



Digitization and Virtualization of SATCOM Networks: What Does It All Mean?

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INTRODUCTION

Satellite ground networks are in the midst of evolutionary challenges that will transform industry business ecosystems and ground network architectures. With up to 50,000 active satellites predicted to be in orbit over the next 10 years¹, the space layer is rapidly changing, bringing a complex and variegated set of orbits and waveforms that satellite communication (SATCOM) networks need to support. This drives the need for SATCOM operators to create flexible and adaptable networks capable of operating on a myriad of different waveforms, orbits, and constellations—while simultaneously maintaining service quality and profitability.

In the past, access to space resources was expensive, “scarcity economics” modulated business ecosystems where a limited number of purpose-built proprietary modems thrived. These rigid solutions that dominated SATCOM networks for decades are now unfit to meet the needs of the current “abundance economics” paradigm. As leading global satellite and space market research firm Northern Sky Research (NSR) recently reported, legacy “satellite ground networks ... lack the scale and agility necessary to avoid the palpable risk of becoming bottlenecks².” Furthermore, the U.S. Space Force, in a recent vision document, expressed the requirement for agile SATCOM networks and modem terminals—i.e., the ability to seamlessly transition between different SATCOM waveforms, orbits, and constellations³.

The need to promptly evolve the SATCOM network architecture leverages two principles that are widely accepted and adopted in the larger telecommunications industry: *Digitization* and *Virtualization*.

¹ C. Daehnick, I. Klinghoffer, B. Maritz, and B. Wiseman, “Large LEO satellite constellations: Will it be different this time?” McKinsey Industry Insights, 2020 [Online]. Available: <https://mck.co/3jFK9o3>

² Northern Sky Research, “Satellite Ground Network Virtualization,” NSR White Paper, 2020 [Online]. Available: <https://bit.ly/3lnTD7G>

³ United States Space Force, “United States Space Force Vision for Satellite Communications,” Vision Document, Jan. 2020 [Online]. Available: <https://bit.ly/3nr4mQJ>

- **Digitization** refers to replacing the L-band Intermediate Frequency (IF) interfaces with Internet Protocol-(IP) based interface, i.e., digital IF. Simply put, the evolution to digital IF is analogous to transitioning from broadcast TV to Netflix. Leveraging digitization, SATCOM operators can reduce Total Cost of Ownership (TCO), improve system performance, and increase network/terminal agility.
- **Virtualization** refers to the abstraction of computing resources from the specific hardware to create a virtual computing environment. Similar to virtual reality, multiple independent virtual computing systems are instantiated to behave like independent computers or servers. These virtual computing environments can share the same physical hardware resources. With virtualization, a panoply of applications and functions is consolidated onto common hardware. Most importantly, virtualization separates application and hardware vendors, which eliminates the need for purpose-built hardware. Leveraging virtualization, SATCOM network operators can reduce TCO, increase terminal/network agility, and, most importantly, accelerate the speed of innovation by separating applications from hardware.

Mobile Network Operators (MNOs), (i.e., Verizon, AT&T) have adopted and developed standard approaches using these principles. Mobile network digitization standards started in 2011 with the Common Public Radio Interface (CPRI) and was superseded in 2019 by enhanced CPRI (eCPRI). In essence, the eCPRI standard provides transport of digital samples over IP networks⁴. Similarly, virtualization was adopted by MNOs through the Network Function Virtualization standard⁵ in 2013, which specified a common architecture and approach to virtualize network functions onto common hardware. While these principles are now common for MNOs, they starting to show promise in SATCOM networks as well.

⁴ CPRI Committee, "eCPRI Specification V2.0," Common Public Radio Interface: eCPRI Interface Specification, 2019 [Online]. Available: <https://bit.ly/3phHVOz>

⁵ ETSI, "Network Functions Virtualization (NFV) Architectural Framework," ETS GS NFV 002 V1.1.1, Oct. 2013 [Online]. Available: <https://bit.ly/3kWfenR>

What exactly does Digitization mean to my SATCOM network?

At the most basic level, digitization of modems means separating the digital modem processing from the Radio Frequency (RF) front end and introducing the new digital IF interface between these two components. In a purpose-built modem, as shown in Figure 1, these functions are combined into a single device. The digital modem transmutes the signals between data bits and digital samples, and the RF front end then transmutes signals between digital samples and L-band IF. As shown in Figure 2, these two functions are separated in a digitized modem architecture, where we call the RF front end an “edge device.” The digital modem and the edge device are connected using the digital IF interface, which is IP-based transport protocol used to communicate digital samples and their contexts across a data network.

