An Efficient and Effective Framework for Capability Enhancement of Wi-Fi Sharing Systems in Ubiquitous Computing Environment

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Abstract: Ubiquitous computing provides the most recent fifth generation mobile networking system with astonishing amount of mobile traffic, mobile users and the networks. The belief is that distribution of Wi-Fi service is a windfall in facilitating 5G Ultra Dense Networks (UDN). This is the most requisite for covering the network and wireless broadband connections completely. Further research activity has been started by the team to beat the boundaries of initial deployment of the Wi-Fi services. Accordingly FOg CloUd Slicing (FOCUS) has been considered as the fitting way for expanding the 5G UDN capacities. With the intend of providing multiple service and multi-tenancy for large service networks , Cloud Slicing which provides end to end networks has been applied on the top layer of Wi-Fi distribution. This satisfies all the requirements defined and makes a complete utilization of the software approach. A real prototype is deployed to evaluate the feasibility of FOCUS system and this allows fetching the accurate results of functional principles defined in FON Wi-Fi distribution system. The outcome of proof- of-concept from the system level can be obtained along with the FON system. The relative results show that FOCUS provides better and appropriate results than FON. FOCUS offer more benefits by providing end to end cloud slicing networks ensuring the deliverable services independently during the run time along with the resource adaptation.

Keywords: Ubiquitous, FOCUS, FON.

1. Introduction

Ubiquitous computing is a platform in which processing of information is linked with each activity or object as received. It involves connecting electronic devices, including embedding microprocessors to communicate information in 5G networks. Devices that use ubiquitous computing have constant availability and are completely connected. The development of various network paradigms such as Ad-hoc network based Mobile Ad-hoc Network, Vehicular Ad-hoc Network and Distributed network based Wireless Sensor Network (WSN), and resource sharing in Software Defined Networks (SDN) paves a stronger foundation to conceptualize a unique applications applicable in various field of civil and military activities. The collaborative challenges of such heterogeneous network with varied communication standards and computing mechanism pose unique challenges to realize the ubiquitous application. The scale, density and types of sensor build the space of ubiquitous computing with wireless sensor network.

An anticipated volume of information has been exchanged in the telecommunication networks with the rise of information and communication integration technologies which are using a wide-ranging spectrum of devices. This results in the larger growth of UDN that contains unforeseen number of connected devices. When the number of devices increases in the UDN, there is a necessity of smaller cells that has to be deployed to include the enormous amount of traffic. The development of UDN is just not restricted to the particular scenarios but its deployment takes over several requirements which range from low latency to higher broadband [1].

Requirements can be tackled in a various dynamic ways flexibly even though the performance growth of 5G networks is independent [2]. At run time, there are several traffic demands that rises with the cognition process. This can be solved by the core mechanism as software process [3] and this software process stands as an outstanding process that can resolve the various traffic demands in any typical network environment of ubiquitous computing.

The research has been conducted into various layers of WSN, which are to be considered as technological evolutions of the methodologies, to realize the success of wireless sensor network. At the same time to realize a smart ubiquitous smart applications lacks, an efficient framework to synchronize every component of ubiquitous application using WSN. The core component of the proposed framework is user centric context aware computing paradigm with gesture, its research approach could be both prototyping and modelling to realize its behaviors as a ubiquitous platform, collaborated with sensor network and evaluate its performance respectively.

Virtualization acts as supporter to the Software process which helps in arranging the cloud computing that results in the creation of Network Function Virtualization (NFV) [4] and Software Defined Network (SDN) [5]. In order to meet the targets in the application, 5G Networks are integrated with the Network Slicing [6] model which provides flexible services in meeting the requirements. Since Slicing can be portioned logically, each individual tenant can customize and share the common infrastructure service. Slicing can be implemented in two ways, Cloud Slicing (CS) and Radio Access Network (RAN). Cloud Slicing virtualizes the functions of the network by slicing the infrastructure. Time multiplexing and spectrum frequency is taken care by the RAN. To obtain the better and end to end results, both the methods have to be pooled.

