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방송통신 융합망에서 QoS 향상을 위한 Fast Wakeup and Connection 기술

QoS-aware Fast Wakeup and Connection Mechanism on Broadcasting Convergence Network

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[요 약]

방송 기술과 통신 기술의 융합은 유비쿼터스 네트워크를 위한 핵심 기술 중 하나이다. 본 논문에서는 AT-DMB(advanced terrestrial digital multimedia broadcasting) 방송망과 통신망의 융합망을 제안하고, MIIS(media independent information server/service)를 통한 방송 시스템과 통신 시스템 간 연동을 제공하는 융합 시스템을 제안한다. 특히, 방송통신 융합망에서 QoS (Quality of Service)와 전력절감의 향상을 위한 fast wakeup and connection 기술을 제안한다. 제안하는 기술은 사용자 단말의 휴지기 인터페이스로 유입되는 서비스 지연과 해당 인터페이스의 전력소모를 최소화하는 기술이다. 끝으로, 시뮬레이션 및 성능분석을 통해 제안하는 기술이 서비스 지연을 감소시키면서 전력소모를 최소화할 수 있음을 확인하였다.

[Abstract])

The convergence of broadcasting and telecommunication technologies is a key issue of the ubiquitous networks. So this paper offers the convergence of integrated telecommunication networks and broadcasting system, Advanced Terrestrial Digital Multimedia Broadcasting (AT-DMB), and the interconnection of them via the Media Independent Information Server/Service (MIIS). Then, this paper proposes the fast wakeup and connection mechanism with concepts for improving QoS and energy efficiency simultaneously. In the proposed convergence network, our mechanism places the key on the minimization of both the incoming service delay destined to a turned-off interface by using the broadcasting network and the additional energy consumption. This paper further evaluates the performance of proposed mechanism through the numerical and experimental analysis and has confirmed the decrease of both service delay and energy consumption.

Key words : Quality of Service, Energy saving, Broadcasting, Advanced Terrestrial Digital Multimedia Broadcasting, Media Independent Information Service.

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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 Internet Protocol Television(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 convergence has been a key issue of the ubiquitous, the symbol of NGN, among various groups including researchers, network operators, and service providers. Especially, the convergence of telecommunication and broadcasting becomes very important since the broadcasting technology has rapidly grown as well as the user demand for broadcasting services such a DMB. Therefore various emerging future technologies in both the network and service planes will play a fundamental role in converging telecommunication and broadcasting.

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 mechanism focuses on the convergence of integrated telecommunication networks and broadcasting system which is the Advanced Terrestrial Digital Multimedia Broadcasting (AT-DMB). To interconnect those emerging technologies without the development of new components, we employ the Media Independent Information Server/Service (MIIS) introduced in IEEE 802.21 Media Independent Handover (MIH) standard. In the proposed convergence network, our mechanism guarantees both the significant improvement of QoS by reducing wakeup delay as well as connection delay and the energy efficiency. The key concepts of the proposed mechanism are:

A. Fast wakeup of the designated interface according to the quick transfer of wakeup signal via AT-DMB channel.

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

C. Minimization of the additional energy consumption caused by AT-DMB interface.

The remaining of this paper is organized as follows. In the next section, we explain the proposed system architecture unifying the telecommunication and broadcasting systems. In section 3, we propose the fast wakeup and fast connection mechanisms improving QoS. Section 4 evaluates and analysis the performance of the proposed mechanisms, and then we conclude this paper in Section 5.

Ⅱ. AT-DMB and MIIS

2-1 Multimedia Broadcasting Systems

The Terrestrial Digital Multimedia Broadcasting (T-DMB) system is designed to provide multimedia broadcasting service in a mobile reception environment over a European Digital Audio Broadcasting(DAB) system known as Eureka-147. The DAB system can provide a reliable and multiplexed digital audio broadcasting service including data for mobile devices and portable and fixed players with a simple non-directional antenna [7]. But, as the DAB system was designed mainly for audio broadcasting services, the T-DMB uses state-of-the-art technologies such as compression and synchronization in order to provide high quality Audio Visual(AV) services. H.264/Advanced Video Coding(AVC) for video compression, Bit-Sliced Arithmetic Coding(BSAC)/High Efficiency Advance Audio Coding(HE-AAC) for audio compression, and Binary Format for Scenes(BIFS) in the MPEG-4 system for other in-band data accompanied by audio/video streams are adopted by the T-DMB system [8].

With the well deployment of the T-DMB service, the Digital Video Broadcasting-Handheld(DVB-H) developed by Nokia and the Media Forward Link Only (MediaFLO) developed by Qualcomm were proposed and deployed for mobile multimedia broadcasting service recently. In comparison with those following technologies, T-DMB has the advantage of the broad coverage and the low cost of installation. However, it is weak in supporting high quality services due to the lack of both serving channels and data rate. So, there has been a need to research and develop the enhanced multimedia broadcasting technology, and thus the AT-DMB system is emerged. AT-DMB provides higher quality of multimedia broadcasting services using the hierarchical modulation and the scalable AV coding scheme while it is fully backward compatible with the conventional T-DMB system [9].

