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Fog Computing for Network Slicing in 5G Networks: An Overview

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Abstract

5G is visualized to be a multi-service network assisting a huge range of modern-day technologies with a different set of performance and service requirements. Slicing a single physical network into multiple isolated logical networks has provided as a key concept to realizing this vision. Fog computing is a new paradigm arise with expand the IoT devices that extends computation, communication, and storage functions towards the edge in 5G networks. Compared to traditional central cloud computing, fog computing provides a low delay for sensitive service requests from end users with reduced energy consumption and low traffic congestion. Motivated by the increased wireless traffic from different applications and devices, efficient resource allocation schemes for fog computing develop the flexibility of network resource allocation and size of 5G networks depend on network slicing. This article gave a literature on fog computing important in various 5G network slices predicated on a detailed description of network slicing, covering three different application domains (i.e., IoT, eMBB, and uRLLC). The article also provides a high-level addressing of a multi-slice environment that helps of network slicing to provide the appropriate customization and highlights the technology challenges and research directions.

Keywords: 3GPP; 5G; eMBB; Fog computing; mMTC; Network slicing; uRLLC

Introduction

5G will serve as a nervous system for the digital society, economy and people's everyday lives. The future Internet service paradigms (IoSs) will enable anything as a service (AaaS), which devices and terminals, as well as smart devices and robots, will be tools that produce and use applications, services, and data. In addition, the future Internet will increase the need to improve QoS/QoE, supported by customized services and adaptable at runtime, depending on contextual conditions, to allow less access time, high mobility, high scalability, Real-time. These demands can only be partially realized through current cloud computing solutions [1].

Network slicing differs critically from QoS because it will support virtual networks from end to end and include computing, storage, and networking functions. The current QoS approach is a point solution that provides a subset of functions at best when compared to network slicing. Network slicing generates a lot of interests in 5G discussions especially because it will open up many new business opportunities. Network slicing is an essential for the overall recent trend to make network services in 5G more virtual and thus benefit from lower costs and increased innovation that the IT industry has done with moving into the cloud and everything as a service. The slicing of the network is unlikely to require new revolutionary technical standards. Instead, the technical changes will be implemented through countless techniques and standards that focus on key areas for improved network intelligence, system integration, and traffic engineering [2].

The classification of 5G wireless network services into three categories; enhanced mobile broadband (eMBB), Massive machine-type communications (mMTC), and ultra-reliable and low-latency communications (uRLLC).

- eMBB ambitions to satisfy the demands of users in a growing digital lifestyle and focuses on services that have high bandwidth requirements such as HD video, VR, and Augmented Reality (AR).
- mMTC pursuits to meet industry and government requirements for an increasingly digital society, focusing on scenarios that require high-density communications, such as intelligent transport, smart grid, and intelligent manufacturing.
- uRLLC aims to meet market and enterprise requirements for digital industries contemporary, and focuses on emergency-sensitive services, such as automated and assisted driving, remote control [3].

In this regard, despite the fact that technologies such as multiple multi-input (MIMO) products are necessary to enhance capacity in the fourth generation era, it is not economically feasible to deploy such technologies in the fifth generation. In contrary, the 5G cellular networks is a revolution by basically introducing intelligence to enhance the spectrum efficiency (SE) and energy efficiency (EE). Specifically, 5G cellular networks introduce many options for radio resource management (RRM), mobility management (MM), management and orchestration (MANO) and service provision management (SPM) mechanisms. Therefore, it is no longer necessary to construct networks dedicated to individual services (for example, GSM-Railway networks). By contrast, given the development of the more intelligent 5G networks, it would be possible to provide end-to-end dedicated network slicing to meet ultra-low latency in URLLC and ultra-high throughput at the same time, in eMBB [4].

The 5th generation network is anticipated to be the basis for a range of applications sectors and use cases to identify any particular use cases ranging from general access to broadband with global coverage to the specialized sensor or mobility networks. The stark variations between these use cases translate into a set of heterogeneous necessities that

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cannot be met corresponding a single structure that fits all elements. With this in mind, alternative architectural proposals for 5G have recently emerged to accommodate use cases with diverse requirements [5].

A new paradigm called fog computing has invented to meet these necessities. The fog expands cloud computing and services on the edge of the network and produces data, computing, storage, and application services to users that can be on the edge of the network devices such as access points. It reduces service response time and improves QoS/QoE quality, resulting in a superior user experience. Fog will support emerging Internet applications for everything (IoE) (industrial automation, transportation, sensor networks and engines) that will need real-time mobility and prediction. Therefore, fog can be considered as a candidate technology for networks that exceed 5G, where the cloud will be deployed among the client's devices [1].

Network slicing has also attracted a lot of trendy researches interest in academia, according to Riccardo et al. [6], they examine the legacy of the fourth generation around slicing networks (where relevant early concepts can be found), to review the current status of the 5G system standardization in this regard, and to focus on critical open points that require considerable effort before 5G. In a study [7] The common system for the distribution of capacity and the sub-channel for network slicing on two-tier of spectrum sharing, where both co-tier and cross-tier Interferences are taken into consideration. The authors show that the proposed resource allocation schema can allocate network resources flexibly between different slices, thus effectively sharing network resources in 5G systems. On the other hand, the motivation in a study [8] is to review the literature on fog computing is three:

1) To learn how to use the fog computing model to construct sustainable smart cities on top of the IoT infrastructure.

2) To pick out the most important functions of the typical fog computing platform.

3) To concentrate on open challenges and discuss research trends in the development of fog platforms to work with wide range of scenarios.

In a study [9] the authors provide a comprehensive study of the architectural frameworks of both SDN and NFV as key assistors for achieving network slice performance. Although these two approaches are not yet common in the practice of existing networks, especially in wide area networks (WANs), their integration offers the promising potential to meet slice requirements appropriately. In fact, many 5G research and clarification projects (such as 5GNORMA, 5GEx, 5GinFIRE, or 5g! Pagoda) address the 5G slicing by combining SDN and NFV. Thus, an example of how NFV functional groups, SDN controllers was provided, and their interactions can fully understand the concept of network slicing. In addition, the main challenges were identified that arise from the implementation of network slice in 5G systems. Authors in a study [10] discuss the need for deep customization of the mobile phone Networks with different levels of accuracy: per network, per application, per group of users, per individual user, and even per-user data. They assess the potential of network slicing to provide appropriate allocation and highlight technology challenges. To cope with the above, this article is to produce an overview of the network slicing, types of the slice in 5G and the use of fog computing for delivery of network slicing Services. In addition, as the 5G architecture is still improving the specification of isolated slices operation and management, these bring to the surface the new requirements and challenges that need to be addressed and how the fog computing provides solutions for many open issues in the 5G era. The reminder of this article is structured as the following:

In Sec. II network slicing architecture including types of the network slicing.

In Sec. III, the discussion of the concept and system architecture is provided for 5G radio resource management.

In Sec. IV mobile edge computing including the fog computing and its roles. Following that, Challenges and future research directions is provided in Sec.

V. Finally, a summary of this overview is given in conclusion Sec. VI.

Network Slicing Architecture

Network slicing concept and system architecture

The previous generation supported certain aspects of network slicing through the functions of dedicated core networks. Compared to this, 5G network slicing is a stronger concept and includes the whole PLMN. In the 3GPP 5G architecture, the network slice refers to a bunch of specific 3GPP features and functions that form a complete PLMN network to provide services to the user equipment. Network slicing allows for the controlled PLMN structure of the specific network functions with their specific characteristics and the provision of services required for a particular scenario.

The concept of slice virtual networks deployed across a single network is actually not new (for example, VPN), although there are specialties that make network slices a new concept. It has been defined network slices as end-to-end (E2E) networks (physical or virtual), mutually isolated, with independent control and management, which can be created in needs. These stand-alone networks must be flexible enough to accommodate simultaneously the different use case situations that are business-driven by multiple players on a common network infrastructure [9]. The M2M network slice, for example, can provide inadequate UE battery power features, since these features imply an unacceptable for typical smartphone uses in Figure 1.

