimeter-wave spectrum will play a key role in the next evolution of the wireless landscape as industry moves toward 5G implementation. It will bring many new challenges to overcome, but also exciting possibilities to improve wireless performance to even higher levels to match the more than 50-percent growth of data traffic seen every year. Operators conducting trials to date said millimeter-wave technology has yielded positive results.

The HetNet Architecture and Efforts to Bring the Network Closer to the End User

Along with bringing new spectrum to market, operators are making changes to their radio and core networks as well as trying new backhaul techniques to keep up with increased traffic projections. A combination of licensed and unlicensed spectrum, various technologies and a strong fiber backbone will all be needed to keep up with network demand. In a HetNet architecture, the wireless networks consist of macro, micro, small cells, outdoor and indoor Distributed Antenna Systems (DAS) along with Wi-Fi hotspots and other in-building systems that work in synch to hand a mobile session off from the top layer to the lower and vice versa as needed. This allows for more efficient spectrum usage and an interference control environment.

Today operators are deploying smaller wireless communications equipment to make their networks denser. Small cells are a miniature version of the traditional macrocell; they have the attributes of a cell tower (i.e. radios and antennas), but they are compressed into a low-power, easy-to-deploy radio device. Small cells have a range varying from 10 meters to a few hundred meters and are used by operators either to offload traffic from the macrocellullar network in a high-density, short-range environment or to strengthen the range and efficiency of a mobile network. Other network densification methods include incorporating wireless hardware into street furniture (such as light poles and other network equipment concealment solutions) and integrating wireless hardware with Wi-Fi technology.

To optimize the short- and long-term success of network densification, network deployments are contingent on many factors. Some key factors include:

- Location of sites that improve coverage, can be structurally supported and deployed at the right height
- Cooperation with the local jurisdiction
- Ease of deployment and scalability
- Availability of backhaul and power
- Ease of maintenance and upkeep

These factors directly impact the business case to deploy wireless network infrastructure. Using new and existing street furniture can augment the typically more-efficient macrocellular deployments.

In-building deployments

Network densification also can also be achieved by deploying in-building systems to provide cellular coverage inside buildings of every size. In-building systems can include Distributed Antenna Systems (DAS), Distributed Radio Access Networks (D-RAN) and Cloud or Centralized Radio Access Networks (C-RAN). Tier-one venues represent about 30 percent of the in-building market for wireless infrastructure deployments, whereas mid-tier venues, ranging in size from 100,000 square feet to 500,000 square feet, are now emerging as the biggest growth area for DAS deployments.[7]

As the demand for ubiquitous cellular coverage accelerates, traditional funding models for in-building wireless are changing. Industry is challenged on whether operators, enterprise owners or third-party providers should pay to deploy and maintain the networks. Cost-effective solutions are available today. Each venue has unique needs and may use various technologies to meet those needs.

Building owners' motivations are to increase rent rolls of their properties. Typically, they do this by securing long-term tenants and providing the most desired amenities, while minimizing both disruptions to tenants and encumbrances on building properties. Most building owners want in-building solutions that provide cellular coverage and capacity for multiple wireless operators and bands. Even single-tenant building owners and managers want the flexibility of multiple wireless operators, especially with the Bring Your Own Device (BYOD) trend, which many businesses use to provide their employees cellular service at work. Building owners should work with trusted partners to secure connections to the major wireless operator's signal source.

Operators and building owners want in-building solutions that accommodate today's current cellular offerings, complement existing Wi-Fi investments, and can reasonably be viewed to accommodate near-horizon technology advancements such as CBRS and 5G. Single platforms that can deliver multiple services and/or operators are available today.

When it comes to antennas, for example, 5G will demand massive MIMO (multiple input, multiple output), pushing the limits on antenna design. However, aesthetics will play a fundamental role from the building owner perspective, so even with an 8x8 MIMO deployment, chances are the building owner expects to still see only 1 radiating element on the ceiling. On the remote radio end, building owners look for a small form factor with broadband capabilities as opposed to frequency-specific radios and consequently complex passive distribution systems to consolidate all services. From the head-end side, C-RAN architectures are already enabling drastic reductions in the required real estate to deliver the same services.

