SDN for 5G

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Rotation October 2015

1 Introduction

The 5G (fifth Generation) wireless technology is still under investigation and needs more research stages. Researches are currently exploring different architectures to imply main concepts of this new technology. SDN has been proposed as a promising technique for these networks, which will be a key component in the design of 5G wireless networks. The 5G is going to be based on user-centric concept instead of operator-centric as in 3G or service-centric as seen for 4G. Hence, multiple incoming flows from different technologies would be combined at mobile stages [1].

This new generation 5G of wireless broadband network will provide the fundamental infrastructure for billions of new devices with less predictable traffic patterns will join the network. To be succeed with this new technology, going through intelligence is really crucial, to proceed to successful deployment and realization of a powerful wireless world.

It is expected to save wiring costs to achieve higher convenience and efficiency. Principals of virtual network management and operation, which can be implemented by network function virtualization (NFV), and Software-Defined Networking (SDN) are the main element of the network architecture to support the new requirements of the new powerful wireless communication in the future. Therefore, the 5G technology bandwidth will face inevitable challenges in the future [2].

2 5G Mobile Wireless Communication

5G of wireless communication is going to face a large number of unknown patterns and new applications. Managing and operating of the network should be based on the applications that are utilizing the network. It deals with the QoS and policies that is dictated over the network, hence it should be application-driven. Application-driven networks consist of interconnecting end-user devices, different modules, and several machines, sensors, and actuators, with billions of clients connected to the Internet for supplying big data applications.

5G network is still under investigation and needs to be provided more accurately. The main requirements, based on the next generation mobile networks alliance, are first, tens of thousands of users of the next wireless network generation should be provided by data rates of several tens of megabits per second. Second, it should provide high virtual access networks in the same physical network, for example at least one gigabit per second to several people working at the same office. Also, massive sensor deployments should be able to support several hundreds of thousands of simultaneous connections. In comparison with 4G, spectral efficiency, signaling efficiency and coverage should be improved. And finally, latency should be reduced significantly compared to LTE [3].

5G networks is going to be designed to be open, more flexible, and able to evolve more easily than the traditional networks, and will not be based on routing and switching technologies anymore [4]. They will be able to provide convergent network communication across multi-technologies networks, and provide open communication system to cooperate with satellite systems, cellular networks, clouds and data-centers, home gateways, and many more open networks and devices. Additionally, 5G systems will be autonomous and sufficiently able to adapt the situations depending in required QoS to handle application-driven networks dynamically. Security, resiliency, robustness and data integrity will be the first priority in the design of future networks [5].

Moreover, the 5G network will be able of handling user-mobility to guar-

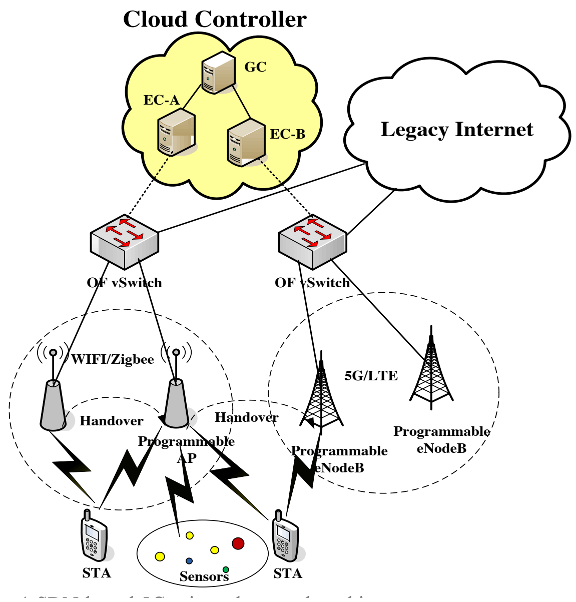

Figure 1: SDN-based 5G oriented network architecture [8]

antee the connectivity at any situation. The end users' terminals make the final choice among different access networks for the best connection. Also, the terminals will also stay awake and looking for to choose the best technology to connect, with respect to the dynamic changes at the current access technology. The infrastructure of the wireless networks will be based on SDN, which provides arrange the communication between the applications and services in the cloud and user's mobile terminal. Therefore, the network can be managed on the real-time needs and status dynamically, and it will have benefit from resource virtualization. The architecture of 5G network based on SDN scheme has shown in Fig. 1.

