International Journal of Computational and Electronic Aspects in Engineering
Volume 4, Issue 3, September 2023, pp 68 - 77
https://doi.org/10.26706/ijceae.4.3.20230903

Software Defined Networking towards 5G Network

Abhita Gokhale[1*], Labdhi Gada[2], Kolambi Narula[3], Amol Jogalekar[4]

Dept. of Computer Science, Mithibai College of Arts , Chauhan Institute of Science and Amruthben Jivanlal College of Commerce and Economics, Mumbai University Mumbai, India

abhita.gokhale@gmail.com[1], labdhigada12@gmail.com[2], kolambi376@gmail.com[3], amol.jogalekar@mithibai.ac.in[4]

[*]Corresponding Author Email: abhita.gokhale@gmail.com

Abstract—With increased importance of mobile networks and their expected ability to be user-centric puts strain on the current mobile networks. To tackle this, 5G networks will beused which offers user-oriented operation at effective costs with excellent infrastructure capabilities which can deal with heavy network traffic. Along with this, 5G networks will be useful in varied fields - from business use cases to medical ones. SDNtechnology has certain components which can be integrated with the 5G network following proper analysis and after realizingits proper applicability. The 5G network coupled with SDN will bring out some outstanding innovations in the network and its infrastructure. Leveraging SDN and NFV architecture as well as technology to build effective 5G networks is highlighted inthis paper. SDN simplifies the network complexity because ofits existing framework which suits the network framework in discussion. This paper summarizes the different approaches taken to achieve the above said aim. The primary focus remains using SDN for 5G networks and utilizing related technologies to getthe best result.

Keywords : Software Defined Network (SDN), Network Function Virtualization (NFV), 5G, Mobile Networks

Article – Peer Reviewed
Received: 17 June 2023
Accepted: 12 August 2023
Published: 12 September 2023

Cite this article: Abhita Gokhale, Labdhi Gada, Kolambi Narula, Amol Jogalekar, "Software Defined Networking Towards 5G Network", *International Journal of Computational and Electronic Aspects in Engineering*, RAME Publishers, vol. 4, issue 3, pp. 68-77, 2023. https://doi.org/10.26706/ijceae.4.3.20230903

1. Introduction

In recent years, the 4G mobile communication technology has been effectively running in various nations. When it comes to higher devices which have high mobility, now the industry's attention is on fifth-generation mobile systems and technologies related to it have become one of the most popular topics of research. Security, resiliency, data integrity and robustness are the primary priorities in the design of 5G networks. There is a growing interest in academia and industry to apply SDN to the next generation of mobile networks 5G. Software-Defined Network has emerged as an architecture for network architectures which offers multiple functionalities.

The 5G technology is still under process and requires more research on it. SDN will be the key component for 5G. The main component of the network architecture is to support the new requirements of the powerful wireless communication which can be implemented by Network Function Virtualization and Software-Defined Networking. To effectively meet the growing demand for network capacity, where spectrum resources are still in short supply, is a significant problem in the 5G era. Future networks, for example, are anticipated to be able to manage the difficult operational context characterized by a tenfold increase in traffic with ensured quality of service (QoS). Energy efficiency has been identified as a crucial problem since providers are continually concerned about operating expenditures (OPEX), the influence on changing climate, and air pollution. The 5G network, a much anticipated one, is said to revolutionize networking.

It not only promises improved speed, reach and accessibility with a primary goal of being user-centric; but also proves meritorious for industries like healthcare, automobile and energy amongst many others. In order to provide these services, a 5G network must be capable of handling accelerating network traffic volume, network flexi- bility and omnipresent services taking into consideration the ever-increasing integration needs. Further 5G networks should support extensive integration of heterogeneous infrastructure, all at a reduced cost. Such a network requires a strong architecture which can be facilitated by the use of SDN and NFV known for supporting flexibility and scalability and can help acknowledge the challenges these networks may face. The NFV architecture is capable of supporting the 5G network challenges as well as provides exceptional ways of virtualization, which shall be highlighted later in the paper. Similarly, the SDN architecture primarily facilitates flexibility, cloud security, efficient resource allocation amongst other advantages.

