The Development of 5G Policy Control Function

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Abstract

The world of telecommunication nowadays has seen numerous improvements in line with improved performance since the First Generation (1G) to the Fifth Generation (5G). From the analogue system, to where we are today, the Internet of Things (IoT) era. The new 5G policy control function (PCF) combines the legacy online charging function and offline charging function into one converged charging system. Without PCF, network operators could not have transparency and control over the data consumption during real-time service delivery. Operators also unable to manage the network slicing for each subscribers group according to their selected plan and could not make a profit from it. Therefore, the policy is a critical provider of network control and differentiation. This project aims to develop a new PCF that will support the new 5G charging control system and Quality of Service (QoS) policy. Three main objectives of this project are to study and analyze the 5G network architecture and policy charging framework for the 5G system, to design and implement the PCF to meet the demand for 5G technologies and to test the PCF. This project applies Scrumban methodology since there are always changes in the use cases and it involves global software development (GSD). The result from the smoke test at the end of this project proves that the PCF is working. Now, network operators can control and manage network resources by implementing the new PCF to replace the existing 4G policy and charging rules function (PCRF).

Keywords: *Service-Based Architecture, 5G, Network Function, Policy Control Function, Wireless Communication*

1. Introduction

The evolution of the wireless industry has demonstrated a spectacular growth ever since Guglielmo Marconi, an Italian inventor, introduced his work on long-distance radio transmission by transmitting the letter 'S' in the form of three-dot Morse code along the distance of 3 kilometre using electromagnetic waves [1]. For the last two decades, the wireless network has evolved in a very short time frame. Since the First Generation (1G) technologies were deployed in the 1980s, the world has seen new generations of wireless network technologies rapidly evolved, from 1G to the Fourth Generation Long Term Evolution-Advanced (4G LTE-A) [2]. The key driving forces to the rapid growth of wireless technologies have been the need for higher bandwidth and lower latency. Skyrocketing

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numbers in mobile cellular subscribers throughout the world showed that wireless technologies are robust, viable voice and data transport means [3].

This success gave rise to the evolution of newer generations of wireless technologies. Despite being still under development, 5G network is predicted to provide an enhancement to the mobile networks data throughput, latency, its extensibility, connectivity and energy-saving network [4, 5]. 50 billion devices are expected to be connected to the global Internet Protocol (IP) network in which would appear to present a challenge will grow by well over a factor of 100, from under 3 Exabyte in 2010 to over 190 Exabyte by 2018 and is going to exceed 500 Exabyte by 2020 [6].

2. Literature Review

2.1. The Evolution of Wireless Technology

The application demands and business models projected for 2020 and beyond are the major contributing factor that drives the wireless communication to evolve from the Fourth Generation (4G) towards the Fifth Generation (5G). Recently, the automation and communication industries have a keen interest in adopting wireless technologies for factory applications [7]. A new mobile cellular generation emerges every ten years approximately. Up to this day, cellular networks have been evolved into four generations. The First Generation (1G) technologies based on the analogue signal was introduced in the 1980s and then followed by the Second Generation (2G) that implements digital technology of Global System for Mobile communication (GSM) in the 1990s.

The Third Generation (3G) technologies allow the users to have a faster mobile Internet experience was deployed in 2001 and 4G Long-Term Evolution (4G LTE) was brought into action in 2008 [8]. After 3G technologies have been improvised, the 4G architecture can support a maximum data of 1 Gigabit per second (Gbps) for local wireless access and 100 Megabits per second (Mbps) for mobile access [9]. Throughout the years, the cellular networks have been developed in a way to bridge the gap between the preceding 1G, 2G, 3G and 4G and then expecting for 5G wireless technologies [10].