2-2 Media Independent Handover Services

IEEE 802.21 introduces the MIH services to improve the handover performance across heterogeneous access networks. MIH offers a framework that defines Media Independent Handover Function (MIHF). It is logically designed as a shim layer between the link layer (L2) and upper layers in the protocol stack of both the MS and network elements. Especially, MIHF employs three kinds of services as the key element of the interaction. These services are responsible for provision of handover-related information such as link status, link layer intelligence, serving and neighboring access networks information, and operation policies. In addition, they help upper layers coordinate and manage handovers, while supporting both network-initiated and mobile-initiated handovers. The above three services are Media Independent Event Service (MIES), Media Independent Command Service (MICS), and MIIS [10].

Ⅲ. Fast Wakeup and Connection via AT-DMB

3-1 Proposed System Architecture

In this paper, we propose a convergence network architecture unifying telecommunication and broadcasting systems as shown in Fig. 1. In addition to legacy telecommunication technologies such as cellular, WMAN, and WLAN, the proposed network employs the AT-DMB system as the signaling interface. And the MIIS is adopted into the proposed network in order to interconnect legacy networks and AT-DMB system. In the proposed convergence network, the basic concept of our approaches is that urgent messages from legacy telecommunication networks can be delivered to MS via the multimedia broadcasting channel given by both MIIS and AT-DMB system.

In order to guarantee QoS, we propose the fast wakeup and connection mechanisms which reduce the wakeup delay and the reconnection delay respectively. First of all, we design the enhanced AT-DMB system architecture as illustrated at Fig. 2. When the MIIS detects an incoming service to the interface turned into energy saving mode, it provides both wakeup and connection information to the enhanced AT-DMB system. Accordingly, this system generates the Fast Information Group (FIG) type 4 based on the receiving information from MIIS by

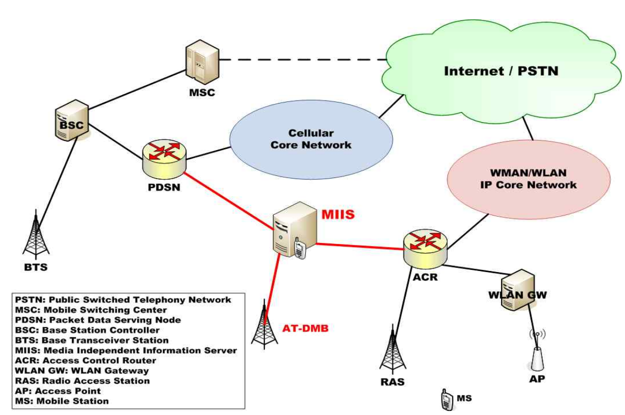


그림 1. 제안하는 융합망 구조.

Fig. 1. Proposed convergence network architecture.

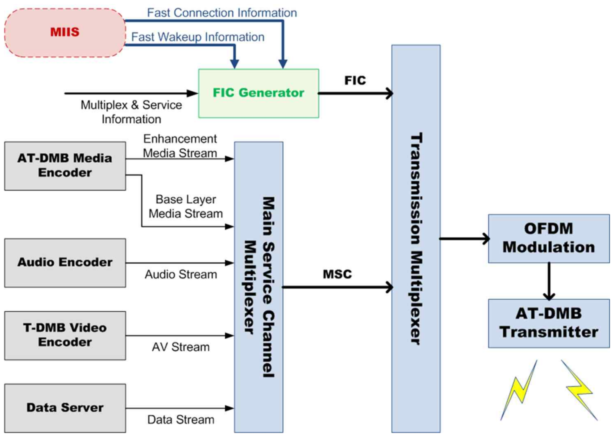
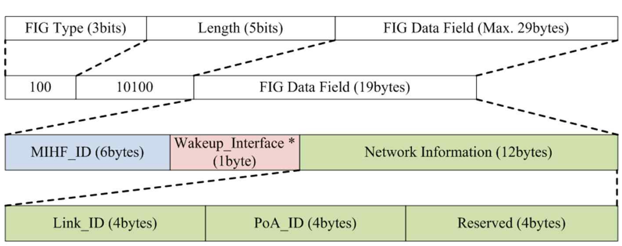


그림 2. 제안하는 AT-DMB 시스템 구조.
Fig. 2. Proposed AT-DMB transmission system architecture.

using the Fast Information Channel (FIC) generator. Then it broadcasts the FIC, i.e. including the FIG type 4, in addition to the Main Service Channel (MSC).

Secondly, we define the FIG type 4 delivering the fast wakeup and connection information as depicted in Fig. 3. It is composed of FIG type, length, and FIG data field. Note that the FIG type and length field have the fixed value of binary '100' and '10100' respectively. And the FIG data field, as detailed in Table 1, consists of MIHF_ID, wakeup interface, and network information, which is containing LINK_ID, PoA_ID, and reserved field.



* Wakeup_Interface : 0-3GPP, 1-3GPP2, 2-WiMax, 3-WLAN, 4-WPAN, and reserved

그림 3. 제안하는 FIG type 4 메시지 포맷.
Fig. 3. Proposed FIG type 4 message structure.

표 1. FIG Data Field 구성 항목.
Table 1. FIG Data Field information.

Field	Length	Description
MIHF_ID	6bytes	This identifies the MS appointed to receive an incoming service.
Wakeup Interface	1byte	This indicates which interface must wakeup.
LINK_ID	4bytes	This identifies the network delivering an incoming service.
PoA_ID	4bytes	This identifies the Point of Attachment (PoA) transmitting the service.
Reserved	4bytes	Reserved for future use.

