Handover between GSM (2G), UMTS (3G) and Wireless Local Area Networks (WLANs)

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***Abstract--* This document is only a literature summary, intended for the purpose of understanding the available Inter-RAT (Radio Access Technology) Handover techniques. The References section at the end of this report encompasses the sources of information. This study is done as part of the course – Advanced Telecommunications, provided at the department of Information Technology, LTH.**

***Index terms--* Handover, Handoff, I-WLAN, TTG, VHO, tight coupling, pre-SAE**

A. Introduction

Investigation of Handovers (HO) between different radio access technologies opens up a wide range of optimization possibilities in terms of utilization of network resources and better coverage capabilities. The chief challenge lies in making this process seamless, in the sense that the end to end connection remains intact throughout the process and the engine that runs the machinery of making this switch shields the upper layers from noticing any change in the basic bearer Quality of Service (QoS) expected for the ongoing service. The study here mainly concentrates on the challenges involved in handovers between the 3 most ubiquitous technologies encountered in everyday scenario- 2G (GSM/GPRS, almost legendary system), 3G (WCDMA/UMTS, fastest growing mobile system), WLAN (IEEE802.11, along with HIPERLAN, the best pedestrian-based, high speed packet access system). The study here is expected to equip one with the basic understanding of the primary problems, implementation issues and design challenges involved in transitioning of a system that supports intra-system HO to one that supports inter-system HO, involving heterogeneous networks.

B. Handovers/ Handoffs

In the Context of telecommunications, the main purpose of doing a handover is to transfer the radio connection between radio channels, whilst maintaining an ongoing connection. Accordingly, ETSI and 3GPP define handover as “The transfer of a user’s connection from one radio channel to another (can be the same or different cell)” [1]. A handover operation that can minimize or even eliminate the delay for establishing the new connection to the new access point (AP) is called a fast handover. If the handover operation minimizes the data loss during the establishment of the new connection, then it is called a smooth handover. A handover that is both fast and smooth is called a “seamless” handover [6].

In the recent years, Intersystem HOs has been one of the most active areas of mobility since the overlay of heterogeneous networks has become more prominent especially in areas of dense data traffic. Continuous investigations are carried out regularly with new algorithms being proposed at a high rate trying to find the best solution for various environments, mainly to minimize the latency encountered in carrying out the procedure.

