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Abstract

This document is an appendix to Deliverable D3.4 ("Report on C4MS standardization"). It complements the latter document as well as D3.3 ("Protocols, performance assessment and consolidation on interfaces for standardization"), in which the cost of C4MS signalling was evaluated. For this purpose, this document presents a detailed analysis of signalling overhead for non-C4MS signalling.

Keywords List

C4MS, 3GPP, Overhead Analysis.

[1] Dissemination level codes: **PU** = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
CO = Confidential, only for members of the consortium (including the Commission Services)

Executive Summary

The study presented in this document complements Deliverable D3.3 (“Protocols, performance assessment and consolidation on interfaces for standardization”), where the cost of C^4MS signalling was evaluated, and Deliverable D3.4 (“Report on C^4MS standardization”) with a detailed analysis of signalling overhead for non-C4MS signalling and an analysis of C4MS signalling for larger scale scenarios (detailed numerical results are presented which are expected to be a key requirement for driving C4MS related standardization in the future).

First, an analysis of the C4MS signalling introduced due to ON management for the scenario on opportunistic capacity extension through neighbouring terminals (i.e. SCE#2a) is performed for a set of specific test cases. The main aim of this analysis is firstly to complement the analysis provided in D3.3 (by providing signalling overhead analysis for larger scale scenarios) and secondly to determine the peak overhead (i.e. the worst case which represents the highest level overhead) in order to evaluate the potential cost of using C4MS. The C4MS overhead was studied with respect to the network context, e.g. the number of terminals in the congested and non-congested BSs, the number of terminals that switch to ON, the number of ON links, etc., as well as the devices capabilities, e.g. the number of air interfaces, the number of possible operating RATs per interface, etc. In the worst case scenario, it was proved that the total amount of bytes that were exchanged in order to create the ON was around 120 KB, which is very low for today’s networks. In addition, cases where periodic maintenance messages are transmitted were studied and in the worst case it was estimated that the required bitrate was around 12 KB/s which is also very low for LTE/UMTS and Wi-Fi networks.

Next, an analysis of the ON-related non-C4MS signalling introduced due to ON management for two ON implementation options (which are used as a basis to realize ONs in case of the “Core Network based centralized Architecture” or “Application Function based centralized Architecture” of the OneFIT system) is provided. The non-C4MS signalling is related to different procedures which do not involve exchange of information between CMON and CSCI entities (and thus cannot be qualified as a part of C4MS) but are required by the underlying radio systems to enable ON operation (e.g. setting up links, executing handovers, security). The main aim of this analysis is to determine the potential cost (in terms of signalling load) of using the proposed implementation options as a basis for realization of ONs and thus to enable evaluation of the total system overhead introduced by the ONs. The analysis is conducted for air interfaces as well as core network interfaces involved in the ON management. The results proved that in all cases the signalling load was low and around 1-15 KB.

Finally, the last section summarizes findings of this document and D3.3 and provides the estimated total system overhead (in terms of signalling load) which is introduced by the operation of ONs in SCE1, SCE#2a, SCE#3 and SCE#4 scenarios. The analysis is provided for the “Application Function based centralized Architecture” (assuming “Non-3GPP IP access” implementation option) and includes the C4MS signalling as well as ON-related non-C4MS signalling (excluding the signalling over OJ/OC interface).

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Table of Acronyms

Acronym	Meaning
3GPP	3rd Generation Partnership Project
ANDSF	Access Network Discovery and Selection Function
C^4MS	Control Channels for the Cooperation of the Cognitive Management System
CCR	Cognitive Control Radio
CMON	Cognitive Management system for the Opportunistic Network
CPC	Cognitive Pilot Channel
CSCI	Cognitive management System for the Coordination of the Infrastructure
D2D	Device-to-Device
ETSI	European Telecommunications Standards Institute
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
LTE	Long Term Evolution
MAC	Medium Access Control
MIH	Media-independent handover
ON	Opportunistic Network
OneFIT	Opportunistic networks and Cognitive Management Systems for Efficient Application Provision in the Future InterneT
ProSe	Proximity Services
RAT	Radio Access Technology
RRC	Radio Resource Control
RRM	Radio Resource Management
RRS	Reconfigurable Radio Systems
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
WLAN	Wireless Local Area Network

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1. C4MS signaling overhead

The following section provides analysis of the C4MS signalling introduced due to ON management for the scenario on opportunistic capacity extension through neighboring terminals (i.e. SCE#2a). The main aim of this section is to 1) complement the analysis provided in D3.3 (by providing signalling overhead analysis for larger scale scenarios) and 2) determine the peak overhead (i.e. the worst case which represents the highest level overhead) to evaluate the potential cost of using C4MS and enable evaluation of the total system overhead introduced by the ONs. The analysis is conducted for the CI/OM interfaces between different nodes and is valid for all the possible architecture options identified in D2.2.2 (see [2], Section 3.2 for more detail on the possible architecture options). Specific test cases are considered for the evaluation as provided in the following table:

Table 1: Considered test cases

Case	Considered Attributes
1	• Total BSs: 7 • Non-congested BSs: 6 • Congested BSs: 1 • Terminals in non-congested BSs: 15 • Terminals in congested BS: 40 • Terminals switching to ONs: 12 • # created ONs: 12 • # links per ON: 2 • # of interfaces in BSs: 1 • # of interfaces in terminals: 2 • # of RATs (per interface): 1
2	• Total BSs: 7 • Non-congested BSs: 6 • Congested BSs: 1 • Terminals in non-congested BSs: 20 • Terminals in congested BS: 80 • Terminals switching to ONs: 24 • # created ONs: 24 • # links per ON: 2 • # of interfaces in BSs: 1 • # of interfaces in terminals: 2 • # of RATs (per interface): 1
3	• Total BSs: 7 • Non-congested BSs: 6 • Congested BSs: 1 • Terminals in non-congested BSs: 25 • Terminals in congested BS: 160 • Terminals switching to ONs: 48 • # created ONs: 48 • # links per ON: 2 • # of interfaces in BSs: 1 • # of interfaces in terminals: 2 • # of RATs (per interface): 1

