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802.16e 표준 기반 광대역 무선 이동 망을 위한 동적 스캐닝 기법

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Adaptive Scanning Scheme for Mobile Broadband Wireless Networks based on the IEEE 802.16e Standard

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요 약

기술의 발전과 유선망에서와 동일한 성능을 요구하는 사용자의 기대치 증대로 인해 광대역 무선 이동망은 중요한 연구 분야로 떠오르고 있다. 본 논문에서는 IEEE 802.16e 기반 시스템의 매체 접속제어 계층에서 핸드오버 성능 증가를 위한 기법을 제안한다. 이를 위해 본 논문에서는 셀 재설정 과정이라 불리는 스캔 시작 과정의 문제점을 식별하고 이를 해결하기 위한 수신 신호 강도 기반 동적 스캔 시작 기법을 제안한다. 모의실험을 통해 제안 기법은 필요한 스캔 지속 시간을 고려한 수신 신호 강도 예측을 통해 적시에 스캔 과정을 시작하여 불필요한 자원의 낭비와 늦은 핸드오버를 야기시키지 않는다는 것을 보였다.

Abstract

Mobile broadband wireless network is emerging as one of the hottest research areas due to technical advances, and the demands of users who wish to enjoy the same network experience on the move. In this paper, we investigate the handover process at the medium access control (MAC) layer in an IEEE 802.16e-based system. In particular, we identify problems concerned with the scan initiation process called cell reselection and propose a received signal strength (RSS) estimation scheme to dynamically trigger a scanning process. We show how the RSS estimation scheme can timely initiate a scanning process by anticipating RSS values considering scan duration required.

▸ Keyword : Handover prediction(핸드오버 예측), error compensation(오류 보정), broadband mobile wireless network(광대역 무선 이동 망)

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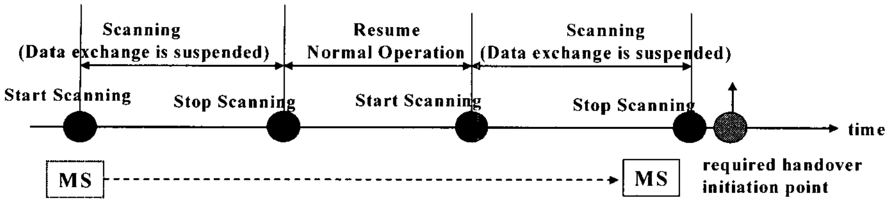
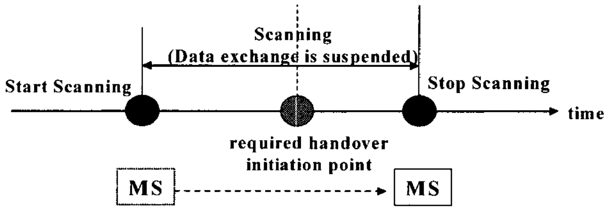


(a) Early scan initiation may result in waste of resources due to unnecessary scanning



(b) Late scan initiation may result in service discontinuity due to late handover initiation

그림 1. 스캔 시작 문제.
Fig 1. Scan Initiation Problem.

I. Introduction

In IEEE 802.16 WG (Working Group), TG (Task Group) e has recently completed a project to specify a mobile broadband wireless access (BWA) system based on the baseline standard [1] that mainly concerns fixed terminals. During the amendment, several medium access control (MAC) level features related to supporting the terminal mobility were added such as handover, power saving modes of operation, and etc. The official standard of IEEE 802.16e-2005 including the specifications of the features was published in Feb. 2006 [2]. Currently, extensive discussions are leaded by WiMAX forum, where many manufacturers and service providers are involved, on implementing and promoting the mobile broadband wireless system based on the standard. As a result, the WiMAX forum released mobile system profile version 1.0 approved specification in May 2007 [8]. In particular, early deployment of the mobile wireless access system is spurred in South Korea under the service name of Wireless Broadband (WiBro).