Fog Computing [7] are the devices that processes the large amount of generated data. Additionally, 5G is likely to hold up several wireless networks. At the same time, it should also satisfies the different marketing requirements such as Internet of Things, e-commerce, e-health and also in the field of agriculture, food industry, automation industry. By pleasing all the mentioned scopes, it promise to deploy the UDN with advanced density for low cost [7].

2. Literature Survey

ITU-R report briefs that the necessities of vast data traffic and elevated data rates of 5G networks can be met by the Ultra Dense Network. 5G UDN also meets the requirement of coverage of networks broadly and enhances the capacity of cellular network. UDN faces challenges in the environment like public Wi-Fi connections because of more users than expectation up to 25% hike in the Wi-Fi service users, thus creating a high traffic density. The solution to this crisis is increasing the number of small cells more widely which ensures the required throughput. To re-use the spectrum, low power cells have been deployed on the top layer of the macro cells. In addition to this, one can dense the low power cells and offload the network data in the indoors Wi-Fi services, where 80% of the traffic occur. Wi-Fi can be shared only when the users allow the Wi-Fi broadband to be accessed by external devices [8].

FON is leading in the deployment of Wi-Fi services by making the connections global. FON provides 21 million hotspots by integrating residential and public Wi-Fi connections. Fonero, which is FON enabled CPE allows the users to connect to their nearest FON hotspot by running a particular node in the Operating System. Two virtual networks will be accommodated within one Wi-Fi spectrum with the help of slicing concept triggered by the Fonero. Two Virtual Access Points (VAP) are created and SSID is provided, one VAP is made as the ‘public access’ and the other as the ‘private access’, which can be accessed only when it is connected to the owner’s network. There are some critical issues associated with 5G UDN,

- All the incoming traffics have to be subjected to eco-system service network irrespective of the different slicing of Wi-Fi. Therefore 5G imposes Fonero to meet different requirements at the same time.
- Fonero assumes that it can provide a solution to the local level CPE, for this to happen there is a need to differentiate the network layers separately which in practical requires the help of experts advanced in the field of networks.
- Fonero can provide facilities only to the minimum level of isolated networks. It fails in the customization of traffic handling when the traffic is arriving from public and private wireless nodes towards the cloud. It cannot handle the traffic coming from concurrent nodes.

Further research has been carried out due to encountering the limitations of FON. NFV can be applied in critical areas which contain a set of use cases defined by ETSI groups [9]. Inherited advantages of CPE reduce the complication in the networks. Decoupling of local platform networks and network functions provides a better flexibility and also allows integrating newer networks. Research carries the process of integrating Wi-Fi into the 5G networks to build the UDNs strongly. It expends the capacity of CPE along with satisfying the demands of the future requirements like Internet of Things. Some key factors has to be considered to expand the CPE,

- According to the tenants demand, multiple services have to be given by supporting the multiple tenancies.
- Resources of CPE have to be shared with the tenants to meet their requirements.
- During the run time, services have to be simplified and devices have to be mana-ged by programming approach.
- Requirements Consistent service can be given by virtualization of network functions which enhances the above key features.

Infrastructure of the cloud data center will be offloaded which makes several approaches [10] to bump into certain constraints as the application is restricted to fixed set of layers. None of the discussed approaches have a solution to overcome the drawbacks of 5G UDN, the next section discusses distinctive methods of 5G wireless and mobile network communications.

3. FOg CloUd Slicing (FOCUS)

End to end service will be provided from FOCUS by creating and managing the cloud slicing. This service is provided from Wi-Fi slicing to the cloud system. Isolation can be achieved by partitioning the network resources and computing which defines the network cloud and applications can be executed along with the network functions as virtualized structure. Connections of the wireless network are promoted at urban center with the available Wi-Fi networks at one end of the Network Slicing. To provide better service at the end nodes, FOCUS manages the widely distributed WLAN by configuring CPE. To meet the 5G UDN requirements in the future, Cloud computing and software process have been combined together with the slicing technology. Resources are allocated before running the application services and network functions since slicing have been deployed as sovereign virtual elements. Multiple virtual services are offered by FOCUS to overcome the current challenges of 5G UDN. This provides isolation between the Wi-Fi slices and cloud slices. By deploying physical components, FOCUS provides end to end service hence improving efficiency in running the virtual machines by supporting network functions and the services run by several application. Solutions can be given to share the Wi-Fi in home environment as well as Small Office Home Office (SOHO) environment by lowering the cost of WLAN CPE. Network functions which access the internet such as firewall, Wi-Fi, NAT is traditionally supported by CPE.

