UDC 004.75

METHOD OF LTE FUNCTIONAL UNITS ORGANIZATION WITH EVOLVED PACKET CORE VIRTUALIZETION

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Today LTE functional units are implemented on software and hardware that limits its scalability. Moreover, all information flows tied to the network operator topology to sites where are special network equipment for traffic counting and to monitor QoS. The usage of network functions virtualization can help to replace a specialized network device on the software that runs on general-purpose processors. Thus, it can reduce costs through the application of ready-made servers for the implementation of new network functionality. In the article the method of distribution of EPC functions between the active network equipment and cloud infrastructure, which is used for computation. Also algorithm of interaction of network elements at client connects to the network is proposed. This will increase the flexibility and productivity of the process provision services mobile broadband.

Introduction

The transformation of today’s networking infrastructure into a more robust, cost-effective solution that supports rapid innovation includes two key elements: the first, the move away from customized, propriety hardware platforms to lower-cost, industry-standard platforms with features that support communications functions and, the second, the transition to software-driven network architecture [1].

EPC virtualization has the potential to revolutionize the classical functional architecture of mobile networks [4].

The architecture of the Evolved Packet Core (EPC) is the last of the core network architecture for cellular systems and this architecture includes examples of network functions such as MME (Mobility Management Entity), S / P-GW (Serving / Packet Gateway) and others.

In IP Multimedia Subsystem (IMS), which is session control architecture for supporting multimedia services via supply EPC and other networks based on IP, network functions examples include P-CSCF (Proxy Call Session Control Function), S-CSCF (Serving Call Session Control Function), and others. HSS (Home Subscriber Server) and PCRF (Policy and Charging Rules Function) are other network functions in 3GPP, which are necessary to complete the architecture functioning and to provide in conjunction with the EPC and IMS full service. Similarly, online and offline charging system (OCS and OFCS) are the systems that capture billing records as part of the session management connection.

Core of mobile networks EPC with virtualization of Mobility Management Entity (MME), Serving Gateway (SGW), Packet Data Network Gateway (PGW) functions can be one of the objects of virtualization. Virtualization of IP Multimedia Subsystem as a platform that provides services in the EPC and other batch domains can also be considered as an object of virtualization [2].

Network Functions Virtualization in Evolved Packet Core area

In [3] Network Functions Virtualization is defined as a network architecture concept that aims to transform the way that network operators architect networks by evolving standard software virtualization related technologies to consolidate many network equipment types onto industry standard high volume servers, switches and storage, which could be located in a variety of network nodes and in end user premises.

Software mobile core will help to create more flexible services and radically change the infrastructure and functioning of networks. Network virtualization is expected to offer key advantages, such as operational sustainability with improved connectivity for dense data traffic and during natural disasters, as well as in the event of hardware failure. It also will accelerate delivery of new services and drive more efficient infrastructure investment [5].

In the virtualized architecture of the EPC, the product functions of the IP Mobile Core can be decomposed into virtualized sub-functions that are hosted on individual virtual machines. Different virtual machine types are defined to perform different virtual sub-function tasks.

According to [6] the virtualization of EPC architecture approach must support different aspects:

• The EPC network functions have a cloud-optimized architecture that takes full advantage of NFV/SDN architectures;

• Scalability, to provide maximum operator flexibility in deploying virtualization EPC functions in large or small increments wherever and whenever they are needed;

• Capacity support for mobile broadband services with the same level of performance to meet end-user experience expectations;

• Network availability and reliability that is as good or better than that provided by the existing packet core, thanks to new protection schemes;

• Common operations management of the network functions across the virtualized and physical EPC.

For the mobile core, the expected benefits of virtualization are:

• Improved operational efficiency: NFV infrastructure will deliver some operational efficiencies through reduced network costs and simplified operations.

• Optimized network configuration and/or topology through performance monitoring: automated virtual machine connectivity and optimization can be provided through an SDN employing policy based routing.

• Support for multi-tenancy: Multiple network functions can be configured on the same NFV infrastructure.

• Faster time-to-market for new services: cloud automation will speed delivery of new services.

• Targeted service introduction based on geography or customer location.

In the first instance, virtual EPC will tend to be deployed in parallel to the main production EPC and will focus on machine-to-machine and customized enterprise services. These types of services can have specific traffic profiles that might benefit from a particular EPC configuration (and specifically, a virtual P-GW configuration), and they provide an opportunity for operators to experiment with a virtual core without putting mass-market services at risk [7].

