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Design of an Interconnection Architecture and Sizing of Two (2) EPC Core Networks: The Case of Orange-Guinea

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Abstract: With the arrival of the 4G and 5G, the telecommunications networks have experienced a large expansion of these networks. That enabled the integration of many services and adequate flow, thus enabling the operators to respond to the growing demand of users. This rapid evolution has given the operators to adapt, their methods to the new technologies that increase. This complexity becomes more important, when these networks include several technologies to access different from the heterogeneous network like in the 4G network. The dimensional new challenges tell the application and the considerable increase in demand for services and the compatibility with existing networks, the management of mobility intercellular of users and it offers a better quality of services. Thus, the proposed solution to meet these new requirements is the sizing of the EPC (Evolved Packet Core) core network to support the 5G access network. For the case of Orange Guinea, this involves setting up an architecture for interconnecting the core networks of Sonfonia and Camayenne. The objectives of our work are of two orders: (1) to propose these solutions and recommendations for the heart network EPC sizing and the deployment to be adopted; (2) supply and architectural interconnection in the heart network EPC and an existing heart network. In our work, the model of traffic in communication that we use to calculate the traffic generated with each technology has link in the network of the heart.

Key words: 5G network, 4G network (EPS (evolved packet system)), 3G network (UMTS: Universal Mobile Telecommunications System), EPC network of the heart, architecture, dimensional, Orange Guinea, technology, service.

1. Introduction

As humanity evolves, the need for telecommunications services continues to grow and diversify. From text, voice and data communications, telecoms are now moving into the multimedia arena, encompassing multimedia and video. The provision of these services is made possible by ongoing scientific, technical and technological progress. These services are generally provided by cellular networks, which have evolved from the first to the fifth generation [1-3].

Users of these services are very demanding in terms of quality, availability, etc. [1].

These requirements inevitably lead operators, the providers of these services, to regularly adapt their networks through extensions and migrations [1, 4].

This is the logic behind Orange Guinea, which is constantly making improvements to its network—thereby accentuating the quality of its services—through extensions, migrations and, above all, modernization of its network—for the benefit of its ever-growing customer base [1, 5].

On the other hand, the increase in the quantity of services means high bandwidths—guaranteeing quality—and exorbitant costs [4, 6].

The researcher's job is to choose the most economical solution that guarantees the required quality [7, 8].

Sizing is a network engineering operation used to determine the volume of equipment and software to be

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deployed to provide telecommunications services; it is followed by planning [9, 10].

This research work is part of the design and realization of an interconnection architecture and the dimensioning of two EPC (evolved packet core) core networks taking into account the 5G access network [1, 8].

Sizing the EPC core network of the 4G/5G NSA (non-standalone-autonomous) network involves determining not only the equipment, but also its capacity [11].

The main objective of this project is to set up an interconnection and dimensioning architecture for two EPC core networks supporting 5G access network traffic. The EPC core network is a backbone network, as it can support multiple access technologies without interrupting traffic. The study is based mainly on 3G, 4G and 5G networks, and is applied to the Orange Guinea operator [12, 13].

2. Materials and Methods

2.1 Location of the Study Area

Orange Guinea is a subsidiary of the Sonatel Group, which is a subsidiary of the Orange Group. Orange Guinea is a mobile operator created in 2007. On December 14th, 2011, it launched 3G+. Since August 2013, Orange Guinea has been the market leader in cellular telephony in the Republic of Guinea (Source: www.guineenews.org of October 29, 2013). In 2019, it launched the 4G network. It offers cell phone and internet services. Orange Guinea has two (2) sites housing the core networks: the Sonfonia exchange and the Camayenne exchange [5].

2.2 Material

To design and build this architecture, we used the following tools: bibliographical information; Word and PowerPoint software. The work was carried out at the LEREA laboratory (Laboratoire d'Enseignement et de Recherche en Energétique Appliquée: Applied Energetic Research Lecturing Laboratory).

2.3 Methodology

2.3.1 Method Description

The study is based mainly on the EPC core network of the 4G and 5G NSA networks. In the case of Orange Guinea, we propose to create an interconnection architecture for the EPC core networks of the Sonfonia and Camayenne sites, taking into account the 5G access network. To this end, we have used the Orange Guinea core network in 2015, in 2020 and we have studied the architecture of the EPS (evolved packet system) network and that of the NSA 5G network [12, 14, 15].

2.3.2 Orange Guinea Core Network Hardware Configuration (2015) [5, 16, 17]

Orange Guinea’s core mobile network consisted solely of GSM (Global System for Mobile Communication) and UMTS equipment supplied by Huawei. This equipment mainly comprises two MSC (Mobile service Switching Center) NGNs (Next Generation Network), each of which consists of an MSC server attached to a MGW (media gateway):

- The first MSC NGN in question consists of the MSoft X3000 attached to a UMG 8900 MGW, and is located at the Sonfonia site;
- The second MSC Server or “Call Server” and its MGW are installed together at the Camayenne site.