2.2. 5G Service-Based Architecture

According to 3rd Generation Partnership Project (3GPP) in the Technical Specification 23.501 (TS 23.501), there are two types of 5G Core (5GC) architecture: (i) the service-based and (ii) point-to-point based [11]. Nowadays, the service-based model is the best approach to adapt to the implementation of cloud services and the need for service agility. The service-based architecture (SBA) looks better for the operators to view the 5G functionality as well as enhancing the modularity of the product [12]. This has enhanced the flexibility to develop new services as the addition of new components becomes possible without the need for new interfaces [13]. Figure 1 shows the new architecture for the non-roaming as specified in 3GPP TS 23.501.

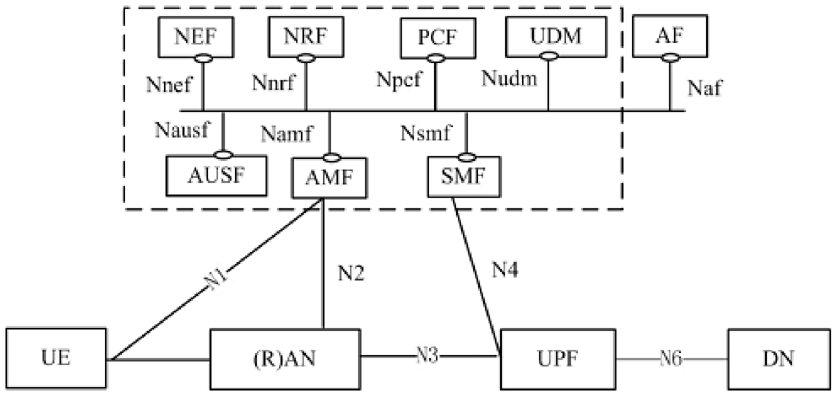

Figure 1. Service-Based Architecture [13, 14]

Based on Figure 1, the control-plane function is shown in the dotted line and is connected to other network functions via the service-based interface (SBI). The Access Management Function (AMF) and the Session Management Function (SMF) connects to the user plane nodes via the N1, N2 and N4 to handle new subscriber, managing the sessions and mobility [13]. N2 and N3 interfaces will be determined by how the 5G network attaches to the core and it is dependent on the 5G radio access network (RAN) architecture.

2.3. 5G Policy Control Function

The policy control function (PCF) is at the heart of 5G services. This Network Function (NF) provides a policy framework to govern the behavior of network and includes Quality of Service (QoS) determination parameters according to the services provided by the network slices [15]. It performs the same function as the policy and charging rules function (PCRF) in the 4G networks but even more critical role such as the following:

(i) Handles more device types and density of device populations connecting to the network spontaneously.

(ii) Defines and enables network slicing for different segments and devices; some might require high bandwidth and others need lower bandwidth with ultra-reliability.

(iii) More sophisticated devices require more sophisticated, device-level control whereby a single device can attach at the same time to multiple slices and network types (3G/4G/5G) depending on the network resources availability and service requirements.

(iv) Serves as a key enabler of service continuity in a hybrid (non-standalone) 3G/4G/5G networks.

(v) Backward compatibility – ensure the 4G service control in an evolved 5G environment. This also ensures the readiness of 5G in an evolved 4G toolset.

(vi) There will be no high risk waterfall platform upgrades. Instead, cloud-based, microservices architecture evolves to provide simple updates with no downtime.

(vii) Openness and web-style, using RESTful API to expand the use case opportunities with 3rd parties and ensures the policy can easily communicate to other evolving 5G functions especially charging.

(viii) Enables self-service with the use of intuitive graphical user interface (GUI) and service blueprints to dramatically reduce the service setup costs and operating expense.

(ix) Greater ability to easily define and test services in hours instead of weeks or months and scale automatically.

The role of policy is to be said as similar to an air-traffic controller in a busy airport. Different device segments connecting to different network slices create service options mesh and control requirements. Networks need to smoothly evolve to 5G while its 3G/4G assets work seamlessly with the new 5G assets. Importantly, all of these need to be smoothly monetized.

2.4. Policy Control Function Architecture

5G PCF architecture is outlined in Figure 2.

