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5G Networks - Structure and Implementation for the Internet of Things

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Abstract

The new technologies of wireless networks aim to offer new levels of speed, low latency and greater reliability. The 5G networks will provide new capabilities not only to consumers, but also to different sectors in the industry, service providers, infrastructure, technology, etc. The present work seeks to give an approach to the architecture of 5G networks, their current environment and give some examples of its application to the boom of the Internet of Things. Likewise, some concepts such as routing methods and deployment of it will be addressed.

Keywords: Redes, 5G, IoT, Software-defined network.

1. INTRODUCTION.

Mobility and connectivity are two of the most important trends that shape the modern business climate. People and devices need reliable, ubiquitous and real-time connectivity to be productive and competitive in today's world. The demand for faster and more reliable communication capabilities can only grow as time goes by, so you should start planning for the future if you do not want to be left behind. 5G networks will allow significantly higher mobile speeds to allow real-time connectivity for mission-critical devices and applications. 5G networks will connect billions of Internet of Things (IoT) devices with a wide variety of speed and data volume requirements. This document will present a brief introduction to the new architectural trends that will be adopted for the implementation of 5G networks.

Likewise, a new routing model for this type of network will be presented and finally it will be shown how one of its main fields of implementation will be the Internet of Things, where 5G networks will play a very important role.

2. ARCHITECTURE.

5G networks will require a change in architecture with respect to current technology. It must be designed to support a higher demand in video transmission, better data transmission speed, greater connectivity, low latency, low power consumption, greater mobility for communications, and of course support all smart devices that will connect to the network, with the Internet of things (IoT), among others. In order to meet these requirements, the current paradigm of communications networks must be changed [1], since current technologies have generated a bottleneck in terms of resources in the current spectrum, making it difficult to improve capacities with limited bandwidth available. There are several changes in technology that are required for this new network. This document will discuss the main technologies that will allow 5G networks to meet their objectives, wireless software-defined network, network function virtualization, milimeter wave spectrum, massive MIMO, hybrid beamforming, device to device communications.

2.1 WSDN.

Software defined networks (SDN) allow managing services and applications of the network through software, providing greater mobility, scalability. Its main objective is to separate the plane of the data from the control plane. The ultimate goal of SDN is to create a network that does not need the design or adjustments of the administrator's interference, so the network can be implemented in a fully automated way [5]. On the other hand, the main wireless commercial networks are hardware based and are more inflexible in their architecture.

The requirements of 5G networks such as ultra-high capacity, lower latency, and higher data speed can not be met with current technology, which is why the use of software-defined wireless networks is proposed, a highly flexible architecture that can accelerate innovations for both hardware forwarding infrastructure and software network algorithms through control and separation of the data plane [2]. For this case, the author proposes a new software architecture called SoftAir.

The main elements of SoftAir: The SoftAir architecture, like an SDN, is divided into 2 parts, the control plane and the data plane.

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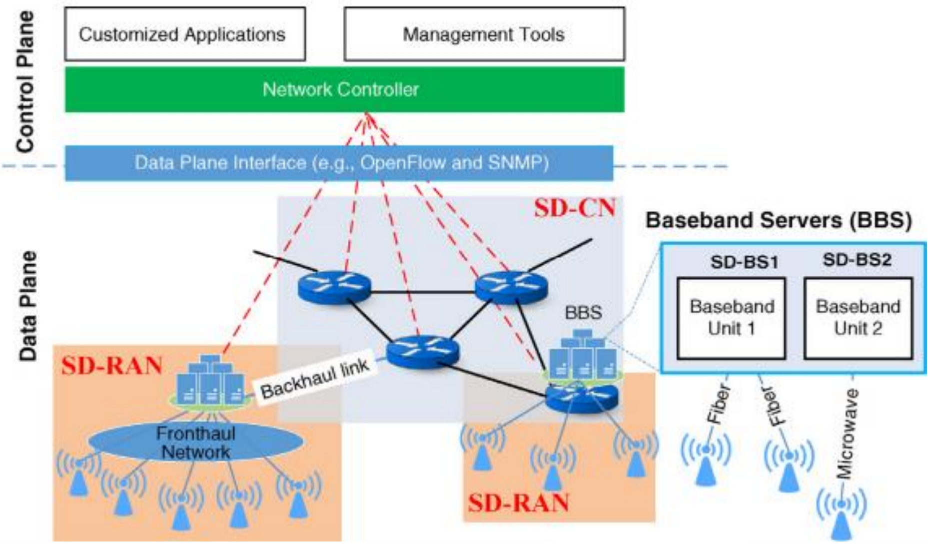