SDN has several limitations, it has some advantages such as resource sharing and session management. The main limitation is on the computing capabilities and resources of mobile devices. As a result because mobile users send request over and over to the embedded controller for flow rules in OpenFlow messages, the overhead increases more significantly. Hence, further researches are required on leveraging SDN for 5G networks.

3 Software Defined Networks

Software-Defined Networking (SDN) has emerged as a new intelligent architecture for network architecture to reduce hardware limitations. The main idea of introducing SDN is to separate the control plane outside the switches and enable external control of data through a logical software component called controller. SDN provides simple abstractions to describe the components, the functions they provide, and the protocols to manage the forwarding plane along with Mobile IP from a remote controller via a secure channel. In conclusion, the inability of mutual access between different parts of heterogeneous networks would be solved. This abstraction is used instead of the common requirements of forwarding tables for a majority of switches and their flow tables. Hence, the controller monitors network packets, publishes policy, or solves errors according to the monitoring results.

A number of northbound interfaces (connection between the control plane and applications) that provide higher level abstractions to program various network-level services and applications at the control plane. The OpenFlow standard has been exploited as the dominant technology for the southbound interface (connection between the control plane and network devices). This scheme allows on-demand resource allocation, self-service provisioning, completely virtualized networking, and secures cloud services. Thus, the static network would be evolved into a truly flexible service delivery platform that can respond rapidly to the network changes such as: end-user and market needs, which greatly simplifies the network design and operation. Moreover, the devices themselves no longer need to understand and process thousands of protocol standards but they should be capable of understanding instructions from the SDN controllers [5].

Facing the rapidly growing needs of users, Internet service providers cannot afford huge upgrades, adaption, or building costs, as hardware elements are expensive. Therefore, another advantage of exploiting SDN is to make it easier to introduce and deploy new applications and services than the classical hardware-dependent standards.

The ultimate goal of SDN is to create a network that does not need any the design or adjustments of the administrator interference, so, the network can be implemented fully automated administration. The administrators can manage the network through the controller plane more easily with dictating the required policy to the routers and switches, while they have a fully function monitoring over the network.

Software defined networking (SDN) is bringing about a paradigm shift in networking through the ideas of programmable network infrastructure and decoupling of network control and data planes. It promises simplified network management and easier introduction of new services or changes into the network. Use of SDN concepts in 4G/5G mobile cellular networks is also being seen to be beneficial (e.g., for more effective radio resource allocation through centralization, seamless mobility across diverse technologies through a common control plane)

4 Background on Implantation of SDN for 5G

Based on the main character of SDN, the paper [6], has modeled the system?s architecture such that SDN controller should adjust bandwidth dynamically for each radio access points (RAP) to baseband unit (BBU). Hence, SDN controller provide flexible management and router selection for all radio access network (RAN) to core network connection, where the core network of the SDN controller is made up of two main parts, as unified control entity (UCE) and unified data gateway (UDW). Role of UCE is to define control rules such as: mobility management entity (MME), service gateway control plane (SGW-C), and packet data network gateway control plane (PGW-C). Wehere as, UDW determine the rules for data forwarding such as: service gateway data plane (SGW-D) and packet data network gateway data plane (PGW-D).

Therefore, we need to guarantee the steady connection between each user and RAP; so, this paper tries to design a radio protocol that provides us the required interconnection between data plane and control plane. Meanwhile, the paper explores different network architecture and techniques which could

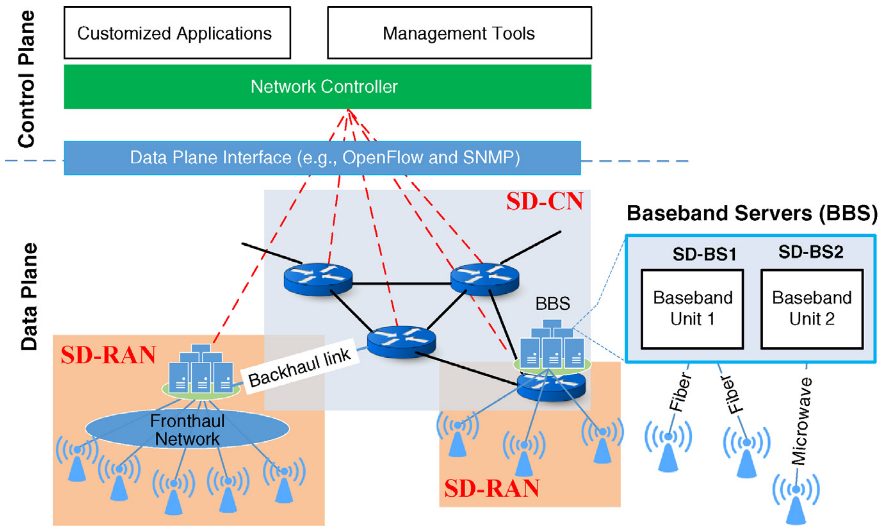

Figure 2: Overall architecture of SoftAir [7]