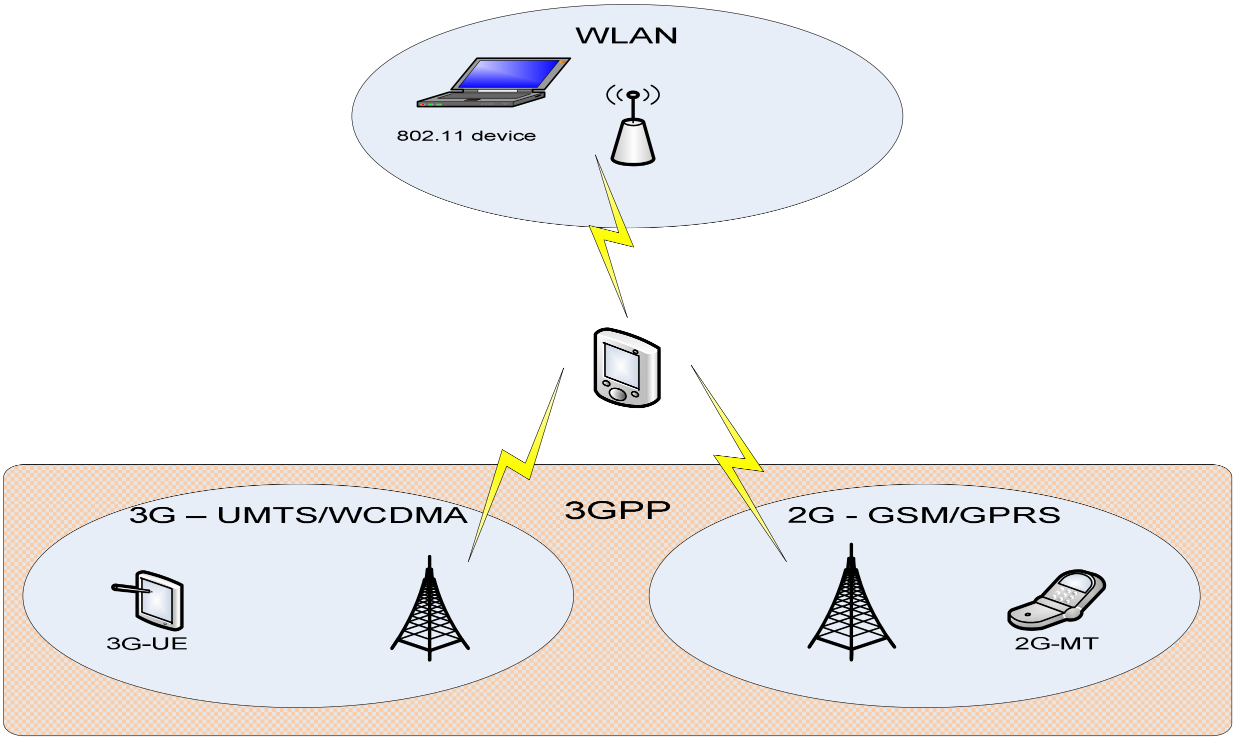

Fig. 1. A Release 8 3GPP prototype

a. Reasons for Handover

The most important and very obvious criterion for handover to occur is the degrading signal quality. Also the Cellular structure, used to enhance the spectral efficiency and provide frequency reuse ability, is a chief entry factor for handovers to be predominant from the start. To allow for HO, adjacent cells are designed so as to overlap and constitute areas for reception of signal from multiple base stations (BS).

Some of the chief reasons for HO are listed down:

C. Better RSSI from another CELL
D. Traffic based, load based
E. Reception Quality, BER
F. Service based
G. Speed based

b. Types of Handovers

The various types of HO are broadly categorized based on the Point of Access (POA), before and after the HO.

– Softer HO
– Soft HO
– Intra-frequency hard HO
– Inter-frequency hard HO
– SRNS Relocation
– Combined Hard handover and SRNS Relocation
– Inter-RAT hard HO.

These can be further summarized into,

1. Intra-cell HO
2. Inter-cell HO
3. Inter-System HO, the case of interest here.

Inter-System HO is the most challenging type of HO, due to the difference in the properties of the various networks. Another notation for Inter-system handover is Vertical HO (VHO) to point out the heterogeneity of the involved networks [5]. Hence, the Intra-System HOs are also referred to as Horizontal HO.

c. Criterion for HOs

Origins for handover may be further distinguished into radio related handovers and service related HO [5].

1. RF Criteria

a. signal level
b. connection quality
c. power level propagation delay

2. Traffic Criteria

d. current traffic loading per cell
e. interference levels,
f. maintenance requests

As a rough classification, horizontal handovers fall mainly in the category of radio related handovers, while vertical handovers subsume service related handovers. Compared to horizontal handover, vertical handover introduces new degrees of freedom [5]. A VHO can be triggered due to QoS aspects, even though the actual link quality in the current cell is excellent. As another system with extensive service quality in terms of data rate and provisioning is available, the decision space is then no longer restricted to sole link parameters.

d. Specific Properties in case of Inter-System HO

1. Time Critical-
   The downward VHO is quite flexible with respect to time usage as it is covered over a long time from its old connection, whereas, upward VHO is required to happen ideally instantaneously when the coverage drops, since the mobile terminal (MT) may soon move out of range from the WLAN pico-cells.
2. Decreased transparency in Service provisioning-
   Supported bit rates at WLAN pico-cell and UMTS or GPRS varies tremendously and hence guarantee of the service quality to demanding applications is not feasible.
3. Higher order in HO decision space-
   Since the Intersystem HO falls under the service/traffic criterion for decision making, it hence allows metrics that can be user defined. This also, allows for algorithms to be applied in HO decision which concentrates on rating of these specific parameters.
4. Business Models-
   VHOs results in new business models along with the added expenditure in operation, maintenance and administration.

C. 2G – 3G Handovers

a. Handover from WCDMA to GSM [9]

As and when the signal strength in WCDMA system falls below a given threshold, the WCDMA network orders the mobile terminal to perform GSM measurements. Typically, the mobile terminal is instructed to send a measurement report when the quality of a neighboring GSM cell exceeds a given threshold and the quality from WCDMA is unsatisfactory.

In fact UTRAN initiates handover when received measurement report message indicates that all the conditions to do handover is fulfilled—for instance when MT moves outside the coverage area of WCDMA system or when MT enters to a full WCDMA cell.

1. UTRAN asks the target BSS to reserve resources.
2. target BSS prepares a handover command message(to MT), which includes the details of the allocated resources (This GSM message, which is sent to the mobile terminal via the WCDMA radio interface, is transferred within a container that is transparently passed on by the different network nodes)
3. Next step is to move to the target GSM cell. MT after receiving command message, based on the parameters included in command message establishes the new connection in GSM cell.
4. After successfully establishing the connection MT sends a handover complete message to BSS.
5. Afterwards GSM network initiates to release WCDMA radio connection.

