

**A 5G urban computing framework service model****Um modelo de serviço da estrutura de computação urbana 5G**

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**ABSTRACT**

This paper is about a fifth generation (5G) network technology structure model that is a facilitator that can provide new services to several segments in smart cities. It was verified that applications in smart cities include citizens and pervasive devices interaction which requires continuous monitoring to provide collaborative support and to raise environmental awareness. In order to implement the expected goals from the 5G ecosystem, this model incorporates software defined network and virtualized controllers to support new services. Examples of smart city services are traffic efficiency, security, surveillance, localization, healthcare services, infrastructure support among others. Any of these services will be able to get information from their users and from the network through our model, once an important issue in smart city is the challenge to collect or deliver useful and processed data to stakeholders. In this proposal, the evaluation of the model was conducted through emulations on Mininet and POX controllers. The results were analyzed using the Gephi tool, and they have demonstrated that the proposed model is applicable to support and provide new services such as intelligent transportation, road monitoring, energy consumption, public safety among others in smart cities.

**Key word:** 5G structure model; Services facilitator, Smart cities.

**RESUMO**

Este artigo é sobre um modelo de estrutura de tecnologia de rede de quinta geração (5G) que é um facilitador que pode fornecer novos serviços para vários segmentos em cidades inteligentes. Verificou-se que os aplicativos em cidades inteligentes incluem a interação de cidadãos e dispositivos difundidos, o que requer monitoramento contínuo para fornecer suporte colaborativo e aumentar a conscientização ambiental. Para implementar as metas esperadas do ecossistema 5G, este modelo incorpora rede definida por software e controladores virtualizados para dar suporte a novos serviços. Exemplos de serviços de cidades inteligentes são eficiência no tráfego, segurança, vigilância, localização, serviços de saúde, suporte à infraestrutura, entre outros. Qualquer um desses serviços poderá obter informações de seus usuários e da rede através do nosso modelo, uma vez que uma questão importante na cidade inteligente é o desafio de coletar ou fornecer dados úteis e processados para as partes interessadas. Nesta proposta, a avaliação do modelo foi realizada através de emulações

nos controladores Mininet e POX. Os resultados foram analisados usando a ferramenta Gephi e demonstraram que o modelo proposto é aplicável para apoiar e fornecer novos serviços, como transporte inteligente, monitoramento de estradas, consumo de energia, segurança pública, entre outros, em cidades inteligentes.

**Palavra-chave:** modelo de estrutura 5G; Facilitador de serviços, Cidades inteligentes.

## I. INTRODUCTION

The 5G networks will integrate the internet of things (IoT), people and vehicles in several environments. Its relevance was demonstrated by the Information Handling Services of Markit (IHS Markit), a global financial information and service company that has conducted a study about the global economic impact [1]. The conclusion was that in 2035 5G will produce USD 12.3 trillion (United States dollars) in goods and services, with USD 3.5 trillion in the value chain, and 22 millions of jobs. It shows that 5G mobile technology will produce benefits to the world's population and will be a new network infrastructure to service provision.

In this direction, 5G can support the smart cities that overcome challenges associated with increasing worldwide urbanization rates. Many companies are working on the smart cities' ecosystems to create technologies and employment opportunities, such as International Business Machines Corporation (IBM), Intel Corporation, General Electric Company (GE), and other ones. They have projects to integrate their products and services into smart cities frameworks [2]. It is clear that smart cities integration with the 5G networks is unavoidable. This fact will connect billions of devices and sensors, allowing their dynamic reaction in the applications' context. In such a scenario, the data are collected by several sources spread throughout the cities, as sensors for temperature, humidity, energy, presence, vehicle and telephone networks, among others. New services and applications will emerge in different areas through the cyber-physical systems by the 5G network.

The creation of a 5G model as new services facilitator to smart cities is the main idea of this paper. Integrated environments will have connections among people and IoT to offer better controlled urban services everywhere and every time. So, this 5G model proposal includes service modules, software defined networking (SDN), network function virtualization (NFV), mobile edge computing (MEC), fog and big data concepts. Through emulations, we have show that it can be used in the smart city and 5G contexts.

This paper is organized in the following way: Section II presents the related works; Section III describes the proposed 5G model as smart city facilitator; Section IV presents an example of a service module for the model proposal and results obtained; and so, Section V discusses the conclusion of this paper.

## 2 RELATED WORK

This section describes the related works that address the main smart cities concepts: information and communication technology (ICT), IoT, integration, continuous monitoring, cloud, fog computing, big data, MEC, cloudlet servers, and services.