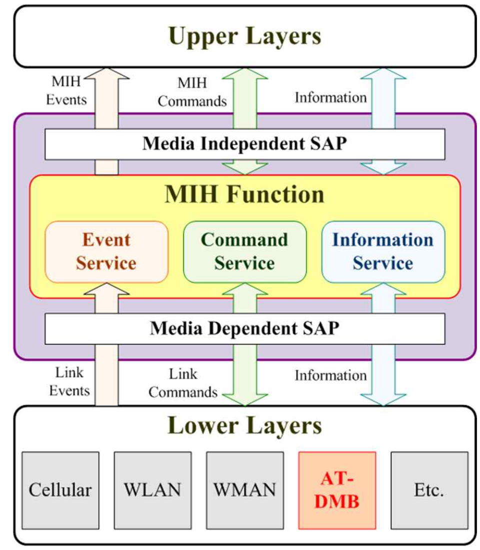


그림 4. 제안하는 MIHF 구조.
Fig. 4. Proposed MIHF architecture.

표 2. FIG Data Field 구성 항목.
Table 2. FIG Data Field information.

Name	Type	Description
MIH_Monitor_FIC	MICS Primitive	This commands AT-DMB interface to turn into FIC monitoring mode.
MIH_FastInfo	MIIS Primitive	When AT-DMB detects FIG (type 4 and length 20), the contained data is delivered to MIHF via this primitive.
MIH_Incoming_ServiceInfo	MIIS Message	When there is incoming service of which destination is in energy saving mode, network components such an ACR send this message, including the network address of MS and the interface designated, to MIIS.
MIH_Net_FastInfo	MIIS Message	This delivers fast wakeup and connection information such as MIHF_ID, wakeup interface, LINK_ID, and PoA_ID to AT_DMB transmission system.

This paper then specifies the MIHF adding on the management of the AT-DMB system as shown in Fig. 4. To manage AT-DMB, we propose MIH primitives that are MIH_Monitor_FIC of MICS and MIH_WakeupInfo of MIIS.

Table 2 describes those novel primitives as well as new MIH messages used to provide the information for fast wakeup and connection.

3-2 Proposed Fast Wakeup and Connection Mechanism

Using the proposed system architecture, our fast wakeup and connection mechanism reduces both wakeup delay and connection delay. Fig. 5 shows how the proposed mechanism improves the end-user QoS by minimizing the delay of incoming service.

First, the legacy wakeup and connection mechanism performs as following.

A. If there is no ongoing call or service from WMAN/WLAN networks, MS turns off WMAN/WLAN interfaces. 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 service is delivered to MS immediately, otherwise, the network has to wake up the designated interface of MS via cellular network. Therefore, it initially sends wakeup message to WMAN/WLAN core network.

C. Once WMAN/WLAN core network receives wakeup message, it delivers that message to cellular core network through Internet backbone network.

D. After receiving the wakeup message, cellular core network relays that message through PDSN and BSC to BTS (from cellular core network to cellular in figure).

E. Then, BTS transmits wakeup message to cellular interface of MS.

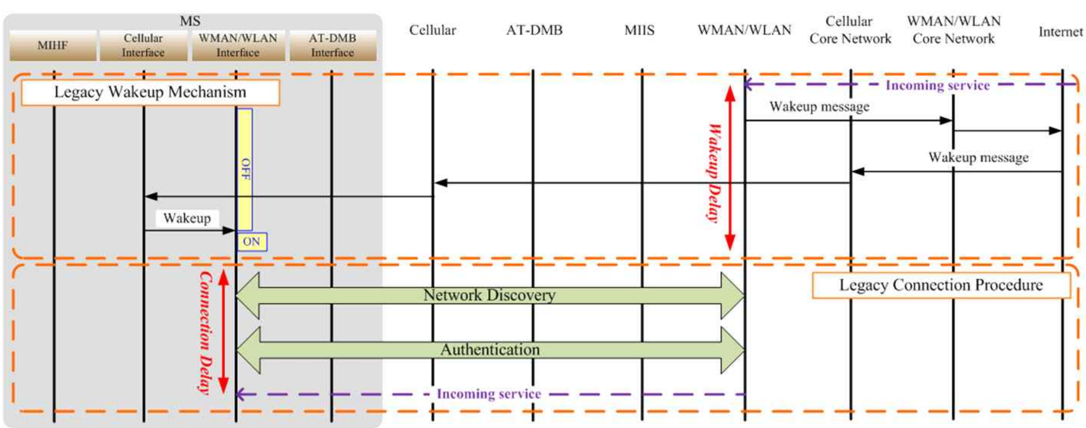
F. If obtaining wakeup message, cellular interface wakes up the designated interface.

G. Once the interface is recovered, it performs network discovery phase to find out the target PoA and network to connect.