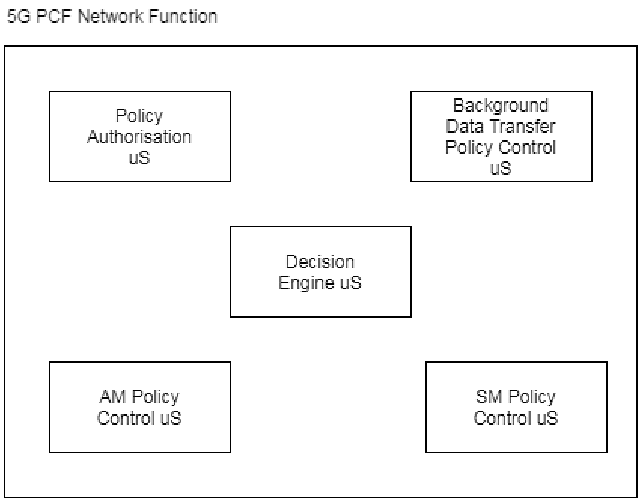

Figure 2. 5G PCF Architecture

The above architecture consists of five microservices:

(i) Policy Authorisation microservice: implements the Npcf_PolicyAuthorisation service-based interface from 3GPP TS 29.514.

(ii) Background Data Transfer Policy Control microservice: implements the Npcf_BDTPolicyControl service-based interface from 3GPP TS 29.554.

(iii) Decision Engine microservice: implements an API that makes policy decision in a centralized but scalable fashion.

(iv) Access and Mobility (AM) Policy Control microservice: implements the Npcf_AMPolicyControl service-based interface from 3GPP TS 29.507.

(v) Session Management (SM) Policy Control microservice: implements the Npcf_SMPolicyControl service-based interface from 3GPP TS 29.512.

The following network function (NF) service clients are needed for PCF:

(i) Nudr_UnifiedDataManagement: the PCF needs to manage the policies in the Unified Data Repository (UDR). The relevant SBI is defined in 3GPP TS 29.504, TS 29.505 and TS 29.519.

(ii) Nbsf_Management: the PCF needs to manage session binding information in the Binding Support Function (BSF). The relevant SBI is defined in 3GPP TS 29.521.

(iii) Nchf_SpendingLimitControl: the PCF needs to query the spending limit control with the Charging Function (CHF). The relevant SBI is defined in 3GPP TS 32.290 and TS 32.291.

(iv) Nnwdaf_EventSubscription and Nnwdaf_AnalyticsInfo: the PCF may use the Network Data Analytics Function (NDAF) to query or subscribe to the load on Network Slice Instance (NSI). The relevant SBI is defined in 3GPP TS 29.520.

(v) Nnrf_NFManagement and Nnrf_NFDiscovery: the PCF may use the Network Repository Function (NRF) to manage (register, de-register and update) its NF service instance and to discover other NF instances or NF service instances it interacts with. The relevant SBI is defined in 3GPP TS 29.510.

3. Methodology

3.1. Software Development Methodology for 5G Policy Control Function

Global software development (GSD) is applied to this project. Therefore, Scrumban model is the most suitable methodologies to be used for the 5G SBA PCF to minimize the coordination and communication issue. As the team is located at various locations around the world, the distributed software development (DSD) is applied through multi-geographic and multicultural environments. The commonly encountered issue in the development process is the oldest buzzword in any business, teamwork. The team communicated via collaboration tools like Skype to talk and discuss the project requirements, progress, blocker and set a new schedule.

Lack of effective communication mechanisms results in communication issues within the team. In such cases, a communication mechanism plays a significant role in planning the project stages collaboratively, despite the cultural and time differences. By implementing Scrumban in this project, both formal and informal communication is required so that all team members have the same level of understanding regarding the project. Daily standup meeting was being carried out regularly throughout the project and it takes about 15-20 minutes every day to improve the work process. Also, Scrumban is a suitable method for this project as there are frequent changes to user stories and priorities. Moreover, since the 5G system is still new, there are a lot of new features to be added in the future and at the same time, the existing 4G PCRF need to be supported as well. Table 1 shows how the result of implementing Scrumban in coordinating DSD environments.