Figure 1. WSDN architecture [2]

2.2. NFV.

Network Function Virtualization offers a new way of deploying and managing services on the network. Functions such as NAT, intrusion detection, firewall management, DNS, among others based on hardware applications, can be implemented directly on software. Its architecture must take into account components for infrastructure (NFVI), virtual network functions (VNFs), hypervisors and administration and orchestration (NFV MANO) [3].

2.3. mmWave.

Higher data rates (multi-Gbps) drive the need for higher bandwidth systems, and the available bandwidth in the spectrum up to 6 GHz is not enough to meet these requirements. This has moved the target operating frequency bands towards the millimeter wave (mmWave) for the next generation of wireless communication systems. [13]

High frequencies will provide greater availability of bandwidth and smaller antenna dimensions for a fixed gain, or a higher gain for a given antenna size. However, this increases the complexity of the modem in the baseband and RF designs. To study the performance, we also need an accurate channel model for the new 5G frequencies [4].

The use of millimeter waves must face some challenges, short transmission trajectories and high propagation losses over long distances and anything that is not in line of sight, therefore, there may be weak signals in gases and precipitation. However, the short transmission routes and the propagation loss characteristics of mmWave allow the reuse of the spectrum, by limiting the interference between adjacent cells. In addition, due to the extremely short wavelengths of the mmWave signals, the transmission paths can be extended using small, dynamic multi-element beam antennas that can be installed on user equipment, such as smartphones.

2.4. MIMO.

Networks and 5G devices will require substantially different architectures, radio access technology and physical layer algorithms. The dense networks of small cells will complement the macro base stations, operating in millimeter wave technologies and employing arrays of massive MIMO antennas.

Massive MIMO (Figure 2) is a form of multi-user MIMO in which the number of antennas in the base station is much greater than the number of devices per signaling resource. The large number of base station antennas in relation to the user's devices results in a channel response that is almost orthogonal and has the potential to produce huge gains in spectral efficiency [4].

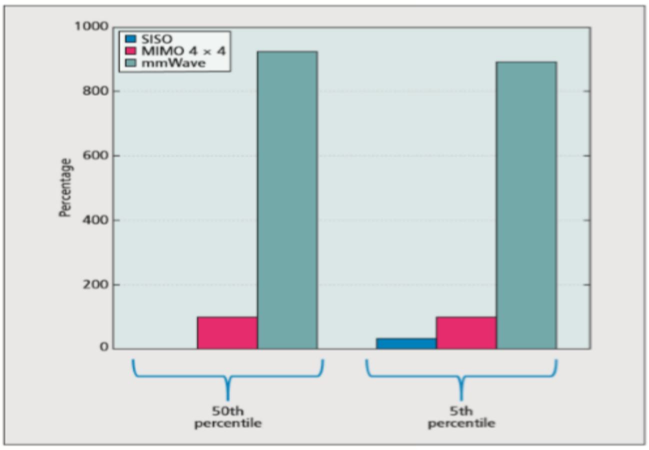

Figure 2. Cell data rate comparison between microwave systems using 50 MHz of bandwidth (single-user single-antenna and single-user MIMO) and a mmWave system with 500 MHz of bandwidth and a single user. [4].

2.5. Hybrid Beamforming.

While the smaller wavelengths allow the massive implementation of MIMO within the small form factors, the challenges of the signal path and propagation associated with the mmWave frequencies also increase. To achieve a better control of the beam formation and flexibility, it would be ideal to have an independent weighting control on each element of the antenna network, with a transmission / reception module (T / R) dedicated to each element. But this is generally not practical due to cost, space and energy limitations.