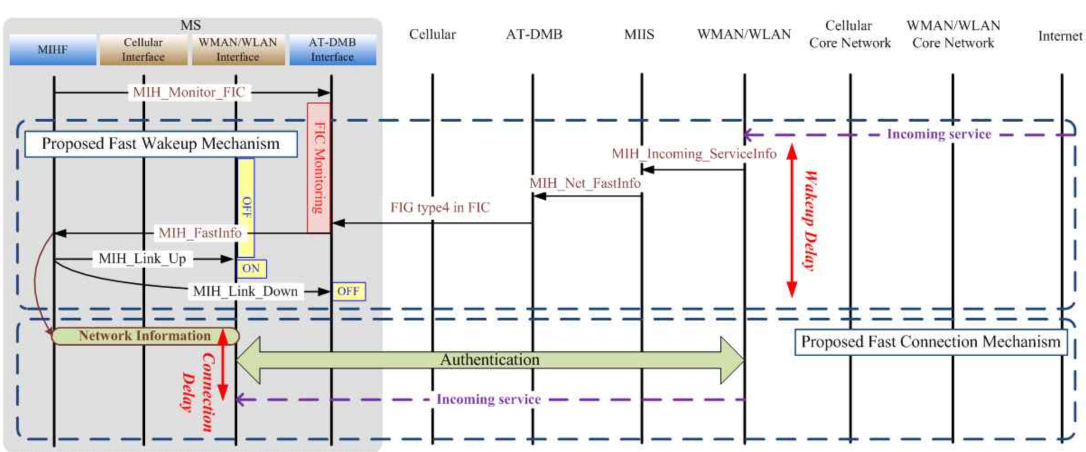
H. Lastly, MS authenticates with the target access network based on the result of network discovery phase.

Then, 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. Then, in order to detect incoming service, MIHF permits AT-DMB to be switched-on in FIC monitoring mode, which consumes very



(a) Operation of wakeup and connection procedure in legacy energy saving schemes



(b) Operation of fast wakeup and connection mechanism in proposed energy saving scheme

그림 5. Wakeup and connection 기술의 비교.

Fig. 5. Comparison of wakeup and connection mechanism.

low energy, by using MIH_Monitor_FIC primitive.

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 service is delivered to MS through the legacy network, otherwise, the MIHF-employed ACR has to wake up the designated interface of MS by sending MIH_Incoming_ServiceInfo message to MIIS.

C. Once MIIS receives MIH_Incoming_ServiceInfo, it finds out the fast wakeup and connection information such as MIHF_ID, LINK_ID, and PoA_ID by checking the network address of MS with the database of MIIS. Then it transfers MIH_Net_FastInfo message including those connection information and the wakeup information to AT-DMB transmission system.

D. As described in Fig. 2, FIC generator in AT-DMB forms the proposed FIG of type 4 and length 20 according to the obtained information when it receives MIH_Net_FastInfo containing fast wakeup and connection information. Then the generated FIG type 4 is appended to FIC, and AT-DMB broadcasts it in addition to other channels.

E. For saving energy, AT-DMB interface in FIC monitoring mode of MS executes no protocols for DMB service and is listening for not entire DMB channel but FIC. When detecting FIC with the FIG type 4, it transfers MIH_FastInfo primitive containing whole data fields of the FIG to MIHF.

F. After the reception of MIH_FastInfo, MIHF primarily confirms MIHF_ID to determine whether this information is destined to itself. If the received MIHF_ID matches with which of MS, MIHF immediately wakes up the interface indicated by wakeup interface field in MIH_FastInfo primitive, and also switches off AT-DMB interface to save energy.

G. 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.

Ⅳ. Performance Evaluation

4-1 Analysis Model

To compare and evaluate the performance, we initially design the numerical analysis models for the wakeup and connection procedure in terms of the QoS and the energy respectively.

We introduce the numerical model of the QoS degradation factors, the wakeup delay and the connection delay. In equation (1) and (2), the wakeup delay of legacy wakeup procedures (D_{old_WU}) and which of the proposed fast wakeup mechanism (D_{fast_WU}) are derived respectively.

$$D_{old\_WU} = T_{ACR-Core} + T_{WCore} + T_{Inter} + T_{CCore} + T_{PDSN-Core} + T_{BSC-PDSN} + T_{BTS-BSC} + T_{MS-BTS} + D_{ON} \quad (1)$$

$$D_{fast\_WU} = T_{MIIS-ACR} + T_{DMB-MIIS} + D_{ATDMB} + D_{ON} \quad (2)$$

Note that T_{X-Y} is the message delivery time between X and Y, while T_Z is the message traverse time over Z where *WCore* means WMAN/WLAN core networks and *CCore* means cellular core network. Moreover, D_{ON} is the delay caused by the warming up of recovered interface, while D_{ATDMB} is the propagation delay between the AT-DMB transmitter and the receiver. These equations are simplified by assuming that:

$$T_{Net-Net} = T_{ACR-Core} \cong T_{PDSN-Core} \cong T_{BSC-PDSN} \cong T_{BTS-BSC} \cong T_{MIIS-ACR} \cong T_{DMB-MIIS} \quad (3).$$

So, the simplified numerical models of the wakeup delay are described in equation (4) and (5).

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

$$D_{fast\_WU} = 2T_{Net-Net} + D_{ATDMB} + D_{ON} \quad (5)$$

We further derive the numerical models of the connection delay as shown at equation (6) and (7).

$$D_{old\_Con} = D_{Discovery} + D_{Authentication} \quad (6)$$

$$D_{fast\_Con} = D_{Authentication} \quad (7)$$

Regard that $D_{Discovery}$ is the delay due to the network discovery phase of MS, and that $D_{Authentication}$ is the delay due to the authentication phase of MS.