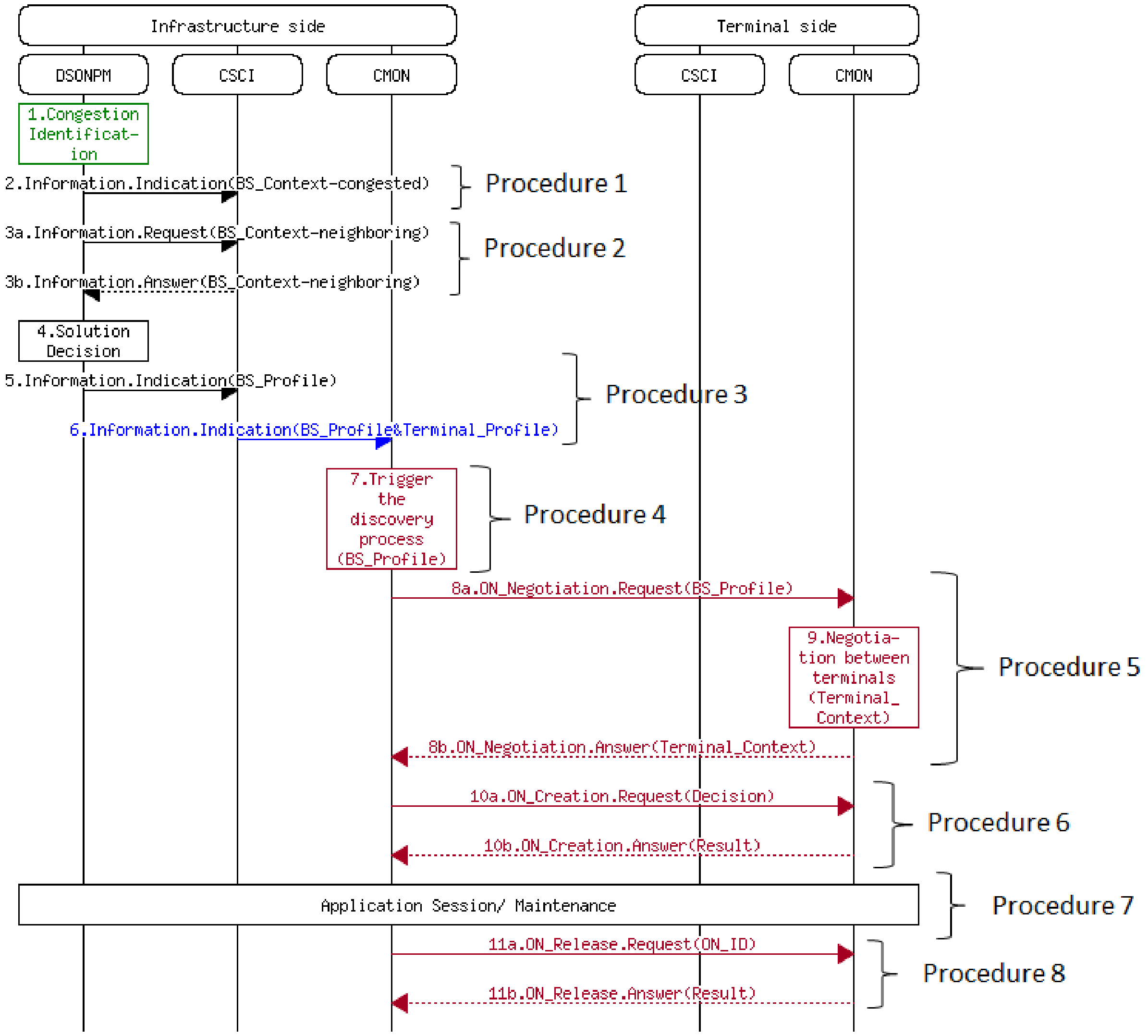

Figure 1: Mapping of messages and related information to procedures

The charts that follow provide associated signalling load for the creation, maintenance and termination of ONs according to the provided input parameters in Table 1. For the calculation of the signalling load, the structures and formulas provided in D3.3 [3] [4] are exploited. The considered procedures in Figure 2 reflect the procedures that have been identified in Figure 1. For the suitability determination-creation and termination relevant procedures (i.e., procedures 1-6 and 8), triggered-based events are considered. On the contrary, for the maintenance phase (i.e., procedure 7) a periodic exchange of signalling messages is also considered.

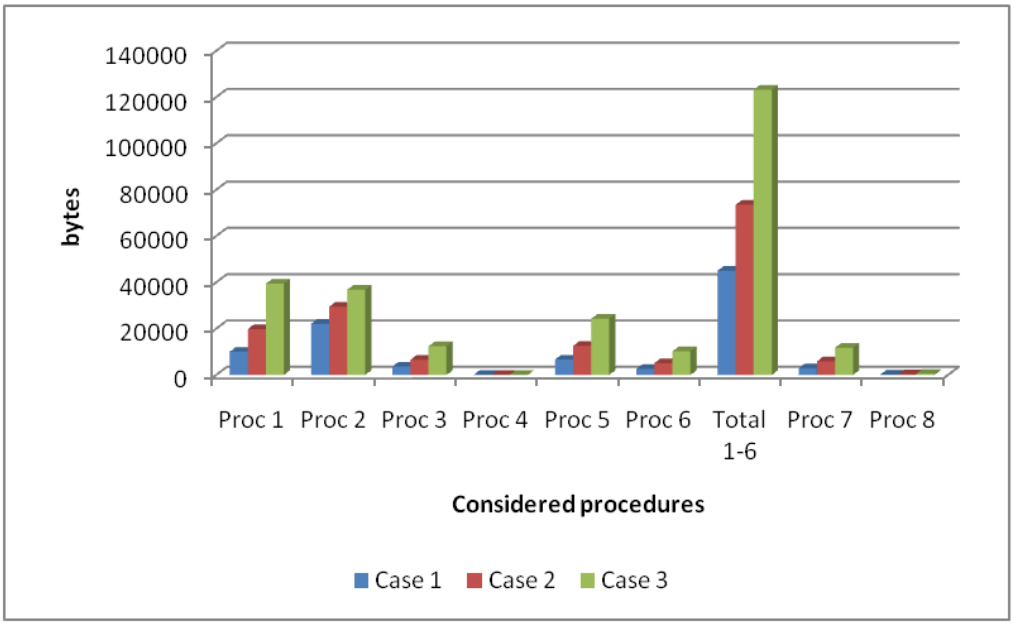

Figure 2: Signalling load associated with specific procedures

Figure 3 provides an estimation of the periodic signaling load which is considered to take place during the maintenance phase of the ON. Specifically, during this phase, terminal context is considered to be sent periodically (every 1, 5 or 30 seconds) in order to know the status of the nodes involved in the ON (e.g. their current location, current energy level, current links etc.). It is observed that as long as the intervals of transmission are more closely defined, the signaling load per second (bytes/s) is higher (for each case considered).