The key technological elements to solve for the insatiable demand for data requires:

- Full software virtualization
- Open Network Automation Platform (ONAP)
- Adaptive network capacity
- Ability to embrace CBRS and advanced LTE standards
- Operational cost reductions
- Can be deployed anywhere in the network
- 3GPP standards compliance
- Information assurance and security
- Access controls and authorizations

Today's network is evolving with the concept of Network Function Virtualization (NFV), which focuses on functions such as voice call handling, charging, and call control and moving them to a software-based platform that operates on the new Evolved Packet Core (EPC) all-IP network. Much of the virtualization is occurring in the core of the network because there is much to gain here and these are the services that are easiest to transform into software operating on standard servers.

However, as the core takes shape and services become data centers of computing power, similar to a Google or Facebook data center, the focus is shifting to the edges of this core network. At the edges are the outer layer known as the Radio Access Network (RAN), which provides the cellular RF source for mobile devices. As more and more enterprises and other large venues are paying for and managing in-building wireless systems, the RAN brings with it a set of cost and complexity challenges that require specialized hardware and onsite personnel. At the 2018 Mobile World Congress, companies demonstrated and introduced technology advances designed to flatten the network, improve operational efficiencies, enhance throughput, improve capacity and provide a path to 5G.

Critical Role of Fiber

A fiber backbone is a key foundational component of any smart community. While fiber networks span the globe, connecting communities that are continents apart, the scope of fiber networks addressed within this report include metro fiber and dark fiber that will address the need for further densification of fiber networks within communities to support the high number of wireless network access points, wireless devices and end users.

Fiber networks enable a myriad of connectivity solutions, even in a mobile-first society. Wireline fiber networks provide high-speed broadband services used by educational institutions, public-safety officials and hospitals. Whether a device is connected via licensed spectrum or unlicensed spectrum, fiber networks play a critical role as the "backhaul" network for all mobile, fixed-wireless and other forms of wireless networking. According to Cisco's 2017 Visual Network Index Forecast, wireline networks support nearly 90 percent of all Internet traffic, the majority of which is generated by wireless devices. Today, smartphones account for a large source of wireless-originated Internet traffic, but the adoption of IoT devices will only increase wireless-originated traffic.

As wireless traffic continues to grow, additional fiber network infrastructure must be deployed to meet the projected demand. A 2017 report by Deloitte Consulting LLP states that "Unlocking the full potential of 5G in the United States rests on one key assumption: the extension of fiber deep into the network."[8] 5G promises higher mobile data rate speeds, including several hundreds of Megabits per second (Mbps) in urban environments and 1 Gigabit per second (Gbps) or higher in indoor environments, all of which will require supporting fiber networks that can meet capacity increases as wireless traffic grows. Without additional fiber network infrastructure deployments that reach deeper into metropolitan centers and edge communities, Deloitte's report also asserts that "carriers will be unable to support the projected four-fold increases in mobile data traffic between 2016 and 2021."

How did we get here?

As anybody who has not been stranded on a deserted island for the last 15 years can attest, the rate of growth in speed and volume of data usage in mobile communications has been spiraling upward at an astounding rate. We take for granted that our phones, laptops, tablets, and other devices will have connectivity wherever we are and whenever we want it – not only at home or in the office, but everywhere all the time. A casual look around any place people gather – a coffee shop, airport terminal, on a bus or a train – shows how many people from all walks of life are on their devices seemingly incessantly. It's easy to be caught up in the moment and feel like it's always been this way. In fact, for the youngest among us, our digital natives, it has. For their benefit and the rest of us, it might be healthy to ask, "How did we get here?"