We design the numerical models of the energy consumption depending on the type of interface. Our model supposes that the interface types are limited to the wireless such as WMAN and WLAN, the cellular, and the AT-DMB. In equations (8) ~ (10), the energy consumption models of wireless ($E_{wireless}(t_1,t_2)$), cellular ($E_{cel}(t_1,t_2)$), and AT-DMB ($E_{dmb}(t_1,t_2)$) are derived, respectively.

$$E_{wireless}(t_1,t_2) = E_{w\_idle}(t_1) + E_{w\_busy}(t_2) \quad (8)$$

$$E_{cel}(t_1,t_2) = E_{cel\_idle}(t_1) + E_{cel\_busy}(t_2) \quad (9)$$

$$E_{dmb}(t_1,t_2) = E_{dmb\_FIC}(t_1) + E_{dmb\_busy}(t_2) \quad (10)$$

Note that $E_{X\_idle}(t)$, $E_{X\_busy}(t)$, and $E_{X\_FIC}(t)$ are the consumed energy of the interface which is in idle mode, busy mode, and FIC monitoring mode during time t, respectively. Also, the idle mode is turned-on state without any active service and operation, while the busy mode is turned-on state in order to provide service. Regard that AT-DMB interface is only activated by end-user demand in legacy MS so that there is no idle mode. Therefore, the total energy consumption ($E_{MS}(t_{all})$) of the MS including wireless, cellular, and AT-DMB interfaces is computed as shown in equation (11).

$$E_{MS}(t_{all}) = E_{wireless}(t_{wi},t_{wb}) + E_{cel}(t_{ci},t_{cb}) + E_{dmb}(t_{dF},t_{db}) \quad (11)$$

Note that t_{all} is the total operation time of MS, while t_{dF} is the duration of FIC monitoring mode of AT-DMB. Additionally, t_{wi} and t_{ci} are the idle mode duration of each interface, while t_{wb}, t_{cb}, and t_{db} are the busy mode duration of each interface.

Using those equations, the total energy consumption of each MS employing different energy saving mechanisms are derived in equations (12) ~ (14).

$$\begin{aligned} E_{none}(t_{all}) &= E_{wireless}(t_{wi},t_{wb}) + E_{cel}(t_{ci},t_{cb}) + E_{dmb}(0,t_{db}) \\ &= E_{w\_idle}(t_{wi}) + E_{w\_busy}(t_{wb}) + E_{cel\_idle}(t_{ci}) \\ &\quad + E_{cel\_busy}(t_{cb}) + E_{dmb\_FIC}(0) + E_{dmb\_busy}(t_{db}) \end{aligned} \quad (12)$$

$$\begin{aligned} E_{old}(t_{all}) &= E_{wireless}(0,t_{wb}) + E_{cel}(t_{ci},t_{cb}) + E_{dmb}(0,t_{db}) \\ &= E_{w\_idle}(0) + E_{w\_busy}(t_{wb}) + E_{cel\_idle}(t_{ci}) \\ &\quad + E_{cel\_busy}(t_{cb}) + E_{dmb\_FIC}(0) + E_{dmb\_busy}(t_{db}) \end{aligned} \quad (13)$$

$$\begin{aligned} E_{new}(t_{all}) &= E_{wireless}(0,t_{wb}) + E_{cel}(t_{ci},t_{cb}) + E_{dmb}(t_{dF},t_{db}) \\ &= E_{w\_idle}(0) + E_{w\_busy}(t_{wb}) + E_{cel\_idle}(t_{ci}) \\ &\quad + E_{cel\_busy}(t_{cb}) + E_{dmb\_FIC}(t_{dF}) + E_{dmb\_busy}(t_{db}) \end{aligned} \quad (14)$$

Equation (12) represents the total consumed energy ($E_{none}(t_{all})$) of the MS without any energy saving mechanism. In addition, $E_{old}(t_{all})$ defined in equation (13) is the energy consumption of the MS using legacy energy saving mechanisms, while which of the MS adopting the proposed mechanism ($E_{\neq w}(t_{all})$) is defined in equation (14). Also, $E(0)$ means that there is no energy consumption since the corresponding mode is not triggered.

4-2 Performance Analysis

Based on equations (4) ~ (7), we derive the total delay of incoming service when using legacy wakeup and connection mechanisms (D_{old}) and when using proposed fast one (D_{fast}), as described at equation (15) and (16) respectively.

$$\begin{aligned} D_{old} &= 4T_{Net-Net} + T_{MS-BTS} + D_{ON} + T_{WCore} + T_{Inter} \\ &\quad + T_{CCore} + D_{Discovery} + D_{Authentication} \end{aligned} \quad (15)$$

$$D_{fast} = 2T_{Net-Net} + D_{ATDMB} + D_{ON} + D_{Authentication} \quad (16)$$

These numerical results show that the legacy mechanisms suggested for energy efficiency barely consider the QoS issues, and thus induce both long wakeup delay and long connection delay before the user experiences 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. This is because our mechanism guarantees the fast wakeup of the sleeping interface in accordance with the rapid wakeup signaling by the help of AT-DMB and MIIS. Furthermore, it ensures the fast connection to the network waiting for the service provision, according to the early distribution of network information to the sleeping interface via AT-DMB channel.

