

A Secure Context Management for QoS-Aware Vertical Handovers in 4G Networks*

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Abstract. In the 4G mobile networks which are expected to be very complex systems interconnecting various technologies, new intelligent services will need to be aware of various contexts. In this paper, we present the context management framework that exploits the agent technology in mobile communications and services. We focus mainly on the seamless secure handover which uses context information regarding location privacy, security, network environment, and QoS priority. We designed QoS Broker that can perform the autonomous decision making for context-aware handover without the direct intervention of users. To minimize the signaling overhead, we present an efficient context transfer mechanism among the Brokers. We also designed the context model for the seamless vertical handovers so that the Brokers could ensure the right context is available in the right place at right time. We developed the testbed and analyzed the performance of QoS-aware secure roaming with context transfer. Analytical results show that our context-aware vertical handover provides better performance and security with lower latency.

Keywords: 4G, context-aware, home network, QoS, vertical handover, mobile networks, security.

1 Introduction

The some key features in the vision of fourth generation (4G) wireless networks are high usability at anytime, anywhere, and with any technology, to support for intelligent services at low transmission cost[1]. The core component towards 4G architecture is system integration [2], where a unified wireless access system is to be established through the convergence of the services offered by current access technologies such as of wireless LANs (WLANs) with third-generation (3G) mobile networks including Universal Mobile Telecommunications System (UMTS) and CDMA2000. In these heterogeneous networks, providing seamless

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roaming services, as well as preserving security and privacy, is the most challenging problems in the integrated services. The seamless communication environments require a variety of context such as user identity, current physical location, weather conditions, time of day, date or season, and whether the user is driving or walking. The pervasive systems need to adapt to context changes, including mobility, network condition, security level and quality of service (QoS).

However, the context information is difficult to manage, because the its amount can be enormous. The context information is distributed in both network and mobile terminal. The context information can be either static or dynamic, location dependent. Wireless link is the bottle neck for context exchange. Furthermore, mobility management is more complicated in the integrated networks. A mobile node (MN) is equipped with multi-mode wireless interfaces to connect to one, multiple or all wireless access networks anytime anywhere. In security management for the vertical handovers (handovers between heterogeneous networks) encryption keys and authentication data may need to be exchanged at every handover, which further complicates and slows down the handover procedure.

A context management framework with intelligent tools can assist the users and applications in delivering the required QoS. Agent technology is expected to become the tool for development of future computing environments such as mobile computing, e-commerce, telecommunication network management, etc. [3]. In this paper, we present the context management framework that exploit the agent technology in communications with more emphasis on QoS-aware mobile agents. We focus mainly on the QoS-awareness in seamless handover. QoS-aware vertical handover between heterogeneous networks is one of many possible adaptation methods for seamless services.

We designed *QoS Broker* and enhanced *Location Manager* that perform the autonomous decision making for context-aware handover without the direct intervention of users. When the secure vertical handover occurs, the MN and the access router need to exchange keys and authenticate each other. This process is time-consuming and creates a significant amount of signaling. To minimize the need to signal over the wireless link, context transfer mechanism could be one solution. We present an efficient context transfer mechanism among *QoS Broker* and *Location Manager*. AAA servers in different domains forward the AAA pre-established information to the new AAA servers. We also designed the context model for QoS-aware vertical handover for 3G/WMAN/WLAN interworking systems. With our context model the *Brokers* could ensure that the right context is available in the right place at right time. We have been developed the testbed and analyze the handover performance of location-aware secure roaming with context transfer in an IP-based 4G network with UMTS and WLAN access networks.

The rest of this paper is organized as follows. Section 2 describes the context model used in our solution. Section 3 presents our context management framework in the 3G/WLAN/WMAN interworking system. Section 4 describes our prototype for QoS-aware vertical handover. Section 5 describes our testbed

and experimental result for QoS-aware vertical handover with context transfer. Section 7 concludes this paper.