be exploited in the future 5G systems. A survey on literature and implementation concepts of these techniques are also investigated. These techniques include non-orthogonal multiple access (NOMA), massive multiple input and multiple output (MIMO), cooperative communications and network coding, full duplex (FD), device-to-device (D2D) communications, millimeter wave communications, automated network organization, cognitive radio (CR), and green communications.

Another paper, [7], proposes a new architecture for leveraging SDN for 5G wireless network, called SoftAir, and explores solutions and challenges in this matter. The main goal in this paper is to exploit the benefits of using cloudification and virtualization at these networks to provide a scalable, flexible and more resilient network architecture.

At the proposed architecture, control plane managed by network servers, provides the management and optimization tools for data plane, which is managed by cellular core network, consists of software-defined base stations (SD-BSs) in the RAN and software-defined switches (SD-switches). The controller serves physical, MAC, and network functions on computers and remote data centers. The overall architecture and controller/data plane scheme of the system have been shown at Fig. 2 and Fig. 3, respectively.

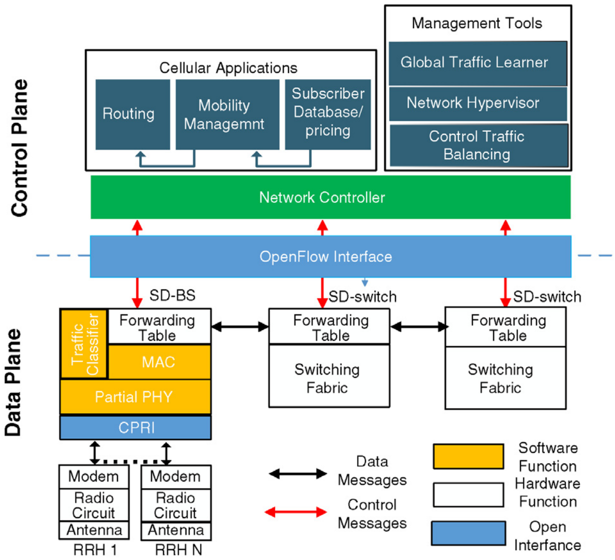

Figure 3: controller/data plane scheme of SoftAir [7]

The main contribution of the proposed SoftAir architecture can be categorised as five main properties. First, programmability, such that SDN nodes (SD-BSs and SD-switches) can be reprogrammed dynamically associating with different network resources. Second, cooperativeness, such that SDN nodes can be implemented and linked at data centers for joint control and optimization for improving the general network performance. Third, virtualizability, such that several virtual wireless networks can be implemented on a single SoftAir platform, while each operates regarding its own protocols customizes and interacts with allocated network resources without interfering with other service providers. Fourth, openness, such that data plane elements (SD BSs and switches), have common data/control interface protocols, regardless of the different data forwarding technologies provided by different vendors, such as: CPRI and OpenFlow, thus the data plane monitoring and management can be simplified. And finally, fifth, visibility, such that controllers are able to have an overall view over the whole network collected from data plane elements.

To sum it up, SoftAir tries to design a high flexible architecture providing maximum spectrum efficiency exploiting benefits of cloudification and virtualization processing; also, advance steady convergence for different network elements by different independent virtual interfaces, and enhance energy efficiency by scaling the computing capacity of data plane elements.

Paper [8] proposes a new multi-tiered cloud controller scheme and event processing mechanism for Software Defined Wireless Network (SDWN) architecture for the 5G network toward Openflow standard which results in an user-centric and service-oriented architecture. To provide the proper radio environment required for 5G wireless communication, SDN along with NFV architecture is a promising technique to overcome the isolation of heterogeneous radio access networks such as such as LTE, Wi-Fi and W-CDMA. Mainly, because the spectrum efficiency of LTE has achieved very close to the Shannon's capacity limit. Hence, this paper declares that an efficient way to decrease traffic for the networks in the 5G is improving the heterogeneous radio access.