In such systems, the handover of a mobile station (MS) is one of the most important factors that affect their wide deployment. A handover is a process that a MS switches its wireless link and state information (for example, counters, timers, security information, etc.) from one base station (BS) to another. In the context of the 802.16e standard, a handover process is composed of three phases: cell reselection, handover initiation, and network re-entry. In the cell reselection phase, a MS scans multiple channels to find neighbor BSs and selects a set of candidate BSs for handover. In the handover initiation phase, the MS selects a target BS for handover and informs the serving BS that it intends to handover to the target BS based on the scan results and the estimated link quality between a MS and its serving BS. Finally, the MS takes the network entry steps again with the target BS to complete a handover. Even the 802.16e standard specifies the handover procedures, however, the standard leaves lots of implementation issues at each phase of the handover process that affect the performance of a MS and a network. For example, it is not clear in the specification when and how to trigger the cell reselection and handover initiation phase. There have been recent proposals on the handover initiation problem [3][4]. Regarding the cell reselection phase, however, the issues have not been addressed adequately (even identified) even if it is challenging to find a target BS that is most suitable for the mobility path and application requirements of a MS.

According to the 802.16e standard, data exchange between a MS and its serving BS is temporarily suspended while the MS scans neighbor BSs. Therefore, if the scan duration is not carefully engineered, the scanning process may degrade system throughput and service quality of ongoing applications by possible violation of quality requirements in terms of the packet transfer delay, delay variation, and packet loss rate. Fig. 1 shows the problems related to scan initiation time. Typically, it is the current best practice to trigger a scanning process when the received signal strength (RSS) between a MS and its serving BS degrades below some threshold. Usually a static threshold is configured at the network deployment time by heuristics of a network manager, considering the long-term aggregate behavior of mobile stations in the network. Static threshold is easy to implement, however, results in poor performance when individual MS does not confirm to the aggregate behavior. If the threshold is too high (fig. 1-(a)) multiple scanning processes would repeat until a MS decides to handover. This makes the resources used for scanning useless. In addition, the premature scanning wastes the energy of a MS due to frequent channel switching. On the other hand, if the threshold is too small (fig. 1-(b)) the scanning process is likely to finish after the link quality between the MS and its serving BS deteriorates below the threshold for handover initiation. Since the MS cannot receive MAC management messages from its serving BS while scanning neighbor BSs, the resulting handover process may not provide seamless service to the MS. Therefore, in this paper, we focus on timely triggering a scanning process. The basic concept of our proposal is to decide *optimal scan initiation time by estimating link* quality between a MS and its serving BS for a scan duration.

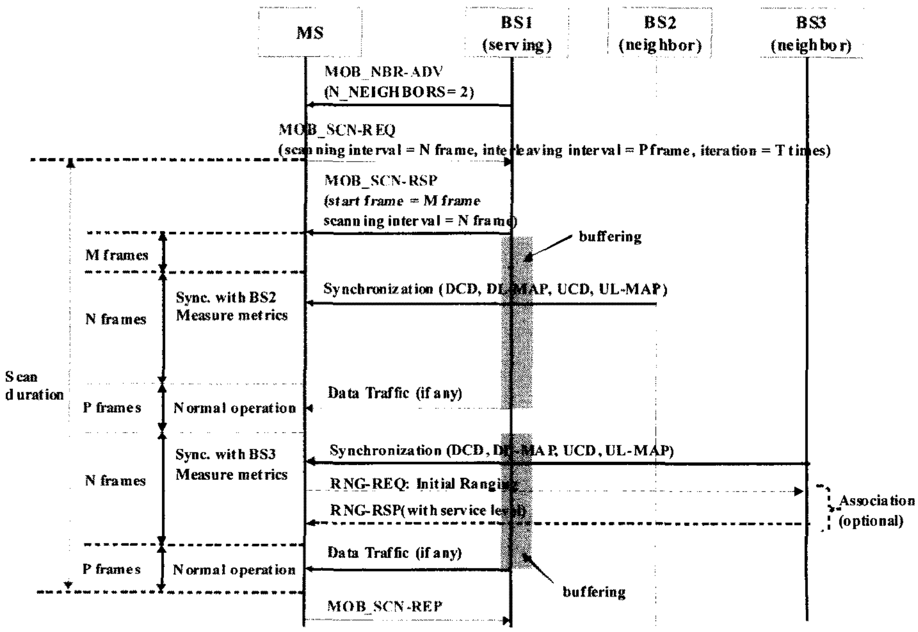


그림 2. IEEE 802.16e 표준에서 정의된 스캔 프로세스.
Fig 2. Scanning process of the IEEE 802.16e specification.