Fig. 1 below illustrates the current configuration of Orange Guinea’s core network. The UMTS core network at the Camayenne site is linked to the Sonfonia site by IP links between the MGW at each site. This configuration gives a picture of two different networks (or different operators). Orange Guinea’s core network was then equipped with switching by:

- Huawei with two (2) MSC Servers with a capacity of 1,759,000 2G/3G subscribers, two (2) MGWs, three (3) BSCs with a capacity of 3072 TRXs (Tranceiver) each and two (2) RNCs (Radio Network Controllers);
- The Alcatel HLR (Home Location Register) type SDM (Subscriber Data Manager) 8650 release 3.1 has been deployed on two (2) sites: Sonfonia and Camayenne nodal (the capacity of a FE (Front End) is 5.85 million active subscribers and the capacity of a BE

(Back End) is 7.1 million active subscribers);

• The backbone interconnection is made in full IP through Huawei Backbones and MPBN (mobile packet backbone network) with SIGTRAN (Signaling Transport over IP) signaling and to third parties;

• International traffic is interconnected via ACE (Africa Coast to Europe).

2.3.3 The EPS Network Architecture

2.3.3.1 Network Features

The special feature of the EPS network compared with the 2G and 3G networks is that it only offers a data transmission service in PS (Packet Switching) packet mode, characterised by an increase in the maximum data rate. To provide a telephone service, the EPS network only transports voice and signaling, which are treated as data; voice and signaling processing is carried out by the IMS (IP multimedia subsystem) network outside the EPS network [16, 18, 19].

Tables 1-3 below show the modes and flow rates of the various networks.