Another important challenge for the future user-centric and the service-oriented 5G mobile communication system is the quality of user experience (QoE). The 5G will face with tremendous number of devices that have wide rages of different patterns for the modeling the information with different protocols. However, the legacy needs for quality of service and different specific application requirements are the main determiner for accepting more and more applications, besides to the system capacity. Some of the future applications require few milliseconds end-to-end delay. In this way, the varying throughput, latency and jitter requirements of application enhance the complexity of state and resource provisioning.

The main contribution of this paper is to provide an ubiquitous cloud radio access for 5G wireless network in the coexistence of other heterogeneous wireless networks by designing the proposed multi-tiered cloud controller. Also, by monitoring the status of network in real time, any time that the network faces a problem such as congestion or bottleneck at data forwarding, the appropriate command is sent based on the required QoS.

Another significant part of the proposal method in this paper is designing a layered cloud net scheme for the multiple controller with two parts: Edge Controller (EC) and Global Controller(GC). The main logic behind this design is to reduce the response latency and balance the network load for the cloud of controller. The EC processes the event within a single RAN domain, and the GC takes events across various RANs into account. Controller architecture is as Fig. 4

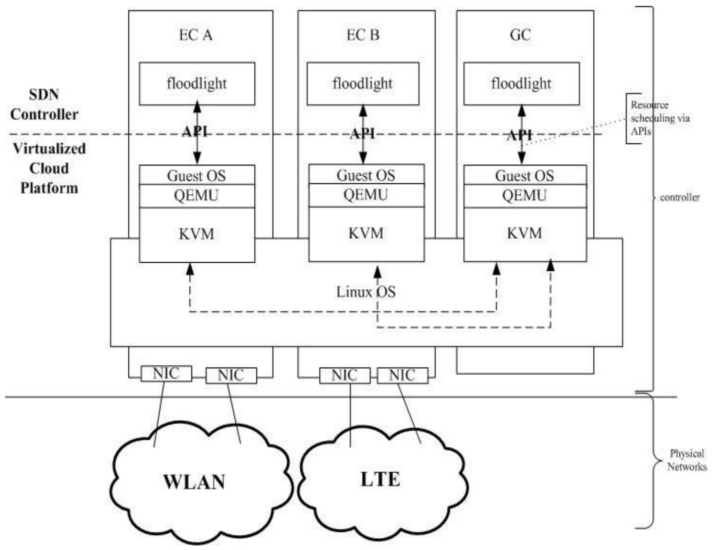

Figure 4: Virtualization architecture of the cloud-controller [8]

The proposed architecture has two main processing blocks: on-line transaction processing (OLTP) block and on-line analytical processing (OLAP) block. The OLTP works on the low-level events and real-time statistics, such as event of spectrum access. The OLAP works on the high-level events and long-time statistics of network status, such as load balance on mobile devices.

The EC provides the statistics of all the access points belong to one RAN into a database related to monitoring server. Second, According to the event type and the required QoE, EC will deliver it to the OLTP block and the OLAP block, or send it to the GC. The OLTP and the OLAP parse the events with some specific algorithms. Third, the EC makes the right decision based on the defined standards and sends the control signal, to the responsible component.

Furthermore, NFV can provide SDWN based 5G network to increase the capability by allowing several virtual operators working in the same infrastructures and resources. The spectrum can be divided into slices, where each slice will be dedicated to a virtual cloud of RANs based on the defined characters of the policy. So, the client have access dynamically to Internet regardless the type of radio access network or the network operator.

After that, the paper goes through the separation scheme of data plane and control plane concepts. So, as before the controller plan will run on the cloud

