

Cloud Networking in 5G

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**Abstract**

The following survey aims to cover the importance of developing a faster and more efficient communication technology than 4G, the brand new 5G, in the views of the past and current research, as well as a quick pick at the future trends of this system, all in order to adapt to the user’s needs of services delivered over cloud computing. Nowadays the data is increasing in size, with more and more people using their smartphones rather than their computers since it is the device carried all around. For the user it all comes down to the basic idea of scalability, flexibility, and easy usage as the population is facing an area of rapid development in all fields of technology. The expansion of such technology will not only provide the user with more complex services available on the smartphone or tablet but will give more possibilities to the companies to have more clients on their platform for a wider coverage. This paper will cover the challenges in terms of network design, the research made on the 5G technology, the solutions and future implementation of it, but also how these applications and services will improve and give more when 5G will be the standard.

**Introduction**

The society that we are living in has a need that cannot be stopped which is linked to our natural human behaviour, the need for information. The more information a person has access to, the more it will help that person to have better standards and knowledge about the world he/she is living in. Cellular networks have played a major role into providing information [1], from the simple voice call that would make it possible for someone to talk to a person located further away to the Internet’s services and applications made available through the smartphones which gave us access to even more than just call talk. The goal of the cellular network technology is to provide each person with access to information in all the possible locations with any device, from a simple and cheap phone that has access to the Internet to the smartphones that would give people more complex services and applications to fulfil their needs [2]. The information access has to have low latency and very high bandwidth so that all these services to be accessed instantly. The following paper is covering the evolution of the cellular networks and how it got to this point, the architecture that would make 5G available to the wide population, the technologies that are emerging for this network, applications and services using 5G and then concluding with the future predictions alongside the overall picture of how cloud computing will have more capabilities in a 5G world.

**Wireless Technology Evolution**

Wireless technology has evolved in many ways since 1980 when the first generation of mobile technology has been released in Japan, also called 1G. The main aspect of the first generation is the fact that it was analogue with a speed of 2.4Kb/s. More countries like Denmark, Sweden, Norway launched it and by 1983 the United States as well [3]. It was replaced by the second generation, 2G which would be digital instead of analogue in 1991. The difference between 1G and 2G was the fact that phone conversations would be digitally encrypted, wireless penetration level would be bigger which would provide a signal on longer distances, and also the feature of sending SMS messages compared to 1G. 2G has two categories: GPRS, which has a transfer speed of 40Kb/s and EDGE which can lead up to 1Mb/s speed. One of the features of 2G is that the phone battery would last longer because of the radio signal which is on low power [4].

One of the breakthroughs of wireless technology development was represented by the launch of 3G. Compared to 2G the speed increased. The low limit was 7.28Mb/s and the maximum were up to 21.6Mb/s. Also, the user equipment can authenticate before connecting to a network and also the applications started to vary since the bandwidth evolve. Some of the main applications that uses 3G are: GPS (Geolocation Positioning System) that would give the possibility to locate a person on the map which also meant the development in technologies like Google Maps. Mobile television is another application which provides the ability to watch live streaming tv services on the phone alongside video conferencing which will increase the workflow by giving people the power to make video calls wherever they are (5). In 2009, the first generation of 4G was released in some parts of the world with the idea that 100 MB/s would be the low limit speed of it. This was followed by LTE (Long Term Evolution) Advanced that would get impressive speeds, the peak upload achieved 500 MB/s and the peak download 1000 MB/s or 1Gb/s, something that was not possible before. The above results were able to be produced in a controlled medium; once the technology was released the masses achieved an upload speed of 50 MB/s and the download peak of 100 MB/s (6). The major difference between 3G and 4G is simply the speed and how that is helping people to get the information or services desired faster.

