360⁰ VIEW ON ZERO-TOUCH (ZERO-TOUCH) NETWORKS

Somayya Madakam[1], Shlomo Mark[2], Yotam Lurie[3]
[1]Atlas SkillTech University, Mumbai (India), [2]SCE Shamoon College of Engineering, Ashdod, (Israel), [3]Ben-Gurion University of the Negev, Beer Sheva (Israel)

NOTE: Corresponding author: Somayya Madakam, somayya.madakam@atlasuniversity.edu.in

Abstract *– In modern telecommunication sectors, zero touch (Zero-Touch) networks are a novel idea. A combination of quick, context-aware network and service configuration, adaptable new service development, and dynamic, effective resource allocation are required for everyone. An innovative telecommunication management software, Zero-Touch Networks (ZTNs), were released to address these complicated conditions. The primary objective of the zero-touch network is autonomous operation, which is governed by higher layers of policies and regulations and allows for self-configuration, self-monitoring, self-healing and self-optimization without the need for human interaction. This conceptual study document is based on white and grey literature in the Google and Web of Science databases. Text, image, audio and video formats all existed for the data. The manuscripts examined the theories, enabling technologies, problems and difficulties associated with zero touch networks. The primary goal of this manuscript is to provide an overview of ZTN so that aspiring academics, researchers, students and businesspeople can profit from it.*

Keywords – *Zero-touch, zero-touch automation, zero-touch management, zero-touch network and service management, zero-touch networks, zero-touch operations, zero-touch provisioning, zero-touch service and network management*

1. INTRODUCTION

The 21st century is overflowing with cutting-edge, disruptive technologies that, despite being intended to enhance living quality, fundamentally alter it. The list of new technological advancements that the tech giants are continuously funding and putting effort into for improved business operational efficiency includes Artificial Intelligence (AI)/ Machine Learning (ML), deep learning, big data, data lakes, edge/fog computing, Internet of Things, 5G, Fintech, blockchain, robotic process automation, and so forth. In keeping with this, the business community is talking about "Zero-Touch Networks," a new buzzword for fully automated network management technology. By using cutting-edge ML capabilities, zero touch networks' end-to-end automated and self-healing technology not only detects systemic issues but also automatically repairs them. Automation is an ancient idea that has been used to manage processes for many years. The automation process was introduced in the manufacturing sector approximately a century ago, for example, in the industrial engineering and automobile industries. A few years later, the industry developed "RPA," a sophisticated automation technique in which all the repetitive processes are replaced by automated software. To cut costs and improve operational efficiency, the outsourcing sector, human resources divisions of financial institutions, telecommunication firms and insurance organizations all embraced this technology early on. Instead of wasting time on mundane tasks, this technology saves labour and frees up human resources to develop innovative solutions. Many businesses and industries are currently attempting to use the benefits of robotic process automation technologies. The sister technology of RPA, known as hyper-automation, is again being discussed. With the use of AI/ML and RPA, even complicated processes in cyber-physical systems can be automated. Now, "Zero-Touch Networks" is another technology that the big telecommunication technology companies have introduced. The concept behind "Zero-Touch Networks" is the complete automation of all network operations. The technology underlying this is the intelligent automation of telecommunication procedures. Automating telecommunicating systems for Communication Services Providers (CSPs) is made possible by "Zero-Touch Networks". Moreover, the next section will include the literature review, the need for the study, the web of science analytics and the different technologies behind this phenomenon. Mainly intensifying on methodology, as the topic falls under contemporary issues, this research comes under an exploratory study: Further to this is the thematic narration of literature and future challenges on ZTNs. Finally, the conclusion stresses future directions of the ZTN.

2. RESEARCH METHODOLOGY

The term "Zero-Touch Network" is new and refers to a modern phenomenon. Consequently, an exploratory study is necessary to grasp this idea entirely. Only a few pieces of white literature, such as conference proceedings and journal articles, as well as a small number of grey literature sources, such as blogs, wikis and YouTube videos, are available on the zero-touch network. The contribution of this study is twofold: it not only provides a synthesis and overview of the grey literature, something which is important in engineering fields like IT since tech professionals are constantly coming up with fresh ideas for new hardware and software solutions but the methodology used is a powerful tool contributing to the research by bringing to the fore the most comprehensive selection of grey literature available at this time. While not receiving the same scrutiny as white writing, grey literature has recently gained acceptance in the academic community. So, a few online portal blogs and YouTube content about "Zero Touch" are also considered for the narrative of this piece. The information was gathered in four different media formats, including blogs, images, videos and pdf files, as well as both white and grey literature. Data was collected between 1 November and 31 December, 2021. This conceptual-literature study can be a foundation for new researchers (budding), network specialists and telecommunication suppliers to expand their understanding in this area.