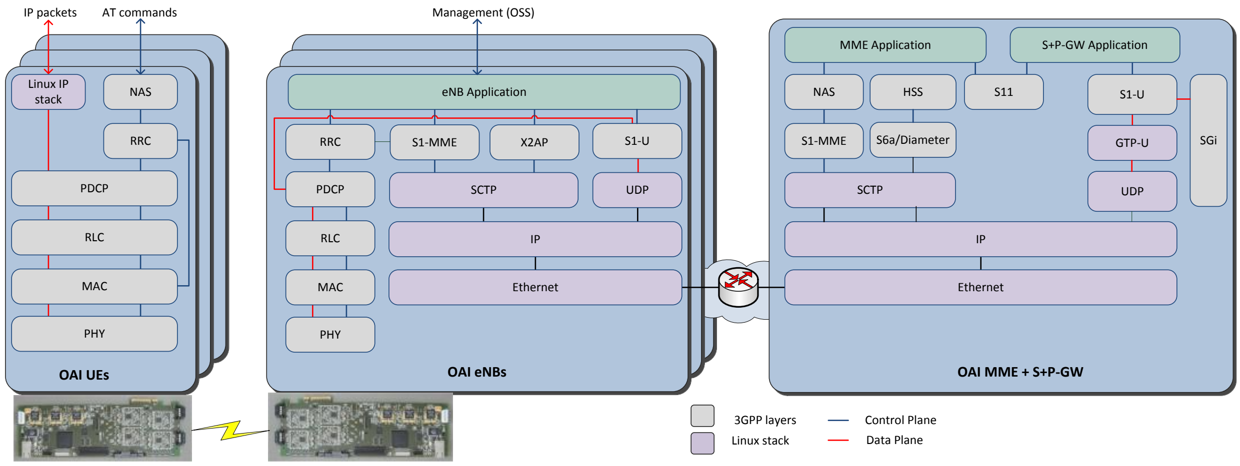

Figure 5: Network configuration of the proposed OpenAirInterface [9]

of controller, and the access points are just used to transmit data physically. Furthermore, the physical transmission can be adjusted with SDR techniques. Forwarding the data follows Openflow standard, which is flexible enough to manage the data flow rules over switches for each operator.

The paper [9] offers OpenAirInterface (OAI), an open-source and complete 3GPP standards, which is flexible platform using SDN. The OAI works on the two main components of the LTE system architecture; first, the E-UTRAN; and second, the EPC. The presented model is a highly realistic model that investigates entire protocols from the physical to the networking layer. Also, the paper asserts that OAI has the potential to become a reference evaluation platform for 5G technology development by providing researchers with an easy and rapid prototyping and testing environment.

At the scheme of OAI, similar to the other type of SDR approaches, the base station, access points, mobile terminals and core network are realized via a software radio point connected to a core host for processing. Moreover, OAI is the only SDR based solution that provides a complete software implementation of all elements of the 4G LTE system architecture. The network configuration has been shown in Fig. 5

To sum it up, the two unique features of the OAI platform are as follows. Firstly, it is an open-source real-time software implementation of the 4G mobile cellular system that follows the the 3GPP LTE standards and can be used for in-door/outdoor experimentation and demonstration. Second, it has built-in emulation capability that can provide repeatable and scalable experimentation in the controlled laboratory environment on the real practical environment while respecting the frame timing constraint.

In the paper [10], it has been discussed that today?s Internet is mostly using only one single path between the two communication endpoints, and packet switched networks is the infrastructure of the communication basically. It is obvious that using only one path would not provide enough security to have a secure communication with low loss rate, mainly because it is vulnerable against being manipulated, moreover, we can have more throughput by using multi-path communication. Also, for long distances, the situation gets worse, specially with the long delay that is avoidable.

This paper uses code centric networks, and tries to have more throughput, resilience, security and low delays. Furthermore, the router on the way are allowed to use different network coding based on the network situation. The proposed method is a promising way over lossy networks. The proposed scheme enables dynamic allocation of distributed clouds on top of each router, and places the cloud close to the user, which decrease the delay over the network. Hence the code centric operation over SDN components improves the performance.

In the paper [1], a cross-layer scheme combining SDR and SDN characteristics has been proposed. Based on the fact that the 5G technology spectrum and bandwidth will face unavoidable challenges in the future for the huge number of different and unpredictable clients, integration between the frequency spectrum, and bandwidth will be an inevitable topic. Combining software defined radio and software defined networks would be the best tool for this integration. However, they are difficult to exchange the information because they belong to different layers. Therefore, the main contribution in that paper is to design a cross-layer integration mechanism to combine the benefits of integrating SDN and SDR. The paper declares that the co-existence of SDR and SDN is crucial, and the best performance can be achieved only by mutual cooperation. The architurcture combing these two layers has been shown in Fig. 6.

