WLAN-3GPP Integration Architectures for Packet Based Data Services

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Abstract

With the rapid successful deployment of WLANs worldwide in numerous hotspots for high data rate, wireless access for data services has created the need to integrate the Cellular Networks with WLAN Networks. The integrated wireless environment will provide the end user a much better service experience along with a single subscription and a single bill.

In this paper we focus on inter-working approaches, which combine WLANs and Cellular Networks into an integrated wireless environment capable of ubiquitous access to data services and very high data rates in hotspots areas. We first list the key requirements which are currently being standardized within the 3GPP for integration with WLANs networks. We discuss two inter-working architectures namely loosely coupled and tightly coupled. This paper will detail the loosely coupled inter-working approach while briefly discussing the tightly coupled inter-working. Finally, we will conclude that the loosely coupled approach is evolutionary and less intrusive than the tightly coupled approach.

1. Introduction

The ability to access information, receive information and send information while on the move has become a necessity for most business users. The rapid and continuously successful deployment of Wireless Local area Networks (WLANs), also known as Wi-Fi networks in com-mercial, residential and public environments like airports, shopping complexes and hotels has attracted the attention of cellular network operators. WLANs provide a radio access infrastructure characterized by high bit rates, somewhat non-secure data transfer, limited mobility and limited coverage. On the contrary, cellular networks are currently

providing a radio access infrastructure characterized by relatively low bit rates, secure data transfer, higher mobility and larger geographical coverage to their subscribers. Cellular operators, as well as, Wireless LAN operators will benefit by integrating these two classes of Radio Access networks. There will be mutual commercial benefits while simultaneously exploiting the advantages of both types of Radio Access Networks i.e. high speed access offered by WLAN and secure data services offered by the Cellular Networks. Such an integrated wireless access environment will simplify WLAN UE capable user faster access to packet data services in hot-spots areas covered by WLAN networks while maintaining a single subscription with his Cellular operator.

We will start with the integrated wireless environment for WLANs and Cellular Networks. Then we will explain the key requirements in details, which are currently being standardized within the 3GPP for inter-working with WLANs Networks. We elaborate on the core objectives of integration and then look into various possible inter-working requirements for an inter-working setup. We then list out the fundamental issues of inter-working like security, subscriber data management etc.

We focus on loosely coupled integration approach in detail. We propose a generic, scalable, and flexible approach for integrating 3GPP based cellular networks and WLAN access networks. We define the functional interface requirements between WLAN-3GPP networks; protocol requirements, security (AAA) and subscription related requirements in 3GPP networks. We illustrate the overall operation of a loosely coupled inter-working model, through sample signaling flows, in order to explain the inter-working of WLAN access capable UE and a 3GPP network, while maintaining a single subscription with the cellular service provider. We finally identify key issues/areas which require further study.

A prime and distinctive feature of this paper is that it does not assume any particular WLAN access network architecture or technology like 802.1x or HIPERLAN/2. Our approach is quite generic in the sense, that it elaborates on the functional and interface requirements in such a manner that any WLAN access network fulfilling these functional requirements shall be able to inter-operate with

GPRS/W-CDMA Cellular networks. We finally conclude that this approach of inter-working between WLAN access networks and cellular networks is less intrusive, cost effective and easy to implement.

2. INTEGRATED WLAN AND CELLULAR NETWORKS ENVIRONMENT

[Figure 1] illustrates an integrated wireless environment in which a subscriber has multiple access network options. There are two configurations in the area of ownership of the

WLAN. In one case the Cellular operator owns and manages the WLAN. In the second case the WLAN is not owned by the Cellular operator. Lets consider the following scenarios.