Hybrid Beamforming is a technique for splitting beam shaping between the digital and RF domains to reduce the cost associated with the number of RF signal chains. It combines multiple matrix elements in subarray modules, with a T / R module dedicated to a subarray in the matrix.

2.6. Device to Device Communications.

Device-to-device communication (D2D) refers to a radio technology that allows devices to communicate directly with each other, that is, without routing data routes through a network infrastructure. Possible application scenarios include, among others, services based on proximity where devices detect their proximity and, subsequently, activate different services (such as social applications activated by the proximity of the user, advertisements, exchange of local information, intelligent communication between vehicles , etc) [4]. Other applications include public security support, where the devices provide at least local connectivity even in case of damage to the radio infrastructure.

3. ROUTING.

The existing routing schemes fail to incorporate content sources within the core networks. Therefore, it is practical and vitally important to develop a rapid request routing protocol that adapts to the new network architecture, considering jointly the redirection of the source and the flow routing.

Conventional routing protocols, focused on the optimization of maximum link utilization, operate in lower layers, such as OSPF in the link layer and improved OSPF schemes in the network layer [6], which provides a routing of optimized flow for a given set of source traffic from sources. demands. For fixed source and destination requests, next-generation lower-layer routing algorithms include link-state protocols, multi-stream flow model protocols, and the latest hybrid SDN study [7]. We found 2 papers that propose different types of routing for 5G Networks.

3.1. Near-optimal Request Routing Protocol.

One of the works currently proposed in routing for 5G networks is the work of Jun He and Wei Song "Evolving to 5G: A Fast and Near-optimal Request Routing Protocol for Mobile Core Networks "[8]. In the protocol, the central controller periodically calculates the redirection decisions of the source, as well as the decisions of division of the flow according to the condition of the network and the pattern of request in the current period. Then, a redirection decision of the source with respect to the request specifies the amount of flow that will be charged to each potential source. With these parameters, the central controller notifies the involved source nodes to deliver the corresponding amount of flows for each request destined for the requesting node. This operation is implemented in the application layer. Meanwhile, the controller generates and disseminates a flow division table to each node with respect to flow division decisions. A tuple of the table consists of three elements: destination identifier, outbound link identifier, and division rate.

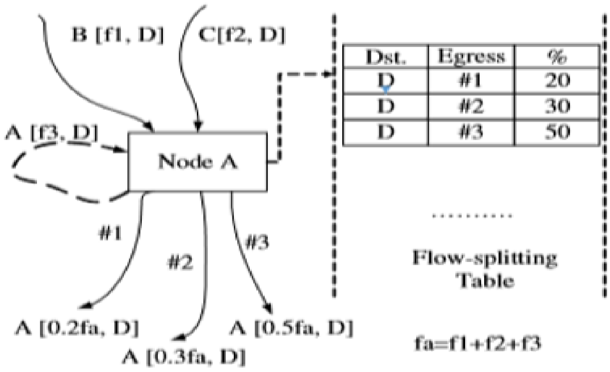

Figure 3. Routing example [8].

An example of routing based on the flow division table. A has two incoming physical flows f1 from B and f2 from C with the same destination D, as well as an incoming logical stream f3 generated by itself (A is a target source node selected for some objects requested by node D). For transmission purposes, A reads the destination identifier of each incoming flow and then groups flows with the same destination, for example, D. For each destination, A searches for the local flow division table to obtain the division fractions for the destinations. nodes of the next jump. After that, it combines flows with the same destination, divisions, and remits aggregate flows to respective bonds, that is, # 1, # 2, and # 3, according to the fractions of flow division (Figure 3).

3.2. Advanced QoS Routing Algorithm [10].

A new module is established that provides the best QoS and the lowest cost for any multimedia service given that by simultaneously using all available wireless and mobile access networks for a given traffic flow. This adaptive QoS module with adaptive QoS routing algorithm is called an advanced QoS routing algorithm (AQoSRA, Figure 4), which is defined

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independently of any existing and future radio access technology.