Finally, the latest wireless technology set to be released in 2020 in most of the countries and in the early of 2019 in particular ones is the 5G. The part that evolved most is the speed which in an eMBB (Enhanced Mobile Broadboard) usage scenario can top a data rate of 20 Gb/s. It is important to mention the fact that the energy consumption will be equal to 4G which means that we have a data rate 20 times faster than 4G but with the same energy consumption. Latency will also be around 1ms compared to 4G’s 53ms. Apart from the specifications presented above, 5G will help a new market to increase in size and popularity: The Internet of Things (IoT) since the bandwidth is increased, the latency is low, and the connectivity will be very high. There will be more smart devices leading to smart homes that will decrease the time a person spends doing everyday things with a greater accuracy and speed. (7)

**5G Network Architecture**

Based on The International Telecommunication Union (ITU) and cited in Huawei’s report for 2016 [8], the 5G is categorized into 3 categories:

1. Enhanced Mobile Broadband (eMBB) is mainly used for high bandwidth and requirements used for High Quality video playing, virtual reality and augmented reality;
2. Ultra-reliable and Low-latency Communications (eRLLC) focuses on automated driving and remote management since they require low latency
3. Massive Machine Type Communications (mMTC) aims to cover the smart part of the things such as developing smart cities and agriculture.

In terms of architecture, the current used one is meeting the requirements of the current generation but is proven to be insufficient for the future starting with 5G and this is mainly due to the complex interfaces, large number of NEs, and more than one 3GPP version update [9]. Following Huawei’s thoughts, they see the architecture of 5G as follows:

* As many complex network connections that are capable of comprising more than one service, with different KPIs or site category, as well as other standards, such as Wi-Fi or LTE;
* Capable of coordinating a multi-connectivity as it is expected to co-exist with the older LTE and Wi-Fi for a quite long period of time. This will need to be created while considering the traffic and the mobility it requires in order to remain accessible on the cloud;
* It will be believed to work as an anchor that will have the capability to maintain resources both in real time as well as in latency;
* A flexible connection of functions is mandatory as especially eMBB will need a large throughput, and eRLCC “requires a ultra-low latency and high reliability” [9, page 6];
* A short period for any service or action to take place, especially with the rapid expansion of the new services that have such requirements, along with 5G;

In order to sustain the diversification that comes together with the revolutionary 5G, an E2E “network automatic slicing” is implemented. A short description based on NVF, Network Functions virtualization, and SDN, Software-Defined Networking, is that E2E is a new base created of three different layers of DCs, adapted in order to support both macro and micro stations and support the implementation on real-time actions. Huawei [8] describes the three layers as “bottom layer […] being the central office, which is closest in relative proximity to the base station side. The second layer is the local DC, and the upper layer is the regional DC, with each layer of arranged DCs connected through transport networks”. They are also discussing these while thinking of a single foundation, independent of the other infrastructures and with a private physical condition, capable of support all three categories of 5G, eMBB, uRLLC, and mMTC.

Hansen et al. [10] think of 5G as not necessarily a new technology, but an old, improved one, that can support the same old documents, files, or services, in an improved way. It is not about inventing the fire again, but more about improving it to give a better and faster result. They are following by discussing the same needs and key capabilities that the new 5G will show, starting from multi-platform support to M2M communications within milliseconds that together lead to a high reliability and efficiency. However, their big focus and what individualizes their report is the complex focus on SDN and NC. They talk extensively about the need for SDN, previously defined as software-defined networking, to shift from the current OpenFlow platform, to an improved and more time effective one. Even more interesting are their thoughts on the combination of this with network coding, This would not only favourable for having an interface capable of communication different platforms, but also would allow a better “level of redundancy per link” while allowing the choosing of NC parameters to the needed standards. Nevertheless, the authors of this idea acknowledge the little research done on this topic, as well as the little overlapping between the two forces, which both lead to a limited understanding of the topic.

In order to fully understand why the research on 5G is following the stages and topics covered in this report, it is also important to understand how and why 5G will “face an exponential increase in data traffic” [11, page 69]. Firstly, every day there are more devices that search connection to a network, with 5G facing the larger number of devices ever seen. Secondly, all these devices are not only higher in numbers, but they are also more powerful and capable of accessing data and resources of upper quality. As an example, if the beginning of last decade can be simply understood in terms of technology as devices capable of manipulating 2D videos and web-search, the emerging of the next decade will be almost solely towards 3D and real-time interactions, all embedded into a more diverse way. Moreover, all these devices and applications will be used more in the day-to-day life and industries, such as healthcare, transport, security, but also in the daily shopping, movie time or bed-time story. Finally, a trend already visible nowadays but which is expected to skyrocket in the next few years is the dependency on the smartphone or tablet for doing more complex tasks that necessitated a desk or portable computer in the past. In Rost’s et al. [11] words, “this implies that per-user storage and processing requirements will further increase, while per-device capabilities will not increase at the same pace” (page 69).