3. RESEARCH NEED

The rapid expansion of mobile devices and the development of new services were the impetus for introducing virtualized networks. Regarding the service agility and elasticity of 5G networks containing Internet of Things (IoT) devices, virtual networks are set to play a crucial role. With over 50 billion connected IoT devices, as per Cisco's Cisco Business Solution Groups (CBSE), data is continuously transmitted through cutting-edge Internet technology to the relevant central nodes and vice versa for completing tasks in various networks, including intra-networks and extra-networks. This data transmission uses a variety of forms. Using RFIDs, sensors and social networks connected to local, metropolitan, state or global area networks, data is transmitted at a very high rate of yottabytes per second. In large telecommunication networks, the full-duplex mode is used to share a lot of business communications, video streaming, remote work, integrated software data access, cloud data, financial operations, supply chain management and digital commerce payments data. There are numerous intricate communication procedures between various telecommunication service providers, physical data cable layout procedures from businesses to customer locations, including dirty environments, detailed slicing procedures, unintentional cabling faults at underground/duct locations, and interoperability between telecommunication hardware and software for on-time data delivery. Integrating these products with communication service providers like AT&T, Comcast, Reliance, Bharti Airtel, and other vendors is complicated by the numerous suppliers' heterogeneous telecommunication products and services and closed-source and open-source technologies. It became difficult to handle network management, from physical cabling through fault detection to fixing network problems for efficient communication. Several telecommunication engineers, ISP providers, network engineers and telecommunication operators were left perplexed by this. They had to reevaluate their unique network solutions before developing the cutting-edge "Zero-Touch Network" technology. As a result, the European Telecommunications Standards Institute (ETSI) Zero-Touch Network and Service Management (ZSM) [1] working group has made Zero-Touch Management (ZTM) a hot topic in the current process of network standardization. A potential solution to the problematic network provisioning and infrastructure service deployment procedure is the Zero-Touch Provisioning (ZTP) idea [2]. With the development of virtualized, software-based mobile networking, which requires advanced network visualization and automation solutions to accommodate this fundamental paradigm change, network administration has become increasingly difficult [3]. So, it is the need of the hour of automation.

4. WEB OF SCIENCE ANALYTICS

One of the most famous scientific databases for all fields in academic institutions and the corporate world is the Web of Science (WoS). Together with Scopus, PubMed and other databases that are accessible internationally, this database serves various purposes for obtaining conceptual, literary, empirical and editorial communications. As a result, the authors utilized the keyword "Zero-Touch Networks" as search terms in the Web of Science

databases to find research publications on the "Zero-Touch Networks" phenomena. Unfortunately, the database only contains 21 manuscripts. This demonstrates that the phenomena are still in its infancy and that more scientific study will come. The total number of citations for these 21 papers since their initial publication is 60. The average number of sources per manuscript is 2.86, and the articles' h-index is 4. The manuscripts and their data are included in Table 1 (by year), Table 2 (by publisher) and Table 3 (Document types). Tables 1, 2 and 3 were taken from the Web of Science databases to comprehend the publishing analytics. Also, it can be deduced from Table 1 that academic research began in 2015, slowed down in 2018 and then picked up in 2019 with another two publications. 2020 has a sharp increase in comparison to other years. Unfortunately, the year 2021 will not see as many publications as the year before. In contrast, Table 2 shows that IEEE published 20 of the 21 articles, while Elsevier only managed to produce one. This demonstrates how IEEE has always been a technology leader in zero-touch networks. Also, the publishers should consider including research on zero-touch networks, in particular issues and even regular submissions. Scholars must advance their studies on this idea in the upcoming years. In addition, as shown in Table 3, of the 21 publications, 17 articles were included in conference proceedings, while just four submissions were published in journals. To better understand the "Zero-Touch Network" state-of-the-art study, the database also contained figures 1 (Country), 2 (Publishers) and 3 (Authors).

