QoS-guaranteed Fast Wakeup and Connection Mechanism in Multi-Interface Communication Systems

Moon Kim, Ki-Sik Park and Wan-Tae Kim, *Member, KIMICS*

***Abstract*— In this paper, we propose the fast wakeup and connection mechanisms for various energy saving schemes in order to improve QoS. First, we offer the interconnection of heterogeneous access networks via the Media Independent Information Server/Service (MIIS). Then, we propose the fast wakeup and connection mechanism for multi-interface communication systems. The proposed novel mechanism focuses on the fast provision of incoming service destined to the interface currently in energy saving mode by using MIIS-assisted interconnection. We further evaluate the performance of proposed mechanism through the numerical and experimental analysis.**

***Index Terms*— QoS, Energy saving, Multi-interface, Heterogeneous networks, MIIS**

I. INTRODUCTION

The evolution and the deployment of various telecommunication technologies such as Global System for Mobile communications (GSM), Code Division Multiple Access 2000 (CDMA2000), Universal Mobile Telecommunications System (UMTS), Wireless Local Area Networks (WLAN), and Worldwide Interoperability for Microwave Access (WiMax) have brought the tremendous improvement of user circumstances. Simultaneously, the user demands for new added value services such as Voice over IP (VoIP), Video on Demand (VOD), Digital Multimedia Broadcasting (DMB), and IPTV have grown continuously. However, such user demands for higher data rate, higher mobility, and Quality of Service (QoS) have not been fulfilled by each telecommunication technology alone. Therefore, the Next Generation (or 4G) Networks (NGN) are integrating those multiple telecommunication technologies into a common convergence network.

The ubiquitous network is expected to guarantee 'any-service with any-device through any-network at any-where in any-time'. In order to support this ubiquitous service, there are essential requirements which are very high data rate for 'any-service', multi-interface systems for 'any-device', integrated heterogeneous networks and high mobility for 'any-network', and so on. However, lots of challenges still remain on various research areas. In particular, the multi-interface systems, i.e. becoming all-in-one systems recently, suffer from the serious lack of energy as it have many parts of a communication running simultaneously and it is also short of the energy management functions. So, lots of research efforts in the literature have dedicated to the investigation of the energy management, usually called power saving, schemes in multi-interface systems. The works in [1]-[3] suggested using secondary low-energy consuming wakeup interfaces to reduce the energy consumption of other interfaces such a WLAN. In [4], it was further proposed to implement a separate low-energy consuming radio on the Mobile Station (MS), in addition to other radio interfaces that already exist on the MS for supporting user applications, and to use it as an always-on wakeup and signaling channel. The approaches in [5], [6] offered a new gateway to interconnect cellular and WLAN networks. The proposed gateway serves as a Session Initiation Protocol (SIP) server to handle incoming VoIP services for WLAN and to wakeup WLAN interface via cellular network. However, most of these efforts have only focused on the energy saving issue of multi-interface systems without the QoS concern, i.e. delay of the incoming service through the interface already turned into the energy saving mode. Even though some approaches have considered QoS as well, there is still the critical degradation of QoS because:

A. Offered wakeup procedure using legacy telecommunication networks causes long delay, referred as wakeup delay in this paper.
B. The designated interface has to establish the connection to the network after it wakes up, that also induces delayed service. We call it connection delay in this paper.

In this motivation, we propose the fast wakeup and connection mechanism. This paper initially focuses on the interconnection of heterogeneous access networks without the development of new components by employing the Media Independent Information Server/Service (MIIS) introduced in IEEE 802.21 Media Independent Handover (MIH) standard [7], [8]. In the proposed heterogeneous network, our novel mechanism guarantees the significant improvement of QoS by reducing wakeup delay as well as connection delay, and the maintenance of energy efficiency.

Manuscript received October 4, 2010; revised October 10, 2010; accepted October 21, 2010.
Moon Kim is with the Department of Information and Telecommunication Engineering, Graduate School of Korea Aerospace University, Korea (Email: moonkim@kau.ac.kr)

The remaining of this paper is organized as follows. In the next section, we explain the proposed fast wakeup and connection mechanism improving QoS. Section 3 evaluates and analyzes the performance of the proposed mechanism, and then we conclude this paper in Section 4.

