Final Report – A Survey for the Fifth Generation Cellular System

CIIC 4070 – Computer Networks

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I. Introduction

This paper is a project for the CIIC4070 course at UPRM. It will expand upon the research of the student surrounding the topics and questions prompted by the professor regarding the topics of Fifth Generation Cellular Systems. All of this is to complete a complete survey of the gradual progress of technologies and the details entailing each facet until the newest and latest iteration of cellular networks. It will describe what makes it so novel and the benefits/detractors that it may have upon its users.

II. History and the current status

a. 1G

The first generation of cellphone technology to be developed and to be commercially available to the public for general use and consumption. Its only capability was to perform voice call, nothing else. It lacked security, quality of transmission and most of the time the calls were interrupted or dropped due to interference and the poor infrastructure surrounding the devices. In short, it only served as the base/precursor for innovations that would make the use of this network tolerable and fit for everyday use. The first country to use this system and have it available for all its citizens was Japan in 1984. Currently the only country preserving a 1G network is Russia.

b. 2G

The second generation of cellular networks and devices came shortly after the immense success of the 1G devices in Finland. This iteration introduced the first encryption protocols (GSM), it improved the voice reception and transmission to be less static. It also made this network be filled with more concurrent users and to be more accessible in terms of pricing. It also introduced texting, MMS and it used less power than its predecessors. This generation is still widely used in Europe and in some parts of America. However, it has been discontinued in many countries around the world and removed from many notable companies such as AT&T, T-Mobile and Verizon. The peak era of this generation lasted from 1984 to 2003.

c. 3G

The third generation of cellular technology as introduced commercially around 2001 in Japan. It later arrived in the form of UMTS in Europe and CDMA2000 in the USA. It basically introduced to the world to streaming, video conferences and social media as we know it today. The high bandwidth and transfer capabilities of this network instantiated a social change regarding the use of phones (which led to the development of Smartphones, spearheaded by Apple and Motorola). It was also the first network that allow the development of EDGE technologies and

remote service providers. Today 3G is mainly used as backup for 4G networks in case of loss of speeds and bit rates.

d. 4G

The fourth generation of cellular technologies are still today's standard network service for just about any cellular device or Wi-Fi related hardware. It was introduced in Norway and it came as the first network to be included into the LTE (long term development) classification. It differentiated itself from its predecessor by changing the old, circuited design for the connection of their devices with IP route packets. Its used worldwide and provides some of the highest data transmission throughputs available for the public and its consumption.

III. Market trends of 5G systems

The growing need for higher speeds (far beyond the limits of 4G) have propelled the interest in the market for higher bandwidth in the next upcoming generation of cellular devices, 5G. The private 5G network market is expected to witness a tremendous growth rate since the workplace for many of the workers around the global are slowly relying in virtual spaces, entertainment and much about the day to day of a vast number of individuals and organizations rely heavily on streaming and remote transmission. Therefore, this influx of shares into the respective developers of 5G technologies does not come as a surprise. Some other trends are quite noticeable in the rise of 5G:

- Based on component, installation and integration service segment accounted for the largest market share and is estimated to exhibit the faster CAGR over the forecast period. Increasing activities for installing a private 5G network for ensuring information security is contributed to the segment's growth.

- In terms of frequency, the sub-6 GHz segment is predicted to hold most of the market share and witness an exponential growth rate during the forecast period. Recently, governments of major developed and developing countries have brought sub-6 GHz frequencies in their countries to provide reliable 5G services.

- By spectrum, the unlicensed/shared is emerged as the dominating segment and is expected to maintain the same trend during the coming years. The segment's growth is attributed to a substantial rise in the demand for faster private 5G networks with affordable options. Unlicensed spectrum bandwidth is highly preferred for massive machine-type communications due to its easy accessibility.

- Amid the COVID-19 pandemic, there is a huge demand for higher data capacities and faster connectivity observed across different industry verticals. Private organizations and other potential users have started giving emphasis on the incorporation of private 5G networks to meet their requirements.

IV. Applications of 5G systems

5G systems are mostly applied in three distinct areas for the time being:

- Enhanced mobile broadband.
  5G mobile technology can usher in new immersive experiences such as VR and AR with faster, more uniform data rates, lower latency, and lower cost-per-bit.

- Mission-critical communications
  5G can enable new services that can transform industries with ultra-reliable, available, low-latency links like remote control of critical infrastructure, vehicles, and medical procedures.

