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Chapter 2: Reinventing telecommunications infrastructure in the age of hyperconnectivity and artificial intelligence

2.1. Introduction

It is generally accepted that today we indeed live in an age of hyperconnectivity, as expressed by many in key identified items such as "the world is flat", "the connected world" and "the Internet of Things". What is also generally recognized is that ubiquitous connectivity has seen the convergence of layers of communications, information and social media service infrastructures, driven by the consumer electronics industry's revolution through fast-advancing smart computing and communication device technologies. Wireless broadband access "last miles", complemented with fiber optic backhaul and increasingly wired "trunking", are becoming treated as mere extensions of the backbone, incorporating controlled and managed protocols/services. In turn, the telecoms industry is experiencing the need to reconceptualize, reinvent and re-deploy its decades-old purposes and roles (Costa-Perez et al., 2013; Dighriri et al., 2015; Liang et al., 2015).

At the core of both economic and social pillars underpinning nation- and state-building, promoting knowledge-based development and social cohesion in a democratically inclusive mindset, telecommunications infrastructures have witnessed major shifts in development, deployment and management models. Public sector agency, interest and responsibility, as the more visible part of these infrastructures' capital and operating modeling and layering, is no longer guaranteed, as growingly citizens and stakeholders expect shared risks, rewards and responsibilities with the public sector, which needs to take on 'leading by enabling' roles with respect to private-sector participation in telecommunications infrastructures' development, deployment and management. In turn, embracing and facilitating the concept and intention of the digital commons that underpins hyperconnectivity, as much as it drives its fundamental economic and social pillars, as we explore further in this work, is a new 'sine qua non' that becomes imposed in turn on the private sector as a 'user-pay' accountability element (Zaki et al., 2010; Zhu & Hossain, 2016).

2.1.1. Background and Significance

Unlike most technologies today, telecommunications infrastructure was an early general-purpose industrial technology that cut across all sectors of the economy and society, contributing to overall productivity and reshaping their boundaries. Many of what today are considered northward-shifting sectors offer lower productivity growth than services. However, there is increasing debate regarding whether the historical experience is being repeated. The present is characterized not only by extraordinarily rapid technological change but also by rapid expiation of these technologies, in particular artificial intelligence. Artificial intelligence depends heavily on telecommunications infrastructure to collect, feed, and train its models, and then to propagate reliable predictions based on them, through the most effective business processes engaging customers and also suppliers. Acceleration of business use of AI building on telecommunications infrastructure lies at the very heart of the production transformation intensifying in our time. With employment-based wages in our economy hardly above 1.5 percent, and firm owners with enviable profits through high capital velocity linked to both general-purpose and narrow-purpose technological change, the idea of just-in-time production using large stocks of cash suggests the emergence of new business forms utilizing megaplatforms and staffless micropoints of sale in customers' localities.

What was telecommunication infrastructure? The basic, and still foundational, piece was the telephone. From about 1920 to 1980, there was one simple, but radical, change in gazing, in scale, speed, and underlying technology: Its waveforms were analog until the late 1960s and they were digitized after that. Also, from 1915, people were able to connect from one telephone to any other telephone directly, and by 1927, people were able to connect to one another using telephones at the level of quality they now considered common for all conversation and proof of rapid growth of availability of telephones in scale and speed.

2.2. The Evolution of Telecommunications

In the past, telecommunications was simply another branch of industry, like agriculture, that was in the right place at the right time. Over the next several decades, it grew, at times a little niche, like the value-added services marketed in the 1970s, and at others major player in the global economies. It came of age in the 1990s, setting out towards restructuring operations and opening to new entrants, building value in their shares. It was riding high in the early 2000s on their dot-com successes. In business and economics, history is about cycles, about ups and downs. What goes up must come down, quickly be it through euphoria, greed, and shortsightedness, or reverses of fortune flooding through blunders in judgment, exceeding capacity and seeking purely financial arguments.

Telecommunications walked straight into the flailing audience. The revenues were disappearing, the costs piling on them, the shareholders complaining. The job was ever more difficult: A company must take on difficult decisions, make heavy investments, take risks in technology future paths. The conundrums became innumerable: market regulations, public service delivery, universal service supporting; new technologies-tests; roll-out billions for optical-fiber deployment during stagnant economy; management upheaval over promoter-transfer and no-visibility benchmarks; dominator pricing into financial reserves; prices downward on line-rental/revenue ratios; technology convergence of telecommunications, computing, broadcasting and the Internet; but also a blazing pace of ingenuity and creativity, predominantly by the new customers, rethinking traditional constraints of product utilization.

