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QoE-Aware Mobility Management Scheme

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Abstract

In this paper, we introduce a quality of experience (QoE)-provisioning mobility management scheme. The emphasis is on a mobility-aware QoE solution enabling network components to recognize the mobility pattern of an end-user and to prepare a handover in advance. We further focus on an energy-adaptive QoE solution based on the energy profile providing the preferred pattern of energy consumption and an energy preference check engine determining whether the provision of the service that the end-user requested is suitable to QoE or not. Lastly, we concentrate on a network-based intelligent mobility management scheme adopting the calm service and the balance. Consequently, we conclude that the proposed schemes improve the handover latency, QoE metrics, and energy efficiency simultaneously.

Index Terms: Energy efficiency, Handover, Heterogeneous networks, MIH, Mobility, QoE

I. INTRODUCTION

The future Internet is represented as ubiquitous, which guarantees “any-service” with “any-device” through “any-network” “any-where” at “any-time” to every user. To support this, certain crucial requirements need to be met, such as a very high data rate for “any-service,” multi-interface systems for “any-device,” and integrated heterogeneous networks and high mobility for “any-network.” Therefore, it is essential that multi-interface systems roam seamlessly across heterogeneous wireless access networks, and a great deal of effort has been devoted to the development of seamless roaming techniques [1-3]. However, the developed networks have not met the condition of a seamless handover because they do not consider both the wireless signaling overhead and the processing overhead of a user terminal [4, 5]. Moreover, with increased competition, improving the quality of the offered services as perceived by the users, commonly referred to as the quality of experience (QoE), has become very important to providers in order to reduce the customer churn rate and maintain or increase their competitive edge. QoE has been defined as the totality of the quality of service (QoS) mechanisms, provided to ensure a smooth provision of multimedia services over IP networks [6-8]. Therefore, previous studies have mainly focused on the original quality of the multimedia service and the quality of its delivery. The former refers to the encoding/decoding and the compression of multimedia data, while the latter refers to the routing protocols [9, 10]. However, the consideration that the QoE must be measured at the end-user has been disregarded thus far. The main considerations of the previous works only reveal how a service can be effectively provided to the end-user, irrespective of the exact experience of the end-user. In other words, the QoE is greatly affected by end-user conditions such as mobility, battery life, and expense. For example, what if the end-user moves too fast to receive undamaged IPTV packets? What if the end-user’s terminal powers off during a video call instead of a voice call? What if the end-user is billed an unexpected cost because of a large number

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of wireless VoIP packets? Therefore, such end-user conditions have to be considered to be the key factors affecting the QoE.

In this paper, we propose a QoE-aware mobility management scheme that provides both a complete QoE solution and a seamless handover solution for heterogeneous wireless networks. The proposed scheme is based on two concepts: user condition-based QoE provision and network-based "calm" service. The first concept offers not only legacy QoE solutions, such a QoS-driven scheme, but also the proposed novel QoE solution, i.e., a mobility-aware and energy-aware scheme. Therefore, all the end-users are provided with a stable, green service through the proposed complete QoE solution. Secondly, the calm service guarantees that the end-users barely notice when, where, and how the service is provided and the handover is performed, as the network devices, such a point of attachment (PoA), back the end-user terminal up for most of the QoE and handover processes. Therefore, the calm service significantly reduces the energy consumption of a user terminal, the service delay, and the handover latency.

The rest of this paper is organized as follows: in the next section, we explain the mobility-aware QoE solution based on the mobility pattern of an end-user. In Section III, we describe the energy-aware QoE solution based on the user's energy preference and a fast wakeup and connection mechanism. Then, in the next section, we introduce the proposed QoE-aware mobility management scheme. Section V presents an analysis of the performance of the proposed schemes, and Section VI concludes this paper.

II. MOBILITY-AWARE QOE SOLUTION

User mobility has a considerable impact on the QoE at the end-user side. In particular, the fast velocity of the end-user and the short communication range of the network make users experience critical QoE degradation in terms of the link duration, the call blocking/dropping probability, the data packet delivery ratio, and the control packet overhead. However, the movement and the velocity of users are completely dependent on their intention, and thus, the management of these mobility aspects is not a compatible solution for QoE improvement. On the other hand, what if the service providers or network managers are able to expect these mobility aspects of the end-users? According to the development of transportation, the life zone of the end-users is broadening. In particular, since the availability of various types of public transportation enables users to save time and money, public transportation is the most common way for users to move around. Here, when going to work or leaving their office, most users always use the same mode of transport that regularly moves along fixed paths. Therefore, it enables one to expect the movement and the velocity of users on various modes of transport.