- Massive IoT
  5G is meant to seamlessly connect a massive number of embedded sensors in virtually everything through the ability to scale down in data rates, power, and mobility—providing extremely lean and low-cost connectivity solutions.

V. Key technologies

a. Physical layer

- Massive MIMO

Massive MIMO — which is an extension of MIMO — expands beyond the legacy systems by adding a much higher number of antennas on the base station. The “massive” number of antennas helps focus energy, which brings drastic improvements in throughput and efficiency. Along with the increased number of antennas, both the network and mobile devices implement more complex designs to coordinate MIMO operations.

The objective of MIMO operations is to improve the transmission and reception of the same data through different propagation paths (EM-Waves, electrical currents, etc.). Massive MIMO increases network capacity, improves the coverage of the network and the user experience in general by reducing interference periods and bad reception obstacles.

- mmWave

Is one of the two types of 5G networks that will be available for the consumption of the general public. It is the fastest and most powerful version of it but the most limited in range. *mmWave* refers to higher frequency radio bands ranging from 24GHz to 40GHz, making it almost 4 times higher than the Sub-6GHz bands that are used in the real world. mmWave's limitations make it best suited for dense, urban areas, or specific targeted spots like airports or concerts. This however has the benefit of relieving network congestion in such areas, reason why current installations are mostly located in cities and not in rural areas.

b. Data link layer and MAC sub-layer

- Non-orthogonal multiple access (NOMA)

NOMA's primary functions are to provide service to multiple users using the same time and frequency resources. It mitigates interference through SIC, it cans support massive influx of simultaneous users and does not require rescheduling algorithm (consequence of the parallel nature of user participation/interaction with the network and each other). Finally, it maintains user fairness among participants allowing for a homogenous exchange of data.

c. Network layer

- Software-defined networking

The main concept of software defined networking is to decouple the infrastructure of wireless networks from expensive, closed hardware and shift it to an intelligent software layer running on commodity hardware. This includes the democratization of proprietary firmware the adoption of an open-source modality for collaboration and optimization of models.

- Network function virtualization

Network Functions Virtualization (NFV) is the decoupling of network functions from proprietary hardware appliances and running them as software in virtual machines (VMs). NFV uses virtualized networking components to support an infrastructure totally independent of hardware.

- Network slicing

5G network slicing is the use of network virtualization to divide single network connections into multiple distinct virtual connections that provide different amounts of resources to different types of traffic. A clear benefit of 5G network slicing for network operators will be the ability to deploy only the functions necessary to support customers and particular market segments.

d. Other major issues

- Network densification

5G network densification refers to integrating more elements into a given space by widening the range of frequencies that can carry signals as well as increasing the amount of information that can be carried on any given frequency. Collectively, the goal of all these efforts is to make 5G networks faster and to reduce latency, or lag times.

- Edge computing

This form of computing, that introduces remote centers/nodes for data processing and with high return speed rates could become a beneficial addition for future 5G technologies.

- Internet of Things

The increase of speed in this new iteration will expand in an exponential degree the number of interactions and users connected to the grid. It will also introduce the need to develop new security measures, protocols and standards to regulate the influx of new vulnerabilities that the network will face in the next coming years.

- Cellular vehicular to everything (C-V2X)

C-V2X will be a leading factor in improving car safety and in reducing fatalities on the road. It will increase object recognition and tracking accuracy and reliability to the required levels required for much safer driving and for fully autonomous self-driving cars in the years ahead.

VI. The future of cellular systems

6G and beyond will fulfill the requirements of a fully connected world and provide ubiquitous wireless connectivity for all. Transformative solutions are expected to drive the surge for accommodating a rapidly growing number of intelligent devices and services. Major technological breakthroughs to achieve connectivity goals within 6G include: a network operating at the THz band with much wider spectrum resources, intelligent communication environments that enable a wireless propagation environment with active signal transmission and reception, pervasive artificial intelligence, large-scale network automation, an all-spectrum reconfigurable front-end for dynamic spectrum access, ambient backscatter communications for energy savings, the Internet of Space Things enabled by CubeSats and UAVs, and cell-free massive MIMO communication networks.

VII. Conclusions

In conclusion, the student managed to survey in it’s totally the upcoming spectrum of technologies and caveats accompanying the 5G generation and to explain the development through history. He

managed to explain every generation predeceasing the newly added one and to explore what additions, improvements and issues it will bring to our society once fully implemented an open to all consumers.

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