Integrating WMAN with WWAN for Seamless Services*

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Abstract. Nowadays, wireless packet data services are provided over Wireless WAN (WWAN), i.e., cdma2000 1x/1xEV-DO mobile networks and Wireless MAN (WMAN) is being standardized for users to demand higher data rate services. WMAN can provide high data rate services, but its service coverage is relatively small. If WMAN may be integrated with WWAN, users are able to choose the optimal service according to service areas and get seamless services while they are moving around. At the same time, it is cost-effective for operators to construct and maintain the integrated network. In this paper, we propose an interworking scheme for the purpose of effectively integrating WMAN and WWAN. The proposed scheme adopts a tightly-coupled architecture for unified authentication/accounting and seamless services. In addition, we develop a performance model for handoffs between WMAN and WWAN. Through extensive simulations, it has been validated that the proposed scheme reduces packet losses dramatically compared with the loosely-coupled scheme.

1 Introduction

Recent advances in wireless communication technologies have provided driving forces behind the emergence of various wireless services. First of all, the mobile communication systems (WWAN) have been developed and evolved into the third generation. As a result of CDMA's enhanced capabilities and simplified migration path, the cdma2000 3GPP2 mobile communication system, one of the IMT-2000 standards, has been nation-widely deployed in Korea since the early of 2000, which is the world's first successful commercial deployment. Moreover, the number of Internet users has increased rapidly so that voice-centric services have changed into data-centric services. The cdma2000 mobile communication system has been evolved into 1xEV-DO and 1xEV-DV for high speed data services. The cdma2000 1xEV-DO services are also available in several countries including Korea.

As a result of the consecutive successful development of wireless networks, a new WMAN service, so-called WiBro (Wireless Broadband), has been defined

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in Korea for higher bandwidth with broader coverage. It has been developed to enable users to access the Internet anywhere anytime with high speed and good quality using portable equipments such as laptops, PDAs, and smart phones. WiBro network is based on IEEE 802.16 broadband wireless access [1]. It adopts OFDMA/TDD for multiple-access and duplex schemes, and aims to provide mobility rates up to 60km/h and data service rates up to 50Mbps. It has several additional functions to the IEEE 802.16 specification such as handoff, sleeping mode, periodic ranging, and bandwidth stealing [2].

The differences between WiBro and cdma2000 mobile communication systems can be considered in terms of cost, data rate, and coverage. That is, WiBro can provide high speed data communication with low costs but its service area is relatively small. If it effectively cooperates with existing cdma2000 mobile networks which are serviced in the whole country, customers are able to use enhanced and seamless services without interruption depending on service areas. Moreover, it will allow service providers to offer high speed data services with low costs through reducing expense for network construction and management. Considering handoffs between WiBro and cdma2000 services happen frequently, the technologies for seamless and continuous services should be carefully considered. In this paper, we propose an integration scheme between WiBro and cdma2000 mobile networks to provide seamless services. In addition, we develop a performance model for handoff between WiBro and cdma2000 mobile networks, and show the excellence of the proposed scheme through extensive simulations.

The remainder of the paper is organized as follows: Section 2 investigates various existing interworking schemes between 3G networks and WLANs as related work. In section 3, we propose our integration scheme in Section 3 and evaluate its performance through extensive simulations in Section 4. Section 5 presents some concluding remarks and future work.

2 Related work

As there is no research effort on the integration of WiBro and 3G mobile networks to the best of our knowledge, we introduce the integration schemes between 3G networks and WLAN as related work. The early version of several research efforts on the integration of 3G mobile network and WLAN [3–8] can be summarized as: (1) loosely-coupled and (2) tightly-coupled integration. In the loosely-coupled integration model, 3G network and WLAN exist independently and they also provide independent services. This integration model adds a gateway to support authentication and accounting for roaming services, and uses the mobile IP to provide mobility between WLAN and 3G network. Most existing research efforts on the integration of 3G networks and WLANs have focused on the loosely-coupled integration model [3–7] than the tightly-coupled integration approach, because of the service features of WLANs - that the mobility range of mobile nodes is very small. The advantage of the loosely-coupled integration is that it can be simply adapted to the existing communication systems and it thus can minimize the development efforts on making new standards.

On the other hand, in the tightly-coupled integration model, an AP in WLAN is connected to the SGSN or the PDSN in 3G networks, and thus it is possible to support integrated authentication, accounting, and network management. The tightly-coupled integration model requires further standardization work and, thus it may take far longer time to achieve the final step supporting seamless services and service continuity. Motorola laboratory proposed a tightly-coupled interworking method to integrate GPRS with WLAN [8]. Since the GPRS layer 1 and 2 in the proposed tightly-coupled integration model are simply substituted by the WLAN PHY and MAC, whereas the layer 3 of GPRS is used, the integration system requires additional non-trivial overhead on a mobile node and needs a gateway to support the functions of the GPRS layer 3. To the best of our knowledge, this is the unique research to present the tightly-coupled scheme for WLAN and GPRS.