"A Very Short History of Big Data" by Gil Press in Forbes/Tech May 9, 2013, looks at the "information explosion" a term first used in 1941 according to the *Oxford English Dictionary*. The article cites that in 1944, "Fremont Rider, Wesleyan University Librarian, published **The Scholar and the Future of the Research Library**. In it, he estimates that American university libraries were doubling in size every 16 years. Given this growth rate, Rider speculates that the Yale Library in 2040 will have 'approximately 200,000,000 volumes, which will occupy more than 6,000 miles of shelves... [requiring] a cataloging staff of over six thousand persons.'... In 1961, Derek Price published **Science Since Babylon**, in which he charts the growth of scientific knowledge by looking at the growth in the number of scientific journals and papers. He concluded that the number of new journals has grown exponentially rather than linearly, doubling every 15 years and increasing by a factor of 10 every half-century. The article includes numerous other references that cite the growth of data. Significantly, the article also includes in June 2008 "Cisco releases the [first] **'Cisco Visual Networking Index – Forecast and Methodology, 2007–2012 (PDF)'** part of an 'ongoing initiative to track and forecast the impact of visual networking applications.' It predicts that 'IP traffic will nearly double every two years through 2012' and that it will reach half a zettabyte in 2012. The forecast held well, as Cisco's May 30, 2012 report estimated IP traffic in 2012 at just over half a zettabyte and noted it 'has increased eightfold over the past 5 years.'" (Forbes/Tech, May 9, 2013 @ 09:45 AM "A Very Short History of Big Data," Gil Press, Contributor accessed 3/14/18 7:36 PM). Since then, Cisco has continued to produce reports continuing to predict growth in IP traffic on a recurring basis through 2017, the latest of which is the subject of this paper.

In a retrospective blog in 2015 in SP360: Service Provider, "The History and Future of Internet Traffic," by Arielle Sumits, August 28, 2015, the Cisco team looked back at the growth of data on the Internet from 1984 and generated the figure 1 graphic below.

The authors felt, "It may be a bit unfair to take 1984 as our starting point for the increase in Internet traffic. After all, the nature of growth rates is that they will be absurdly high in the first few years of any even modestly successful product or industry, since the base starts from nothing and moves to something." So they decided to look at a shorter window from 2000-2014 and found, "Internet traffic in 2014 was over 564 times what it was in 2000. For fun, we've compiled a mixed bag of metrics for a quick 'then and now' comparison of 2000 and 2014."

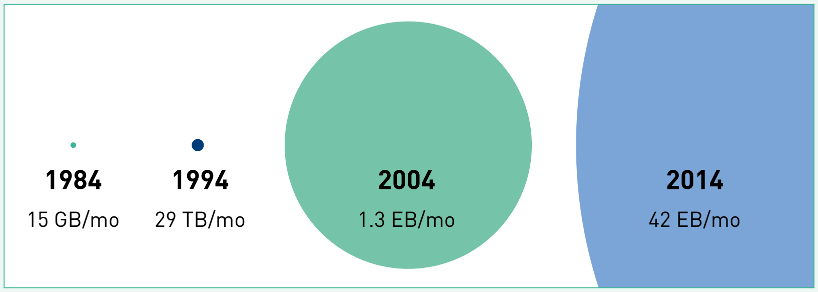


Figure 1 – *The History and Future of Internet Traffic 1984-2014*

With those references, but before launching headlong into a view of things to come, it may be helpful for all of us to look back to how all this communication and computing activity got started, how it grew, and how we got to where we are today to give us context for the rest of our discussion.

Analog Computing Dawns

As the 1900s dawned, non-programmable analog computing was being used for scientific purposes. The efforts of Guglielmo Marconi, Michael Faraday, James Maxwell, Heinrich Hertz, Edouard Branly, and Nikola Tesla came together to create wireless communication. Marconi established wireless telegraphy service. Its importance was shown by the British navy in Anglo-Boer War (1899-1902), first trans-Atlantic transmission in 1901, and life-saving value in rescuing survivors of the Titanic in 1912. In 1921, the Detroit, Michigan, police department began using one-way AM radios in their police cars. Like all AM broadcasts at that time, the transmissions suffered from noise and interference. World population stood at 1.9 billion.

During the 1930s and World War II, both radio technology and computation advanced dramatically. In 1933, Edwin Armstrong received a patent for FM radio. FM provides much higher received signal quality in the presence of environmental and man-made noise than AM. The U.S. military adopted FM modulation in battlefield radios, e.g. walkie talkies, during WWII. Analog computers were replaced by digital computers with electronic circuit elements. The first electronic digital programmable computer was Colossus, designed by the British to break high-level German codes during the war. World population in 1945 was 2.5 billion.