With providing QoS - a user-centric specification, comes the need for efficient resource allocation which was proposed to be provided by virtualization and resource isolation and management. This however poses some challenges in implementation.

2. SDN ARCHITECTURE

SDN architecture solves problems faced by traditional net- works making it all the more useful for the 5G network. It generally has a programmable architecture which offers a central view of the network. This architecture consists of a Control plane, Data plane, Application Plane and ManagementPlane.

2.1. Data Plane

Data planes consist of flow tables which define or state the routes to be used for forwarding flows (from their incoming source to destination). Thus, switches - a network forwarding component- are a part of this plane.

2.2. SDN Controller

The controller instructs the data plane on how to modifyor forward data planes. Further, data planes use a lower-level communication protocol, this conversion to a lower-level is done by the controller. Hence the controller is also considered to be central to the network

2.3. Application Plane

SDN offers an abstracted global view of the network which can benefit the application plane. This is because the application plane consists of network service are split up into individual VNFs can work together to form a virtual router.

2.4. Management Plane

This plane handles tasks which are better executed outside the above-mentioned components. Its tasks include setting up the network parameters and/or configuration. However, the management plane should not be programmable from outside to prevent network attacks and hence should be isolated and not visible to the user.

2.5. North-bound Interface (NBI)

NBI can be used for authentication and authorization of applications. It is an interface between the application and SDN controller and makes network resources accessible from the application level. The South-bound Interface (SBI) directly connects the network forwarding elements to the applications. Certain applications may require different behaviour of the controller which may increase the complexity of the SDN network. Thus, proper management of the network is required which can be enforced via the management plane, in the controller or as a distinct application.

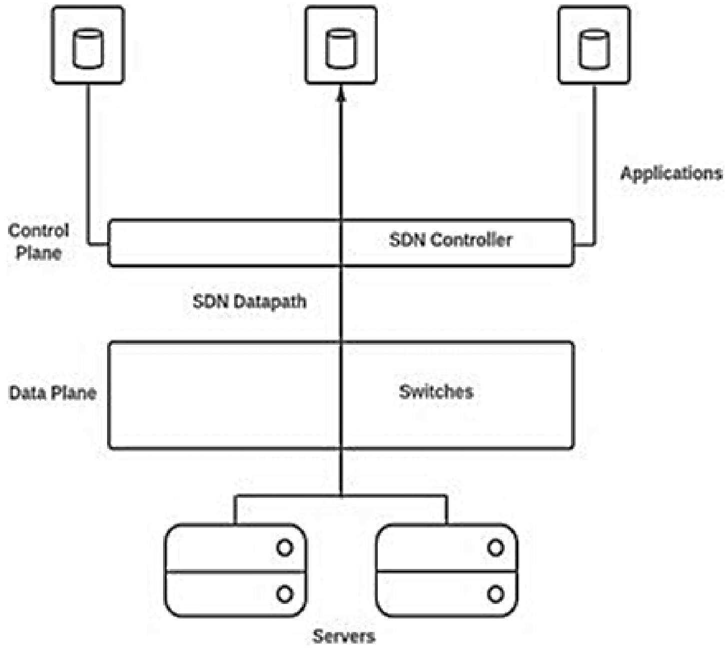

Figure 1. Architecture of SDN

3. NFV ARCHITECTURE

3.1. Virtualized Network Function (VNF)

The building block of an NFV architecture is a VNF. It isa component of a virtualized network. For instance, we referto base station virtual network functions (VNF) and router VNF if a router is virtualized. The term ”VNF” refers to a network element that has even one sub-function that has been virtualized. For instance, in the case of a router, distinct routerfunctionalities that are split up into individual VNFs can work together to form a virtual router.

3.2. Element Management(EM)

The functional administration of VNF using FCAPS is handled by the VNF element management system (Fault, Configuration, Accounting, Performance and Security Man- agement). Through exclusive interfaces, the VNFs might be managed in this way. Each VNF may have its own EMS, oran EMS may be able to oversee several VNFs. A VNF can even be an EMS system.