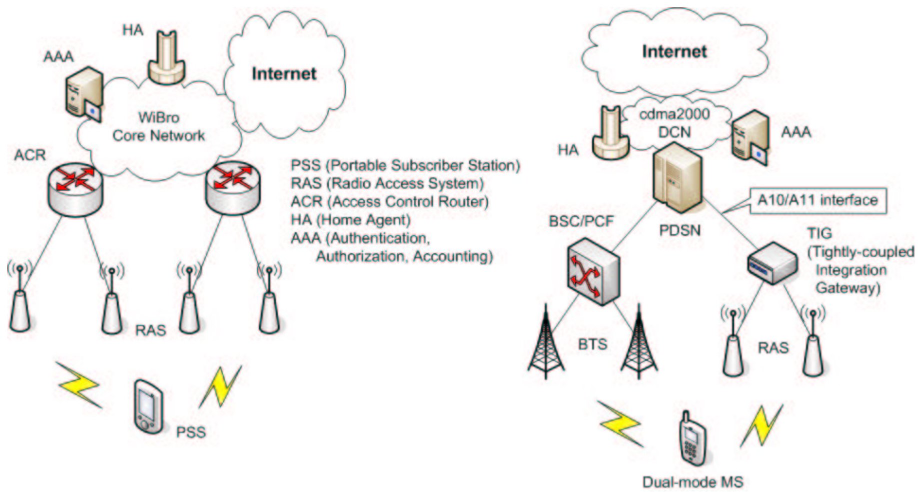
3 The proposed scheme

3.1 The network architecture

First of all, we introduce the current architecture of the WiBro network in Figure 1(a). There are four main components in the architecture: PSS, RAS, ACR, and WiBro Core Network. PSS communicates with RAS using WiBro wireless access technology. The PSS also provides the functions of MAC processing, mobile IP, authentication, packet retransmission, and handoff. The RAS provides wireless interfaces for the PSS and takes care of wireless resource management, QoS support, and handoff control. The ACR plays a key-role in IP-based data services including IP packet routing, security, QoS and handoff control, and foreign agent (FA) in the mobile IP. The ACR also interacts with AAA server for user authentication and billing. To provide mobility for PSS, the ACR supports handoff between the RASs while the mobile IP provides handoff between the ACRs.

In order to integrate the current WiBro architecture in Figure 1(a) with cdma2000 mobile network, the loosely-coupled integration model which was introduced in Section 2 may be considered. However, whereas WLAN provides services for fixed stations, WiBro can provide mobile services. As the service area of WiBro is smaller than that of cdma2000, vertical handoffs between WiBro and cdma2000 networks may happen frequently. Hence, the integration scheme for seamless services on handoff must be carefully considered.

Figure 1(b) depicts a tightly-coupled integration architecture. As shown in Figure 1(b), RAS in WiBro can be connected to PDSN in cdma2000 network through TIG which converts packets from RAS into ones conformed to A10/A11 interfaces [9], and vice versa. While adopting the tightly-coupled integration architecture, we should also take into account that cdma2000 networks have already been deployed and widely used. That is, the modification of existing nodes in cdma2000 networks should be minimized. To do that, we develop an efficient integration scheme in the next subsection.



(a) Current WiBro architecture (b) Proposed integration architecture

Fig. 1. Network architecture

3.2 The integration scheme

In cdma2000 packet data services, a mobile station first creates a PPP connection with PDSN. During that procedure, user authentication and IP address allocation are performed. On the other hand, in WiBro, EAP for user authentication and DHCP for IP address allocation are being considered. For the tightly-coupled architecture in Figure 1(b), however, it is efficient that WiBro adopts the mechanism of cdma2000 packet services. That is, a dual-mode MS handles PPP connections for WiBro as well. There are several advantages for doing that. First, the implementation of dual-mode MS is less complicated by adopting the same mechanism. Second, there is no modification of PDSN - this is the most important because cdma2000 networks have been deployed already. Third, the functionality of TIG is only to convert packet formats (i.e., not to process signaling messages and data traffic), and thus, TIG can be implemented with ease.

