A Study of Throughput for USSD Services over IMS

Thierry Kondengar
Polytechnic School
Dakar, Senegal
kondengart@gmail.com

Mamadou Alpha Barry
Multinational Higher School of Telecommunications
Dakar, Senegal
alpha.barry@esmt.sn

Boudal Niang
Multinational Higher School of Telecommunications
Dakar, Senegal
boudal.niang@esmt.sn

Samuel Ouya
Polytechnic School (ESP/UCAD)
Dakar, Senegal
samuel.ouya@gmail.com

***Abstract*— The USSD is a very popular and simple way to reach services in all mobile network generation. The telecom protocols based in IP (SIGTRAN) are used to integrate the USSD server to the mobile network. With the 4G and 5G networks the IP Multimedia Subsystem (IMS) is deployed for the services integration. The SIP is used by default to transport the signaling information in the IMS core. There is a big different between using SIGTRAN and SIP to transport the USSD messages. The goal of this paper is to analyze the resources usage and the more optimize protocol to transport the USSD messages. The results are obtained by using the USSD server with UTRAN radio access and the USSI with eNodeB/gNodeB in Non-Stand-Alone configuration.**

I. Introduction

As part of the digitization of the switched telephone network, the need arose to improve the speed of signaling exchanges. To this end, the ITU (International Telecommunication Union) established a global signaling standard called Signaling System N°7 (SS7). This standard defines the procedures and protocols required for signaling and communication. As a result, communication speeds and signal quality have increased, as has the separation of voice and data from signaling services.

This separation has encouraged the emergence of a large number of services such as SMS (Short Message Service) and USSD (Unstructured Supplementary Services Data). USSD is a two-way communication technology used to exchange data securely and instantaneously between a telephone operator and a user, without the need for an Internet connection. This service is compatible with all types of GSM phones, thanks to its simplicity of use and security.

USSD has become an essential lever for the development of innovative services, and is now being integrated into the next-generation 4G and 5G networks thanks to the IP protocols SIGTRAN and SIP. These protocols are both used to exchange signaling messages in the IP network, but there are major differences.

That's why, in this article, our research focuses on the integration of the USSD server over the SIP and SIGTRAN protocols, to determine which of the two best optimizes resources in the network.

In Proceedings of FRUCT conference there are two sections: Full Papers and Work in Progress. In the first section are articles having positive recall of most reviewers. In the second section will be published articles that need to be completed according to the reviewers. Also, in Work in Progress are published abstracts for performances.

II. Integration USSD server and USSI

A. *USSD server*

The USSD server provides exchange of USSD messages between mobile subscribers and external applications in PLMN. With the USSD server, the PLMN can provide subscribers with several attractive services: balance inquiry, payment card activation, profile management, and other services. [1]

The USSD server supports flexible algorithms of USSD message routing, considering service identifiers, message body and MSC-address sources, which allows to manage access policies and bandwidth individually for each application. Phase 1 and Phase 2 USSD support is provided, making it possible to create dialog USSD services with multi-level USSD menus. The SMPP v3.4 protocol allows for easy interaction with external content providers.

The system has a built-in convenient visualized USSD menu constructor with the possibility of integration with external information systems. Using this constructor, we can quickly and efficiently create new USSD services or modify the structure of the USSD menu using his own resources. Diameter, Open XML and ODBC interfaces are supported for interaction with external systems and databases, as well as interfaces for billing USSD requests.