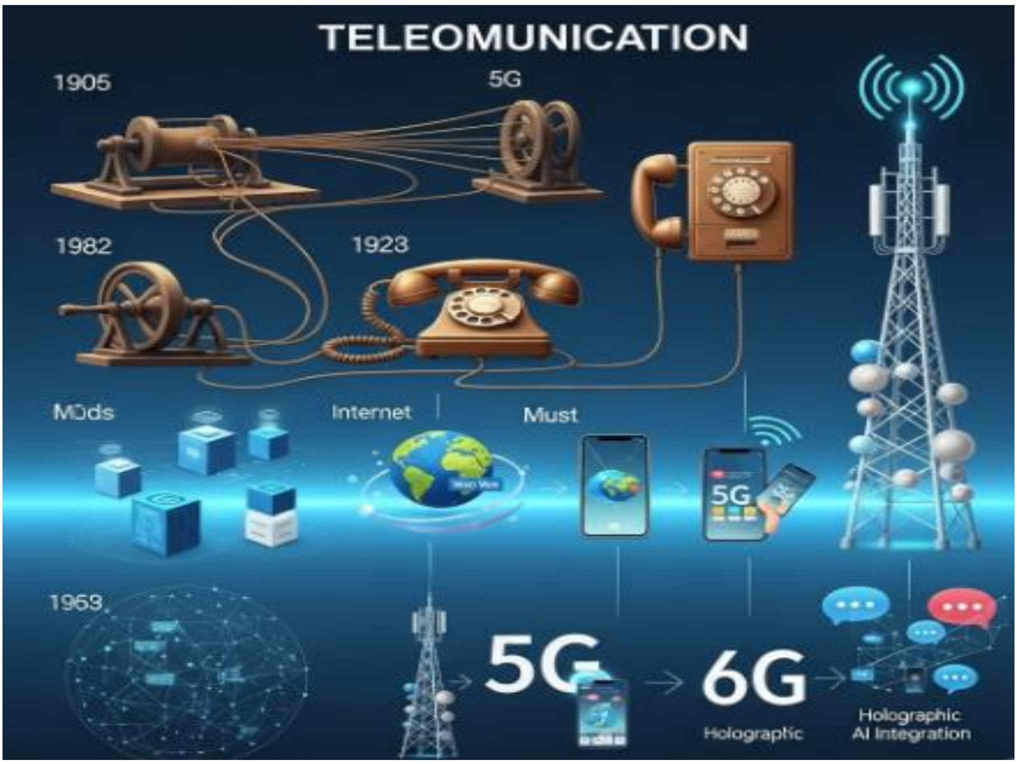

Fig 2.1 : The Evolution of Telecommunications.

2.2.1. Historical Overview

Telecommunications is dominated by an international satellite-based service offers, a highly-open mobile and fixed telephony services market, a broadband Internet and data services market still characterized by some monopolization effort by industry leaders, and a growing presence of next-generation and hyper-connectivity applications and services that merge telecom, Internet, and media functions at high level. The transformation of telecommunications can be broadly sketched and compared with the transformations of electricity and transportation in their respective historical evolution.

The major historical milestones on the path of telecommunications evolution were established by the invention of the steam engine and the telegraph in the early nineteenth century, the invention of the telephone in the late nineteenth century, the invention of the radio and the development of cable, microwave, and satellite technologies for radio transmission in the early- and mid-twentieth century, and the invention of the semiconductor, the laser, and the optical fiber in the late-twentieth century. Invention and diffusion of the telegraph, telephone, and radio created the sparse economy of first-stage telecommunications connections, characterized by small annual volumes of telegrams and phone calls connecting a small fraction of U.S. and world populations, and of communication flow in the form of news.

2.2.2. Key Technological Advancements

Unless two users are doing a point-to-point exchange, telecommunications systems typically incorporate sophisticated multiplexing and switching techniques. Multiplexing enables many different users to transmit information on the same physical channel. In time-division multiplexing, a single channel carries many signals, each on a different transmission slot in a repeating time frame. Frequency-division multiplexing uses different frequency channels on the carrier to separate different signals. Filtering is often needed in multiplexing to subdivide the capacity of a transmission channel.

For example, in digital signaling, a single transmission channel may use digital signal waveforms having a very broad frequency content and use filtering to limit the bandpass of the channel while allowing multiple different signals to be sent simultaneously. Removing the silicon advantage is also sometimes used to create a cheap alternative to forestalling the digitization of nearly all other processors, using special coarse-grain modules for more rapid prototyping and soft processors if needed. As VLSI technology advances, specialized ICs become cheaper and more capable.

Major switching systems in the telecommunications infrastructure include circuit switches, message switches, and packet switches. Circuit switching connects two users by a dedicated communications path through the switch for the duration of the exchange, while message and packet switching are both message switching techniques which entail the temporary storage of messages or message packets and then resequencing of the messages into their transmitted order for delivery to the destination when access to a buffer capacity in the destination trunk is available.

2.3. Understanding Hyperconnectivity

Hyperconnectivity is a new stage we have reached within the World Wide Web, which in conjunction with humankind's growing willingness to become immersed in a co-creative world amid the metaverse fueled by Artificial Intelligence, opens up new, previously unimaginable, and perhaps even utopian perspectives. Our internal connectedness, increasingly open to outside interference and manipulation from different players in the digital ecosystem, continues to grow in terms of strength. However, the majority of this ever-growing co-creative energy still does not seem to go beyond the negative boundaries of consumption, designed by big technology to get us hooked to their platforms and heavily exploited via attention-grabbing business. Transforming this energy into concrete, unparalleled offer from the creative potential unique to humankind, generates an ever-increasing degree of demand-supply imbalance, with negative ramifications for the economy. Despite our strong connectivity flows and depth of exchange with like-minded persons across the globe, the apparent lack of trigger effect to the "real" economy increasingly puzzles researchers from multiple disciplines.