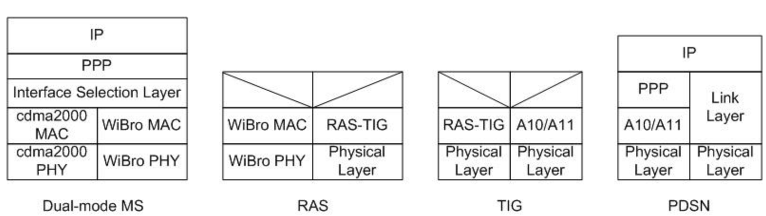


Fig. 2. Protocol architecture

Figure 2 shows the proposed protocol architecture for our scheme. The dual-mode MS in Figure 2 shares IP and PPP layers between cdma2000 and WiBro services. The ISL (Interface Selection Layer) selects the optimal interface according to link quality, signal strength, and so on. As TIG communicates PDSN with the standard A10/A11 interfaces [9], existing PDSN can be employed without any modification.

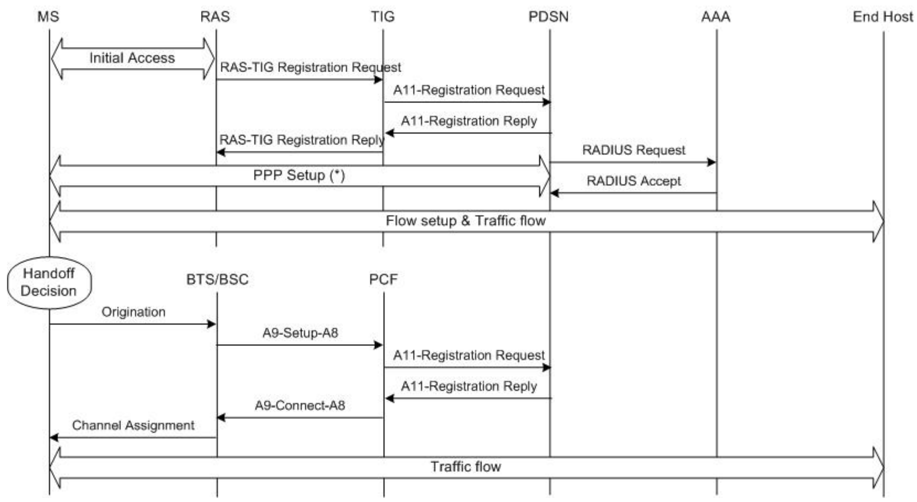


Fig. 3. Signaling and data flows

Figure 3 illustrates an example of the signal and data flows in the proposed scheme. The WiBro data service procedure is shown in the first part of Figure 3 as mentioned earlier. Once MS gets out of WiBro service area, MS performs a vertical handoff to cdma2000 network. In the meanwhile, PDSN buffer packets to the MS and send them after handoff completion. The buffering in PDSN reduces packet losses dramatically during handoff, which will be validated in the next section.

4 Performance evaluation

The proposed scheme in Section 3 was intended for seamless services on vertical handoffs between WiBro and cdma2000 mobile networks. In this section, we evaluate the performance of our scheme through extensive simulations compared with the loosely-coupled integration which is based on mobile IP.

4.1 Simulation model

The handoff delay of the proposed scheme ($D_{proposed}$) consists of $t_{release}$ (time to release the link in old network), t_{access} (time to create a wireless link in new network), and $t_{signaling}$ (time to deliver/process signaling messages in new network).

$$D_{proposed} = t_{release} + t_{access} + t_{signaling} \tag{1}$$

In Eq. (1), $t_{release}$ and $t_{signaling}$ can be calculated as $t_{MS-BTS}+t_{BTS-BSC}+t_{BSC-PCF}+t_{PCF-PDSN}$ and $t_{RAS-TIG}+t_{TIG-PDSN}$, respectively, when MS moves from cdma2000 to WiBro network. They can be also calculated similarly on the reverse direction (i.e., from WiBro to cdma2000 network). After $t_{release}$, PDSN may be informed that a MS has moved to the other network, and hence, PDSN can buffer packets to the MS and can send them after handoff completion. So, the packet loss time is only $t_{release}$ in our scheme (i.e., $L_{proposed} = t_{release}$).

On the other hand, to calculate the handoff delay in the loosely-coupled integration scheme ($D_{loosely}$), the time for mobile IP registration ($t_{mobileIP}$) should be added to Eq. (1).

$$D_{loosely} = t_{release} + t_{access} + t_{signaling} + t_{mobileIP} \tag{2}$$

In Eq. (2), $t_{mobileIP}$ is calculated as $t_{MS-RAS}+t_{RAS-ACR}+t_{ACR-HA}$ when MS moves from cdma2000 to WiBro network. In loosely-coupled interworking, the packet loss time ($L_{loosely}$) is given $D_{loosely}$ because any node in new network is not aware of the handoff event before the mobile IP registration. In order to reduce the large delay on handoff based on mobile IP, several works are in progress including fast handoff in mobile IPv6. However, there is no scheme which is being standardized in WiBro and cdma2000 mobile network.