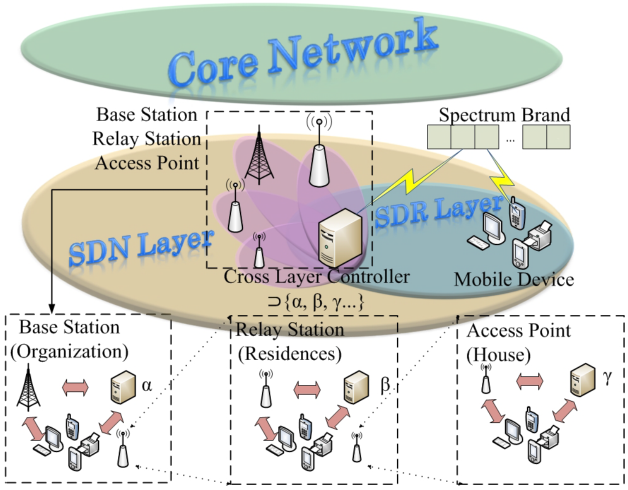

Figure 6: Hybrid architecture of SDN and SDR [1]

Spectrum resources and network resources are mostly similar, and both have a specific area of responsibility. The software-defined approach is an appropriate method to create routing tables, handshaking, certification mechanisms, etc. During sending packets, these mechanisms send out requests and signaling messages, which waste bandwidth. Moreover, with increasing the VLAN, old and new L2 Domain conversion efficiency will decrease.

The SDR Layer contains all the devices that can access radio. The perception of SDR is carried on at terminal, and it cannot manage the usage of the spectrum. Hence, effective channel using and switching is not possible, and there should be a centralized hub. The administration component is used as the arbitrator to determine the frequency band or to avoid interference. The proposed cross layer controller knows who sent a request for frequency spectrum usage; hence, it can easily determine whether the device is authorized. This can avoid many cases of illegal access to spectrum resources, and monitoring all frequency users and interference.

This paper suggest to reuse the spectrum to decrease the traffic flow for some specific frequencies, which can lead to a significant improvement in 5G network to allow more devices to have high quality of services. A cooperation between SDN and SDR such that SDR can have access to monitoring results of frequency spectrum or switching bands and SDN can use the frequency

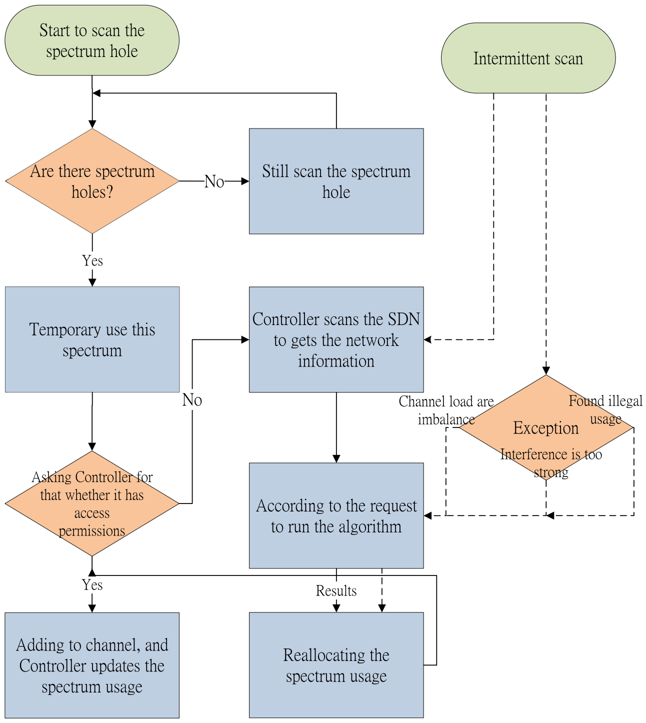

Figure 7: Network configuration of the proposed OpenAirInterface [1]

spectrum conditions provided by SDR, when policy has changed. Therefore the proposed architecture crosses the SDN Layer and SDR Layer.

The main component of the proposed architecture is the cross layer controller, which has administration rules to supervising and making proper decisions. Also, the scheme exploits a unit in controller, which makes decisions based on the trade-off between received information from the two layers as shown in Fig. 7. Any time that users want to access spectrum resources, users should request the cross layer controller about accessibility of the band. After the confirmation of the user authorization, the cross layer controller investigates the flow traffic information of the requested band, and allows the access or suggests switching to a better band. Moreover, based on the dynamic network environment, the controller can adapt itself based on spectrum usage and overall network conditions. Therefore, cooperation of the two layers can result in better planning and performance.