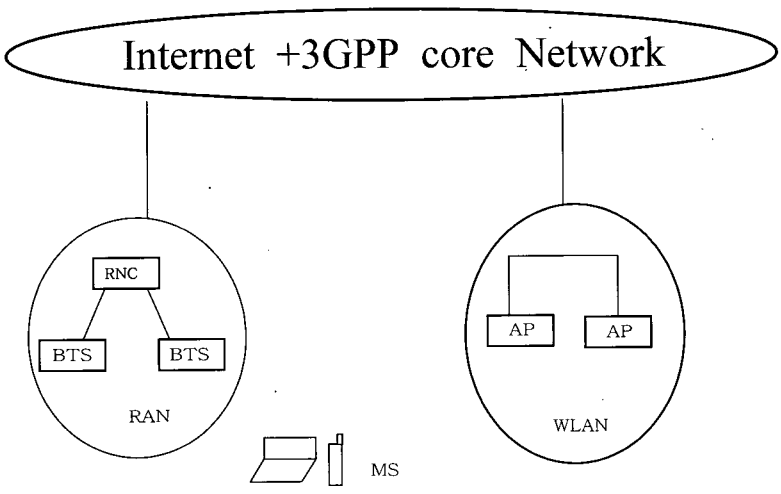
Scenario 1: Consider a cellular subscriber wanting to access internet at an airport where WLAN is deployed. There are two cases possible. The cellular operator owns the WLAN or the WLAN is not owned by the cellular operator. The cellular user shall be able to use the high-speed data service of WLAN independent of its ownership as long as cellular user is WLAN capable user. If the cellular user is not WLAN capable then it can not take advantage of this WLAN high-speed access network.

The cellular customer is able to take advantage of integrated environment in terms of common billing. The revenue will be shared by the WLAN Netwotk Operator and the Cellular Operator as per mutual revenue sharing agreements.

Scenario 1: A cellular WLAN capable user while accessing internet through WLAN access moves to an area where only cellular access is available. The following cases shall be considered:

- The user session terminates and it has to be re-started using cellular access.
- The user session continues with notice-able disruption in service.
- The user session continues without notice able disruption in service.

The session continuity during mobility without user intervention is an evolutionary step, which shall be kept in mind while working on inter-working solutions.



[Figure 1] Multiple access options in an integrated wireless access environment

Scenario 3: Lastly a cellular subscriber wanting to access cellular services like IMS, MMS, WAP, Location based services etc. using WLAN access network. This is called service selection. Even the Internet access can be selected through the cellular network instead of WLAN access network if so desired by the cellular customer. This integrated wireless access environment provide a WLAN capable cellular customer a very convenient way of using high-speed access where its available.

3. REQUIREMENTS CURRENTLY BEING STANDARDIZED WITHIN 3GPP

Standardization activities for 3GPP WLAN integration are currently undergoing under SA2 working group in 3GPP. This group is working towards inter-working interfaces towards WLAN systems. The design and development of WLAN interfaces is out of scope of this working group. The foremost aim of these activities is to ensure inter-working across several WLAN systems and cellular networks, irrespective of multi-vendor equipment involved.

INTERWORKING OBJECTIVES AND REQUIREMENTS

A. General Objectives

1. Independent Evolution of WLAN and 3GPP systems:

One on the principal objectives of inter-working is to allow the independent evolution of 3GPP and WLAN standards. The extent of interdependence between these standards has to be minimised or localised at the point of interconnection.

2. Support for Legacy WLAN Users:

This is perhaps the most important objective of a 3GPP-WLAN inter-worked setup. A legacy WLAN user is a user with a WLAN capable device and a subscription to 3GPP services. He may or may not be 3GPP capable. Such users should be able to access 3GPP services without substantial hardware/software upgrades. Such a setup would result in a strong business case, leading to extend the facility of 3GPP services to users who although have a 3GPP subscription but do not want to spend on the additional hardware/software upgrade.

3. Single Subscription

B. Inter-working Requirements/Scenario

1. Common Billing and Customer Care.

This is the simplest form of inter-working, which provides only a common bill and customer care to the subscriber but otherwise requires no real inter-working between the

WLAN and 3GPP data networks.