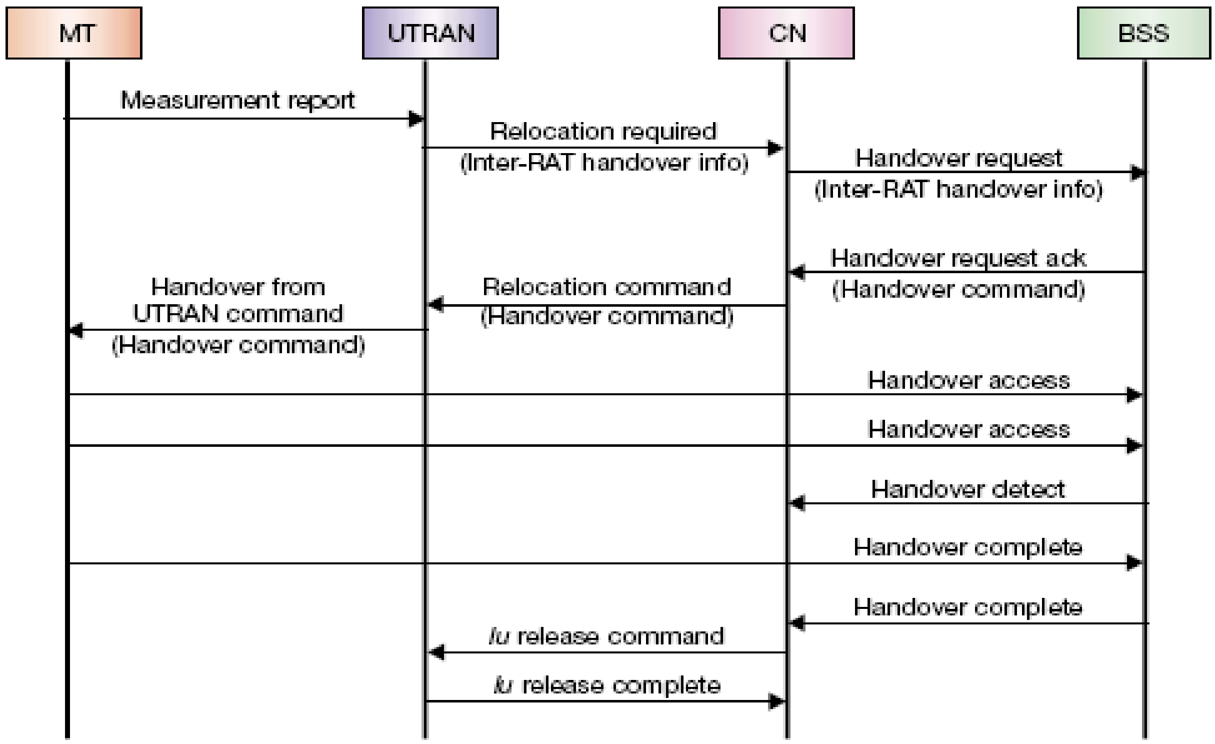

Fig. 2. Handover from WCDMA to GSM.

b. Handover from GSM to WCDMA [9]:

Like the same, when the signal strength in GSM system falls below a given threshold, the network orders the dual-mode mobile terminal to perform WCDMA measurements by sending the measurement information message. The message contains information on neighboring WCDMA cells and the criteria for performing and reporting measurements.

As shown in Figure 2, when the criteria to WCDMA handover have been met:

1. BSS initiates the allocation of resources for the WCDMA cell (BSS also sends the WCDMA capabilities of mobile terminal to UTRAN)
2. As soon as the resources of the WCDMA target cell have been allocated, UTRAN compiles the handover to UTRAN command message, which typically includes the identity of the pre-defined configuration for the service in use
3. Afterwards Handover to UTRAN message is sent to the mobile terminal through the CN (core network) and BSS.
4. When the mobile terminal receives the handover-to-UTRAN command message it tunes to the WCDMA frequency and begins radio synchronization
5. Mobile station sends handover-to-UTRAN complete indication when the handover is successfully done
6. When all the process is accomplished GSM resource is released.

