Sustainable Information and Communication Technology: Path to 5G Mobile Communications

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Abstract-As an enhancement of cellular networks, the futuregeneration 5G network can be considered an ultrahighspeed technology. It is expected that the 5G network may include smart technology so as to provide value for money, efficient services. The researchers through surveys of previous generations and future demands for explosive growth of communication tools suggest new architectures and service management schemes. There is demand for resolving capacity issues related to data traffic, high data rate and reliability to ensuring Quality of Services (QoS). The Cloud Computing, Virtualisation, Big Data, Internet of Things (IoT) and Software Defined Networking (SDN) are upcoming technologies for next generation network. The main objective of this manuscript is to review existing and future technologies especially 5G mobile communications.

1. INTRODUCTION

Mobile communication and wireless networks have advanced phenomenally during the last decade. The ever growing increase in the demand for resources, especially for multimedia data, with high quality of service (QoS) requirements, has promoted the development of 3G and 4G wireless networks. Nevertheless, the achievements of the development in technology cannot fulfill the proper satisfaction. Therefore, the idea of 5G networks that represent networks beyond 4G has become the need of the hour. 5G networks have come into existence owing to the numerous challenges facing 4G networks, such as need for higher data rate and capacity, lower cost, lower end to end latency and massive inter device connectivity. However, a comprehensive analysis of future networks or next generation networks of information systems that discusses in related forums and standardization is really challenging.

With the rapid advances and development in the field of mobile and telecommunication sector, the evolution of generations has proved to greatest invention. Wireless telephones started with pre cell phone mobile technology. The mobile radio telephone systems (0G) preceded cellular mobile technology. Different technologies like PTT (Push To Talk), MTS (Mobile Telephone System), IMTS (Improved Mobile Telephone System), AMTS (Advanced Mobile Telephone System), OLT (Norwegian for Offending Landmobil Telefoni public Land Mobile Telephony) and MTD (Swedish abbreviation for Mobilelefoni System D). [4]

The First generation of wireless mobile communication is totally based on analog signal. It is also known as Analog Mobile Phone System (AMPS) implemented in America, another variation Total Access Communication System (TACS) was implemented in Europe and rest of the world. The First Generation telecommunication standard was introduced in 1980s [1]. The second generation (2G) used digital signals, 1G wireless networks are used as analog radio signals. In this technology voice call is modulated at higher frequency about 150 MHZ and above using Frequency Division Multiple Access (FDMA) technology.

The second generation 2G system was developed for voice transmission with digital signal with speed up to 64kbps. The bandwidth required for 2G transmission is about 20 to 200KHz. In 2G time period, the mobile telecommunication industry experienced exponential growth of subscribers especially due to valued added services [2]. There were two standards in 2G technologies namely Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA) based on multiplexing type and efficient use of bandwidth. The CODEC (Compression DeCompression Algorithm) compresses and multiplexes digital voice data.

Another cellular wireless technology was developed in between 2G and 3G. The technology is also named as General Packet Radio Services (GPRS). It provides data rate from 56Kbit/s to 115Kbits/s. It was developed for Wireless Application Protocol (WAP), Access Multimedia Messaging Services (AMMS), and internet communication services such as email, mobile games and World Wide Web (WWW) etc. The cost of use for data transfer in GPRS was charged on megabyte of data transferred basis, whereas it was for per minute of connection time in traditional circuit switching. The third generation (3G) technology for multimedia cell phones was operational in 2000. The transmission speed was increased upto 2Mbps. The data transfer rates were increased to accommodate web based applications, audio and video files.

In 3G, there are three type of cellular access technologies: CDMA 2000, WCDMA and TDSCDMA based on 2G code division multiple Accesses. The CDMA 2000 was 1.25 MHz channel bandwidth with 144Kbps. The Universal Mobile Telecommunication System (UMTS) WCDMA was Wide band CDMA on 5MHz channel bandwidth with 2Mbps. The Time Division synchronous Code Division Multiple Accesses (TDSCDMA) was proposed by China wireless telecommunication standards groups [2] for fast communication Internet, mobile Television, Video calls, conferencing, Multi Media Messaging Service (MMS), 3D gaming etc.

There was another protocol after 3G popularly known as 3.5G with technical name High Speed Downlink Packet Access (HSDPA). It was providing 8.1Mbit/sec data transmission rate [3]. The 4^{th} generation (4G) offers a transmission speed of 100Mbps. It is enhanced protocol with new services e.g. MMS, Digital television in High Definition (HD), entertainment services. The Long Term Evolution (LTE) and Advanced (LTEA) is considered a part of 4G technology. The 4G is known as ubiquitous networking. The major key challenges in 4G are Mobile stations, systems and services.

The communication devices (mobile phone) have various new features to provide applications to the subscribers that 4G offers. For example, auto reconfiguration mode to download and configure software for system updates from the available network service providers. The other important features are Location and handoff management that handles the tracking of the communication device, its authentication and assures QoS statistics. 4G offers vertical and horizontal handoffs caused due to client's device movement between GSM network and Wireless Fidelity (WiFi).