In this paper, we propose a mobility-aware QoE solution that expects the mobility pattern of users. It enables network components 1) to recognize the moving path of an end-user beforehand, 2) to prepare a handover in advance, and 3) to manage the power consumption of an end-user device. In order to allow these functions, the proposed QoE solution employs the media-independent handover (MIH) services defined in the IEEE 802.21 standard. MIH improves the handover performance across heterogeneous access networks, i.e., a vertical handover, and optimizes the service (or session) continuity during handovers, i.e., a seamless handover. Therefore, it provides generic link layer intelligence and other related network information to the upper layers. In particular, MIH offers the message flow between handover-related entities to provide information on handover candidate networks and to deliver handover commands by using the media-independent event service (MIES), media-independent command service (MICS), and the media-independent information service (MIIS) [2, 11].

In the proposed mobility-aware QoE solution, novel MIIS messages are introduced for allowing a network component such a PoA to notice the end-user mobility beforehand. Table 1 explains the newly defined and modified MIIS messages. Further, the operation of the proposed solution by using these messages is illustrated in Fig. 1 and detailed below.

> "If the end-users regularly use the same public transportation at the same time, they register the mobility pattern including the departure place and time to the MIIS by using a novel MIIS message, *MIH_Register_Mobility_Pattern*."

1) MIIS gathers the designated user's mobility pattern, i.e., MIHF_IDs of the serving PoAs, during the trip and creates a mobility pattern table specifying the frequent movement path of the designated user.

2) When the user is connected to the PoA at the point of departure, he/she sends the mobility type information indicating the pre-registration of his/her own mobility pattern through MIH_MN_User_Profile. In addition, the user device turns off all the interfaces not in use for energy conservation.

3) The serving PoA requests the neighboring network information by using the modified MIH_Get_Information_ Request message with the Mobility Type field set.

4) MIIS searches the mobility pattern table for the pre-registered mobility pattern data of the designated end-user. Then, it compares both the departure link ID in the pre-registered data with the current link ID of the user and the departure time in the data with the current time.

Table 1. Detailed information of the proposed novel MIIS messages

Name	Field	Description
MIH_Register_Mobility_Pattern	Source identifier	Identifier of the entity where the registration is initiated
	Destination identifier	Destination identifier of registration
	Departure link identifier list	List of IDs of the departure access networks to which the end-user regularly connects
	Departure time data list	List of departure time data at which the end-user regularly connects to the departure access network
MIH_MN_User_Profile	Source identifier	Identifier of the entity where the message is initiated
	Destination identifier	Destination identifier of the message
	Current link identifier	Identifies the current access network over which the command needs to be sent
	Mobility type	Specifies whether the user has registered the mobility pattern or not.
	Energy preference	Specifies the type of service that the user preferred in the order of energy consumption
	Basic energy	Indicates the quantity of required energy for the basic functions of the user device
* MIH_Get_Information_Request	Source identifier	Identifier of the end-user device
	Mobility type	Specifies whether the user has registered the mobility pattern or not
* MIH_Get_Information_Response	Source identifier	Identifier of the end-user device
	Target network data list	Data list related to the target access network information

* shows additional field only.

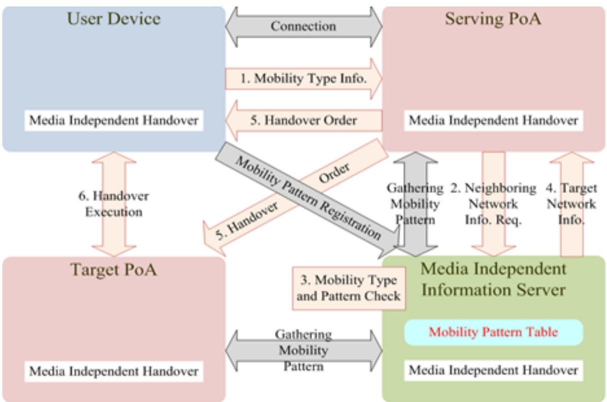

Fig. 1. Operation of proposed mobility-aware QoE solution.

5) If these data correspond, MIIS sends the modified *MIH_Get_Information_Response* message containing the information of the next target PoA to the serving PoA.

6) When a handover is required, the serving PoA orders a handover for the user device and the next target PoA that is designated by the MIIS, without further queries.

7) The end-user device turns on the designated interface and handovers to the target PoA without the handover latency caused by the queries and the discovery of neighboring networks.