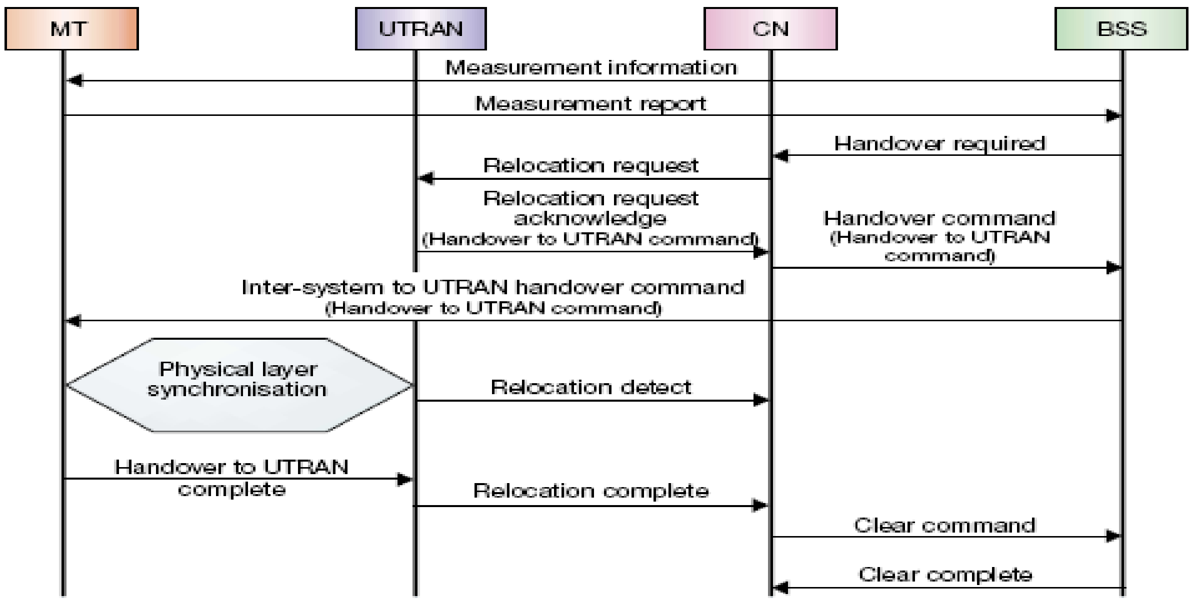

Fig. 3. Handover from GSM to WCDMA

c. Main challenges to materialize WCDMA-GSM interworking

1. Minimizing the changes to the existing GSM infrastructure-
   In order to overcome the problem the message is encapsulated in a "container". When the network sends a message in WCDMA in order to initiate handover to GSM, part of the WCDMA message includes a GSM message which looks exactly the same as if it had been sent on the GSM radio interface. The same principle is used for handover from GSM to WCDMA [9].

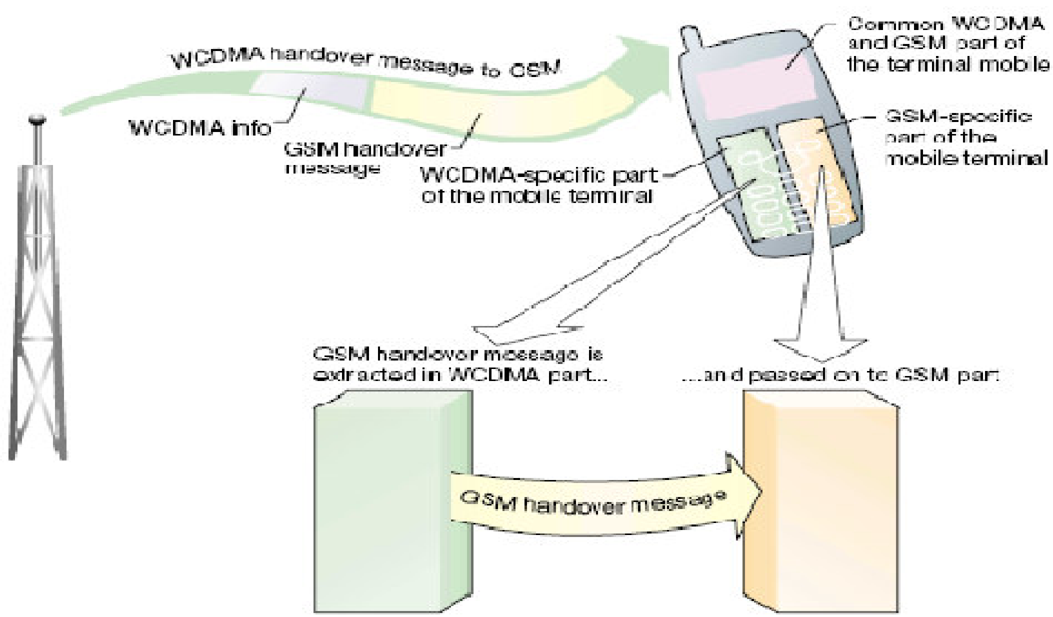

Fig. 4. Encapsulation of the GSM handover message in a "container" that is part of the WCDMA handover message.