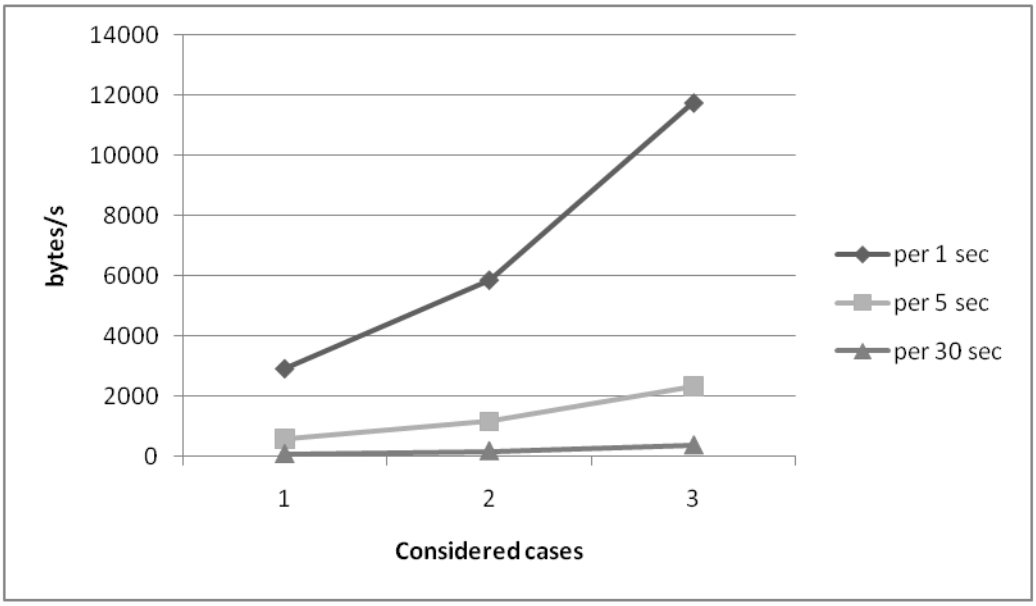

Figure 3: Calculation of periodic signalling load associated with procedure 7 (ON maintenance)

2. Non-C4MS signaling overhead due to ON management

The following section provides analysis of the ON-related non-C4MS signalling introduced due to ON management for two possible ON implementation options (see [2], Section 3.2 for more detail). The non-C4MS signalling is related to different procedures which do not involve exchange of information between CMON and CSCI entities but are required by the underlying radio systems to enable ON operation (e.g. setting up links, executing handovers, security). The main aim of this section is determine the potential cost (in terms of signalling load) of using the proposed implementation options as a basis for realization of ONs and thus to enable evaluation of the total system overhead introduced by the ONs. The analysis is conducted for air interfaces as well as core network interfaces involved in the ON management.

2.1 "Native 3GPP" implementation option

The following section estimates the ON-related non-C4MS signalling for a "native 3GPP" ON implementation option which provides the necessary basis to realize ONs in case of the "Core Network based centralized Architecture" (see [2], Section 3.2.2 for more detail on "Core Network based centralized Architecture").

In D3.3 section 6.7, figures were given to evaluate the cost of C4MS signalling on the air interface for the building of a WLAN-based ON, controlled by the ON Manager through native ePC/eUTRAN c-plane .

The present section aims at identifying the ON-related non-C4MS signalling cost on each of the ePC/eUTRAN interface, i.e. the cost of additional legacy signalling as a "side effect" of the management of ON.

For this evaluation, we consider the 2 basic scenarios for ONs:

1. a UE-to-network connection over a UE-relay
2. a direct UE-to-UE connection

The simplified architecture for the "native 3GPP" implementation option is as follows:

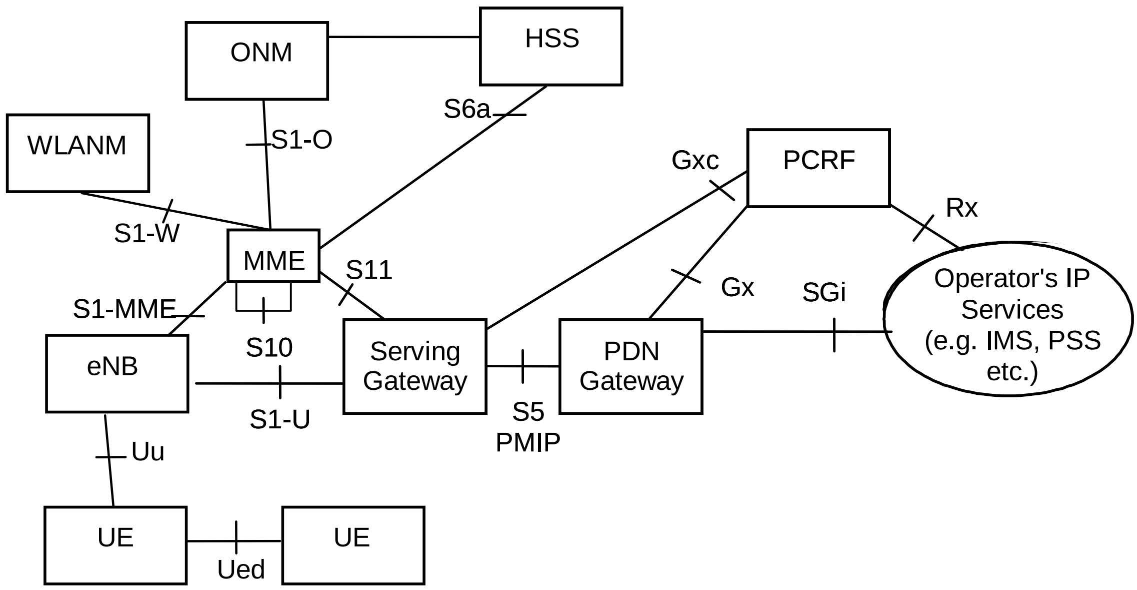

Figure 4: Simplified architecture for the "native 3GPP" implementation option

The legacy interfaces to consider are essentially: Uu, S1-MME and S6a.

2.1.1 Direct UE-to-UE communication

In D3.3 section 6.7, we identified that the total signalling messages for the creation and the termination of an ON between two UEs to 16 messages and 928 bytes in size (464 bytes per UE).

This is to establish and release a WLAN connection between the 2 UEs and an IP path on top of this L2 connection.

This was the cost on the Uu air interface, but we can easily do a rough estimate of the cost on the network interfaces because, as shown in D3.3 PartB section 2.3.5, we propose an architecture where the information required for creating/terminating the ON is transparently transported through the ePC/eUTRAN via container in existing messages of interfaces S1 and Uu.*

So the “payload” being the 928 bytes mentioned above, we can safely estimate that the full cost of transporting it on S1 interface is below 1.5kByte.

With regard to extra non-C4MS signalling possibly due to the ON management, we have identified none: all the legacy procedures continue to be performed via the cellular connection, with no additional complexity or triggers.

2.1.2 UE-to-network communication over UE-Relay

The “UE-Relay” scenario implies 5 procedures:

1. Initial Attach, for the relayed UE to perform a normal attachment to the network
2. Detach procedure, for the relayed UE to perform a normal detachment from the network
3. Cellular-to-Relay Handover, when the relayed UE already had an active cellular connection
4. A Relay-to-Cellular Handover, when the relayed UE is moved back to normal cellular communication
5. A Relay-to-Relay Handover, e.g. to tackle the mobility of the UE-Relay

2.1.2.1 Initial Attach procedure

In this scenario, the first phase is to establish a L2 link between the UEs, similarly to the direct UE-to-UE scenario previously described. Depending on implementation choices, this establishment may be without security, nor IP layer setup: then the signalling cost is at maximum equal to the 928 Bytes already mentioned.