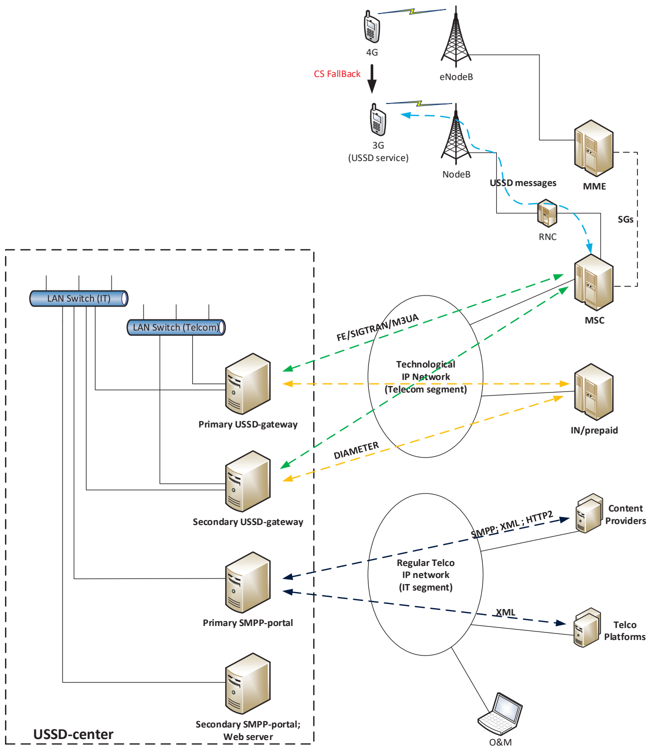

Fig. 1. Architecture USSD-Centre

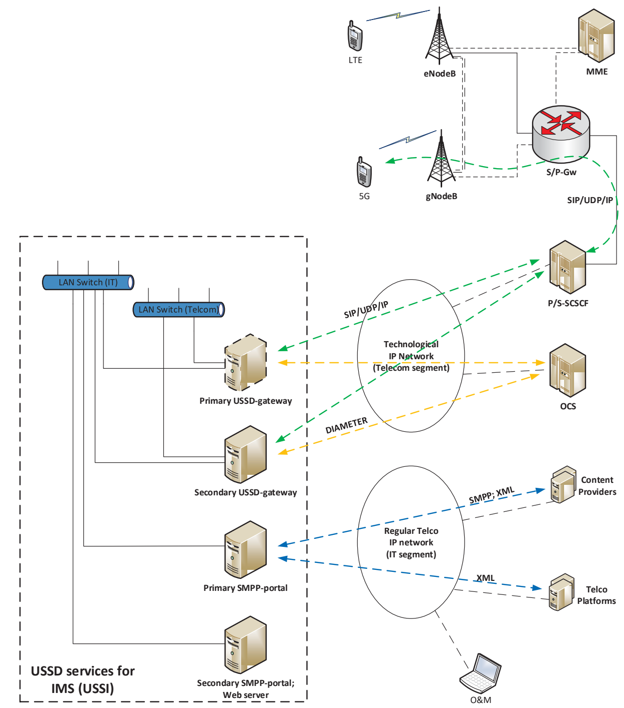

Fig. 2. Integration USSD services with IMS

B. USSI (USSD over IMS)

To enable integration with IMS networks, USSI functionality is supported [9]. The SIP protocol is used in LTE and 5G NR networks to transport USSD messages. Operators are gradually migrating from SIGTRAN-based USSD platforms to USSI platforms based on the IMS core.

III. SERVICE SCENARIO EXAMPLE

A. USSD on 3G radio access

There are several service scenarios based on USSD technology. The USSD requests from the UE are transported through base station and core network to the USSD Center. Then, depending on the code, the processing will be done by the application servers (AS):

- Balance check for voice, SMS and data services;
- Scratch card activation, credit transfer via the voucher management system;
- Purchase of multimedia content (Personalized Ring Back Tone);
- Mobile money transfer, Web payment, domestic bills payment, mobile money account check via the operator's platform (or digital financial service provider) [3].

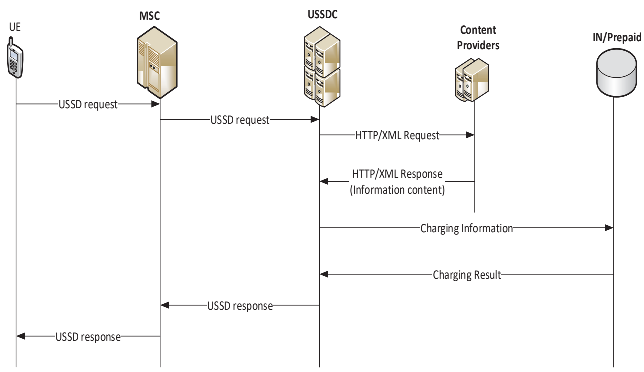

Fig. 3. USSD service orchestration using 3G radio access

The 3G/4G network generations use the same USSD platform based on CSFB access technology. The 4G subscribers switch to circuit switched networks when sending USSD requests. The IMS allows 4G/5G users to send USSD requests directly over an IP network [4].