2. Multiple RAT measurement:
   The MT needs to perform measurements on GSM while communicating in WCDMA and vice versa. But because of continuous transmission and reception in WCDMA case, mobile terminal can't measure GSM while it is active in WCDMA.
   To overcome this problem compressed mode method is introduced. Here, a short gap is created in transmission and reception. To maintain a perceived constant bit rate, the actual transmission bit rate is increased just before and after the gap.(but of course for some applications like web browsing, constant bit rate is not crucial and transmission can thus be delayed to create a gap. [8]

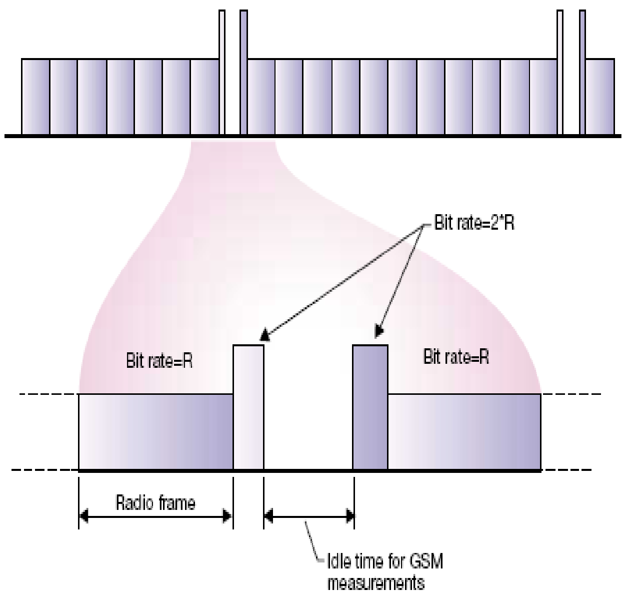

Fig. 5. Compressed mode creates idle spaces in time for WCDMA mobile terminals to perform measurements on GSM cells.

3. Length of handover message in GSM to WCDMA case is a problem:
   As handover message length increases, the handover performance decreases. Moreover, GSM bit-rate doesn't allow carrying of long WCDMA handover messages.
   Hence, instead of signaling each parameter of the actual configuration the network can signal a small size reference to a pre-defined WCDMA radio channel configuration. The pre-defined WCDMA radio channel configuration describes bit rates, data block sizes and other radio parameters of voice or video call service [9].

4. Measurements comparison problem:
   WCDMA and GSM are two different technologies and comparing measurement results are difficult.
   To overcome this problem, the measured results are compared with a technology specific threshold [8].

d. Mobility procedures for Interworking between WCDMA and GSM [8]

Two basic modes of operation for handling mobility are:

1. The terminal controlled mode. (MT initiated)
2. The network controlled mode. (Network initiated)

In mobile terminal controlled mode (based on the network broadcasted parameters) mobile terminal selects the cell to which it will connect.

In the network-controlled mode, the network explicitly orders the mobile terminal to connect to a specific cell. The network takes this decision based on the measurements done by mobile terminal.

In either cases network has to consider the cells of different technologies. For instance network has to consider radio link quality and load existing in each cell.

D. HO BETWEEN 3G (UMTS) AND WLAN (802.11)

3GPP TSG SA1 (Services) group standardizes the interworking between UMTS and WLAN. The seamless mobility between IEEE 802.11 and 3GPP is in a juvenile state as 3GPP attempts to find the best possible solution. As per 3GPP's Feasibility Study on UMTS-WLAN Interworking [2], the interworking has been broadly classified under 2 categories,