The rest of the paper is organized as follows. We first provide a brief overview of the IEEE 802.16e cell reselection process. Dynamic scan initiation scheme is discussed in section 3. The experimental results though ns-2 simulations with the IEEE 802.16e extensions [9] are shown in section 4. Finally, conclusions and future works follow in section 5.

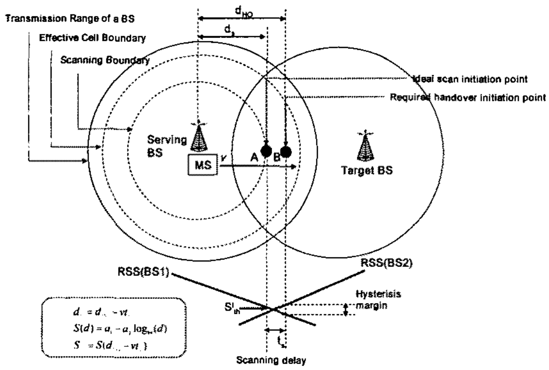


그림 3. 스캔 시작을 위한 최적 RSS 임계값.
Fig 3. Optimal RSS threshold for scan initiation.

II. Cell Reselection Process

Cell reselection is the process that a MS scans and/or makes an association with one or more BSs in order to monitor and determine their suitability as a target BS for handover. The cell reselection may be assisted by a backbone network connecting base stations. The process of scouting neighbor BSs is also called as the network topology acquisition in the IEEE 802.16e specification.

Fig. 2 shows the cell reselection procedures with optional association. Before measuring performance metrics of a BS, a MS must receive channel information of the BS for synchronization. Since the channel information is periodically broadcasted by a BS, a MS must wait on average for half of the broadcast period to get the information. According to the specification the maximum value of the period could be 10 seconds, this long delay for acquiring channel information is unacceptable for delay sensitive applications. To overcome this problem, the serving BS periodically broadcasts information about the network topology using the MOB_NBR-ADV message in order to expedite the synchronization between the MS and its neighbor BSs. The assumption in the IEEE 802.16e standard is that neighbor BSs exchange their downlink channel descriptor (DCD) and uplink channel descriptor (UCD) over the backbone network. Since the information is contained in the MOB_NBR-ADV message along with the number of neighbor BSs, a MS does not need to wait for channel information of neighbor BSs when it scans them.

The MS and its serving BS negotiate the scanning interval during which the MS scans available BSs. A MS requests its serving BS a scanning interval using MOB_SCN-REQ message. The serving BS grants or denies the scan request using MOB_SCN-RSP message. A MS may request multiple scanning opportunities by embedding the scanning interval, the interleaving interval for normal operation and the number of iterations in the MOB_SCN-REQ message to avoid multiple exchanges of MOB_SCN-REQ/RSP messages. If a MS receives a MOB_SCN-RSP message that accepts the request, the MS starts to scan one or more BSs for the scanning interval after the start frame time in the MOB_SCN-RSP message. Between scanning intervals, normal operation is interleaved for the interleaving interval. The scanning and normal operation repeats for the number of iteration times. During the scanning interval, data exchange between the MS and its serving BS is suspended. The upstream traffic originated from the MS is buffered at the MS, and the downstream traffic destined to the MS is queued at the serving BS. The coordination between a MS and its serving BS enables both entities to resume data exchanges without loss of data after the scanning interval. The MS may send MOB_SCN-REP message to report the scan results to the serving BS.