This data link is then used for carrying normal legacy messages for performing the attachment of the relayed UE to the network: these messages are again transparently forwarded by the UE-Relay in both directions. As a result, each message is de facto transmitted twice on the air interface.

This is a “worst case” view as one could argue that there are actually 2 separate air interfaces because they use different radio resources.

Apart from this “double” cost on the air interface, there is a slight cost between UE-Relay and the network in order to establish a specific bearer for relaying the signalling of the relayed UE. As attachment occurs rarely, this additional cost can be considered negligible.

With regard to network interfaces, no additional cost is identified as the procedure is strictly identical to the legacy one, e.g. viewed from the HSS.

2.1.2.2 Detach procedure

When the relayed UE wants to detach from the network, the cost is similar to the Attach procedure, excluding the cost of establishing the data link between the UEs.

2.1.2.3 Cellular-to-relay handover procedure

This procedure is used only when the relayed UE had an active communication on the cellular link prior to the decision to have this UE relayed by another one.

This means that, in addition to the setup of the datalink between the 2 UEs et the additional bearer between UE-Relay and the network, the "u-plane switching" part (involving MME and SGW/PGW) of the legacy inter-eNB handover procedure must be performed.

So the cost of this handover appears similar if not inferior to the one for a legacy handover.

2.1.2.4 Relay-to-cellular handover procedure

This procedure is used to terminate the relaying situation.

Again the relaying path is used for carrying the legacy messaging: so only the "second" transmission over the air interface is an additional cost.

Again, as it is a rare procedure, the cost can be considered as negligible.

2.1.2.5 Relay-to-relay handover procedure

This procedure is very similar to a legacy inter-eNB handover.

1. Establish the data link with the new UER
2. U-plane switching
3. Release the data link with old UER

Steps 1 and 3 have similar cost to the 968 Bytes already mentioned. Step 2 is inferior to the cost of a complete legacy inter-eNB handover.

So the cost of this handover appears similar if not inferior to the one for a legacy handover.

2.2 "Non-3GPP IP access" implementation option

The following section provides analysis of the ON-related non-C4MS signalling for the Untrusted non-3GPP IP access which is used as a basis to realize ONs in SCE#1, SCE#2a and SCE#4 in case of the "Application Function based centralized Architecture" (see [2], Section 3.2.3 for more detail on "Application Function based centralized Architecture" and Section 3.4.2 for more detail on security for Non-3GPP access). The main aim of this section is determine the potential cost (in terms of signalling load) of using Untrusted non-3GPP IP access as a basis for realization of ONs and thus to enable evaluation of the actual gain introduced by the ONs in SCE#1, SCE#2a and SCE#4.

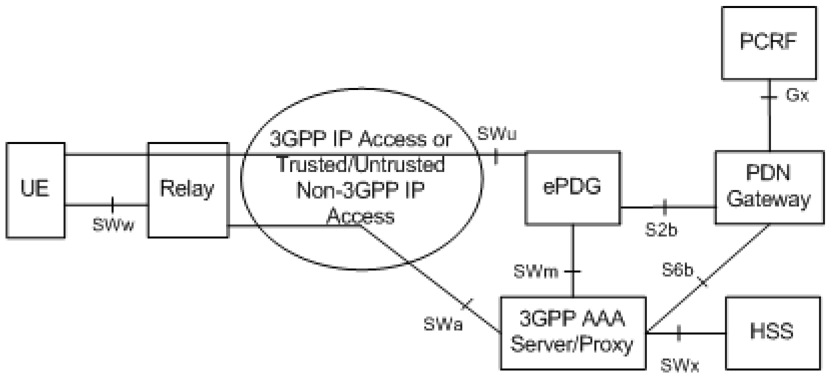

Figure 5: Simplified architecture for Operator governed Device based Mobile Relays [2]

The analysis conducted in this section is focused on determining the cost of procedures for NON-ROAMING scenarios (i.e. when UE and Relay belong to the same operator) with network-based mobility (see [9] for more detail) related to 1) initial network attach, 2) network detach and 3) handovers. The analysis is based on MSCs which are compiled using [9], [17], [16], [7], [12] and the calculation of the message sizes to determine the signalling load using [14] (for GTP based S2b), [13] (for Diameter based SWa, SWm, SWx, S6b interfaces), [11] (for Diameter based Gx interface), [20] (for IKEv2 based SWu interface), [18] (for EAPOL based SWw interface), [6] (addresses and identifiers).

The following assumptions are considered during the analysis:

- General assumptions:
  - Infrastructure employs GTP-based S2b (Gxb interfaces is not required [12])
  - Infrastructure and Opportunistic Networks are based on IPv4 protocol
  - Relay has an active IP connection and a valid subscriber certificate (see [2], Section 3.4.2.3 for more detail)
  - UE and Relay have an active L2 connection over a short range radio interface (overhead related to L2 association is not considered)
- EAP AKA related assumptions:
  - 3GPP AAA Server does not require user identity to be delivered using AKA-identity (no additional EAP exchanges),
  - 3GPP AAA Server and the UE do NOT indicated the use of protected successful result indications over AKA-Notification (no additional EAP exchanges)
- IKEv2 related assumptions:
  - Public key certificate size – 712 Bytes[2]; public-key length – 128 Bytes,
  - Nonce size – 136 Bytes; Considered cryptographic algorithms – AES-CBC, HMAC-SHA-96, Diffie-Hellman group 2, PRF-HMAC-SHA1; Number of cryptographic algorithm proposals – 1 (4 transforms), Number of traffic selectors – 1, number of trusted Certification Authorities – 1;
  - Support for NAT traversal, support for MOBIKE;
- PCC related assumptions:
  - PCRF shall be responsible only for activation/deactivation of different predefined PCC rules which are preconfigured in PCEF (no dynamic PCCs),
  - Application Detection and Control (ADC), IP flow mobility and Access Network Information Reporting in not supported [11]

2.2.1 Initial attach procedure

The following subsection analyzes the signalling introduced by the procedures which allow an UE to be properly attached to the network over a Relay based access. The analysis is based on a compilation of MSCs for non-roaming scenarios from [9] (Section 7.2.4, 12.1.1, 12.1.4), [17] (Section 8.2.2), [16] (Section 6.1.1.1), [7] (Section 7.2), [12] (Section 4.1). Table 2 summarizes the signalling load introduced by the procedures on different interfaces.

