**University of Ulster**

**COM 351 - Communications**

**5G Communication Networks**

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## Abstract

“Extending 5G capabilities to the 3+ billion unconnected people for education, healthcare, and participation in the global community that can spread economic prosperity. To me, that’s one of the most important challenges – and responsibilities – for those of us developing 5G.” (Fettweis, G., co-chair IEEE 5G)

When discussing about 5G communication networks it can be stated that the communication industry is determined to readapt the role of satellite communications. Network Function Virtualisation (NFV) and Software Defined Networking (SDN) technologies are also directed to the improvement and better integration of satellite and terrestrial communication segments.

In the present day, for wireless networks, energy efficiency has become of a significant importance. To meet the needs of an increased capacity, a better data rate and increased quality service, wireless networks will need to adopt the efficient energy architecture. With the use of high powered wireless networks, the attempt to reduce the carbon footprint is important, an achievable goal by the reduction of the power consumption.

5G networks in connection with D2D, device-to-device communication paradigm, can provide an infrastructure for different smart city applications, for example public safety.

The wireless communications evolution from 4G to 5G has been driven from the demands of the business models and the applications developed for the industry. Factory automation, as an example, is a wireless application with high demands of communication requirements.

The architecture of the upcoming 5th generation networks do not yet have a standard definition. Referring at the complexity of the 5G network, it can be stated that the 5th generation network is a network for the networks and not a single access radio interface. Considering the statement “network for the networks”, the integration of a variety of other networks will require to change the way the networks communicate and complete one another to deliver data from high speeds with an end latency of milliseconds.

## Introduction

5G technology will change the way we use wireless networks with a high bandwidth.

When discussing about 5G, what it must be understood from the start is that 5G does not refer to the speed of the network, it stands for the 5th Generation of Network Technology. 5G is a name used in research, projects and papers to outline the next phase of telecommunication following the 4G/IMT.

The internet traffic is characterised by an always increasing demand. The challenge for the network operators is to find new ways to accommodate the demand of traffic without a high increase of the infrastructure and operational costs.

Technical details suggest that in the following emerging technologies the intelligence of the 5G network will be elaborated. As presented at the beginning of the paper, technologies as Software Defined Networking and Network Function Virtualisation are among the technologies that will benefit from the implementation of 5G networks. Along with the implementation and help of these technologies the network operators will have the capacity of increasing the speed of their services to cover the need for faster data rate. As other named benefits, these technologies will also contribute to the reduction of the cost of the equipment and the reduction of the power consumption needed to run the network.

Since the implementation of the first generation of wireless communication, a gradual but calculated evolution of wireless communication has begun. The evolution has continued with the second, the third and last, the fourth generation of wireless communication. Towards this evolution a significant impact has had the implementation of packet-based internet, physical layer technologies, digital modulation and the key factor, the growth in popularity of smart devices, oriented towards multimedia applications which became part of the everyday life.

In 2014 the total mobile traffic experienced on the globe has increased with approximately 70%, compared with previous years. The increase in smartphone usage along with the advancement of smartphone technology has led to the growth in traffic allocated to multimedia video. To support the explosion and the exponential growth of the multimedia traffic is an extremely demanding task for the 4th generation network which is in use in the present day. The development of the 5G network has started along with the concern of the sustainability issue of the 4G network in regards with the exponential growth of the internet traffic in the long run.

The capacity of a wireless network has a high dependency of the bandwidth. Technically, most wireless network uses a spectrum of mm-wave bands starting from 300MHz to 3GHz, often called a “sweet spot”. The strength of the 5G network is exploring the remaining wave-band ranging from approximately 0 MHz to 300MHz. This spectrum can sustain a capacity of hundreds of times extra data rate in comparison with the current currently used spectrum, thus opening new possibilities towards communication via wireless networks.

The effect of combining the new possibilities emerging from the newly discovered wave spectrum access, along with different researches from the industry has made the possibility of identifying the 5G networks with the following characteristics:

* Data rates in networks from 1Gbps to 10Gbps;
* Round trip latency up to 10 times smaller than the current 4G network, approximately about 1ms;
* Massive number of devices connected to the network. The emerging 5G network will have the capability to provide connectivity for thousands of new devices;
* Availability of 99%, the network can be available always;
* High Bandwidth for a sizeable number of devices connected for a longer period in a specific location;
* The reduction of the device’s power consumption while connected to the network;
* Green technology is being considered for development by investors. In theory the energy consumption should be reduced with nearly 90% and still be able to provide high data rates and connectivity.