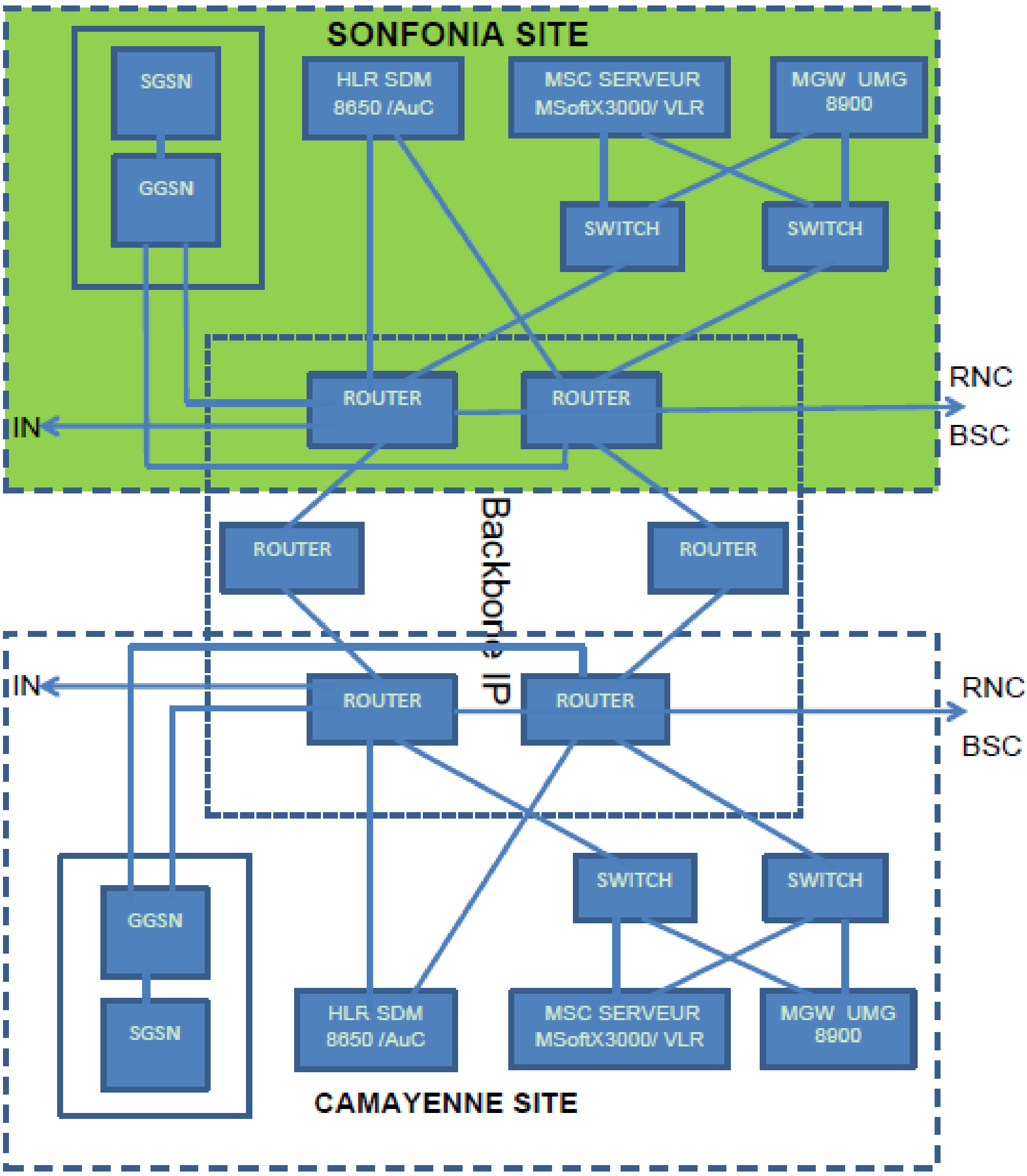

Fig. 1 Orange Guinea's core network architecture in 2015 [5, 16].

SGSN: Serving GPRS Support Node; GGSN: Gateway GPRS Support Node; MGW: Media Gate Way; HLR: Home Location Register; MSC: Mobile Switching Center.

Table 1 2G network data rates [16, 17].

2G	Network	GSM (2G)	GPRS (2.5G)	EDGE (2.75G)
	Switching mode	CS	PS	PS; CS little used
	Data rate	14.4 kb/s	171.2 kb/s	473.6 kb/s for PS mode

Table 2 3G network data rates [7, 16].

3G	Network	UMTS (3G)		HSDPA	HSUPA	HSPA+ (3.75G)
	Switching mode	CS	PS	PS	PS	PS
	Data rate	64 kb/s	384 kb/s	14.4 Mb/s	5.76 Mb/s	11.5 Mb/s in Uplink 43.2 Mb/s in Downlink

Table 3 4G network data rates [16, 20].

4G	Network	EPS
	Switching mode	PS
	Data rate in Uplink	75 Mb/s
	Data rate in Downlink	302 Mb/s

Table 4 AN and CN for 2G networks [16, 21].

2G	Network	GSM (2G)	GPRS (2.5G)	EDGE (2.75G)
	AN	BSS	BSS (evolution)	BSS (evolution)
	CN	NSS	GSS	GSS

Table 5 AN and CN for 3G networks [16, 19].

3G	Network	UMTS	HSDPA	HSUPA	HSPA+
	AN	UTRAN	UTRAN (evolution)	UTRAN (evolution)	UTRAN (evolution)
	CN	NSS and GSS	GSS	GSS	GSS

Table 6 AN and CN for 4G network [15, 16].

4G	Network	EPS
	AN	E-UTRAN
	CN	EPC

The 4G network is also distinguished from the 2G and 3G networks by its AN (access network) and its CN (core network).

Tables 4-6 show the different ANs and CNs for 2G, 3G and 4G networks respectively.

2.3.3.2 Network Components

The EPS network consists of an EPC core network and an E-UTRAN (evolved universal terrestrial radio access network) access network.

The EPC core network comprises the MME (mobility management entity), the SGW (serving gateway) and PGW (packet data network gateway), the HSS (home subscriber server) and EIR (equipment identity register), and the PCRF (policy and charging rules function), which determines the QoS (Quality of Service) and charging rules (see Fig. 2).

The EPC core network has the following differences from the GSS (GPRS sub-system) core of the GPRS (General Packet Radio Service) and UMTS networks [14-17]:

- a specific MME entity is responsible for exchanging signaling with the mobile and with the access network. In the case of GPRS and UMTS networks, these functions are performed by the SGSN (service GPRS support node);
- two anchor points (SGW and PGW) are created. In the case of GPRS and UMTS networks, the only anchor point is provided by the GGSN (gateway GPRS support node).

The MME entity manages and stores contexts relating to mobiles:

- the private identity of the mobile IMSI (international mobile subscriber identity);

- the temporary private identity S-TMSI (temporary mobile subscriber identity);
- the TAI (tracking area identity) location zone;
- authentication and encryption data;
- the mobile's capabilities;
- the quality of service assigned to the medium.

The MME entity is responsible for managing mobility, attachment and detachment and updating the TAI location zone. It manages the authentication procedure and the allocation of the temporary S-TMSI identity. It transfers the mobile context to the SGSN during inter-system mobility (EPS to UMTS).

The SGW entity also manages and stores mobile-related contexts:

- the mobile's IP address;
- the quality of service assigned to the bearer;
- the IP addresses of the eNode B and PGW entities;
- the mobile session identifier TEID (tunnel endpoint identifier).

The SGW entity transfers incoming data to the eNode B entity and outgoing data to the PGW entity. It initiates paging to the MME entity for incoming data. It is the anchor point for intra-E-UTRAN mobility. During inter-system mobility, it transfers data to the SGSN or RNC of the UMTS network.