The deployment of a virtual EPC and associated service delivery require sophisticated orchestration of the virtual resources inside the data center, as well across as the physical mobile backhaul network.

Operators need a more flexible infrastructure that supports granular configuration and able to meet unexpected bursts of capacity requirements. Given the mobility of users and the load on the network during transferring permanent traffic, the network should respond much faster than that in the general case allows existing current model of resource allocation [9].

The idea is that the infrastructure must adapt resources and performance to the needs of applications and bursts of user's activity.

With the right (in each case) organization of virtualization infrastructure can more accurately respond to changes in demand: server becomes scaling unit.

According to [9] a network service can be viewed architecturally as a forwarding graph of Network Functions (NFs) interconnected by supporting network infrastructure. These network functions can be implemented in a single operator network or interwork between different operator networks. The underlying network function behaviour contributes to the behavior of the higher-level service. Hence, the network service behaviour is a combination of the behaviour of its constituent functional block, which can include individual NFs, NF Sets and/or the infrastructure network. Fig. 1 shows basic layout of this approach.

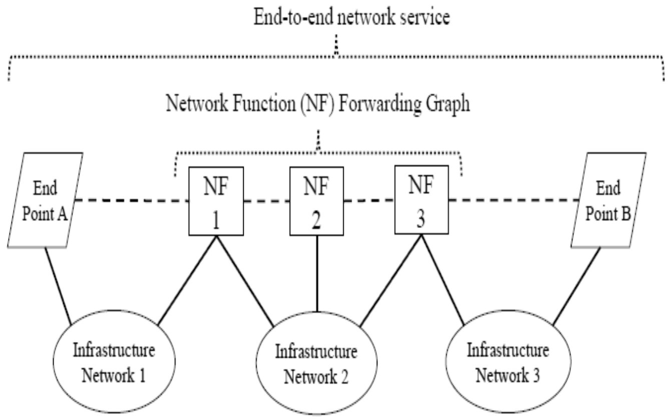

Fig.1 Graph representation of an end-to-end network service

Today, most services require multiple functions. If such functions are virtualized for network optimization, you need to get them to work together in the easiest way. It was difficult to implement without an orchestration layer that supports NFV. Orchestration layer helps to integrate and use the network functions in the best way. The orchestration system leverages service templates that define the automation workflow for various processes.

NFV also can provide a new set of operations management requirements in the area of orchestration.

The main question is what level of optimization is to achieve, which in turn depends on one factor – when will be hosted virtualized functions. Optimization in general should be directed to the task of maintaining the required level of performance and quality of service (QoS).

In [9] is proposed that the NFV design will implement one or more virtualized network functions, or VNFs and this term means a virtualization of a network function in a legacy non-virtualised network.

A VNF can be composed of multiple internal components and by itself does not automatically provide a usable product or service to the provider's customers. To build more complex services, the notion of service chaining is used, where multiple VNFs are used in sequence to deliver a service. Fig. 2 shows the general scheme of resources virtualization with NFV usage which proposes in [9].

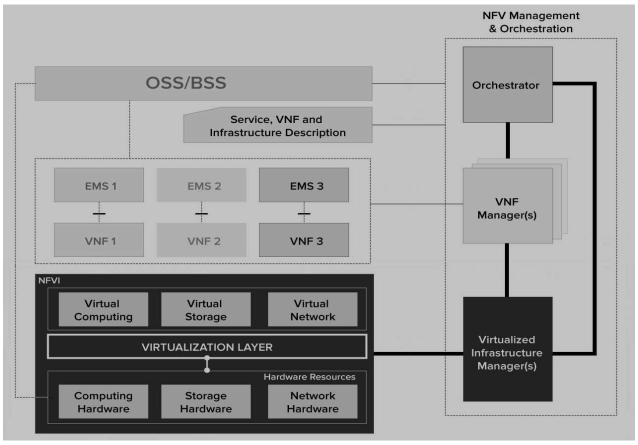

Fig.2 Network Functions Virtualization scheme

Cloud infrastructures that assume using virtual machines (VMs) provide methods to enhance resource availability and usage by means of orchestration and management mechanisms, applicable to the automatic instantiation of virtual appliances in the network, to the management of resources by assigning virtual appliances to the correct CPU core, memory and interfaces, to the re-initialization of failed VMs, to snapshot VM states and the migration of VMs.