Virtualization is an essential process for network slicing as it enables the effective sharing of resources between slice. Virtualization is the abstraction of resources using appropriate techniques. Resource abstraction is a resource representation in terms of attributes that match predefined selection criteria while hiding or ignoring aspects that are not relevant to these standards, in an attempt to simplify the usage and management of this resource [11].

Vertical slicing and horizontal slicing are two types of independent slices. The end-to-end network in a vertical slice connected the core network to the edge devices throughout the fog nodes. The traffic flow in a horizontal slice is usually establish between two end nodes of the same tier slice. In vertical slicing, Nodes are operating similar function to support the particular slice. In horizontal slicing, in the other hand, nodes support multiple functions for a different slice. Figure 2 illustrates vertical and horizontal network slicing concepts [12].

Network slicing management architecture

SA5 determines the need to automate management by introducing new management functions such as a communication service management function (CSMF), network slice management function (NSMF) and a network slice subnet management function (NSSMF) to provide an appropriate level of automation [13]. Different management models can be used in the context of network shredding.

1) Network Segment as a Service (NSaaS): can be provided by CSP to its CSC in the form of a communications service. This service

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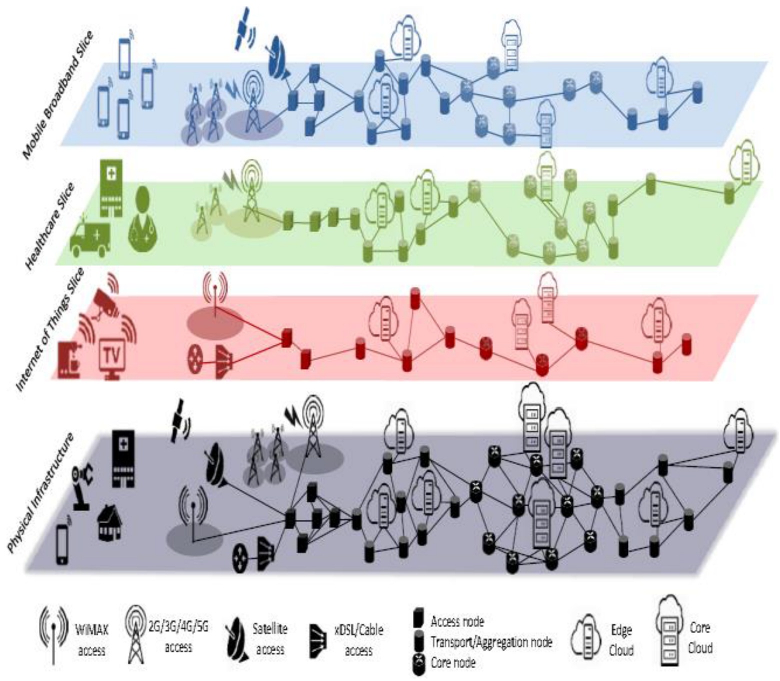

Figure 1: Overall operator network domain.

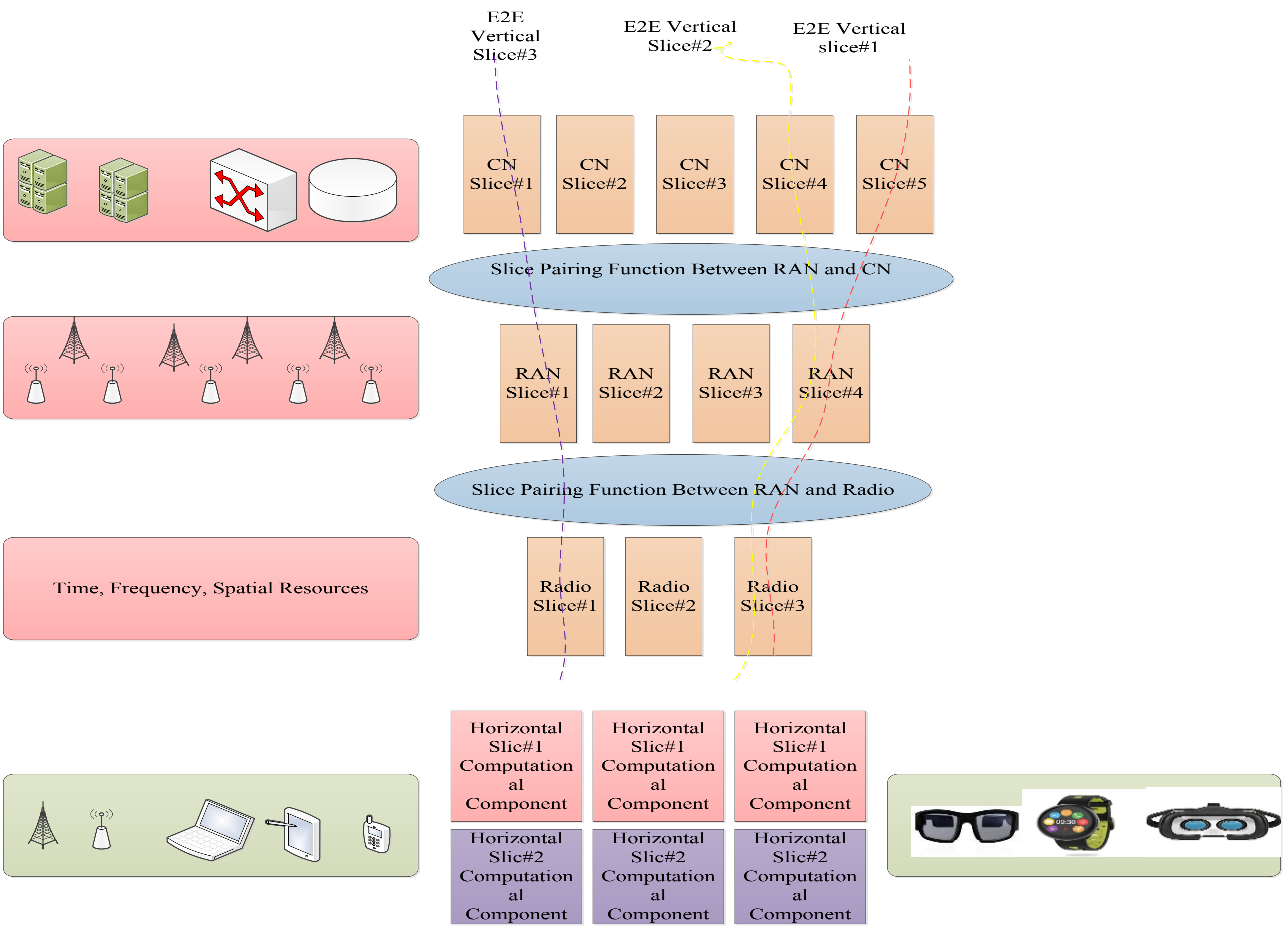

Figure 2: Vertical and horizontal network slicing.

allows CSC to optionally use the instance of the network chip. In turn, the CSC can play the role of CSP and provide its own services (such as telecommunications services) the highest instance of the network segment. MNSI (the instance of the Managed Network Services for IoT) represents the shape of the network slide instances and represents the CS connection service

2) Network slices as network operator (NOP) internals: Network slices are not part of the CSP service view and are therefore not visible to CSCs. However, NOP may decide, to provide support for telecommunications services, deployment of network slices. for example, For internal network optimization purposes.

3GPP SA5 management architecture will take care of a service-oriented management architecture that is introduced as an interaction between the service provider and the management service provider. For example, the management service consumer can request operations from management service providers for error monitoring, performance management, service, information etc. [14].

According to a study [15], the basic architectural components of SDN networks are resources and control units. For an SDN, the resource is anything that can be used to provide services in response to client requests. This includes infrastructure resources and NFs, but also network services, in the application of the recursive principle. A controller is a logical central entity created at the control plane, where the runtime runs SDN resources to best serve the services [16]. Therefore, SDN mediates between clients and resources, and operate simultaneously as a server and client across client and server contexts, respectively. Both contexts are conceptual components of the SDN controller that enable client-client relationships in Figure 3.

When performing the virtualization function, the SDN controller performs abstraction and aggregation/division of underlying resources. With virtualization, each client context provides a specific set of resources that can be used by the client associated with that context to achieve its service (s). Through orchestration, the SDN controller typically sends the specified resources to separate resource groups. The interaction between each of the control functions enables to meet the varying service requirements of all customers while maintaining isolation among them.