1. Loose Coupling
2. Tight Coupling (seamless HO possible)

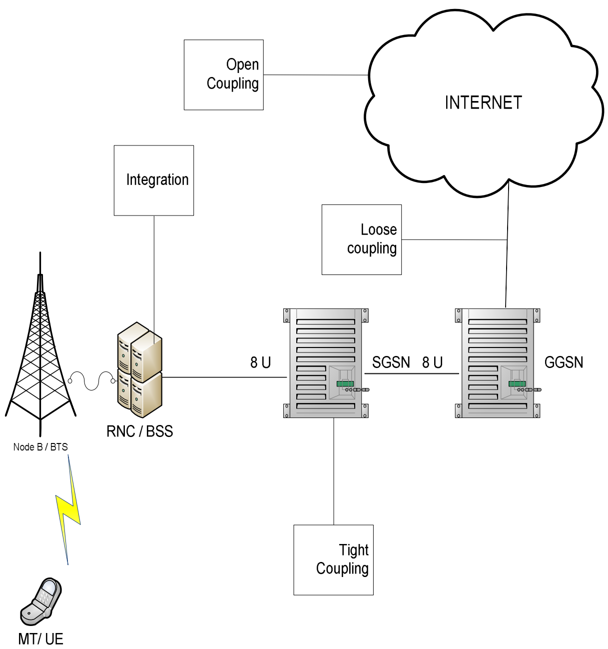

Fig. 6. Architectural Plug-in points

The main difference here is where and how the WLAN network is coupled to the 3G UMTS network. Trade off is made based on constraints such as, the complexity involved in the modification of the existing standards, degree of seamless access provided by the interworking and the infrastructure required. Apart from these, Open coupling and integration [12] are also considered. In the former, the 2 technologies only share a common billing system and no real integration effort is done whereas in the latter, the coupling at RNC level renders WLANs to be considered as a cell in the UMTS network giving rise to multitude of changes in the network planning making the system highly complex.

Handover capabilities for combinational services between WCDMA and WLAN networks are currently being considered for inclusion in 3GPP Release 8 [5] under [10].

In [7], About 4 alternative solutions for the interworking between the 2 technologies are proposed as a Technical Report (TR) to 3GPP by Xiaobao CHEN, which is currently succeeded by [10] as a draft. The latest release version of v0.3.0 of the document in [10] was released on 28th of April, 2008 but is still not accessible.

One out of the 4 proposed architectures of [7] is shown below with the HO condition dealt in detail (Alternative 1 chosen here)

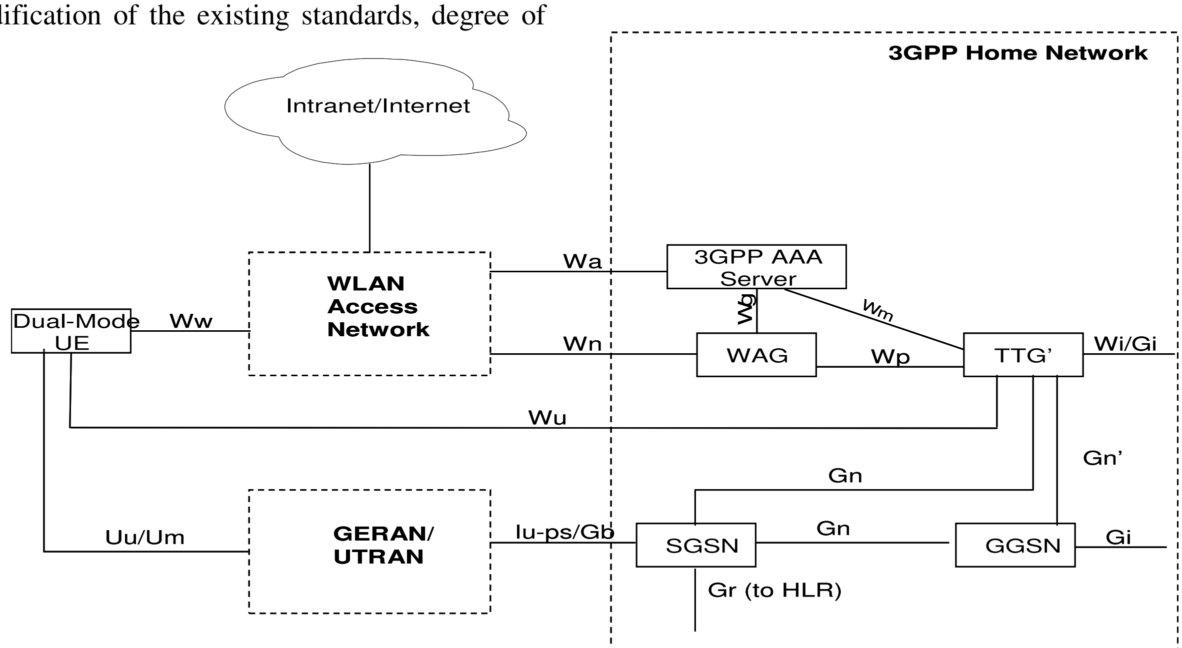

Fig. 7. Non-Roaming Architecture for I-WLAN Mobility [7]

a. Architecture Description

The following are the chief proposed architectural changes to the pre-SAE (System Architecture Evolution) 3GPP core network for supporting interworking and HO between 3GPP network and the IEEE 802.11 WLAN-