This chapter further elaborates on the underlying forces which transform the Internet from a simple communication medium into a hyperconnective ecosystem able to co-create new value. By understanding this transformation, as well as the tensions enacted within society, as seen through the eyes of real humankind, decision-makers shall be able to make feasible moves that ensure that, rather than just riding this new digital wave, humankind rules a process taking place at the crossroads of zero marginal cost economies, Artificial Intelligence capabilities, and collective creativity.

2.3.1. Definition and Characteristics

Hyperconnectivity is defined as a condition in which any object in the universe can be permanently connected to the global system of exchanges with permanent effects. It is the primary condition that will unlock the full potential of cognitive technologies as it entangles together smart capabilities, digital exchanges and AI and ML capabilities. This entanglement will create the first viable framework for what we call tight coupling between cognitive technologies and concrete, physical systems. Hyperconnectivity is an advanced version of the digital hyperconnectivity enabled by the Internet and the Web but primarily characterized by the connection of all objects and realities into the global exchange system for permanent effects. Hyperconnectivity is measurable in exchange and connectivity terms while digital hyperconnectivity is exclusively measurable in connection terms.

There are three main characteristics that distinguish hyperconnectivity from digital hyperconnectivity. These characteristics are: First, the enabling of two types of cohesive loops: weak cohesive loops and strong cohesive loops. Hyperconnectivity creates the conditions for the permanent cohesion between people and assets/resources. People rely on their cognitive capabilities and those of the cognitively augmented AI and ML engines for reaching the weak cohesion with the assets/resources. Strong cohesive loops require the involvement of intelligent agents acting as intermediaries on behalf of people in configuring and monitoring the cohesive interaction with the agency type of the assets/resources. This is enabled by hyperconnectivity and AI-powered intelligent digital twins and avatars. Coherent with the principle of agency delegation, these smart avatars will relieve people from a lot of responsible cognitive, sensory and even physical activities that are affected by the principle of agency delegation.

2.3.2. Impacts on Society

The effects of hyperconnectivity on human behavior and society are important because changing patterns, such as the shifting relationship between people and things, impact a variety of fields, including politics, economics, and law. The cycle of producing social changes—structural metaphor for the increased fragility of society, characterized by identity confusion, growth in social risk, moral vacuum, and loss of meaningfulness—has repercussions for the world of communication, with an increase in the speed of transmission and the emotional connection to information, provoking sensationalism. As a consequence, there is an increasing risk of social upheaval and loss of control on the part of the governing powers, with a potential propagation of truth and democracy promoting realities, together with false news and misinformation, capable of influencing public opinion, pushing for unrest and change.

The speed of communication is one of the distinctive elements of hyperconnectivity, stratified by the accuracy and completeness of the information. The little time available for acceptance results in the propagation of information icebergs; that is to say, volumes with scarce surface area in which the part visible from the interaction contains a small amount of information, while most of the iceberg is unseen. Today's hyperconnected society is susceptible to fluctuating interests. Often provoked by equally fleeting triggering factors, the search for ephemeral interests offers hyperconnectivity an ever-changing framework. The increasing convergence of characteristics and aspects of hyperconnectivity, merging into a fluid and unpredictable connectivity system; capable of positively or negatively influencing human beings and behaviors, takes into consideration and assigns importance to various and different knowledge, concerns, and doubts.

2.4. The Role of Artificial Intelligence

The construct of hyper-connectivity is enabled by technical developments such as the pervasive deployment of the Internet of Things, new wireless communication technologies, Next Generation Internet protocols, and new telecommunications services. Such complex ecosystems would require an unprecedented level of coordination and network management operations which is made feasible by the capabilities offered by Artificial Intelligence. The complexities that telecommunications companies have to face from such a hyper-connected environment requires the redefinition of how they conduct their operations. From everything starting with how infrastructure is constructed, maintained, and optimized throughout its lifecycle over how services are designed and delivered to businesses and consumers all the way to how customer experiences are manufactured require radical innovation, in terms of how the telecommunications industry utilizes data. AI serves as the engine for this level of data-driven innovation.

Over the last several years, AI has become a key enabling technology for telecommunications infrastructure operators especially in the domain of network management. Networks are already extremely complex and dynamic systems which rely on a very large number of interconnected elements and involve a large number of operations which need to be conducted on that infrastructure daily. AI has been permeating all network management functions, whether they are infrastructure planning, energy management, resource allocation, threat detection, network performance or configuration management, among others. Different areas of telecommunications which had separate AI artifacts are now being brought together to deliver an end-to-end management cycle that can be fully automated. AI applications in network management go from Machine Learning-based solutions focused on specific tasks to Digital Twin solutions where a full model of virtualized or physical networks reflects current configurations and performance indicators while being open to receive data and perform operations.