2. 3GPP Based Access Control and Charging:

This requires authentication, authorization, and accounting (AAA) for subscribers in the WLAN to be based on the same AAA procedures used in the 3GPP data networks. It means a cellular subscriber can use its SIM/USIM to access WLAN services. There are no requirements imposed on the services to be offered in the WLAN.

3. Access to 3GPP Based PS Services:

The aim of this requirement is to allow the cellular operator to allow access to its 3GPP data services to subscribers in a WLAN environment. It means a cellular subscriber shall be able to access/select 3GPP data services through the WLAN access network. Although the user is allowed access to the same 3GPP data services over both the 3GPP and WLAN access networks, no service continuity across these access networks is required under this scenario.

4. Service Continuity:

The goal of this requirement is to allow access to 3GPP data services as per scenario 3, and in addition to maintain service continuity across the 3GPP and WLAN systems. It means a cellular subscriber shall be able to continue its session while moving across 3GPP and WLAN systems. Under this requirement it is possible that service quality changes and/or there is a noticeable disruption in service. Some data services, which can not tolerate high delay, may also terminate under this scenario.

5. Seamless Services

The goal of this requirement is to allow seamless service continuity across the 3GPP and WLAN systems. It means that a user session during mobility across these networks shall not only continue but also shall not have noticeable service change in terms of quality and disruption.

6. Access to 3GPP CS Services

The goal of this requirement is to allow the 3GPP operator to offer access to circuit-switched services like voice calls from the WLAN systems. Seamless service continuity is a must requirement for these services.

With the above stated requirements and objectives, we present the two architectures for WLAN and 3GPP data networks inter-working namely loosely coupled and tightly coupled.

INTERWORKING ALTERNATIVES: LOOSE AND TIGHT COUPLING

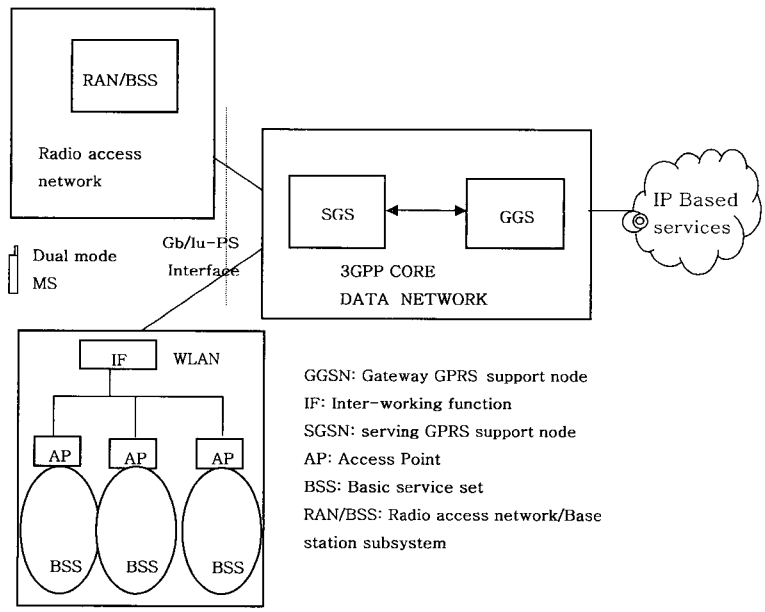
Inter-working between 3GPP and WLAN systems would involve interconnection

between the two systems. There are two models for inter-working, termed loosely coupled and tightly coupled, and fundamentally differ on the point of interconnection of 3GPP and WLAN systems. While loose coupling involves interconnection on the basis that WLAN system is not a cellular access interface, tight coupling involves interconnection on the basis that WLAN system is a cellular access interface. This subtle difference in the point of interconnection leads to significant differences between the overall system architecture, operation and characteristics. [Fig. 3] illustrates the loosely coupled architecture and [Fig. 2] illustrates the tightly coupled architecture.