In Table 3, we compare the QoS performance of the proposed mechanism with which of the others in terms of wakeup delay and connection delay. Especially, some approaches enhancing QoS, i.e. the tightly coupled and the very tightly coupled, are also evaluated in this table. Note that the session management and the handover issues are not concerned here. In result, it is shown that the tightly coupled and the very tightly coupled approaches slightly improve QoS, by reducing connection delay solely, in

표 **3.** QoS 성능의 수치적 분석.

Table 3. Numerical analysis of QoS performance.

Mechanisms	Wakeup Delay	Connection Delay
Legacy	$4T_{Net-Net} + T_{MS-BTS} + D_{ON} + T_{WCore} + T_{Inter} + T_{CCore}$	$D_{Discovery} + D_{Authentication}$
Tightly	$4T_{Net-Net} + T_{MS-BTS} + D_{ON} + T_{WCore} + T_{CCore}$	$D_{Discovery} + D_{Authentication}$
Very Tightly	$4T_{Net-Net} + T_{MS-BTS} + D_{ON}$	$D_{Discovery} + D_{Authentication}$
Proposed	$2T_{Net-Net} + D_{ATDMB} + D_{ON}$	$D_{Authentication}$

comparison with legacy ones. Nevertheless, it is obvious that our mechanism is much more sufficient than the others taking into account the concurrent reduce of wakeup delay and connection delay simultaneously.

Then, we analysis some experimental results of the QoS achievements based on the average delay of incoming service. In the simulations, the time parameters verified by the experimental results based on demonstration [11] are used to bring more reliable evaluation. These are $D_{Discovery}$ and $D_{Authentication}$ distributed between 200~300 ms and 5~20 ms respectively, and D_{ON} set as 1000 ms [11]. Moreover, we arranged D_{ATDMB} between 50~200 ms in accordance with the fact that the transmission interval of AT-DMB is 96ms [8].

Fig. 6~8 depict the average delay of incoming service depending on various energy saving mechanisms including the proposed one. In Fig. 6, we compare the service delay of each mechanism according to the message delivery time between network components, i.e. $T_{Net-Net}$. It shows that the bigger $T_{Net-Net}$ network induces the longer incoming service delay which 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 1153~1667 ms, while that of the others such as legacy, tightly coupled, and very tightly coupled approaches are about 2056~3147 ms, 1706~2926 ms, and 1350~2526 ms, separately.

Fig. 7 and 8 describe the average delay depending on the message delivery time between MS and BTS, i.e. T_{MS-BTS}, and the time duration of network discovery phase, i.e. $D_{Discovery}$, respectively. In result, according to the increase of T_{MS-BTS} and

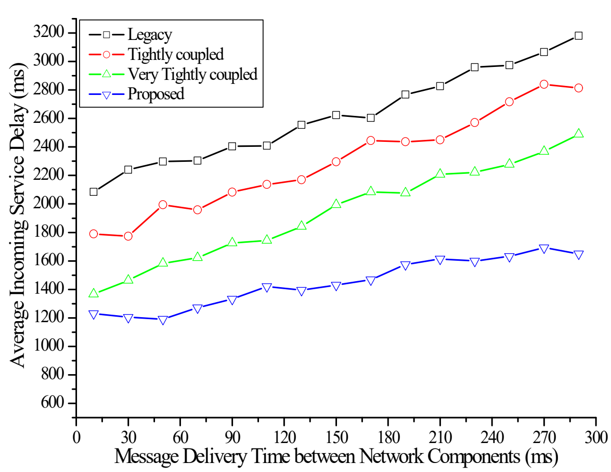


그림 6. $T_{Net-Net}$에 따른 평균 서비스 유입 지연.

Fig. 6. Average incoming service delay vs. $T_{Net-Net}$.

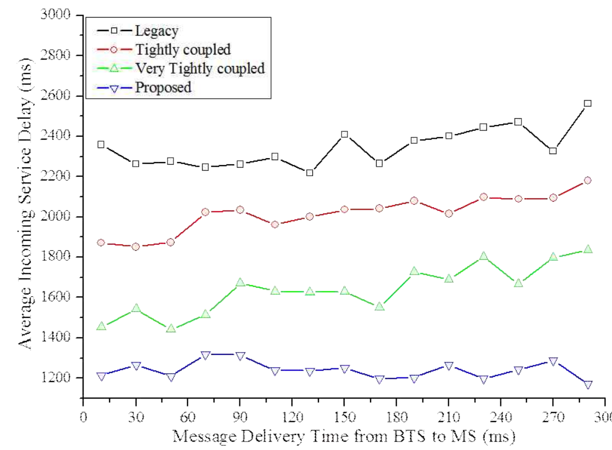


그림 7. T_{MS-BTS}에 따른 평균 서비스 유입 지연.

Fig. 7. Average incoming service delay vs. T_{MS-BTS}.