B. USSD on 4G/5G radio access

The 3G/4G network generations use the same USSD platform based on CSFB access technology. The 4G subscribers switch to circuit switched networks when sending USSD requests. The IMS allows 4G/5G users to send USSD requests directly over an IP network [4].

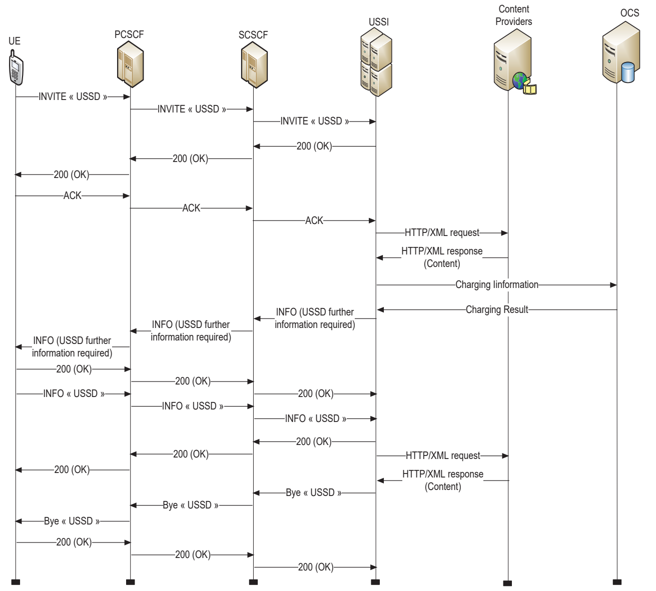

Fig. 4. USSD service orchestration using 4G/4G radio access

IV. PROTOCOL STACKS

A. Protocol study

The USSD service is carried by the signaling network in all mobile generations. The MAP/SIGTRAN protocol is deployed between USSD server and the Core Network elements. The SIP protocol is deployed between USSI server and the IMS core elements. The SCTP is used by SIGTRAN User Adaptation (UA) protocol layers to provide secure and reliable transport [2], [6], [8], [12].

We performed a TCPdump on an MSC-server to retrieve messages exchanged between it and other elements of a mobile operator's core network. This mechanism enabled us to copy a .pcap file for use on Wireshark.

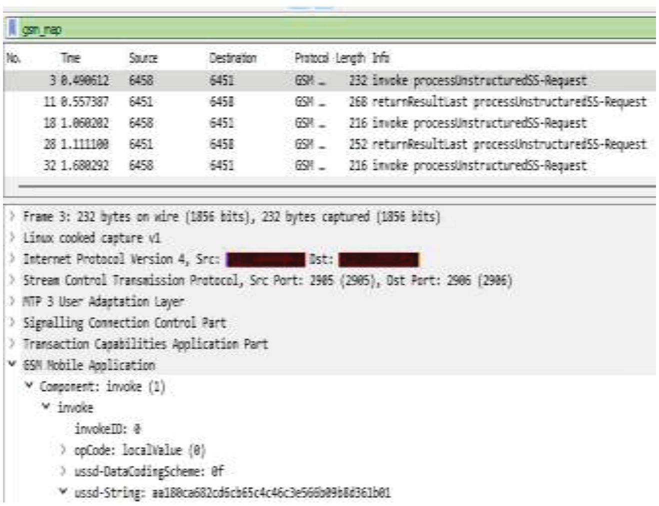

Fig. 5. SIGTRAN protocol stacks illustration in Wireshark

The implementation of SIGTRAN and SIP illustrates that the various RFCs defined within the IETF are being used by industry. The protocol stacks are obtained from the specification and the Wireshark tool.