The paper [11], proposes a new scheme to deliver data flow in an intelligent

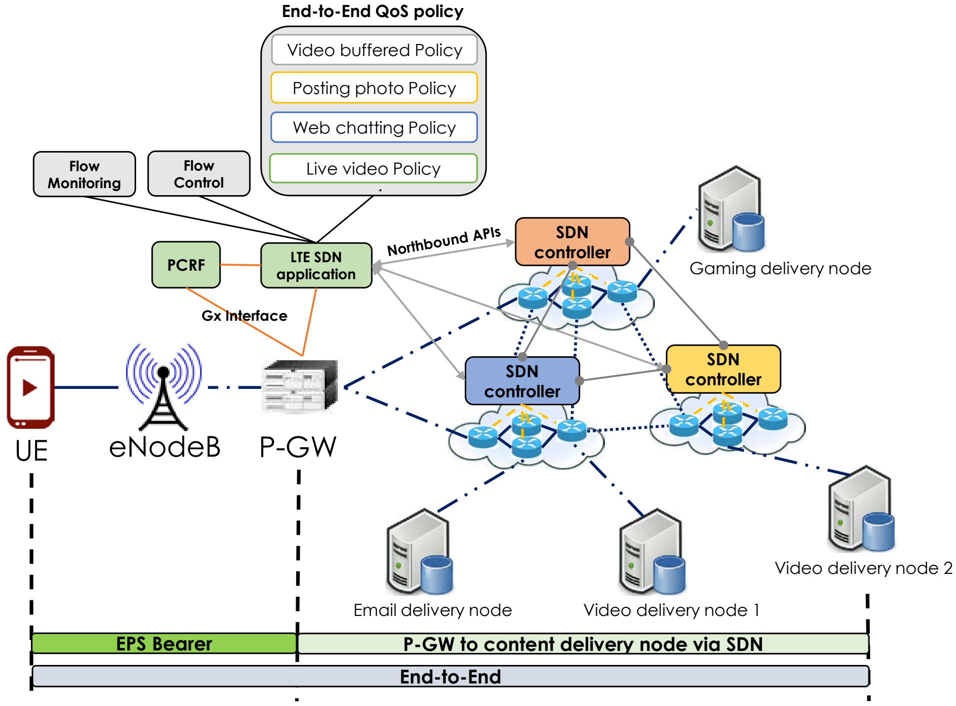

Figure 8: SDN based network configuration to deliver content intelligently over LTE [11]

way. In the proposed scheme, when the quality of service at the network is anticipated based on the network status which is provided by the SDN controllers, the SDN application sends request to the controllers. Then the controllers analyzes network conditions such as throughput and packet loss rates of the traffic flow, so to find the point at which the congestion or the bottleneck has happened. After that for resolving the congestion, the SDN controller first determines the QoS budget, such as the maximum allowed amount for packet delay per network segment. Based on the policy pf the network, the SDN controllers determine that any other alternative routing are allowed or not. Moreover, the controller can dynamically update routing paths among WAN routers in a network based on the situation. Also, it can assign another content delivery node for the client to provide higher networking performance.

This paper proposes to Build an application-awareness, simply by sharing the LTE QoS parameters with the SDN controllers that have difficulty implementing the application-awareness. With the LTE QoS parameters, an SDN controller can provide more accurate and consistent end-to-end QoS, which results a completely application-aware network. Moreover, in an LTE, QoS and QoE factors can be estimated using DPI. Layer four through layer seven inspection is provided by DPI, which yields not only context-awareness but also extracting meta data attributes, and other data that is used to calculate networking performance statistics for each flow. Furthermore, the proposed scheme performs a dynamic end-to-end flow control from P-GW. P-GW sends request to the SDN controller to obtain network conditions on each path between the P-GW and each content delivery node. The information can be used at user terminal to select the best available content server at the moment. The network scheme is as Fig. 8.

The paper [12] proposes a new scheme called as SoftRAN, which is a centralized architecture as an alternative to the distributed control plane similar to the SDN architecture. It takes out all the base stations in one geographical zone, which are just radio elements with a few control logic, as one virtual huge base station. These radio elements are managed by a logically centralized element which makes control plane decisions for all the radio elements in that geographical zone. Hence, this logically centralized entity is called as the controller of the huge base station. The controller maintains a whole view of the radio access network and provides a framework on which control algorithms can be implemented.