2.4.1. AI in Network Management

Artificial Intelligence (AI) has evolved remarkably since its inception, and its impressive advancements have positioned it as a transformative force in numerous sectors. The global impact of Artificial Intelligence in areas such as education, healthcare, finance, and beyond is unprecedented and increasing enormously. Telecommunications companies are also leveraging AI's enormous potential realizing that it can not only add immense value but also create a much needed competitive differentiator. Given the increasing complexity of their current and future networks, a primary segment in which telecom companies are looking to leverage AI is in Network Management where it can be used to drive Intelligent Automation. Due to the emergence of the Software Defined Environment, networks are now easier to manage, optimize, and control than ever before. As these environments continue to evolve towards industries of Cyber Physical Systems and Hyper-connectivity, the management of networks is expected to become increasingly complex, requiring ever greater levels of automation. This level of automated orchestration can be realized using Artificial Intelligence together with Advanced Analytics, which need to work seamlessly underneath current network management applications to support smarter, real-time operations. Incorporating the Automated Intelligence paradigm will also help telecom players realize better efficiency while controlling costs.

Significantly higher demands from users, devices, and applications combined with evolving operational models make deployment of intelligence at scale a strategic necessity for Communications Service Providers. Their Infrastructure pools are becoming vast and complex, and concentrated at the same time given virtualization and cloudification. As these environments continue to evolve towards Cyber Physical Systems landscape with Human and Machine interactions, the management of networks is expected to become increasingly complex requiring increased levels of orchestration and intelligence. The next generation of intelligent operations will thus make the leap from enabling visibility, performance assurance, and troubleshooting to support for real-time management and optimization, necessitating advanced techniques in machine learning, statistics, and formal methods.

2.4.2. AI-Driven Customer Experience

Providing great customer experience is paramount for success in any market. Incorporating AI capabilities allows offering a fully personalized, human-level experience at a practically infinite scale. From retail to healthcare, from financial services to travel booking services, AI chatbots are changing the relationship between service providers and their customers. The telecommunications market is no different – in our hyper-connected economy and society, voice and data communications services are an intrinsic part of our lives. Telecommunications companies have therefore to differentiate based on the customer experience.

The AI-driven customer-centric business model allows one to benefit from enhanced satisfaction from customers, increased loyalty, and more revenue. Luckily, moreover, most telecommunication companies know their customers well, so they already have access to a lot of information on which to base their service optimizations and personalization. The algorithmic filtering methods we usually encounter when booking a hotel, or ordering a book or piece of furniture with online retailers can apply equally well in the telecommunications domain. This data assets can assist at every stage of the customer's journey and funnel. Whether it is onboarding, with rich profiles to engage customers across online, ranging from configuration to virtual site visits to appointment scheduling, service delivery and operation and maintenance, both helping to catch and select timely troubleshooting issues, reassuring customers observable events drive text-survey outreach to solicit open-ended comments, reputation management through online review response and posting status updates, escalation through journeys for easy questions via FAQs, triage to experts via avatar pathways, virtual agents, or smart bots, awareness about services available alongside upgrade recommendations and real-time alerts for outages, or any other life-cycle aspects and events, customer experience is rich.

2.5. Challenges in Current Infrastructure

Telcos face challenges in building the 'good' part of the new Internet infrastructure on par with Big Tech. Network infrastructure needs to be built to natively address challenges. New Internet infrastructure, such as privacy-aware, open, distributed, reliable, and highly performant, should be based on local decentralized and global centralized Internet services model. Global Internet services belong at the edge, national Intranets should be decentralized and managed by agencies, while local infrastructure within cities should be managed privately or by local agencies. Infrastructure promoting localized cloud services accessible for high-performance workloads should be unified. Encryption is a double-edged sword: It not only makes security more complicated for infrastructure and services interacting via an insecure Internet, but also allows telcos to defend a new infrastructure/services model by offering highly private secure-by-default services for Internet and edge access.

ML/AI is one of the primary driving forces behind hyperconnectivity. Internet services should support ultra-low latency performance for AI workloads at a very high per-device basis. Cellular-like services should be complemented by a service infrastructure with a mix of packet and circuit switching complemented by ad-hoc private local networks. The per-device basis of ML/AI workloads makes normalized Access a nightmare. Access speed and reliability equalization across devices and their uniqueness recognizes differential Access.

Yet, the two-packet swamping issue at network edges driven by hyperconnectivity causes the network congestion collapse for the current model. Infrastructure must provide variable delay, reliability, and bandwidth Access services abstracted by unique identifiers supporting normalized per-device basis of devices used for ML/AI workloads.

The network core must abstract the dynamics currently supported by the routing control packets. A new network core is a step in this direction. Any new infrastructure should allow incremental growth using technologies without upheaval for infrastructure.

2.5.1. Scalability Issues

One of the most vectors of progress in the Internet's growth has been its scaling: how larger deployments and address spaces that arose out of the need of billions of general users ended up creating the largest, basic layer infrastructure monetizable by the few top companies in terms of online marketing reach and advertisement effectiveness. Unfortunately, the negligence in favor of profit and business model short-termism of the major telecommunications operators led them to abandon their natural roles in constant innovation of the basic infrastructure. Therefore, tens of thousands of the most rich users develop and operate their "edge clouds" on the top of a global platform built by a patchwork of volunteer infrastructure, lucky cloud migrants, and access providers whose role is only to connect teachers to the hope that delivers reachability. In testimony to the lack of scaling of the old operator-provided infrastructure, consider a general user or a small business owner: to optimize for an online recommendation and sales system of potential buyers, they cannot ignore the design issues of creating a highly responsive service with low latency, low error rates and high availability. Similar factors apply to any other property that functions as a guide for multi-side platform development since they can engage their users once in a while, but cannot rely on their memory to the highly negative post-usage experience because then that would put at risk the platform profits, not to mention their growth or survival in the still early phases of building the value proposition.