2 A Context Model for QoS-Aware Services

Toward seamless services in 4G networks, a simple set of information is insufficient and a rich set of context is required [5]. In this paper we focused mainly on QoS and location context which is needed to support seamless vertical handovers. The entire context model is shown in Fig. 1. We propose the classified profiles[4] and the dynamic context to accommodate more adaptive and optimal service environments. A key advantage of the classified profiles is that QoS-aware and location-aware services can be customized to fit user's specific needs. Users and QoS Brokers adaptively modify the profile usages for the heterogeneous wireless networks. This mechanism could bring the maximized QoS and security as well as minimized leakage of privacy information. The layout of the context features could be identified according to the profile types(User, Nobile Node, Service, QoS Policy and Network Profiles). Profile types would be registered with Policy Servers, and each specification would lay out fields for use by the context transfer protocol. Default values, if specified, are already indicated by the profile type. The dynamic context provides current information about users and networks such as current user location, current user device, current QoS and service parameters. The dynamic context also includes the handover parameters that indicate to which network handover is most likely. This information changes dynamically when the user location or the network QoS changes.

3 Context Management Framework for Seamless Services in Future Mobile Networks

In this section, we propose the context management framework which is designed to meet the QoS and security requirements. The main objective of our framework is to ease the integration of heterogeneous networks by providing customized context profiles with QoS Brokers and Location Managers which can be assembled to create future seamless services. The Fig. 2 shows the proposed context management framework. The QoS and location-aware 3G/WMAN/WLAN interworking system is designed for satisfying the key requirements of 4G wireless networks. We assume that a MN is a triple-mode terminal with three interfaces 3G, WLAN and WMAN. For secure interworking we considered that authentication and key management should be based on the UMTS authentication and key agreement (AKA) and EAP-AKA or EAP-SIM for WLAN [6]. On the 3G/WLAN interworking a feasibility study [7] was conducted by the 3GPP with the loosely and tightly coupled solutions. The loose coupling solution allows a customer to access 3G packet-switched (PS) services over WLAN and to change access between 3G and WLAN networks during a service session. QoS is a critical issue for the service continuity.