3.3. VNF Manager

One or more VNFs are under the control of a VNF Manager,who also oversees the cycle of VNF instances. VNF life cycle management includes installation, upkeep, and decom- missioning. The FCAPS is further carried out by VNFM (VNFManager) for the virtual portion of the VNF. It is importantto understand the distinction between EM and VNFM. The monitoring of functional components is handled by EM. The administration of the virtual components is handled by the VNFM. An illustration would help to clarify. If Mobile Coreis virtualized, the EM will manage the functional portion (for instance, problems with mobile signalling, whereas VNFM will control the virtual portion

3.4. Network Functions Virtualization Infrastructure (NFVI)

VNFs operate in an environment known as NFVI (NFV Infrastructure). This covers the virtualization layer, physical resources, and virtual resources, all of which are detailed below.

3.5. Compute, Memory and Networking Resources

Virtual elements that are used by VNFs in the end arecreated from the physical resources through abstraction. This layer abstracts physical resources into virtual resources. In the field, this layer is commonly referred as a ”Hypervisor.” By separating the software from the hardware, this layer enables the software to develop independently of the hardware. One would infer that VNFs would use physical resources directlyif there was no virtual layer. But in this situation, neither the names ”VNFs” nor ”NFV architecture” are acceptable.

3.6. Virtualized Infrastructure Manager (VIM)

This is the NFVI management system. Within one operator’s infrastructure domain, it is in charge of managing and control-ling the NFVI computing, network, and storage resources. It is also in charge of gathering performance metrics and incidents.

3.7. Network Functions Virtualization Orchestrator

It produces, maintains, and decomposes VNF-specific net- work services. If there are several VNFs, the orchestrator will allow for the establishment of an end-to-end service over numerous VNFs. The administration of NFVI resources globally is another duty of the NFV Orchestrator. Managing, for instance, the computing, storage, and networking resources of the NFVI across several VIMs in the network The VNFM and VIM are used by the Orchestrator to communicate with VNFs rather than directly. Let’s use an example where it is necessary to link many VNFs together to construct an end- to-end service. They can come from the same provider or someone else. Both VNFs will be required to build an end-to- end service.

3.8. Support Systems

The term support systems refer to an operator’s Operational Support System or Business Support System. Network control,fault, configuration, and service management are all covered by OSS.BSS handles customer, product, and order manage- ment, among other things. Control and Orchestration may be connected with an operator’s present BSS/OSS utilising standard interfaces in the NFV architecture.