But in order to achieve fast startup, high expected long-run performance, and high odds for survival, general users and businesses must choose one of the few public cloud service providers whose non-routed overlay runs on top of the existing infrastructure and that have perfected the provisioning of virtualized large-scale server farms. Hence, they can rarely escape the critical design choice of trading excess power for service redundancy and speed. This is a dramatic design difficulty because, even though forecasts predict a tripling in the number of users, statistical models can confirm that prediction, growth and traffic bursts create a disproportionate service overhead.

2.5.2. Security Concerns

In the past decades, new technology advancements became available for companies and individuals, allowing more and more communication devices to connect wirelessly to local area networks and public networks. However, the industry was unable to anticipate the security concerns that would accompany this development. Honeypots and monitoring programs deploying operations around the globe indicate an exponential increase in Evasion and System Targeting Attacks in telecommunications. As much as security corporations and agencies have investments in diversion and prevention strategies, their technology has failed to keep pace with that of the evaders and aggressors. Until today, the cyberwar floors that are dealing with Cyber terrorism and espionage, Cyber warfare, and Cyber crime are constantly demanding better security data and protection level solutions.

Current security systems available to companies are not even designed to consider or deal properly with security concerns of other parties operating in the same or similar operational environment. Words such as False Positives, Evasion Attacks, Recovery, and Adversarial Neural Networks have risen to an alarming frequency among technology suppliers and the organizations involved in Data Leak Prevention Systems, Intrusion Prevention Systems, and Security Information & Event Management Solutions. Moreover, personalities from the data security community suggest that we may only be five years ahead of already operating adversarial AI defensive systems, which would contribute silicon and software acceleration to security resources already utilized by the division and diversion industries. These exiguity expressions are hoisting a growing amount of executives on stages while carrying out security product campaigns that indicate the imminence of malicious AI usage properly orchestrated by the rogues of the world.

2.5.3. Regulatory Hurdles

One of the fundamental roles of telecommunications regulators is to ensure fair competition while preventing carriers from leveraging their monopoly power. As a result, telecommunications are some of the most heavily regulated parts of the economy. When the first generation of telecommunications networks were built in the early 20th century, they consisted of copper wires connecting sets of customers to a switching facility. Telecommunications service grew in simple ratio to the number of wire-width carriers in a fiber-sized pipe. With this kind of service, the only economic imperative to deploy any telecommunications capacity at all was to make the capital expenditure on the network profitable. In this case, the regulators are placed in the position of fire fighters, trying to adjust the market rules in the aftermath of carriers' investment decisions.

With mobile carriers owned by other nations, networks are being built. The rapid expansion of new technologies for telecommunications has mandated a rapid re-evaluation of the way service is provisioned and regulated. Artificial intelligence is transforming the limitations on the capacity of telecommunications networks, enabling bandwidth-speed carriers to treat demand as elastic. In a capitalist economy, regulatory power is justified not by the failure of the invisible hand to manage the economy, but to enhance and enhance the corrective power of the invisible hand. It is the regulators' role to enable telecommunications to fulfill its special role in the economy, to be the first among equals in the economy's ecosystem. What is most important to telecommunications regulation is the infrastructural nature of networks. It is through the provision of special, non-exclusive services to distinct customer sectors, that carriers have previously generated profitable but non-utilitarian monopolies. How will value be allocated?

2.6. Innovative Solutions for Infrastructure

Fifth Generation (5G) Telecommunications Systems have been conceived and designed to meet the punctually high demanding Basic Characteristics of Hyperconnectivity and Ad-Hoc Connectivity Usage Scenarios. In order to accomplish these demanding objectives, the 5G initiative provides a considerable number of cutting edge and state-of-the-art innovative solutions to be mixed and matched at the OpEx and CapEx adjusted demand. Among it, the introduction of millimeter wave bands and higher carrier bandwidths availability, Massive MIMO transmission technology, extreme density deployment of RAN equipment based on Small Cell solutions relying on new concepts like Cloud RAN and Network Slicing, New Virtualized Core Network Architectures enabling Service Differentiation for general-purpose services and for Critical Service like Tactile Internet and C-Aerial services, Services Security and Services Trustworthiness generation concept are some of the most advanced concepts.

Artificial Intelligence and Machine Learning solutions are part of the 5G add-on Smart Communication System Family Capability Designed to automate the 5G architecture, all with the goal of optimizing system performance and service enabling and experiencing efficiency. What is very important is that such complex and heavy loaded 5G Technology deployed Infrastructure enables the basis for the next generation of communication systems for the Telecommunication Area and scalable to Cosmo Communication System Talking about planned to be deployed in the future for the Space Communication Area based on Optical and Quantum Communication Technology. Hyperconnectivity for the future and its key economics enabler will take in lessons learned from the application and service for the Telecommunication Area, with the goal of redefining the technical details of the future solutions.