1. An entity called Tunnel Termination Gateway (TTG, a modified version of the PDG-Packet Data Gateway) is placed between the SGSN and the GGSN thus showing tight coupling design. The data traffic arriving either at the SGSN or the WLAN Access Gateway (WAG) is forwarded always to this utility for all the I-WLAN subscribers. Other functionalities of the TTG are as per [4].
2. A Gn interface between SGSN & TTG' and between GGSN & TTG' exists alongside the legacy interface between SGSN & GGSN.
3. HSS, the Home Subscriber Server (HLR equivalent in the IMS architecture) needs to be upgraded to hold the newly assigned 3GPP-WLAN APN list.

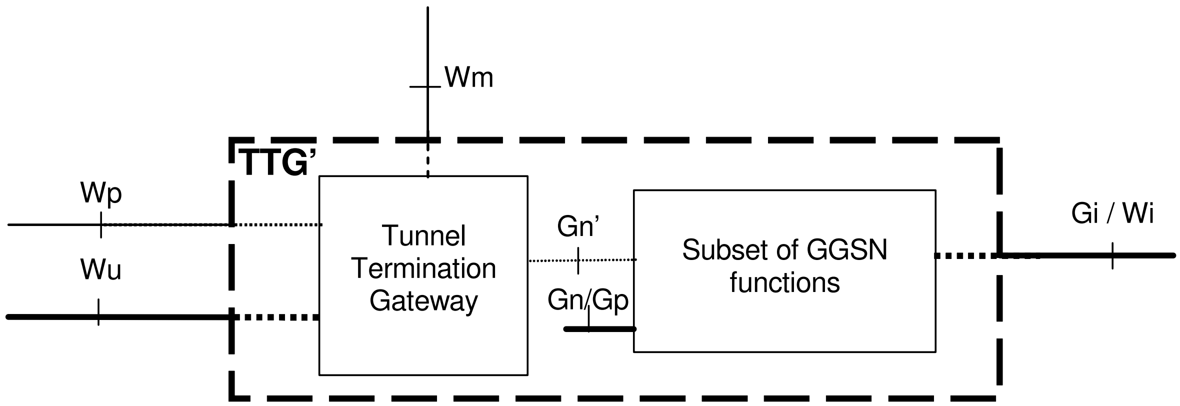

Fig. 8. TTG' (modified PDG) implementation re-using GGSN functionality [7]

b. I-WLAN to 3G Handover

1. The user is connected to WLAN and has not yet attached to 3GPP network.
2. Based on the HO criterion, the I-WLAN UE requests a tunnel setup to TTG'. The IKE-Internet Key Exchange procedure follows as per [11].
3. EAP-Extensible Authentication Protocol procedures are initiated through the SIM to authenticate the user as per [11].
4. The service authorization follows where the TTG' consults AAA- Authentication Authorization Accounting of the WLAN network or HSS/HLR of 3GPP for subscription profile information.
5. An IPsec tunnel is established between the IWLAN UE and TTG', which provides the Wi interface to PDN [11].
6. Now the user is attached to Pre-SAE 3GPP system and the HO procedure starts (maybe due to weak WLAN signal etc.).
7. PDP context activation request to the registered SGSN
8. SGSN forwards this to the TTG'. Since the TTG' already has the session information, it has to only switch the traffic route to 3GPP from WLAN => Wi interface unchanged.
9. PDP context accept from SGSN
10. Established GTP tunnel between SGSN and TTG'.