The PGW entity connects the EPS network to the PDN (Packet Data Network) data network (the Internet). It is equivalent to the GGSN entity in the UMTS network. It is responsible for allocating the mobile's IP address. It is the anchor point for inter SGW mobility.

The PGW entity hosts the PCEF (policy and charging enforcement function) which inspects data received from the PDN or SGW fixed data network, marks IP packets for incoming data according to the quality of service applied to the medium and generates charging tickets for the CG (charging gateway) entity.

The HSS database is an integration of the functions performed by the HLR (Home Location Register) and AuC (Authentication Center) databases.

The PCRF (Policy and Charging Rules Function) entity provides the PCEF function of the PGW entity with the rules to be applied for charging and quality of service when support is to be established for the mobile. In the case where the mobile is connected on a visiting network, the PCRF entity of the host network is connected to the PCRF entity of the visiting network. If the telephone service is provided by the IMS network, the latter provides the rules to be applied.

The E-UTRAN access network is simplified and comprises a single type of entity, the eNode B radio station (Base Station), which integrates the functions previously assigned to the BSC base station controllers of 2G networks and RNC base station controllers of 3G networks (see Fig. 2).

The eNode B entity is responsible for managing the radio resources, controlling the allocation of the medium to the mobile, and its mobility. It compresses and encrypts data on the radio interface.

The eNode B entity routes the data from the mobile to the SGW entity and, for the outgoing data, marks the IP packets according to the quality of service assigned to the medium.

The eNode B entity selects the MME entity assigned to a mobile. It processes the paging request sent by the MME entity so that it can be broadcast in the cell.

2.3.3.3 Interfaces

An interface is the boundary layer between two elements through which exchanges and interactions take place. In computing and telecommunications, an interface is a device that enables exchanges and interactions between different players: for example, a human-machine interface enables exchanges between a human and a machine, a programming interface enables exchanges between several software programs, etc. Interfaces therefore provide links between the different entities of the same network or of several networks [16, 22].

The interfaces between the different entities of the EPS network shown in Fig. 2 are listed in following Table 7.

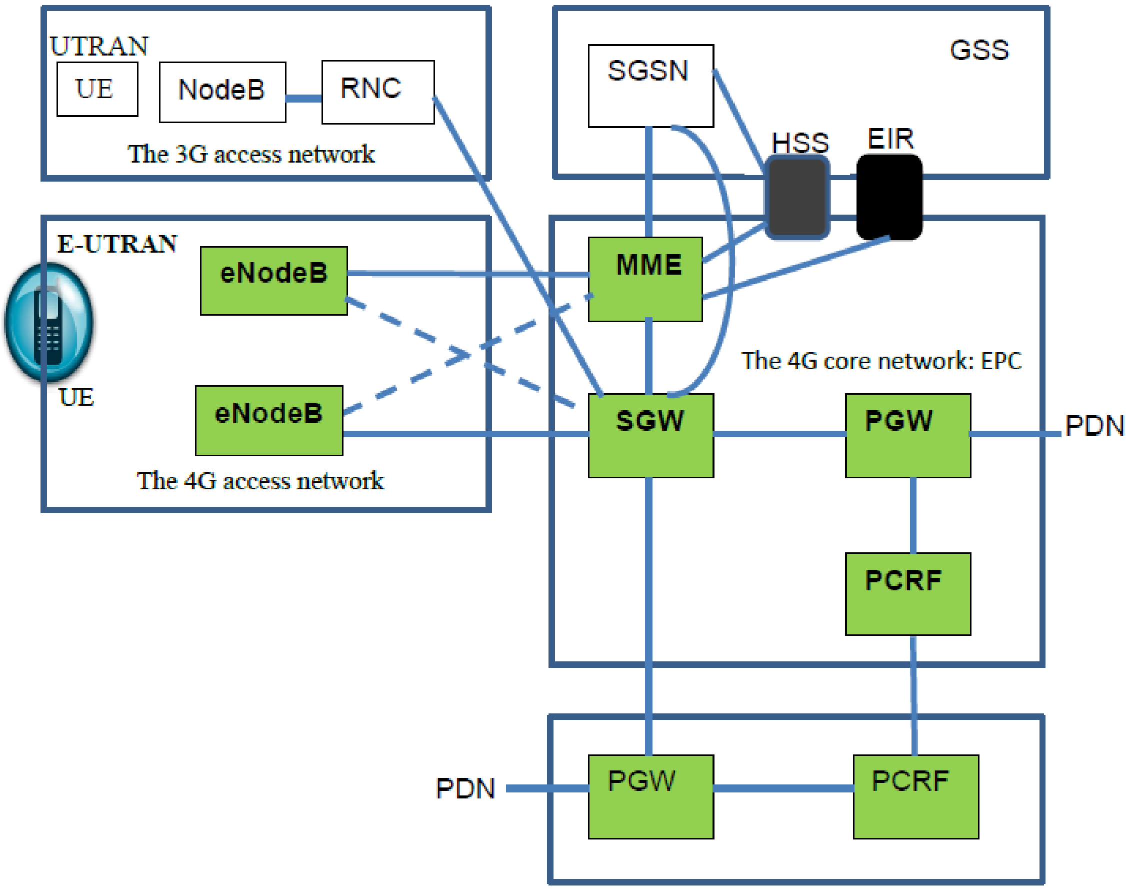

Fig. 2 Physical architecture of the EPS network [16, 18].