Parameter	Value	Parameter	Value
t_{MS-BTS}	10ms	t_{MS-RAS}	8ms
$t_{BTS-BSC}$	5ms	$t_{RAS-TIG}$	5ms
$t_{BSC-PCF}$	1ms	$t_{TIG-PDSN}$	1ms
$t_{PCF-PDSN}$	1ms	$t_{RAS-ACR}$	5ms
$t_{PDSN-HA}$	1ms	t_{ACR-HA}	1ms

(a) Network model

Parameter	Value
T_{CDMA}	60s (exponential distribution)
T_{WiBro}	60s (exponential distribution)
p, q	0.2, 0.5, 0.8 (low, medium, high mobility)
r	100kbps $\sim$ 1Mbps (uniform distribution)
T_{think}	5s (exponential distribution)
M	60KB (exponential distribution)
s	100KB(streaming), 500KB(interactive)

(b) Mobile station and traffic model

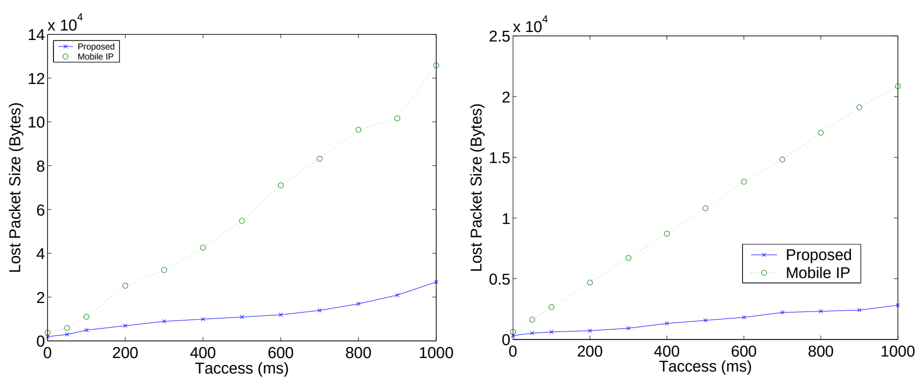
Table 1. Simulation parameters

For the purpose of modeling the behavior of users, we assume the following scenario: a MS gets the cdma2000 service for T_{CDMA} seconds and moves to WiBro network with the probability of p. After T_{WiBro} seconds, the mobile station moves back to cdma2000 network with the probability of q. The large values of p and q indicate the high mobility.

As for the traffic model, we consider two types of services: real-time streaming and interactive. The interval to transmit packets in real-time streaming services is given $\tau_{streaming} = s/r$, where s is the packet size and r is the data rate of a stream. In interactive services, users request a web page of M bytes every T_{think} seconds. The packet interval $\tau_{interactive}$ is set considering the round-trip time between service end-points. Table 1 summarizes the simulation parameters used in this paper. Since our concern is centered on only the comparison of interworking architecture, we assume there is no packet loss in wireless links.

4.2 Simulation result

Figure 4 shows the packet loss per handoff for 30 mobile stations. The x-axis of Figure 4 means t_{access} described in Eq. (1) and (2). The values of t_{access} are expected to be diverse according to the implementation details. Luo *et al.* measured the wireless link access time ($400 \sim 600ms$) from their WLAN and 3G inteworking prototype [5]. As shown in Figure 4, the packet loss in the proposed scheme is very small across all the values of t_{access}. This is due to buffering in PDSN as mentioned in Section 3.



(a) Real-time streaming service (b) Interactive service

Fig. 4. Simulation result: packet loss per handoff

More specifically, on $t_{access} = 500ms$ which is the average value of wireless link access time measured in [5], handoffs in the loosely-coupled integration scheme may cause to large loss of packets, resulting in the degradation of service quality. In addition, whereas our scheme does not require any re-authentication on handoff, user authentication in each network should be performed on handoff in loosely-coupled interworking. This will cause that far more packets may be lost in the loosely-coupled architecture. Therefore, the loosely-coupled interworking requires additional schemes to reduce packet losses. It may be achieved by terminal support like reducing t_{access} or by network support such as fast handoff.

5 Conclusion

In this paper we proposed an integration scheme between WiBro and cdma2000 networks to provide seamless services. We have designed a practical model considering the fact that cdma2000 mobile communication networks have already been implemented and widely used. We defined not only an efficient interworking model but also practical implementation methods in node operations, protocols, and interfaces between nodes, and so forth. Thus, this paper can give a theoretical and practical guideline to design WiBro which cooperates with current cdma2000 mobile networks.

In addition, we have developed a performance model for handoffs between WiBro and cdma2000 networks. From the model, it has been validated that the proposed scheme reduces packet losses compared with the loosely-coupled scheme. This is because PDSN can buffer packets during handoff period in our scheme. However, the increased round-trip time on handoff period may cause to degradation in TCP performance. We are currently tackling the problem.

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