[2] A certificate example generated using openssl

Table 2: Signaling load introduced by the Initial Attach procedures

Interface	Signalling load on the link between UE and Relay [B]	Signalling load on the link between Relay and Network [B]	Signalling load on within the Core Network [B]
SWw	225	N/A	N/A
SWu	3137	3137	N/A
SWa	N/A	4139	N/A
SWm	N/A	N/A	1895
S2b	N/A	N/A	412
S6b	N/A	N/A	696
SWx	N/A	N/A	2545
Gx	N/A	N/A	691
Total	**3362**	**7276**	**6239**

Table 3: Signaling load introduced on the SWw interface during the authentication and authorization procedures

Message	Message size [B]	Direction
EAPOL-start	0	UE->Relay
EAP-Request/Identity	5	Relay ->UE
EAP-Response/Identity	59	UE->Relay
EAP-Request/AKA-challenge	108	Relay->UE
EAP-Response/AKA-challenge	48	UE->Relay
EAP-Success	5	Relay->UE
Total	**225**	**N/A**

Table 4: Signaling load introduced on the SWa interface during the authentication and authorization procedures

Message	Message size [B]	Direction
Diameter-EAP-Request (EAP-Response/Identity)	394	Relay->AAA server
Diameter-EAP-Answer (EAP-Request/AKA-challenge)	388	AAA server ->Relay
Diameter-EAP-Request (EAP-Response/AKA-challenge)	383	Relay->AAA server
Diameter-EAP-Answer(EAP-Success)	381	AAA server ->Relay
Total	**1004**	**N/A**

Table 5: Signaling load introduced on the SWa interface during the IPsec tunnel setup for secure exchange of authentication and authorization information

Message	Message size [B]	Direction
IKE_SA_INIT_Request(NAT detection, ...)	460	Relay->AAA server
IKE_SA_INIT_Response(NAT detection, Cert Request, ...)	485	AAA server ->Relay
IKE_AUTH_Request(Cert, Cert Request, AUTH, Selectors, ...)	1114	Relay->AAA server
IKE_AUTH_Response(Cert, AUTH, Selectors, ...)	1075	AAA server ->Relay
Total	**3135**	**N/A**

Table 6: Signaling load introduced on the SWu interface during the authentication and authorization procedures

Message	Message size [B]	Direction
IKE_SA_INIT_Request(NAT detection, ...)	460	UE->ePDG
IKE_SA_INIT_Response(NAT detection, ...)	460	ePDG->UE
IKE_AUTH_Request(APN-info, User ID, ...)	291	UE->ePDG
IKE_AUTH_Response (ePDG ID, ePDG Certificate, EAP-Request/AKA-challenge, AUTH, ...)	1103	ePDG->UE
IKE_AUTH_Request (EAP-Response/AKA-challenge)	144	UE->ePDG
IKE_AUTH_Response (EAP-Success)	101	ePDG->UE
IKE_AUTH_Request (AUTH)	232	UE->ePDG
IKE_AUTH_Response (AUTH, UE IP address, Traffic Selectors, ...)	346	ePDG->UE
Total	**3137**	**N/A**

Table 7: Signaling load introduced on the SWm interface during the authentication and authorization procedures

Message	Message size [B]	Direction
Diameter-EAP-Request (EAP-Response/Identity)	417	ePDG->AAA server
Diameter-EAP-Answer (EAP-Request/AKA-challenge)	312	AAA server->ePDG
Diameter-EAP-Request (EAP-Response/AKA-challenge)	374	ePDG->AAA server
Diameter-EAP-Answer(EAP-Success, EAP-Master-Session-Key, APN-Configuration, …)	792	AAA server->ePDG
Total	**1895**	**N/A**

Table 8: Signaling load introduced on the SWx interface during the authentication and authorization procedures

Message	Message size [B]	Direction
Multimedia-Auth-Request	388	AAA server->HSS
Multimedia-Auth-Answer	422	HSS->AAA server
Total	**810**	**N/A**

Table 9: Signaling load introduced on the SWx interface during the Non-3GPP IP Access Registration Procedure (User registration)

Message	Message size [B]	Direction
Server-Assignment-Request	348	AAA server->HSS
Server-Assignment-Answer	781	HSS->AAA server
Total	**1129**	**N/A**

Table 10: Signaling load introduced on the SWx interface during the Non-3GPP IP Access Registration Procedure (PGW update)

Message	Message size [B]	Direction
Server-Assignment-Request	348	AAA server->HSS
Server-Assignment-Answer	258	HSS->AAA server
Total	**606**	**N/A**

Table 11: Signaling load introduced on the S2b interface during the GTP tunnel setup

Message	Message size [B]	Direction
Create-Session Request	272	ePDG->PDN-GW
Create-Session Response	140	PDN-GW->ePDG
Total	**412**	**N/A**

Table 12: Signaling load introduced on the S6b interface during the Authorization Procedure over S6b

Message	Message size [B]	Direction
AA-Request	451	PDN-GW->AAA server
AA-Answer	245	AAA server->PDN-GW
Total	**696**	**N/A**

Table 13: Signaling load introduced on the Gx interface during the IP-CAN session establishment (for non-3GPP IP access) over Gx

Message	Message size [B]	Direction
CC-Request	436	PDN-GW->PCRF
CC-Answer	255	PCRF->PDN-GW
Total	**691**	**N/A**

2.2.2 UE/ePDG initiated detach procedure

The following subsection analyzes the signalling introduced by the procedures related to UE/ePDG initiated detach which allow an UE attached to the network over a Relay based access to detach. The analysis is based on a compilation of MSCs for non-roaming scenarios from [9] (Section 7.4.3, Section 12.1.2), [7] (Section 7.3.2), [12] (Section 4.2.2). Table 14 summarizes the signalling load introduced by the procedures on different interfaces.

Table 14: Signaling load introduced by the 3GPP to Relay based access handover procedures

Interface	Signalling load on the link between UE and Relay [B]	Signalling load on the link between Relay and Network [B]	Signalling load within the Core Network [B]
SWw	0	N/A	N/A
SWu	0	0	N/A
SWa	N/A	526	N/A
SWm	N/A	N/A	0
S2b	N/A	N/A	40
S6b	N/A	N/A	481
SWx	N/A	N/A	753
Gx	N/A	N/A	570
Total	**0**	**526**	**1844**

Table 15: Signaling load introduced on the S2b interface during the GTP tunnel deletion procedure

Message	Message size [B]	Direction
Delete-Session Request	17	ePDG->PDN-GW
Delete-Session Response	23	PDN-GW->ePDG
Total	**40**	**N/A**

Table 16: Signaling load introduced on the S6b interface during the PDN GW Initiated Session Termination procedure

Message	Message size [B]	Direction
Session-Termination-Request	300	PDN-GW->AAA server
Session-Termination-Answer	181	AAA server ->PDN-GW
Total	**481**	**N/A**

Table 17: Signaling load introduced on the SWa interface during the AAA Initiated Detach procedure

