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Performance analysis of a novel architecture to integrate heterogeneous wireless systems

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Abstract

Current wireless world witnesses multiple heterogeneous systems such as Bluetooth, IEEE 802.11, UMTS, and satellite networks. These systems are envisioned to coordinate with each other to provide ubiquitous communications to mobile users. A novel architecture, Architecture for ubiquitous Mobile Communications (AMC), is introduced in this paper that integrates these heterogeneous wireless systems. AMC eliminates the need for direct Service Level Agreements (SLAs) among service providers by using a third party, Network Inter-operating Agent (NIA). Instead of developing a new architecture, AMC extends the existing infrastructure to integrate heterogeneous wireless systems. It uses IP as the interconnection protocol to provide transparency to the heterogeneities of individual systems. Third-party-based authentication and billing algorithms are designed for AMC. New handoff management protocols are also designed to support seamless vertical handoffs between different wireless systems in AMC. Performance analysis is carried out to determine the latency associated with vertical handoffs and the load on the NIA that arises because of these vertical handoffs. Toward this, a network deployment scenario that consists of three types of wireless systems: WLAN, 3G, and satellite networks is considered. Moreover, the number of SLAs required in AMC is also determined for a given number of network operators. It is also shown that by using hierarchical structure, AMC can realize the integration of heterogeneous wireless systems around the globe.

Keywords: Architecture; Heterogeneous wireless systems; Authentication; Vertical handoff

1. Introduction

Various heterogeneous systems exist in the current wireless world. They adopt different radio technologies and have different network architectures and protocols, such as Bluetooth for personal areas, IEEE 802.11 for local areas, Universal Mobile Telecommunication System (UMTS) for wide areas, and satellite networks for global area. These systems are designed for specific service needs and vary widely in terms of bandwidth, area of coverage, cost, and Quality of Service (QoS) provisioning [2]. However,

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none of them can simultaneously satisfy the low-latency, high-bandwidth, and ubiquitous-coverage needs of mobile users at low cost. Since different wireless systems, each of which is optimized for some specific service demands and coverage area, are complementary to each other, they can co-operate to provide ubiquitous "always best connection" [3] to mobile users. This necessitates the design of intelligently integrating the existing wireless systems so that the users may receive their services via the best available wireless network anytime anywhere.

The integrated wireless system must keep the best features of individual networks, while at the same time, eliminates their weaknesses and drawbacks. It must be able to support for the best network selection based on users' service needs so that each user is always connected to the best available network or networks; must have mechanisms to ensure high quality security and privacy; and must have protocols to guarantee seamless inter-system mobility. Moreover, the architecture should be scalable, i.e., able to integrate any number of wireless systems of different service providers who may not have direct service level agreements (SLAs) among them.

The concept of integrating two or more systems to get better performance is already in use and has been proven to be highly efficient. The existing integrated architectures address the following issues: integration of two specific systems, integration of any two systems, integration of networks of multiple operators but of the same technology, and integration of networks of different operators employing different technologies. These architectures are described below.

In [4,5], specific pairs of different systems are integrated through an additional gateway, such as interworking of Digital Enhanced Cordless Telephone (DECT) with Global System for Mobile Communications (GSM) and interworking of IS-41 with GSM. The additional gateway proposed between a pair of systems takes care of interworking and inter-operating issues such as transformation of signaling formats, authentication, and retrieval of user profiles. In addition, different architectures are proposed to integrate WLAN and 3G wireless networks [6,7]. All the above architectures are limited to the integration of a specific pair of systems and hence are not scalable to integrate multiple systems.

The Boundary Location Register (BLR) approach [8] is proposed to integrate any two adjacent networks with partially overlapping areas. In [9] a handoff algorithm is proposed to carry out seamless inter-system roaming under this architecture. However, this approach is not scalable in the sense that one BLR gateway is needed for each pair of adjacent networks when integrating multiple networks. Moreover, the above architecture assumes the existence of SLAs between the networks, which is not desirable.

GSM association has proposed an inter-PLMN (public land mobile network) backbone using GPRS Roaming eXchange (GRX) [12] to globally integrate the GPRS networks deployed by various providers who may not necessarily have direct SLAs among them. This architecture uses multiple peer GRX nodes for connecting several GPRS networks. This architecture is limited to only one technology, i.e., GPRS networks.

In SMART project [13], a new architecture is proposed to integrate heterogeneous networks. The architecture uses two distinct networks: *basic access network* and *common core network* for signaling and data traffic, respectively. This architecture is scalable, but requires the development and deployment of the new basic access and common core networks. Hence, it is not cost-efficient.

Heterogeneous network integration using Mobile IP [15] and Session Initiation Protocol (SIP) [22] are proposed in [14,22], respectively. In these architectures, Mobile IP and SIP use Authentication, Authorization, and Accounting (AAA) agents to carry out authentication and accounting during inter-network roaming. However, these architectures do not have any mechanism to decide the best available network. Moreover, although Mobile IP and SIP protocols are used to carry out inter-system handoff, seamless support of inter-system handoff is not always guaranteed [1].

None of these existing architectures satisfy all the previously specified requirements of the integrated heterogeneous systems. This is our motivation behind the design of a new architecture for heterogeneous wireless systems with all the desired characteristics.

In this paper, we present the design of a novel architecture for ubiquitous mobile communications, AMC. AMC integrates heterogeneous wireless systems using a third-party, Network Inter-operating Agent (NIA), thereby eliminates the need for direct SLAs among different network operators. We design the protocols for authentication and billing in AMC. We also design the mobility management protocols to support best network selection and inter-system handoff. AMC achieves transparency