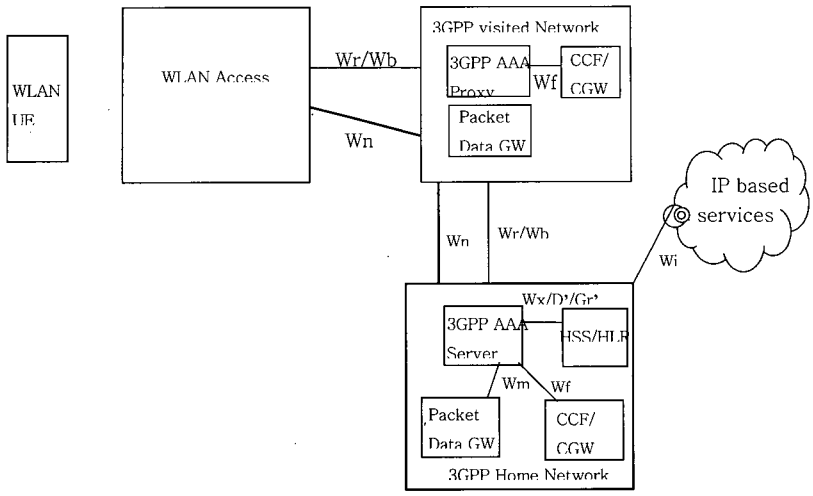
Tightly Coupled Architecture:

In this section, we briefly describe the tightly coupled architecture of inter-working between the WLAN and 3GPP systems. Figure 2 illustrates the proposed system architecture. The WLAN is deployed as an alternative RAN and connects to the 3GPP data network through the standard Gb/Iu-PS interface. From the 3GPP network point of view, the WLAN is considered like any other GPRS routing area in the system. In other words, the 3GPP GPRS network do not really identify the difference between a routing area with WLAN radio access and one with 3GPP radio access (RAN/BSS).

The key aspects of this approach of inter-working are as follows:



[Figure 2] WLAN-3GPP integration with tight coupling approach



[Figure 3] WLAN-3GPP integration with loose coupling approach

• MS's are dual mode. It means the MSs use the same set of core network protocols like GMM/SM but different radio access protocols with an additional adaptation function in between.

• The WLAN access network connects to the 3GPP core network with the same interface as the UTRAN/BSS of cellular access systems. This also requires an inter-working adaptation function in the WLAN access network.

• The WLAN access network looks like a single routing area with a single cell to the 3GPP packet data network.

• This requires that the WLAN access network shall be able to advertise its routing area.

Though this architecture is very novel but lacks many practical and commercial aspects. The main disadvantages of this inter-working approach are listed below:

• This approach of inter-working does not support legacy WLAN users as well as legacy WLAN access networks.
• This approach use the GPRS nodes for data routing which are not designed for this type of high-data rate access networks. So, will result in scalability problem.
• This approach also prevents independent evolution of WLAN access networks as certain cellular type access constraints are imposed on the WLAN access network.

With this description of tightly coupled architecture we conclude that this type of inter-working architecture is well suited for cellular operator owned WLAN access networks and not for multi vendor WLAN access network providers and operators.

Loosely Coupled Architecture

In this section, we will describe the loosely coupled architecture of inter-working between the WLAN and 3GPP systems. Figure 2 illustrates the proposed system architecture. The WLAN access network connects to the 3GPP data network like a different type of radio access network for inter-working. This way of inter-connection allows for the support of the legacy WLAN access networks, which commonly support RADIUS/DIAMETER protocols in the WLAN access network.