In terms of architecture of the future 5G, Rost et al. [11] are supportive of the adaptable and scalable network as the connection will need to work concomitant with its older relatives. All concepts need to be as transparent as possible in order for this to be satisfied, as previously mentioned, this technology is believed to occupy the market only after a while. He mentions three important elements that need to be satisfied of its architecture:

1. Be completely compatible capable of supporting the process centralization of RAN;
2. Take into consideration the increased traffic and number of devices connected, as well as the backhaul, when considering the “optimal functional split” (page 71);
3. Be able to submit a function capable of supervising the “interaction of functions distributed on different network entities” (page 71);

As a side but interesting note, Andreev et al. [12] is talking, besides the all other common techniques discussed in this paper survey, about “the complications of HetNets and D2D connectivity between people are aggravated today by the challenges coming from the integration with the Internet of Things infrastructure” (page 3). He raises the problem that 5G might not be capable of ensuring a proper communication while using the current tools.

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**Emerging Technologies**

Chen et al. [13] are discussing about a ‘cloud-based wireless network architecture with four components, i.e., mobile cloud, cloud-based radio access network (Cloud RAN), reconfigurable network and big data centre’ (page 704). All these are thought to be capable of providing a better and virtualized wireless connection. The ongoing increasing number of the populations and the continuous developments are bringing to the news the need for an improvement in the technical area of all services and devices. With this in mind, Chen et al. [13] are mentioning that a mobile traffic in 2020 is expected to be at least 500 times the one that was seen at the beginning of this decade. This increased traffic is bringing with itself the need for better communication systems starting with the connectivity, performance of the network, and ending with resources.

Similar to Chen et al. [13] and Demesthicas et al. [14], Rost et al. [11] is also discussing about the “multi-cell interface”. This is all a result of a centralized process that allows denser networks to work properly, regardless of their complexity. It also makes space for the usage of RRM, or radio resource management algorithms, to be implemented across more than one cell. Furthermore, it “allows optimization of the radio access performance at the signal level, for example, through joint multi-cell processing and intercell interference coordination (ICIC)” (page 69). The two, RRM and ICIC, will lead to a better RAN implementation as it can avoid cancelling between two neighbouring cells. In the recent past C-RAN has brought the attention of extensive research as a possible method for optimally centralizing the available and needed resources. However, its requirement for optical fibre makes it hard to use as it lacks to support the speed, and its described in the present as having little flexibility as the fibre is not omnipresent in the world and is believed to be an element that will create the future.

On the same topic, Rost et al. [11] is discussing about the “ultra-dense deployments” that are key enablers for the 5G technology. These are supposed to “use […] very dense, low power, small-cell networks” (page 69). He mentions two main such effects. The first one is solely referring to the distance between the radio access point and the user. This needs to be as small as possible in order to concrete in very high information rates. The second one, refers to the “recycling” of technology, where some resources are re-used across multiple cells. From the traditional small cell deployment these would use less power and supplies, which is of course implying a better usage of these while shortening the transmission time.

Together with other social plans, 2020 is expected to be the year where the 5G technology will be the world leader in terms of mobile communication. This is only because of its supposed power to connect anywhere in the world, at any time, and any need, but also because it is bringing to the public a revolutionary dynamic way of protecting planet’s decreasing resources. Chen et al. [13] are creating a perfect parallel between the already 5 types of G, “from an ordinary consumer’s point of view, the original 1G and 2G cellular communication systems are expected to provide communication capability for users, need to assure the communication quality; the 3G and 4G cellular communication systems are expected to provide more broadband services, while the goal of future 5G mobile systems is to enhance the user’s experience, build a user-centric service model, and allow users to enjoy a new life style of mobile broadband (page 705). In other words, if the first two were simply designed to offer a way of communication, with the emergence of 3 and 4, a shift towards service quality and user preference was already visible, with 5G having completely the user and his/her needs at the base of its design.

Both Chen et al. [13] and Demestichas et al. [14] have focused a big part of their research on the Cloud RAN, or Radio Access Network. The two papers make a comparison between the traditional RANs and the new Cloud RAN. In the past, RANs were offering low utilization, not sufficient expendability, and a limited capacity. Not only the actual usage of the current base is staying low, but this might be for the simple reasons that the areas requires for the constructions of new bases of extensive, as well as not offering the ideas transmission or reception signal. At base, the new RAN will separate the two bands, BBU (base band unit) and RAU (radio access unit). Chen et al. [13] was writing as a way of working that “Cloud RAN break the intrinsic connection between RAU and BBU, each sending or receiving signal from RAU is finished at a virtual base, and the processing capacity of the virtual base station is assigned by BBU in real-time, which can achieve global optimum utilization of physical resources” (page 708).