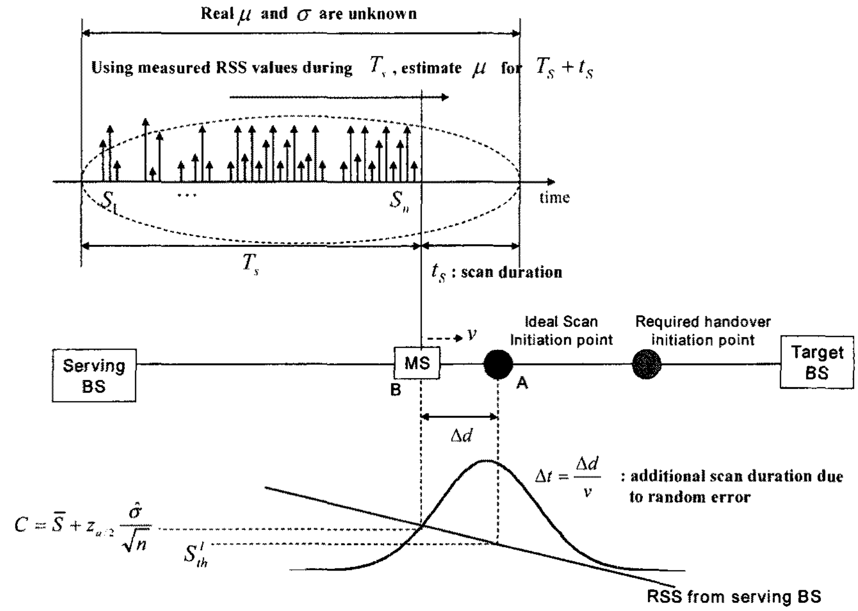


그림 4. RSS 예측 및 신뢰구간을 고려한 스캔 시작.
Fig 4. RSS estimation and scan initiation with the consideration of confidence interval.

The final step of the cell reselection is the association procedure between the MS and the neighbor BSs which is optional feature in the IEEE 802.16e standard. The association is an initial ranging process between the MS and the neighbor BSs. The association enables the MS to record initial ranging parameters and service availability information of the neighbor BSs by exchanging ranging request (RNG-REQ) and response (RNG-RSP) messages with the BSs. Therefore, if the MS handovers to one of the BSs with which it made association, the MS may further expedite the handover process by reusing the information. The IEEE 802.16e specification defines three levels of association. A MS and its serving BS choose a level when they exchange MOB_SCN-REQ and MOB_SCN-RSP messages.

III. Adaptive Scan Initiation

In this section, we detail our adaptive scan initiation scheme. The purpose of our scheme is to timely trigger a scanning process in order to avoid waste of resources due to unnecessary scanning while satisfying given handover initiation requirement. For this, we first derive the ideal condition for triggering a scanning process considering the speed of a MS, the required scan duration, and the given handover initiation distance from a serving BS. Since RSS at a distance randomly fluctuate due to fading effects and measurement errors, we propose a RSS estimation method to overcome the negative effects of the random errors so that the decision whether to begin a scanning process is robust against the errors.

3.1 Ideal RSS Threshold

Fig. 3 illustrates the relationship between a target handover distance, speed of a MS, and the ideal scan initiation point. Denote dHO as the given distance from a serving BS that handover should be started to provide seamless services to a MS. We also denote tS as the scan duration which is the time required for a MS to scan neighbor BSs. If we assume that a MS does not changes its speed (v) during tS as in [5] then, a scanning process should begin when a MS is at a vtS distance from the dHO of its serving BS. Our assumption is valid if tS is small enough. For example, if tS is 0.2sec and the speed of a MS is 120km/h, a MN can move 6.7 meters in 0.2sec. It is very unlikely that a MS moving with 120km/h changes its direction and/or speed within 0.2sec. Therefore, a scanning process should begin when a MS crosses a scanning boundary of radius (dS)

$$d_S = d_{HO} - vt_S. \quad \cdots\cdots (3.1)$$

Given dS, the RSS threshold for scan initiation can be obtained from a path loss model. Depending on the cell size, and radio propagation environments such as indoor, outdoor, tunnels, etc., various path loss models can be used to relate the signal power received by a MS from a BS at a distance [7]. These models have the form of

$$S(d) = a_1 - a_2 \log_{10}(d), \quad \cdots\cdots (3.2)$$

where S(d) is the signal strength in dB that a MS receives from a BS when the distance of the MS to the BS is d, a1 represents the gain of the transmission and reception antennas as well as the wavelength dependent part of the operating frequency, and a_2 represents the environment-specific attenuation characteristics. From eq. (3.1), and (3.2), the ideal RSS threshold for scan initiation (S^I_{th}) is determined as

$$S^I_{th} = S(d_{HO} - vt_S). \quad \cdots\cdots (3.3)$$

In other words, the MS should start a scanning process if the RSS value from its serving BS is smaller than S^I_{th}. However, in real radio propagation environments, RSS at a distance randomly fluctuates due to multipath fading effects called shadowing error. Therefore, the decision based only on the ideal RSS threshold may trigger a scanning process too early or too late if the shadowing error is not carefully considered.