This inter-working approach defines some new interfaces with well defined functions and commonly

Used protocols. All the new interfaces are explained below:

Wb/Wr interface: This interface connects the WLAN access network either with the visited 3GPP data network or the home 3GPP data network. The Wr interface transports authentication, authoriz ation and other related information. The Wb interface transports charging related infor mation. The Wr interface logically connects the WLAN capable user to the AAA server, which resides in the cellular operator home network. The WLAN capable user is authenti cated and authorized by the AAA server. The WLAN related subscription information for the user will be stored in home HLR/HSS. The Extensible Authentication Protocol (EAP) is used for this purpose between the WLAN capable user and the AAA server. This protocol is transparently transported by Wr protocol.

To accommodate the existing WLAN access networks, which support RADIUS or DIAMETER, the Wr/Wb interface shall use DIAMETER protocol towards AAA server. The principle of authentication is mutual authentication. There are two methods of mutual authentication currently defined namely EAP/SIM and EAP/AKA. The EAP/AKA method is used for subscribers with USIM and EAP/SIM method is used for subscribers with SIM. The existing SIM subscriber authentication in cellular networks is not based on mutual authentication. This is the reason that the authentication methods are different for SIM and USIM based WLAN users.

Wn interface: The Wn interface transports tunneled WLAN user data towards the packet data gateway in the home network and vice versa. The same interface is used to transport tunneled data between the home packet data gateway in the home network and visited data border gateway in the visited network if the WLAN access network is not directly connected to the home network. It is also possible that the packet data is directly routed by the WLAN access network to the external IP networks. This is the reason that this interface is service specific. If the packet data

is routed by the packet data gateway then there are two ways of transporting the user packet data to the packet data gateway. One method is establishing a secure tunnel between the WLAN access network and the packet data gateway. This method is also called network based tunneling as the WLAN user is not involved. The other method establishes direct secure tunnel between the WLAN user client and the packet data gateway. This method is also called client based tunneling. The Wr interface is used to inform the WLAN access network about the tunneling related information.

Wx interface: This interface connects the AAA server with the HLR/HSS. The AAA server retrieves the authentication vectors over this interface from the HLR/HSS. The AAA server also retrieves the WLAN access-related subscriber infor- mation using this interface. The AAA server, to register itself, for an authorized WLAN capable user with the HLR/HSS also uses this interface. This interface also helps the AAA server to get indication of subscription related changes from the HLR/HSS. The AAA server shall also generate temporary identifiers for the WLAN user for security. These temporary identifiers shall be used as far as possible over the WLAN radio access network by the WLAN user.

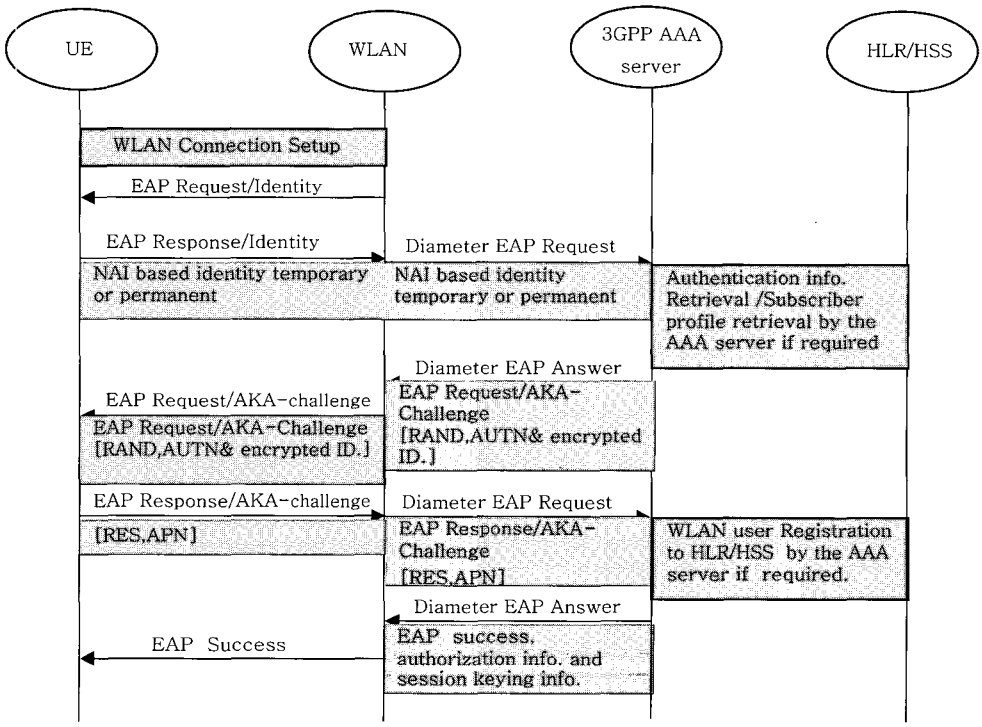
Functionally this interface is quite similar to MAP Gr interface defined between SGSN and HLR/HSS. This interface shall be based on MAP or DIAMETER protocol.