Considering these aspects several organisations from the industry have begun the collaboration in several aspects of the 5G network communication. Many organisations are also collaborating with governments, different universities and associations to try and develop new and innovative applications and technologies. The industry is focusing the attention on the delivery of rich media content in real time and the persistent wireless connectivity. In technical terms it has been established that lower wave frequencies will attend to the network coverage and the higher frequencies will be responsible for higher data rates.

## Background

First generation of cellular communication has been introduced in the la 1970’s. Frequency modulation and multiple division access have been used for the voice channel. The major disadvantages have been great amount of power consumption, poor voice quality and large equipment size.

The second generation, 2G, has been introduced in the 1980’s. The second generation has been oriented towards voice with data services at low speed. The 2G network has been constructed on GSM technology or global system for mobile communication. The GSM system did not achieve high data rates such as multimedia or video data.

The 3rd generation of wireless communication is capable of handling video data and supports data rates at higher speeds. The third generation of wireless networks is making use of CDMA or Code Division Multiple Access Technique. 3G technology facilitates 2G phones streaming of videos and the use of multimedia applications. Also, 3G wireless networks had an increased bandwidth in comparison with its predecessors.

In 2009 the requirements for the 4G wireless networks have been specified. The 4G network has been expected to provide secure connection of the devices connected to the network. Technologies such as COFDM or Coded Orthogonal Frequency Division Multiplexing, MIMO or Multiple Input Multiple Output have been adapted to suit the good functionality of the 4G wireless networks.

The 5G wireless network is in continuous research and it is expected to cover the whole requirements that have not been cover by the 4G network. In its early implementation it has changed the use of devices on networks with high speed bandwidth. A big advantage in 5G networks is represented by the excellent support of consultancy together with software.

All the devices connected to a 5G network are expected to have a private IP address. 5G network is expected to be capable to broadcast data supporting over 65000 connections.

The 5G network will replace the 4G technology with ease with the aid of a technology called Beam Division Multiple Access or BDMA. The concept of BDMA is similar to the communication of cellular stationary station and the cellular mobile station.

## Technical Information

For the development of the 5G networks, techniques of multiple access in the network need improvements. The existing technologies are quite capable of accomplishing the task required for the 4G networks, will still be available for the next decades, and can be used for the functionality of the 5G network. Also, there is no need to make any modification to the network setup used from the start of the 1G network all the way to the 4G network.

To be able to cover the massive increase expected in traffic extra spectrum must be added to complete the gap. The World Radio Conference has focused of covering the need of spectrum by completing with additional spectrum below 6.5GHz and soon the range will be extended over the 10GHz step. Nevertheless, the researchers consider that to address a range of frequencies with a single structure of radio interference is not the best approach. Many issues as compatibility, propagation, implementation and frequency bands must be considered as impediments in the good functionality of the network. Up to a certain frequency the network can run on the same principles as the existing networks but with higher frequencies, simplified radio interface structures need to be put in use.

### Antennas

Beamforming advanced antennas will be able to improve the data rate capacity and the capacity of the system. Due to challenging propagation conditions the network deployments must be dense, meaning that the networks that are operating in high frequencies will be first implemented in areas with high population like centre of cities, airports and large offices. MIMO antennas or antennas with raised number of elements can be used to reduce the imperfections occurred in radio frequencies and control the interferences found in the networks.

### Lean Design

The current implemented system is transmitting continuously signals and is broadcasting data used by the terminals as the data is moving across the cells. Having a dense network deployment and increased number of nodes the network transmissions are not viable from an interference point of view and an energy consumption perspective. Ultra-lean design having signals in an always-on state but reduced to a minimum, must be considered as a key design principle in the future following systems. Ultra-lean design is an efficient network design with low operation cost and a low level of interference, a starting point for deployment in dense local area networks.

### Flexibility of the Spectrum

The currently available networks are deployed in a licensed and legal spectrum. The existence of the licensed spectrum will guarantee the control of interference and coverage. In the future the systems must provide an increased flexibility for the spectrum area in order to make use of the high frequency bands. The unlicensed spectrum can be used to boost the handling, the signalling and the capacity of the network. An example of flexible spectrum is represented by systems that can access additional spectrum with a license shared access.

Flexible duplex, where the resources of the spectrum are assigned to any transmission direction, will give access for the full bandwidth to be used in every direction needed. It is also important to know the fact that flexible duplex can explore the spectrum allocation that have not yet been paired.

Full duplex operations, with same time transmission and reception over the same carrier, can also be used assuming that techniques for cancelling interference are in place.

### Low Latency

To achieve low latency over a wave link it is important to reduce the time intervals and increase the wide of the bandwidth in the block where a specific amount of information is transmitted. The design also needs to include fast decoding receivers to be capable to reduce the processing delay times. In specific cases, a communication with low latency is a must between devices situated in a nearby proximity, and in such cases device to device communications helps provide the much-needed transmission with low latency.