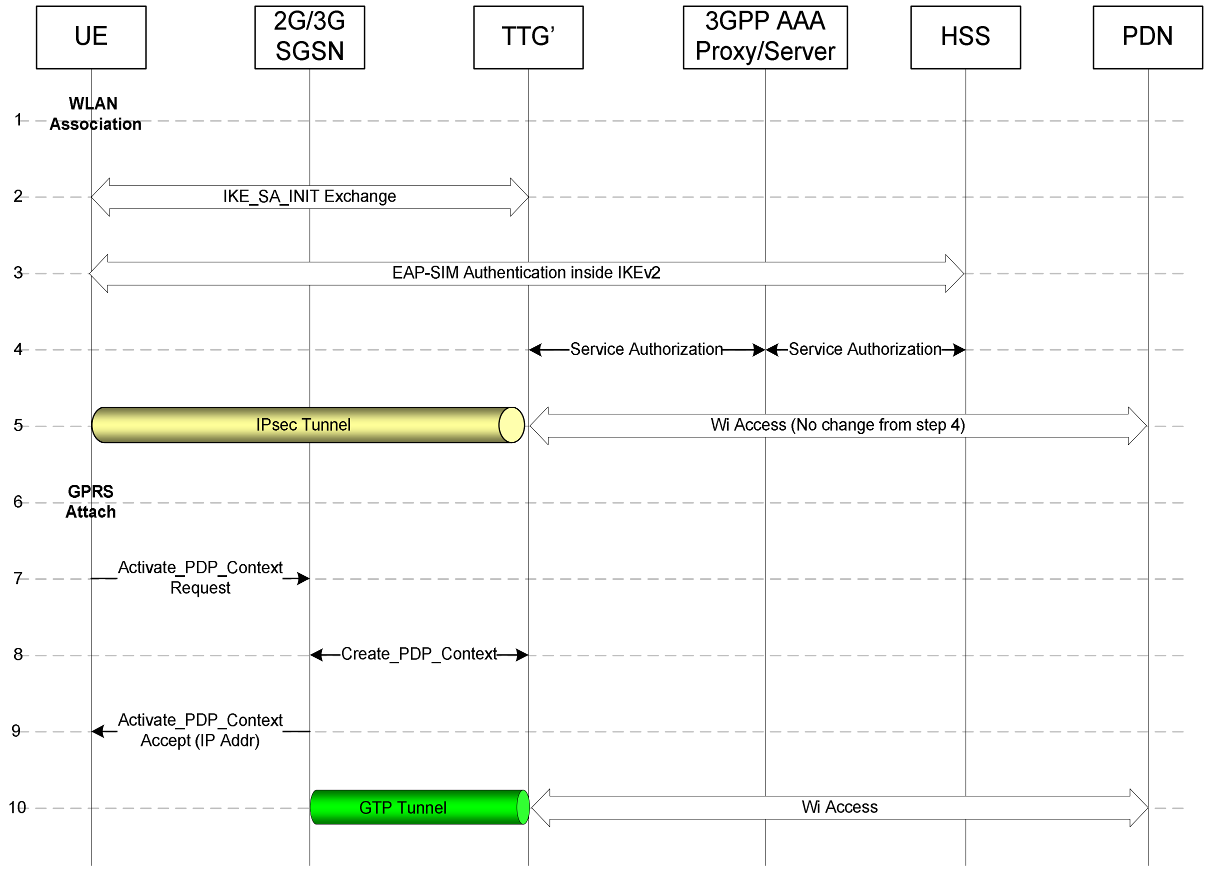

Fig. 9. I-WLAN to Pre-SAE 3GPP HO [7]

c. *3G to I-WLAN Handover*

1. UE in 3GPP coverage, send PDP activation request to SGSN. NOTE: the change here is, for I-WLAN UEs, the requested APN is a new modified version like w.service.op.com instead of service.op.com.
2. Seeing this new APN, the SGSN forwards the request to TTG' which assigns the IP address instead of GGSN. The resolution of the validity of the request is self-explanatory at the entities.
3. The PDP request is ACKed.
4. The GTP tunnel is established between SGSN and TTG'.
5. UE starts associating with WLAN.
6. UE sends IKE_SA_INIT message to TTG' as per the normal association procedures of [4] and [11]. The TTG' plays dual role in terminating the IKE and IPSec messages for the session.
7. Authentication and authorization procedures are carried out inside the IKEv2 as per [11] which involves the UE, TTG', AAA server, HSS/HLR. NOTE: Same IP address of the GPRS session is assigned to the WLAN session as TTG' has the knowledge of the user session.
8. The data traffic is now routed from GPRS to WLAN by TTG'. An IPSec tunnel is established between the UE and the TTG'. Wi interface again is unchanged.

Note that the TTG' works as the Central IP Point of Connectivity for all I-WLAN based User Equipments.

E. SUMMARY

The WLAN coverage will grow, and the number of applications and services will increase. This could be beneficial, for both operators and users. Operators have to increase the WLAN coverage, and charge the user for their great applications and services. Users benefit from the increasing number of new and useful applications and services, they can use. They can also maintain the online connection, when moving from one wireless system to another.

Seamless HOs within compatible technologies like 2G-3G has been established for some time now and operators are already looking into breaking barriers across other hierarchy of networks. Vertical HO is currently in the standardization state at 3GPP and propositions and designs are available in plenty to choose the best solution, keeping interoperability and backward compatibility in mind.

F. ABBREVIATIONS

Refer [1].

G. REFERENCES

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