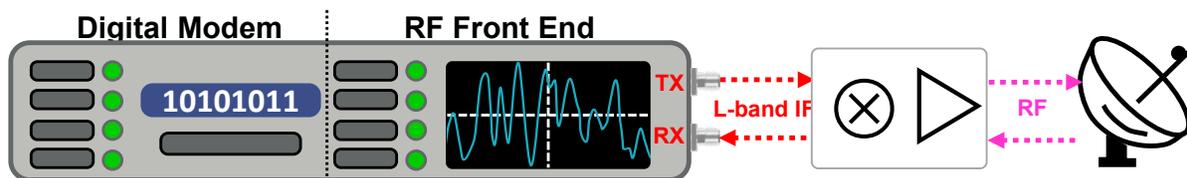


Figure 1: Traditional purpose-built SATCOM modem architecture.

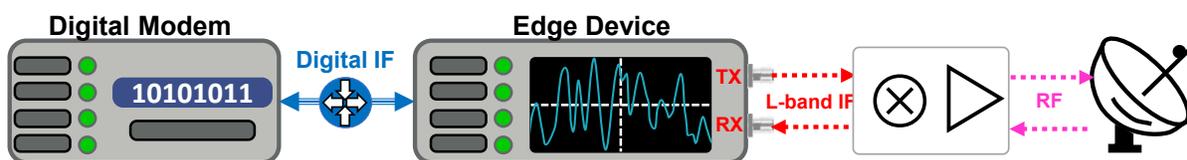


Figure 2: Digitized SATCOM modem architecture.

While the differences between Figure 1 and Figure 2 may seem subtle, there are significant implications for SATCOM networks. Digitized SATCOM modem architectures provide the following advantages⁶:

- Reduced TCO
- Increased RF Performance
- Increased Network Agility and Capability

⁶ A. J. Vigil and J. Hicks, “The Case for an All Digital Military Satellite Communications Earth Terminal,” MILCOM, 2009 [Online]. Available: <https://bit.ly/3ypEnxv>

Reduced TCO

Managing SATCOM networks' costs is important in maintaining profitability and longevity. When comparing capital expenditures, instead of expensive analog transmission lines and distribution equipment, digital IF transmissions are based Commercial-Off-the-Shelf (COTS) IP routers and switches, which, generally, have lower capital and operation costs. Additionally, network reconfiguration or migration doesn't require operators to disconnect transmission cabling for equipment replacement. These network operations can be entirely managed by reassigning digital IF IP addresses or simply plugging in a new digital modem into a router.

Increased RF Performance

Increasing Signal-to-Noise Ratio (SNR) improves signal quality and SATCOM network throughput. The major disadvantages of using analog L-band IF are cable power loss and distortion from L-band switching systems, which degrade the SNR. In digitized architectures, L-band switching equipment is replaced with more efficient IP switched systems. Additionally, since the edge device is not fixed to the modem, edge devices can be placed much closer to the antennas, minimizing L-band IF cable length, transmission power loss, and maximizing SNR.

Increased Network Agility and Capability

Network and terminal agility are becoming more important due to the rapidly changing space layer. Agile networks and terminals will enable easier migration to waveforms and constellations, streamline network resource reconfiguration, and modernize deployment of new capabilities. In a digitized architecture, digital modems are decoupled from edge devices, supporting easy reconfiguration of the network. With a standardized digital IF interface, digital modems could replace and back up one another for redundancy through simple IP network configurations. Additionally, digital IF streams could be duplicated, combined, and separated digitally to provide new capabilities like diversity gain, beam forming, and amplifier distortion correction. Finally, with a reliable digital IF transport, digital modems can communicate to distant edge devices adding additional network redundancy and even leverage cloud computing.

What exactly does Virtualization mean to my SATCOM network?

Purpose-built modems have compounded the complexities and costs of managing SATCOM networks. In an exponentially growing SATCOM market, managing purpose-built modems has scalability constraints due to rack space, power, and operation knowledge necessary for the managing many different models and vendors. A network with N different modems means a network with N times more rack space, switching equipment, network cost, and complexity. Additionally, with purpose-built modems, the design-integrate-deploy lifecycle is costly and time consuming. These lifecycles will stifle the deployment of new technologies. With a rapidly changing and diverse space layer shortening lifecycles, purpose-built systems will create evolutionary bottlenecks.

Virtualization will enable many different types of waveforms and modem features to be consolidated onto common hardware, thereby eliminating the need to manage purpose-built hardware and N different modem types. A digital IF architecture provides a smooth transition to virtualization since digital modem processes can now run on COTS servers. As digitization enables network agility, virtualization enables modem and terminal agility by more effectively providing dynamic reprogrammable functionality onto the digital modem. A diagram showing logical abstraction of a virtualized computing environment using a digital modem as the virtualization host is shown in Figure 3.