After the war, technology moved ahead quickly. The world's first stored-program computer, The Manchester Small-Scale Experimental Machine, at the Victoria University of Manchester ran its first program on June 21, 1948. The bipolar transistor was invented in 1947 and integrated circuits became available in 1958. In communications, FM became the industry standard for most two-way radio communications. With the technology available and demand for services, the FCC authorized telephone companies and radio common carriers to provide radiotelephone (voice) services in 1946 and 1948, respectively. Mobile telephone was limited to a small niche market of high-end users due to a lack of available authorized spectrum

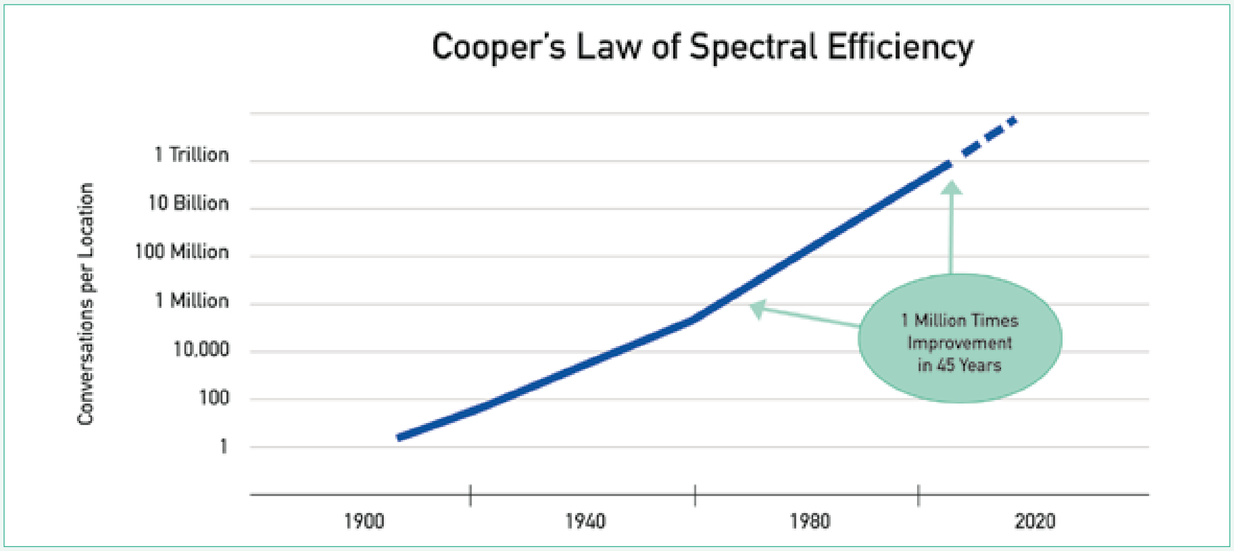


Figure 2 – *One way to observe the improvement in the way we use the spectrum is to compare the number of "conversations" (voice or data) that can theoretically be conducted over a given area in all of the useful radio spectrum. It turns out that this number has doubled every two-and-a-half years for the past 104 years. This observation was made by Martin Cooper, Chairman Emeritus of ArrayComm, and is dubbed "Cooper's Law." Cooper is credited with inventing the handheld cellphone while at Motorola in the 1970s. Source: ArrayComm*

until the 1980s. World population in 1980 was 4.4 billion.

Advancements in electronics and integrated circuits led to the ability to pack more computing power in less space and resulted in mainframe computers, handheld calculators, word processors, minicomputers, the personal computer (in 1981), laptop computers, personal digital assistants (PDAs, essentially electronic organizers with calendar, contacts and computer synch capability), tablets, manufacturing automation, control systems of all kinds, and robotics. This rise of computing and automation became known to some as the Third Industrial Revolution.

With all these computing devices coming into the world, it made sense to find a way to connect them. The Advanced Research Projects Agency Network, ARPANET, had established a packet switching network in the 1960s and added Transmission Control Protocol and Internet Protocol, or TCP/IP, a communications model that set standards for how data could be transmitted between multiple networks in 1983.

Through the 1980s and into the 1990s, cellular phones and service were expensive. The business, while serving a much larger subscriber base due to the increase in available spectrum and improved technology, was still limited primarily to business and professionals.