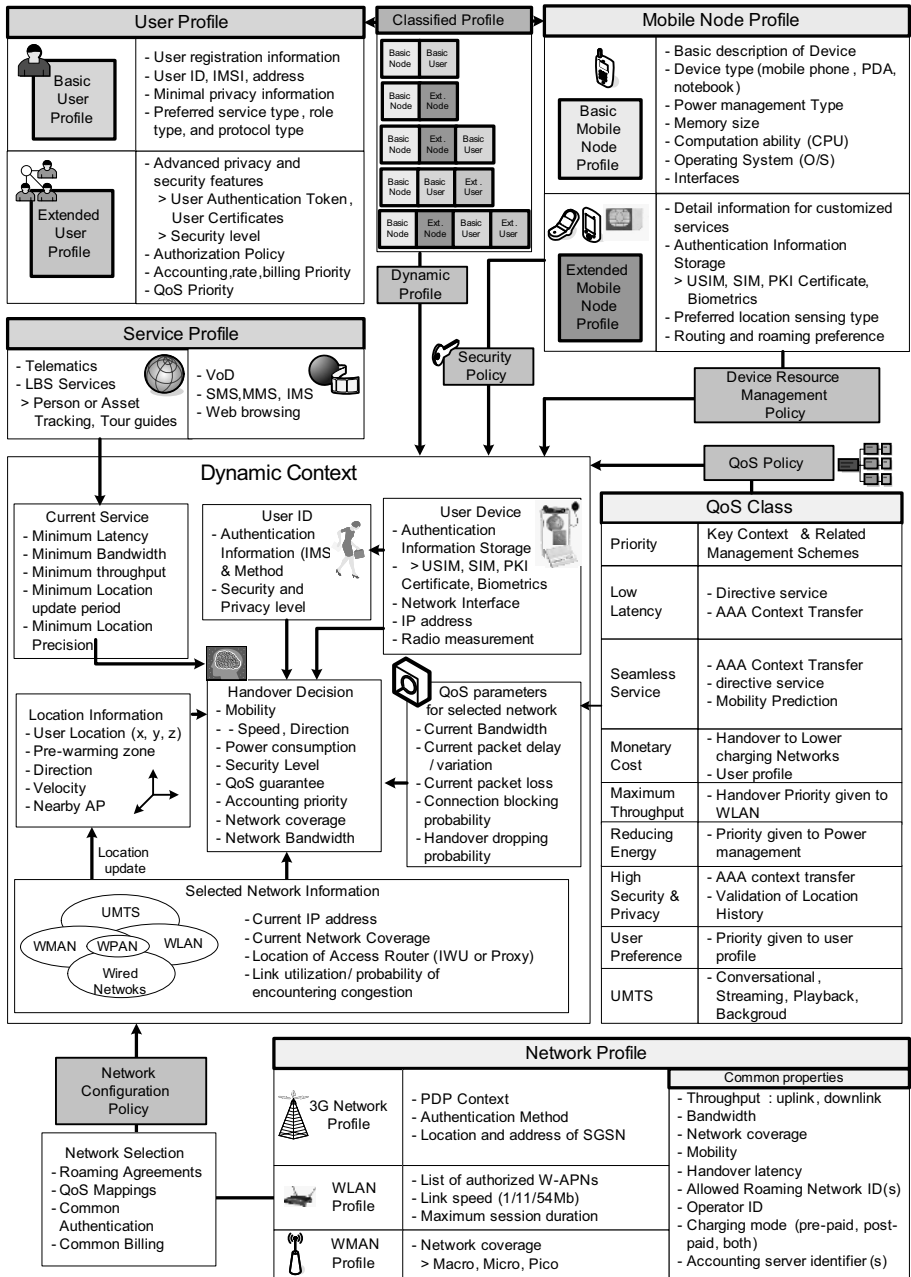
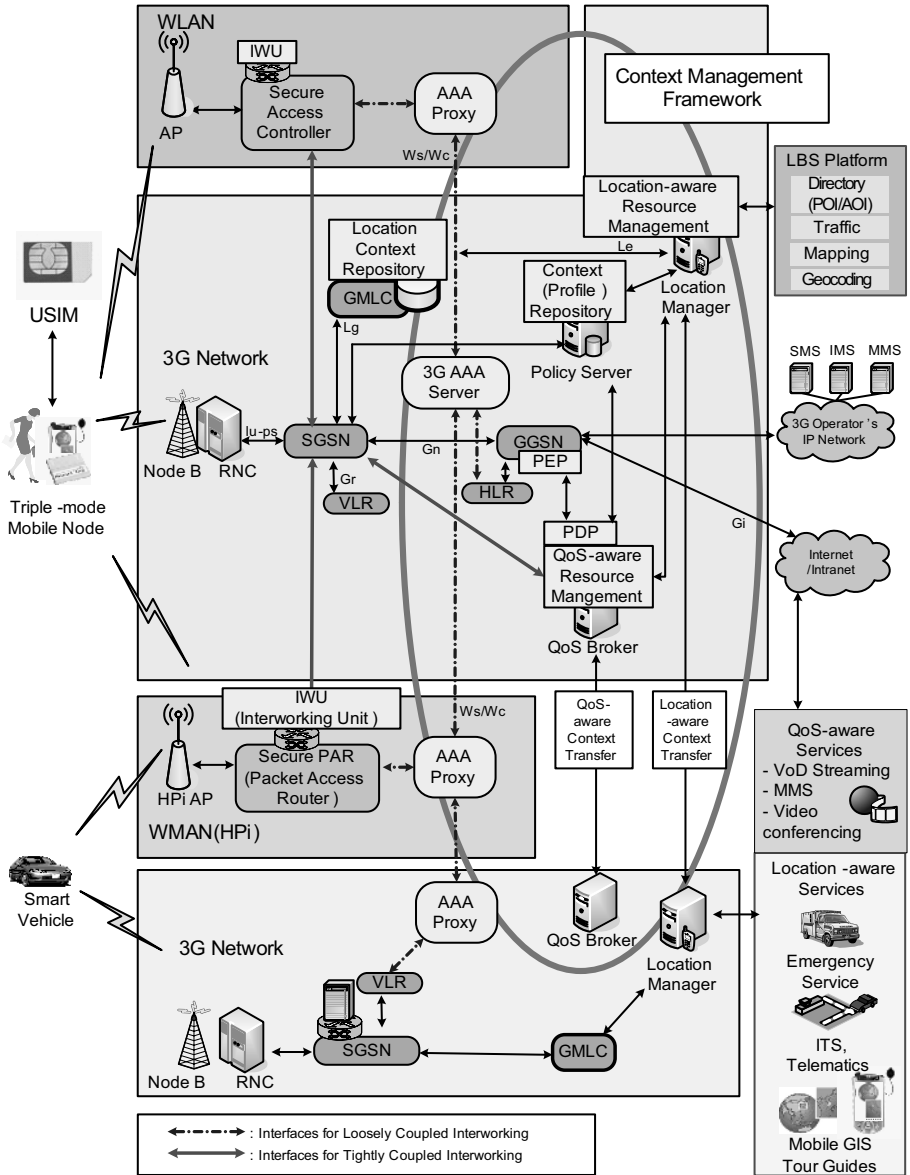