Smart cities are still seen as futuristic places because there are several challenges on the urban infrastructure building about resource management, cooperative mobility management, and increasing of the next generation ICT use which requires a wide range of domains such as: cloud and mobile edge computing, sensing and actuation, low power communication, mobile crowd sensing and big data analysis [3]. In [4], the authors say that those challenges require thematic data crossing and harmonization. They also suggest that will be necessary the integration and the coordination among several departments to monitor future smart cities. Besides it, each one of these smart cities must deal with different issues to get sustainable development and, by the ICT availability and advancement, the citizens' participation will add value to the governance initiative in them. In that work, the cloud applications in smart cities include citizens and pervasive devices interaction through IoT, what requires continuous monitoring to 1st, provide collaborative support based on the evidence for urban planning policy decisions; 2nd, raise environmental awareness based on the daily citizens' information to eventually propose behavioral changes in their lifestyle. Also, the interconnected devices make easier the environmental data gathering to help on the solution of the challenges. But for that, enough computing data storage resources and real-time processing are required; because a city is a single unit that deals collectively with challenges related with the environment, socio-economy, public services, security, health and well-being, education, and others [4].

Perera et al. [5] explained that IoT intends to connect all devices through the Internet to support the smart cities viability, as the large amount of data that they generate must be sent to the cloud for further knowledge processing. The fog computing pushes the data analyses to the edges even their devices having limited computational capabilities. But both cloud computing or fog computing not overcome their challenges alone, that's the reason why they need to work together to build a sustainable IoT infrastructure for smart cities.

In the work developed in [2], the authors present a fog computing architecture for big data analysis in smart cities. Nowadays, in several enterprises, the cloud computing is used to address the big data analysis by its scalable and distributed data management scheme, but data centers in the cloud got an over expected amount of big data that has asked for additional requirements of location awareness and low latency at the network edge. For this reason, the fog appears with latency-sensitive applications at the network edge, and also with latency-tolerant tasks at powerful computing nodes on networks intermediation, what means that above the fog, cloud computing still can be used for

deep data analysis; since the computing nodes provide a faster control to ensure the critical infrastructure components safety. Hu et al. [6] completed affirming that some network edge applications include business transformation, technology integration and industry collaboration and, all of these can be enabled by MEC and a wide variety of use cases can be supported for new and innovative markets, such as e-Health, connected vehicles, industry automation, augmented reality, gaming and IoT services.

The work developed by Enayet et al. [7], explained that the smart city conception involves the integration of healthcare, transportation, communication, and other services to improve urban citizens' quality of life. But most services have become a great volume data-driven that require real-time access, sharing, storing, processing and analysis at anywhere in any time to support intelligent decisions. The mobile cloud computing is what allows the devices to access and offload big data from powerful cloudlet servers that ensure the end users quality of service (QoS) demands. Cloudlet is a data center in a small scale or a computer cluster designed to provide cloud computing services as quick as possible to mobile devices. The problem is that the mobile devices connectivity is sporadic with varying signal strengths and, the cloudlet resources heterogeneity is a great challenge to the community takes the better decision about which execution code must be used.

For this integration, in [8], smart ubiquitous networks (SUN) have been developed by international telecommunication union (ITU) with frameworks like telecommunication infrastructures to smart and ubiquitous environments which need operational processes to support context-aware networking. Vilalta et al. [9] proposed the TelcoFog architecture, validated through a proof of concept for IoT services. It is a fog computing infrastructure that is new, secure, highly distributed, and ultradense. It is able to support wired/wireless network extreme edge to allow a telecommunication operator to provide new 5G services, such as NFV, MEC, and for third parties like smart cities, vertical industries and IoT. In this way, it is expected the distributed and programmable fog technologies strengthen the mobile network and cloud markets position by its integrating capability in network ecosystems. Its dynamic new low-latency services deployment ask for an architecture that consists of three main building blocks: a scalable specific node which is integrated in the telecom infrastructure; a controller which is focused on service assurance and integrated in the management and orchestration architecture of the telecom operator; and services which are able to run on the telecom infrastructure.

The work of Rao and Prasad [10], lighted out that the services shall be available on multiple portable devices and its interactions and interfaces may include all kinds of user recognition. With it is expected that mobile communication will be always available for smart socio-economic well-being, which requires since nowadays the delivery of faster connectivity anytime and anywhere. As the

demand for data, new services and network performances continues to increase, operators must evolve their existing infrastructures to support full digitalization and meet current and upcoming market trends.

In summary, the increasing ICT use in 5G requires domains such as cloud and mobile edge computing. The new domains require integration and coordination among several departments of monitoring to deal with different issues such as sustainable development. Citizens ubiquitous and pervasive devices interaction through IoT will be the solution to the environment challenges such as security, public services, and others.

### **3 A 5G MODEL AS NEW SERVICES FACILITATOR**

The 5G technologies include all type of advanced features which makes the 5G mobile communication powerful, more fast and reliable. In 5G, there are some network requirements such as high data throughput (between 1 to 20 Gbps), massive connection density (estimated on 1 million connected devices per km<sup>2</sup>), ultra-reliable low latency (1 ms) communications and high-speed mobility support (up to 500 km/h) for different use cases.