III. ENERGY-AWARE QOE SOLUTION

What if the remaining energy of the user device is less than the required energy for the service that the user wants? The answer is definitely dependent on the user preference. If the user prefers the energy savings, the answer is the denial of the service, while if the user prefers to access the service irrespective of the discharge, the answer is the provisioning of the service. This is because the best solution for the end-user QoE is the fitting the service to the user preference.

Therefore, we propose an energy-adaptive QoE solution based on the user preference. First, we design the energy profile to inform the user preference in terms of the pattern of energy consumption to the connected network. This profile contains both the type of service the user preferred in the order specified in the Energy Preference field, and the quantity of required energy for basic functions as specified in the Basic Energy field, as described in Table 1. Then, we offer the energy preference check engine, which determines whether the provision of the service that the user requested is suitable for the end-user QoE or not, in terms of the energy consumption. The operation of the optimized solution is depicted in Fig. 2 and detailed below.

1) When the user is initially connected to the network, the energy profile information is delivered to the serving PoA through the MIH_MN_User_Profile message.

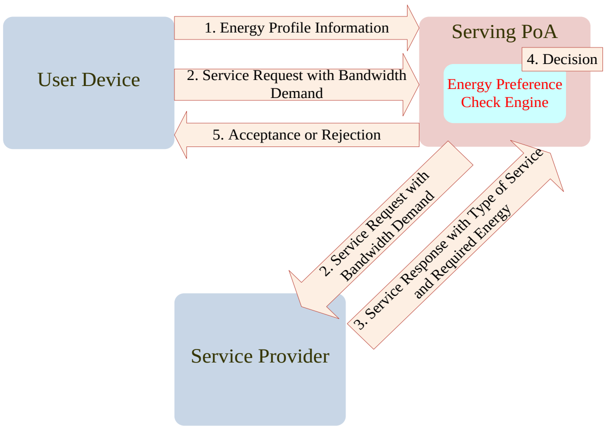

Fig. 2. Operation of energy-adaptive QoE solution.

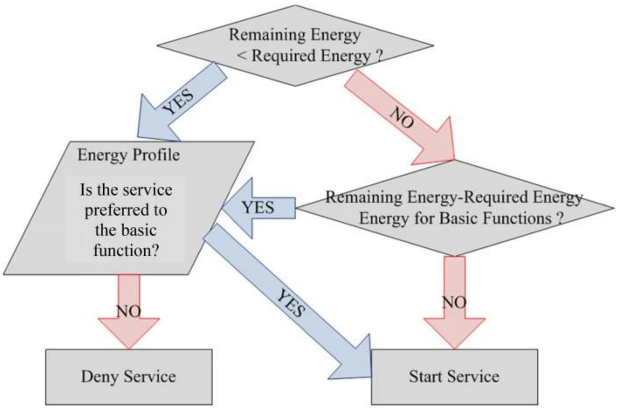

Fig. 3. Flow chart of the intelligent service decision algorithm used in the energy preference check engine.

2) If the user requests a service, the quantity of the remaining energy of the user device is added in the medium access control (MAC) header of the service request message and then delivered to the PoA and the service provider.

3) The service provider answers with the service response message containing the type of service and the required energy for the service; this message is delivered to the PoA.

4) The energy preference check engine on the PoA decides whether to accept or to reject the service taking into account the logic as described in Fig. 3.

5) According to the decision, the PoA delivers the service response message including the acceptance or the rejection to the user device.

In addition, a considerable amount of research effort has been dedicated to the investigation of energy management, usually called power saving, schemes in multi-interface systems [12-18]. However, most of this effort has been focused only on the energy saving issue of multi-interface systems without the QoE concern, i.e., delay of the incoming service through the interface already turned into the energy saving mode. In this paper, we propose a fast wakeup and connection mechanism employing MIIS [19]. The key concepts of the proposed mechanism are as follows:

1) Fast wakeup of the designated interface according to the quick transfer of a wakeup signal via MIIS.

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

IV. QOE-AWARE MOBILITY MANAGEMENT SCHEME

The IEEE 802.21 MIH offers a framework of the message flows between handover-related entities to provide information on handover candidate networks and to deliver commands related to handovers. It defines both mobile-initiated and network-initiated handover frameworks. Both consist of MIH discovery, network selection, mobility management, and MIH completion. During the MIH discovery phase, the information query to MIIS is executed by using the MIH_Get_Information_Request/Response messages. This information query may be attempted as soon as MS is first attached to the network. The network selection phase allows the handover initiator, i.e., either MS or one of the network components, to check the resource availability through candidate networks by employing MICS messages. It further enables the handover initiator to decide the handover target network and then, requests resource preparation to the target access network. The following phase is mobility management. It is responsible for both the handover process, such as FMIPv6, and the establishment of the link layer and upper layer connections. Lastly, resource release is performed by either the MS or the access network [2, 11].