Fig. 1. Context Model used in Location and QoS-aware Interworking System

Tight Coupling refers to the alignment of WLAN interfaces with the access interfaces of the 3G network. WLAN is connected to Gateway GPRS support



PDP Policy Decision Point, HLR Home Location Register, VLR Visitor Location Register
 Wt/Wb: This interface carries AAA signaling between the WLAN and the 3G visited or home PLMN in a secure manner
 Ws/Wc: This interface provides the same functionality as Wt/Wb but runs between a AAA proxy and a 3G AAA server
 Wx: This reference point provides communication between AAA infrastructure and HSS
 Wg: An AAA interface between 3GPP AAA proxy and WAG for provisioning of routing enforcement functions for authorized users
 Wt: This is used by a 3GPP AAA server to communicate with the online charging system
 Wf: The interface between 3GPP AAA server and charging gateway function
 Wt: Reference point between the packet data gateway and a packet data network
 D/Gr: This optional interface is used for exchanging subscription information between the 3G AAA server and the HLR

Fig. 2. The 3G/WLAN/WMAN Interworking System for QoS-aware Mobile Services

node (GGSN) via GSM Serving GPRS Support Node (SGSN) in the 3G network. The principle advantage of this solution is that the mechanisms for mobility, QoS, and security in the UMTS core network can be directly reused. We have also considered the interworking of the wireless metropolitan area networks (WMANs) with IEEE 802.16[8]. For several networking interfaces we adopt the notation and functionality specified in [9]. Location Managers get location information directly from Gateway Mobile Location Center (GMLC) [10].

The framework supporting context-aware vertical handovers includes QoS Brokers which evaluate QoS parameters makes decisions about adaptations to context changes. Policy server which gathers, manages profiles and policies as the result of service level agreement (SLA). Location Managers help QoS Brokers to make decision about location-aware resource management. AAA Proxies are responsible for the secure AAA information exchanges in executing handovers.

4 QoS-Aware Vertical Handover

4.1 Context Evaluation for Location-Aware Vertical Handover

In the traditional handover process, a MN seeks its nearest access points (APs) as candidates for the next handover. However with the variety of node densities, network coverage, and QoS guarantees of the interworking systems, the paradigm of handover through nearest AP must be reconsidered. Furthermore, an efficient QoS and location-aware scheme should allow the MN to consume less power to extend the battery life by minimizing the cryptographic operation during the secure handover. In the case of vertical handovers, we designed the QoS setup procedures supporting QoS-aware vertical handover. Our vertical handovers are based on the evaluation of dynamic context and decision priorities. We extended the concept of the context evaluation matrix [14]. The evaluation matrix can be as follows (1):

$$AP_i = L_i \sum_{j=1}^M S_j \sum_{k=1}^N c_k q_k p_k \quad (1)$$

- L_i is the parameter which will affect the location-aware handover decision. L_i represents the possibility of handover based on mobility prediction of the MN.
- S_j is the service which is both supported by the network and the mobile node.
- c_i is the coefficient of different parameters which represent user preference or operator specific parameters.
- q_i is parameter which will affect the QoS-aware handover decision. For example, q_1 can be the QoS priority and p_2 handover dropping probability.
- p_i are parameters which will affect the decision. For example, p_1 can be the currently available bandwidth of different APs and p_2 could be the signal strength of different APs.

In this evaluation matrix, AP_1, AP_2, \dots are the access points. Each AP is evaluated by context information and the highest one is chosen.

4.2 QoS Management with QoS Broker

In our framework the QoS management procedure with QoS Broker includes the following three major steps.

Step1: QoS Specification and QoS Profile Setting

- Candidate application configurations and their resource assignments
- Application adaptation policies, Application state template

Step2: Service registration

Step3: QoS Setup Procedure with QoS Broker

- Service Discovery and authorization
- Location-aware resource control with Location Manager
- Application Configuration Selection
- QoS Profile Downloading
- Resource Allocation

We designed QoS Broker as shown in Fig. 3, the enhanced the model of [15][16]. QoS Broker plays key roles in QoS-aware handover with core modules like Application specific Control, QoS Service Management, QoS-aware resource Management and interworking interfaces to SGSN, Secure Access Router, AAA Broker and QoS Broker. QoS Broker acts as a Policy Administration Point (PAP) in service level agreement step and a Policy Decision Point(PDP) in QoS-aware service step. As a PAP, it creates a policy set to Service Level Agreements (SLAs) with users. The policy includes user profiles and other QoS parameters like QoS priority class, network preferences.