Table 7 Interfaces between the various entities in the EPS network [16, 23].

Entities	Interfaces
UE and eNode B	Uu
eNode B and MME	S1-MME
eNode B and SGW	S1-U
MME and SGSN	S3
SGW and SGSN	S4
SGW and PGW	S5
MME and HSS	S6a
SGW of the visiting network and PGW of the host network	S8 (variant of S5)
PCRF of host and visitor networks	S9
MME and MME	S10
MME and SGW	S11
RNC and SGW	S12
MME and EIR	S13
PGW and PDN	SGi
PCRF and PCEF	Gx
eNode B and eNode B	X2

2.3.3.4 Protocols

Protocols are conventions that facilitate communication without directly forming part of the subject of the communication itself. The most commonly used communication protocols are network protocols. A network protocol is a set of conventions needed for remote entities to cooperate, in particular to establish and maintain information exchanges between these entities [16, 20].

- The RRC (radio resource control) protocol ensures the exchange of signaling and traffic between the mobile and the eNode B;
- The PDCP (packet data convergence protocol) is responsible for ROHC (robust header compression) header compression, data security and sequential data delivery in the event of handover;
- The RLC (radio link control) protocol provides control of the radio link between the mobile and the eNode B entity for control and traffic data, and signaling of this control;
- The MAC Protocol: the MAC (medium access control) layer is responsible for multiplexing RLC data in the transport blocks, allocating the resource via a scheduling mechanism and managing and correcting errors via the HARQ (hybrid automatic repeat-request) mechanism;
- The NAS (non-access stratum) protocol ensures the exchange of signaling between the mobile and the MME corresponding to mobility and session management;
- The S1-AP (application part) protocol ensures the exchange of signaling between the MME and eNode B during mobile attachment, session establishment and intra eUTRAN handover based on the S1 interface;
- The GTP-U (GPRS tunnel protocol user) protocol provides tunneling of mobile traffic (the IP packet) between the eNode B and SGW entities. It also ensures tunneling of mobile traffic during inter-system handover between the SGW and SGSN entities. It also ensures the tunneling of the mobile traffic between the SGW and PGW entities;
- The GTP-C (GPRS tunnel protocol control) protocol handles the signaling exchanged during inter-system handover between the MME and SGSN entities. It also ensures the exchange of signaling between the SGW and SGSN entities. It also ensures the signaling relating to the management of the tunnel and the handover with relocation of the SGW entity between the SGW and PGW entities;
- The DIAMETER protocol provides signaling for access to mobile data (authentication, service profile) between the MME and HSS entities. It also provides signaling for the transfer of quality of service and charging rules between the PCRF entities of the host and visitor networks, and between the PCRF and PCEF entities. It also provides signaling for checking the mobile’s IMEI (international mobile equipment identity) between the MME and EIR entities.

2.3.4 Orange Guinea’s Core Network Architecture in 2020 [1, 5]

This architecture is achieved by integrating the EPC network architecture into the Sonfonia and Camayenne sites.