According to the ONF view, the SDN architecture normally supports the partitioning process, where the client context provides the complete abstract set of resources (as a resource group) and supports the control logic that forms a slice, including the entire set of relevant customer service attributes.

Another key functional aspect that makes the ideal SDN structure to adopt 5G slicing is recursion. Due to the different layers of abstraction provided by the Recursive Principle, the SDN control plane can include multiple hierarchically arranged controllers that extend client-server relationships at multiple levels. According to these premises, it is clear that SDN can support the iterative combination of slices. This means that the resources (i.e. Resource Group) provided by a particular controller to one of its clients in the form of a dedicated slice (i.e the client context) can, in turn, be virtualized and orchestrated by that client if it is an SDN controller. In this way, the new controller can use the resource(s) that it can access through its own context (s) to identify, expand, and provide new resources and slice to its own client.

5G radio resource management

The current 4G cellular networks rely heavily on orthogonal frequency-division multiplexing (OFDM) as the signal carrier and associated access scheme base. Since OFDM can be used in both

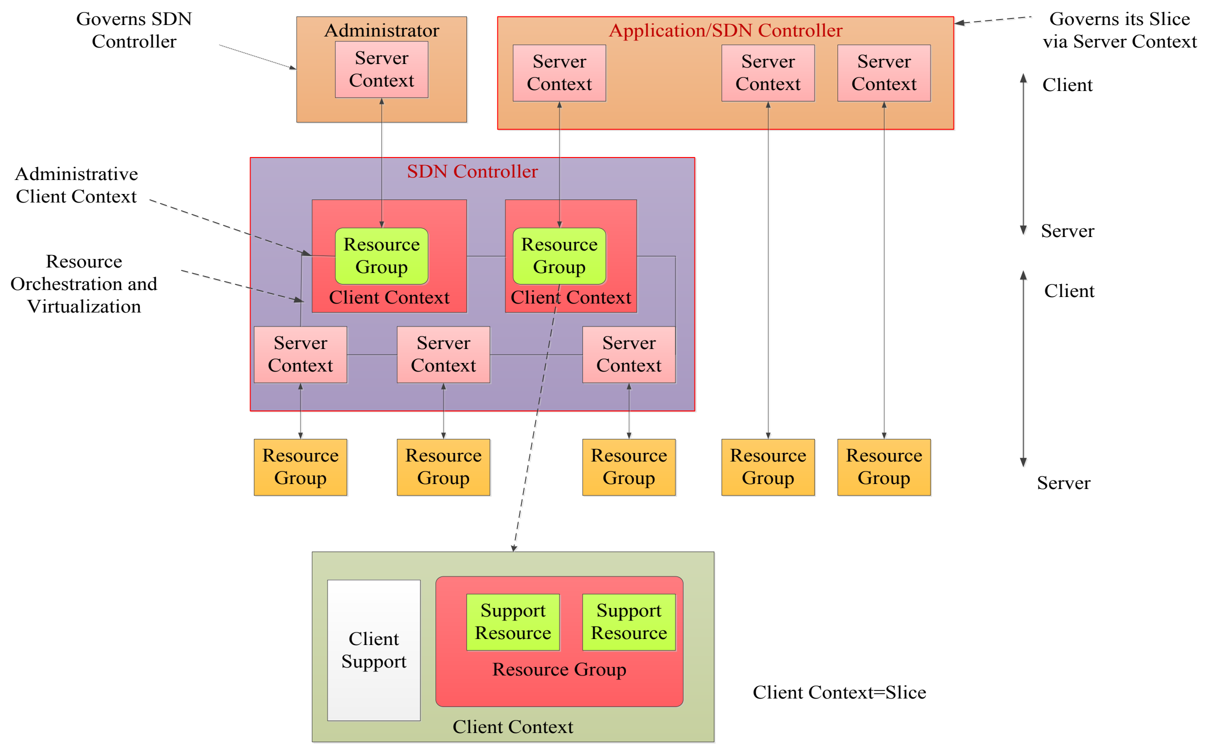

Figure 3: ONF SDN network slicing architecture.

frequency-division duplex (FDD) and time-division duplex(TDD), FDD and TDD 4G cellular networks share a similar frame structure by combining a fixed number of sub-carriers and symbols into a single resource block (RB). By utilizing the OFDM sub-carriers, information transmitted at different radio levels to the receivers can be decoded at a limited computing cost. However, it is intractable to use OFDM to meet concurrent service requirements from different users with different channel conditions, user-side capabilities (multiple access support, full duplex mode, feature of smartphones) mobility, frequency bands, and so on. Because of this, cellular networks 5G aim to introduce new waveforms and provide smoother interfaces. Specifically, filter-bank multi-carrier (FBMC) and unified-filter multi-carrier (UFMC) are popular candidates for the more flexible frame and waveform structures in the fifth generation era. As their names indicate, FBMC and UFMC add filters to combat out-of-band leakage through sub-carriers and make them unnecessary for strict synchronization across RBs. Therefore, cellular networks 5G can provide different interface identification solutions in different RB systems, where different access schemes can be defined, TTI parameters (transmission time interval), waveforms, duplex mode.

Similar to the evolution from OFDM to FBMC/UFMC, 5G cellular networks are adopting multiple non-orthogonal access systems (NOMA) such as sparse code multiple *access* (SCMA) [17]. These NOMA schemes interfere with information from transmitters at the same radio source and apply the SIC (successive *interference* canceller) to decode the received information. Apparently, the NOMA can increase productivity. In addition, another feature of NOMA is that it allows UL-enabled transmission without UE and preamble to set UL to be unassigned. Rather than waiting for resource allocation orders as in cellular 4G networks, it is possible to decrypt overlapping information from UEs on the same resources using SIC receivers.

Artificial Intelligence for 5G Cellular Networks

Cellular networks have various choices in the fifth-generation era to access service delivery mechanisms and thus get the idea for applying Artificial Intelligence. However, 5G cellular networks lag behind what is truly needed in reality. First, the number of configurable parameters in a standard 4G node hyperbolic to 1500 from 500 at node in 2G and 1000 in the 3G node. If this trend continues, a standard 5G node is supposed to contain 2000 or more parameters. Therefore, it is vitally necessary to boost intelligence in the 5G era to get self-regulatory features (e.g., self-configuration, self-improvement, self-healing). Second, the types of services (such as eMBB, URLLC, and mMTC) are specified in the fixed 5G era. Although, new sorts of services are constantly evolving, and therefore the current service pattern is changing dynamically. In this case, cellular networks 5G still lack the functionality to automatically determine a new type of service, to deduce the suitable supply mechanism, and to create the desired network slice. Thirdly, cellular networks 5G depend heavily on a centralized network structure in SDN, and still lack flexibility and power under the network scenario. Heterogeneous and increasingly complex cellular. To self-regulate the parameters that become much larger, automatically create network slices for emerging services, and gain sufficient flexibility for network maintenance, it is necessary for cellular networks to notice environmental changes, learn uncertainty, plan response procedures, and properly configure networks. Coincidently, Artificial Intelligent is fundamentally resolving how to learn differences, classify problems, predict future challenges, and look for potential solutions through interaction with the environment. Therefore, cellular networks can take advantage of the concept of cognitive radio and interact with the environment using AI, so as to accelerate the development fully and enter into a completely new 5G era. Artificial Intelligent has developed into interdisciplinary techniques such as automated learning, optimization theory, game theory, and control theory. Among them, automatic learning belongs to one of AI's most important subfields. Usually, depending on the nature of learning objects and references to the learning system.

Figure 4 illustrates the structure of a possible 5G cellular network from AI, where the AI controller acts as an application on top of ONOS (Open Network Operating System) or an independent network entity and communicates with RAN or CN or global SDN controllers using open interfaces. Specifically, the Artificial Intelligence Center will read service level agreements (such as requirements for rate, coverage, failure duration, redundancy, etc.), UE-level information (e.g. receiver category and battery limitation) and network-level information (e.g.