Table 1 – Publications by year

Year	**Publications**
2021	7
2020	9
2019	2
2018	2
2015	1

Table 2 – Publications by publisher

Publisher	**Publications**
IEEE	20
Elsevier	1

Table 3 – Publications by publication type

Document type	*Publications*
Proceedings papers	*17*
Articles	*4*

Fig. 1. demonstrates the number of nations and their involvement in "Zero-Touch Networks" research and publications. We know that a country's level of development can be determined by how much Research and Development (R&D) is conducted, how much money is allocated, and how many creative goods and solutions are discovered. Spain has published eight articles on this research topic, compared to four for Japan and four for the United States in second place, along with three each

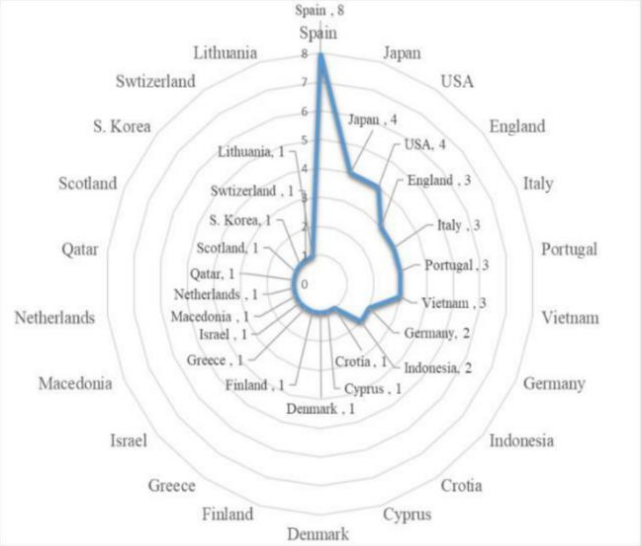

Fig. 1 - Countrywide publications

for Italy, England, Portugal and Vietnam. The phenomenon is only very slowly catching up with the rest of the world. Among them are Croatia (1), Cyprus (1), Denmark (1), Finland (1), Greece (1), Israel (1), Macedonia (1), the Netherlands (1), Qatar (1), Scotland (1) and South Africa (1). According to the most recent database, which is seen below, Korea (1), Lithuania (1) and Switzerland (1) are the top three countries. Yet, this demonstrates that the phenomenon is still in its early stages and that there is still more to be done regarding "Zero-Touch Networks" research, design and deployments by various nations.

The number of articles is shown in Fig. 2 according to the Web of Science's subject-specific categorization. Even though there are 21 publications in Fig. 2, there are various subject representations of the same article here according to subject-wise categorization. Because of this,

there are more than 21 articles in this subject category, even though there are only eight categories. Fig. 2 displays the subject's specifics and the number of papers. It was noted from the graph that the idea is more closely tied to telecommunications and has strong connections to electrical and electronic engineering; although it was computer science that established the automated process. The slicing procedure is represented in the publications with optics.