Virtualization is affected negatively since large amount of resources are consumed. Virtual CPE concept can be introduced to avoid the negative impact by offloading the data in the cloud which is in turn applied to the respective network functions. CPEs are trustable since it helps in reducing the CAPEX or OPEX and it will not restrict to work with the specific hardware dependencies. It also removes the timing constraints which provide more flexibility for the service. Even though timing constraints have been removed, there are many delays in reaching targeted VNF in cloud which is an essential criteria to achieve the 5G use cases. To overcome these drawbacks, computational capabilities are expanded by FOCUS which shares WLAN CPEs. This is achieved by implementing the FOG computing which provides support to the cloud slicing thus creating direct link with Internet enabled devices. To conduct the fully fledged operations in the cloud life cycle, software design have been adopted by FOCUS. Remote platforms are provided when operations have to take place flexibly in the cloud. When the slice creation is taking place in the network cloud, resources has to be allocated by considering the appropriate requirements. Resource allocation is done by the FOCUS at all the instances and rest of the operations is controlled during the run time of the services. FOCUS is dependent on the APIs of SDN northbound and SDN southbound to configure the network resources dynamically and FOCUS is dependent for the entire life cycle of Cloud Slicing. Allocation of cloud resources at Fog and cloud infrastructure implies the computing resources in the eco system. Improvising UDN technology results in a great value for Wi-Fi services. This can be achieved by providing the Wi-Fi services at various environments. The FOCUS's network cloud can enhance these features with expected results.