Virtual network functions range from mobile deployments, where mobile gateways (e.g. SGW, PGW, etc.) and related functions (e.g. MME, HLR (Home Location Register), PCRF (Policy and Charging Rules Function), etc.) are deployed as VNFs, to deployments with “virtual” customer premise equipment (CPE), tunneling gateways (e.g. VPN gateways), firewalls or application level gateways and filters. It should be much quicker to integrate new Virtualized Network Functions into the OSS because there is no need for the OSS to deal with any hardware management functions.

Since each VM works in isolation and is independent of other VMs, they don’t impact on performance of one another. These VMs can be configured dynamically (links, network topology etc.) as per required capacity and traffic pattern.

Approach to Evolved Packet Core virtualization

The main idea that we propose, is to use a certain amount of VNF managers at Evolved Packet core virtualization approach to provide operational control at the point of virtualized functions allocation in the framework of general scheme and the factor of certain level of centralization during resources virtualization.

For automated orchestration to work, essentially everything that in the past was configured manually must now be made into machine-readable description formats.

The cloud infrastructure uses the descriptions provided by the tenant to orchestrate virtual networks as well as all other resources. Virtualized Infrastructure Managers orchestrate resource requests across multiple sites and layers of functionality.

One of the aspects of proposed EPC components virtualization is replacement of real IP Edge device with code executing on virtualized platform [10–15]

Fig. 3 shows the basic scheme of the EPC.

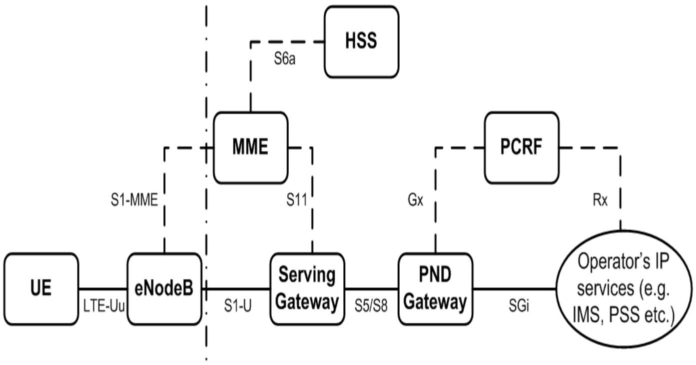

Fig. 3 Basic scheme of the EPC

MME is a control node, which passes through all the signaling traffic between the UE and the Core Network (CN). Protocols which are used to transmit control traffic between UE and CN, known as NAS (Non-Access Stratum). The functions performed by MME, divided into the following two sets:

- Flow Control (Bearer Management);
- Manage Connections (Connection Management);

All IP packets that are transmitted to the UE transmitted via the S-GW, which is an anchor for the data flows when the UE moves between different base stations (eNodeB). In addition, S-GW stores all the information about the streams UE, when the UE is in idle mode (idle mode). S-GW also temporarily stores the data sent to the UE, while MME starts a paging process of UE, in order to create a stream (radio channel) for sending data to the UE.

Besides the above functions, SGW also provides some administrative functions in the visited network. For example, collection if information for the account write-offs.

The functions of PGW unit contain allocation of an IP address for the UE, monitoring of QoS parameters and implementation of write-downs on the accounts based on a set of rules derived from the PCRF. P-GW also provides filtering of the incoming IP packets to various client streams with a specific set of QoS parameters at the same time using TFT (Traffic Flow Templates).

Serving Gateway and Packet Data Network Gateway categories of nodes can be split into two entities the control plane and data plane functions. The split will enable moving the control plane functions i.e. SGW-Ctrl and PGW-Ctrl onto centralized cloud platform. A

VNF Managers will serve multiple VNFs running on each virtual machine and will be responsible for VNF lifecycle management (e.g. insantiation, update, query, scaling, termination). Fig. 4 shows proposed approach.