Wf interface: This interface connects the AAA server with the 3GPP charging control function or charging gateway function. The Wf interface transports charging information towards the 3GPP charging control/ charging gateway function. The charging information will be collected by the AAA server from either packet data gateway over Wm interface or Wb interface from WLAN access network or both. This interface shall be based on DIAMETER or GTP.

Wo interface: This interface connects the AAA server with the 3GPP online charging system for credit control checks for WLAN capable user. This interface shall be based on DIAMETER protocol.

Wm interface: This interface connects the AAA server with the packet data gateway for transport of charging related information and tunneling related information to the AAA server from packet data gateway. This interface shall be based on DIAMETER protocol.

Wi interface: This interface connects the packet data gateway with the packet data network. The packet data network may be an external public or private data network or operators internal packet data network. The protocol for this interface is dependent upon the packet data network.



[Figure 4] Authentication and Authorization steps for loosely coupled integration of WLAN-3GPP

4. PRINCIPLES OF SERVICE SELECTION:

GPRS provides service selection with the Access Point Name (APN) mechanism. There is expected to be different APN for different IP based services like WAP, IMS etc. The same mechanism can be used for service selection in WLAN-3GPP inter-working. The access of APNs can be stored in WLAN user subscription profile stored in HLR/HSS.

Scenario 3 requires that the WLAN user shall be able to select any IP based service offered by the 3GPP cellular network. This service selection can be either be achieved by the network tunneling or client tunneling solution. It is important to understand that the network tunneling has minimal implementation requirement on the WLAN UE user. The client tunneling solution requires either Mobile IP or IPsec client to be implemented in the WLAN UE.

Network tunneling solution though easy to implement but lacks support for session mobility. Client tunneling solution will be able to support session mobility. It is not required that all WLAN service providers have to support all scenarios. It is also possible that a WLAN provider may support both types of tunneling solutions and shall be able to enforce any tunneling option for the WLAN user

depending on its capability.

Client tunneling using Mobile IP requires support of Home Agent (HA) functionality in the 3GPP cellular network. The HA functionality can be either co-located with GGSN node or it can be an independent node within the 3GPP cellular network. The WLAN user registers its Care of Address (COA) with the HA. During session mobility, the WLAN user acquires a new COA from the respective radio access network and registers it with the HA.

This way all the packet data destined for the WLAN capable user can be routed to the packet data gateway by the HA when the user moves to the WLAN access network.

When network tunneling is used, the session establishment consists of the following steps:

- Authentication between the WLAN capable UE and the 3GPP AAA server.
- Communicating the APN information by the WLAN UE to the 3GPP AAA server. This step takes place after the authentication but before the completion of authentication.
- The 3GPP AAA server verifies the APN information and authorizes the WLAN user to use the requested service.
- The 3GPP AAA server communicates IP and tunneling parameters to the WLAN access network over Wr interface using DIAMETER protocol.
- The WLAN access network sets-up the appropriate tunnels with the remote packet data gateway of the cellular network.
- The WLAN access network grants the WLAN capable user network access and provides the required IP configuration parameters for the UE. This ends the successful authentication and authorization procedure with the UE using the EAP protocol. This protocol requires authorization steps carried out before the completion of successful authentication.