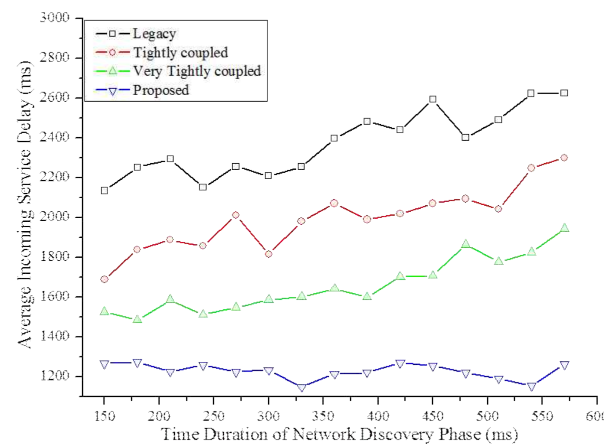


그림 8. $D_{Discovery}$에 따른 평균 서비스 유입 지연.

Fig. 8. Average incoming service delay vs. $D_{Discovery}$.

$D_{Discovery}$ the service delay of legacy mechanisms slightly increases as well. However, the proposed mechanism maintains the service delay at about 1200 ms regardless of those X values, because it does not require the network discovery phase and it employs the AT-DMB integrated network architecture. In this manner, our fast wakeup and connection mechanism reduces the incoming service delay significantly as shown in Fig. 7 and 8.

We additionally evaluate the QoS achievement of energy saving mechanisms in terms of wakeup delay and connection delay in Fig. 9. It clearly shows the robustness of the proposed mechanism compared with the others. In result, the proposed fast wakeup and connection mechanism causes total incoming service delay of 1112.93367 ms including wakeup delay of 1100.667 ms and connection delay of 12.26667ms. On the other hand, legacy ones induce total incoming service delay of 2335.4003 ms including wakeup delay of 2064.667 ms and connection delay of

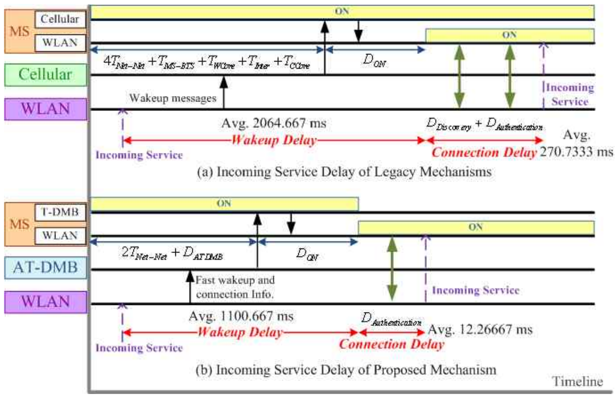


그림 9. 제안하는 기술의 QoS 성능.
Fig. 9. QoS performance of the proposed scheme.

270.7333ms. Regard that these delay values are computed by referring above three simulations.

In terms of energy efficiency, we firstly simplify equations (12~14) by eliminating zero components $E(0)$ as described in equations (15) ~ (17).

$$E_{none}(t_{all}) = E_{wireless}(t_{wi}, t_{wb}) + E_{cel}(t_{ci}, t_{cb}) + E_{dmb\_busy}(t_{db}) \quad (15)$$

$$E_{old}(t_{all}) = E_{w\_busy}(t_{wb}) + E_{cel}(t_{ci}, t_{cb}) + E_{dmb\_busy}(t_{db}) \quad (16)$$

$$E_{new}(t_{all}) = E_{w\_busy}(t_{wb}) + E_{cel}(t_{ci}, t_{cb}) + E_{dmb}(t_{dF}, t_{db}) \quad (17)$$

In equation (15), we can derive a simple fact, i.e. $t_{all} = t_{wi} + t_{wb} = t_{ci} + t_{cb}$, since there is not an energy saving mechanism which turns off the idle interface. In addition, as the FIC monitoring mode is not defined in legacy mechanisms, the energy consumption of which mode ($E_{dmb\_FIC}(0)$) becomes zero and is eliminated as shown at equation (15) and (16). Equation (16) explains the consumed energy of MS employing one of legacy energy saving schemes. The consumed energy of wireless interface in idle mode ($E_{w\_idle}(0)$) is zero because the scheme turns off the wireless interface of idle mode. Instead, the cellular interface is always-on state in order to detect an incoming service destined for the turned-off wireless interface and to wakeup it, accordingly the fact, $t_{all} = t_{ci} + t_{cb}$, can be derived. Likely, as described at equation (17), the proposed mechanism also turns off the wireless interface in idle mode, and so reduces the energy consumption. However, our mechanism proposes the use of AT-DMB system instead of cellular as the always-on wakeup interface, though it induces additional energy consumption referred to as $E_{dmb\_FIC}(t_{dF})$. But, note that the energy consumption of AT-DMB in FIC monitoring mode ($E_{dmb\_FIC}(t_{dF})$) is low enough as well as the cellular interface in idle mode. In this manner, the proposed mechanism compensates the QoS degradation of legacy ones with the fast wakeup and connection without the serious degradation of energy efficiency.

Then, we evaluate some experimental results of the energy efficiency based on the average energy consumption. In the simulations, some energy parameters given by interface manufacturers of cellular [12], DMB [13], and WLAN [14] are adopted to offer more reliable evaluation. These parameters are explained in Table 4.