Edge Computing

Edge Computing has its fundamental primary objective in the end-user content generation and in the bringing to the user devices of the outer content/services. This new

Information Technology Concept and Solutions Concept responds to the three most important drivers for the next generation of Information Technology: Low Latency; Data localization; Privacy and Service Security.

2.6.1. 5G and Beyond

The ongoing deployment of 5G mobile systems is driven by huge market expectations, with tens of billions of connected devices, in the coming years in vertical markets, including smart cities, Industry 4.0, automated factories, factories of the future, vehicular, road and rail traffic automation, automated agriculture, e-health, telemedicine, and many more. 5G systems should build on benefits from both earlier generations, aiming at supporting up to one million new cellular-connected devices per square kilometer with both ultra-reliable low-latency connectivity for mission-critical applications and massive ordinary data transport services, including for user-dedicated high-resolution video surveillance, including 8Ks, VR, AR, unlicensed, or LYCRF for vehicular by bidirectional long-range communication and many more.

It should be noted that the perspectives for many of these vertical markets hinge onto action in a few additional design and dimensional use case vectors. These include target service cost, specific communication/networking services are often needed, be it wide-area or localized, broadband or narrowband, short, medium, long or instantaneous connection time with extremely high or very peculiar levels of reliability, privacy, selectivity, security, throughput, or delay, with task-specific physical location accuracy, error or service interruption detection and recovery time-specific, and desired device, entity, or end-user shape or mobility. System design should consider local return on investment among others.

2.6.2. Edge Computing

Edge computing is a cutting-edge design approach that aims to change data handling for communications in order to save bandwidth and maintain performance. To implement a new design, it is crucial to ensure that storage, computing, power consumption, latency, and cost at the edge are reduced by the appropriate use of different telecommunications infrastructures. As we all now know, cloud computing has grown rapidly in the needs of industry and society in the recent past with incredible consequences.

Yet the cloud may not be able to address all new demands from new smart industries and verticals, nor all demands even from some current Internet users. Many data processing and communication services would be provided better by local cloudlets with lower support technologies than the big giants of current cloud computing. For a multitude of missions with ultra-low latency conditions, user-centric applications like augmented and virtual reality systems and time-sensitive services like real-time 3D control for smart factories and utilities require processing far closer to the user. Once in the smart zone, data needs fast processing and enhanced privacy protection, especially when collecting private data.

Edge computing is a design consideration introduced recently in cloud computing to process data closer to their source and to the users, instead of routing it to centralized mega data centers. These formal or informal cloudlets distributed in the local zone of the communication are suitable for a multitude of use cases requiring ultra-low data transport latency and ultra-low data processing latency or for enhancing data privacy: smart vehicles, enhanced public safety, industry, and smart health. Here and more generally in all industries and communities, edge computing is a diversification solution that brings telecommunications towards the diversity of AI and big data with their infrastructures. Transport latency problems, data localization issues, and special processing offered at the edge need special cooperation between cloud computing and edge computing.

2.6.3. Software-Defined Networking (SDN)

Software-Defined Networking (SDN) is one of the most relevant solutions to cope with the issues presented attributed to the Magic Triangle. The SDN paradigm was initially proposed for Local Area Networks (LAN) and, in particular, for Datacenters (DC). In this regard, and with the clear objective of meeting the important requirements introduced by Cloud Computing and DCs, SDN proposed a clear separation between the data and control plane in networking, where the Forwarding Devices (FDs) were logical entities responsible for data flows saturation in routing, and where the network intelligence and control logic were logically centralized in the Network Operating System (NOS), responsible for managing traffic in the entire network through programming interfaces with the corresponding FDs.

As part of the Internet trend given its increasing complexity, Functional Disaggregation and Network Programming give rise to fundamentally new paradigms for telecommunications infrastructures in general, and for Telecommunications Networks (TN) in particular. Similarly to Data Plane IPv4 compression, so-called Network Virtualization allowed multiplexing a single Infrastructural (Physical) Network among multiple virtual logical networks, multiplexing a single Infrastructural Network into multiple virtual networks sharing the same Infrastructural Network resources.

As far as reduced costs and Network Operating System capabilities are concerned, TNs must be ordered, planned, and programmed with efficient algorithms embedded in the

Network Operating System. In this regard, TN functional disaggregation allows the development of more flexible, efficient, and low-cost solutions than TNs relying on traditional vertical integrated solutions. These new solutions are particularly convenient for TNs that might be partially planned and programmed to facilitate their operations through reduced operational costs.