[Figure 4], illustrates these steps for a WLAN capable user using EAP/AKA method for USIM based subscriber.

5. CONCLUSION:

The recent evolution and successful deployments of WLAN systems worldwide has fueled the need for inter-working mechanisms between WLANs and 3GPP cellular data networks. As described above, there are two generic approaches for WLAN-3GPP cellular integration namely tight coupling and loose coupling.

With tight coupling the WLAN connects to the SGSN on a standardized interface (Gb or Iu-PS). The main advantage of tight coupling is enhanced mobility across the two access networks, and its entirely based on GPRS mobility management protocols. The tight coupling is well suited for WLANs owned by cellular operators and can not support third party WLANs. The main dis-advantages of tight coupling are unable to support legacy WLAN terminals, scalability and not evolutionary.

Loose coupling is primarily based on IETF protocols, which are already supported by most of legacy WLANs. Consequently, it imposes minimum requirements on WLANs. It also supports legacy WLAN terminals with minimum changes. However, it requires the provisioning of new equipment by the 3GPP cellular operator namely AAA server and Packet Data Gateway. It also requires the implementation of Mobile IP (MIP) for supporting mobility across the two access networks.

In the end we conclude that the loose coupling approach is best suited for multi-vendor WLANs inter-working with 3GPP data networks. This approach of inter-working is evolutionary in the sense that a WLAN operator can first start with scenario 1 &2 and then gradually move towards other scenarios. It is also less intrusive because it supports both legacy WLANs as well as legacy WLAN terminals. These are some of the reasons that justify the current trend towards loose coupling within the standarization for WLAN-3GPP integration.

OPEN ISSUES :

- The optimum place of HA functionality within the 3GPP cellular network for inter-working with WLANs.
- The Foreign Agent (FA) functionality placement within the loose coupling approach.
- The selection of visited network by the WLAN user. It is likely that a WLAN network is connected to many cellular networks and the WLAN user home network has roaming agreement with only one. How does the WLAN network do this selection ?
- The selection of WLAN networks by the WLAN user if an area is covered by multiple WLANs.
- Simultaneous access to both the access networks. Shall this be supported?
- Separation of authorization from authentication. Currently authorization is carried out in conjunction with authentication because of EAP protocol limitation.

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Biography

Swapnil Kumar Raktale received his M. Tech in Computer Science and Engineering from IIT Delhi in 2000. He joined Hughes Software Systems in 2001, and has been engaged in radio interface protocol software development, for UMTS radio network controller. His research interests include wireless systems, push architecture and high speed data radio interface technology.

I am currently working as a Senior Consultant at Hughes Software Systems (HSS) in India on 2.5G (GPRS/EDGE) and 3G (UMTS) technology. In my role as a consultant, I am involved with tracking the 2.5G and 3G specifications from various inter- national bodies, providing consultancy to various projects on 3G and providing the product direction for the 2.5G and 3G products at HSS.

I have been involved in the design and development of Telecommunications systems both Wireline and Wireless for over 15 years. Prior to the present assignment, I have worked in organisations like Centre for Development of Telematics (C-DOT), Siemens and Interwave Communications in the United States of America. The assignments in my previous organisations involved development of DSS1 switch , Wireless office , cummunity wireless networks supporting N-ISDN , GSM, DCS ,PCS technologies. I have also worked as system analyst for GPRS systems and training faculty for GSM/GPRS .

I have published papers On Mobile IP in Cellular Networks and WLAN-3GPP interworking Architectures. I have been an invited speaker at IEEE conference in India on convergence of Wireless Communication and Internet and IBC asia conference in Singapore on All IP networks .

I obtained my B.E(Hons) in Electrical & Electronics Engineering in 1983 with distinction from Birla Institute of Technology & Science , in India.