3.2 Dynamic Scan Initiation

The shadowing error is known to be a random variable that follows a Gaussian distribution with mean zero and standard deviation σ_{dB} in decibel (dB). However, the model represents long time scale (say, a week, or month) behavior of the shadowing error in a specific radio propagation environment. Since a MS moves different radio propagation environments and the decision for scan initiation is made in a relatively short time scale (i.e. the same time scale as t_S), the random shadowing error can not be known when a MS needs to make a scan decision. Thus, we employ a RSS estimation method as in fig. 4 without any assumption on the underlying error. The estimation is done at every T_s. The RSS estimation is to anticipate the unknown real mean and variation of the RSS value for T_s with measured RSS values during a training interval of T_s, assuming that the radio propagation characteristics for consecutive T_s + t_S intervals are the same. The T_s should be large enough so that the number of measured RSS values is sufficient for statistical decision, and small enough such that the RSS values in T_s + t_S are strongly correlated. Suppose that S_1, S_2, ⋯, S_n are RSS values measured during T_s. If we denote the mean RSS and its standard variation for T_s + t_S interval as μ and σ respectively, then, we can establish a confidence interval for μ by considering the sample distribution of $\overline{S} = \Sigma_{i=1}^{n} S_i / n$. According to the central limit theorem, we can expect that $\overline{S}$ is approximately normally distributed with mean $\overline{\mu} = \mu$ and standard deviation $\overline{\sigma} = \sigma / \sqrt{n}$. When σ is unknown, sample standard deviation ($\hat{\sigma}$) during T_s can replace σ

when $n > 30$. Then, a (1-a)100% confidence interval for μ is given

$$(\bar{S}-z_{a/2}\hat{\sigma}/\sqrt{n}, \bar{S}+z_{a/2}\hat{\sigma}/\sqrt{n}), \quad (3.4)$$

where $z_{a/2}$ is the z-value that leaves an area of a/2 to the right in the standard normal distribution probability density function. We denote $C=\bar{S}+z_{a/2}\hat{\sigma}/\sqrt{n}$ as the confidence limit for the average RSS value for t_S. C is interpreted as the safety margin for the random shadowing error, and fig. 4 shows the relationship between C and S^I_{th}. Therefore, a scanning process begins when the confidence limit is smaller than the ideal RSS threshold for scan initiation, i.e.,

$$C \le S^I_{th}. \quad (3.5)$$

Fig. 4 also shows the difference between ideal scan initiation point and adaptive scan initiation point. The point A is where a MS starts scanning when there is no shadowing error. With our adaptive scheme, a MS triggers a scanning process when it is at point B. We denote Δd as the distance between point A and B. If Δd is small, the proposed scheme triggers a scanning process $\Delta t=\Delta d/v$ earlier than the ideal case due to RSS measurement errors.

표 1. Mobile WiMax 시스템 파라메터들.
Table 1. Mobile WiMax System Parameters.

Parameters	Values
Operating Frequency	2.5GHz
Duplex	TDD
Channel Bandwidth	10MHz
Frame Duration	5msec
BS-to-BS Distance	2.8km
Min. MS-to-BS Distance	36m
BS Height	32m
MS Height	1.5m
BS Antenna Gain	15dBi
MS Antenna Gain	-1dBi
BS Maximum Power	43dBm
BS Minimum Power	23dBm
Propagation Model	COST231 Hata
Shadowing Deviation	8dB

Ⅳ. Performance Evaluation

In this section, we present the performance of the adaptive scanning initiation scheme. We implemented the proposed scheme in the ns-2 simulator that has IEEE 802.16e extensions [9]. In our simulations, we used the same parameters as those used by the WiMAX Forum™ for evaluating the performance of a 802.16e system [6] which is summarized in table 1. The suburban area represented by the COST 231-Hata path loss model [7] is used with 8dB shadowing standard deviation (σ_{dB}). Currently, we implement two speed estimation methods to determine the optimal RSS threshold for scan initiation. The first one is to use location information using a GPS to obtain instantaneous speed of a MN, and the other method is to use the maximum speed that an IEEE 802.16e system can support (v_m=120km/h). In the following, we denote S^{I1}_{th} as the ideal RSS threshold when GPS is used, and S^{I2}_{th} as the ideal scan threshold when vm is used.

