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APPLICATIONS OF 5G IN HEALTHCARE SECTOR

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ABSTRACT

Healthcare is undergoing a rapid transformation from traditional hospital and specialist focused approach to a distributed patient-centric approach. Advances in several technologies fuel this rapid transformation of healthcare vertical. Among various technologies, communication technologies have enabled to deliver personalized and remote healthcare services. At present, healthcare widely uses the existing 4G network and other communication technologies for smart healthcare applications and is continually evolving to accommodate the needs of future intelligent healthcare applications. As the smart healthcare market expands the number of applications connecting to the network will generate data that will vary in size and formats. This will place complex demands on the network in terms of bandwidth, data rate, and latency, among other factors. As this smart healthcare market matures, the connectivity needs for a large number of devices and machines with sensor-based applications in hospitals will necessitate the need to implement Massive-Machine Type Communication.

Further use cases such as remote surgeries and Tactile Internet will spur the need for Ultra Reliability and Low Latency Communications or Critical Machine Type Communication. The existing communication technologies are unable to fulfill the complex and dynamic need that is put on the communication networks by the diverse smart healthcare applications. Therefore, the emerging 5G network is expected to support smart healthcare applications, which can fulfill most of the requirements such as ultra-low latency, high bandwidth, ultra-high reliability, high density, and high energy efficiency.

Keywords*- 5G, smart healthcare, software-defined network, network function virtualization, the Internet of Things (IoT), device-to-device (D2D), ultra reliability and low latency communications.*

1. INTRODUCTION

Smart healthcare has a significant role in the economy. In Europe, the average spending on smart healthcare is approximately 10% of gross domestic product (GDP), and up to 99 billion Euros of healthcare cost can be saved through smart healthcare by 2020. In smart healthcare, internet of things (IoT) plays a pivotal role to improve and deploy a diverse range of applications, including smart medication, telemedicine, assisted the living, as well as remote and onsite monitoring ofassets in hospitals, patients behavioral change and treatment compliance.

According to a survey,IoT in healthcare will be about 117 billion US Dollars market by 2020. A diverse range of smart healthcare applications that integrate wireless mobile networks has been proposed in the literature. In smartphone using the next-generation wireless mobile network, namely 5G and IoT basedapproach has been proposed for continuous monitoring of chronic patients. In a mobile health system using 5G and IoT has been proposed for constant assessment and monitoring of diabetes patients.

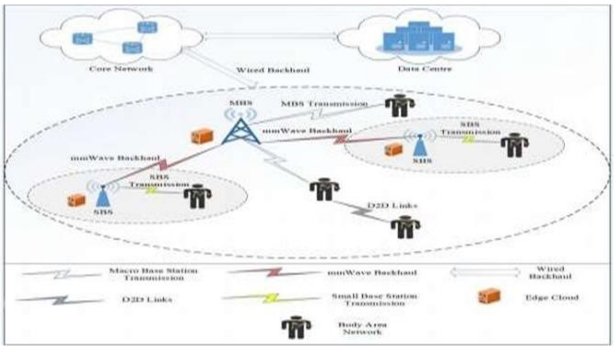

Fig 1: 5G smart healthcare architecture

In wearable devices using IoT has been submitted to support smart healthcare applications (e.g. remote monitoring, remote medical assistance). Wearables devices (e.g., sensors, smart watches, smart clothes) collect information, such as heart rate, amount of sleep, and physical activities for continuous health monitoring (e.g. heart rate, blood pressure, blood sugar level). In mobile gateways using IoT has been proposed for intelligent assistance in mobile health environment such as continuous monitoring of chronic patients (i.e., continuous remote health monitoring in real time).

2. TECHNICAL DETAILS OF THE PAPER

Overview of 5g in Healthcare:

5G is the next generation of the current 4G communication network that can provide more features such as high speed, capacity and scalability of the network. Standards, capabilities and technologies vision for 5G are still under consideration and discussion. ITU has defined a few parameters which can be considered key capabilities for 5G technology.

- Requirement of low latency must be supported (1ms or less than 1ms).
- 10Gbps to 20Gbps data rate must be achieved in different scenarios and condition.
- High mobility (up to 500km/h) must be achieved in network. 5G and IoT are expected to become important drivers of next-generation smart healthcare.

What is IOT?