The paper [13] uses SDN scheme to reducing the delay for data forwarding at the network. Since the SDN controller can manage multiple eNodeBs over OpenFlow protocol, it can send any update for new forwarding rules, which results that network can remove the managing rule messages between eNodeBs. Also, the end point of sending data can be based on a set of predefined policies, QoS or network status, which again can helps the network to remove the massages between eNodeB and MME (Mobility Management Entity). Finally, the data flow goes over the data plane based on the decision made at the controller for the end point node.

As the above paper asserts: per industry standards, the handover delay should ideally be 0.7 seconds, when both planning and execution phases are included. At the most, a delay of up to two minutes during handover between 3G and LTE networks can be accommodated. By using SDN architecture, the policy or data path need to be defined over OpenFlow protocol and the processing time for any OpenFlow message decreases significantly, which results in reducing the latency at the handover considerably by approximately 30 percent and allows for a faster handover.

5 Conclusion

As it was shown, many different researches are trying to provide faster and more reliant base for 5G wireless networks. SDN as the main component of providing the virtualization, gained increasingly attraction. In this paper, a survey among different recent papers in this area has been carried out, and the main goal of each technique to improve different parts of this scheme has been reviewed. Meanwhile, the proposed architectures and basic rules of each paper has been clarified. However, there can be more ways to develop these scheme, as the 5G is still at the middle stages of researches.

The 5G network will consist of a huge number of devices, applications and technologies. Sharing the spectrum and the bandwidth over each single LAN domain among larger and larger number of users is an avoidable concepts. Providing more flexible network with high rate throughput is still needed to be more investigated.

References

[1] H. Hung Cho, C. F Lai, TK Shih, H. C Chao, "Integration of SDR and SDN for 5G", *IEEE Access*, vol. 2, pp. 1196?1204, 2014.

[2] B. A. A. Nunes, M. Mendonca, X. N. Nguyen, K. Obraczka, and T. Turletti, "A survey of software-defined networking: Past, present, and future of programmable networks", *IEEE Communications Surveys & Tutorials*, vol. 16, no. 3, pp. 1617-1634, Aug. 2014.

[3] "Wikipedia". https://en.wikipedia.org/wiki/Software-defined_networking.

[4] W. H. Chin, Z. Fan, R. Haines, "Emerging technologies and research challenges for 5G wireless networks", *IEEE Wireless Commun*, vol. 21, no. 2, pp. 106?112, Apr. 2014.

[5] Akram Hakiri, Pascal Berthou, "Leveraging SDN for The 5G Networks: Trends, Prospects and Challenges", *arXiv:1506.02876*, June 2015.

[6] Zheng Ma, ZhengQuan Zhang, ZhiGuo Ding, PingZhi Fan, HengChao Li, "Key techniques for 5G wireless communications: network architecture, physical layer, and MAC layer perspectives", *Science China Information Sciences, Springer*, April 2015, Volume 58, Issue 4, pp 1-20.

[7] Ian F. Akyildiz, Pu Wang, Shih-Chun Lin, "SoftAir: A software defined networking architecture for 5G wireless systems", *Computer Netwworkins, Elsevier*, 2015.

[8] Guolin Sun, Feng Liu, Junyu Lai, and Guisong Liu, "Software Defined Wireless Network Architecture for the Next Generation Mobile Communication: Proposal and Initial Prototype", *Journal of Communications* , December 2014.

[9] Navid Nikaein, Mahesh K. Marina, Saravana Manickam, Alex Dawson, "OpenAirInterface: A Flexible Platform for 5G Research", *ACM SIGCOMM Computer Communication Review*, v.44 n.5, October 2014.

[10] ND Szabo, F Nemeth, B Sonkoly, A Gulyas, FHP Fitzek, " Towards the 5G Revolution: A Software Defined Network Architecture Exploiting Network Coding as a Service", *Proceedings of the 2015 ACM Conference on Special Interest Group on Data Communication*, August 2015.

[11] Hyunwoo Nam, Doru Calin, Henning Schulzrinne, "Intelligent Content Delivery over Wireless via SDN", *IEEE WCNC*, 2015.

[12] Aditya Gudipati , Daniel Perry , Li Erran Li , Sachin Katti, "SoftRAN: software defined radio access network", *Proceedings of the second ACM SIGCOMM workshop on Hot topics in software defined networking*, August 2013.

[13] Rafat Jahan, "Unlocking the True Potential of 5G: Techniques for Latency Reduction", *White Paper, TCS' Telecom Business Unit*, 2015.