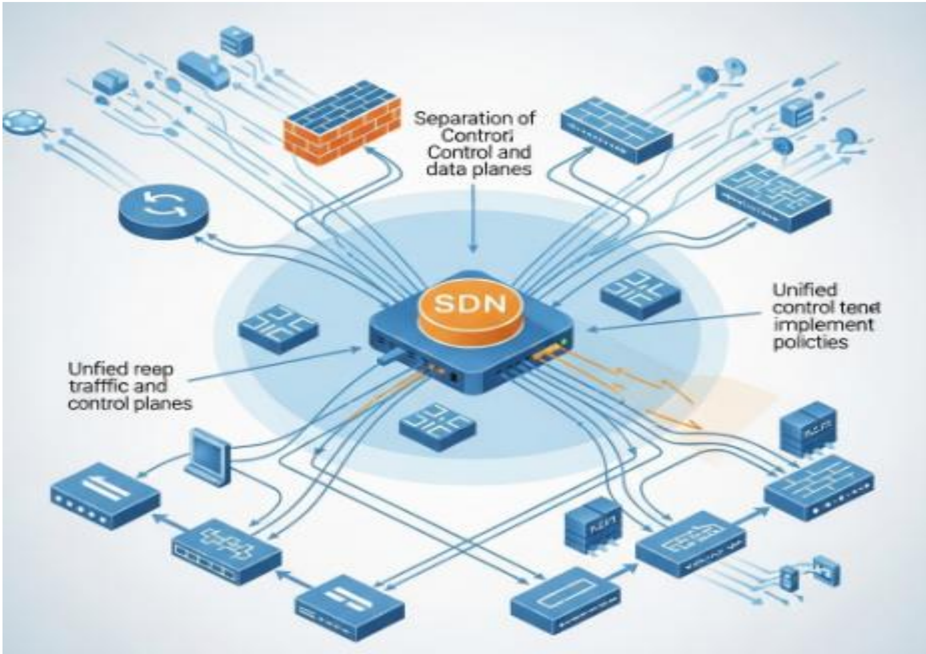

Fig 2.2 : Software-Defined Networking (SDN).

2.7. Case Studies of Successful Reinventions

It is easy to criticize legacy telecommunications service providers for being slow to respond to the urgency of reinvention; however, many of these companies are responding rapidly to avoid irrelevance in the future. Dozens of large telecommunications companies are working diligently to change their historic business models and capitalize on the emerging opportunities that are developing in conjunction with accelerating hyperconnectivity and the convergence of telecommunications, entertainment, and technology. Their first-mover advantages in physical infrastructure and size have enabled many market-leading telecommunications companies to take the meetings with the largest premise-based businesses and governments. But the speed and scale of change are creating uncertainty and opportunity everywhere.

Numerous startup companies are disrupting the once well-ordered business structure of the telecommunications industry and innovating beautifully in communities around the world. Social impact entrepreneurs with dreams of building a better world are creating municipal broadband systems, communications cooperatives, and new wireless systems that rival the performance of the existing monopolists. These new and emerging telecommunications companies are competing with the existing giants for price-sensitive consumers who are tired of the monopolists' outdated business practices, demonstrated by the links between poor customer service and market share reassignment in the rapidly disappearing legacy voice markets. Balancing the need for social sustainability with economic viability is one of the most complex challenges of the next phase of telecommunications innovation.

2.7.1. Global Leaders in Telecommunications

Our thesis argues that, in the context of hyperconnectivity and artificial intelligence disruption, successful reinvention of telecommunications companies is pre-vetted for us: it is immediately apparent in the footprint of global leaders who hold outsized value creation in the industry. Therefore we will first map out revenues and profits for the leaders in this sector and how the positioning has evolved, and then carry out a close-up study of their trajectories. In telecommunication services, we see three companies consistently and powerfully standing out in most years: China Mobile, AT&T, and Verizon. It's thrilling to build a business as big as theirs; and it's painful to continually disappoint shareholders by handing out higher dividends from the cash generated, while showing systems revenue declines year after year.

Those payments come from two-to-three times the earnings before interest depreciation and amortization margins of systems-integration and managed-services junior partners and debt levels at China Mobile, AT&T, and Verizon which are but a fraction of theirs. China Telecom, America Movil, Telefonica, British Telecom, and Deutsche Telekom show evidence that these relatively lame businesses can provide handsome returns as long as management teams perceive shareholder value to be generated by higher dividends and operating expenses are kept low — but there is only so long those companies can cover their cost of capital, and then the growth must show its head or valuations on those latter companies converge to zero.

2.7.2. Emerging Startups

As outlined in the analysis presented in the previous chapters, telecommunications infrastructure is a core enabler of the hyperconnected society. New ideas and novel approaches need to be developed and deployed, ensuring the success of telecommunications as a pioneer in the wholesale adoption of AI in society, enabling the preparation of new business domains and technologies. New players should take the lead in the rapid transformation that is required, considering technologies with low barriers of entry to market, ensuring the alignment of technology with business-enabling opportunities.

In global telecommunications, new specialized infrastructure actors are emerging in the form of startups and emerging small companies. These new entities are challenged by the legacy approaches deployed by the last thirty years in the frugal design and deployment of telecommunications networks. Nevertheless, these same companies benefit from a more favorable position to explore further outside-in design approaches opened to them by the new realities imposed by the emergence of AI, virtualized and cloud native networks, the need for extreme sustainability, being it economic, environmental, energy-based or planetary.