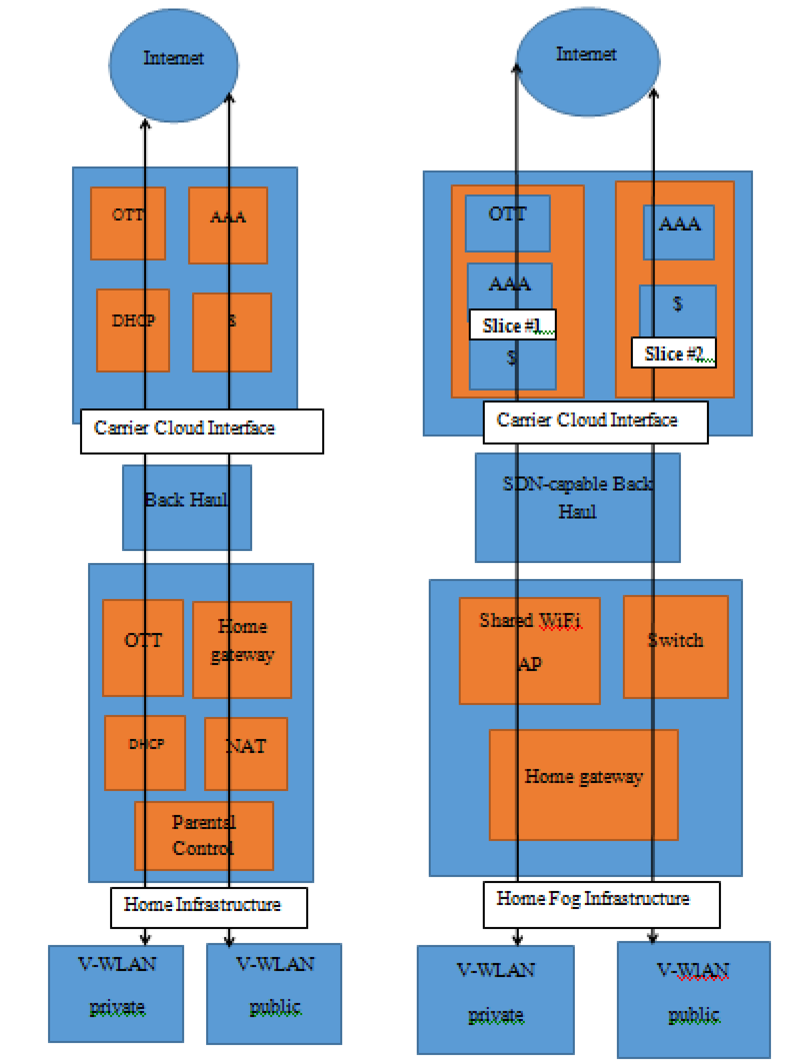

Figure 1: Typical and FOCUS approaches for Wi-Fi sharing

There is a necessity of only few components like virtualized substrates, few network services and software components. Figure 1 represents how FOCUS removes the other components which are not essential and thus makes the architecture very simple. To obtain outstanding results all the network functions has to be offloaded in the cloud infrastructure. When the network functions are offloaded, computing activities will also be reduced and hence excellent performance will be obtained. The benefits of FOCUS are demonstrated in figure 1 by grouping only specific network resources. The grouping is done at the Fog infrastructure as well as the cloud infrastructure. Multiple systems can be executed along with its respective services on the FOCUS platform. Complete wireless connection is provided between the WLAN and the Internet. Slicing is done at the carrier cloud infrastructure as shown in figure 1b. Within the slicing, all the networks and components are isolated and are executed independently whenever needed by the tenants. Bidirectional communication flow have been given in both classical approach and in FOCUS approach but the difference between the two is that Slicing is done only in the FOCUS cloud networks but not in the classical approach.

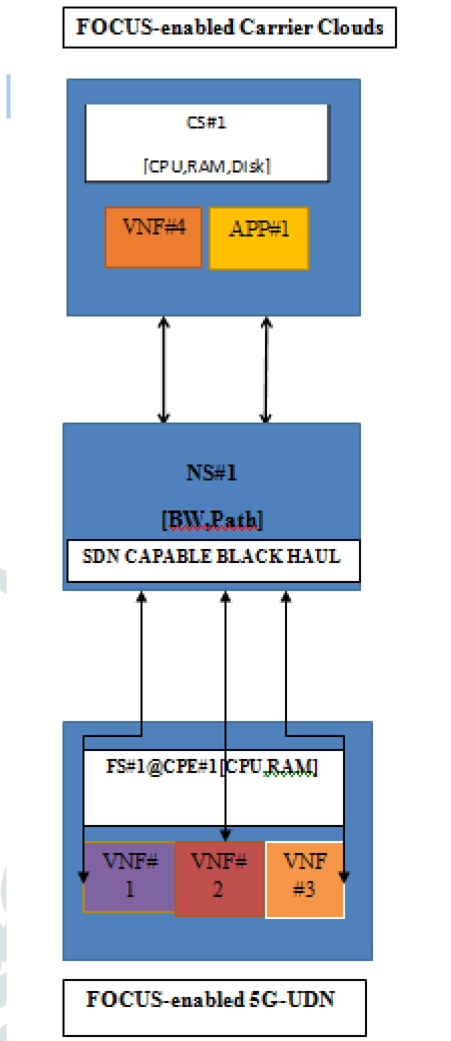

Figure 2: A typical FOCUS cloud architecture for Ubiquitous Environment

Encountering to the Fog Slice FS#1 in the figure 2, containerized VSNs are included which have been represented in the three separate blocks to differentiate between them and to avoid the clashes during the service run time. Each of the VNF is named as VNF #1, VNF #2 and VNF #3 whereas every individual VNF is configured to the CPU and RAM independently. Virtual Network Interfaces (VNI) are created separately for all the three VNF and the connection of each VNI is given to all the three VNF respectively. To transfer the packets that belongs to the Fog Slice 1 (FS #1), another VNI is created and used in transferring process. All the packets which are linked to NS #1 has to be moved using the forward rule and Virtual Switching Process is run by FOCUS to apply the forward rule to the packets. The sequence followed in forwarding is V-WLAN@CPE#1--> VNF #1--> VNF #2--> VNF #3--> NS #1**.** Cloud Slice #1 is initialized at the focus enabled carrier cloud infrastructure and it is attached to the CPU, RAM and Disk. And the other two components VNF #4 and APP (application service) are placed. Assuming that there is a direct physical link between the Fog node and the Cloud node, end to end networking function is activated between the two nodes by FOCUS with the help of forwarding rule.