2.3.5 Architecture of the Non-autonomous 5G Network (NSA) [12, 24-26]

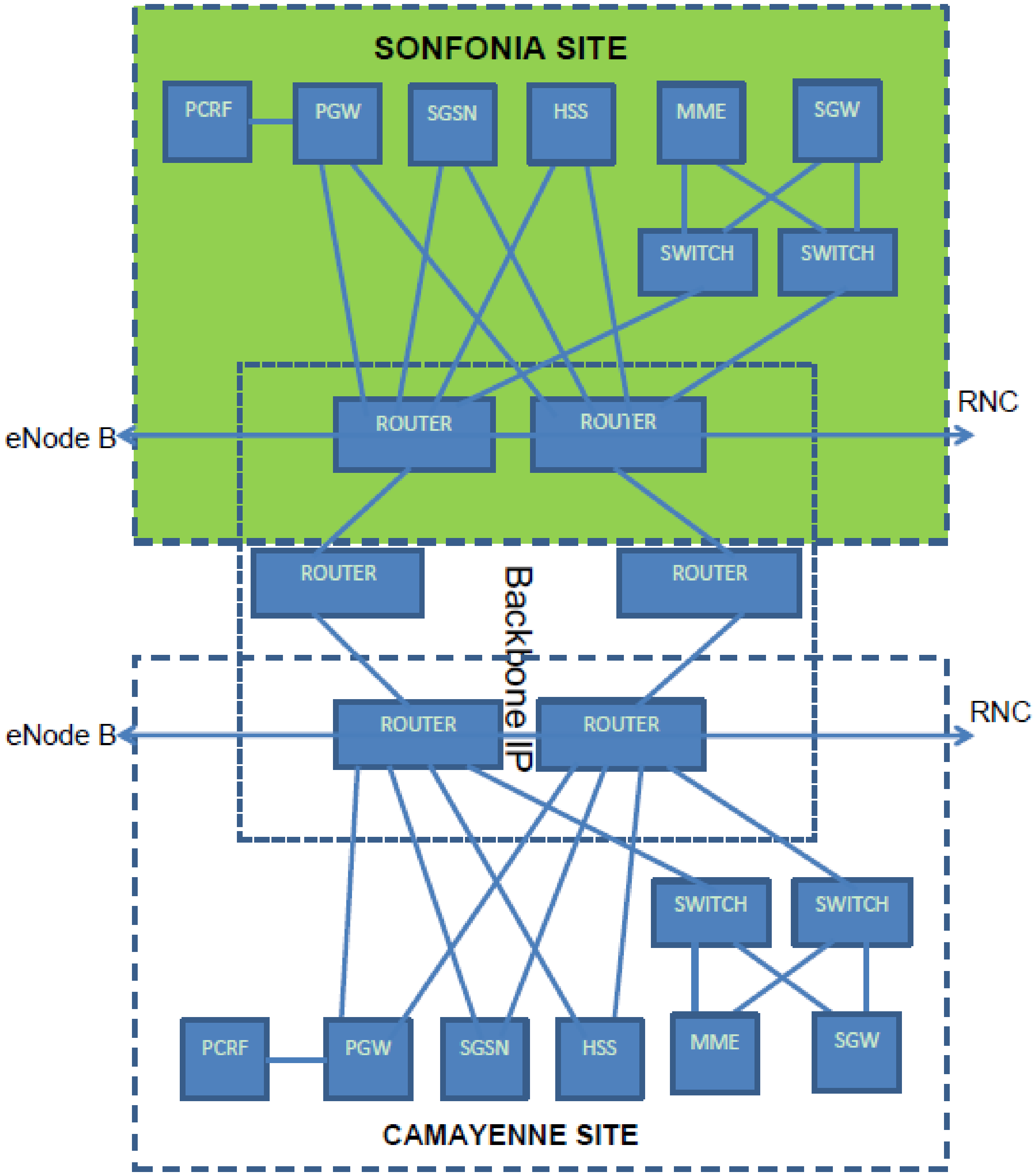

Fig. 3 Orange Guinea's core network architecture in 2020 [1, 5].

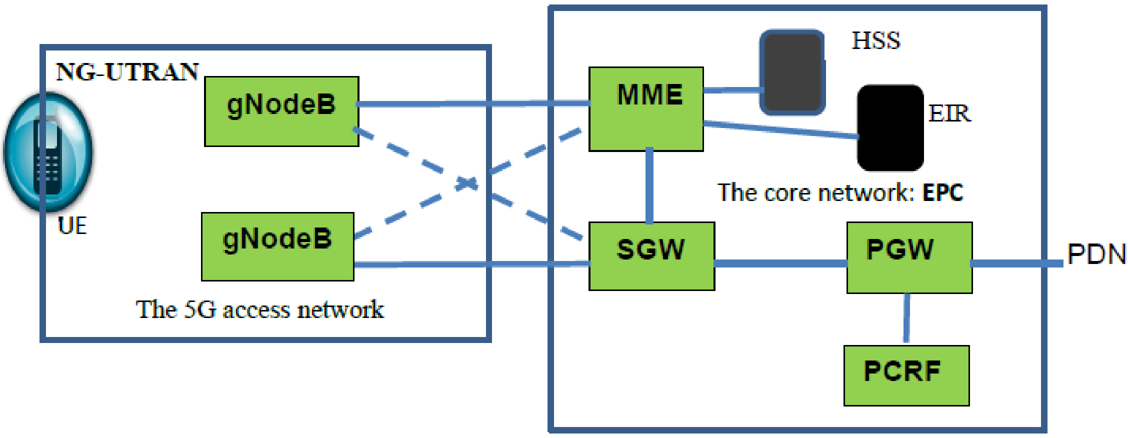

Fig. 4 5G NSA network architecture [12].
gNodeB: next generation Node B.