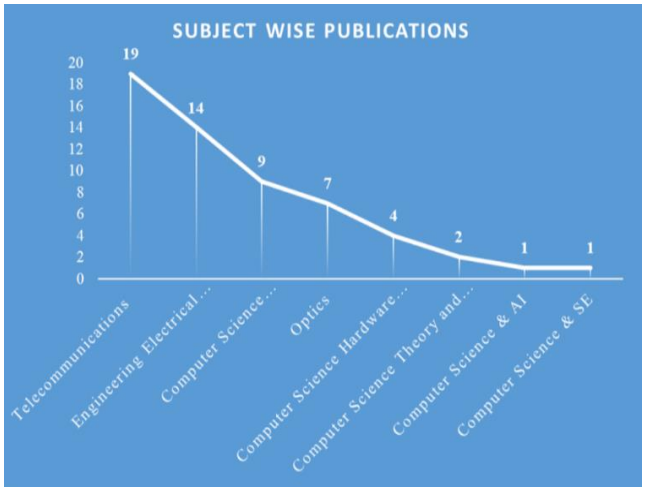

Fig. 2 – Publications by subject

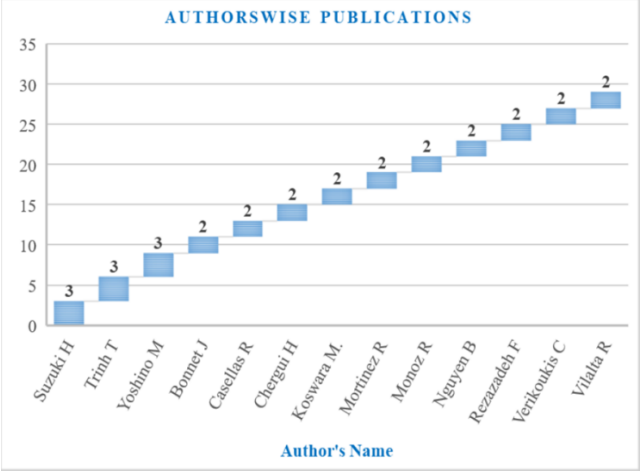

Fig. 3 – Publications by author

There are not many author publications because the idea is fresh. Yet, researchers like Suzuki H. (3), Trinh T. (3), Yoshino M. (3), Bonnet J. (2), Casellas R. (2), Chergui H. (2), Koswara M. (2), Mortinez R. (2), Monoz R. (2), Nguyen B. (2), Rezazadeh F. (2), Verikoukis C. (2) and Vilalta R. (2) began their studies on this idea. This demonstrates the enthusiasm of these authors for this study.

5. KEY INSIGHTS FROM LITERATURE

The term "Zero-Touch Networks" is commonly used in the telecommunications sector. Zero-touch technology is still little discussed though. Less writing was done by researchers in the form of books, book chapters and journal articles. Even a few webinars were held during the pandemic by telecommunication engineers, industry professionals, policymakers and academics. This suggests that this idea is a recent one. It is a cutting-edge telecommunications industry solution designed especially for communications service providers (CSP). To maximize the virtualization functionality, zero-touch networks' solutions are software-based rather than hardware-based. According to Anodot's study, autonomous networks that can heal and adjust themselves are called "Zero-Touch Networks" or simply "ZTNs." All network actions are based on the signals in the data they gather and analyze. Instead, "Zero Touch" refers to automation that monitors 24/7 networks and services and fixes errors with minimal human involvement. Zero-touch networks eliminate human intervention while minimizing operational expenses and service outages [4]. This technology's features include early problem identification, autonomous learning, problem solving, decision-making and support for various telecommunication network optimization goals. The entire telecommunications business is benefiting greatly from this technology, as is customer pleasure. Zero-touch is described using a variety of technical terms by both academic researchers and major players in the industry, including zero-touch automation, zero-touch provisioning, zero-touch management, zero-touch operations, zero-touch service and network management, and zero-touch network service management. In terms of managing telecommunication networks and infrastructure, this event represents a paradigm change: the ETSI-proposed Zero-touch network and Service Management (ZSM). The ZSM group was introduced by ETSI in December 2017 to speed up the definition of the necessary architectures and solutions. Zero-touch networks and service management are gaining popularity quickly, as per research [5].

Everyone needs quick, context-aware network and service configuration, adaptable new service development and dynamic, effective resource allocation. To create intelligent and autonomous

orchestrators, telecommunication research communities increasingly attempt to incorporate ZSM goals [6]. ZSM, which stands for the next stage of automation, is an all-encompassing framework for network orchestration that relies on data-driven AI and runs without the assistance of a human [7]. To accommodate the needs of numerous consumers and vertical businesses, a ZTN is built using cloud and SDN technology, according to Van Rossem et al. (2017) [8]. Zero-touch networks are designed to deliver various autonomous ICT services, infrastructure and capabilities with zero-touch based on being fully integrated, self-serving, self-fulfilling and self-assuring to automatically meet and respond to client requests and resource availability. The zero-touch concept includes more steps after the initial bootstrapping and configuration of network devices, which enables zero-touch provisioning of new additions to the network. A cloud-native Open RAN system must include automated orchestration and management to be effective. The process of setting up a radio site or provisioning a service follows the infrastructure setup. Zero-Touch Provisioning (ZTP) is an automated process that requires no manual involvement at all to deploy a service. In contemporary, dynamic Open RAN contexts, ZTP enables the development of agile, flexible, elastic and efficient applications. Key benefits are:

- automates software installation and configuration
- decreases complexity
- reduces time, errors and costs
- relatively safe for RAN installation
- easier to deploy many sites, as no site visits are needed.