To propose a 5G model as a new services facilitator in smart cities, among the basic capabilities expected from the 5G ecosystem, it is a context-aware network. Smart cities will have several sensors installed around them but, in addition, smart phones themselves may contain built-in sensors such as accelerometer, gyroscope, magnetometer, barometer, proximity sensor, and global positioning system, providing useful information as long as it is authorized by the user in accordance with protection rules of each country. The information collected, according to the time scale configured by each operator will, then, be provided and processed by applications in the user equipment (UE) or in the 5G ecosystem, depending on the application's context.

As shown in Fig. 1, based on technical specification (TS) 22.261, the context requirements are classified into three layers following the logical SDN structure: applications, priority communications and infrastructure. Contexts such as prioritization of certain applications and the collection of smartphone data with user consent are at the application layer. The priority communications layer has contexts of emergency services, security, priority level or type of user signature. The infrastructure layer has contexts such as network conditions and customer service at the operational level. All of these contexts are just examples that can be addressed by the proposed model. Other contexts can be elaborated. For example, contexts that involve metrics of complex networks with the similarity of interest and social bonds as trust between users, vehicles or any other object in the network.

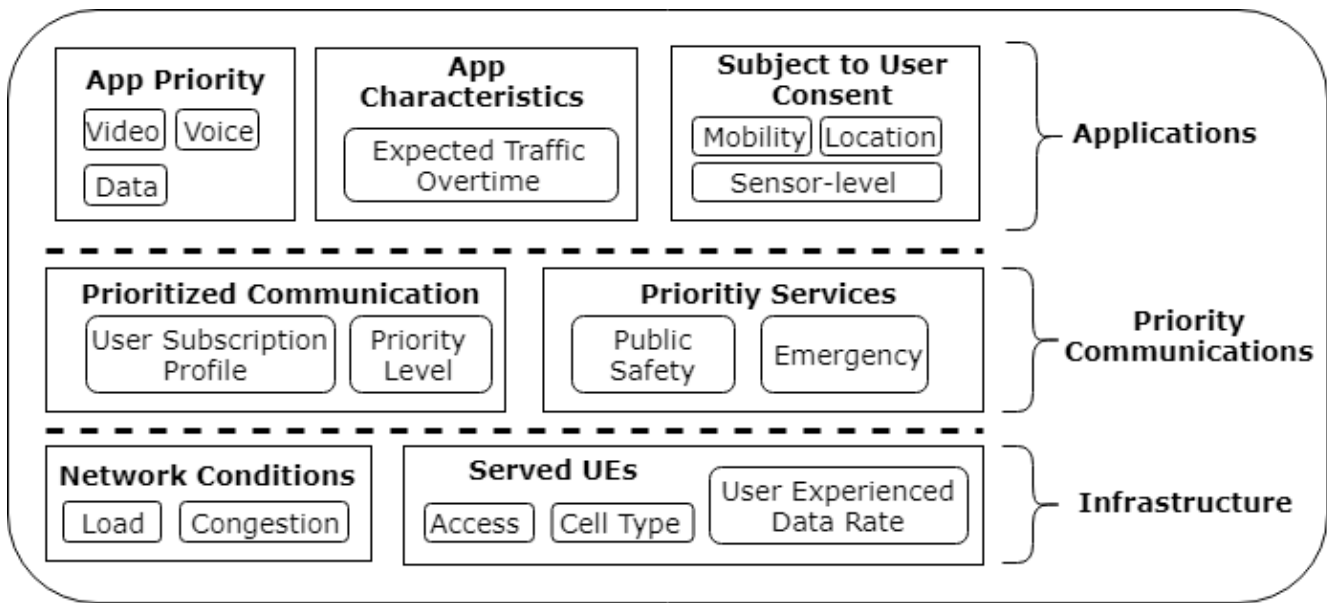


Fig. 1. Context requirements.

A 5G network is more than a connectivity infrastructure collection, but a programmable platform able to make available new applications based on collaboration among several systems. The set of resources model and functionalities to develop the 5G network is provided through the reference architectures found in the 3GPP Release 15 and TS 23.501. Important trends and key technological enablers for the 5G architecture realization were developed by the 5G public-private partnership (5G-PPP) initiative of a working group, which has harmonized the architectural concepts developed in various projects and has also provided a consolidated view over the technical architecture design directions the 5G era.

The 5G access network is created by the 5G deployment scenarios with multi-radio access technology (RAT) on baseband unit (BBU) pool at the backhaul aggregation network and by the massive multiple-input multiple-output (MIMO) antenna on the fronthaul IoT, UE, and cars through 5G new radio connections. The 5G core is created by SDN virtualized controllers with service modules and with other functions on the user plane that connects data network to the big data repository in the cloud. The use of SDN supports new services on the fog and smart cities environments. In order to implement the expected objectives from the 5G ecosystem, a model in which SDN elements and the virtualized controllers are incorporated and specific servers can be enabled in the central data center office to support the new services is shown in Fig. 2.