As computing and communications reached higher level of development, people began to use two popular devices, electronic organizers and cellphones. A logical progression was to combine the functionality of the two devices. Simon, the first device that merged the functionality of both a PDA and mobile phone into a single device, appeared in 1993. It was the first smartphone. Jointly developed by IBM and BellSouth, Simon operated on narrowband PCS Mobitex network operated by RAM Mobile Data. Simon (see Figure 3) combined a sensitive touch screen, a fax machine, a PDA, a pager, a mobile phone, and an optional memory card. Applications included games, email, notepad, calculator, world clock, address book and a calendar. Unfortunately, Simon had only one-hour battery life. It was priced at $899 with a two-year service contract for coverage in a 15-state service area.

Figure 3
Source: Simon (by Bcos47)

In 1999, two major events occurred: In the U.S., Lucent and Apple teamed up to offer Wi-Fi in Apple computers. The Wi-Fi standard quickly grew in popularity and was adopted as wireless connectivity for PDAs and other devices. In Japan, **NTT DoCoMo** released the first i-mode smartphones to achieve mass adoption in any country and had an estimated 40 million subscribers by the end of 2001. I-mode was a proprietary network operated by DoCoMo. Despite its success in Japan, it never got off the ground overseas.

Smartphone technology continued to advance throughout the early 2000s. In 2003, Canadian manufacturer Research in Motion Ltd. Introduced the BlackBerry, a device that functioned as a telephone, allowing people to send and receive emails and text messages, and browse the web. The Blackberry achieved huge popularity and became the first of what we would think of as being the modern smartphone.

Then it happened. In January 2007, Apple introduced the **iPhone**, which combined a cellphone, iPod and Internet-capable device into one handheld.) Effectively, Apple put the power and convenience of a PC in a person's hands with built-in software distribution capability. The touchscreen eliminated the need for a physical keyboard. Integrating a camera with apps fueled social media growth and made photography ubiquitous. The iPhone (see Figure 4) replaced mobile gaming devices. Music, and video moved to the streaming services. Apps made navigation, news, sports, weather, file-sharing, mobile payments, dating, fantasy sports, health and fitness monitors, and e-readers as close as your phone. As people spent more time using apps on their phones, advertising moved to the mobile space benefitting Google, Facebook and others. Mobile apps created business opportunities for companies like Uber, Lyft, and Airbnb.

Figure 4
Source: Pexels

Due to the increase in wireless traffic, dark fiber network operators, or operators that deploy high-capacity fiber networks and then lease capacity (in the form of number of fiber strands) to customers ranging from enterprises to mobile network operators, have become significantly important to addressing wireless traffic growth. These fiber networks are only activated – or "lit" – when their customers need increased bandwidth.

Legacy fiber backhaul networks are typically built with:

- relatively low fiber capacity that is heavily multiplexed with dense accessibility (e.g., fiber-to-the-home networks) or,

- high fiber capacity and sparse accessibility (e.g., enterprise fiber networks).

Also, backhaul networks in a typical dense urban environment are designed for lateral splice locations every few thousand feet.

To obviate the limitations of legacy networks, a new fronthaul access network must be architected differently, with high fiber capacity as well as easy accessibility, allowing for lateral splices every few hundred feet or less. Such a fronthaul network also must provide relatively short links to interconnect the baseband processing to the distributed RF interface locations to meet stringent latency requirements. The new fronthaul network architecture primarily differs from legacy backhaul architectures due to the density of fiber lateral splice points necessary and the number of dedicated fibers required to serve each end point. To visualize the difference between backhaul topology and the front network topology, think of the backhaul network as an expressway with sparsely spaced onramps and the fronthaul network as the local roadways with a collocation facility acting as the interface between the two network topologies. The "Network of Neighborhood Networks" model offers an analogy with the legacy central office topology where large voice switches are replaced with baseband processing cloud equipment and the 2,400 pair copper trunks are replaced with 1,728 or greater fiber-optic cables (3,456 fiber cables are shipping today). Similar to legacy copper plant, the fiber network must taper down as it becomes an access network and routes along the neighborhood streets, providing accessibility everywhere along its path. However, unlike the copper plant, which is more easily intercepted and spliced into, to enable the new network model, innovative techniques for ducts, cables and fiber splicing must be developed to support the unique nature of fronthaul access topology.