ZTP allows carriers to open network lines and automatically activate various services without operator involvement [Yoshino et al., 2020]. According to another study, zero-touch network Slicing (NS) is seen as a promising fully-automated Management and Orchestration (MANO) technology that can help B5G communication systems reach their full potential [9]. The monitoring systems, according to Gartner, a technology research and consulting firm with headquarters in Stamford, Connecticut, undertake three processes: (1) observe; (2) engage; and (3) act. The technologies that provide these three characteristics end-to-end are known as zero touch, according to Gartner. With AI, network administration can become a cognitive process that allows the network to self-adapt and self-react to change conditions with little to no human involvement (zero-touch) [10].

Monitoring telecommunication networks has advanced so much in the past five years [11] that autonomous remediation will overtake other features when the industry's top communication service providers (CSPs) adopt it. Through three crucial steps, including (1) anomaly detection, (2) correlations and root cause analysis, and (3) remediation, Artificial Intelligence (AI), Machine Learning (ML), and mainly unsupervised machine learning, enable the transformation of traditional communication network and service operations towards automation and intelligent operations. These autonomous monitoring tools are a crucial idea on the path to digital transformation for telecommunications (CSPs) and other verticals using exceedingly complex systems. For telcos to fully utilize their networks, which are already quite tricky and will only get more so in the future, end-to-end network and service monitoring and automation are considered crucial. All operational procedures must be entirely automated without any human involvement. The flexibility and efficiency offered by zero-touch automation of network and service management allow for the quick creation, customization and distribution of new services while avoiding expensive operational mistakes. For instance, M/s. CSPs can deliver their services 10x faster and with greater flexibility, thanks to Inmanta. The working process is automated and streamlined using Inmanta's intent-based service orchestrator. The whole service lifecycle is managed by Inmanta. Service design, onboarding, testing, deployment, upgrading and decommissioning are all included in this functionality, which also supports monitoring, analytics and rules. Each type of resource specified in the service model has management support in Inmanta. The ultimate ZTN's main objective is autonomous operation, which is managed by higher-level laws and regulations and allows for self-configuration, self-monitoring, self-healing and self-optimization without human interaction.

Some abstracts for zero-touch network concepts, methods and practices from various academic researchers are shown in Table 4. These publications explore a variety of tools and technologies, including AI, 5G, CellOS, software-defined networking (SDN), fibre to the home (FTTH) and multicast dissemination protocol (MDP), to mention a few. Moreover, there needs to

be incisiveness of all disciplines for firms, government agencies and corporates for better automation of companies for operational efficiency.

Table 4 - Important literature

Authors	*Abstract of the manuscript*
Demchenko, Yuri, et al. (2015) [2]	The purpose of this paper is to examine the characteristics of the ZTP model and to determine whether ZTP can enhance the services offered by the GEANT network and its associated National Research and Education Networks (NRENs) to the European research and education community.
Andrus et al., (2019) [12]	The authors in this paper discussed automated network service provisioning and virtual network function orchestration, which are demonstrated using P4-based VNF acceleration. Zero-touch provisioning of distributed computing resources at the edge and central office is validated with a video analytics use case.
Benzaid and Taleb (2020) [13]	The authors mainly focused on introducing zero ZSM. It has also highlighted the AI-based boundaries and risks associated with it, in order to make ZSM a reality.
Sanchez-Navarro et al., (2020) [3]	This paper presents a novel holographic immersive network management interface to extend the ETSI Zero-Touch Network and Service Management (ZSM) reference architecture to allow network administrators to view real-time automated tasks in a 5G network without the need for any human interaction.
Carrozzo, Gino, et al. (2020) [14]	The authors clearly depicted the concept of zero-touch security and trust architecture for ubiquitous computing and connectivity in 5G technology networks.
Bonati, Leonardo, et al. (2020) [15]	In this paper, the authors introduced CellOS, a completely automated optimization and management framework for cellular networks that requires little intervention (Zero-Touch). CellOS relies on softwarization and automatic optimization techniques to be able to bridge SDN and cross-layer optimization.
Yoshino et al., (2020) [9]	Authors proposed and examined multi-service activation procedures for telecommunication carriers' zero-touch provisioning workflows based on network virtualization technologies.
Rezazadeh et al., (2020) [16]	The authors of this paper addressed the problem of cloud-RAN joint slice admission control and resource allocation by first converting it into a Markov Decision Process (MDP).
Nejabati et al, (2021) [6]	The authors describe a zero-touch network orchestrator that provides an automated end-to-end orchestration platform for orchestrating, monitoring and profiling network services.
Trinh, Tri, et al., (2021) [17]	Researchers have proposed a novel server design implementing Fibre-To-The-Home (FTTH) Zero-Touch Multi-service Provisioning (ZTMP), which is gaining widespread attention from telephone companies (Telcos), particularly the Vietnam Post and Telecommunication Group.