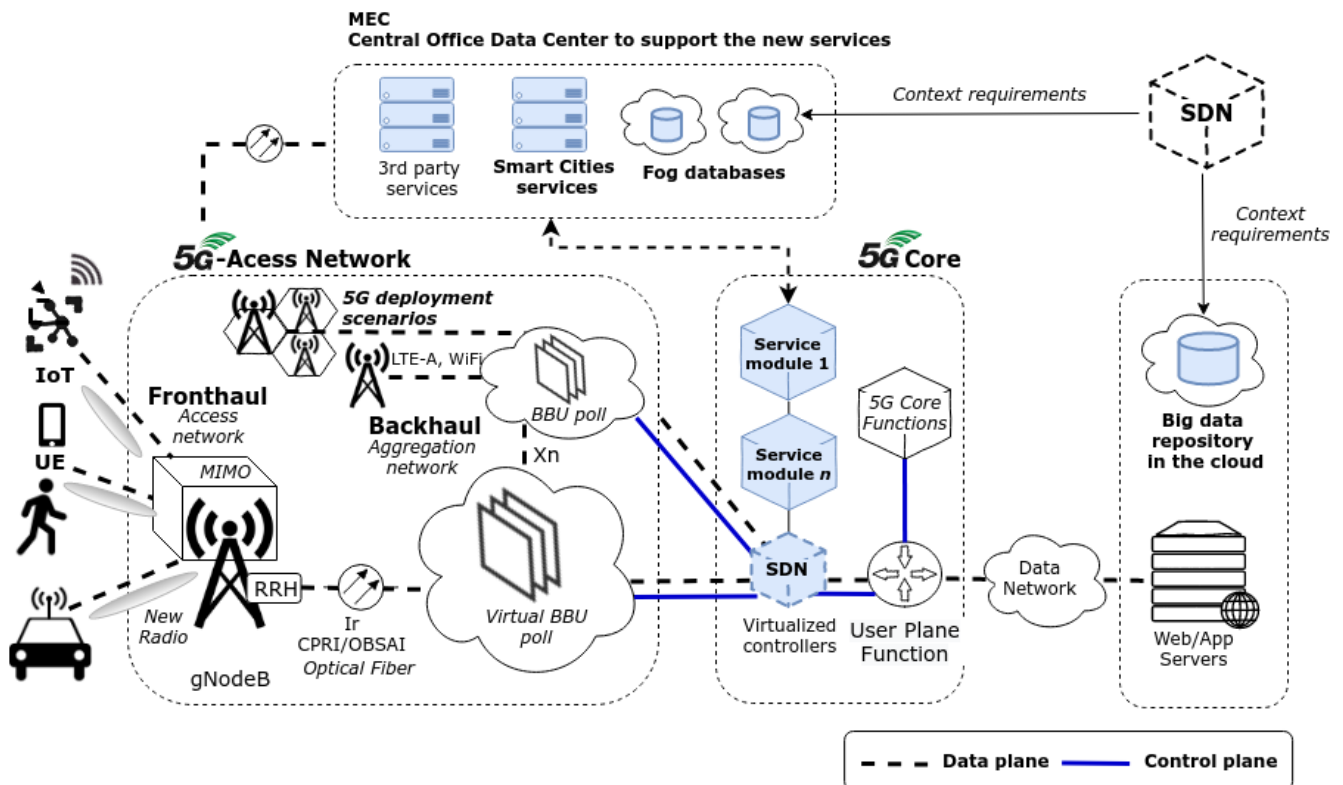


Fig. 2. 5G model proposal.

A general 5G cellular network architecture was presented by Gupta and Jha [11]. Its core network is the support for the servers and to the Internet. The authors introduced the concepts about interconnectivity among different technologies making the connection between the MIMO antennas and the NFV cloud. In our model, the SDN controller allows the separation of the control plane from the data plane that is critical in a network whose dominant traffic will be the online things, often device-to-device. In addition, data science processes, such as knowledge discovery in databases and big data, will allow adjustments in the quality of service, performance, and capacity planning. SDN offers the prospect of the network as a programmable resource configured on-demand because it has the power to change how services will be delivered in the future, bringing new revenue, streamline network maintenance, and automate creation. Such as SDN and NFV, network slicing is a form of virtual network architecture that allows a network operator to provide dedicated virtual networks with specific functionality to the service or customer over a common network infrastructure, what means that it will be able to support the numerous and varied services envisaged in 5G.

In this direction, the 5G model architecture adopts the SDN mobile control (SDMC) concept by focusing on wireless-specific functions. It splits wireless functionality into SDN functions that are being controlled and remain relatively stable, and the overall network control functions are executed at the controller. As the SDMC concept is not limited to data plane functions but includes control plane functions of the mobile network, so it can be placed arbitrarily in the edge cloud or the central

cloud, where the wireless functionality is controlled. If it is associated with the 3GPP network management system, it can take advantage of the legacy performance monitoring, forming a logical global radio access network (RAN) information base that can be used to control various network functions. The control of wireless networks comprises, among others, channel selection, scheduling, modulation and coding scheme selection, and power control. The name of it is inter-slice resource control, in which following the network slice concept, infrastructure domain-hosted SDMC allows the infrastructure provider to assign unutilized resources to support third-party services [12].