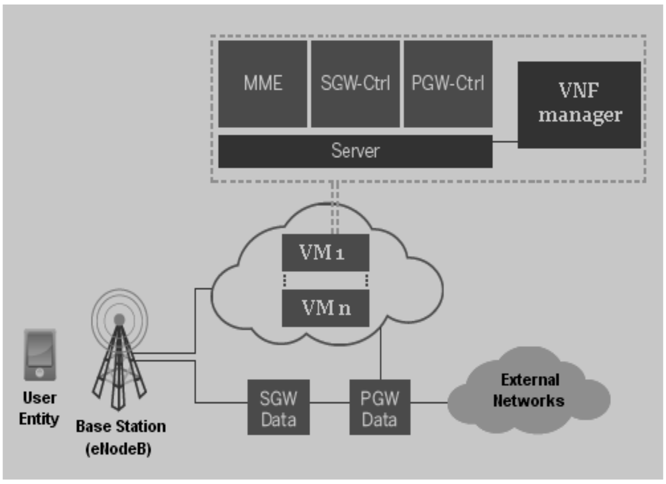

Fig.4 EPC virtualization with several VNF managers

According to Fig.4 network operation in general will be based on several servers or data centers. We propose to organize SGW/PGW and MME functions on different data centers complexes.

We propose that in virtualized EPC and IMS virtualized S/P-GW PDN work through PDN connection and IMS communication session, respectively. Interaction of network functions units provides by standard interfaces (s6a for MME – HSS interaction, s11 for MME – S/P-GW and s5 for different S/P-GW units). Network operation is shown in Fig. 5.

The proposed approach makes it possible to scale the S/P-GW and the MME network functions independently in accordance with their own resource requirements. For example, a situation may arise when it is necessary to increase the resources in the user plane resources without affecting the control plane and vice versa.

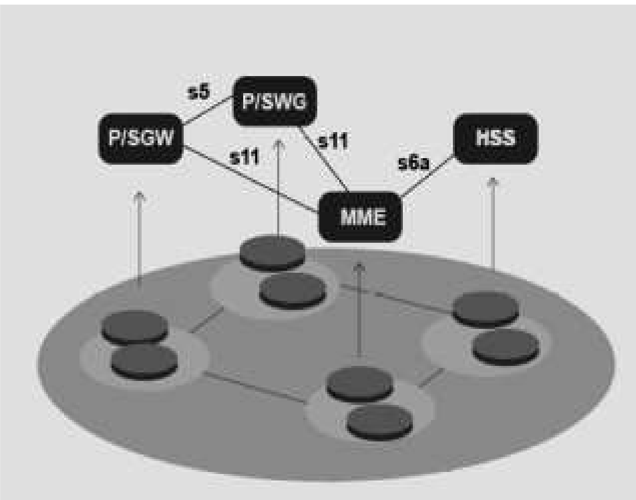

Fig. 5. Interaction of network functions units

When the dynamic reconfiguration of a virtual network function is the fault of failure or overload with automatic or manual control mode, the movement controlled sessions and/or compounds should be handled appropriately to achieve the desired technical availability and reliability of service.

Method of LTE functional units organization with EPC virtualization

PCRF – functional element in the communication networks of the 3GPP group recommended networks, whose main function is to implement policies of customer service, such as enabling/disabling services or set parameters of quality of service (QoS), i.e., the application of certain rules to useful information flows. Furthermore, the functional element PCRF establishes a charging rule according to various conditions such as user profile settings, time of day, location of the subscriber, the traffic volume and others.

Today, the PCRF functions are implemented in software and hardware infrastructure, which limits its scalability. Thus all information flows are tied to the operator network topology, because for providing traffic counting and service quality control, all of the information flows must interact with PCRF block. That is why the appearance of the concept of software-defined networking and network functions virtualization (SDN and NFV) made possible to improve the functioning of PCRF unit.

The proposed method involves the virtualization of some PCRF functions, which lies in the fact that a number of functions implemented on the basis of virtual machines hosted in the cloud. It is thus possible scaling of the PCRF during deploying a network without the need for some real physical server capacity.

Organization of interaction of PCRF virtual machines with nodes of communication network is a task worthy of special attention. An important issue is the distribution of functions between virtual PCRF and other functional elements of the 3GPP system which passed through a flow of information.

Functional nodes that interact with PCRF serve a certain segment of the network, respectively, we proposed to organize virtualization nodes responsible for a segment on one "cloud" server to optimize unit interaction. To optimize the management functional units controllers serving different segments of the network will be organized on separate virtual machines. Exactly controller nodes of PCRF functional elements will interact with other elements of operator's server architecture.

Consider the functional elements and interfaces that interact with PCRF.

The first element, PCRF (Policy and Charging Enforcement Function) – a functional element in the

3GPP communication networks, which carries out the use of PCC-law received from the PCRF, to a pass-through traffic. It performs billing of traffic in OCS / OFCS tariffication system of mobile operator.