Key points that can be extrapolated from the section above are as follows:

- Most 5G experts visualize an infrastructure that requires extreme densification to achieve the goals for downlink speeds, latency and coverage

- The existing backhaul fiber infrastructure, supporting legacy Distributed RAN architecture, is not sufficient to support the dense C-RAN deployments on the horizon

- A significant financial investment must be made in high capacity, highly accessible fronthaul networks and distributed baseband collocation facilities

The underlying question of who is going to pay for a community's connectivity is an ongoing challenge.

Putting the Right Policies in Place

All stakeholders want to efficiently deploy resources; therefore, the proper policies need to be in place at the federal, state and local levels to encourage more wireless broadband deployments and investment. Sensible policies must be implemented that make placement of towers, small cells, fiber and DAS equipment as efficient as possible. This can be accomplished by ensuring providers have access to place equipment on structures in public rights of way (ROW), completing siting decisions and reviews expeditiously, and assessing reasonable and nondiscriminatory fees for collocating equipment on street furniture and existing structures.

Municipalities should consider enacting wireless siting ordinances that simplify or eliminate time-consuming review processes, especially when an antenna placement in a public right of way does not substantially deviate from the physical properties of the existing structure.

For years, the Wireless Infrastructure Association (WIA) has developed model legislation that encourages collocation on existing facilities and provides municipalities guidelines on how to effectively develop their own wireless siting ordinances. The legislation balances municipalities' concerns about the aesthetic and safety impacts of wireless facilities with citizens' demand for ubiquitous wireless communications. To date, 20 states have adopted wireless facilities legislation using WIA's model as a guide although bills have been introduced in more than two dozen states. These efforts reflect that states across the country have recognized the vital need of small cell deployment that is necessary to meet the increasing demand for wireless services.

Updated model legislation crafted by WIA incorporates streamlined small cell deployments, access and accelerated timelines for rights of way, along with regulated rates for attachments and elimination of exclusive use agreements. Future model bill highlights include reasonable/nondiscriminatory rates for attachments to municipal properties outside rights of way, accommodations for strand-mounted wireless facilities, clarification of Class II/III/IV tower build standard requirements, and an opportunity for streamlined compound expansions.

Municipal Policies that may Encourage Broadband Investment

As the result of informal polling and surveys, several municipal practices were identified that may encourage broadband network investment by the private sector. These include:

- Treating companies that obtain State Public Utility Commission certification the same as other telecommunications providers and utilities, e.g., requiring an electrical permit only for placing wireless equipment on existing utility poles, provided that the applicant obtains attachment rights with the pole owner in accordance with other federal and state regulations.

- Development of city-wide master agreements for access to public ROW for fiber and/or pole attachments with fee provisions related to municipal cost of management of ROW as the economic model (as compared with revenue-generation models in those states that do not prohibit municipal charges). Baltimore, Md., for example, charges an annual fee of $100 per year for access to all city right-of-ways.

- Comprehensive master agreements for access to the ROW and attachment to city-owned infrastructure, including street lights and traffic signal poles with low-cost fees acknowledging the greater community interests and indirect economic development benefits. Such agreements must offer access to many municipal locations with expedited permitting on a large scale rather than processing each site request individually. This supports economies of scale by allowing uniform attachment of an approved form factor and reduces the workload for city employees tasked with overseeing the permitting process. Examples include the City of Boston, which charges a base ROW fee and a per-node fee for pole attachments; and White Plains, N.Y., which has a fee system based on access, not revenue, and charges a per-year, per-pole fee for attachments to city-owned infrastructure with approved options for small cells. Master access agreements are being used successfully in Boston, New York City, Baltimore and several other cities.

- Revisiting and overhauling existing regulations, policies and procedures on pole attachment, ROW access and permitting so that expediency and new technologies such as small cells are considered —particularly in smaller cities and larger suburban towns and counties.

- When appropriate, approaching municipal projects with a "dig once" policy where public works projects include inexpensive conduit as part of any project where streets are opened. This single action incentivizes telecommunications companies to lay more fiber because most of the cost of such projects is associated with labor to open and later close the road surface. If conduit is already laid, this can reduce project costs by 90 percent or more. Digging once also minimizes disruption to transportation and the local businesses and residents along such routes.