However, the legacy mobility management scheme simply combines the MIH and FMIPv6 frameworks irrespective of efficiency, and thus, it still has critical problems including handover latency. To solve them, several studies have been conducted on the use of MIH services as a way to reduce the handover latencies [4, 5]. In these works, legacy MIH messages bring neighboring network information to MS instead of the RtSolPr/PrRtAdv messages; accordingly, the handover latency caused by the RtSolPr/PrRtAdv message delays is reduced as shown at Table 2. However, there are still many reasons degrading handover efficiency. In particular, a number of wireless signaling messages are still used in those works that induce handover latency, packet loss, and the power loss of MS. Moreover, in a case wherein the end-user moves fast, it causes various problems

Table 2. Comparison of mobility management schemes

Scheme	Preparation delay	Initiation delay	Execution delay
Legacy MIH-FMIPv6	Long	Long	Long
Enhanced MIH-FMIPv6	Midway	Short	Short
Proposed MIH-FMIPv6	Short	Short	Short

such as a shorter link duration and a higher control packet overhead; in particular, in access networks with a shorter range, a frequent handover will be perceived by users. These remaining problems are some of the most critical reasons for the degradation of QoE, including QoS in heterogeneous wireless access networks.

In this paper, we propose a QoE-aware mobility management scheme that provides both a complete QoE solution and a seamless handover solution for heterogeneous wireless networks. The proposed scheme has three concepts including the QoE provision based on user conditions as explained in Sections II and III. It offers not only legacy QoE solutions, such as a QoS-driven scheme, but also the proposed novel QoE solution, i.e., a mobility-aware and energy-aware scheme. Another concept of the proposed scheme is a network-based calm service. It states that the end-user may not notice when, where, and how the service is provided and the handover is performed. Therefore, the enhanced scheme entrusts most of the handover processes to network components by employing novel MIIS messages, as shown in Table 1. These are, in detail, the expectation of the user mobility pattern, the discovery of neighboring networks, the decision of the target handover network, the detection of handover need, and the handover order.

Lastly, the third concept of the proposed QoE-aware mobility management scheme is the balance. It is assumed to mean that the more resources there are, the more message capacity there is. Note that wired networks have considerably more resources (or bandwidth) than wireless networks. Therefore, the balance means that the networks above PoAs, i.e., wired networks, are given more messages