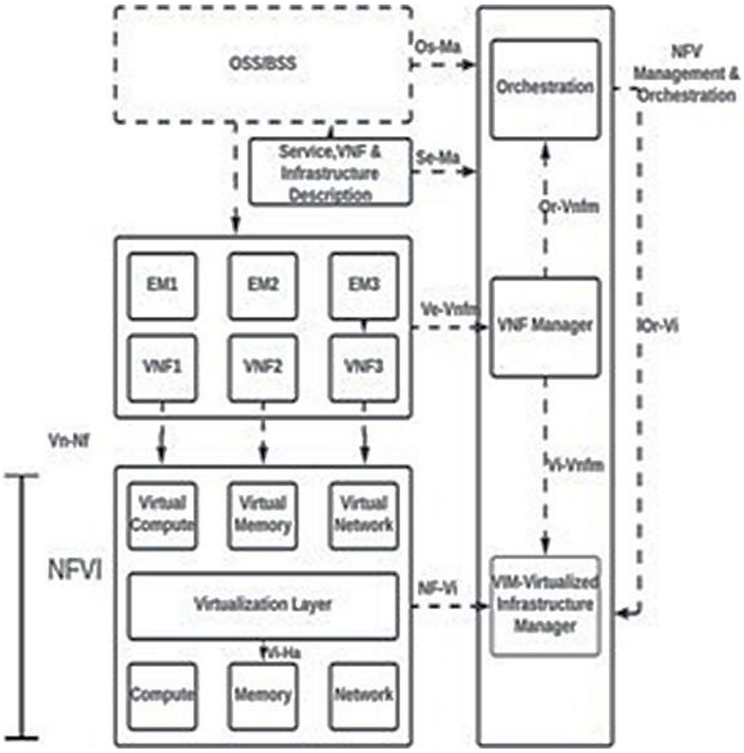

Figure 2. Architecture of SDN

4. Convergence of SDN and NFV

Networking that is defined by software is known as SDN. By abstracting all of the physical network components and connectivity into a customizable, software-defined architecture, it makes use of the same principles as virtualization. It is a centralized framework that runs on non-proprietary, inexpensive hardware. The flexibility that SDN offers is what makes it so appealing: the ability to centralise command and control, to quickly build new network configurations, to simplify operations, and to save costs by using non-proprietary hardware. The network is controlledcentrally via the virtualization layer, allowing adjustments to be done from a single console. As a result, there is lessof a need to visit the site to remove and replace switchesand routers or to change the physical network connections. Fully operational savings can be immediately obtained by investing in SDN. The virtualization layer centrally controls the network, enabling changes to be made from a single console. As a consequence, fewer site visits are required to upgrade the physical connections or replace or remove switches and routers. By investing in SDN, savings that are fully operational may be realised right now.

The virtualization of network services and applications (such as EPC, content filters, security monitors and sandboxes, load balancers, etc.) that exist and operate within an SDN framework is known as network functions virtualization, or NFV. These applications, which were formerly the domain of specialist appliances, are now delivered in a software-only configuration, commonly referred to as a VNF format. These virtual network functions (VNFs) are made up of one or more virtual machines and are set up to carry out each function as effectively as possible. The VNF may be readily transported over the network for deployment or backup purposes and can be duplicated as a file, much like any VM or series of VMs. The VNF can dynamically scale up and down according to traffic requirements and can do so at a more detailed level in the case of the Affirmed Networks Mobile Content Cloud.

The SDN layer isolates the network itself, enabling a virtualized environment where NFV applications may live and flourish. SDN and NFV converge at this point. SDN and NFV are two separate networking strategies, however they mayalso be seen as a dynamic team. SDN and NFV combine to provide a breakthrough architecture that is far more durable, effective, and lucrative than previous legacy approaches. The network of the future is really made up of how these two ideasare combined. But just because the SDN layer is the overall strategy doesn't mean it has to arrive first. NFV may be utilisedby networks that are installed without SDN and vice versa. Operators may choose the sequence in which their network transformation will occur since the two network techniques are complementary rather than interdependent. The sequence in which SDN and NFV are implemented is not as crucialas the fact that doing so would ultimately allow operators to realise their full potential.

5. 5G Architecture Based on NFV and SDN

Here, we suggest a 5G network design based on NFV and SDN. The data, control, and application layers are the threelevels that make up the proposed 5G architecture.

5.1. Data Layer

Two components make up the data layer: the CN and RAN data planes, the latter of which is made up of middleboxes and general switches (e.g., firewall, etc). These switches and middleboxes differ from typical gateways (such as S-GW and P-GW in LTE) in that they primarily forward traffic flowin accordance with the information about controls acquired from the control layer. For the purpose of best management, these nodes can also transmit certain status information tothe theoretically centralized controller while caching popular material to decrease mobile traffic in accordance with cache policy. Additionally, some events with tight latency require- ments should take into account the switch and middleboxes' processing power as well as the lag in data and control plane communication. In contrast to the CN data plane, the RAN data plane is created by the 5G eNB, which may be built ona general-purpose processing platform or a system software (like OpenRadio, etc.). This is done to separate the wireless network's decision function from its processing function and remove the framework from the hardware. With the aid of these technologies, the eNB may be virtualized, allowing usto dynamically generate and operate many virtual base stationsinside of the same physical eNB (perhaps utilising different protocols). Similar to how Open Flow's OpenFlow API allowsswitches and routers to be configured, the aforementioned5G eNB lets different users, apps, and MVNOs to create different wireless protocols using declarative rule-action-based programming. Additionally, to further lessen network traffic and response latency, 5G eNB can enable local caching with the right policies. It is apparent that the data layer is primarily in charge of handling all data processing, forwarding, andcertain control tasks.