The QoS Brokers and Location Managers can support end-to-end QoS. Fig. 4 shows the location-aware end-to-end QoS support in vertical handover of UMTS-to-WLAN. The MN initiates the handover procedure and sending a handover request to its new Access Controller(AC) in WLAN (message 1). The request is then forwarded to the AAA server (message 2). AAA server sends QoS setup request to QoS Broker (3a). QoS Broker dumps the profile and performs QoS-aware resource configuration (3b). Then, QoS Broker interacts with Location Manager for location-aware resource management (3c). Upon successful authentication, AAA server performing the required association between user and MN, and informs the MN via the AR (3e+4). The messages 5~8 represent the authorization procedure for the QoS setup in the vertical handover.

5 The Implementation Testbed

We developed the core components of our framework in Fig. 2 and we analyzed the performance of QoS-aware secure roaming with context transfer in an IP-based 4G network with UMTS and WLANs. Table 1 summarizes the parameters underlying the performance experiments. QoS Broker and Policy Server are running on SUN workstations with Solaris 8 operating system (O/S). AAA Servers are running on SUN workstations with Linux O/S and the modified FreeRADIUS library for RADIUS functionality. MNs are running on Pentium III machines and Lucent Orinoco 802.11b WLAN cards.

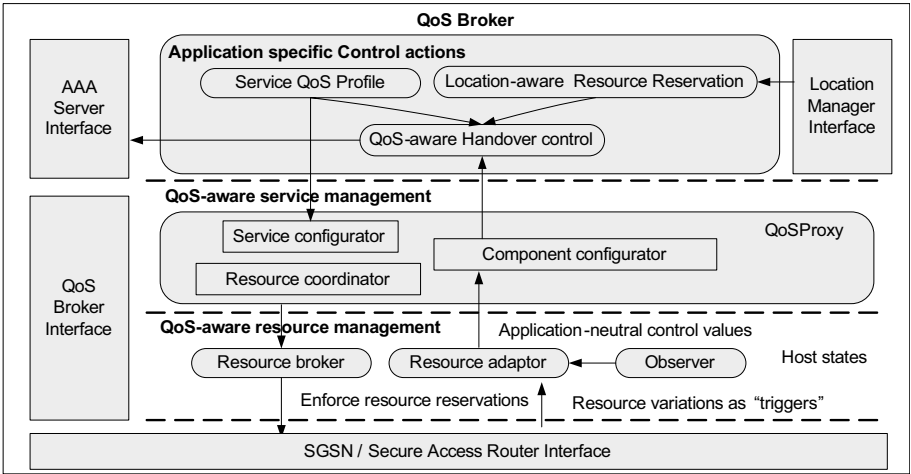
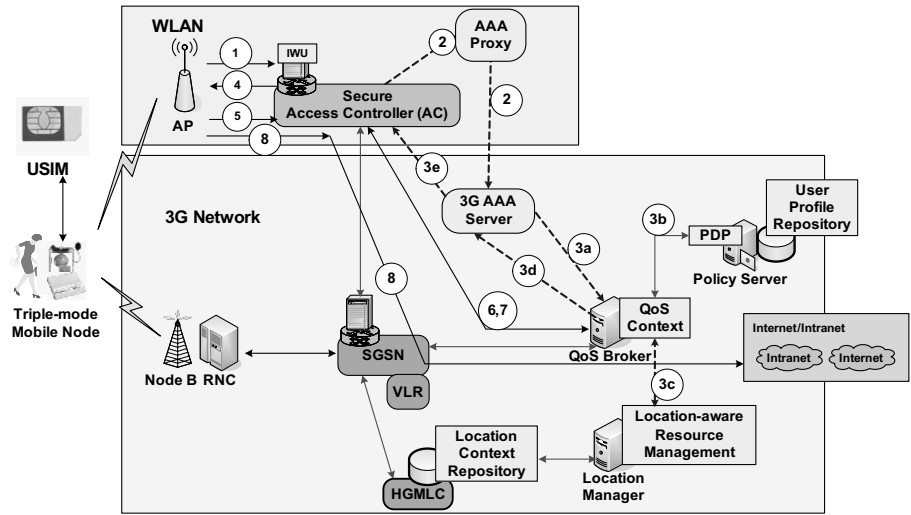