In the times of 4G, a new term NGN came up that is defined by Next Generation Networks (NGN). The term NGN is used to develop advanced architecture and protocols to cater to the demands of the burgeoning subscriber base. Along with it another very important concept cane up of connecting all the devices with WiFi or communication network that is making device compatible for communication on the basis of internet protocol (IP technology). It was named as Internet of Things (IoT). The main purpose is the convergence of communication networks to reduce cost and offer integrated internetworking services. The motivation behind the migration of networking systems from the traditional telecommunication network to NGN has been developed based on the advantages of backbone cost reduction, possibility of fast and new service deployment, controllable QoS, compatibility between fixed and wireless networks, network management centralization, and so on.

The outcome is 5G system name stands for Fifth Generation Mobile technology. The research groups see the IEEE important protocols as important for this technology viz 802.11 Wireless Local Area Network (WLAN), 802.16 Wireless Metropolitan Area Network (WMAN) and Adhoc Wireless Personal Area Network (WPAN).The fifth generation communication system is designed to give user the best possible services to satisfy future needs. The focus in 5G is to develop Open Wireless Architecture (OWA), Open Transport Protocol (OTP) to offer multimedia, applications, entertainment, radio broadcasting, digital television services will achieve the best performance in terms of coverage capability, energy consumption, data speeds of 1 Gbps, better security and energy efficiency compared to previous networking systems. Throughout the world research projects are going on 5G eliminating the limitations of current technologies. The key requirements of fifth generation are real wireless communication without any limitation of coverage, access policy and density areas; the network should be able to support high resolution multimedia (HD) broadcasting services; it should provide faster data speeds comparatively than earlier version and should support wearable devices and connecting connection of Things (namely IoT). The next generation wireless network will mainly focus on new spectrum, multiple input multiple output (MIMO) diversity, transmission access and new architecture for capacity and connection time [5]. Despite IoT there is another technology for interconnecting computing hardware and software with unlimited power through Cloud Computing for the users to access services from any location irrespective of host or end device. The controllability, management, and optimization of computing resources are the main factors that may affect networking performance in the case of cloud computing. Many organizations are working together or individually on the standardization issues of IoT to create a unique platform for future generation networks.

The network management is also a challenging issue owing to the limitations of traditional hardware based networking, e.g. complex and costly network architecture and fault management. Hence a novel technology, Software Defined Networking (SDN), can be employed to overcome the limitations of the current networks with the separation of network control from the switching devices. The SDN provides flexibility in changing network policies, ease in hardware implementation and helps in employing network innovation and evolution [6, 7]. A view of entire network using open interface known as Open Flow and centralised network controller is possible by integrating SDN with Network Function Virtualization (NFV).

In this manuscript, we provide a comprehensive overview of ongoing research on fifth generation network. The model for network control, SDN and NFV; cloud computing model from network operation and management viewpoints. The architectures and applications of IoT for 5G networks; and mobile access networks are discussed in next section(s).

A. SoftwareDefined Networking (SDN)

The SoftwareDefined Networking (SDN) is defined as an emerging architecture that is dynamic, manageable, cost effective and adaptable, where control is decoupled from data forwarding and the underlying infrastructure and directly programmable for network services and applications [8-11]. According to definition, SDN has the following characteristics: it decouples network control from the switches and routers; it allows the control programmed using an open interface OpenFlow [12, 13]; and it uses a SDN controller to define the behaviour and operation of the networking infrastructure. The SDN provides the flexibility to change the network configuration at the software level reducing the necessity of modification at the hardware level making easier to deploy new applications and services than through the traditional hardware operated networking architectures while ensuring QoS as per client requirements.

B. Network Function Virtualization (NFV)

The SDN and NFV are mutually beneficial, being complementary to SDN, NFV can effectively decouple network functionalities and implement them in software.

Clearly meaning that it can decouple network functions like routing decisions, from the underlying hardware devices (e.g. routers and switches). It helps in centralising these at remote network servers (in cloud) through an open interface such as Open Flow. The main advantages are cost reduction, efficient power consumption, fast processing, centralized network provisioning by decoupling the data plane from network control plane, extension of capabilities, hardware savings, cloud abstraction, guaranteed content delivery, physical versus virtual networking management, QoS and so on. The functionalities of SDN are programmability: network control is directly programmable using different software development tools along with the customization functions as per user requirements. The controller network is logically centralized providing a comprehensive view of the network. The SDN provides flexibility to manage, configure, secure and optimise network parameters through dynamic SDN programs. The SDN affords the flexibility of synchronization through the Network Operating System (NOS) approach on different physical or virtual hosts. SDN has the features to control the traffic flow with different granularity on the protocol layers and at the aggregate level. The SDN is protocol independence and helps control networking protocols and technologies on different SDN network layers. SDN controllers simplify network operation and design based on controller instructions applied through an open standard. It has the ability to modify the network traffic flow dynamically that covers widearea networks and in data center networks. NFV and SDN can easily manage resources using its centralized controller. The NFV is responsible for creating or processing flow rules, and SDN is responsible for the management of the said rules. Integration of SDN and NFV will be a promising technology for 5G.