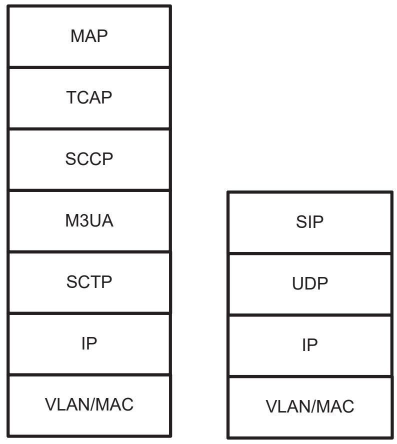

Fig. 6. SIGTRAN and SIP protocols stacks

B. Protocol header size

Protocol headers are given in bytes and have been defined through a detailed analysis of messages exchanged in the CS core and the IMS domain.

TABLE I. OVERHEAD OF PROTOCOLS

Protocol	Size (bytes)
MAC/VLAN	38
MAC	34
IP	20
UDP	8
SCTP	28
SIP	78
M3UA	32

The size of the SIGTRAN and SIP protocol headers is calculated from the sum of the headers and showed in the table II.

TABLE II. PROTOCOL STACKS SIZE

Protocols stacks	Size (bytes)
M3UA/SCTP/IP/VLAN/MAC	32+28+20+38
SIP/UDP/IP/VLAN/MAC	78+8+20+38

IV. THROUGHPUT

A. Bandwidth equations

The following parameters are used to calculate the throughput for the both protocols SIP and SIGTRAN:

- $N_{subscribers}$ - the number of subscribers using the USSD service;
- P_{SIP} - intensity of incoming SIP requests carrying USSD messages;
- L_{SIP} - the average size of a SIP message;

- K_{SIG} - the correction coefficient of the signaling;
- N_{SIP} - the average number of SIP messages required to establish a USSD session;
- $P_{SIGTRAN}$ - intensity of incoming SIGTRAN requests carrying USSD messages;
- $L_{SIGTRAN}$ - the average size of a SIGTRAN message;
- $N_{SIGTRAN}$ - the average number of SIGTRAN messages required to establish a USSD session.

The bandwidth required to transport SIP protocol messages is calculated using the following formula [13]:

$$V_{SIP} = k_{SIG} \times \frac{N_{subscribers} \times P_{SIP} \times L_{SIP} \times N_{SIP} \times 8}{3600} \quad (1)$$

The bandwidth required to transport SIGTRAN protocol messages is calculated using the following formula:

$$V_{SIGTRAN} = k_{SIG} \times \frac{N_{subscribers} \times P_{SIGTRAN} \times L_{SIGTRAN} \times N_{SIGTRAN} \times 8}{3600} \quad (2)$$

B. Number and length of messages

The table III illustrates the average number of USSD messages forwarded between the USSD server (i.e. USSD Center) and the core network to implement different types of service.

TABLE III. MESSAGE FLOW BETWEEN USSDC AND CORE NETWORK

Message Flow type	Note	Direction	Number of messages	Message Length
USSD between UE and USSDC / IN	Balance check	From UE to USSDC	4	118
USSD between UE and USSDC / Voucher Management System	Balance activation	From USSDC to UE	4	118
USSD between UE and USSDC / Location-Based Services Enabler	Bulk services (i.e. location-based services)	From USSDC to UE	4	118
USSD between UE and USSDC/ Telephony Application Server	Call Back	From USSDC to UE	6	118
USSD requests between UE and USSDC/Roaming Gateways	Roaming services	From USSDC to UE	8	118
USSD requests between UE and USSDC/ Mobile Money Platforms	Mobile Money services	From USSDC to UE	8	118
USSD requests between UE and USSDC/ Content Platforms	Content activation	From USSDC to UE	6	118

The table IV illustrates the average number of USSD messages forwarded between the USSD server and the IMS core to implement different types of service.