Fig. 3. QoS Broker Architecture



Step	Message	Parameters	Remarks
1	AA request	NAI; credentials; CoA	Network selection
2	AA request	NAI; credentials; CoA	
3a	QoS setup request	NAI; credentials; CoA, AR	Initiate QoS setup procedure
3b	Profile dump	MN, AR, profile subset	Profile with dynamic context
3c	Location validation request/response	NAI; credentials, MN, AR	Location history Validation
3d	QoS setup response	profile subset, session timeout	Location-aware resource control
3e	AA response	key (MN, AC), profile subset, session timeout	Information for AC and MN
4	AA Response	key (MN, AR), profile subset, session timeout	
5	Service Request	QoS Broker Point, CoA, destination address	AC as proxy for MN
6	Authorization request	QoS Broker Point, CoA, destination address	AC configuration
7	Authorization confirmation	Policy for the requested service	Providing QoS-aware services
8	User data		

Fig. 4. QoS-aware End-to-End Support in vertical handover of UMTS-to-WLAN

Table 1. Base parameters of the Testbed

Entity	Operation	Description	Performance
MN-AAA	802.1X full authentication (EAP-TLS)	Average delay	1,600ms
QoS Broker	QoS-aware Handover Control	QoS profile setting and resource configuration	80ms
MN-AP	802.11 scan (active)	Average delay	40~ 300ms
MN-AP	Fast Handover (4-way handshake only)	Average delay	60ms
AAA AAA Server	Proxy- AAA Context Transfer Response	Average delay	15ms
UMTS /802.11	Intradomain UMTS to WLAN Handover with EAP-SIM authentication	Average delay	9,300ms

Fig. 5(a) shows that the vertical handover from WLAN-to-WLAN introduces a minimum delay of 1.2360s, while for our handover with context transfer the minimum delay is 0.7161s. Fig. 5(b) shows that the vertical handover from UMTS-to-WLAN introduces a minimum delay of 1.9484s, while for our handover with context transfer the minimum delay is 0.8915s. The modified AP represent that We modified the state machine of APs to support context caching in AAA context transfer. It is important to note that the improvement of our handover scheme with context transfer is about 54.3%.

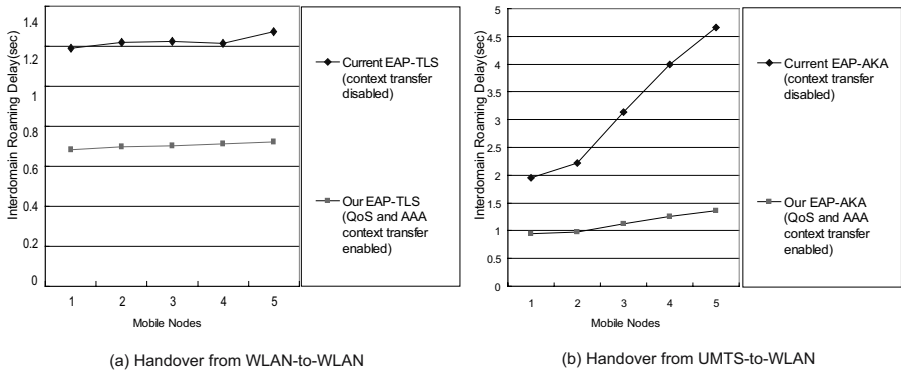


Fig. 5. Delay performance of the QoS-aware Vertical Handovers

6 Conclusions

In this paper, we analyze the context-aware computing issues and present the context-aware management framework designed to maximize the efficiency and interoperability for the desired QoS guarantee in 4G networks. The proposed framework can integrate a variety of wireless technologies (3G, WLAN and WMAN) into a seamless communication environment. We design QoS Broker to meet the various QoS requirement and Location Manager to effectively solve

location-aware resource management problems. The experimental results of the fast QoS-aware handover with context transfer have been presented. The proposed QoS-aware handover mechanism is being integrated with the secure Web Services infrastructure[4] and new 3GPP/WLAN interworking systems[11].

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