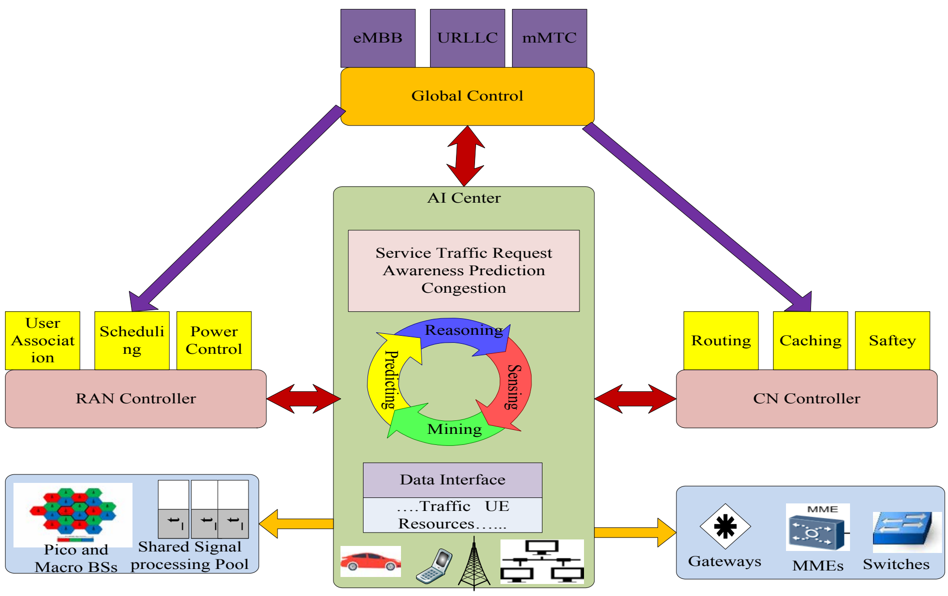

Figure 4: 5G cellular networks enabled by AI.

spectrum, number of subscribers) , Quality of service (QoS), key performance indicators for network functions, scheduled maintenance period, etc.), infrastructure tier information (such as server type, CPU, memory, storage, network standard) of SDN controllers joined with data Cellular networks such as traffic information, UEs, and network resources.

The Artificial Intelligence Center will then use its integrated modules (eg, sensing, mining, prediction, and inference) to process the information obtained, and the learning results of the comments, which may include traffic analysis reports (e.g., service provisioning suggestion), UE-specific controlling information (e.g., display priority, bandwidth allocation, and mobility tracking command), and notification of the network configuration (for example, parameter modification, access method, and network error alert) to SDN controllers. For example, AI is strengthening the sensor module to track the location of power supply units and using the forecasting unit to predict mobility patterns based on the historical movement pattern it takes advantage of the reasoning module and proactively notifies the UEs to update the location record, so as to prepare handover resources and save signaling cost of mobility management.

On the other hand, 5G cellular networks can still work at the normal status under the condition of potential damages (e.g., hacking) to the AI center. Although, the AI center could (semi-)periodically exchange information with the SDN controllers in ordinary states, while it starts emergent responses to schedule the minimum required resources, once the conventional SDN controllers encounter malfunctions. Therefore, compared to the complete centralized architecture in conventional networks, the AI center and the SDN controllers virtually constitute a multi-tier decision-making system, thus being able to improve the network robustness [4].

Cellular IoT and 5G

5G is the future of mobile communication and IoT, promising blistering speeds and ultra-low latency for a huge range of devices/services. Of course, the path to 5G runs through 4G infrastructure as an overlay using fixed wireless, enhanced mobile broadband, low latency and automated data communication. This has critical effects for cellular IoT. Even as 5G holds great promise for IoT devices, carriers don't have to wait. Cellular IoT can be deployed today using 4G networks and will occupy a substantial portion of 5G networks in the future. As a next step, providers must find ways to monetize the service and decide on reasonable prices for commercial customers. The IoT is about making human life easier by helping us make smarter decisions faster. We are going to see cellular IoT applications deployed in a world of 5G, including the proliferation of high speed, low latency use cases like true, real-time vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, and remote medical [18].

LTE-M and NB-IoT

There is no ideal technology or single solution suited to all the different potential massive IoT applications, market situations, and spectrum availability. As a result, the mobile network vendors try to standardizing many technologies, including Long Term Evolution for Machines (LTE-M) and Narrow Band IoT (NB-IoT). NB-IoT is typically suitable for low bandwidth, infrequent communication from a stationary device, while LTE-M is more suitable for higher bandwidth or mobile and roaming applications.

A typical application for NB-IoT is using remote environmental sensors to measure temperature, wind, pressure and so on. These devices can send frequent updates from a fixed location while battery saving use. Such a device could live for up to ten years, or longer if solar-powered and put in the right location. Also, an asset tracker with monitoring of condition through many sensors, which is mobile and roaming from country to country, is working in LTE-M solution that offers highway speed mobility, international roaming even between countries or operators, and regular firmware updates.

Cellular future for IoT

Advantages of cellular connectivity for IoT include:

- The open standards that used depended on existing infrastructure means the coverage will reach almost everywhere where people live.
- Many devices can operate simultaneously because of the advanced co-existence mechanisms in the LTE standard and licensed-band operation, as is already proven today with a large number of cellphones used concurrently within a small area.
- No limiting regulatory regulations, so you can transmit up to 23dBm and negotiate for as much airtime as you need
- Standard Datagram Transport Layer *Security* TLS/DTLS security for end-to-end security is supported on top of the on-air encryption of the LTE network aided by the SIM credentials. This keeps data secure from the device to the cloud server
- As cellular networks all around the word cover more than 90 percent of the world's population and can recently be offered in low complexity, low power variants, the cellular network is a great choice for the world's IoT needs, both now and in the future [19].

Confluence of fog and cloud in RAN

There are two system design paradigms: cloud and fog. The cloud-based design paradigm applies centralized resource pooling to achieve efficient resource utilization. Leveraging the advantages of both cloud-based and fog-based designs, a hybrid architecture that integrates the C-RAN and the F-RAN has been proposed.

The fog-cloud integrated RAN, which combines the C-RAN/heterogeneous C-RAN (H-CRAN) and the F-RAN, was proposed. In this architecture, there are four types of clouds:

Global centralized communication and storage cloud, centralized control cloud, distributed logical communication cloud, and distributed logical storage cloud. Here, a hybrid architecture example is given as shown in Figure 5. The global centralized communication and storage cloud in the centralized BBU pool provides flexible management of radio signaling processing and resources in subordinate radio access points such as RRHs and fog-computing-based access points (F-APs).

In F-RANs, distributed logical communication and storage clouds are used. These clouds are composed of edge devices, such as RRHs, F-APs, and user equipment's (UEs), which support direct device-to-device (D2D) communication with other UEs. Application processing can be performed on the edge devices to reduce latency and traffic loading to the BBU pool. Furthermore, adjacent edge devices can be interconnected to provide coordinated and cooperative functionalities among the devices. Thus, each edge device may exchange application data, and then relay the caching data to UEs [20].

Each network topology (e.g., mesh, tree, or star topology) has its own pros and cons. A logical star topology, where a master F-AP distributes computing-intensive application tasks to its slave F-APs