Another opinion is raised by Rost et al. [11] who considers that Radio Access Network used as a Service is a better solution for 5G instead of the conventional cloud-computing and gives a number of benefits. Although he acknowledges similarities between the two, he is insisting on the ability to enable isolation of the RANaaS platform which can offer a better security for the 5G mobile users. This argument is of high importance in respect to the increasing number of hackings and the importance of data confidentiality and personal safety. Moreover, he is also discussing the possibility to sell an item as both RAN services and their usage as two different products. While understandable from a business and seller perspective, the ethical behind it and the fairness towards the user should be questionable. On a further note, he is discussing about the RAN-Backhaul Operation as a vital part of the 5G survival. This is because the 5G will be dependent on “very dense cell layer that needs to be connected to the RABaaS platform” (page 71).

The above is an ideal cloud, but extensive research is still necessary to reach that stage. At the moment, a big focus in this field is on i) a better allocation of the existing resources and making them more flexible and to work in a dynamic way, even wireless; and ii) finally emerging the base to a complete virtual system that would not require little or no area coverage. Demestichas et al. [14] is discussing on the same matter but extends the idea of the shared storage between the computers and its resources. This would ideally lead to a “total cost of ownership (especially, capital and operating expenditures) savings if wireless networks are based on cloud principles” (page 49). However, as discussed in the chapter below, there is a drastically need for a more flexible cloud that could make shift completely to the mobile devices and not being dependent on fixed servers at any time.

**Cloud Computing With 5G**

The research of cloud computing with 5G is currently looking towards the combination with mobile technology, like smartphones and tablets, towards the creation of a mobile cloud computing. Han et al. [15] describes this as “mobile devices can offload computing intensive work and data storage tasks to the cloud via Wi-Fi, cellular, or other network interfaces to the server. The server then finishes the computing intensive work and returns the result to the mobile device” (page 40). Mobile cloud sensing is starting to emerge in different fields such as healthcare or environment monitoring. Nowadays, it becomes easier for people to monitor their health with the help of only an application installed on the phone that can, based on a given historic inserted into the app, to give a specific risk assessment of the user throughout the entire day and tell exactly when there is need for specialized medical help immediately. In 2015, ON World were discussing that the number of devices specifically created for monitoring fitness and health levels will be reaching 515 million by 2017, thing that did indeed happen and is rapidly increasing. This shows both the need for such shift and the necessary further research and development as well as the appeal it has to the public.

A big consideration when discussing 5G is also the implementation of mobile cloud. In a short description, this can be described and divided into three categories:

1. A remote control, or also known as a more traditional approach, is providing easy access to critical, intensive applications. As an example, Chen et al. [13] are mentioning in their paper the Apple’s iCloud, that offers access to documents, images, music, or storage to a huge number of people worldwide. Although an easy to use and scalable type of mobile cloud, this is also experiences “high latency, large communication overhead and other shortcoming, which do not apply to real-time application scenarios” [13, page 706];
2. The local cloud is a both a provider, as well as focused towards resource consumer. In a few words, it is connecting multiple local devices to connect a network that is capable of sharing resources, such as the above mentioned for Apple’s iCloud. It is a perfect tool when the important element is the time as it offers a fast response;
3. A more nonconformist type, the hybrid cloud, is focused on tasks being moved to a local cloud from an offload computing [13, page 706]. However, it is believed that the nowadays technology and its continuous fast development does not require anymore a local cloud to do the job that will be done with no effort by a, for example, remote control cloud;

In terms of data, the population is facing the emerging trend of big data gathered as a combination of mobile sensing data as well as social sensing data (i.e. millions of tweets daily are creating a perfect for data research). Although this can sound basic to a certain extent, a combination of the two can lead to a more comprehensive research. Han et al. [15] are mentioning a research that will focus on understanding whether the meteorological sensor and the data it transmits to the devices is related to the later mood represented into tweets or other social media posts. This is only possible by using a better network technology, and the emergence of 5G will facilitate this in a better way than the current technologies. Han et al. [15] make an important notice that this will be possible as 5G is promising to come with a speed higher than 1 GB/s, which is more than enough for the upper mentioned data sensing needs and analysis. In their own words, “the network capacity is up to Gigabits, which supports almost 65000 connections simultaneously”, making the bandwidth access to the new technology faster and meeting the requirements of the big data carpeting and analysis.