One of the essential blocks of the FOCUS architecture is Cloud Slice Control Plane (CSCP) which is found inside the network component of the cloud infrastructure. They contains two functional blocks which can interoperate with each other and group the necessary elements of network cloud slice in Cloud tier and Wi-Fi tier. Another important component is the Slice Descriptor which resides in the Network Cloud Control Plane (NCCP) which plays an important role in receiving the requests from the tenants through an external interface. The request from the tenant for a slice creation must include a description that contains the information of the slice framework which needs to obey the template of TOSCA. This framework is considered as the mandatory information which has to be mentioned in every request and optional information can be added if required. And also the information with respect to the requirements of infrastructure, geographical location is compulsory. Network cloud includes computational capabilities such as CPU, memory and other storages along with the networking capabilities. Network tolerance and VM related flavor is stored in infrastructure requirements [11]. The position of the Fog node which roots to the target cloud slice is indicated by geographical location. Geographical area or the geospatial location can be specified by a tenant based on the available WLAN coverage. Fog slice which matches the geospatial location is instantiated by FOCUS in the former method but in the later method the Fog nodes which are available within the range of geographical area are selected by FOCUS. Optional information can also be allowed when a tenant wants to make a sudden decision of adding a scope for the general component like a web server.

For better running services, resources are much needed by the network cloud slice. The knowledge about the different levels in the network and cloud which is present in the entire ecosystem of FOCUS is available from the Resource Manager which is a functional block in the FOCUS architecture. Passive and Reactive are the two operational modes that are available at the cloud level.

In passive mode, resource manager waits for fog slice feedback and fog node announcements. All the QoS conditions are documented in the fog feedback whereas announcements are processed during the run time. In reactive mode, when the request is received from the slice, Resource Manager reacts to it based on the services provided by functional blocks and the availability of resources. Here the response is not given until Resource Manager receives a request, hence the name Reactive mode. Slice local subsystem supports the response of the Resource Manager in both the operational modes which registers the entire knowledge of end to end network. Network control enabling tool contains the network map which includes the details of entire infrastructure from nodes to capacities.

Fog, cloud, and network environments are combined together in ubiquitous computing to form an end to end cloud slice network. This is processed by slice and service orchestrator which plays a vital role in FOCUS architecture. Slice descriptor contribute for the successful processing. Descriptor provides few specifications required by the orchestrator,

- Selection of the artifacts for the service.
- Identification of tier for cloud slices deployment.
- Instantiating VIM for the respective cloud slices.
- Enforcing the cloud slices that connect with the cloud parts.

Artifact is a software component which runs in the form of service application in the cloud slice.

Another module of the FOCUS architecture is the Cloud VIM and Fog VIM which set up end to end cloud network slice by managing the computational process and storage.

Cloud VIM and Fog VIM are technical tools that convert the generic calls into particular VIM implementation. As a part of slice definition, tenants are free to choose any particular VIM implementation. The selected implementation method will be derived during the end to end set up task of network cloud slicing. These details are kept in the slice table of functional blocks maintained by Resource Manager.

Next module in the FOCUS architecture is Service Monitor. This maintains the record of up to date performance results of cloud slice and mention them in the slice table discussed in the previous topic. Resources of cloud slice, slice topology and KPIs running in the service application are monitored by Service Monitor. This holds the knowledge that is necessity to run the cloud slice life cycle.

Fog node control plane is another module in the FOCUS architecture. It controls the Fog slice life cycle. This aims in providing wireless connectivity by enhancing the 5G UDN capabilities. It responds to all the operations that take place in the different levels of the fog node by residing in each fog node. The subsystems that are present here are examined in the subsection of next level. As the control plane controls slice life cycle, it makes fog node to respond to the requests coming from network cloud slice. It collaborates with the third party tool to seek the resources provided at fog node. To run the service application of the container during its installation process and execution, respective enabler tool is used. Virtual switch enabler tool is used to forward the packets that are coming from Wi-Fi service to virtual service. It also allows VNI to transmit and receive the packets and also helps in connecting slice at Fog and Cloud carrier node.