Industry and academia got an important agreement that future 5G mobile networks adopt the NFV and SDN principles. In this way the 5G network architecture specified by the novel radio multiservice adaptative (NORMA) project has already been flexibly allocated on an infrastructure of interconnected central and distributed clouds, facilitating the setup of various network slices that can be optimized for the specific services they support. A specific virtual network associated with NFV and the required infrastructure resources to run them is called a “network slice”. However, some network infrastructure may comprise types of equipment often used by ”multiple slices” that do not support virtualization so, the physical network function (PNF) is characterized by a tight coupling of functionality and underlying hardware, and it is the base station equipment that provides the physical radio layer functions to PNF. The types of equipment that support virtualization are called “common parts” but such technology is still far from the maturity level where they would be suitable to allow NFV. So the better decision is the creation of specific network slices within its infrastructure that can rely on common (not slice-specific) NFV and on common PNF equipment to provide the best (complete) mobile connectivity service [13].

Anyway, from a commercial standpoint, there is a hole in the automation of external processes that make the third party access to mobile networks be clunky and expensive, making external deployment impossible. To offer an alternative process for third-party deploying to networks, the innovation cannot be focused only on the internal processes automation. The supplying services demand shift in both technical and ecosystem dynamics which requires a new platform to orchestrate the communication next generation that can be deployed anywhere to anything, unifying edge resources into an abstraction layer to simplify its deployment.

#### **4 EXAMPLE OF A SERVICE MODULE**

The urban computing framework in 5G networks (CoUrbF5G) proposed in [14] can be used as an example of a service module applied to our 5G model as new services facilitator. In this paper we have created a module through Mininet to evaluate the model. The CoUrbF5G module developed was the facilitator to a smart city application. It also can pass valuable evaluation information to any



application or service. The CoUrbF5G has several components and collects several urban computing data types through the 5G infrastructure, which will be stored in fog or cloud databases. The big data analytics process is executed delivering the results to the environment, where the observation module checks the context-aware behavior based on the results. While the analysis module verifies the current conditions of the network, passive monitoring is indicated by does not generate an overload in the network. This incorporation makes the framework sensitive to the contexts of smart cities applications as the service module illustrated in Fig. 3.

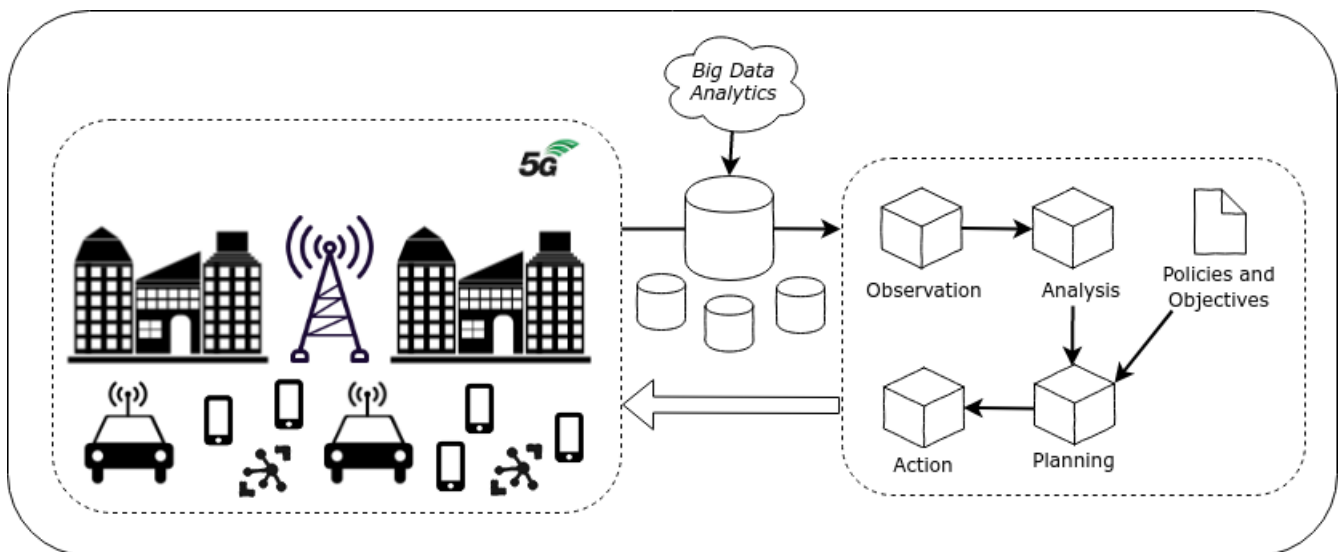


Fig. 3. CoUrbF5G service module.