Internet of Things is dynamic network infrastructure which has the capability of self-configuration on the bases of interoperable and standard communication protocols. In other words, IoT is flexible, complex and dynamic network infrastructure that connects anyone, anything, anytime, anywhere, for any services. The internet of things has numerous applications in healthcare, from remote monitoring to smart sensors and medical device integration. There is now a growing trend in the synthesis of sensors and sensor-based systems with device-to-device communications. 5G wireless systems (5G) are on the horizon, and IoT is taking center stage as devices are expected to form a significant portion of this 5G network paradigm. But the technology is still evolving. While one of the challenges of IoT in healthcare is to manage the data from various source, the future of IoT in healthcare application will depend on deriving meaningful insight from gathered data.

How People Benefit from 5G:

Fig 2 represents benefits of the 5G in healthcare. The selection of clinically relevant use cases for 5G applications to highlight the clinical potential of 5G technology. To stratify the use cases, we will group them by user group and applications and pinpoint the relevant aims and objectives, requirements, and estimated times to Clinical facilities are integral parts of national health services. 5G technologies will optimize communication for areas such as telemonitoring or telehealth and will fundamentally change the way healthcare will be delivered across the 21st century. Hospitals, practitioners, nursing services, and nursing homes, rehabilitation facilities make up our first group. This section includes 5G use cases to manage the hospital and to support the work of specific departments before and after discharge. Regional decision-makers are institutions that are responsible for enabling, managing, and controlling the healthcare system. Examples are health authorities, ministries of social affairs, as well as emergency first-responder and epidemic management. Individual users and their family members use technologies for personal reasons.

Fig 2: Benefits of 5G in healthcare

These provide a more immersive perspective on the use cases and support understanding as well as credibility. For a proper linking of the clinical use cases to the technology, we support every use case with a technical characterization. Firstly, we will present a qualitative evaluation of the use case according to its classifications in the “5G triangle” (requirements for data volume, transfer time constraints, and the number of senders). Secondly, the authors will present a listing of 5G specific technical features and technical properties that the use case requires. Lastly, we will introduce two parameters that provide an estimation of how strong an application benefits from 5G. The first parameter is the “5G benefit score”. It focuses on 5G-specifc features and KPIs and is expressed on an ordinal scale of low, medium, and high. The second parameter estimates the timeline for the implementation of the particular feature from the date of availability of necessary 5G infrastructure. Both parameters, the benefit score and the timeline, have been obtained by a Delphi study with seven experts. Fig 3 indicates the use case specific 5g. To increase the reader’s identification with the use cases that affect individual patents, we will later introduce personas for some use case.

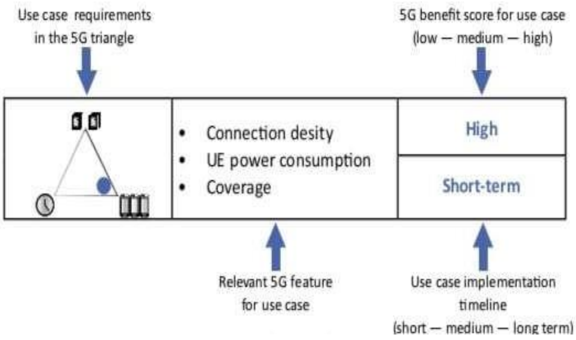

Fig 3: Use case specific 5G classification

3. FEATURES OF 5G

The current trend of 5G technology has a following feature.

- The 5G technology is providing up to 25 Mbps connectivity speed
- 5G technology offer high resolution for cell phone user and bi- directional large bandwidth sharing.
- 5G technology is providing large broadcasting of data in Gigabit which supporting almost 65,000 connections.
- The uploading and downloading speed of 5G technology touching the peak
- The 5G technology also support virtual private network.
- The 5G terminals will have software defined radios and modulation schemes as well as new error- control schemes that can be downloaded from the Internet.
- The development is seen towards the user terminals as a focus of the 5G mobile networks. E.g. The advanced billing interfaces of 5G technology makes it more attractive and effective.
- The 5G technology network offering enhanced and available connectivity just about the world
- The terminals will have access to different wireless technologies at the same time and the terminal should be able to combine different flows from different technologies.
- The vertical handovers should be avoided, because they are not feasible in a case when there are many technologies and many operators and service providers.
- In 5G, each network will be responsible for handling user-mobility, while the terminal will make the final choice among different wireless/mobile access network providers for a given service. Such choice will be based on open intelligent middleware in the mobile phone.