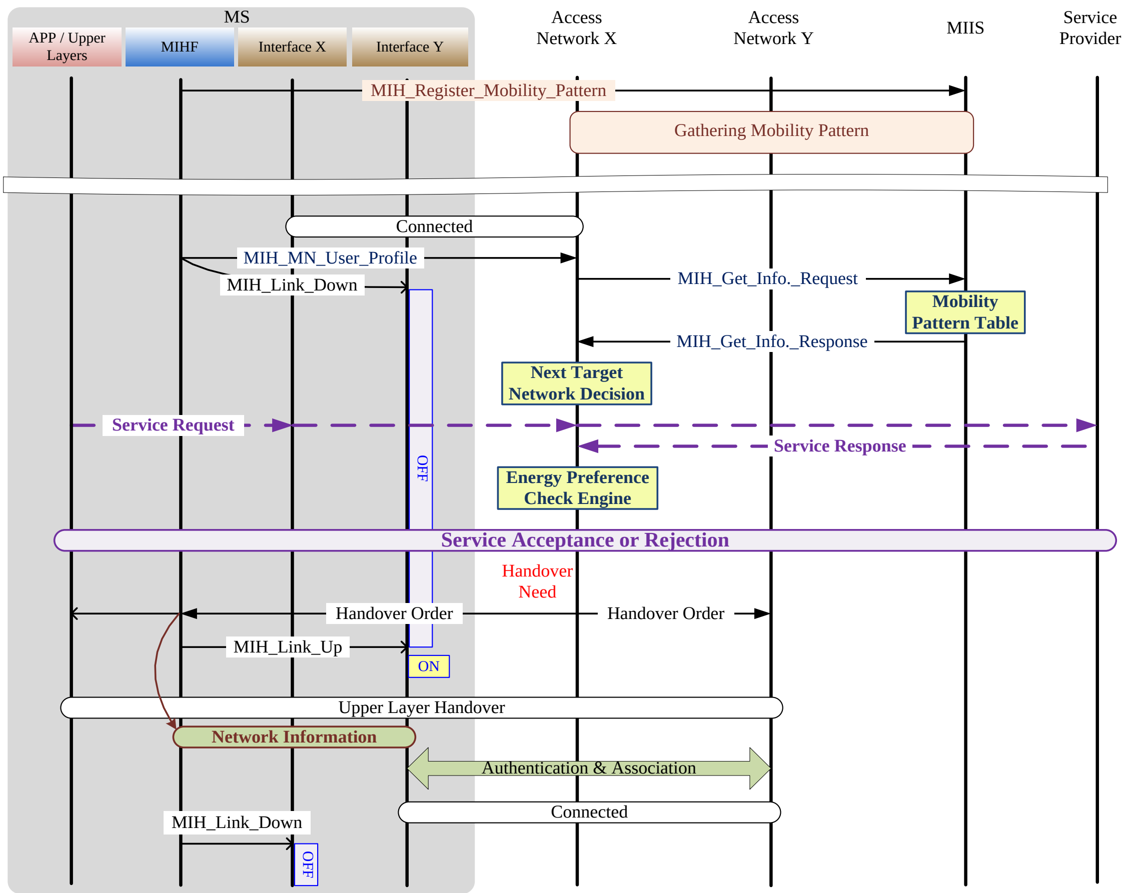

Fig. 4. Operation of the proposed QoE-aware mobility management scheme based on calm and balance.

to process than the networks beyond PoAs, i.e., wireless networks. In this manner, we design a balanced QoE-aware mobility management scheme to reduce the signaling and process overheads in wireless networks and to improve the end-user QoE. It firstly provides the information of the end-user to the serving PoA by deploying MIH_MN_User_ Profile explained above. This message enables the serving PoA to decide the handover type and the energy saving type without further request messages for related information to MS; it thus reduces the handover and service latency. Then, the balanced scheme offers the serving PoA the information on the neighboring networks or the next target network by employing network-initiated MIH_Get_Information_ Request/ Response messages. Therefore, the handover initiation message is no longer required in the proposed scheme.

The operation of the proposed QoE-aware mobility management scheme adopting these three concepts is depicted in Fig. 4 and detailed below.

1) If the end-users regularly use the same public transportation at the same time, the MIHF of the MS registers the mobility pattern including the departure place and time to the MIIS by using MIH_Register_Mobility_ Pattern.

2) MIIS gathers the designated user’s mobility pattern, i.e., MIHF_IDs of the serving PoAs, during the trip and creates a mobility pattern table specifying the frequent movement path of the designated user.

3) When MS is connected to the access network X at the point of departure, MIHF sends MIH_MN_User_Profile containing both the mobility type information and the energy profile information to the network. In addition, it turns off all the interfaces not in use, i.e., interface Y, for reducing the energy consumption of MS.

4) The network requests the neighboring network information by using the modified MIH_Get_Information_ Request message with the Mobility Type field set.

5) MIIS searches the mobility pattern table for the pre-registered mobility pattern data of the designated end-user. Then, it compares both the departure link ID in the pre-registered data with the current link ID of the user and the departure time in the data with the current time.

6) If these data correspond, MIIS sends the modified MIH_Get_Information_Response message containing the information of the next target access network Y to the current access network X.

7) If the user requests a service, the service request message including the quantity of the remaining energy of MS is delivered to the service provider via the current access network X.

8) The service provider answers with the service response message containing the type of service and the required energy for the service; this message is delivered to the network.

9) The energy preference check engine on the access network decides whether to accept or reject the service.

10) According to the decision, the access network provides the requested service to the end-user.

11) When a handover is required, the current access network sends the handover order message with the information of the next target access network Y to MS and delivers it with the user profile information to the target network, i.e., designated by the MIIS, without further queries.

12) MS turns on the designated interface Y and performs the upper layer handover procedure, e.g., FMIPv6.

13) Then, referring to the target network information, the interface Y of MS notices the target access network for connection without any further network discovery procedure. Accordingly, the connection establishment is simply completed after the authentication and association procedures.