- Consider street furniture a potential mobile broadband resource. Light poles at the end of their useful life can be replaced with structures that can support or integrate small cells and DAS. When transportation shelters and other street furniture are placed or upgraded, these deployments can be approached with their potential as an infrastructure resource in mind. Even public waste receptacles potentially can serve as small-cell or DAS sites to provide better network coverage for citizens.

Conclusion

5G and other new network technologies promise life-transformational changes in many aspects of our everyday lives. These changes will demand much more robust, higher capacities and bandwidths, faster speeds, and lower latency performances from wireless networks to accommodate the forecasted exponential growth in mobile traffic and data consumptions over the next decade. Once 5G is deployed, there will be new frontiers of mobile broadband technologies and future innovation and advancement possibilities are endless. To make this evolution possible, all aspects of the wireless networks and technologies will be called upon. From core virtualization, C-RAN and Edge computing, to massive fiber deployment, deployment of low-, mid-, and high-band frequencies in HetNet architectures, and many other features and solutions will be needed to meet the challenges of the data tsunami that is coming. There will not be a single solution that will lead the way to meet these challenges and not one-size-will-fit all because of the introduction of various spectrum ranges and architectures deployed in the networks; however, all aspects of technological solutions known today and solutions to be developed over the next several years will play critical roles in making the wireless networks capable of meeting future demand. Exciting times in the wireless industry are ahead.

About the Authors

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Bernard Borghei is the Co-Founder and Executive Vice President of Operations of Vertical Bridge. He is responsible for Vertical Bridge's daily operations, regulatory compliance, vendor management, engineering services, human resources and emerging technologies.

Borghei has over 25 years of experience in wireless industries and before co-founding Vertical Bridge, he served as Senior Vice President and Partner at Global Tower Partners (GTP), where he oversaw domestic and international market operations, including a portfolio of more than 6,500 towers and 12,000 managed properties.

Borghei has also held executive and senior management positions in operations, engineering, sales, supply chain, site development, and customer care at several wireless operators and service providers including SkyBitz, Wireless Facilities, Inc. Western Wireless International, and at Triton PCS where he successfully ran operations across 24 different countries in Europe, the Middle East, Africa, North and South America.

Bernard has a Bachelor's degree in electrical engineering from Villanova University and an MBA in global management from the University of Phoenix. He also serves on the Advisory Board for the Villanova University School of Engineering

Ray Hild, Triangle Advisory Group

Ray Preston Hild is an accomplished senior management and strategic partnership professional with over 26 years of experience in the wireless industry. He has consulted on several major government and enterprise initiatives and co-authored several industry white papers. Ray has been a member of the WIA Innovation & Technology Council for several years. In addition, he has served on a variety of wireless committees and boards for major industry associations on such topics as: Unified communications, DAS in mid-tier markets, oDAS, mobile broadband, wireless as the 4th utility, enterprise wireless systems and network densification. Lastly, Ray has created the Public Safety Code Guidebook which is meant to track the changing landscape of first responder wireless requirements across the US.

Ray has held management and leadership positions with several prominent corporations over the years. Those include Sprint-Nextel, Corning, Galtronics, Kavveri Telecom and most recently JMA Wireless. He has won dozens of awards over several decades for service and performance. Ray is involved in the Johns Hopkins Mentorship Academy working with teenagers needing guidance in their career choices. He is also invested in supporting those who served through 185 for Heroes, an organization that hosts events for Operation 2nd Chance to help our warriors when they return from duty.

Ray La Chance, ZenFi

As President and Chief Executive Officer of ZenFi, Ray applies proven industry management expertise to deliver cutting-edge communication network solutions to the market. Ray oversees all aspects of business operations, effectively leading a team of experts to solve industry challenges created by the proliferation of mobile data. In addition to Ray's role at ZenFi, he is also a Founding Partner of Metro Network Services, LLC, a company focused on network planning, engineering, deployment and maintenance. Ray is an Information Technology industry veteran with more than 20 years of experience managing teams to design, build and operate complex, high-capacity networks for large enterprises, financial firms and telecommunications service providers. Prior to ZenFi and Metro|NS, Ray served as President and CEO of Lexent Metro Connect, LLC from 2007 to its successful sale in December 2010 to Lightower Fiber Networks. Ray was also the Co-Founder of Realtech Systems Corp., an enterprise network integration and professional services firm, where he served as President and CEO. Ray received a Bachelor of Science degree in Computer Science from the State University of New York at Albany in 1985.