Message	Message size [B]	Direction
Abort-Session-Request	346	AAA server ->Relay
Abort-Session-Answer	180	Relay->AAA server
Total	**526**	**N/A**

Table 18: Signaling load introduced on the SWx interface during Non-3GPP IP Access Registration Procedure (User de-registration)

Message	Message size [B]	Direction
Server-Assignment-Request	495	AAA server->HSS
Server-Assignment-Answer	258	HSS->AAA server
Total	**753**	**N/A**

Table 19: Signaling load introduced on the Gx interface during the PCEF-Initiated IP-CAN session termination

Message	Message size [B]	Direction
CC-Request	315	PDN-GW->PCRF
CC-Answer	255[3]	PCRF->PDN-GW
Total	**570**	**N/A**

2.2.3 3GPP based access to Relay based access handover procedure

The following subsection analyzes the signalling introduced by the procedures that are necessary to conduct a handover from a 3GPP based access (in this case E-UTRAN based access) to a Relay based access in a non-roaming scenario (i.e. when UE and Relay belong to the same operator). The analysis is based on a compilation of MSCs from [9] (Section 7.9.2, Section 8.6.2.1 and Section 12.1.2), [17] (Section 8.2.2), [16] (Section 6.1.1.1), [7] (Section P.7.4.1), [12] (Section E.4.4.1.3). Table 20 summarizes the signalling load introduced by the handover procedure on different interfaces

[3] Assuming deactivation of a single PCC rule

Table 20: Signaling load introduced by the 3GPP to Relay based access handover procedures

Interface	Signalling load on the link between UE and Relay [B]	Signalling load on the link between Relay and Network [B]	Signalling load within the Core Network [B]
SWw	225	N/A	N/A
SWu	3137	3137	N/A
SWa	N/A	4139	N/A
SWm	N/A	N/A	1895
S2b	N/A	N/A	412
S6b	N/A	N/A	696
SWx	N/A	N/A	2545
Gx	N/A	N/A	680
Total	**3362**	**7276**	**6228**

The signalling load on the interfaces SWa, SWm, SWu, SWw, SWx, S2b, S6b, corresponds to the signalling load introduced during the initial attachment, as presented in Section 2.2.1. It needs to be underlined here that S5, S11, and S6a interfaces are not considered in the analysis. This is mainly motivated by the fact that a handover from E-UTRAN based access to Relay based access employs similar procedures as a handover from E-UTRAN to UTRAN. This indicates that the signalling load introduced by the ONs on S5, S11 and S6a interfaces does not differ much from a scenario in which ONs are not employed.

Table 21: Signaling load introduced on the Gx interface during the PCEF-Initiated IP CAN Session Modification Procedure (for non-3GPP IP access)

Message	Message size [B]	Direction
CC-Request	389	PDN-GW->PCRF
CC-Answer	291[4]	PCRF->PDN-GW
Total	**680**	**N/A**

2.2.4 Relay based access to 3GPP based access handover procedure

The following subsection analyzes the signalling introduced by the procedures that are necessary to conduct a handover from a Relay based access to a 3GPP based access (in this case E-UTRAN based access) in a non-roaming scenario (i.e. when UE and Relay belong to the same operator). The analysis is based on a compilation of MSCs from [9] (Section 7.9.2, Section 8.6.1.1, and Section 12.1.2), [7] (Section 7.4.1), [12] (Section 4.3.2.1). Table 22 summarizes the signalling load introduced by the procedures on different interfaces.

[4] Assuming activation and deactivation of a single PCC rule

Table 22: Signaling load introduced by the Relay based access to 3GPP based access handover procedure

Interface	Signalling load on the link between UE and Relay [B]	Signalling load on the link between Relay and Network [B]	Signalling load within the Core Network [B]
SWw	0	N/A	N/A
SWu	0	0	N/A
SWa	N/A	526	N/A
SWm	N/A	N/A	0
S2b	N/A	N/A	93
S6b	N/A	N/A	481
SWx	N/A	N/A	753
Gx	N/A	N/A	656
Total	**0**	**526**	**1983**

It needs to be underlined here that LTE-Uu, S5, S11, S1-MME, and S6a interfaces are not considered in the analysis. This is mainly motivated by the fact that a handover from Relay based access to E-UTRAN based access employs similar procedures as a handover from UTRAN to E-UTRAN. This indicates that the signalling load introduced by the ONs on LTE-Uu, S5, S11, S1-MME and S6a interfaces does not differ much from a scenario in which ONs are not employed.

Table 23: Signaling load introduced on the S2b interface during the PDN GW initiated Resource Allocation Deactivation procedure

Message	Message size [B]	Direction
Delete-Bearer Request	39	PDN-GW-> ePDG
Delete-Bearer Response	54	ePDG-> PDN-GW
Total	**93**	**N/A**

Table 24: Signaling load introduced on the Gx interface during the PCEF-Initiated IP CAN Session Modification Procedure

Message	Message size [B]	Direction
CC-Request	365	PDN-GW->PCRF
CC-Answer	291[5]	PCRF->PDN-GW
Total	**656**	**N/A**

[5] Assuming activation and deactivation of a single PCC rule

Table 25: Signaling load introduced on the S6b interface during the PDN-GW initiated session termination

Message	Message size [B]	Direction
Session-Termination-Request	300	PDN-GW->AAA server
Session-Termination-Answer	181	AAA server->PDN-GW
Total	**481**	**N/A**

Table 26: Signaling load introduced on the SWa interface during the AAA Initiated Detach Procedure

Message	Message size [B]	Direction
CC-Request	365	PDN-GW->PCRF
CC-Answer	291[6]	PCRF->PDN-GW
Total	**656**	**N/A**

Table 27: Signaling load introduced on the SWx interface during Non-3GPP IP Access Registration Procedure (User de-registration)

Message	Message size [B]	Direction
Server-Assignment-Request	495	AAA server->HSS
Server-Assignment-Answer	258	HSS->AAA server
Total	**753**	**N/A**

2.2.5 Relay based access to Relay based access handover procedure

The following subsection analyzes the signalling introduced by the procedures that are necessary to conduct a handover from one Relay based access to another in a non-roaming scenario (i.e. when UE and Relay belong to the same operator). The analysis is based on a compilation of MSCs from [9] (Section C.5), [20] (Section 2.2), [17] (Section 8.2.2). Table 28 summarizes the signalling load introduced by the procedures on different interfaces.