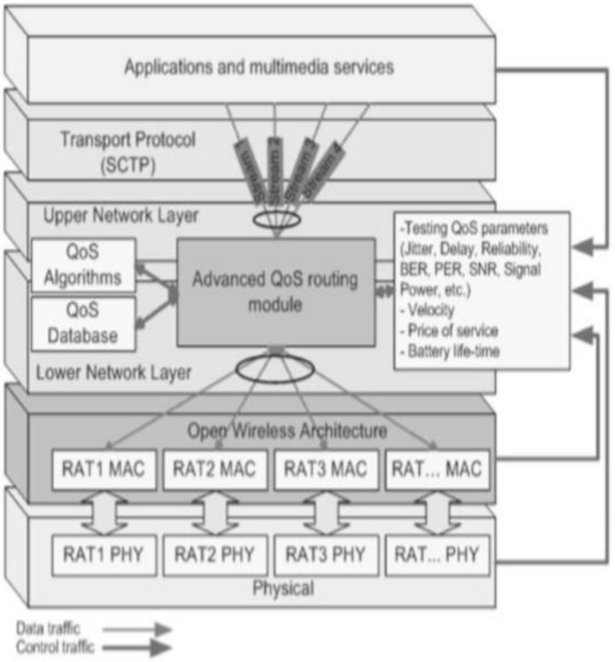

Figure 4. Advanced mobile terminal model [10].

Data measurements for different selection criteria, including user requirements, QoS requirements, operator requirements and indifferent radio link conditions of the RAT (Radio Access Technologies) present in the user's movement area are entries for the n sets of parallel criteria (CF) functions, one set for each RAT (from RAT 1 to RAT n). A RAT CF is configuring and filtering the outputs of the four previous components in four internal threshold functions: the first one is configuring the QoS parameters, the second one is configuring the service price if the service flow goes through that RAT (which depends of the service level) agreements (SLA) between the user and each of the wireless and mobile networks), the third one is configuring the speed support and the last one is configuring the intensity of the signal detected in the mobile terminal from the (s) base station (s) RAT.

Of course, there are no restrictions: a RAT to serve several different multimedia services from a mobile terminal, or a service to review several RATs. In addition, Figure 5 shows an example of a future 5G scenario according to our research vision, where the five RATs of the advanced mobile terminal are used, applying AQoSRA. As can be seen, for the proposed mobile terminal design there are no restrictions on the number of RATs used simultaneously. The advanced mobile terminal proposed with AQoSRA works quite well in a variety of network conditions. Consequently, it provides the highest level of multimedia access probability, performance, the highest number of satisfied users, with a minimum cost per service and optimal use of network resources.

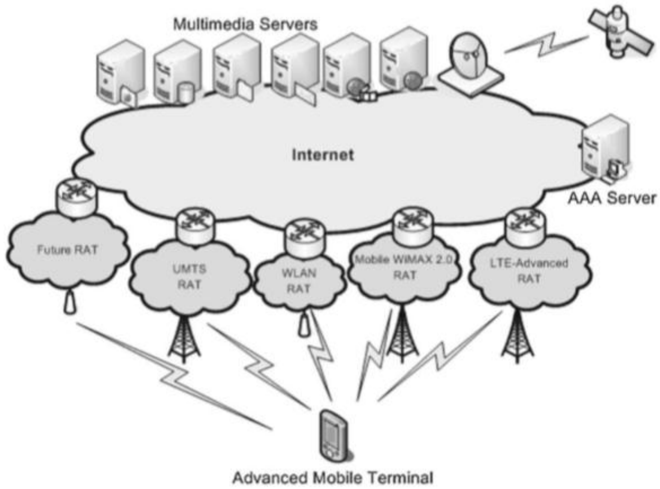

Figure 5. 5G future scenario [10].

4. INTERNET OF THINGS.

The Internet of things, or IoT, is a general term, which means that all devices, vehicles and other objects in our home and in professional life are connected through the Internet. For mission critical users, it presents great opportunities and alarming risks.