5.2. Control Layer

The network intelligence is logically centred at the control layer in the RAN as well as CN controllers are components of the SDN controller. The CN controllers is in charge of the following tasks: prefetching policy, network monitoring, subscriber information base, policy and billing rule, etc. Basedon the status information provided by the data plane, the CN controller may regulate the traffic processing and con-tent caching through the API. On the other hand, the RAN controller is in charge of multi-RATs coordination, resource management, eNB cache policy, interference mitigation, and mobility management. By receiving the data plane's conditionreport and keeping an overall view of RAN, this controller may improve network performance (such as capacity, latency, user experience, etc.) based on these control functions. The aforesaid control operations with regard to the disposition of RAN or CN controllers can be combined using an open IT- based platform on a virtualized environment. In a highly dense heterogeneous network with macro eNB scenario, the macro eNB, which serves as the control plane, may additionally include a RAN controller. In this case, small cells manage the data plane. Open APIs are provided at the application layerby the control layer, which also supervises the data layer.

5.3. Application Layer

The network can be changed to give the many apps that make up the application layer better-differentiated and cus- tomized experience as well as a certain degree of privacy to improve the user's experience. In addition to other perfor- mance factors, SDN and NFV can increase network capacity, programmability, flexibility, and scalability. by separating the control plane from the data plane, separating software from hardware, concentrating network intelligence in the network controller, and virtualizing the network (energy efficiency,cost, etc).

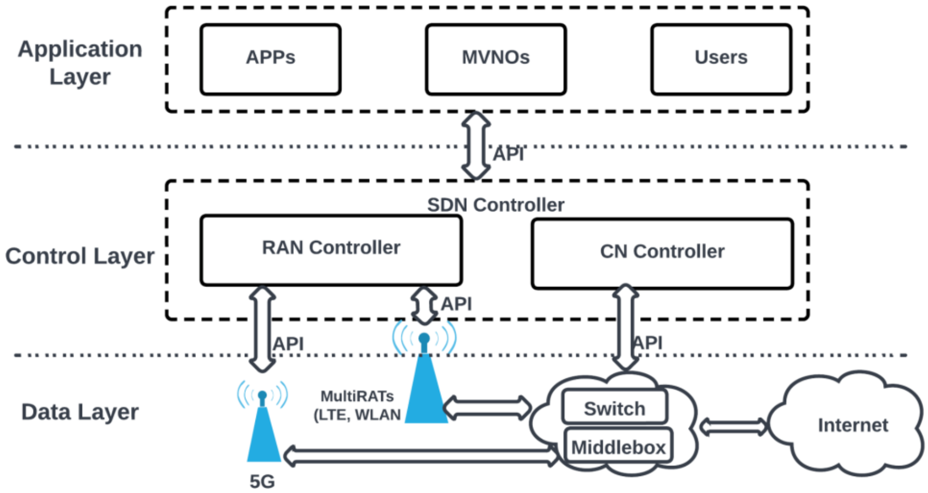

Figure 3. Architecture of 5G Networks based on SDN and NFV

5.4. Network Functions Virtualization Infrastructure (NFVI)

VNFs operate in an environment known as NFVI (NFV Infrastructure). This covers the virtualization layer, physical resources, and virtual resources, all of which are detailed below.

5.5. Compute, Memory and Networking Resources

Virtual elements that are used by VNFs in the end arecreated from the physical resources through abstraction. This layer abstracts physical resources into virtual resources. In the field, this layer is commonly referred as a "Hypervisor." By separating the software from the hardware, this layer enables the software to develop independently of the hardware. One would infer that VNFs would use physical resources directlyif there was no virtual layer. But in this situation, neither the names "VNFs" nor "NFV architecture" are acceptable.