Table 1. Scrumban Effect in DSD Environments [16]

Scrumban features	Distributed Software Development (DSD) Challenges					
	Strategic	Project management	Communication	Cultural	Technical	Security
Iterative and incremental development	Highly improved	Highly improved	More sprints, smoother	More iterations, few challenges	Slightly improved	-
Predictable and well-planned project	No effect on leveraging resources	More iterations and improvement	Effective for the planned tasks	-	Slightly increased	-
Explicitness	Positively impacted on leveraging resources	Positively impacted task management	-	Slightly reduced challenges	-	-
Systematic feedback	Slightly increased	Positively impacted task management	Demands of both formal and informal feedback	Improved	-	-
Work in progress limit	Positively impacted resource management	Decreased challenges slightly	No evidence	-	-	-
Self-organising	Slightly increased	Positively impacted task management	Improved informal communication	-	-	-

4. Discussion

4.1. PCF Use Case

Table 2 shows the some of the 5G use cases:

Table 2. List of 5G PCF Use Cases

Network Function	Area	Feature ID	Features Name	Description
PCF	Access and Mobility Management Policies	PCF-AMP0001	Access Network Discovery and Selection Policies	WLAN Selection Policies and Access Network Nodes A subset of the Non-3GPP (Wi-Fi in Rel. 15) Access Network
PCF	Access and Mobility Management Policies	PCF-AMP0002	Service Area Restriction Policies	**Service Area Restrictions (Tracking Areas)** – This allows the operator to control the policies that applies when we are in a specific locations **Geo-Fencing** (Market restrictions) through Service Area Restrictions (if enabled)
PCF	Access and Mobility Management Policies	PCF-AMP0003	Radio Access Technology (RAT)/Frequency Selection Priority Index	**Policies for RAT/Frequency Selection Priority** Spectrum & frequency prioritization – If a device is in a location, operators may want specific priority order to which radio frequencies they always connect to, or prefer to connect to due to their operating parameters.
PCF	Access and Mobility Management Policies	PCF-AMP0004	User Equipment (UE) Route Selection Policies	**UE Route Selection Policies** - Non-Seamless Wi-Fi Offload, Access Type Preference, Network Slice Selection When a UE registers

				on the network, the PCF will push UE Route Selection Policies (URSP) which are specific to subscriber type.

4.2. PCF Functional Architecture

The functional architecture of the PCF is as shown in Figure 3. The PCF microservice architecture will be described in the following subsection.

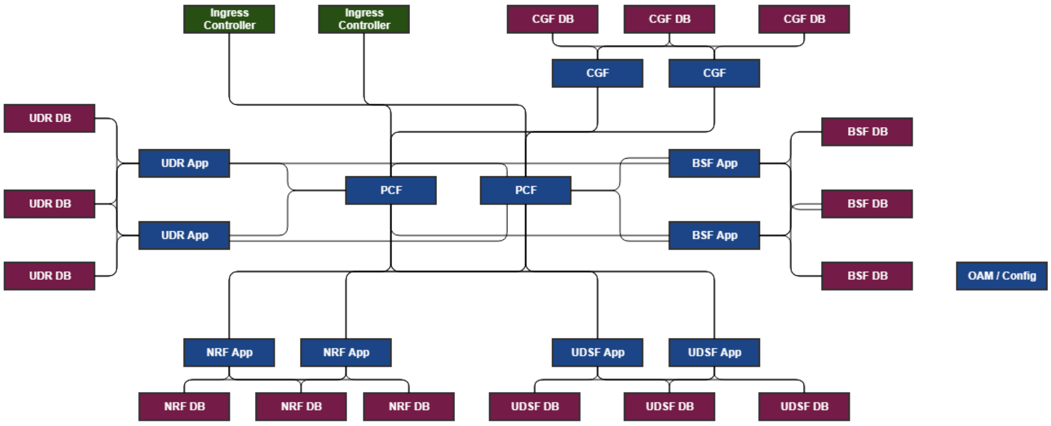

Figure 3. PCF Functional Architecture

4.3. PCF Microservice Architecture

The microservice architecture is as shown in Figure 4.