This component as a PGW functional unit imposed in cloud infrastructure. Interaction of PCEF cloud component composed with PGW-Control with PCRF will be carried out by Gx-interface that uses Diameter and designed to provide service data on the implementation of Flow Based Charging - FBC billing rules. At this interface PCEF sends to the PCRF information that necessary for making PCC-decision: the caller ID information on the location and time zone in which the user, IP address of the device that is being accessed, the channel parameters, and others.

On a real physical hardware will work variant of «thin client» of PGW – PGW-Data – whose task is traffic filtering and application of the rules depending on the instructions received from PGW-Control. Interaction of client and cloud realization of PGW implement on s5 interface.

Packet filtering for users and lawful interception of traffic (we denote this set of features as F1) are made on the PGW «thin client», in cloud infrastructure transfer functional of distribution of the pool of IP addresses for the user devices UE (F2).

Appointment of PCC-rules which transmitted between network PCRF and PCEF units is separation physical data stream (IP-CAN) on logical sessions SDF (Service Data Flow), determination for which applications and services related traffic, providing QoS parameters and information for charging. There are two types of PCC-rules: dynamic PCC-rules that are transmitted from PCRF to PCEF through the Gx-interface and pre-defined rules in the PCEF. Pre-defined rules can be activated by PCRF, or by the PCEF.

Next reviewed element that will be virtualized is BBERF (Bearer Binding and Event Reporting Function). This is functional element in the 3GPP communication networks, which provides notification of PCRF about session establishment with sending caller ID and other parameters for correct determination of QoS-rules of services. Functionality of the component will be transfer in the cloud infrastructure as a part of functional unit SGW-Control.

«Thin client» SGW-Data will perform the following functions: routing of the base packet traffic and intercept of packet traffic (F3), and the functional of "anchor" points (association point) of traffic for handover between base stations NodeB inside one access network in coverage area of the base stations according to a set of rules and regulations (F4) derived from the «cloud» server part SGW-Control.

SGW-Control element, in turn, provides the following functions: "anchor" point for handover between different access networks standards LTE / LTE and LTE / UMTS (F4) and processing functionality of BBERF (F5).

Interaction with PCRF node is performed by SGW-Control (as in the case of PGW-Control), but by the Gxx interface. The interaction between the components SGW-Control and SGW-Data is carried out via s5.

There are also a number of nodes, which functionality we propose to locate in the cloud (with the division of servers by the network segment). Among them are the following:

- TDF (Traffic Detection Function) (F6) is a functional element in the 3GPP communication networks, which provides the definition of the traffic of certain applications and notifications about him PCRF. Depending on the received rules, shall pass this traffic to the subscriber, redirect this traffic and provide the speed limit. Interacts with the PCRF on Sd interface, which is used to install ADC (Application Detection and Control) Rules for management of traffic parameters of specific applications.
- UDR (User Data Repository) (F7) is a functional element that provides storage of user data. Interacts with the PCRF on Ud interface, which is used to get/change user profiles, which contain information about the services available to the subscriber, and other QoS parameters required for making PCC-decisions. Also Ud interface is used to subscribe and receive notifications of changes to the subscriber profile.
- AF (Application Function) (F8) is a functional element that provides a description of the data flow of service and provides informing about required resources for different services. Interacts with the PCRF on Rx interface.
- OCS (Online Charging System) (F9) is a credit control server in real time, which provides billing services, controls the balance of the subscriber maintains information about the charge and debit of the subscriber's balance, applies discounts, counts the volume of consumed services. It interacts with the PCRF on Sy interface, which is used for accounting of the volume of consumed services and the notification of overcoming thresholds meters from OCS to PCRF. Besides PCRF, OCS interacts with PCEF on Gy interface, which implements the service charge.

Fig. 6 shows the proposed scheme of functional nodes (functions marked in red are virtualized in the "cloud" infrastructure).