After the network' behavior has been observed and the analysis has been done, the desired parameters and key performance indicators (KPIs) are consulted through the

policy and objectives module. The resource allocation and planning modules are triggered together with the observation module. The infrastructure layer consists of the vehicles, IoT and UE, user plane function (UPF) and other service provider elements to the users. In the control layer, the SDN controller manages the next generation node base (gNodeB) station and repositories. The application layer represents the abstraction provided by the controller through the services delivery. Between the layers, there are the southbound interface (SBI) and northbound interface (NBI) that are communication interfaces which, respectively, pass along the characteristics of the network elements to the controller, via the data-controller plane interface (D-CPI) and via the application-controller plane interface (A-CPI). The services are geo-location applications, healthcare, water monitoring and leakages, internet of vehicles (IoV) and smart roads, smart lighting, smart house, security-related services, air quality monitoring, vertical automation, and smart manufacturing. The logical structure for CoUrbF5G based on the SDN concept and application, divided into three layers is illustrates in the Fig. 4.

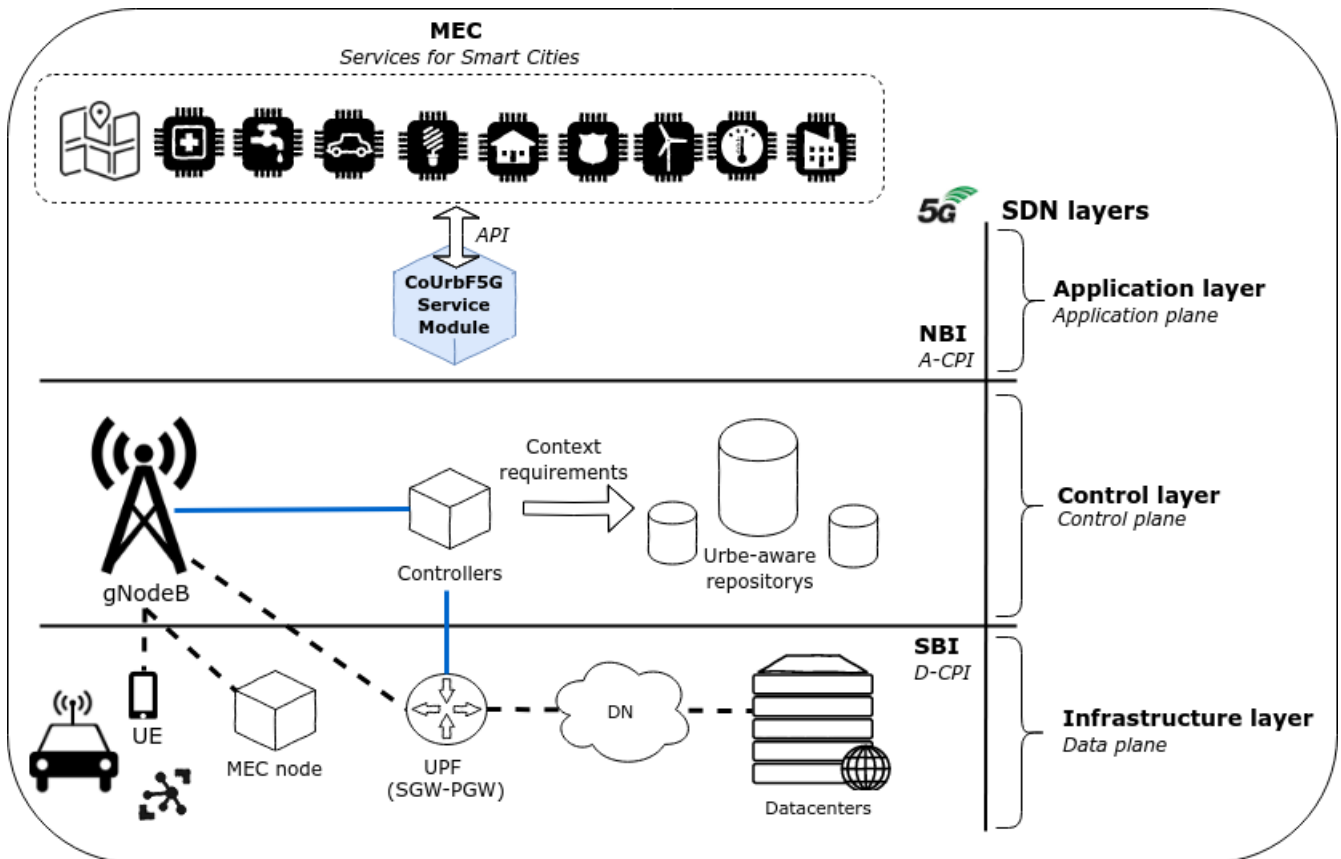


Fig. 4. Logical view of the CoUrbF5G service module.

In this paper, the use of the SDN controller in the CoUrbF5G service module was illustrated on the performed tests by the POX controller and the Mininet emulator that are virtual networks running on the kernel of a physical or virtualized system. POX is an open source development platform for Python-based on SDN control applications, such as OpenFlow SDN controllers. The Mininet emulator by its side is from an open source and also allows testing and development with OpenFlow protocol and SDN and Gephi is the leading visualization and exploration software for all kinds of graphs and networks, being also a free open-source.