6. BACKBONE TECHNOLOGIES

Due to numerous sophisticated related technical advancements like 5G technology, big data, IoT and artificial intelligence/machine learning being used at the back-end level for automation, the necessity for zero-touch network solutions and their advances is growing. By making other telecommunication processes that are not fully automated seem complex because they cannot be handled effectively in terms of better slicing, self-configurations, fault detections and healing, and reducing human interventions, the tech industry believes that these technologies helped to spark a lot of the zero-touch technology.

6.1 5G technology

Another fundamental leap in telecommunications is 5G technology. High data transmissions are continuously occurring from one network to another network as the adoption of smart mobiles, smart gadgets and computers increase for both personal and business use. Another area covered by IoT in communications is the communication of physical items. As a result, enormous amounts of data are continuously transported over networks from various devices, formats and networks located in multiple locations. "5G" has started, and countries are beginning to employ this technology to embrace these complicated data transfers more smoothly. The 5G physiognomies include high-speed data transmissions (up to 10 Gbps data rate), extremely low latency (1 millisecond rate), 1000x capacity per unit area, and 100% coverage with minimal energy usage in network communications.

6.2 AI and ML

Both AI and ML technologies can effectively automate the network management process with the help of supervised learning, unsupervised learning, reinforced knowledge, and many other algorithm techniques. Below is a summary of some empirical studies that have been done using fully-automated network management procedures without manual involvement. A network can self-adapt and self-react to changing conditions with minimal user intervention (zero-touch) when AI governs the network [14]. Network orchestrators are intended to make the idea of zero-touch networks a reality by executing specialized AI solutions [18]. In their landmark publication, Theodorou et al. (2021) [19] developed a unique zero-touch method for cross-domain network slicing service assurance combining enterprise blockchain and a closed-loop automation architecture driven by AI. In multi-tenant Beyond 5G (B5G) networks, resource management and orchestration may now be automated thanks to AI-driven zero-touch network slicing. Moreover, the three pillars of AI, ML and DL are seen as the base of zero-touch networks. This is because they enable systems to be more efficient and autonomous.

6.3 Internet of Things

Nowadays, everybody is whispering about the latest technology, "The Internet of Things". Kevin Aston at MIT, USA, invented this technology in 1999 [20]. Later there were many IoT innovations, such as LG first connected the fridge to the Internet in 2000. The first time an IoT report was released at the WSIS conference was in 2004. ITU also released the importance of IoT in 2005. The Internet Protocol Smart Objects (IPSO) alliance was formed in 2008 for the international standard IoT products, their interoperability development and standard procedures for material communications, including electronic devices in cyber-physical systems. The release of IPv4/v6 took place in 2011. We are living in IoT environments. This implies that even physical things are also connected to the Internet. For example, some governments are using RFID or sensor technologies for tracing the movements and life of certain animals, such as tigers, lions, elephants and apes, to name a few, in zoological parks for better ecological systems. Digital commerce companies in logistics use GIS/GPS technologies for vehicles and driver tracking during supply chain management. GE, Siemens, Philips and Johnson & Johnson companies use EPC or barcodes for product identity in the inventory and sales process. In our personal lives, we connect the home appliances of the fridge, gas, fans, fridges, bulbs and doors to smart devices to control remotely.

6.4 Big data analytics

Data is crucial for all types of business, and big data is another industry concept that emphasizes this. There was once a heated discussion surrounding big data. We know that there are numerous linked devices, sensors, self-driving cars and smart home appliances in the IoT world. These gadgets not only continuously generate enormous volumes of data but also communicate with various computer networks at rapid speeds. As a result, data transmissions are becoming overloaded in speed, latency, interoperability and timely data delivery during the broadcasting process. The communication service providers develop unique telecommunication-level solutions due to the data flow, the 4V features of big data (volume, variety, velocity and veracity). Big data analytics is the prime factor for zero-touch networks.