V. PERFORMANCE EVALUATION

A. Handover Latency

We analyze the numerical result of the proposed QoE-aware mobility management scheme compared with that of the legacy scheme in terms of the handover latency and the wireless signaling overhead. Note that legacy schemes using either mobile-initiated or network-initiated MIH procedures are the same in terms of latency. First of all, we derive each part of the handover latency, including the delay of preparation, initiation, and execution. Eqs. (1) and (2) describe the handover preparation latency, i.e., MIH latency, of the legacy mobility management framework (T_{old_MIH}) and the proposed framework (T_{new_MIH}), respectively. Assume that D_{A-B} is the message delivery latency between A and B.

$$T_{old\_MIH} = 6D_{MS-SPoA} + 4D_{SPoA-TPoA} + 2D_{SPoA-MIIS}\,, \quad (1)$$

$$T_{new\_MIH} = 4D_{MS-SPoA} + 2D_{SPoA-TPoA} + 3D_{SPoA-MIIS}\,. \quad (2)$$

Handover initiation latency, i.e., FMIP latency, is derived in Eqs. (3) and (4), where D_Z denotes the delivery latency of message Z. Note that RtSolPr/PrRtAdv, FBU, and FBack are delivered between MS and the serving PoA (SPoA), while HI and HAck are delivered between SPoA and the target PoA (TPoA).

$$T_{old\_HI} = D_{Pr/Rd} + D_{FBU} + D_{FBack} + D_{HI} + D_{HAck} = 4D_{MN-SAR} + 2D_{SAR-TAR}\,, \quad (3)$$

$$T_{new\_HI} = D_{FBU} + D_{FBack} + D_{HI} + D_{HAck} = 2D_{MS-SPoA} + 2D_{SPoA-TPoA}\,. \quad (4)$$

Eqs. (5) and (6) show the handover execution latency consisting of the network discovery phase ($T_{discover}$) and the authentication & association phase ($T_{auth.\&asso.}$).

$$T_{old\_HE} = T_{discover} + T_{auth.\&asso.}, \quad (5)$$
$$T_{new\_HE} = T_{auth.\&asso.}. \quad (6)$$

Second, we derive the total handover latency by using the above equations, as shown in Eqs. (7) and (8).

$$\begin{aligned} T_{old\_HO} &= T_{old\_MIH} + T_{old\_HI} + T_{old\_HE} \\ &= 10D_{MS-SPoA} + 6D_{SPoA-TPoA} + 2D_{SPoA-MIIS} \\ &\quad + T_{Discover} + T_{auth.\&asso.}, \end{aligned} \quad (7)$$

$$\begin{aligned} T_{new\_HO} &= T_{new\_MIH} + T_{new\_HI} + T_{new\_HE} \\ &= 6D_{MS-SPoA} + 4D_{SPoA-TPoA} + 3D_{SPoA-MIIS} \\ &\quad + T_{auth.\&asso.}. \end{aligned} \quad (8)$$

Thus, we verified that the proposed scheme significantly reduces the handover preparation, initiation, and execution latency, and in turn, decreases the total handover latency. In particular, since the wireless section, i.e., between MS and SPoA (or TPoA), is much slower and more congested than the wired section, the wireless signaling overhead degrades the handover performance critically. In the wireless section, the legacy scheme deploys six MIH signaling messages and four FMIP signaling messages. On the other hand, the proposed scheme deploys only four MIH signaling messages and two FMIP signaling messages. Therefore, the wireless signaling overhead is significantly reduced because of our balanced mobility management scheme.

Lastly, we compare the handover performance of the proposed scheme with that of the legacy frameworks including [4]. We analyze some experimental results of the average total handover latency time depending on $D_{MS-SPoA}$, as illustrated in Fig. 5. In the simulations, certain time parameters verified by the experimental results based on the demonstration are used for a more reliable evaluation. These are $T_{discover}$ and $T_{auth.\&asso.}$ distributed between 200–300 ms and 5–20 ms, respectively [20]. Further, $D_{SPoA-TPoA}$ and $D_{SPoA-MIIS}$ are distributed between 50–100 ms and 25–75 ms, respectively. Thus, we verify that the proposed scheme significantly enhances the handover performance even though the wireless link is excessively congested.

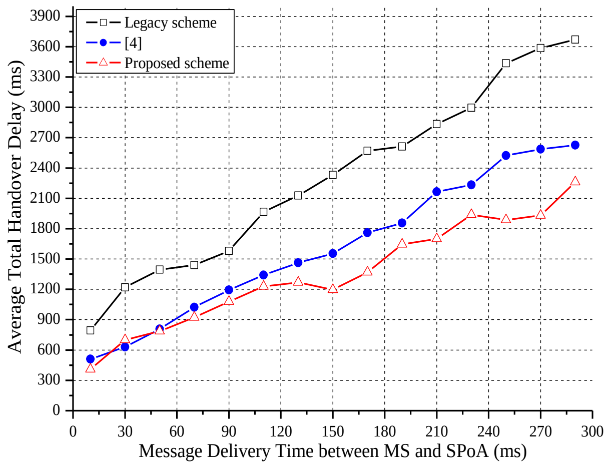

Fig. 5. Average total handover delay depending on the wireless message delay.