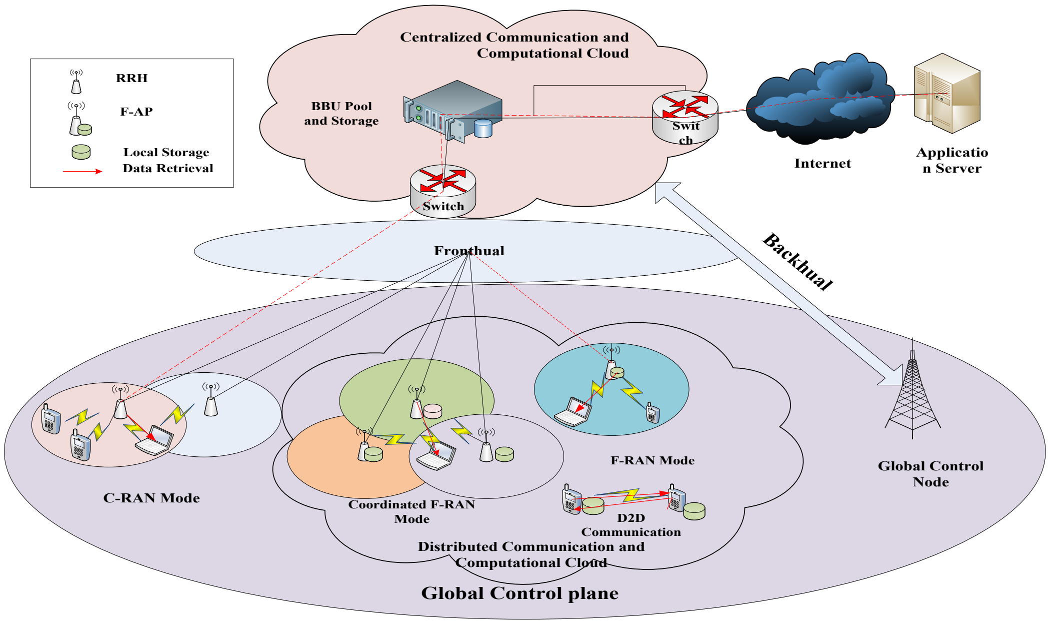

Figure 5: Fog-cloud integrated RAN architecture.

and summarizes the processing results, is used. The performance-cost trade-off is affected by the number of participating F-APs, the number of assigned tasks for each participating F-AP, and the status of F-APs.

The switch/selection of the RAN and application processing among different clouds depends on the statuses of the edge devices and the characteristics of application tasks. On the basis of the four clouds in the fog-cloud integrated RAN, four transmission modes to be selected for a UE are D2D, local coordination, global centralized, and centralized control modes, respectively.

Interworking between F-RAN and user devices

In the fog networking system, computing tasks could be handled by servers, network nodes, and user devices. Dividing a computing task between cloud servers, network edge nodes, and UEs needs to consider the bandwidth consumption, computation load requirement, and delay. For example, wearable devices with low levels of processing and storage capacities could migrate some application processing to nearby edge nodes, which could be co-located with a base station or Wi-Fi AP. Meanwhile, some powerful mobile nodes such as laptops and high-end smartphones could handle more computing tasks in the device and migrate applications to edge nodes occasionally. On the other hand, some proximal user devices might collaboratively handle some application processing tasks. In such a case, D2D communications might facilitate the proximal collaboration between user devices. A hybrid model that integrates computing task migration between a user device, a fog node at the network edge and a cloud server could provide flexible system operation. In a given F-RAN network-centric topology, the network may consist of fog nodes on the network edge, but the user devices do not provide for fog computing. Network-edge fog nodes might also be combined with cloud computing nodes, whereas for a user-provided F-RAN topology, F-RAN architecture might include active engagement of users. User devices might be active in fog computing tasks. In addition, they may collaborate with other user devices [21].

Mobile Edge Computing

MEC aims to negate latency by providing computing capabilities closer to the end device. It emboldens a wide variety of applications such as Virtual/Augmented Reality and is critical for technologies such as autonomous vehicles where every millisecond counts. Edge and fog computing will play a crucial role in 5G, the next generation of connectivity that promises to usher in the age of robotics, autonomous cars, immersive media, AI and IoT [16].

Fog computing - A requirement of 5G networks

Successful 5G relay on fog, it has to support fog computing, otherwise, the low latency radio interfaces will be useless. A typical 5G network has mobile users connecting to a base station, which would, in turn, be connected to the core network through wired links. Requests to a cloud-based application would go through the base station and the core network to finally reach the cloud servers. In such a deployment, even though the low latency radio interfaces enable sub-millisecond communication between the mobile device and base station but sending the request from the base station to the cloud will lead to a delay increase in orders of magnitude.

It is imperative for the 5G networks to be more than just a communication infrastructure. Computation and storage services, when provided by the network, close to the edge devices, will allow applications to take benefit of low latency radio to provide very fast end-to-end response time. This will highly benefit both the customers (by giving timely responses) and the provider (by alleviating the load on the backbone network). This descent of processing from the cloud to the edge forms the definition of fog computing, and it would not be wrong to say that 5G networks cannot fulfill its promises without fog computing. Fog computing is not a feature, but an important requirement for 5G networks to be able to work properly.

The Pico and Femtocells (also known as micro-cells) are key elements of 5G networks that enable fog computing. Small cells can alleviate the burden on roof-top base stations (macro-cells) by allowing endpoints to connect to them. A device can connect either to the macro-cell or to a micro-cell. This makes the architecture of 5G networks a hierarchical one - with the core network (cloud) at the apex, followed by macro-cell base stations and micro-cell base stations, and finally end devices. Hence, from the fog computing point of view, both macro and microcell base stations form the fog nodes, i.e. networking nodes providing computation and storage as well. Packets sent uplink by the devices will be analyzed at the microcell or macro-cell base stations before reaching the core network. Another major advancement in communications that 5G brings along is efficient device-to-device communication. Application data sent will be sent from the sender device directly to the receiver device, with the base station handling only control information of this transfer. This allows inter-device communication to take place without burdening the base station, thus beatifying fog systems with the scalability of handling numerous devices interacting with each other. This will be categorically useful for applications that involve numerous connected points and continuous communication between these points, for example, smart homes [22].

Fog physical network architecture

The physical network architecture of a fog computing over 5G will extend the architecture of the state-of-the-art Heterogeneous Cloud Radio Access Networks. In the traditional HCRAN architecture, all application processing tasks are performed on the cloud inside the core network, which requires billions of end devices to communicate their data to the core network. Such a massive amount of communication may vitiate the fronthaul capacity and may overburden the core network, which will have a detrimental impact on the QoS experienced by the end-users.

An intuitive solution to this problem is to bring down computation and storage capabilities from the cloud near the edge so that the need to send all the data generated by end-devices to the cloud is done away with, hence alleviating the fronthaul and the core network of the immense traffic surge. The devices in each layer are capable of hosting computation and providing storage, hence making it possible for creating complex processing offload policies.

- **Device layer**: The device layer describes all the end-devices connected to the fog network, including IoT devices like sensors, actuators, gateways, etc. and also mobile devices like smartphones, tablets, etc. These devices may be exchanging data directly with the network or may be performing peer-to-peer communication among themselves. Being the source of all data entering the network and the prime actuators performing tasks, these devices are the lowest tier of fog devices. The device layer hosts computation either by embedded coding (for low-end devices like sensors) or as a software running on the operating system of the device.

- **Fog layer**: The fog layer consists of intermediate network devices located between the end-devices in the device layer and the cloud layer. The first point of offload in this layer is the RRHs and small cells which are connected by fiber front haul to the core network. Processing incoming data here will considerably reduce the burden on fronthaul. Macro cells also form a point of offloading processing which sends the processed data to the core network through backhaul links. Both fronthaul and backhaul are realized by Ethernet links and the intermediate devices like router and switches in the path from the radio heads to the core also form potential places where computation and storage tasks can be offloaded.

Deploying applications on these devices is made possible by advances in virtualization technology. Each application is packaged in the form of a virtual machine and is launched on the appropriate device. The application virtual machines run alongside the host OS virtual machine (which performs the original network operations) over a hypervisor on the fog device.

- **Cloud layer**: This layer forms the apex of the hierarchical architecture, with cloud virtual machines being the computation offload points. The theoretically infinite scalability and high-end infrastructure of the cloud make it possible to handle processing that requires intensive computation and large storage – which cannot be done at the edge devices. In addition to application layer processing, the cloud layer contains Base Band Units which process data coming from RRHs and small cells via front hauls and route processed data to application servers [23,24].

Fog computing for vehicular Environments

The smart vehicular network known as the smart transportation system depends on a combination of cloud, fog, and SDN. since the requirement of location-aware services near to the sensing devices have produced the need for the fog computing framework. Fog computing helps to realize the delay-sensitivity of the smart transportation system. In these scenarios, the time required for data transfer and decision-making process is very low in order to avoid vehicle collision. There are several security threats to the smart transportation system. In order to overcome these issues, there is a need for a system which would cater to the data availability, confidentiality, and integrity. System authentication is also another security aspect to have a consideration.