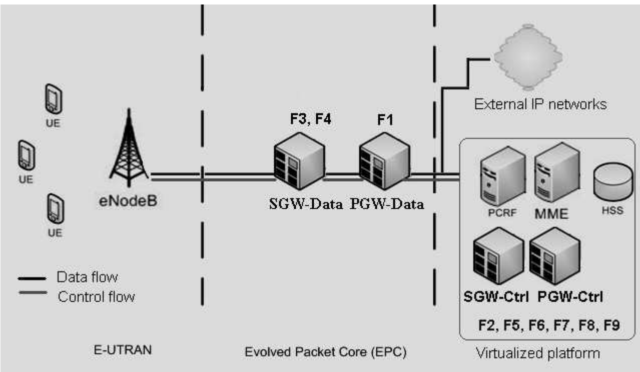

Fig. 6. Organization of functional network nodes

Virtualized Infrastructure Managers can orchestrate resource requests across multiple sites and layers of functionality, using SDN controllers to create virtual network connections derived from the provided descriptions.

IP packets addressed to the UE, tunneled (GTP-U/UDP/IP) in the area between the PGW-Control and the eNodeB (S1 interfaces and S5/S8) for subsequent transmission to the UE. The protocol stack in the area between the UE and eNodeB includes: PDCP (Packet Data Convergence Protocol), RLC (Radio Link Control) and MAC (Medium Access Control) sub-levels.