### Convergence of Access

The design for the future systems will not make a major distinction between the traditional method of the split, between the wireless links (backhaul) and the access links, as this method is bound to diminish and bring several benefits to the design. The connectivity between the nodes of the network and network itself will simplify development, particularly in dense area networks with many nodes. It is also a very promising alternative solution for deployment of fibre optic with increased frequency bands.

Backhaul network it is not a recent technology but compared to the existing technologies where the resources of the spectrum have an exact division between the access and the backhaul or wireless, the spectrum is used with an increased efficiency by having a dynamic split among themselves. This case facilitates the use of the same radio technology for both type of connections. A benefit rising from this connection is the use of the similar type of maintenance and the operational system can be used for both the connections.

### Enablers for Machine Type Communications

The switch to 5G network will lead to a vast number of devices connected to the network that will infrequently transmit tiny amounts of data. The devices, by construction, will be simple and hidden in the construction of the environment, having light radio communication design and relaxed requirements regarding the process of communication. The aim is to acquire “null-overhead” communications by creating simple connection states and provide channels of access with lowered signalling.

Having networks in remote and challenging areas, optional means of transmission must be in place, with control channels to ensure efficiency, to provide connectivity at minimum rates.

By construction, machine type communications are taking place at frequencies under 3GHz and more often even under the step of 1GHz, where older cellular system communication shall remain in place for a long time, leading to the goal intended to be achieved, “spectrum-compatibility”, an interface which will ensure the co-existence of all legacy communication technologies.

### Architecture

The idea in the 5G network is to incorporate different technologies in the design to provide mobility and access for the everyday user. This design has a high importance for the operator as it will provide a unique integrated network that will stand for high efficiency, procures high performance for the end user and from the maintenance/operation point of view it is an extremely viable solution as it will reduce the operational expenses. Multi-connectivity technologies, as an example for the integration of 5G network, where one terminal is connected in the same time at several 5G terminals will support same time data transmission and a quick recovery in the event of a lost connectivity.

The architecture for 5G networks reveals a model based on the IP, for mobile network and wireless networks to work interoperable. The 5G network, in terms of wireless, comprises several radio access technologies and a user terminal which plays a key role in the design.

5G network is functioning on an IP based model. The model through its design will ensure the proper control and direction of data packets to a specified connection. Routing of the data packets is established by the user who is bound to follow certain rules and policies. The connections are set up among the client and the server over the internet via sockets. The socket is an end-point for data transfer and it represents a combination of the IP address and the communication port for the local transport.

In case of operability among networks, the local IP address and the destination IP must have a fixed value. To preserve the integrity of the packets and to reduce data loss, the transport to the destination and the return should be unique and use the same path.

Every technology available to an end-user to attain connectivity has an appropriate IP or Internet Protocol. Every IP is characterised by the subnet mask and the associated parameters with the routing of the packets over the network.

Smart radio, or cognitive radio technology, is yet another important concept for 5G networks. It allows different technologies to use the same spectrum for transmit efficiently by adapting the transmission scheme to the technologies using the current wave spectrum. It is constructed on software defined radio.

## Critical Analysis

The switch to 5G network will have a massive impact over the industry, but the industry will need to solve certain issues regarding the topology of the network and the use of the spectrum. High frequency bandwidth is investigated for use in the future network but, as it offers small cells radius, to resolve the network coverage by using the existing network design will be a major challenge.

The research over “beam-forming”, or the concentration of a transmissions into a beam to have the capability to cover large distances has led to the conclusion that, to function properly the connected device of the end-user must be tracked with the aid of the beams and implementing the technology would mean an expensive deployment of the 5G network.

Regardless of the current technologies in place, the transmission of signals will still be governed by the laws of physics, so to achieve low latency and small delay time, the data to be served to the end-user must be physically situated at a very close range from the end-user’s device.

In 5G network a unique infrastructure can be implemented to be shared by all the providers. It would mean that all the end-users would be attended from one sole source meaning that one single radio network would have to be build and the single radio network would have to be managed by a single organisation erasing all the competitors from the market.

## Conclusion

The nearby future is expected to have a fast-growing technological change. The fast development of wireless technology is pushing the development of the next stage in communications, 5G network. The 5G network is expected to bring a major change in the networks. It will offer reliable high data communication and low network costs. The future generation of network communications are concentrated mainly in the increase of the data rate. 5G technologies will contain a numerous of advanced features that will make 5G network the lead and the most powerful network in the future, depending if it will be fully implemented and made available to all users.

A major concern behind the development of the 5G network lies in the growth of the energy consumption and the emissions of gas. This concern will lead to extensive research in the energy consumption field and cost efficiency and the most important will lead to future possibilities in the different research directions.

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