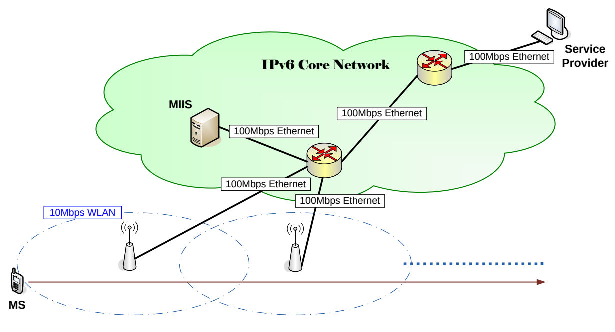

Fig. 6. Simulation topology.

B. QoE Metric

We first analyze some experimental results of the QoE performance perceived by the end-users, depending on the average total service latency time caused by the mobility management mechanisms. Therefore, we design a simple analytical metric of QoE performance (Q), where $NP_{Received}$ denotes the number of data packets that the user received, $NP_{Requested}$ represents the number of data packets that the user requested, and NP_{Sent} indicates the number of data packets that service provider sent, as shown in Eq. (9).

$$Q = \frac{NP_{Received}}{NP_{Requested}} = \frac{NP_{Received}}{NP_{Sent}}. \quad (9)$$

The closer the value of Q is to 1, the better is the QoE perceived by the end-user. In the simulations, we design the simulation topology composed of the IEEE 802.11b WLAN and IPv6 core network by using NS-2 as illustrated in Fig. 6. In addition, we configure that the service provider generates the FTP traffic with a file size of 100 Mb. The radius of WLAN is set to be 50 m, the number of WLAN cells is 5, the distance between the PoAs is 90 m, and MS moves at 10 m/s. Consequently, as shown in Fig. 7, the proposed QoE-aware mobility management scheme allows the mobile end-user to experience a QoE-guaranteed service for a longer

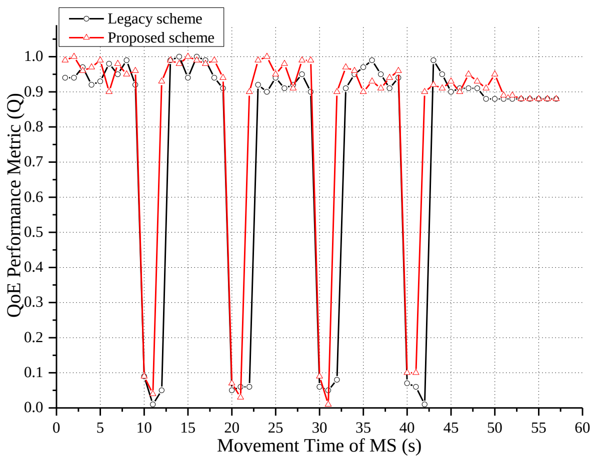

Fig. 7. Measurement of the QoE performance by using the novel QoE metric Q.

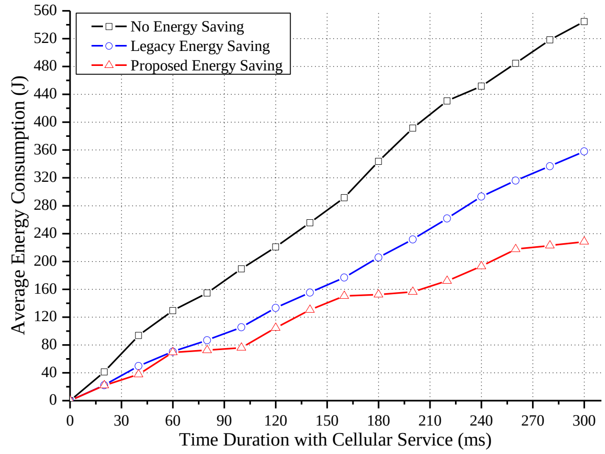

Fig. 8. Average Energy Consumption vs. cellular service duration.

time than a legacy scheme. This is because the proposed scheme provides a faster handover mechanism than the legacy one so that the degradation of the QoE induced by the handover latency is improved.