TABLE IV. MESSAGE FLOW BETWEEN USSI AND IMS CORE

Message Flow type	Note	Direction	Number of messages	Message Length
USSD between UE and USSI / IN	Balance check	From UE to USSDC	16	144
USSD between UE and USSI / Voucher Management System	Balance activation	From USSDC to UE	29	144
USSD between UE and USSI / Location-Based Services Enabler	Bulk services (i.e. location-based services)	From USSDC to UE	16	144
USSD between UE and USSI/ Telephony Application Server	Call Back	From USSDC to UE	16	144
USSD requests between UE and USSI/ Roaming Gateways	Roaming services	From USSDC to UE	29	144

USSD requests between UE and USSI/Mobile Money Platforms	Mobile Money services	From USSDC to UE	29	144
USSD requests between UE and USSI/ Content Platforms	Content activation	From USSDC to UE	29	144

The number of messages required to establish a session for each service is obtained by studying the call flows of the different services. The message size values for each protocol (SIGTRAN and SIP) are obtained from Table II.

V. Curves and Results

The variation curves depend on two parameters:

- the number of subscribers which are identical for the two protocols SIP and SIGTRAN whose values are the following: (one, five, ten, fifteen, and twenty) millions.
- the average number of messages necessary to establish a USSD session according to protocol [6], [8], [10].

A. SIGTRAN Throughput

The figure 7 illustrates the variation in bandwidth as a function of the number of subscribers sending USSD messages carried by SIGTRAN in the core network. We note that the curve increases in proportion to the number of subscribers, which is directly related to the number of SIGTRAN messages.

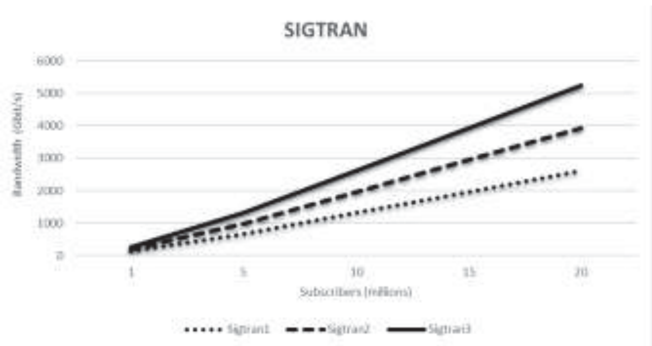

Fig. 7. SIGTRAN curve representation

B. SIP Throughput

The figure 8 shows the variation in bandwidth as a function of the number of subscribers sending USSD messages carried by SIP in the IMS core. We note that the curve increases in proportion to the number of subscribers, which is directly related to the number of SIP messages.

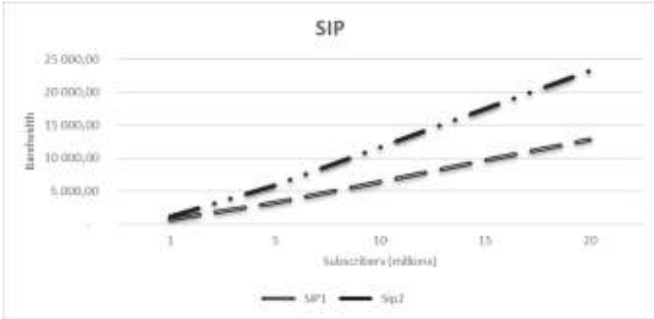

Fig. 8. SIP curve representation

C. Combination of the SIGTRAN and SIP curves

The figure 9 shows the combination of figures 7 and 8. It compares the SIP and SIGTRAN curves. The SIP protocol requires more bandwidth to transport USSD messages. The SIGTRAN protocol is much more optimal for transporting USSD messages in the core network.

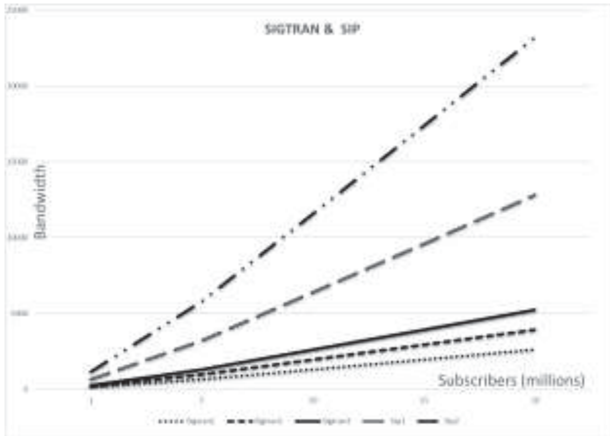

Fig. 9. Combination SIGTRAN versus SIP

D. USSD services

We study two USSD services to compare bandwidth usage. These are the following services:

1) Balance check via USSD: The number of messages for balance check are for SIP =16 and SIGTRAN = 4.