SDN has the ability to provide management and deployment of network services. The SDN based system provides flexibility, scalability, programmability as well as global knowledge. Whereas the fog computing paradigm provides latency sensitive and context-aware services. Figure 6 had proposed a fog and SDN based architecture (FSDN) for vehicular ad-hoc networks (VANETs). The network of vehicles is connected to the fog layer by the cellular networks. The fog network is connected to the SDN controller [17]. SDN layer does the fog orchestration and network management services.

The SDN controller is connected to the cloud computing layer in.

The FSDN VANET architecture can optimally configure service deployments, dynamically reconfigure itself for a better quality of service. The various layers of FSDN architecture are as follows:

(i) **SDN controller**: It has the global knowledge which helps to control all the network situation of the system. Fog orchestration and resource management are provided in SDN.

(ii) **SDN wireless nodes**: The vehicles work as the end-users and also forwarding element.

(iii) **SDN road-side-unit (RSU):** It is a fog device. It runs OpenFlow and it is controlled by the SDN controller.

(iv) **SDN road-side-unit controller (RSUC):** A group of RSUs is connected to RSUC through broadband connection before accessing to the SDN controller. It also has OpenFlow and it is also controlled by the SDN controller. These are also fog devices.

(v) **Cellular base station (BS):** It can also provide fog services and is controlled by the SDN controller.

This is a view of vehicles as the infrastructures for communication and computation, which is a paradigm determined as vehicular fog

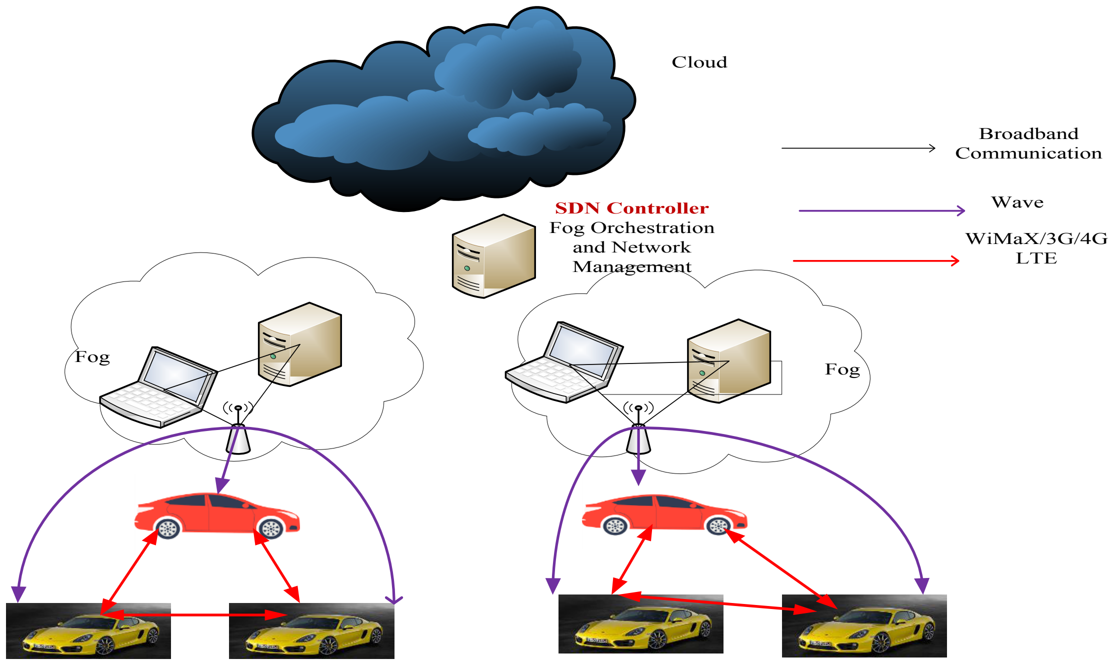

Figure 6: Fog and SDN based architecture for vehicular Ad-hoc networks fog and SDN based architecture for vehicular Ad-hoc networks.

computing. Figure 8 gives an idea about the usage of the fog computing for vehicular networks. The vehicles having sensors and applications have created a fog network which is also known as the multi-service edge. Fog layer provides the distributed intelligence. The fog layer is connected to the core network having cloud servers for data analysis. By utilizing the computation of the edge devices, the fog based vehicular environment can give better QoS to the end users.

The proposed VFC has the advantage of providing more reliable communication with higher capacity. The computational performance gets improved due to the usage of currently underutilized computational resources of individual vehicles. Some authors have proposed an architecture which has the capability of sensing and controlling applications running on cars. This helps in collecting the datasets for public safety surveillance. The connected vehicle applications can be optimized in terms of the latency and bandwidth by using the edge computing cloud infrastructure [25,26].

Integrated fog cloud IoT architectural paradigm

Fog architectural paradigm depicted in Figure 7 is the architecture proposes federated cloud services to IoT devices with the aid of intermediary fog [27]. The federated cloud services can comprise multiple internal and external cloud servers to match business and application in demand. As shown in Figure 7, fog nodes (e.g., edge servers, smart routers, base stations, gateway devices) and partially radio access networks are provided. In a fog computing environment, plenty of the processing takes place on a fog node. the complete fog deployment can be located regionally (e.g., in case of building automation, a company that manages a single office complex) or the fog deployments can be distributed at local or regional tiers that provide information to a centralized parent system and services. Each operational fog node is self-reliant to ensure uninterrupted operations of the facility/service it provides.

A fog node manages all IoT devices that are within its radio network. The IoT devices typically stimulate radio access networks (e.g., WLAN, WiMAX, cellular networks) to communicate with the fog. However, the fog is connected to the federated cloud servers via the core network. A fog can be connected to other fogs through a radio access network. Specifically, when an IoT device moves from the coverage of one fog to another, the virtual machines associated with the IoT device are migrated from the original host edge server to the migrated edge server in the fog nodes facilitates the collection and maintenance of local system statistics and/or locally sensed information supplied by various IoT devices and/or clusters. These local statistics and information can either be used to improve the local content, services, and applications or to update the federated cloud data center. The federated cloud data center gets updates from several fog nodes. The federated cloud data center can then perform big data analytics on the received information to extract information that is representative of a bigger geographical location and to determine global system statistics [28].

Fog computing architectures and frameworks

In this section, the ongoing research activities is discussed, which are being carried out to develop a computational architecture over fog. It can be noted that fog-based systems are mainly inspired by the applications that drive a framework development based on their specific needs. Accordingly, two different architectural models were observed which have been evolved over time. These involve – (a) service-oriented architecture, where the computing infrastructure is optimized based on the modularity of the end-to-end services, and (b) different application specific architectures as evolved from various IoT based Platforms and their computation needs in Figure 8 [25].

State of art of fog roles in 5G network slicing

A summary of related works that investigated the integration of fog computing with the Network slicing in 5G networks is illustrated in Table 1.

Citation: Asrar AB, Malek NA, Sharaf AA (2018) Fog Computing for Network Slicing in 5G Networks: An Overview. J Telecommun Syst Manage 7: 172. doi: 10.4172/2167-0919.1000172