C. Energy Efficiency

We design a numerical model of the energy consumption depending on the type of interface. Our model supposes that the interface types are limited to the wireless network types, such as WMAN and WLAN, and the cellular network. In Eqs. (10) and (11), the energy consumption models of the wireless networks ($E_{wireless}(t_1,t_2)$) and the cellular network ($E_{cel}(t_1,t_2)$) are derived, respectively.\

$$E_{wireless}(t_1,t_2) = E_{w\_idle}(t_1) + E_{w\_busy}(t_2), \quad (10)$$

$$E_{cel}(t_1,t_2) = E_{cel\_idle}(t_1) + E_{cel\_busy}(t_2). \quad (11)$$

Note that $E_{X\_idle}(t)$ and $E_{X\_busy}(t)$ denote the consumed energy of the interface that is in the idle mode and the busy mode during time *t*, respectively. Here, the idle mode is the turned-on state without any active service and operation, while the busy mode is the turned-on state providing a service. Therefore, the total energy consumption ($E_{MS}(t_{all})$) of the MS including wireless and cellular interfaces is computed as shown in Eq. (12).

$$E_{MS}(t_{all}) = E_{wireless}(t_{wi}, t_{wb}) + E_{cel}(t_{ci}, t_{cb}). \quad (12)$$

Assume that t_{all} is the total operation time of MS and t_{wi} and t_{ci} are the idle mode time of each interface, while t_{wb} and t_{cb} are the busy mode time of each interface.

Using these equations, eventually, we derive the total energy consumption of each MS employing different energy saving mechanisms in Eqs. (13)–(15).

$$E_{none}(t_{all}) = E_{wireless}(t_{wi}, t_{wb}) + E_{cel}(t_{ci}, t_{cb}), \quad (13)$$

$$E_{old}(t_{all}) = E_{w\_busy}(t_{wb}) + E_{cel}(t_{ci}, t_{cb}), \quad (14)$$

$$E_{new}(t_{all}) = Limit_{prefer}[E_{w\_busy}(t_{wb}) + E_{cel}(t_{ci}, t_{cb})]. \quad (15)$$

Note that the $Limit_{prefer}[]$ function provides the selective energy consumption for service based on the user preference as explained in Section III.

Fig. 8 shows the average energy consumption of MS containing cellular and WLAN interfaces in accordance with the ongoing service from the cellular network. The consumed energy is measured in unit of joules (J) depending on the energy-saving mechanisms. Accordingly, as the turned-on time passes, MS without any energy-saving scheme spends a considerable amount of energy rapidly, while MSs with energy-saving schemes, i.e., the legacy and the proposed schemes, reduce the unnecessary energy consumption remarkably by turning off the WLAN interface currently not in use. Moreover, the proposed scheme allows the end-user to deny the unnecessary service in accordance with the energy consumption preference of the end-user. Therefore, it is obvious that the proposed scheme remarkably enhances the energy efficiency by reducing the energy spent by both the interface and the service unnecessarily.

Further, we analyze the incoming service latency resulting from the use of proposed mechanism explained in Section III. We initially introduce the numerical model of the QoE degradation factors, the wakeup delay, and the connection delay.

VI. CONCLUSIONS

In this paper, we have proposed the QoE-provisioning mobility management scheme. The keys are placed on the mobility-aware QoE solution based on the mobility pattern of the end-user, and the energy-adaptive QoE solution adopting the user preference of energy consumption. Further, the QoE-driven energy-saving concept using fast wakeup and connection is considered to guarantee both the QoE and the energy efficiency of the end-users. Moreover, we have focused on a network-based intelligent mobility management scheme adopting a calm service and balance. Consequently, we have verified that the following:

1) The proposed scheme significantly reduces the handover preparation, initiation, and execution latency, thus decreasing the total handover latency. The wireless signaling overhead is also significantly reduced because of the proposed balanced mobility management scheme.

2) The proposed scheme allows mobile end-users to experience a QoE-guaranteed service for a longer time than a legacy scheme. This is because the proposed scheme provides a faster handover mechanism than the legacy scheme and the degradation of QoE induced by the handover latency is thus improved.

3) The proposed scheme reduces the unnecessary energy consumption remarkably by turning off interfaces currently not in use. Moreover, it allows the end-user to deny the unnecessary service in accordance with the energy consumption preference of the end-user. Consequently, it is obvious that the proposed scheme remarkably enhances the energy efficiency by reducing the energy spent by both the interface and the service unnecessarily.

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