7. CHALLENGES AND ISSUES

Even though zero-touch technology has several benefits for telecommunication and network management processes, such as slicing, configurations, defect detections and data transport to the proper destinations 24/7, CSPs, telecommunication experts and ISP are still unaware of its potential. Of course, no technology is accessible and this one is expensive in terms of CAPEX and OPEX, but it will pay off in the long run if you invest in it. Together with significant telecommunication oligopolies like AT&T, Verizon, Nippon Telegraph & Telephone, T-Mobile US, Vodafone Group PLC, Telefonica SA and Deutsche Telekom AG, several startup businesses may introduce innovative zero-touch technologies. The automation procedures can only be made better by zero-internationally touch's standardized products. The various zero-touch products, regarding middleware, software and hardware, provide yet another significant problem. In the upcoming years, there might be a proliferation of zero-touch automation software, yet interoperability problems might be unavoidable, like with other technologies. Security problems also significantly harm telecommunication networks' physical and virtual surroundings. In the future, physical security and backup mechanisms will be required. In these complicated situations, the use of innovative

security techniques like zero trust for encrypted communications. The telecommunication business needs to be conscious of zero trust and their moral behaviour. The security for network management systems is implicit in the use of zero-touch networks. However, most current security risks are linked to expanding IoT devices, cloud-based services and mobile-based services. Therefore, to protect not only the network but also the privacy and integrity of data, zero-touch network services must be covered by extra security measures; when combined, DLT, another important supporting technology, can offer the level of security required to implement zero-touch networks. Moreover, the technology providers need to work on issues related to anomaly detection, correlation, root cause analysis, remediation and even on Zero Touch Architectures (ZTA).

8. CONCLUSION

In the manuscript, Web of Science analysis summarizes that little literature is available, but the need for zero-touch networks is growing exponentially. The study argues that for the zero-touch software development team to embed ethical design, interoperability and high security from the start and ultimately result in self-slicing, self-configurable, self-fault detection. Self-healing in the telecommunication infrastructure without manual interventions, the CSPs and telecommunication network administrations should provide precise specifications. The core of the excellent Zero-Touch Networks solutions created globally by many software engineers to effectively handle network functionalities may be found in minimal quantities. This automated technology not only lightens the load on CSPs but also wholly satisfies customers. For better and more reliable Internet connections, all researchers, telecommunication engineers, developers and politicians must work together to create high-quality ZSN products and solutions. Zero-Touch Networks (ZTN) operations are designed to be future-ready by utilizing new technologies, reducing manual tasks and fostering business agility. The study recommends that future research should include international standards and procedures on zero-touch networks and specifically privacy and security mechanisms-related products and services. Continuous incremental evolution rather than sparse, significant modifications strengthens the infrastructure in zero-touch networks. Let us hope full pleadged ZTN in the coming years.

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AUTHORS

Somayya Madakam, Fellow (NITIE, Mumbai), MBA, B. Tech. Dr Somayya Madakam is currently working as an associate professor at the School of Technology (uGDX) at Atlas Skilltech University, Mumbai (India). Before this, he had done his postdoctoral research programme on "Zero Trust Architectures" at Ben Gurion University of the Negev (Israel). He also worked for FORE School of Management, New Delhi, as an assistant professor (IT) for 3.8 years. He was associated with the Tata Institute of Social Sciences (TISS), Mumbai, as a systems analyst-cum-programmer for six years. His research interests include IoT, RPA, AI, zero trust architectures, blockchain and smart cities. He has bagged circa 2600 citations for his academic research work since 2014. His Google H-Index is 13 with google scholar citations more than 2700. He is an evangelist on "New Language of Publications".

Shlomo Mark, Ph. D, M.Sc., B.Sc., is currently the dean of the Faculty of Engineering at SCE Shamoon College of Engineering, Ashdod campus, and he is an associate professor of software engineering at SCE. He leads, together with Prof. Yotam Lurie a research group on the ethics of technology and the process of developing technology dealing, among other things, with cloud technology, Internet of Things and the ethics of Artificial Intelligence related to medicine and ageing. His main research interests are agility, quality, software lifecycle and computational modelling for physical and medical applications.

Yotam Lurie, Ph. D, MA, BA, is an associate professor of business ethics in the Department of Management at the Ben-Gurion University of the Negev in Israel. He served as the chair of the Department of Management and the academic director of the Executive and International MBA Programs at the G. G. Faculty of Business and Management. He was a Fulbright Scholar at the University of Illinois, Urbana-Champaign, where he earned his Ph.D. in philosophy. He leads, together with Prof. Mark, a research group on the ethics of technology and the process of developing technology dealing, among other things, with cloud technology, IoT and the ethics of AI related to medicine and ageing.