4. 5G HARDWARE

1. Ultra wideband networks (UWB):

It is already known that Wi-Fi, Wi-Max and cellular wide area communications are long-range radio technologies. But systems like WPAN need short-range radio technology, which helps in achieving higher bandwidths (around 4000 Mbps) but at low energy levels (UWB network) for relaying data from host devices to devices in the immediate vicinity, i.e., distances of around 10 metres or so. This higher bandwidth (4000 Mbps) level is almost 400 times faster than today's wireless networks. Each network will be responsible for handling user-mobility while the user terminal will make the final choice among different wireless/mobile access network providers for a given service.

Smart antennae : These include the following:

Switched beam antenna: This type of antenna supports radio positioning via angle of arrival (AOA). Information is collected from nearby devices.

CDMA (code division multiple access) technique: This technique converts audio analogue input signals into digital signals (ADC) in combination with spread spectrum technology. The signal is transmitted using modulation according to some predefined code (pattern), and is demodulated using the same pattern since there can be billions of code patterns which can provide privacy and sufficient security.

5G SOFTWARE

5G will be a single unified IP standard of different wireless networks and a seamless combination of broadband, including wireless technologies, such as IEEE802.11, LAN, WAN, PAN and WWWW. 5G will enable software-defined radio, packet layers, implementation of packets, encryption flexibility, etc.

5. KEY COMPONENTS THAT FORM 5G IN HEALTHCARE

Ultra-low latency: Ultra-low latency defines network, which is optimized to process huge amount of data packet with a very low tolerance for delay (latency). Some of the smart healthcare applications required very low latency. For example, in telesurgery, during communication latency impact the operation of robotic instruments. Less than 200 ms end-to-end latency is acceptable for future telesurgery. However, the inherent latency of robotic systems is almost less than 100 ms. The 5G network can minimize latency up to 1 ms, which can lead to new telesurgery applications with strict latency requirements. In future, modern solutions might be possible in the healthcare environment. For example, surgeons can perform operations with robots virtually from anywhere in the world.

High bandwidth: In figure 3.1 shows, Bandwidth is the capability of wireless or wired network communication link to send a high amount of data from one point to another in a given amount of time over a network. Biomedical sensors can send a limited amount of information due to restricted bandwidth in current 3G and 4G network, especially in real time monitoring application. A key feature of the 5G network is to support higher frequencies (including above than 10 GHz frequencies). More spectrum is available by using these frequencies, which leads to very high transmission rates (on the order of Gbps). Physicians can see high-resolution pictures remotely and deployed healthcare solution with ultrahigh-definition (UHD) content through the high-speed 5G network. Furthermore, the 5G network can allocate bandwidth in a scalable and flexible way during communication, which can enable D2D solutions in medical.

Fig 4: Key Components of 5G

6. USES OF 5G IN DIFFERENT SECTORS

Medical Imaging and 5G

As a massive number of images accumulates and manual segmentation requires a lot of time, it becomes a big challenge for analyzing and diagnosing and furthermore, it may not meet the demand ofanalyzing big images data.

7. OVERALL ARCHITECTURE

The existing mobile network architecture was designed to meet requirements for voice and conventional mobile broadband services. However, this has proven to be insufficiently flexible to support diversified 5G services due to multiple 3GPP version upgrades, a large number of components, complex interfaces.

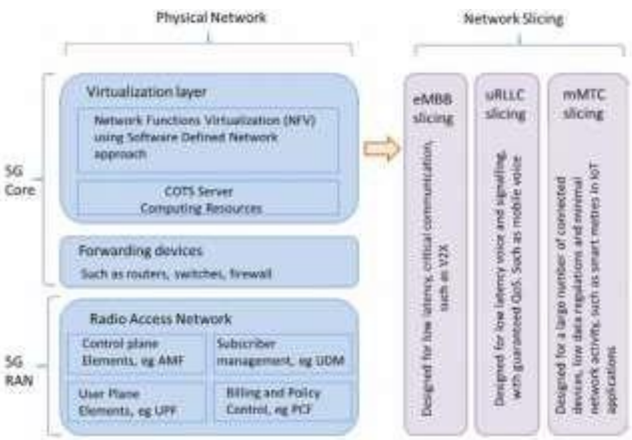

Fig 5 : 5G architecture concepts

Fig 5 shows the overall NGM architecture is split into three layers: infrastructure resource, business enablement and business application. The 5G architecture is a native SDN/NFV architecture covering aspects ranging from mobile/fixed devices network functions, value-enabling capabilities and all the management functions to orchestrate the 5G system. On the relevant reference points, application programming interfaces (APIs) are provided to support multiple use cases, value creation and business models. In 5G-PPP's architectural, orchestration is defined as a separate layer, and the architectural proposal is divided into five layers: resource and functional level, network operating system, network level, service level and E2E secure service orchestrator.