The risks of IoT are related to security and privacy: how all this information of people's homes, their movements, their actions are kept safe and only used properly. Other risks include society's dependence on networks and how blackouts are handled when most things in buildings and cities depend on electricity and communications networks.

5G responds to the challenges established by IoT, where networked devices can be anything. High data speeds, but also efficiency and more cohesive networks are the basic components of 5G.

For mission critical users, this means the opportunity to have new tools, even share large amounts of information with colleagues. 5G technology offers at least one gigabit per second for connection speeds, shorter delays than 4G technology and millimeter wave bands (mmW) for support applications that require large capacity.

With respect to next-generation IoT systems, 5G wireless networks will be required to provide support for massive capacity and mass connectivity, as well as for an increasingly diverse set of services, applications and users, all with extremely divergent requirements for work and life. Flexible and efficient use of all non-contiguous spectra available for very different network deployment scenarios will be necessary.

Mobile networks will increasingly become the main means of access to the network for person-to-person and person-to-machine connectivity. These networks should match the advances in fixed networks in terms of quality of service, reliability and security. To do this, 5G technologies must be able to offer speeds of 10 Gb / s similar to fiber to allow ultra high definition visual communications and enveloping

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multimedia interactions. These technologies will depend on ultra-wide bandwidth with sub-millisecond latencies [9].

4.1. IoT applications.

The applications of 5G networks can be seen reflected in different verticals, in manufacturing, construction, logistics, power generation, distribution and transport, automobile industry (Figure 6).

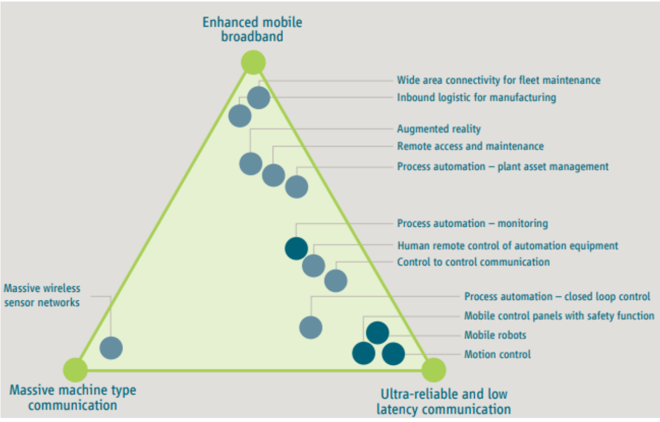

Figure 6. Summary of selected industrial use cases and disposition according to their basic service requirements in 5G [14].

The open innovation system for 5G and development of technologies and services will allow you to test networks with technologies beyond the state of the art:Desde la evolución de LTE al acceso de radio 5G.

- MEC to bring services closer to user access.
- eMBMS allows efficient transmission to mobile users.
- Core network in a cloud environment.
- Cloud systems for applications.

Current services:

- R+D (Research+Development) support in technology and services related to IoT.
- 5G evolution and R+D support.
- Concepts and technologies for care, well-being and fitness, media production and distribution, eHealth in hospitals and on wheels, digital factory, smart grids, Smart Cities, public safety and transportation.

4.2. Markets and potential.

Communications service providers (CSP) present various opportunities for revenue growth enabled from the 5G-based industry and the Internet of Things, the roles that CSPs can play to improve their income:

1. Network developers excel in the operational network infrastructure, including access, core and transport, and apply Information Technology to support consumers and businesses with connectivity solutions designed as they maximize the power of digital technology. This in other words reflects the role of CSPs by offering connectivity and infrastructure provisioning.

2. Service enablers, in addition to enhancing connectivity, provide digital platforms in which companies can easily configure and integrate digital capabilities that enhance value in their business processes in a highly automated manner. Typically, they address approximately 85 percent of the revenue potential of the 5G industry digitalization.

3. The creators of services develop new services and digital applications, create innovative businesses and collaborate beyond telecommunications to establish new digital value systems, in addition to providing digital platforms and infrastructure services. Therefore, a service creator, which in most cases also provides networks and connectivity, as well as enablement, can address 100 percent of the digitalization revenue potential of the 5G industry.