Exemplifying the routing to repositories, the data were collected at two intervals with ten interactions that were performed for each interval. The adopted topology in the first interval was 01 controller, 06 OpenFlow switches and 500 devices; and in the second interval counted with 01 controller, 06 OpenFlow switches and 1000 devices. The Gephi tool was integrated into the Mininet for the network observation and analysis, as proposed by CoUrbF5G. The emulated service was the streaming reception, such as geo-location services in a smart city context, and for that it was necessary to add a streaming client using the door 8282, receiving streams in a constant way.

To exemplify how the model can pass information to the smart cities services, Table I shows the comparison among computed complex network metric means, during the two network execution intervals. The average path length is the measure of the information's efficiency, and it represents the extension of the path to all possible pairs of nodes, or in other words, how much the nodes are close to each other. The network diameter refers to the length of the longest of all the computed shortest paths between all pair of nodes in the network. The average degree is the sum of all vertices of a graph, divided by its number of vertices, and it can be represented by  $[2m/n]$ , where "m" is the number of edges and "n" is the number of vertices. The network density describes the portion of connections between two or more nodes in a network, considering the quotient of the "actual connections" (that actually exists) by the "potential connections" (that could potentially exist) represented by  $[n(n-1)/2]$ . The modularity represents the division of the network nodes into dense communities inside of a graph, which is usually sparsely connected. The ability to view and to analyze the network structure becomes easier when these groups are found. Finally, the connected component is a maximal set of nodes such that each pair of them is connected by a path in a network that is generated by laying down a number of nodes and adding edges between them with a independent probability for each node pair.

In Table I, the average path length is bigger on the first interval (3.949) than on the second one (3.178). The network diameter is the same for both that represent the presence of six OpenFlow switches. The first interval shows an average grade of 2.011 while the second has presented a bigger measure (2.019). The density indicates that the graph has a number of vertices totally connected together or, at least, in large part, unlike a sparse graph that has not many connections between its elements. The first interval has presented higher density (0.012) when compared with the second one (0.006). The modularity in the first interval exhibits greater modularity (0.737) over the 2nd one (0.597). Networks with high modularity have dense connections between the nodes within modules but sparse connections between nodes in different modules. In the realized tests, the intervals present only one connected component. It means that the graph does not have isolated elements, because it is totally connected, or in other words, from any vertices, it is possible to get connected to any other.

TABLE I

METRIC MEANS COMPARISON		
Metrics	1st interval	2nd interval
Average path length	3.949	3.178
Network Diameter	6	6
Average grade	2.011	2.019
Density	0.012	0.006
Modularity	0.737	0.597
Connected components	1	1

In this context, the intermediation centrality, or the betweenness centrality appears as a detecting way about the amount of influence a node has over the information flow in a graph. It is often used to find nodes that serve as a bridge from one part of a graph to another. In other words, it indicates the most influent nodes inside the network which if be removed all connections in the graph would be cut off because it ensures that no nodes are isolated. The betweenness is one of the most interesting measures in the model representing the measure of how many times a node appears in short test paths between nodes in the network. It means that a vertex which occurs in many shorter paths between other two vertices possesses greater betweenness. It can also be seen as the entity's capacity to make connections with other entities or groups. The network with the calculated betweenness and the most influential nodes in the network of these two intervals are shown in Fig. 5.

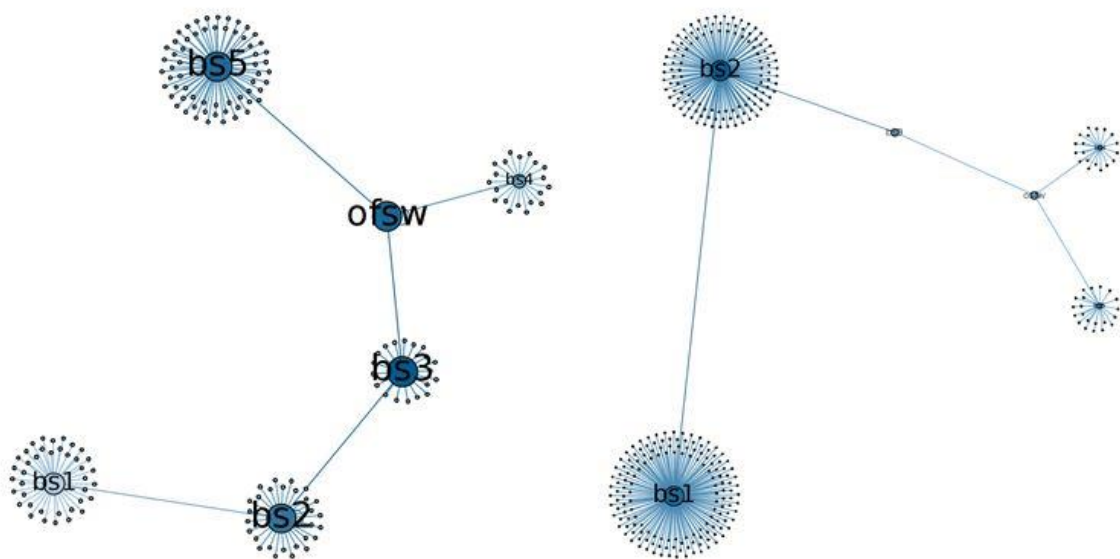


Fig. 5. Determining betweenness of two intervals.