4. Workflow of FOCUS

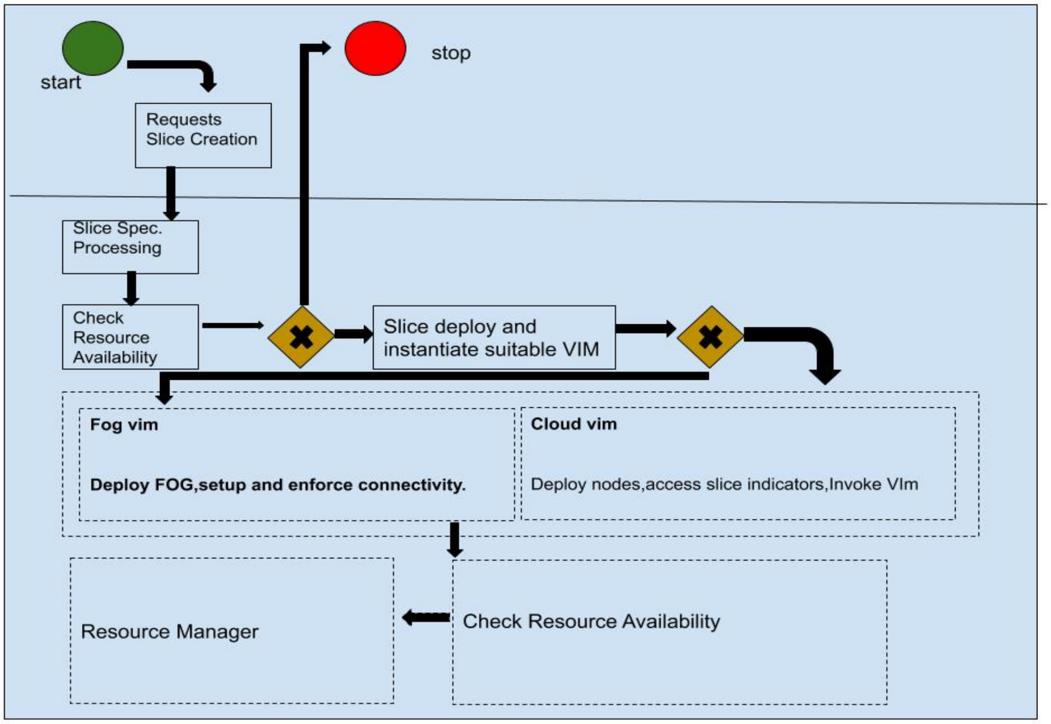

Figure 3: Slice Creation Workflow

The lifecycle workflow involves the tasks like operator creation, configuration, activation, updating and tear down to get associated with its dynamic features. In order to carry the main tasks like network cloud operations such as creation and tear down, Business Process Model and Notation (BPMN) method has to be employed. The documentation is maintained in a simpler way to avoid the confusions and to provide an easy way of understanding. Figure 3 represents the workflow of a slice creation. It also illustrates the new activities that take place between the modules for the creation of new slices. At the service provider, tenant makes a request for the creation of a new slice. Once the request is received, Slice Descriptor analyzes the request with respect to the obtained information and sends this request to service orchestrator to check for the availability of the resources in the cloud. When the requested number of resources is not available, Service orchestrator exits from the slice and sends the feedback to the tenant regarding the resource scarcity. With the help of Fog and cloud VIM, appropriate VIM will be selected by the orchestrator. Later functionalities will be invoked to deploy the fog nodes and cloud nodes. Fog VIM and Fog lifecycle interacts with each other to provide the required network configurations which are essential for the creation of a new slice. Once the network paths are delivered to the new slice, process will be completed and new slice is created.