The SIP protocol requires more bandwidth to transport USSD messages for the balance check service. The SIGTRAN protocol is much more optimal for transporting USSD messages in the case of balance check.

Fig. 10. Balance check: SIGTRAN versus SIP

2) Roaming services activation via USSD: The number of messages for the roaming services activation are for SIP = 29 and SIGTRAN = 8.

The SIP protocol requires more bandwidth to transport USSD messages for the roaming service activation. The SIGTRAN protocol is much more optimal for transporting USSD messages in the case of the roaming service activation.

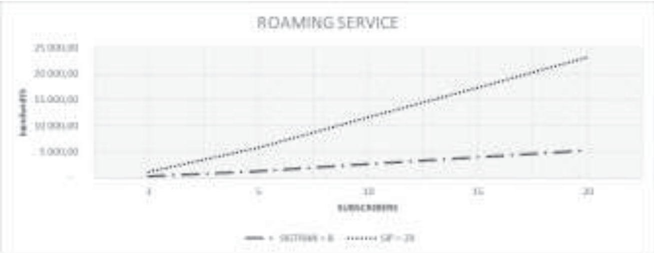

Fig. 11. Roaming service: SIGTRAN versus SIP

VII. CONCLUSION

The IP based protocols are used to integrate USSD server into the next generation mobile network. This is the case of SIP and SIGTRAN which are the subject of our study in this paper. The results are obtained using USSD server with UTRAN radio access and eUTRAN/5G RAN with USSI server for the study of USSD message flow exchanges. We see that the required bandwidth for SIP is more important than SIGTRAN bandwidth based on the same millions of subscribers. This leads us to believe that SIGTRAN is the best way to optimize resources in the next generation mobile network.

The 3GPP and GSMA recommend operators and industry to deploy IMS solution which is SIP based by default. This choice is based on the functionality, rapid deployment and scalability of SIP which also offers multimedia services over IP.

ACKNOWLEDGMENT

We warmly thank our colleagues for their invaluable assistance throughout this project.

We would also like to extend our thanks to the members of the LITA and eINOV laboratories for their willingness to participate and their invaluable contribution to our work. Finally, we extend our appreciation to all the individuals who provided their expertise, feedback, and encouragement throughout this process.

REFERENCES

[1] 3GPP TS 24.390. "Unstructured Supplementary Service Data Data (USSD) using IP Multimedia (IM) Core Network (CN) subsystem IMS; Stage 3 (Release 12)".
[2] IETF RFC 6086 (January 2011): "Session Initiation Protocol (SIP) INFO Method and Package Framework".
[3] 3GPP TS 24.090: " Unstructured Supplementary Service Data (USSD); Stage 3".
[4] 3GPP2 X.S0065-0 v1.0 (April 2012): "Unstructured Supplementary Service Data (USSD) Support".
[5] 3GPP TS 24.080: "Mobile radio interface layer 3 supplementary services specification; Formats and coding".
[6] 3GPP TS 24.229: "IP multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3".
[7] IETF RFC 4967 (July 2007): "Dial String Parameter for the Session Initiation Protocol Uniform Resource Identifier".
[8] 3GPP TS 24.238: "Session Initiation Protocol (SIP) based user configuration; Stage 3".
[9] IETF RFC 3023: "XML Media Types".
[10] IETF RFC 3261: "SIP: Session Initiation Protocol".
[11] 3GPP TS 24.391: "Unstructured Supplementary Service Data (USSD) using IP Multimedia (IM) Core Network (CN) subsystem (IMS) Management Object (MO)".
[12] 3GPP TS 23.221: "Architectural requirements".
[13] Ye Ouyang and Mahshid Fallah, "A study of throughput for Nb, Mc and Nc interface in UMTS core network" in 2009 IEEE 28th International and Performance Computing and Communications Conference (IPCCC). Scottsdale, AZ, USA: IEEE December 2009,