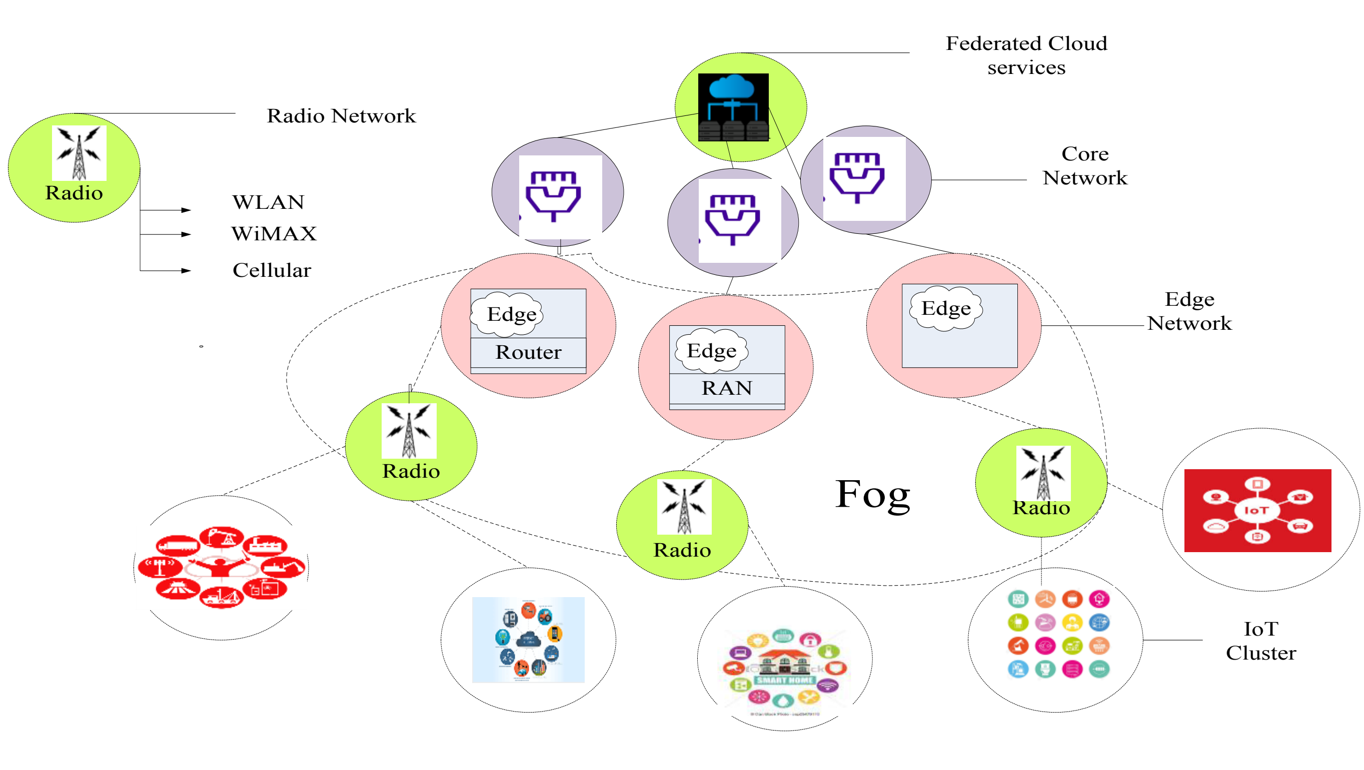

Figure 7: Fog architectural paradigm.

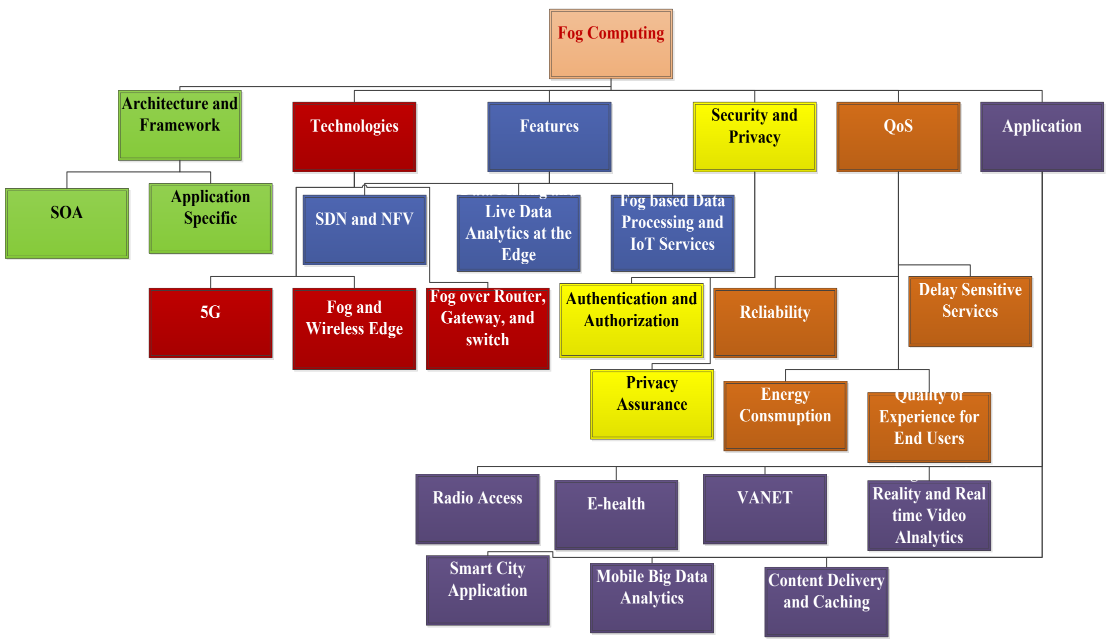

Figure 8: A taxonomy of the research activities over the fog computing.

Challenges and Research Directions

In this section, the identification of the main challenges and future research are illustrating from implementing fog computing for network slicing in 5G systems.

Network slice differentiation

The design Network Slices to fulfill requirements of the key 5G use cases, including eMBB, V2X, mIoT, URLLC. When discussing Network Slice differentiation, it is essential not to make the trivial mistake of

Reference	year	Slice type	Summary of the contribution of fog computing
[29]	2016	mMTC (IoT)	Presents a Fog computing interface (FIT) for processing clinical speech records. In shape builds upon EchoWear, a wearable technology that validated the use of smart watches for amassing medical speech data from patients with Parkinson's sickness (PD). The fog interface is a low-power embedded system that acts as a smart interface between the smartwatch and the cloud. It collects, stores, and processes the speech information earlier than sending speech to cloud storage.
[30]	2015	eMBB	Imparts the device architecture and key strategies of F-RANs. specifically, key strategies and their corresponding solutions, which include transmission mode selection and interference suppression.
[31]	2016	uRLLC	Presents a quantitative analysis of the capacities of vehicular fog computing (VFC). Authors unveil an interesting relationship among the communication capability, connectivity, and mobility of vehicles, and also find out the characteristics about the pattern of parking behavior, which benefits from the understanding of utilizing the vehicular resources.
[32]	2015	mMTC(IoT)	Authors compared Fog Computing, Mobile Edge Computing, and Cloudlets, and illustrate what all three approaches are benefiting for. After observing that, they mentioned three approaches to distributed cloud computing for the Internet of Things and Tactile Internet have emerged relatively independent of each other, they stress that there is room for synergy.
[33]	2016	All	Analyze the resource management problem in the multi-FN (fog node) multi-MDCO (multi-data center operator), and multi-DSS (data center storage) networks. The FNs share computing resource with the MDCOs, and though the MDCOs are able to serve their DSSs with low latency. Based on the proposed model, authors introduce a hierarchical game, where the interaction between FNSs and MDCOs is regarded as a multi-leader multi-follower Stackelberg game, and the interactions between MDCOs and DSSs are regarded as the single-leader single-follower Stackelberg games. By making decisions distributively, all FNs, MDCOs, and DSSs receive high utilities.
[34]	2018	mMTC(Sensors and Actuators)	proposes a fog computing framework enabling autonomous management and orchestration functionalities in 5G-enabled smart cities. The principle follows the guidelines of the European Telecommunications Standards Institute (ETSI) NFV MANO architecture expanding it with more software components. The contribution of the work is totally-integrated fog node management system beside the foreseen application layer Peer-to-Peer (P2P) fog protocol based on the Open Shortest Path First (OSPF) routing protocol for the exchange of application service provisioning information between fog nodes.
[35]	2017	All	Discusses two proposed coding concepts, namely Minimum Bandwidth Codes, and Minimum Latency Codes, and illustrate their effects in Fog computing. Authors also review a unified coding framework that includes the above two coding techniques as special cases and enable a tradeoff between computation latency and communication load to optimize system performance.
[36]	2018	IoT	Presents the state-of-the-art of fog computing and its integration with the IoT by highlighting the benefits and implementation challenges. The review also focuses on the architecture of the fog and IoT applications that will be improved by using the fog framework.
[37]	2017	IoT	Runs analytics guideline experiments over fogs formed by Raspberry Pi computers with an extended computing engine to measure computing performance of different analytics tasks, and create easy-to-use workload models. QoS aware admission control, offloading and resource allocation schemes are configured to guide data analytics services and maximize analytics service utilities. Availability and cost models of networking and computing resources are taken into account in QoS scheme design
[38]	2017	All	Proposes two novel model objects for distributed data stores (DDSs) that are connected to Fog Computing: (1) Fog-aware replica placement, and (2) context-sensitive differential consistency. To realize those design goals on top of existing DDSs, Authors propose the FogStore system. FogStore manages the need of adaptations in replica placement and uniformity management transparently so that existing DDSs can be plugged into the system. To show the benefits of FogStore, they perform a set of evaluations using the Yahoo Cloud Serving Benchmark.
[39]	2017	eMBB	Proposes Single Connection Proxy (SCoP) system based on fog computing to merge multiple keep-alive connections into one, and push messages in an energy-saving way. The new design of SCoP can satisfy a predefined message delay constraint and minimize the smartphone energy consumption for both real-time and delay-tolerant apps. SCoP is transparent to both smartphones and push servers, which does not need any changes on today's push service framework. Theoretical analysis shows that, given the Poisson distribution of incoming messages.
[40]	2016	eMBB	A Fog server serving many users will probably have a longer computing delay than a Fog server with a lighter workload. To clarify the computing delay and communication delay in Fog architecture, authors define a mathematical model of a Fog network and the important related parameters.
[41]	2017	uRLLC	Authors discuss several key security and forensic challenges and potential solutions. resources of individual vehicles, the quality of services and applications can be enhanced greatly. In specific, by discussing four types of scenarios of moving and parked vehicles as the communication and computational infrastructures, they work on a quantitative analysis of the capacities of VFC. Authors unveil pleasant relationship among the communication capability, connectivity, and mobility of vehicles, and they also figure out the characteristics about the pattern of parking behavior, which benefits from the understanding of utilizing the vehicular resources.
[28]	2017	All	Proposes a reconfigurable and layered fog node architecture that analyzes the applications' characteristics to better meet the peak workload demands. Authors efficient the prospect applications of IFCIoT architecture, such as smart cities, intelligent transportation systems, localized weather maps and environmental monitoring, and real-time agricultural data analytics and control.