Fig. 10 ~ 12 show the average energy consumption of MS containing cellular, WLAN, and AT-DMB interfaces. In Fig. 10, the consumed energy of MS without any ongoing service is measured in unit of Joule(J) depending on the used energy saving mechanisms. According as the turned-on time flows away, MS without any energy saving scheme spends lots of energy rapidly, while MSs with energy saving schemes, i.e. legacy and proposed one, reduce the unnecessary energy consumption remarkably by turning off WLAN interface currently not in use. Fig. 11 and 12 compare the energy consumption of MS experiencing cellular service and AT-DMB service respectively. Similarly, it is confirmed that both legacy and proposed mechanisms enhance the energy efficiency of MS. In comparison with legacy energy saving schemes, the proposed one consumes a little more energy due to the use of AT-DMB interface in FIC monitoring mode. However, it is obvious that the consumed energy by AT-DMB is low enough to barely affect the total energy efficiency of MS.

표 4. 네트워크 장치 별 전력 소모량 (mW).
Table 4. Energy consumption (mW) of network interfaces.

State	Cellular [12]	WLAN [14]	AT-DMB [13]
Idle mode	20~125	190*~1140	** 20~40
Busy mode	696~1582	2600~2610	180~220

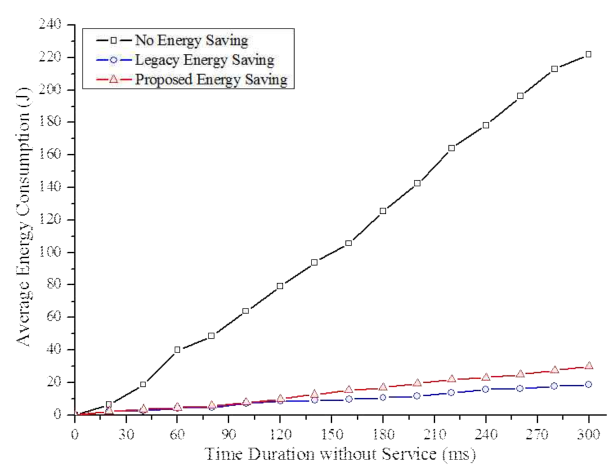


그림 10. Idle 시간에 따른 평균 전력 소모량.
Fig. 10. Average Energy Consumption vs. idle duration.

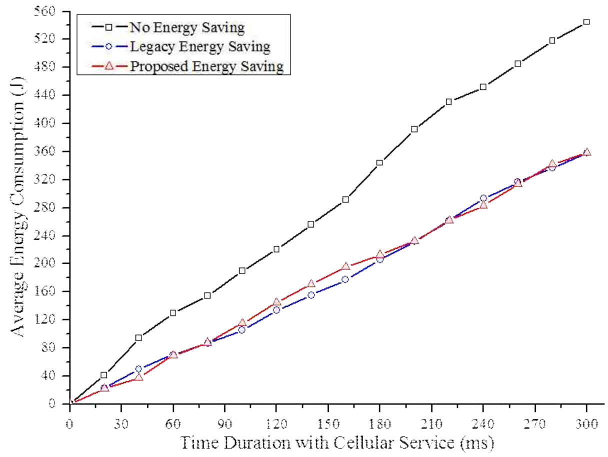


그림 11. Cellular 서비스 시간에 따른 평균 전력 소모량.
Fig. 11. Average Energy Consumption vs. cellular service duration.

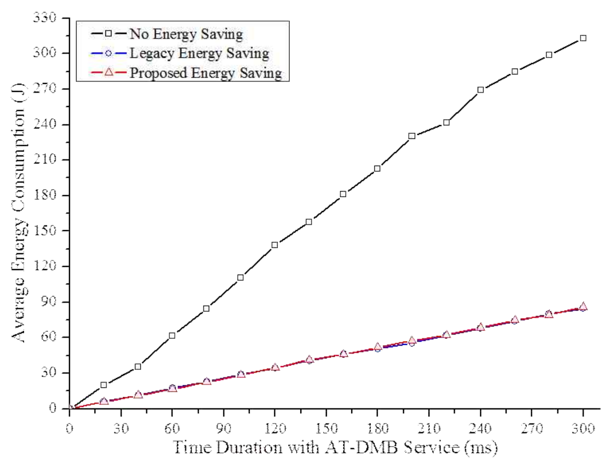


그림 12. AT-DMB 서비스 시간에 따른 평균 전력 소모량.
Fig. 12. Average Energy Consumption vs. AT-DMB service duration.

Furthermore, as verified above, the proposed mechanism with fast wakeup and connection improves the QoS achievements significantly.

Ⅴ. Conclusion

In this paper, we proposed the fast wakeup and connection mechanism for improving the QoS and the energy efficiency simultaneously. We initially focused on the convergence of the integrated telecommunication networks and the AT-DMB broadcasting system, and the interworking of them by adopting the MIIS. In the proposed convergence network, our mechanism concentrated on the enhancement of QoS by reducing both wakeup delay and connection delay, and the minimization of the additional energy consumption caused by AT-DMB interface. Then, we evaluated the performance of our novel mechanism in terms of the average incoming service delay as well as the average energy consumption through the numerical and experimental analysis. In result, it was verified that the proposed mechanism significantly improved the QoS by reducing the incoming service delay without the degradation of energy efficiency.

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