The close relation between the 5G and big data should also be discussed in the wireless support “and mobile network interoperability […] based on an all-IP network (AIPN) model” [15 page 44]. It is viewed to be the future of the communication framework, with only one network capable of transporting all types of information, from data, media, images or audio. This would be feasible by the creation of small packet that will incorporate all these by different criteria, concept similar to the traditional Internet. Han et al. [15] make an important notice that this will be possible as 5G is promising to come with a speed higher than 1 GB/s, which is more than enough for the upper mentioned data sensing needs and analysis. In their own words, “the network capacity is up to Gigabits, which supports almost 65000 connections simultaneously”, making the bandwidth access to the new technology faster and meeting the requirements of the big data carpeting and analysis. Due to the unseen 5G power all these are capable as it is using a so called “autonomous radio access technology” which offer the possibility to gather sensing data from multiple devices into a common network.

NIST (National Institute of Standards and Technology) defines mobile cloud computing as a convenient and fast enabler for the increasing network demand for a number of different resources, such as applications or services, which can be offered within a minimal time and with little effort, as well as only using a low number of resources [16]. It is defined as being highly efficient and scalable, which overcome the few shortcomings still present in mobile devices, such as limited power and resources, as well as computing. However, with all the capabilities, this cloud is still coming short on several different aspects, with more research being vital for its correct implementation. As mentioned above, although having a huge power of connectivity, 5G is still placed in the mobile networks and so, due the devices got limited network resources. Moreover, mobile cloud is working under the assumption that the architecture will be capable of supporting compatibility between different networks, which is not yet reached with the current 4G. It would also need to be supporting a never seen before workload with more and more users and applications every day. Cisco Visual Networking Index [17] was saying that “Global mobile data traffic reached 1.5 exabytes per month at the end of 2013”, with currently looking towards 15.9 at the very end of 2018.

The idea of mobile cloud computing is also supported by Barbarossa et al. [18] who mention among the advantages of this system a longer battery lifetime as there will be less energy consumed by the device to release the information to the cloud, a facilitation towards the usage of more complex applications, including the newer AI and augmented activity, with more storage solutions. All these are functioning while improving its reliability as the data can be released from the device and moved to a static and precise one. The author is also highlighting that all these advantages should be understood on top of the normal cloud computing capabilities.

Mobile computing certainly looks like the direction towards which 5G will feel comfortable embracing. Nicely put by Andreev et al. [12], it is “located at the intersection of mobile computing, cloud computing, and networking […] and inherits the attractive benefits of mobility, communication, and portability” (page 1).

**Opportunities**

In the present time, 5G can be discussed only in terms research and future plans, but also as a trial. EE is the first mobile network operator that has started a “demo” implementation of the new technology. The implementation took place in the most densely populated cities within the UK, such as London, Cardiff, Belfast, Edinburgh, Birmingham or Manchester, with a second wave coming in early 2019 with 10 other major metropolitan areas. It is still not known how the technology is currently working and whether the focus is on business or personal users. In terms of devices, Huawei and OnePlus were among the first that mentioned their devices as capable of supporting the 5G technology [19].

Generally, the current research is following a logical and practical way, however, there is little discussion about the social matters and ethical concerns around the subject. With the relatively new Facebook data matter and the increasing social awareness towards intimacy and the lack of it that the development of technology is bringing with it, the ethical concerns and how 5G will help keep these issues as low as possible should be a more discussed plan. None of the papers cited and discussed in this report are even mentioning the social concerns and how this technology will help protect its users.

**Conclusion**

5G is already shaping the future and the way people will be able to communicate and use powerful applications such as VR, AI based applications, or augmented reality. Although the ideas are separated in the so far research, while some are counting on a combination of multiple cloud systems and others are only considering that there is a best one after all in this discussion, they all agree that the current state of affairs is not enough to support the needs that the 5G is bringing together with its benefits. There is no definite answer on how the technology will certainly run, but there is a general tendency towards resource protection, increase power and portability, decreased time and dependency.

**Recommended Reading**

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