II. FAST WAKEUP AND CONNECTION MECHANISM

A. Proposed Network Architecture

In this paper, we propose a convergence network architecture unifying heterogeneous access technologies and MIIS as shown in Figure 1. In addition to legacy access technologies such as cellular, WMAN, and WLAN, the proposed network employs the MIIS in order to interconnect various access technologies. In the proposed convergence network, the basic concept of our approaches is that the urgent messages from one access network can be delivered to the other access network via MIIS.

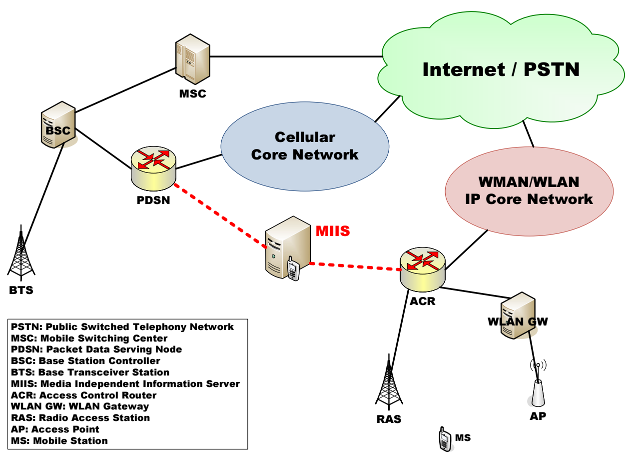

Fig. 1. Proposed network architecture

B. Fast Wakeup and Connection Mechanism

We propose the fast wakeup and connection mechanism employing MIIS. Using the proposed network architecture, our novel mechanism reduces both wakeup delay and connection delay. The key concepts of the proposed mechanism are:

A. Fast wakeup of the designated interface according to the quick transfer of wakeup signal via MIIS.

B. Fast connection to the network, waiting for the provision of incoming service, by providing the network information previously to the designated interface. The network information for the establishment of connection is offered by the MIIS.

In order to provide the information for fast wakeup and connection, we define a novel MIH message, referred as MIH_Net_FastInfo. It delivers fast wakeup and connection information such as wakeup interface, LINK_ID, and PoA_ID to the end-user's Mobile Station (MS) via cellular channel.

Therefore, our fast wakeup and connection mechanism reduces both wakeup delay and connection delay. Figure 2 shows how the proposed mechanism improves the end-user QoS by minimizing the delay of incoming service. Further, the operation of the proposed fast wakeup and connection mechanism is detailed below.

A. If there is no ongoing call or service from WMAN/WLAN networks MS turns off WMAN/WLAN interfaces to save energy. Cellular interface keep functioning in order to detect incoming service, even there is no service from cellular network.

B. When incoming service is received by an access network, e.g. WMAN/WLAN in the figure, it queries whether the destination MS of the service is currently connected to the network. If so, the