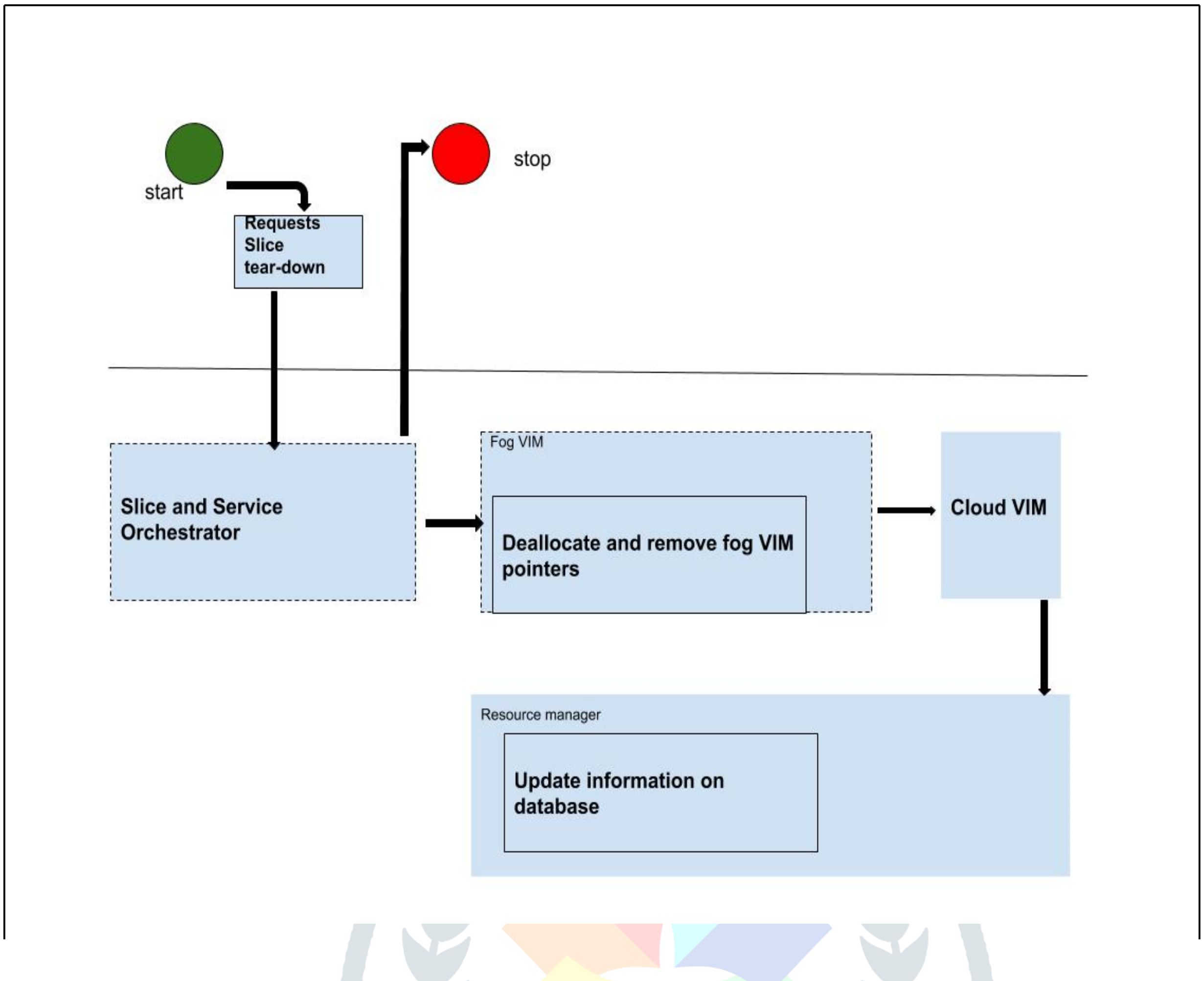

Figure 4: Slice Tear Down Workflow

Figure 4 represents the slice tear down process in detail. The process can be carried out in two ways, either by the request made by a tenant or by understanding that end to end network slice is not necessary for further processing. In the second case, orchestrator removes all the physical resources to carry out tear down task and collects all the information regarding the slice. The tear down request is forwarded to Fog and cloud VIM to de-allocate the allocated resources. Tenant will be notified after the successful tear down of the slice.

5. Results and Discussions

Test bed deployment is done in the UP lab at UFRN, Brazil to show the feasibility of the FOCUS. It ensures that basic principles are met by interacting with functional architecture. System level analysis has been carried out to demonstrate the functional requirements addressed by FOCUS. The test bed deployed is shown in figure 5.