6. Leveraging SDN for 5G

With the emergence of intelligent network topologies like SDN, hardware limitations have been lessened. By shifting the lower-level processes to a standardised control plane, SDN provides an abstract layer that controls all network behaviour through the use of APIs. As a result, regardless of the physical components, network administrators can offer services through the network. We are attempting to boost functionality by combining the benefits of both technologies to get better performance by utilising 5G and SDN together. As data movesacross the 5G network, it can improve data flows in the control plane and significantly reduce network bandwidth and latency. performance by utilising 5G and SDN together. As data movesacross the 5G network, it can improve data flows in the controlplane and significantly reduce network bandwidth and latency. Therefore, by utilising SDN in 5G networks, we are capableof automating and managing network redundancy as well as avoid severe failures by figuring out the real-time flow of datafrom the centralised control plane.

SDN serves as the cornerstone of 5G networks by facili- tating connection between mobile platforms and cloud-based services and applications. Through resource virtualization, the network is able to scale dynamically and be controlled according to real-time requirements. The primary barrier to implementing SDN for 5G, despite its many benefits like re- source sharing and session management, is the computational power and resources of mobile devices. The burden on the embedded controller increases as a result of mobile users repeatedly sending requests for flow rules in OpenFlow mes- sages. Therefore, more study on using SDN for 5G networks is needed. SDN may be used to establish the Operation and Management of wireless mobile networks for 5G, which will improve performance through continuous optimization, quick failure recovery, quick adaptation to alterations in network loads, self-organization of the network, and rapid configura- tion. Additionally, it lessens network bottlenecks and makes it possible to debug and troubleshoot control traffic.

SDN can give methods to get beyond the limits of multi- hop wireless networks, hence increasing the capacity of 5G systems. High capacity may be achieved by employing cutting-edge data caching strategies for the edge network while lever- aging SDN for 5G. As a result, the use of SDN for 5G allows customers and providers more choice to balance operational criteria like network resilience and service performance. In addition, SDN not only offers benefits to 5G technology, such as flexibility, support for numerous subscribers, frequent mobility, real-time adaptation, and so forth, but it also raises security concerns for future 5G design.