표 2. 동적 스캔 시작 기법의 성능.
Table 2. Performance of the Adaptive Scan Initiation Scheme.

(1-a) 100%	50	60	70	80	90
Δd_1(m)	36.5	36.5	63.2	63.2	107.8
Δd_2(m)	34.3	34.3	61.0	61.0	105.6
Δt_1(sec)	1.63	1.63	2.83	2.83	4.83

Δt_2(sec)	1.54	1.54	2.74	2.74	4.73
ΔdB_1 (dB)	0.59	0.59	1.03	1.03	1.79
ΔdB_2 (dB)	0.55	0.55	0.99	0.99	1.75

Table 2 shows the Δd and Δt when the scan duration is 0.2sec, the training interval is 0.4sec, d_{HO}=1.5km, and a MS moves 80km/h on average. ΔdB_1 and ΔdB_2 in the table represent the RSS difference in dB between the case when there is no shadowing error and the case when the adaptive scan is used with the given (1-a)100% confidence limit. The subscript 1 in the table represents the case when S^{I1}_{th} is used for scan initiation, and the subscript 2 represents the case when S^{I2}_{th} is used as the ideal RSS threshold. As the confidence interval increases, a scanning process triggers earlier, which increases total scanning time. When the confidence interval is 80%, a MS starts scan 2.83sec earlier than the ideal environment to avoid late handover (i.e. Δt_1=2.83sec) when S^{I1}_{th} is used. In case that S^{I2}_{th} is used for scan initiation, a scanning process begins 2.7sec earlier (Δt_2=2.74sec) than the ideal case. It must be noted that the table 2 shows the difference in distance, scan initiation time, and the RSS values. Since S^{I2}_{th} is bigger than S^{I1}_{th}, a MS begins a scanning process earlier when it used S^{I2}_{th} as a scan threshold than when the MS uses S^{I1}_{th} as the scan threshold.

V. Conclusions

A mobile broadband wireless access system based on the IEEE 802.16e standard is supposed to enable users to enjoy the same network experience on the move as if they are using wired networks. If the system is to be successfully deployed in the near future, system resources must be managed systematically. In this paper, we consider the problem of scan initiation in a 802.16e system. We present an adaptive scan initiation scheme that dynamically triggers a scanning process.

For more precise control, we are currently extending our study to reduce the time difference between the RSS estimation and ideal cases by considering user mobility patterns into the RSS estimation method.

참고문헌

[1] IEEE 802.16-2004, IEEE Standard for Local and Metropolitan Area Networks,"Part16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems," IEEE, Oct. 2004.

[2] IEEE Std 802.16eTM, "Part16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems - Amendment 2 Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands and Corrigendum 1," IEEE, Feb. 2006.

[3] D.H. Lee, K. Kyamakya, J.P. Umodi, "Fast Handover Algorithm for IEEE 802.16e Broadband Wireless Access System," in International Symposium on Wireless Pervasive Computing, pp. 1-6, Jan. 2006.

[4] S. Cho, J. Kwun, C. Park, O.-S. Lee and K. Kim, "Hard Handoff Scheme Exploiting Uplink and Downlink Signals in IEEE 802.16e Systems," in IEEE Vehicular Technology Conference, pp. 1236-1240, Sept. 2006.

[5] S. Mohanty, and Ian F. Akyildiz, "A Cross Layer (Layer 2+3) Handoff Management Protocol for Next-Generation Wireless Systems," IEEE Trans. Mobile Computing, vol. 2, no. 10, pp. 1347-1360, Oct. 2006.

[6] WiMAX ForumTM, "Mobile WiMAX - Part I: A Technical Overview and Performance Evaluation," Aug. 2006. (available at http://www.wimaxforum.org/)

[7] Eraldo Damosso, "COST 231 - Digital Mobile Radio Towards Future Generation Systems,"

European Commission, Jan. 1999.
[8] WiMAX ForumTM, "WiMAX ForumTM Mobile System Profile Release 1.0 Approved Specification," WiMAX Forum, May 2007.
[9] Software mobility package for ns-2, available at http://www.antd.nist.gov/seamlessandsecure/doc.html

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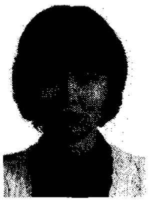

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