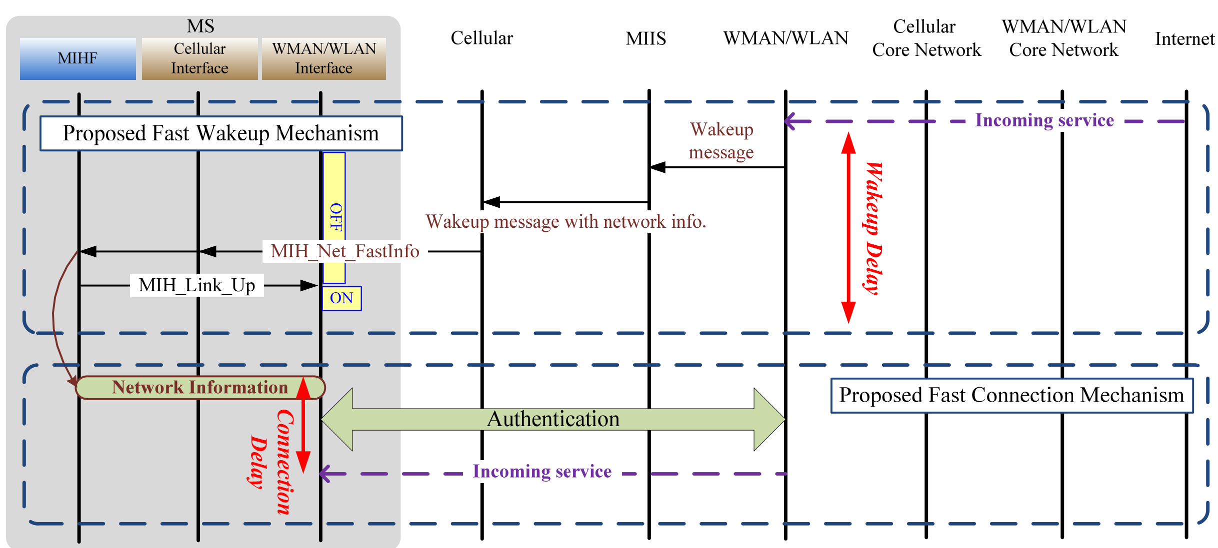

Fig. 2. Operation of fast wakeup and connection mechanism

service is delivered to MS through the legacy network, otherwise, network component such an ACR has to wake up the designated interface of MS by sending the wakeup message to MIIS.

C. Once MIIS receives the wakeup message, it finds out the fast wakeup and connection information such as LINK_ID and PoA_ID by checking the network address of MS with the database of MIIS. Then it transfers the wakeup message including that information to cellular network directly.

D. Then, the cellular network sends MIH_Net_FastInfo to the MIH Function (MIHF) of MS via cellular channel.

E. After the reception of MIH_Net_FastInfo, MIHF immediately wakes up the interface indicated by wakeup interface field in MIH_Net_FastInfo.

F. Then, referring to the fast connection information consisting of LINK_ID and PoA_ID, the recovered interface of MS notices the target PoA and network for connection without further network discovery phase. Accordingly, the connection establishment is simply completed after authentication phase.

III. PERFORMANCE EVALUATION

A. Numerical Analysis

We analysis the incoming service latency resulting from the use of our fast wakeup and connection mechanism explained in section 2. We initially introduce the numerical model of the QoS degradation factors, the wakeup delay and the connection delay. In (1) and (2), the wakeup delay of legacy wakeup procedures (T_{old_WU}) and which of the proposed mechanism (T_{fast_WU}) are derived respectively.

$$T_{old\_WU} = 4D_{Net-Net} + D_{MS-BTS} + D_{ON} + T_{WCore} + T_{Inter} + T_{CCore} \quad (1)$$

$$T_{fast\_WU} = 4D_{Net-Net} + D_{MS-BTS} + D_{ON} \quad (2)$$

Note that D_{X-Y} is the message delivery time between X and Y, while T_Z corresponds to the message traverse time over Z. Moreover, D_{ON} is the delay due to both the wakeup signalling in MS and the warming up of recovered interface.

We further derive the numerical models of the connection delay as shown at (3) and (4).

$$T_{old\_Con} = T_{discover} + T_{auth.\&asso.} \quad (3)$$

$$T_{fast\_Con} = T_{auth.\&asso.} \quad (4)$$

Based on (1)~(4), we derive the total delay of incoming service, resulting from the use of both legacy wakeup and connection mechanism (T_{old}) and proposed fast one (T_{fast}), as described at (5) and (6) respectively.

$$\begin{aligned} T_{old} &= T_{old\_WU} + T_{old\_Con} \\ &= 4D_{Net-Net} + D_{MS-BTS} + D_{ON} + T_{WCore} + T_{Inter} \\ &\quad + T_{CCore} + T_{discover} + T_{auth.\&asso.} \end{aligned} \quad (5)$$

$$\begin{aligned} T_{fast} &= T_{fast\_WU} + T_{fast\_Con} \\ &= 4D_{Net-Net} + D_{MS-BTS} + D_{ON} + T_{auth.\&asso.} \end{aligned} \quad (6)$$

These numerical results show that the legacy mechanisms suggested for energy efficiency barely consider the QoS issues, and thus induce the critical QoS degradation that are very long wakeup delay and connection delay in relation to an incoming service. On the other hand, the proposed fast wakeup and connection mechanism assures the improvement of QoS by reducing both wakeup delay and connection delay significantly. Because, our mechanism guarantees the fast wakeup of designated interface in accordance with the rapid wakeup signalling via MIIS-bridged network architecture. Furthermore, it ensures the fast connection to the network waiting for the service provision, according to the early distribution of network information to the designated interface by using MIIS.