Table 1: Fog computing integration with network slice.

reducing the Network Slicing concept to something close to enhanced QoS support. Rather, different Network Slices will require customized procedures for Registration, Mobility Management, Location Tracking, Session Establishment, to fulfill specific requirements in terms of procedure latency (e.g. V2X), reliability (e.g. URLL) and scalability (e.g. mIoT). Additionally, different Session Management procedures will be designed for different slices, e.g. to support IP, Ethernet, and unstructured PDU sessions.

Related to slice selection, the issue of Slice Availability is also of primary importance: how shall the 5GS communicate to UEs the set of available Network Slices, considering all possible envisioned heterogeneous RAN deployment scenarios, combined with the mobility requirements 5GS shall support. Slice availability issue concerns both Initial Registration and Service Request. 5G RAN and 5GC are responsible to handle Service Requests also in cases where NSI may not be available in a given area. Solutions for slice availability handling may include mechanisms for slice availability information sharing amongst neighbor 5G RAN nodes, or may leverage on mobility restrictions to control and limit UE requests. Finally, a dedicated analysis will be required to address interstice mobility and optimization issues.

Performance issues in a shared infrastructure

At the point when arrange, slices are conveyed over a typical fundamental substrate, the satisfaction of execution isolation prerequisite isn't a simple assignment. In the event that tenant's Resource Orchestrator RO just allocates devoted resources to arrange slices, their required performance levels are dependably met at the cost of forestalling slices to share resources. This prompts over-provisioning, an undesired circumstance remembering that the tenant has a limited arrangement of relegated resources. One approach to determine this issue is to allow resource sharing, in spite of the fact that this implies slices are not yet totally decoupled as far as performance. In this way, it is required to plan sufficient resource management mechanisms that empower resource sharing among slices when fundamental without disregarding their required performance levels. To achieve the sharing issue, the RO could utilize approaches and systems like those utilized in VIMs, (for example, the OpenStack Congress module, or Enhanced Platform Awareness characteristics).

Management and orchestration issues

Given the dynamism and scalability that slicing brings, management and orchestration in multi-tenant situations are not clear. To adaptably dole slice resource on-the-fly to slices, the enhancement approach that oversees the RO must manage circumstances where resource requests differ significantly in generally short timescales. To achieve this:

- A proper collaboration between slice particular management practical blocks and RO is required.
- Policies should be caught in a way that they can be naturally approved. This mechanization empowers both the RO and slices particular useful blocks to be approved to perform the comparing management and setup activities in a convenient way.
- It is required to outline computationally proficient resource allocation algorithms and compromise systems at every abstraction layer.

Security and protection

The open interfaces that help the programmability of the system bring new potential assaults to softwarized systems. This requires a reliable multi-level security framework made out of policies and mechanisms for software integrity, remote attestation, dynamic threat detection and mitigation, user authentication and accounting management. The security and protection concerns emerging from 5G slicing are today a noteworthy hindrance to receiving multi-tenancy methodologies.

New business models

The innovative partnerships between several players, each giving services at various places of the value chain, and the combination of new tenants, for example, verticals, OTT services providers, and high-value enterprises engage promising business models. Given this business-situated approach, new change procedures must be extensively analyzed, taking into consideration a steady development to future 5G arranges and guaranteeing similarity with past infrastructure investments. To achieve this, a profound audit of the telecom regulatory framework has to be made. Innovative methods for estimating, the new reason for cost sharing and institutionalized arrangements, which give the expected help to interoperability in multi-venders and multi-innovation situations, must be considered also [9].

Network reconstruction

Since 5G networks give the wireless connection with everything, both the RAN and CN require recreation to help end-to-end network slicing. Particularly in thick heterogeneous systems, not exclusively should the collaboration of macro cells and small cells are intended to meet the redid slicing requests, yet in addition, the participation of numerous RATs ought to be considered to give seamless mobility and high transmission throughput.

Cooperation with other 5G technologies

In future 5G frameworks, network slicing needs to coincide and coordinate with conventional advances, for example, broadband transmission, mobile cloud engineering (MCE), SDN, and NFV developed from LTE/LTE-A systems. The virtualized cloud of access networks and CN have the upsides of physical resource pooling, conveyance of software architectures, and centralization of management. However, there is still no appropriate way to deal with incorporate network slicing with C-RAN, SDN, and NFV to give point-to-point association between physical radio equipment and radio hardware controller. Participation between slicing and other 5G technologies is important to empower more network slices in future 5G networks [7].

Programming models and architectures

Most stream-and data-processing structures, including Apache Storm and S4, don't give enough versatility and adaptability to fog and IoT situations in light of the fact that their design depends on static configurations. Fog environments require the capacity to include and expel resources progressively in light of the fact that handling nodes are for the most part cell phones that as often as possible join and leave networks [42].

Communications between Fog Servers

Each fog server deals with a pool of resources at various location. Communication and collaboration effort between fog servers are important to keep up benefit arrangement and substance conveyance between them. In the event that the communication efficiency is increased, the performance of the whole framework will be progressed. The information transmission between fog servers faces numerous difficulties that should be tended to. For example, there is a need for service policies where fog servers are sent to various areas with various elements to empower them to adjust to various strategies characterized by owners. What's more, the information transmission between fog servers needs to consider association highlights. in other word, fog servers should have the capacity to interface with each other utilizing either wired or remote association over the Internet [36,43].

Conclusion

Fog computing has the potential to fortify delay sensitive accommodation requests with low traffic congestion, low energy consumption and minimum bandwidth with an aim to reduce the encumbrance of cloud data centers. Fog computing, which is not a supersession for cloud computing, elongates the computation, communication, and storage facilities from cloud to edge of the networks. Albeit, fog computing is a viable solution towards sustainable development of network slicing markets, many unsolved issues still subsist. This article presents an overview of sundry architectures discussed and identifies the key research challenges. Since fog computing is presaged as a next computing paradigm, it can be applied to a wide range of network applications. This paper gave the literature on fog computing roles in various 5G network slices predicated on a detailed description of network slicing, covering three different application domains (i.e., IoT, eMBB, and uRLLC). The challenges and corresponding research directions and the purposes of fog computing with a concentration on the role it may play in emerging technologies are also discussed.

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