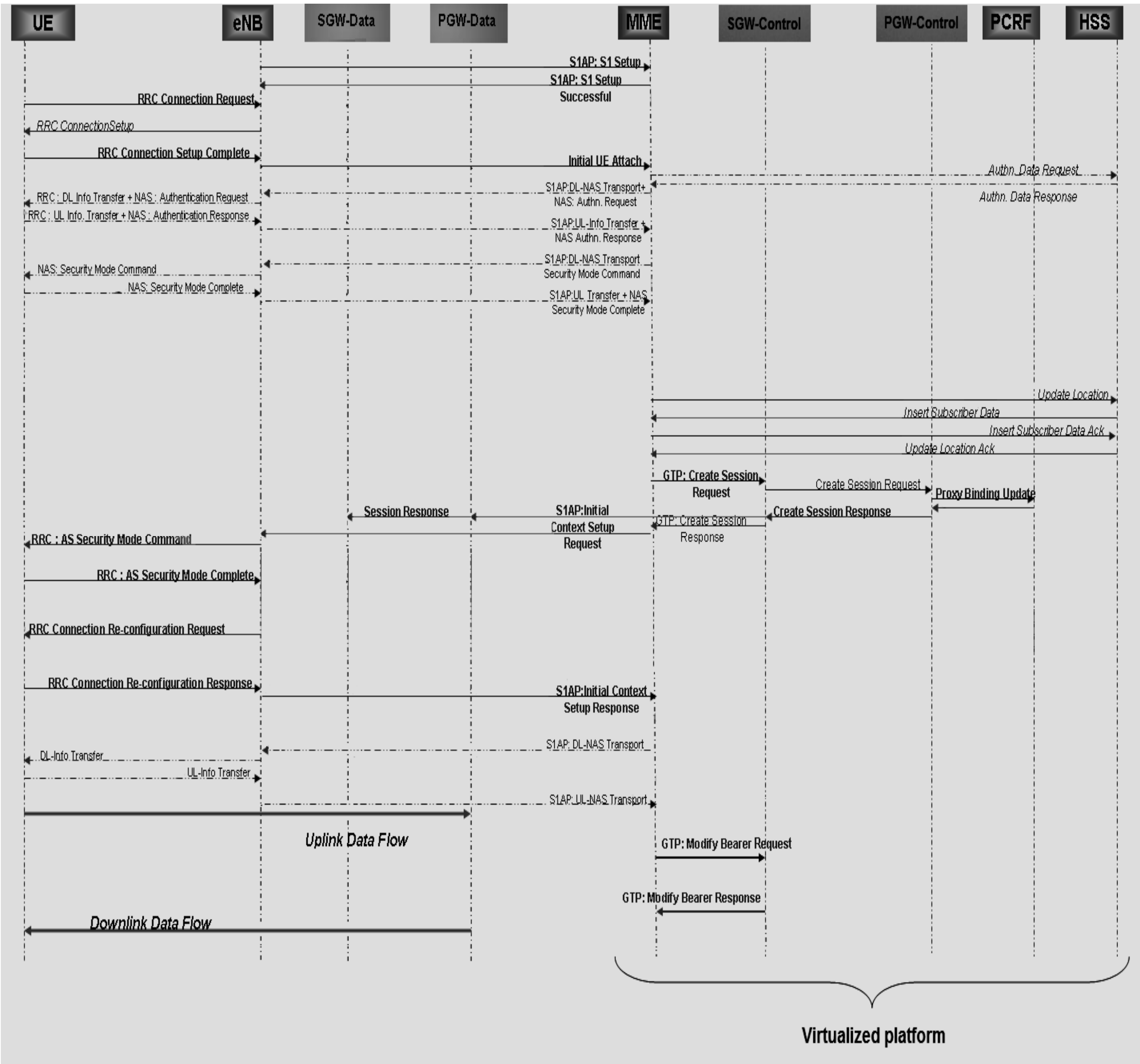

Fig. 7. Diagram of control messaging during client connection to the network

Organization connection to virtualized platform includes different access methods, but it is generally accepted API Web-services. Many of them implemented on the principles of REST or Virtual Protocol Interconnect (VPI), which means the object-oriented scheme, developed over HTTP (using HTTP as a transport) or IPSec.

The transfer of control messages in virtualized EPC

During the interaction of the components of the LTE network we are talking about logical channels that provide services to medium access control MAC (Medium Access Control) protocol within the framework of LTE. The logical channels according to the type of transmitted information are divided into logical control channels or logical traffic channels. Logical control channels are used for transmitting various signaling and data messages. According to the logical traffic channels transmit user data.

The proposed approach to virtualization of EPC enables: firstly, to simplify the organization of the logical channels, so as in the present variant of the resources organization is essentially exists only logical traffic channel UE-Base station – SGW-Data – PGW-Data with output to packet network communication between different parts of the network and the same logical control channel that uses access to packet-based networks for interaction with virtualized cloud architecture; secondly, to unify equipment performs traffic filtering (SGW and PGW) due to functional limitations; and thirdly, provides virtualized server backup functions.

Fig. 7 shows a diagram of the connection establishing of the user device to the LTE network under the proposed variant of the organization of resources.

In general, a sequence of interactions in a mobile network with proposed data virtualization can be described as follows:

1. The subscriber starts a data transmission session (RRC Connection Request). Data received from the base station to virtualized MME unit (S1 Setup) and base station starts UE Attach.
2. MME sends to HSS Authorization Data Request.
3. In cloud virtualized infrastructure BBERF functional sends to PCEF a request to create a session for traffic (IP-CAN) (located on the same virtualized platform).
4. PCEF generates request on Gx interface, and sends it on PCRF. Request is design to form Diameter CCR (Credit-Control-Request) request information about the subscriber and the requested service.
5. PCRF makes a request of the subscriber profile on Ud interface.
6. Gets a profile of the subscriber services.
7. Subscribes to the notification of profile's changes.
8. PCRF makes the PCC-decision of the possibility of providing services to the subscriber, and with what quality parameters. It generates PCC-rules which is sent to PCEF on Gx interface. This is the formation of Diameter CCA (Credit-Control-Answer) response with the included set of PCC-rules.
9. With the response of PCEF establishes credit control session with OCS on Gy interface using messaging of Diameter CCR / CCA.
10. PCRF authorizes the installation of IP-CAN session and sends a response notification to SGW-Control and PGW-Control.
11. SGW-Control sends Initial Context Setup to PGW-Data and Session Response to SGW-Data.
12. Traffic flow (Service Data Flow) begins to flow between the subscriber unit and external communication networks.
13. After some time, the subscriber finished data session and BBERF functional sends to the PCEF request to break IP-CAN session.
14. PCEF performs completion of Diameter sessions on PCRF on Gx interface. Finalizing is also a messaging of Diameter CCR / CCA.
15. PCEF performs completion of Diameter sessions on OCS on Gy interface.

Conclusion

Key benefit of EPC virtualization that uses NFV expect is that several VMs can have different software components running on virtualized infrastructure. Central to NFV is the ability to compose different VNFs to provide rich and flexible end-to-end services. With the adoption of NFV, multiple SGi functions can be dynamically added to an end-to-end path through service chaining.

NFV usage will help consolidate network functions onto economical, high-volume servers, switch and storage, reducing time to market and costs for network operators. Instead of having a separate black box for each network function, they become virtual appliances running on the same server platform.

Virtualization will give a readymade platform for migration of network elements and services to cloud. Scalability and multitenancy capabilities on virtualized platforms will enable easy rollouts, upgrades and operations.

The concept that given in proposed approach can be further extended for different category of network elements that implement control plane protocol and procedures or traffic handling.

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Received in final from April 19, 2015