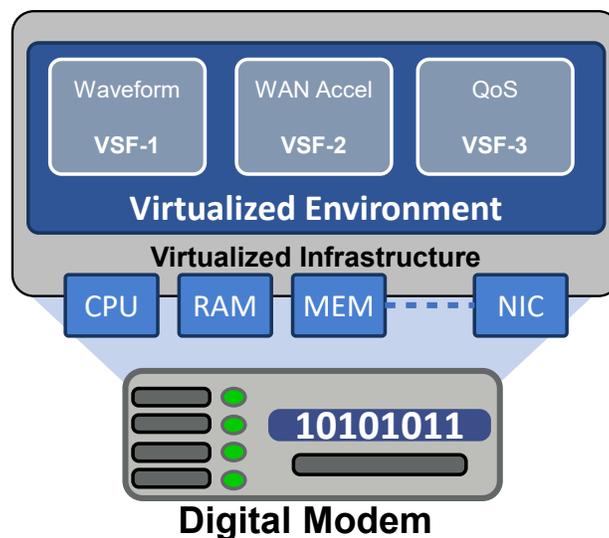


Figure 3: Virtualized SATCOM Functions (VSFs) provide modem agility since VSF functions are not conjoined to specific hardware and software.

In purpose-built modems, several different SATCOM functions are provided. These SATCOM functions include, but are not limited to, waveforms, Wide Area Network (WAN) acceleration, Quality of Service (QoS) management, and more. In purpose-built modems, these functions are almost always conjoined to each other and the underlying hardware. Generally, these conjoined functions are not capable of operating independently or separated easily. In a virtualized architecture, these SATCOM functions are “softwarized” into their own virtual machine/computing environment called a Virtualized SATCOM Functions (VSFs). These VSFs operate independently from other VSFs and the underlying hardware.

Leveraging virtualized SATCOM modem architectures will provide the following benefits:

- Reduced TCO
- Increased Operational Performance
- Accelerated Speed of Innovation

Reduced TCO

Operating and capital expenses are key drivers in network sustainability. When VSFs are deployed, hardware migrations generally are turned into software migrations. Rather than replacing racks of purpose-built modems, migrations with virtualized architectures require only to deploy new VSFs. Because common hardware can be used for multiple architectures, new purpose-built hardware does not need to be purchased or managed. Additionally, consolidation allows more efficient use of existing hardware resources, which can support a multiplicity of functions and simultaneously take advantage of hardware and software economies of scale enabled by larger telecom and IT sectors.

Increased Operational Performance

The rapidly changing space layer requires the SATCOM network to quickly reconfigure itself to deploy new waveforms or capabilities; and to connect with multiple different orbits. With VSFs, these functions can easily be prototyped, tested, and deployed with minimal impacts to network hardware. Additionally, by deploying functionality via VSFs, maturation cycles will be significantly reduced. Targeted services can also be rapidly scaled as required.

Accelerated Speed of Innovation

Since virtualization untethers hardware from SATCOM functions, best-in-class SATCOM functions can be selected independently from distinct application vendors. In this new paradigm, application vendors could offer VSFs like apps are offered in smartphone ecosystems. Additionally, pure software entrants are encouraged to compete since there is no need to develop hardware to enter the market. Virtualized architectures accelerate speed of innovation by fostering a larger pool of competitors, where superior functions can be selected and deployed together.

Conclusion

Digitization and virtualization are the next steps in the evolution of SATCOM networks. Both principles, proven and accepted in the larger telecom space, provide significant savings in terms of operation/capital cost, and increase SATCOM network performance. Incumbent equipment vendors and operators seeking to protect traditional market paradigms might be slow to adapt from their “purpose-built mentality.” Therefore, these incumbents could end up being left behind when the rapidly changing space layer drives these inevitable SATCOM network transformations. Given the new possibilities and capabilities with digitization and virtualization, non-traditional, innovative market entrants and partnerships have an excellent chance at replacing the old with the new.



ABOUT NSR

AHEAD OF THE CURVE

As the satellite & space industry boldly expands in new directions, success is directly aligned with your ability to know where the market is headed and why. NSR helps you get there first.

Founded in 2000, NSR is a global leader in Satellite & Space Market Research and Consulting Services. NSR specializes in the analysis of growth opportunities across four core industry sectors: Satellite Communications, Satellite & Space Applications, Financial Analysis and Satellite & Space Infrastructure.

The NSR team consistently forecasts events and trends well ahead of when they become common industry knowledge. Our clients get results that are broader, balanced, and with the most honest assessment of the impact to their particular business.



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Carlos Placido is an independent consultant with over twenty-five years of international experience in satellite technology and markets. As a seasoned professional, he led numerous analytical and management projects, spanning from global market research studies, to strategic assessment of emerging technologies, to R&D, business development support, and technology or business modeling. He holds an engineering degree from the University of Buenos Aires and an MBA from the University of Maryland, Robert H. Smith School of Business.

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