B. Results

We analysis some experimental results of the QoS achievements based on the average delay caused by wakeup procedure, connection procedure, and incoming service. In the simulations, some time parameters verified by the experimental results based on demonstration are used to bring more reliable evaluation. These are $T_{discover}$ and $T_{auth.\&asso.}$ distributed between 200~300 ms and 5~20 ms respectively, and D_{ON} set as 1000 ms [9]. Furthermore, in the simulations, we assumed that D_{MS-BTS} , T_{WCore} , T_{CCore} , and T_{Inter} are distributed between 50~100 ms, 150~200 ms, 150~200 ms, and 300~400 ms, respectively.

In Figure 3, the wakeup delay critically increases as the message transmission delay over wired link increases. However, the proposed fast wakeup scheme decreases about 29~839 ms of wakeup delay compared with both loosely and tightly coupled schemes. Note that the warming up delay of recovered interface is ignored. Figure 4 also shows that the proposed scheme improves about 3~25% of wakeup delay performance. The reason is that our fast wakeup scheme rapidly notifies the occurrence of incoming service via the MIIS-bridged network architecture.

Figure 5 describes the comparison of connection delay depending on the message transmission delay over wired link. And it is confirmed that the proposed fast connection scheme reduces about 480~760 ms of connection delay compared with legacy connection schemes. This is because our approach ensures the fast connection to the network waiting for the service provision, according to the early distribution of network information to the designated interface by using MIIS.

In figure 6, we compare the average delay of incoming service according to the message delivery time between network components, i.e. $D_{Net-Net}$. It shows that the bigger $D_{Net-Net}$ network induces the longer incoming service delay end-users experience. Further, it is confirmed that the proposed energy saving mechanism, in comparison with the others, significantly improves the QoS by reducing the incoming service delay. In practice, the measured average incoming service delay of our mechanism is about 1350~2526 ms, while that of the others such as legacy and tightly coupled approaches are about 2056~3147 ms and 1706~2926 ms, separately.