The telecom sectors to be invaded by these new kinds of startups are both the connectivity and the network-facilitating service segments. On the connectivity level, new exciting companies are proposing to revisit the massive last mile challenge, developing optical and wireless technologies offering high capacity, low cost and high spectral efficiency. New satellite-based approaches are creating enormous interest, alongside new LEO constellations, or solutions building on networked AI and global communication systems.

2.8. Conclusion

This chapter introduced the major foundations of the work. We detailed the particular context in which telecommunication infrastructures currently evolve, where the challenges faced have reached unparalleled peaks, and the technical means that need implementation to resolve them. Concepts like Hyperconnectivity and virtualization were described throughout the chapter, leading readers to better understand the rest of the work as well as the core goals of this chapter. The background leads to the following points at stake for the following years: the digital gap between local and developed economies is closing, Data centers become key actors of hybridized, geo-localized scenarios, and Dynamicity of controls applied on the cloud cannot happen without a massive deployment of telecom infrastructures.

Indeed, a trend gained credit in other sectors; SMEs trusted the cloud and we see that they need a better provisioning of telecom networks if the cloud players want to keep on having a primary role in the game. For us to better understand the future needs of the telecom revolution, the next chapter will describe the architecture of the telecom networks designed some fifteen years ago. The chapter will briefly survey the adaptations successively defined like NGN or IMS, their limits and what appears like tomorrow's first funds providing a new telecom model.

The entertainment value judgment is becoming more and more subjective for the users. Hybrid poles like OTT need support from telecommunications operators who still remain in charge of providing the on-, off- and mid-security levels. All the use cases from the early days of telecom until today lead to an unavoidable need for security. Telecom infrastructures cannot provide only bits and pieces of information on the secured element behind the data exchange between parties. Choosing a mid option is not enough. Providing an end solution that will allow effective transparency is crucial because players from many disparate areas will compete for the clients' trust. Indeed, many parties involved will someday account on both Telecom and OTT value chains.

2.8.1. Future Trends

The global telecommunications industry is undergoing significant and rapid transformation, driven by the convergence of several recently emerged technology trends, including increased connectivity, emerging use cases, and innovative business

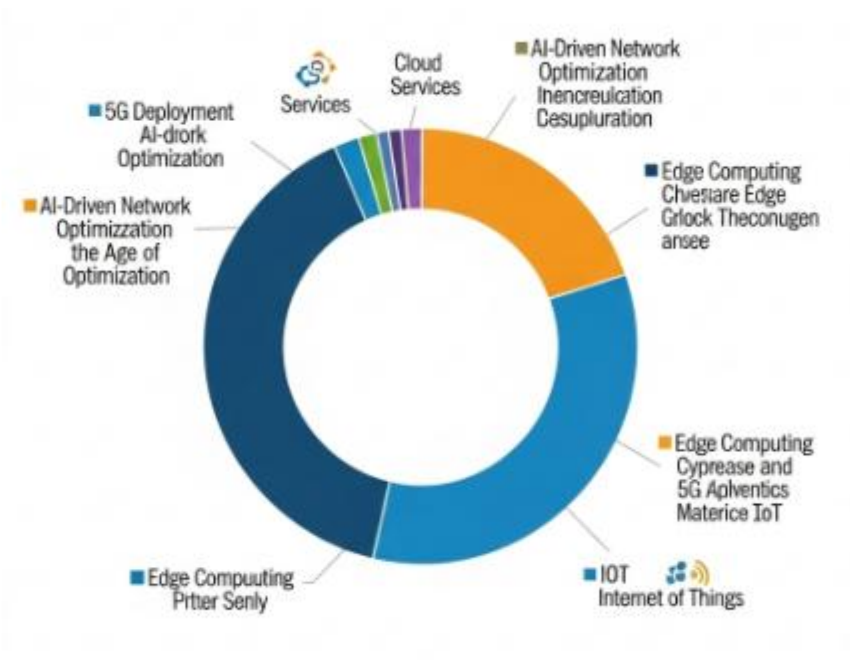

Fig : Reinventing Telecommunications Infrastructure in the Age of Hyperconnectivity and AI.

models enabled by the deployment of advanced technology infrastructure. This rapid technological evolution is ushering in the Age of Hyperconnectivity and AI, posing new challenges with respect to what infrastructure will have to look like to support growth in telecommunications services while reducing the overall carbon footprint and energy usage. It is also creating new prospects for industries and corporations from other sectors to enter the telecommunications industry, further increasing market competitiveness. As established service providers emerge as the leaders in the hyperconnected world, they will be joined by ambitious digital service providers looking to capture new market opportunities or disrupt the business of traditional telecommunications service providers. These emerging players are intent on creating innovative, differentiated service offerings, enabled by effectively deploying the underlying hyperconnected technology stack, and in some cases proactively entering new vertical markets.

This new competitive dynamic will impact the architecture and design of telecommunications infrastructure over the next several years. Some of the growth opportunities for companies and other corporations from other industries will come from harnessing the intelligent edge—linking man, machine, and process by treating data more as an asset—and capitalizing on the heightened importance of trust in the digital economy—balancing new desires for privacy and security with technologies to help ensure success in entering and flourishing in the Age of Hyperconnectivity and AI.

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