But another fundamental point is the detection of communities or clusters, which allows the graph decomposition into groups for their properties mining. The Louvain method, one of the most popular approaches, is an algorithm for communities detecting in networks that maximizes a modularity score for each community, being one of the fastest modularity-based algorithms and working well with large graphs. It also reveals a hierarchy of communities at different scales, which can be useful for understanding the global functioning of a network. This method aims to optimize locally the communities in this model proposal, as illustrates in Fig. 6.

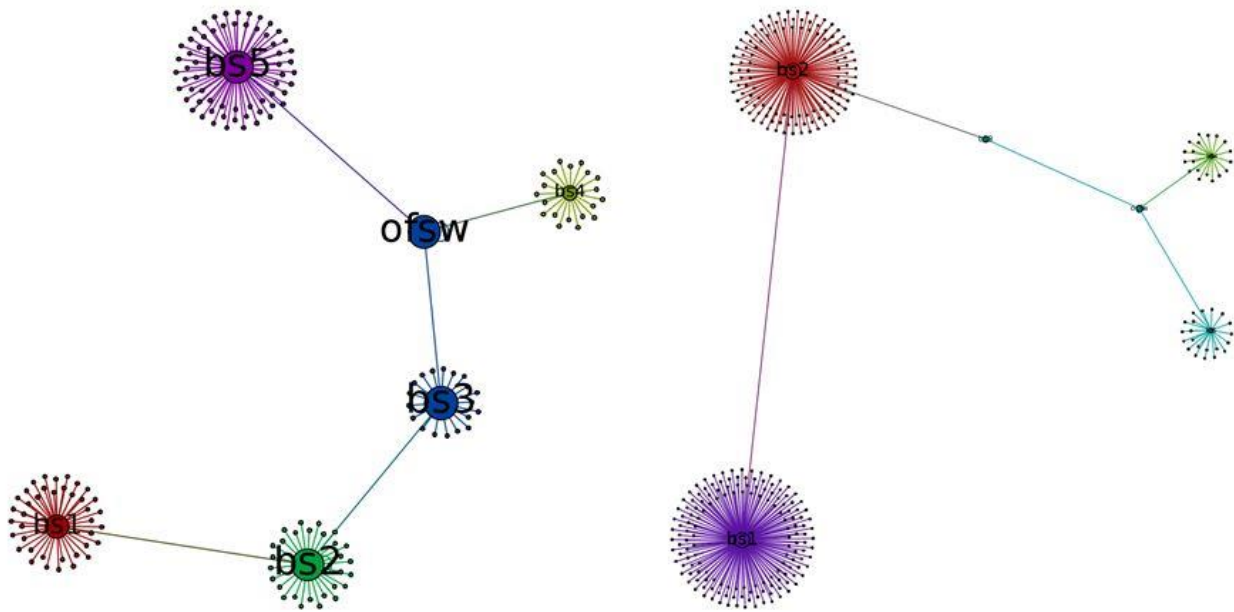


Fig. 6. Detection of clusters between two intervals.

In the performed emulations, the first interval has detected 5 communities in which it is observed that the largest one is represented by 36.21%, followed by 22.98%, 16.67%, 13.07%, and 11.07%. The second interval has detected 4 communities in which it is observed that the largest community is represented by 48.25%, followed by 38.0%, 7.90%, and 5.85%. From these results obtained through a service module, we demonstrate that it is possible to provide useful information and create new services in various segments of smart cities through the 5G ecosystem and that the proposed model is applicable.

## 5 CONCLUSIONS

With the 5G network, it is expected a fully mobile, collaborative and connected society cause it an important role for smart cities. However, there are still many challenges involving urban

environments will use this mobile communication system to perform various services. That's why this work presented a 5G model as a facilitator for smart cities and new services infrastructure.

The proposed model has a very important characteristic of being able to support features, and services that are going to be developed in the future. In this way, the proposal of a facilitating model for the provision of new services is as simple and agile as possible so that they can be effectively delivered to stakeholders in the smart cities. In this sense the operators can provide a basic structure to a stakeholder so that they can develop new and personalized services. The proposed model demonstrated in this paper, through network data collection and deliver to stakeholders can be a smart city services facilitator for innovative applications and services facilities by 5G. The suggestion for future work is to carry out new tests in 5G scenarios and the development of real services applied to smart cities.

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