Table 28: Signaling load introduced by the procedures related to the handover between Relay based accesses

Interface	Signalling load on the link between UE and Relay2 [B]	Signalling load on the link between Relay1 and Network [B]	Signalling load on the link between Relay2 and Network [B]	Signalling load within the Core Network [B]
SWw	225	N/A	N/A	N/A
SWu	664	0	664	N/A
SWa	N/A	526	4139	N/A
SWm	N/A	N/A	N/A	0
S2b	N/A	N/A	N/A	0
S6b	N/A	N/A	N/A	0

[6] Assuming activation and deactivation of a single PCC rule

SWx	N/A	N/A	N/A	0
Gx	N/A	N/A	N/A	0
Total	**889**	**526**	**4803**	**0**

Although not explicitly shown in the MSC (see [9], Section C.5), handovers between Relay based accesses need to be preceded by the authentication and authorization conducted between an UE and a "new" Relay based access over SWw and SWa (see Section 2.2.1). Additionally, the "old" Relay needs to be informed about the handover in order to stop forwarding UE's traffic (this can be achieved over SWa using an AAA initiated detach procedure).

Table 29: Signaling load introduced on the SWu interface during the authentication and authorization procedures

Message	Message size [B]	Direction
IKE_INFORMATIONAL (UPDATE_SA_ADDRESSES, ...)	168	UE->ePDG
IKE_INFORMATIONAL (...)	160	ePDG->UE
IKE_INFORMATIONAL (COOKIE2)	168	ePDG->UE
IKE_INFORMATIONAL (COOKIE2)	168	UE->ePDG
Total	**664**	**N/A**

Table 30: Signaling load introduced on the SWa interface during the AAA Initiated Detach procedure

Message	Message size [B]	Direction
Abort-Session-Request	346	AAA server ->Relay
Abort-Session-Answer	180	Relay->AAA server
Total	**526**	**N/A**

2.2.6 Summary

The following section provided analysis of the non-C4MS related signalling in order to determine the potential cost (in terms of signalling load) of employing Untrusted non-3GPP IP access for realization of ONs in SCE#1, SCE#2a and SCE#4. The following tables summarize the signalling load introduced by the considered procedures (i.e. network attach/detach, handovers) on the links between UEs and Relays, Relays and Network as well as within the Core Network and can be used as an input to evaluate the actual gain introduced by the ONs.

Table 31: Signaling load introduced on the radio link between UE and Relay

Procedure	Signalling load on the UE - Relay1 link [B]	Signalling load on the UE - Relay2 link [B]
Initial Attachment	3362	N/A
Detachment	0	N/A
Handover from 3GPP to Relay	3362	N/A
Handover from Relay to 3GPP	0	N/A
Handover from Relay to Relay	0	889

Table 32: Signaling load introduced on the radio link between Relay and Network

Procedure	Signalling load on the link between Relay1 and Network [B]	Signalling load on the link between Relay2 and Network [B]
Initial Attachment	7276	N/A
Detachment	526	N/A
Handover from 3GPP to Relay	7276	N/A
Handover from Relay to 3GPP	526	N/A
Handover from Relay to Relay	526	4803

Table 33: Signaling load introduced within the Core Network

Procedure	Signalling load [B]
Initial Attachment	6239
Detachment	1844
Handover from 3GPP to Relay	6228
Handover from Relay to 3GPP	1983
Handover from Relay to Relay	0

3. System overhead due to ON management

The following section summarizes findings of this document and D3.3 (see [3], Section 5) and provides the estimated total system overhead (in terms of signalling load) which is introduced by the operation of ONs in SCE1, SCE#2a, SCE#3 and SCE#4 scenarios. The analysis is provided for the "Application Function based centralized Architecture" (assuming "Non-3GPP IP access" implementation option) and includes the C4MS signalling as well as ON-related non-C4MS signalling (excluding the signalling over OJ/OC interface).

3.1 Non-C4MS signaling overhead

The following table is borrowed from D3.3 (see Section 5.3.5) and summarizes the total signaling load introduced by the bootstrapping procedure and the subscriber certificate enrolment procedure which are necessary to issue and deliver the subscriber certificate to the end user (subscriber certificates provide basis to secure communication in SCE#1, SCE#2a, SCE#3 and SCE#4 (see [2], Section 3.4.2 for more detail)). Additionally, the bootstrapping procedure is also used to establish a secure connection between UE and ON Manager (see [2], Section 3.4.2 for more detail).

Table 34: Subscriber certificate enrolment related signalling load for a single request

	Bootstrapping procedure	Subscriber certificate enrolment procedure
HTTP message sizes [B]	1566	3548
number of messages to be exchanged	4	4
Overhead related to IP and TCP [B]	416	416
Total [B]	**1982**	**3964**

Similarly to Table 34, Table 35 is borrowed from D3.3 (see Section 5.3.5) and presents signalling load introduced by two security mechanisms (in our case 802.1X-EAP-TLS and 802.1X-EAP-IKEv2) which can be used to setup a secure connection between two terminals in scenarios SCE#1, SCE#2a, SCE#3 and SCE#4 (assuming that terminals are already in the possession of subscriber certificates).

Table 35: EAP-IKEv2 and EAP-TLS signalling overhead comparison

	EAP-IKEv2 [22]	EAP-TLS [23]
Protocol specific payload (including digital certificates if required) [B]	2717	1783
number of messages to be exchanged	8	10
Overhead related to EAPOL and EAP [B]	143	150
Total [B]	**2860**	**1933**

The following tables summarizes the ON-related non-C4MS signalling introduced during different ON phases (assuming "Non-3GPP IP access" implementation option) for the "Application Function based centralized Architecture" and is based on the results obtained in Section 2.2 and the results presented in Table 34 and Table 35.

Table 36: ON-related non-C4MS signalling for SCE#1, SCE#2a, SCE#4

ON phase	Signalling load on the link between UE and Relay [B]	Signalling load on the link between UE and Network [B]	Signalling load on the link between Relay and Network [B]	Signalling load on within the Core Network [B]
ON Suitability Determination	0	1982	1982	0
ON Creation	1933+3362	3964	3964+7276	6239
ON Maintenance (handover from Relay1 to Relay2)	1933+889 (Relay2)	0	526 (Relay1) + 3964+4803 (Relay2)	0
ON Termination	0	0	526	1844 (in case we detach) or 1983 (in case we handover to 3GPP)

Table 37: ON-related non-C4MS signalling for SCE#3

ON phase	Signalling load on the link between UE1 and UE2 [B]	Signalling load on the link between UE1 and Network [B]	Signalling load on the link between UE2 and Network [B]	Signalling load on within the Core Network [B]
ON Suitability Determination	0	1982	1982	0
ON Creation	1933	0	0	0
ON Maintenance	0	0	0	0
ON Termination	0	0	0	0

3.2 Summary

The following tables summarize the results of analytical evaluations of C4MS and non-C4MS control traffic generated during different ON phases on the links between UEs and Relays, Relays and Network as well as within the Network and can be used as an input to evaluate the actual gain introduced by the ONs in SCE#1, SCE#2a, SCE#3 and SCE#4.

The results for C4MS related signalling presented in the tables were obtained based on the final version of the MSCs presented in the Appendix to D3.3 [4] (see [3], Section 5 for more detail). The results for ON-related non-C4MS signalling were obtained as specified in the previous section (see 3.1).