C. *Cloud Computing for 5G Network*

There present day services for data communication need unlimited storage capacity and availability of data with high speed, thus cloud computing is considered as the only solution that can work as core backbone technology. Cloud computing and associated services can reduce costs for service provider and customer. The cloud computing has become an important reference architectures for fifth generation communication network due to the high data rate, high mobility and centralization management services. A complete standard architecture is required for common protocol of management and operation for cloud service deployment [20].

The proposed cloud computing architecture in [14] uses an actorbased structure. It comprises six major actors: cloud consumer, cloud provider, cloud developer, cloud broker, cloud auditor and cloud carrier. The actors have their own activities, requirements and responsibilities. The associated cloud services are classified into four different groups: IaaS, PaaS, software as a service (SaaS) and anything as a service (XaaS).

The research groups have proposed architecture focused on commercial models, service functions, measurement of service users preferences and satisfaction indexes. The Cloud Security Alliance (CSA) proposed Trusted Cloud Initiative (TCI) [15]. This TCI uses four frameworks to define security polity, namely the Sherwood Business Security Architecture (SABSA), Information Technology Infrastructure (ITIL), the Open Group Architecture Framework (TOGAF) and Jericho. The TCI architecture is complex because it combines several different frameworks and requires developers to understand all frameworks. The National Institute of Standard and Technology (NIST) [16] and IBM [17] have been referenced by industry and academia. The detailed architecture proposed by IBM's research team is called Cloud Computing Reference Architecture (CCRA), and it is based on customer's demands of IBM's cloud products and services. The increasing number of critical applications and services now support cloud computing architecture. Cloud computing is a excellent architecture for future generation networks.

The fifth generation communication will be an enhanced technology with the advantage of higher capacity, powerful accessibility with full on demand mobile applications and services. The service architecture of cloud computing is categorized into three classes: SaaS, IaaS, and PaaS. The SaaS includes applications such as Google Apps, Salesforce and Microsoft Office 365; IaaS includes applications such as Amazon cloud Formation, Google Compute Engine and Rackspace cloud and PaaS includes applications such as Google App Engine, Microsoft Azure and Amazon Elastic Beanstalk. The challenge issues of cloud computing are considered as Security & Privacy, Quality of service, access time and Accessibility, Data access control and transition to the cloud. The cloud customer needs assurance for the safety, reliability and availability of data round the clock.

D. *Mobile Access Networks for 5G*

There are three types of communication with 5G networks: Machine to Machine (M2M); Device to Device (D2D) and Vehicle to Everything (V2X).

The basic purpose of M2M communication is to transmit sensed data of small size with loose time constraints. To meet the characteristics of M2M communication, there are two categories of Radio Access Technologies (RATs) according to spectrum resources: cellular IoT and lower powered wide area network (LPWN).

Device to device (D2D) communication in cellular networks is an emerging technology that enables direct communication between user equipment (UE) with little or no help from the infrastructure such as eNodeB or core networks. D2D communication provides several advantages in terms of spectrum efficiency, power management, coverage expansion, and capacity improvement by reusing radio resources and allowing network functionalities to devices. Furthermore, D2D communication enables new services such as public safety services, location based commercial proximity services, and traffic offloading [18]. Owing to these benefits, D2D communication is considered one of the key techniques. D2D communication can be classified into three types based on intervention from infrastructure with network control: autonomous D2D, network assisted D2D, and network controlled D2D.

The advent of autonomous cars, high traffic information systems, and highly reliable safety services has led to the need for a new communication technology for vehicles with high reliability, high data rate, and low latency. This technology is called vehicle toe verything (V2X) communication, and it includes vehicle to vehicle (V2V), vehicle to pedestrian (V2P), and vehicle to infrastructure (V2I) communication [19]. D2D communication for cellular networks is currently the most suitable option for enabling V2X communication because D2D provides short end to end latency and a long transmission range.

II. CONCLUSION

The expectation of future mobile system or next generation wireless networks comprises highspeed access providing without limitation of time and location. As a consequence, the Next Generation Networks (NGN) has to deal with the high data rate, realtime data handling, centralized views of the entire network with minimum delay, greater security, fewer data losses, and less error rate. The development of any technologies with high data traffic and high QoS of universal network infrastructures depends on the integration of new technologies or new services with the existing network infrastructure. In this manuscript, we have discussed the network architecture, service framework and topologies that will play an important role to meet the requirements of future networking infrastructure. The requirement of 5G will be massive IoT connectivity, virtual experience & media and realtime communication. So, the architecture of 5G will be such that the flexibility and scalability of the future network will be maximized. Therefore, the future network will depend on the combination of new technologies such as cloud computing, SDN, NFV, and E2E networking infrastructure.

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