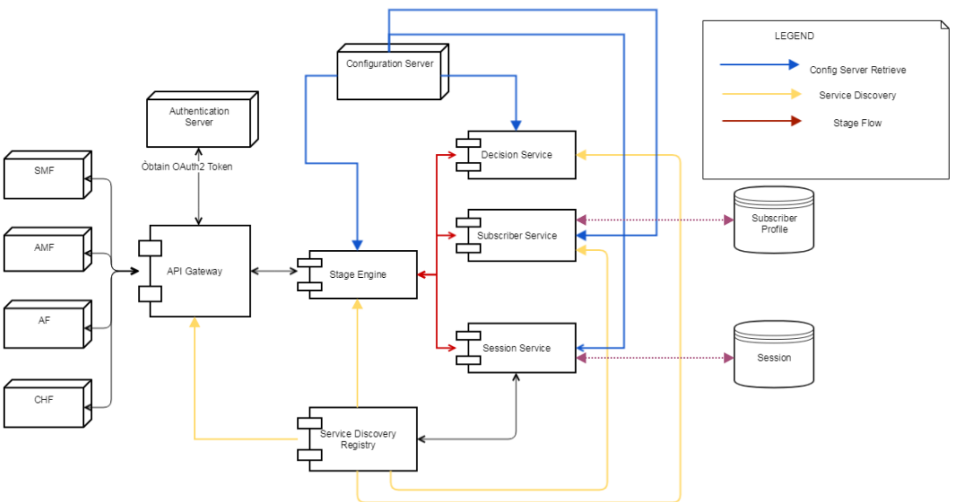

Figure 4. PCF Microservice Architecture

These microservices grouped several independent and modular services into a single application to serve the client with the requested data or action as shown in

Figure 5. Offer Catalog that contains all the Internet plans set by the network operators and the decision engine that provides process automation will act as primary microservice in the 5G PCF. Other microservices, the Access and Management Policy (AMP), Session Management Policy (SMP) and Policy Authorisation (PA) will access and request required information from the Offer Catalog and Decision Engine. The Unstructured Data Storage Function (UDSF) can be optional NF and it can be used to provide storage and to retrieve unstructured data for any NF before sending it to the VoltDB.

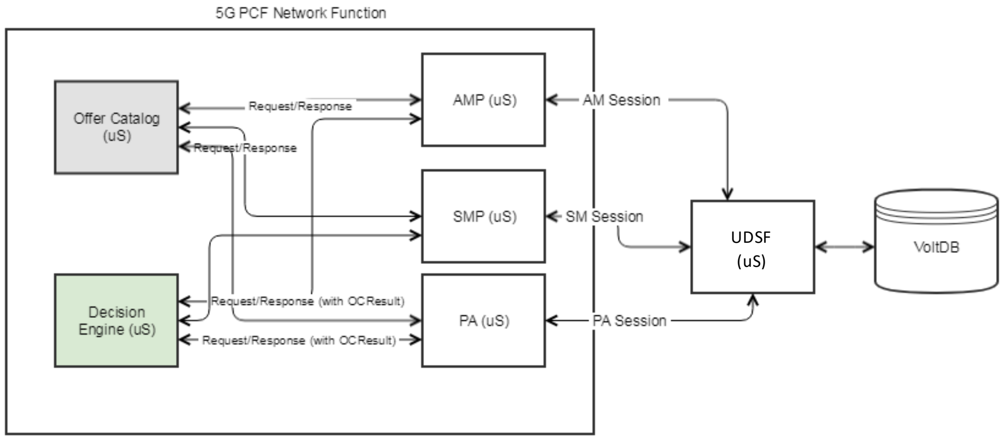

Figure 5. PCF Network Function

4.4. Testing and Verification

The test result from the smoke test runs in Jenkins is as shown in Figure 6. The smoke testing runs a basic create, update, terminate test against each microservices meant for cluster viability for demo. Further details of this smoke test are as shown in Figure 7. The microservices involves are:

(i) Access and Mobility Function (AMF)

(ii) Session Management Function (SMF)

(iii) User Equipment (UE)

(iv) Authentication Policy

(v) Binding Support Function (BSF)

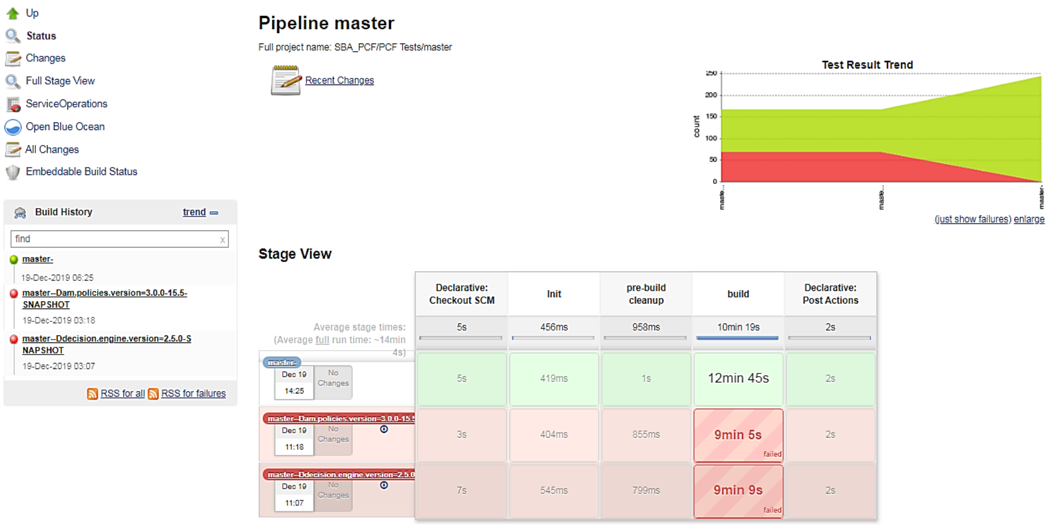

Figure 6. Test Result from Jenkins

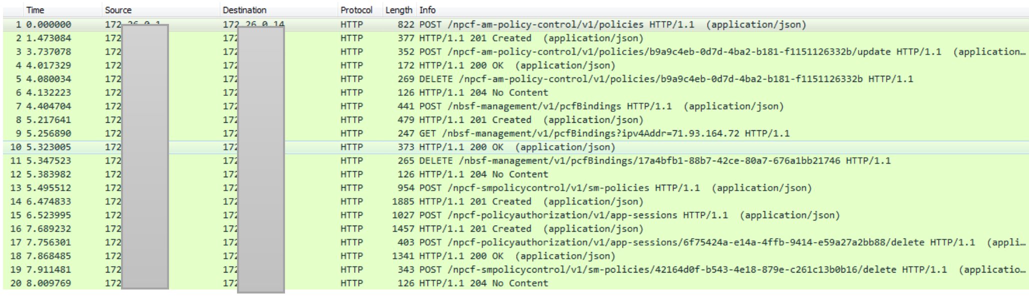

Figure 7. Test Output in Wireshark

5. Conclusion

By implementing the new PCF, network resources can be controlled and managed by network operators. All objectives stated have been achieved. A detailed functional test could not be implemented due to time constraint, only smoke test can be done to test whether the main function is working or not. Other challenges include the network cloud platform and related operating models are not mature enough for production.

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