The following table summarizes the results of analytical evaluations of the control traffic generated during the ON Suitability determination phase in different OneFIT scenarios.

Table 38: Suitability phase signalling load results

OneFIT scenario	#1			#2a		#2B	#3			#4			#5
Approach	Terminal centric		Network centric	Network centric	Terminal centric	Network centric	Terinal. Centric		Network Centric	Terminal centric		Netw. centric	N/A
Case	network supported	terminal initiated	N/A	N/A	N/A	N/A	terminal initiated	network initiated	N/A	network supported	terminal initiated	N/A	N/A
	C4MS related Signalling load [B]												
UE-UE/Relay	467	162	403	0	627	0	160	467	0	467	467	467	0
UE/Relay-Netw	212	0	713	0	365	34	358	535	194	328	0	607	0
netw-netw	0	0	347	0	262	0	0	0	0	0	0	0	359
	non-C4MS related Signalling load [B]												
UE-UE/Relay	0					N/A	0						N/A
UE/Relay-Netw	2*1982 (assuming two UEs)					N/A	2*1982 (assuming two UEs)						N/A
netw-netw	0					N/A	0						N/A
Total	**4643**	**4126**	**5433**	**4998**	**5219**	**34**	**4482**	**4966**	**4158**	**4759**	**4431**	**5038**	**359**

The following table summarizes the results of analytical evaluations of the control traffic generated during the ON Creation phase in different OneFIT scenarios.

Table 39: Creation phase signalling load results

OneFIT scenario	**#1/#4**		**#2a**		**#2b**	**#3**		**#5**
approach	**Terminal centric**	**Network centric**	**Network centric**	**Terminal centric**	**Network centric**	**Terminal centric (terminal initiated)**	**Network Centric**	**Network centric**
	C4MS related Signalling load [B]							
UE-UE/Relay	428	535	**0**	428	268	430	**0**	**0**
UE/Relay-Netw	428	545	159	428	428	637	841	0
netw-netw	348	16	428	126	0	0	0	545
	non-C4MS related Signalling load [B]							
UE-UE/Relay	1933+3362				N/A	1933		N/A
UE/Relay-Netw	2*3964+7276				N/A	0		N/A
netw-netw	6239				N/A	0		N/A
Total	**21703**	**21595**	**21086**	**21481**	**696**	**3000**	**2774**	**545**

The following table summarizes the results of analytical evaluations of the control information which is exchanged during the ON maintenance phase (assuming the need of a handover from Relay1 to Relay2).

Table 40: Maintenance signalling load results

OneFIT Scenario	**#1/#4**				**#2a**	**#2b**	**#3**		**#5**	
approach	**Generic ON paramteres modification**	**Gateway handover**	**ON participant disconnection**	**Gateway disconnection**	**Network centric approach**	**Network centric approach**	**Terminal centric approach (terminal initiated)**	**Network Centric**	**ON parameters modification**	**ON participant disconnection**
	C4MS related Signalling load [B]									
UE-UE/Relay	408	401	166	166	0	0	626	0	0	0

UE/Relay-Netw	408	73	126	126	159	159	279	833	0	0
netw-netw	0	0	0	0	428	0	0	0	508	388
	non-C4MS related Signalling load [B]									
UE-UE/Relay	1933+889		N/A	1933+889		N/A	N/A		N/A	
UE/Relay-Netw	526+3964+4803		N/A	526+3964+4803		N/A	N/A		N/A	
netw-netw	0		N/A	0		N/A	N/A		N/A	
Total	**12931**	**12589**	**292**	**12408**	**12702**	**159**	**906**	**833**	**508**	**388**

The following table summarizes the results of analytical evaluations of the control information which is exchanged during an ON termination and after an ON is terminated.

Table 41: Termination phase signalling evaluation

scenario	**#1/#4**	**#2a**	**#2b**	**#3**	**#5**
approach	**N/A**	**Network centric approach**	**Network centric approach**	**Terminal centric approach (terminal initiated)**	**Network centric**
	C4MS related Signalling load [B]				
term-term	50	0	0	268	0
Term-netw	40	40	40	231	0
netw-netw	0	40	0	0	40
	non-C4MS related Signalling load [B]				
UE-UE/Relay	0		N/A	0	N/A
UE/Relay-Netw	526		N/A	0	N/A
netw-netw	1844		N/A	0	N/A
Total	**2460**	**2450**	**40**	**500**	**40**

4. References

[1] ICT-2009-257385 OneFIT Project, http://www.ict-onefit.eu/

[2] OneFIT Deliverable D2.2.2/D6.4 "OneFIT Functional and System Architecture Version 2.0", December 2012

[3] OneFIT Deliverable D3.3 "Protocols, performance assessment and consolidation on interfaces for standardization", June 2012

[4] Appendix to OneFIT Deliverable D3.3: "Detailed C4MS Protocol Specification", June 2012

[5] ETSI TR 102 682 "Functional Architecture for the Management and Control of Reconfigurable Radio Systems", July 2009

[6] 3GPP TS 23.003 "Numbering, addressing and identification"

[7] 3GPP TS 23.203 "Policy and charging control architecture".

[8] 3GPP TS 23.401 "GPRS enhancements for E-UTRAN access"

[9] 3GPP TS 23.402 "Architecture enhancements for non-3GPP accesses"

[10] 3GPP TS 24.302 "Access to the 3GPP Evolved Packet Core (EPC) via non-3GPP access networks"

[11] 3GPP TS 29.212 "Policy and Charging Control (PCC); Reference points"

[12] 3GPP TS 29.213 "Policy and charging control signalling flows and Quality of Service (QoS) parameter mapping"

[13] 3GPP TS 29.273 "Evolved Packet System (EPS); 3GPP EPS AAA interfaces"

[14] 3GPP TS 29.274 "3GPP Evolved Packet System (EPS); Evolved General Packet Radio Service (GPRS) Tunnelling Protocol for Control plane (GTPv2-C); Stage 3"

[15] 3GPP TS 33.102 "3G Security; Security Architecture"

[16] 3GPP TS 33.234 "3G security; Wireless Local Area Network (WLAN) interworking security"

[17] 3GPP TS 33.402 "3GPP System Architecture Evolution (SAE); Security aspects of non-3GPP accesses"

[18] IEEE 802.1X "Port Based Network Access Control", February 2010

[19] IETF RFC 3588 "Diameter Base Protocol", September 2003

[20] IETF RFC 4555 "IKEv2 Mobility and Multihoming Protocol (MOBIKE)", June 2006

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[22] IETF RFC 5106 "The Extensible Authentication Protocol-Internet Key Exchange Protocol version2 (EAP-IKEv2) Method", February 2008

[23] IETF RFC 5216 "The EAP-TLS Authentication Protocol", March 2008