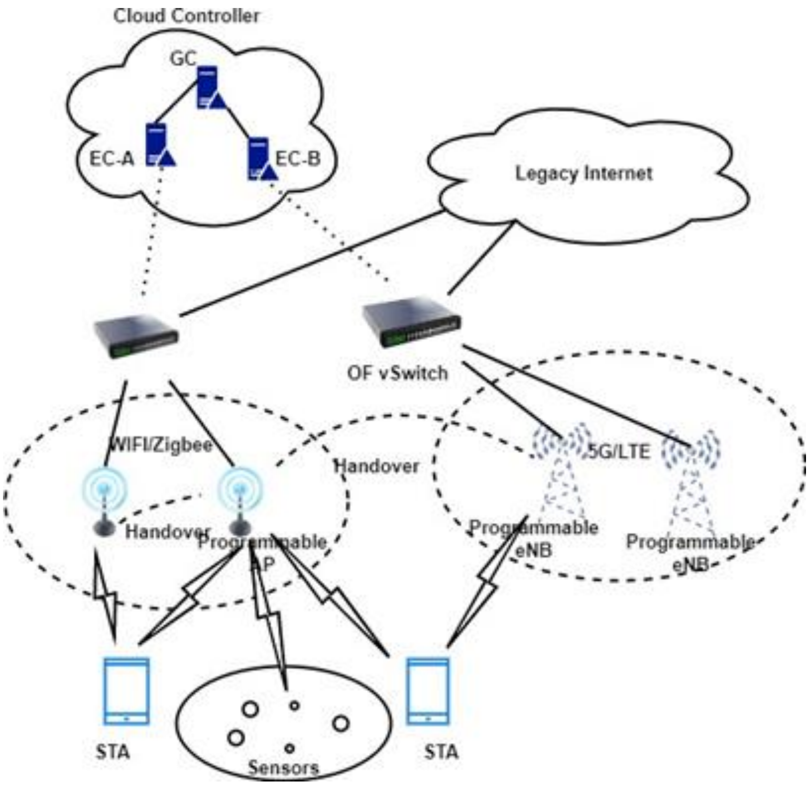

Figure 4. Leveraging SDN for 5G Networks

Table I. Security Issues and Solutions

Security Challenge	***Problems***	***Solutions***
At South bound communication	Communication between the controller and Switches isnot encrypted, which may cause eavesdropping.	Utilizing TLS for encryption prevents the issue by preventing eavesdropping and communication spoofing.
At the northbound communication	Absence of ade- quate permission at this level might potentially result in malicious ac-cess to the appli- cations.	During this level, a powerful authentication process must be used to verify each component's identification.
At Application components	Applications that are not coming from a reliable source might introduce serious security holes.	A reliable authentication system must beused.
At controller Level	DDoS attacks might be vulnerable to the controller. The whole network, flows, and rules are underthe attacker's control once the controller is taken over.	To prevent DDoS attacks, use high availability features and strict securityregulations. Implementing a backup controller is necessary to prevent single points of failure. Therefore, we may move to a different server without interrupting any services in the event that the first one is corrupted or inaccessible. Put a detection mechanism in place to spot unusual flows. Avoid letting any body else inside the SDN controller.
End terminals devices	End terminals might be vulnerable to a number of dangers, such asviruses, trojans, or applications that have been misused or downloaded.	Utilize endpoint security technologies that are strong, like mobile devices. For instance, "Micro Focus" offersend-to- end testing of the security of mobile apps across a range of smartphone platforms, networks, servers, etc. Fortify is a product made by Micro Focus that secures mobile apps before they are downloaded and installed on a device. All data from smart phones must also be encrypted using advancedsecurity methods.

7. Benefits

Automated management: Using SDN ideas, 5G cellular would be able to recognise appropriate changes and know howto handle them automatically.

SDN will be the primary technology for the provisioning and control of QoE in 5G mobile networks.

SDN can provide the adaptability and comprehensive in- formation needed to assist decisions on offloading routing, energy efficiency, and spectrum allocation. Utilizing a uniform, simpler, less expensive, and flexible configuration of network behaviour will be made possible by SDN.

Reduce costs by streamlining network management and setup. SDN will provide answers to the problems with multi-hop cellular systems and enable data storage at the edge network in order to satisfy the high-capacity demands of 5G systems

8. Future

A new age in mobile communications has been heralded by 5G's higher speeds and more dependable connections. Americans have so far contributed 275 billion dollars to the construction of 5G networks. It's critical to remember that 5G isn't simply a new wireless protocol; it also incorporates a number of technical innovations including updated multiple antennas and radio network access services to enhance how networks are created, produced, and maintained. IT managers must simultaneously expand flexibility and functionality while cutting costs in order to accommodate and benefit from this tremendous growth of internet-connected machines, sensors, and other devices. IT managers were forced to operate within the constraints of the telecom business. However, a fresh way of thinking is required to address the need for networks that are stronger, more agile, and more flexible. In order to achieve that, wireless infrastructure must adopt the open- source technique that has just transformed the IT industry asa whole. The cornerstone for the future of Software-defined networking (SDN), a key component of 5G, aims to replace expensive wireless network hardware with more affordable, locked hardware to a sophisticated software layer running on commodity hardware. The ability to automate the numerous processes necessary to support 5G's fast speeds and low latency as well as the vast number of terminals in the Internet of Things is vital for IT managers. The big international carriers Vodafone, Telefonica, Orange, and China Mobile are among those that see that this paradigm is the only way to succeed in the future 5G world. The world community devel- opment model, which entails developers working together on innovations and enhancements to the software while vendors build value-added goods on top of those advancements, isa crucial element of open source's achievement in any areaof technology, and this is no less truly the case for 5G. IT administrators may attempt to access 5G application stores that operators set up, which only contain apps they have tested and certified. This is the network equipment equivalent of application distribution to a smartphone.