Two fundamental technological enablers include softwarisation, e.g. virtualization of network functions, as well as software defined, programmable network functions and infrastructure resources. Vendors have also proposed their architectures. Based on NFV and SDN, the physical infrastructure of the future network architecture consists of sites and three-layer DCs: central office DC, which is closest in relative proximity to the base station side, local DC and the regional DC, with each layer of arranged DCs connected through transport networks. Apart from differences in the architectures proposed by different organizations, slicing also applies to different components: to CN, RAN orboth. The key concept of 5G is a service-driven 5G network architecture, which aims to flexibly and efficiently meet diversified mobile service requirements. SDN and NFV are key technologies that support the underlying physical infrastructure.

Radio access network: RAN and CN are also referred to, largely, as infrastructure network. Compared to LTE, the improvements in the physical layer of the new 5G RAN are

Massive MIMO: MIMO technology has been considered as a vital approach to improving spectral efficiency for wireless communications systems over the past 20 years. In 4G systems, the number of antennas supported at the base station cannot be larger than 64 and, thus, the performance gain from MIMO is quite limited. For 5G systems and beyond, to further improve spectral efficiency and energyefficiency, a new technique named as large-scale antennas has been proposed to serve.

Multiple users in the same time-frequency resource. Massive MIMO uses hundreds, if not thousands, of antennas.

8. OPEN ISSUES AND CHALLENGES

Besides the above-mentioned advances, there are numerous challenges and open research issues in adopting 5G for smart healthcare. The aim of discussing these issues is to provide research directionin this domain for new researchers. [47]

Connectivity in iot: A smart healthcare network consists of billions of devices. Smart healthcare concept can succeed only if it can provide connectivity to every device present in the network with thecapabilities of sensing to produce important information. In smart healthcare, any available communication network can be used by IoT devices, such as Bluetooth, Wi-Fi, cellular network (LTE, emerging 5G). However, guaranteeing connectivity in smart healthcare postures many challenges, such as:

- Guaranteeing connectivity to huge devices deployed in the network in wide range.
- Providing connectivity to high mobility (i.e., highspeed ambulance, carrying patients) devices in thenetwork

Interoperability: Inter operability is an ability of two or more different networks and devices interconnect with each other for exchanging data. Smart healthcare includes different IoT devices from various range of domains (i.e., remote surgery, ECG monitoring and remote health monitoring). Interoperability plays an important role in smart healthcare, providing connectivity between different devices using different communication technologies. Interoperability between different devices in different domains is a key limitation for IoT success due to lack of universal standards.

9. ADVANTAGES

1. Connected ambulance. Some suggest that "connected ambulances" could help emergencyservices meet increasingly stringent targets and overall improve patient outcomes.

2. High definition (HD) virtual consultations.

3. Remote patient monitoring.

4. Video-enabled medication adherence.

10. FUTURE SCOPE

1. A reflection on the enormous number of advanced technologies rapidly occurring in this new Information Age emboldens the authors to make certain „extrapolations of known advancements in science‟ to suggest „forward-looking statements‟ about likely technology outcomes for the future. However, It is apparent that some of the emerging technologies, such as, 5G communications, AI, telemedicine (and telesurgery), automatic image interpretations, genetics, proteomics58,59 and others are radically (and rap idly) changing the practice of medicine. Two areas need to be addressed. The core technologies in 5G communication, that are supporting most every industry and the healthcare specific technologies for medical needs.

2. The assumption is that the 5G and subsequent generations of wireless communication technologies will provide service now and in the future with exponentially increasing bandwidth (for data/information flow), decreasing latency.

11. CONCLUSION

The works along with research opportunities on the networking aspect of 5G and IoT for smart healthcare. We firstly presented an architecture for 5G smart healthcare and the essential techniques (i.e., D2D communication, Small cells, Software-defined network (SDN), Network function virtualization (NFV), mm Waves and Edge computing) to enable 5G smart healthcare. Secondly, we presented the taxonomy of 5G smart healthcare, and analyzed the new requirements (i.e., ultra-low latency, high bandwidth, ultra-high reliability and high battery lifetime) and objectives (optimizations of resources, enhancing QoS, reducing interference and improving energy efficiency) for 5G smart healthcare. Thirdly presented a detailed review of network layer solutions, including scheduling, routing, and congestion control, applied to IoT based 5G smart healthcare covering both recent work and future research opportunities.

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