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Mr. Landry is the Corporate Vice President of Product and Market Strategy at JMA Wireless. He is a technology, business and marketing executive with a long history of developing winning product portfolios and is well-known for his successful execution of vision and strategies in the areas of IT and communications infrastructure.

Mr. Landry held executive positions in companies that include NEC Corporation, where he led the evolution of their software and cloud-based unified communications platform and NEC's Smart Enterprise initiative globally. Prior to NEC, Mr. Landry was at Sphere Communications, a startup software company, where he led an initiative to establish a scalable all-software UC platform (later sold to NEC Corp). At 3Com's CommWorks and U.S. Robotics, he led strategy, product management and is best known for creating the industries on-ramps for access to the Internet and the first packet data connectivity infrastructure solutions for mobile operators.

Mr. Landry is very active in industry workgroups, standards organizations, and customers worldwide. He is a member of the Board of Directors for the Alliance for Telecommunications Industry Association (ATIS), an Advisory Board member on the Chief Marketing Officer (CMO) Council and has served on multiple industry standards boards during his career. He holds two granted patents and has several patent applications filed in areas of communications and wireless systems.

Joe Mullin, InSite Wireless Group

Joe Mullin oversees all DAS projects for InSite. He has more than 25 years of experience designing and deploying wireless networks, including expertise developing specialized in-building coverage solutions for medical, industrial, and entertainment venues throughout the U.S. Previously, Mr. Mullin was Vice President of Engineering for Arch Wireless, where he was responsible for network design, facility management, and regulatory compliance. Mr. Mullin also has developed and marketed wireless network products with Glenayre Electronics and Harris RF Communications. He managed construction projects for the U.S. Army Corps of Engineers in the U.S. and Europe. Mr. Mullin holds a B.S. in Civil Engineering from Worcester Polytechnic Institute and an MBA from Boston University. He is a Registered Professional Engineer and is a member of the IEEE and the Radio Club of America.

Steve Noonan, Cheytec Telecommunications

Steve has over 20 years of executive telecom experience leading business units, corporate finance, strategy, corporate development, and M&A. Most recently at Ericsson, Steve created and led their corporate venturing group and subsequently became the global head of M&A. In this role he sought out, vetted, invested in, and managed investments focused on in-building solutions, LTE/5G advancements, fundamental RF technologies, IoT, and analytics. Prior to Ericsson, Steve was CFO at Telcordia, a Warburg-Pincus, Providence Equity software portfolio company, where he led a turnaround of the LBO and eventual successful sale of the company. Earlier at Telcordia, Steve ran two large integrated operating units having responsibility for software development, product management, and sales. Steve holds a bachelor's degree in Finance from Hofstra University and an MBA from Seton Hall University.

José Sangiuliano, Cheytec Telecommunications

Prior to joining Cheytec, José worked for Ericsson for 20 years. At the beginning of his career, José was dedicated to the RF design of macro cellular wireless networks. In that capacity, he designed and optimized macro wireless networks for all major operators in North and South America.

In 2002/2003 José started designing In-Building networks and quickly became specialized in that type of design and very passionate about the subject. As a pioneer of some of the high capacity design strategies that are widely applied today in sport venues, transportation hubs and enterprises, José's specialized experience led him to the CTO team for the Verizon account.

As the SME for all In-Building solutions delivered to Verizon Wireless, which included Distributed Antenna Systems (DAS), Centralized Radio Access Networks (C-RAN), Distributed Antenna Networks (D-RAN), Neutral Host Distributed Antenna Networks (NH D-RAN) and Small Cells, aiming to optimal wireless coverage and increasing the building value.

Later, José worked on business development inside the Verizon account, focused on end-to-end In-Building solutions and equipment licensed services. José has a Bachelor of Science degree in Electrical Engineering from Mauá College of Engineering, in São Paulo, Brazil.

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Endnotes

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