3. Results and Recommendations

3.1 Result Obtained

3.1.1 Architecture for Interconnecting 5G Access Technology to the EPC Core Network

Using the 5G access network (gNode B) and the EPC core network architecture, our proposed architecture is as follows [14, 16, 27].

3.1.2 Target Architecture

Using the existing Orange Guinea core network architecture (Fig. 3) and the interconnection architecture of the 3G, 4G and 5G access networks to the EPC core network (Fig. 5), the architecture we propose for Orange Guinea is as follows (Fig. 6) [12, 16, 18]:

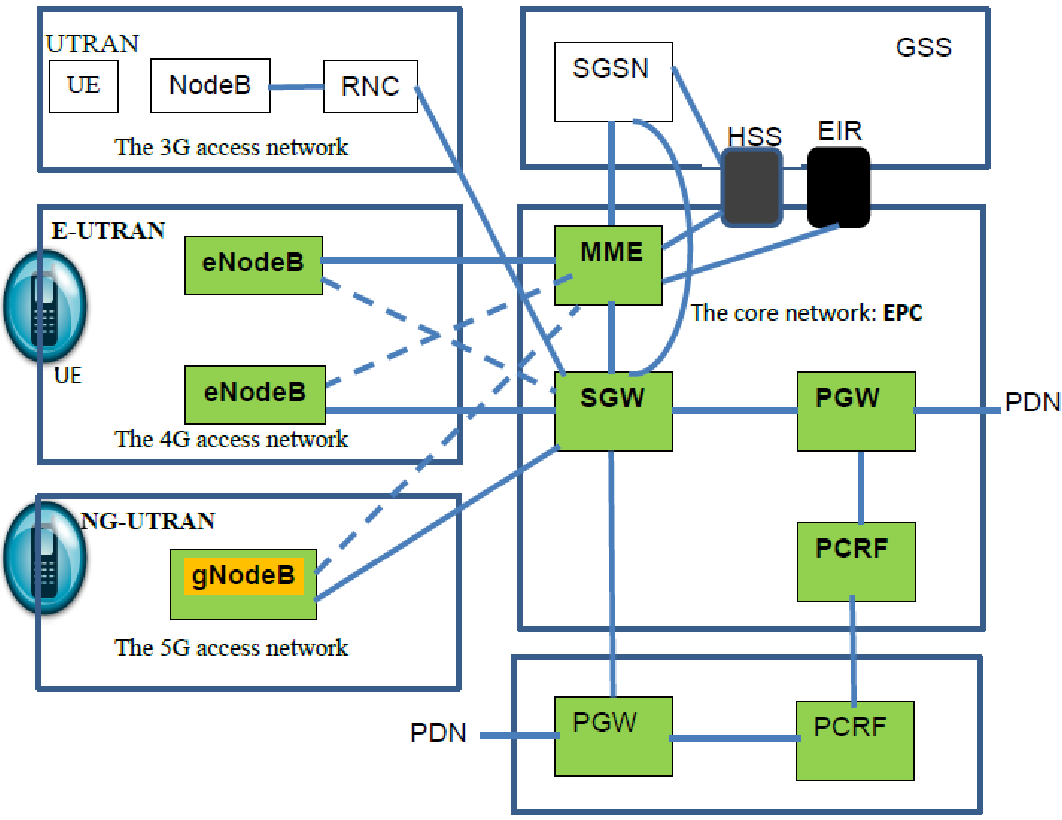

Fig. 5 Architecture for interconnecting 3G, 4G and 5G access networks to the EPC core network [26].