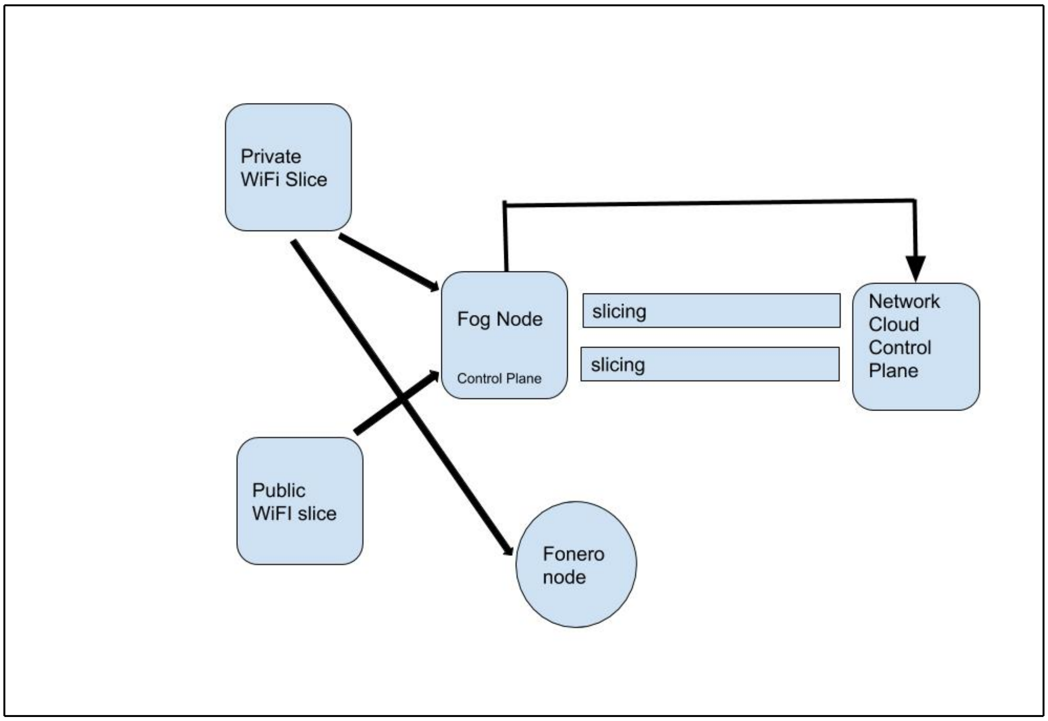

Figure 5: Test-bed Configurations

Test-bed is employed with enabling technology to represent the usage of resources for end o end network. Docker maintains the container management in fog node. Two forwarding queues are relied upon Fonero to handle the wireless packets. 20 mbps is set for the link that connects the Wi-Fi tier and cloud infrastructure tier. Two laptop clients involved in the testing for the traffic generation, one was attached to the private and other to public Wi-Fi slice. 6.8 mbps was offered by private slice whereas public slice offered only 1.4 mbps.

This work demonstrates the parameters utilized for test bed pilot. Different resource demanding was introduced to show the dynamic behavior of Wi-Fi sharing slices. At the end of the entire test, FOCUS was able to deploy independent network cloud slice at the top of shared system.

6. Conclusion

The study shows that 5G UDN techniques can be enhanced with the use of Wi-Fi sharing in a efficient manner. Network cloud slice helps FOCUS achieving this goal by covering the distance between Wi-Fi sharing slice and cloud system. The resources of Wi-Fi network can be shared efficiently by FOCUS with the co-existence of multiple slices. FOCUS supports high flexibility and end to end isolation during the runtime. It addresses the 5G UDN functional requirements and outstands the FON in its performance. Software process has contributed for the customization of multiple services. Implementation of the slicing method also enables the 5G UDN to work with high intensity in end to end network. Deployment of proper slices in the right time with respect to the suitable VIM enhances the features. Selecting the appropriate artifacts required for the process and its identification methods for deployment of cloud slice plays a vital role and proved that end to end service is achieved successfully by 5G UDNs. It ensures cloud slices are connected with the respective cloud slice parts which results in accurate functional networking.

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