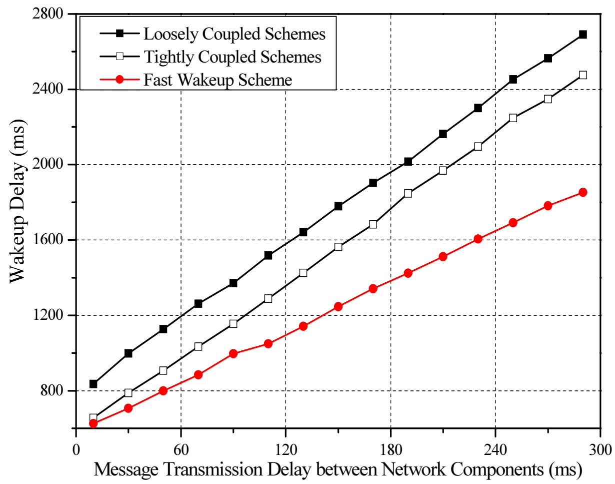

Fig. 3. Wakeup delay depending on $D_{Net-Net}$

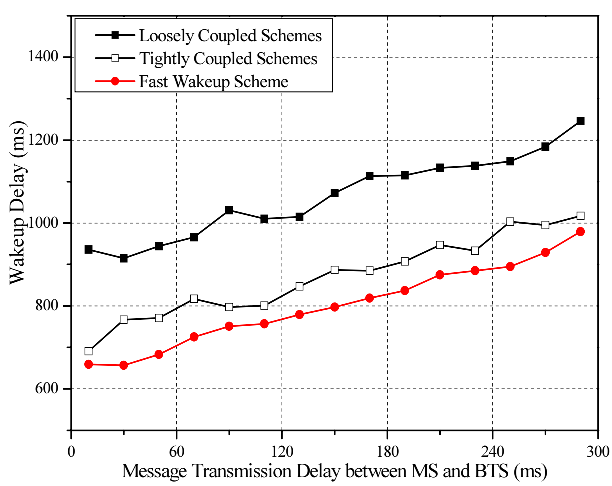

Fig. 4. Wakeup delay depending on D_{MS-BTS}

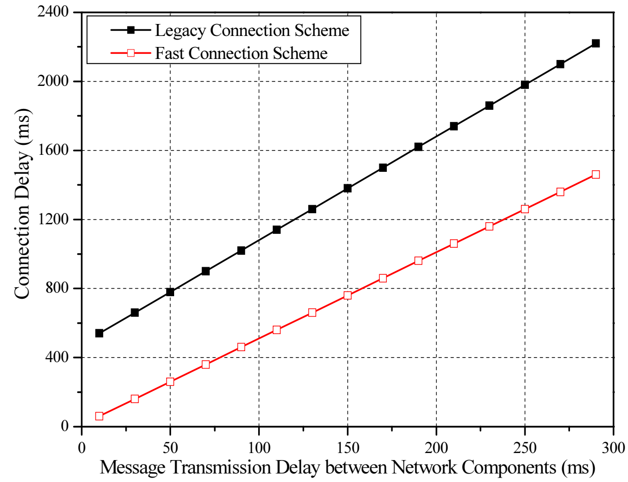

Fig. 5. Connection delay depending on $D_{Net-Net}$

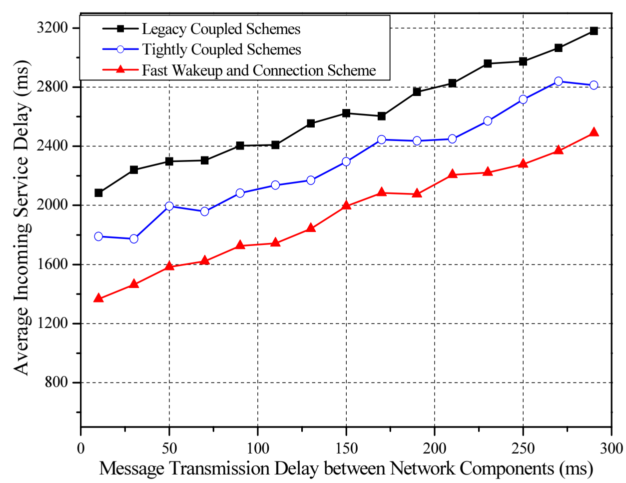

Fig. 6. Service delay depending on $D_{Net-Net}$

IV. CONCLUSIONS

In this paper, we proposed the fast wakeup and connection mechanism for improving QoS. We initially focused on the interconnection of heterogeneous access networks by using MIIS. In the proposed network architecture, the proposed mechanism assures the improvement of QoS by reducing both wakeup delay and connection delay significantly since our mechanism guarantees the fast wakeup of the designated interface, in accordance with the rapid wakeup signaling via MIIS-bridged network architecture. Furthermore, it ensures the fast connection to the network waiting for the service provision, according to the early distribution of network information to the designated interface by using MIIS. Furthermore, we evaluated the performance of our novel mechanism in terms of the wakeup delay, connection delay, and average incoming service delay through the numerical and experimental analysis. In result, it was clearly verified that the proposed mechanism significantly improved the QoS by reducing the incoming service delay.

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Moon Kim
Received the B.S., M.S., and Ph.D. degree in the Department of Telecommunication and Information Engineering form Korea Aerospace University in 2004, 2006, and 2010. His research interests include QoS, QoE, Mobility, and heterogeneous network.

Ki-Sik Park
Received the B.S., M.S., and Ph.D. degree in the Department of Telecommunication and Information Engineering form Korea Aerospace University in 1991, 1996, and 2000. Since 2001, he has been a professor in the Department of Information and Communication Engineering, Inha Technical College. His research interests include mobile network, WLAN, and NGN.

Wan-Tae Kim
Received the M.S. degree in the Department of Telecommunication and Information Engineering form Korea Aerospace University in 2003. Since 2007, he has been a Ph.D. course student in the same university. His research interests include mobile network, LTE, and NGN.