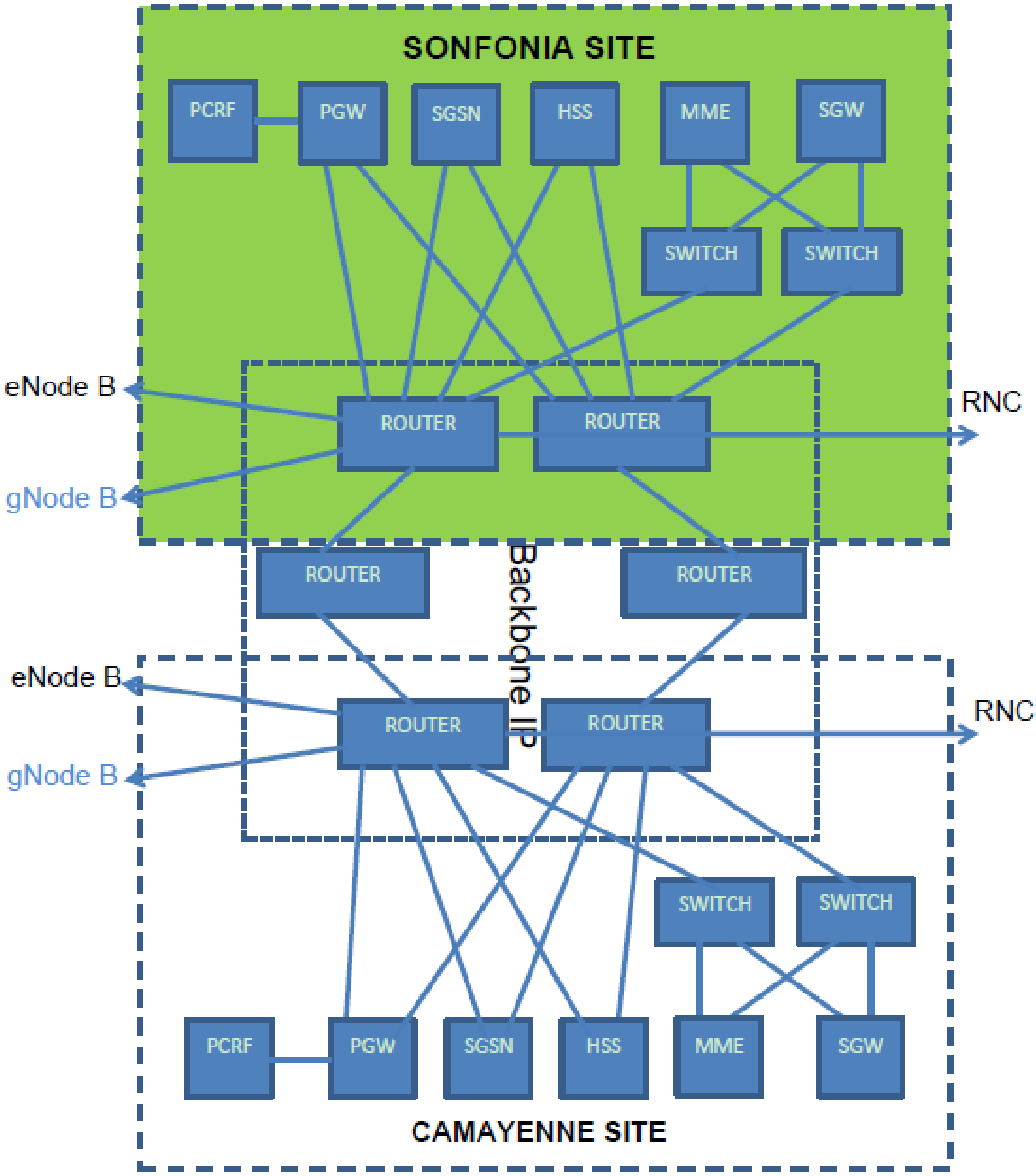

Fig. 6 Architecture target [24, 26].

3.2 List of Recommendations

Several recommendations can be used to deploy/size the EPC core network, including:

- Start by developing a strategy and action plan for the deployment/sizing of the EPC core network;
- Deploy the 5G access network (gNode B) and interconnect it to the EPC core network at the Sonfonia and Camayenne sites;
- Taking into account the advantages of the EPS network (throughputs, user throughput 7 times higher than HSPA+, data processing speed, capacity, higher number of frequency bands, full IP, packet switching, simplicity, reduced cost of operations, the possibility of connecting to several sites, etc.), deploy/size the EPC core network at the Sonfonia and Camayenne sites;
- Optimise the sizing of the EPC core network at these sites;

- Equip each exchange with an MME of sufficient capacity;
- Install the application servers and the HSS at each exchange;
- Interconnect this EPC core network to the existing core network using the target architecture in Fig. 6.

4. Conclusion

The ever-increasing need for high-speed networks for the Internet on the one hand and multimedia services on the other is forcing operators to adapt their networks by adopting new core network architectures. This is the background to our research project, in which we proposed the interconnection and dimensioning architecture of two EPC core networks for 4G/5G NSA networks as a solution in the Orange Guinea telecommunications network.

4G technology, launched in France in 2012 and deployed in November 2012 and in Guinea in 2019, continues to be deployed by operators, despite the emergence of the 5G network launched in France in 2020 and deployed in November 2020. The EPC core network is a backbone for all access technologies; it is reliable and efficient for data switching. It offers huge data rates (up to 100 Mb/s or even 1 Gb/s) [14, 24].

We began by presenting the architecture of Orange Guinea's core network in 2015 and 2020. We studied the EPS network, presenting its architecture, functional entities, interfaces and protocols. We presented the architecture of the 5G NSA network. We used the architecture of the Orange Guinea core network in 2020, that of the EPC core network and that of the 5G access network to create the interconnection architecture of the two (2) EPC network cores, which we called the target architecture.

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Conflict of Interests

We declare that there are no competing interests.

Author Contributions

The first author planned the study and wrote the protocol and manuscript. The second, third and sixth authors drew up the diagrams. The fourth, fifth and seventh authors carried out the bibliographic research.

All the authors read and approved the final manuscript.

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