9. Conclusion

5G networks are an effective innovation to deal with the rising concerns of network traffic and user-centric network requirements. With the right approach to building, rendering the best results will ultimately enhance the overall network performance. The need of 5G is prominent and the need for it to be of good quality with long-term benefits even more prominent. Thus, building a system using and leveraging technologies like SDN, NFV will help give us the best end- result which can cater to the increasing network demands. Utilizing the existing technologies to improve an upcoming technology is a resource and time-efficient manner when building a new system. To conclude, the 5G network has a variety of avenues to which it can be applied. Coming-up with a proper 5G system will solve many problems and make the overall network performance exponentially effective and useful.

References

[1] Fatma, Nilofer, and Jihad Qaddour. 2019. "Integration of SDN and 5G and Its Related Challenges and Security Issues." Scientific Academic Publishing. doi:10.5923/j.ijnc.20190902.03

[2] Hakiri, Akram, and Pascal Berthou. 2015, "[1506.02876] Leveraging SDN for the 5G Networks: Trends, Prospects and Challenges." https://doi.org/10.48550/arXiv.1506.02876

[3] Hicham, Magri, Noureddine Abghour, and Mohammed Ouzzif. 2018."International Journal of Engineering Technology." International Journal of Engineering Technology.

[4] Ksentini, Adlen, Miloud Bagaa, and Tarek Taleb. 2016. "On Using SDN in 5G: The Controller Placement Problem." On Using SDN in 5G: The Controller Placement Problem. https://doi.org/10.1109/GLOCOM.2016.7842066

[5] Sun, Singlin, Liang Gong, Bo Rong, and Kejie Lu. 2015. "An intelligent SDN framework for 5G heterogeneous networks." https://doi.org/10.1109/MCOM.2015.7321983

[6] Tayyaba, Sahrish Khan, and Munam Ali Shah. 2018. "Resource alloca- tion in SDN based 5G cellular networks." Resource allocation in SDN based 5G cellular networks. https://link.springer.com/article/10.1007/s12083-018-0651-3

[7] Yadav, Swati, and Sugandha Singh.n.d. "SDN and NFV in 5G: Advance- ments and Challenges." International Journal of Computer Science and Mobile Computing. https://doi.org/10.1109/ICIN.2017.7899398

[8] Zolanvari, Maede. 2015. "SDN for 5G." S Fatma, Nilofer, and Jihad Qaddour. 2019. "Integration of SDN and 5G and Its Related Challenges and Security Issues." Scientific Academic Publishing. doi:10.5923/j.ijnc.20190902.03

[9] Hakiri, Akram, and Pascal Berthou. 2015, "[1506.02876] Leveraging SDN for the 5G Networks: Trends, Prospects and Challenges." https://doi.org/10.48550/arXiv.1506.02876

[10] Hicham, Magri, Noureddine Abghour, and Mohammed Ouzzif. 2018."International Journal of Engineering Technology." International Journal of Engineering Technology.

[11] Ksentini, Adlen, Miloud Bagaa, and Tarek Taleb. 2016. "On Using SDN in 5G: The Controller Placement Problem." On Using SDN in 5G: The Controller Placement Problem. https://doi.org/10.1109/GLOCOM.2016.7842066

[12] Sun, Singlin, Liang Gong, Bo Rong, and Kejie Lu. 2015. "An intelligent SDN framework for 5G heterogeneous networks." https://doi.org/10.1109/MCOM.2015.7321983

[13] Tayyaba, Sahrish Khan, and Munam Ali Shah. 2018. "Resource alloca- tion in SDN based 5G cellular networks." Resource allocation in SDN based 5G cellular networks. https://link.springer.com/article/10.1007/s12083-018-0651-3

[14] Yadav, Swati, and Sugandha Singh.n.d. "SDN and NFV in 5G: Advance- ments and Challenges." International Journal of Computer Science and Mobile Computing. https://doi.org/10.1109/ICIN.2017.7899398

[15] Zolanvari, Maede. 2015. "SDN for 5G." SDN for 5G https://doi.org/10.4236/cn.2020.121002