Among other activities with high potential in the market are:

- Open and scalable innovation platform to experience 5G technology, business models and services.
- Adapt test network extensions to vertical system sites / service providers.
- Vertical system and service providers obtain the cutting edge environment to develop the solution to their problem enabled by 5G and IoT technologies.
- IoT and 5G network companies have realistic test environments, based on real vertical system and service needs and requirements.

4.3. Devices location.

The future deployment of "ultra-dense small" network cells presents unprecedented opportunities to create an Advanced Location System (Figure 7) that meets the demands of future location-based services and their functionalities.

Figure 7. Location of Devices.

The concept of ultra-dense small cells results in new opportunities and small system development and local localization in 5G networks that have, in general, many new features compared to existing radio networks. Recently, it has been proclaimed that 5G networks should be able to locate a User Node with an accuracy in the sub-meter range [11].

5G location techniques can offer improvements in terms of power consumption of user nodes when network-centric location is used and frequently transmitted to link signals. The 5G location can also be a solution to the challenging problem of indoor location, since it does not depend on the connections of the connections and it is possible to provide reliable altitude estimates.

Measurements for location: The locations of the user nodes can be determined by multiple measurements. The distance between a user node and an access node can be estimated from the power of received signal strength (RSS) of an uplink pilot signal with known transmission power by converting the resulting propagation loss into a distance with the help of a path loss model.

The location of the user node can also be estimated based on directional information, that is, estimates of arrival address, collected with smart antennas, that is, arrays of antennas or reconfigurable antennas, deployed on the access nodes.

Properties of ultra-dense networks: The distance between sites of the Access Nodes in ultra-dense small cell networks is expected to extend from a few meters (indoor) to 50 m (outdoor). Completely new location-based services can be provided through ultra-dense networks due to high location accuracy, rapid movement tracking and location prediction. In general, these services can be classified as external and internal. In external services, location information is shared with third parties, who can use it to avoid collisions in cars that drive on their own, traffic monitoring on the streets and advertising, just to name a few. Internal services, in turn, include sharing location information with user nodes. This allows navigation with extremely low power consumption and without the need for visibility of satellites or fingerprint printing databases. Location recognition can also be used on the network side to allow better use of radio-esteem, space and frequency, including effective mitigation of interference. The prediction of the locations of the User Nodes can also increase the performance of the high mobility nodes (through the formation of geometric beams) and enable the administration of resources of the proactive radio resulting, for example, in communications from end to end optimized with power and latency.

In general, future implementations of 5G ultra-dense small cell networks provide unprecedented opportunities to create an advanced location system that meets the demands of services based on network location and functionality.

5. CONCLUSIONS.

Over the past two decades, the world has witnessed a rapid evolution of cellular communication technologies from the Global 2G Mobile System (GSM) to the Advanced Long Term Evolution System (LTE-A) 4G. The main motivation has been the need for more bandwidth and less latency. While performance is the actual data transfer rate, latency depends largely on the processing speed of each node data flow through. Along with performance-related performance improvements, some related parameters, such as instability, interference between

Channels, connectivity, scalability, energy efficiency and compatibility with legacy networks are also taken into account when developing a new mobile technology.

When technology advanced from 2G GSM to the 3G universal mobile telecommunications system (UMTS), a higher network speed and faster download speed allowed real-time video calls

The data rate has improved from 64 kbps in 2G to 2 Mbps in 3G and 50–100 Mbps in 4G. 5G is expected to improve not only the data transfer speed of mobile networks, but also the scalability, connectivity and energy efficiency of the network. It is assumed that by 2020, 50 billion devices will be connected to the global IP network, which seems to present a challenge. Remote operation of critical commercial equipment and machines in a reliable 5G network will be possible without delay. Real-time control of machines using mobile devices will be possible, making Internet of things (IoT) more available to everyone. Finally, but not least, network nodes that consume less energy will be needed to achieve a greener world. Therefore, the following are the most important elements in the description of 5G: high performance, low latency, high reliability, greater scalability and mobile communication technology of low consumption.

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