HAJAR, M.S., CHAHINE, M.K., HAMDAN, R. and QDAH, M.S. 2021. Performance analysis of vertical handover using predictable LGD event based on IEEE 802.21. In *Proceedings of the 2021 IEEE International conference on communications workshops (ICC workshops 2021), 14-23 June 2021, Montreal, Canada*. Piscataway: IEEE [online], 9473639. Available from: https://doi.org/10.1109/ICCWorkshops50388.2021.9473639

Performance analysis of vertical handover using predictable LGD event based on IEEE 802.21.

HAJAR, M.S., CHAHINE, M.K., HAMDAN, R. and QDAH, M.S.

2021

© 2021 IEEE. Personal use of this material is permitted. Permission from IEEE must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collective works, for resale or redistribution to servers or lists, or reuse of any copyrighted component of this work in other works.

OpenAIR @RGU

This document was downloaded from https://openair.rgu.ac.uk

SEE TERMS OF USE IN BOX ABOVE

DISTRIBUTED UNDER LICENCE

Performance Analysis of Vertical Handover using Predictable LGD Event based on IEEE 802.21

Muhammad Shadi Hajar
Department of Computer & Automation Engineering
Damascus University
Damascus, Syria

Mohamed Khaled Chahine
Department of Electronics & Communication Engineering
Damascus University
Damascus, Syria

Raouf Hamdan
Department of Computer & Automation Engineering
Damascus University
Damascus, Syria

Mohammad Sharf Qdah
Faculty of Information & Communication Technology
Al-Balqa Applied University
As-Salt, Jordan

***Abstract*—Next Generation Wireless Networks (NGWN) aim to provide any service at any time and anywhere with seamless mobility between homogeneous and heterogeneous networks. IEEE defines the IEEE 802.21 standard to facilitate seamless handover, namely, Media Independent Handover (MIH). IEEE 802.21 provides layer two events to upper layers with a view to enhance the operability and enable them to make the right decision on time. Link Going Down (LGD) is a predictive event triggered when a link quality degradation is expected in the near future. Connectivity losses and quality decreases are usually foreseeable during the handover process. Therefore, in this paper, we analyze the performance of our effective prediction model for generating the Link Going Down (LGD) event. The network performance metrics, such as packet loss, end-to-end delay, and throughput, have been evaluated using the Network Simulator NS2.**

***Index Terms*—Next Generation Wireless Networks, Prediction, MIH, Handover, MIPv6, LGD**

1. Introduction

As no wireless access technology can provide unlimited coverage or the desirable quality of service (QoS), a multi-interface mobile node is introduced to maintain link connectivity and ensure user satisfaction. Thus, many mobility management protocols have been proposed in the literature to allow seamless roaming between all IP-based heterogeneous wireless networks for mobile users. Media Independent Handover (MIH), which is defined in the IEEE 802.21 standard, enables the Mobile Node (MN) to use any radio access technology while moving across homogeneous or heterogeneous networks to achieve seamless and efficient handover [1].

Seamless handover is the crucial solution to provide a high level of service continuity without disruptions while the MN moves across different coverage areas. Two types of latency are expected during the handover process. The first one is generated by layer two switchings, while the second one is the layer three latency when vertical handover is conducted. As time-sensitive applications such as Voice Over Internet Protocol (VOIP) do not tolerate service degradation caused by the handover process, Media Independent Handover Function (MIHF) provides link layer triggers to upper layers that facilitate the handover process [2].

Handover-related entities exchange the required information to achieve the handover to the candidate network by using three kinds of flows: event, command, and information, which are all provided by the MIH framework. Link Going Down (LGD) event is used to assist upper layers in initiating the handover procedure in due course. Therefore, a new link can be established while the old link is still maintained if the LGD event is provided on time (make before break) [3]. However, as there is no algorithm defined in the IEEE 802.21 standard to trigger this event, false triggering will cause unnecessary handovers, which will degrade the QoS. Therefore, a timely triggering LGD event is a demand [4].

The rest of this paper is organized into five sections as follows. Section 2 describes the background of the MIH standard briefly, while section 3 presents the IEEE 802.21 and LGD event. In section 4, we present the experimental setup and performance analysis. Finally, the conclusion will be provided in section 5.

2. Background of the IEEE 802.21 standard

The Institute of Electrical and Electronics Engineers (IEEE) introduces the IEEE 802.21 standard as an abstract logical layer (layer 2.5) between the link and the network layers of the OSI model. The main goal is to provide the necessary support and mechanisms for upper layers by hiding all the link layers' complexities. Generally speaking, the IEEE 802.21 standard is developed to provide the following points:

- A generic framework that facilitates seamless handover between both homogeneous or heterogeneous network technologies.
- Providing the mobility protocols in the upper layers, such as MIPv6, with the required information to optimize the handover process by defining a set of handover-aided functions for local and remote entities.

- IEEE 802.21 defines a technology-independent SAP for the link layer by mapping it with each technology-specific primitives [5].

As illustrated in Fig. 1, Media Independent Handover Function (MIHF), which is a logical entity in the protocol stack, receives information from different link layers and provides them to upper layers. From the MIHF perspective, the MN has mobility management protocols named MIHF users responsible for controlling the handover procedure. To enable the communications between these entities, IEEE 802.21 defined the following three services:

- Media Independent Information Service (MIIS).
- Media Independent Command Service (MICS).
- Media Independent Event Service (MIES).

Based on the inputs from MIHF, MIH users can make handover decisions.

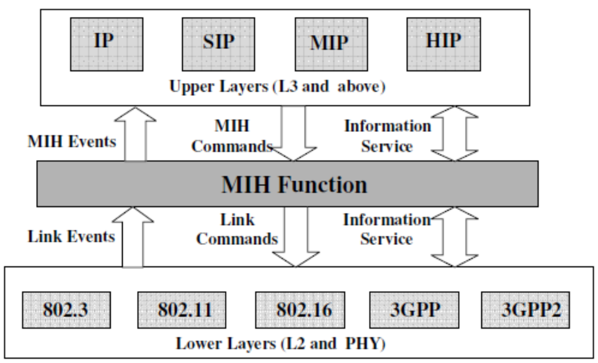

Figure 1. Media Independent Handover Framework [1]

2.1. Media Independent Information Service (MIIS)

The main aim of this service is to give the MN the ability to obtain information about all available networks within the geographical area that facilitates seamless handovers. The provided information will affect the selection process of choosing a suitable network. The bidirectional communication between the Information Server (IS) and the MN layers can share information like the availability of service, QoS, and performance information.

2.2. Media Independent Command Service (MICS)

In order to control and determine the lower layers' status, MIH defines command services to be sent from higher layers down to the lower ones [6]. MIH commands are classified into two main groups:

- Link commands: are generated by MIHF instead of MIH users in order to configure and control a specific access link as some modifications are required to communicate with the new link.
- MIH commands: in this type of commands, upper layers send MIH commands to the local or remote MIHF to provide network selection and handover initiation.

2.3. Media Independent Event Service (MIES)

The MIES aims to help MIH users select and maintain the link to which the MN will connect. These events, which could be divided into two types, have the ability to affect the MIH decision engine provided in the upper layers:

- Link events: These events are generated in the link layer and sent up to the MIHF. Among all link events, two categories are related to the link state. The first one is the 'link state change' while the second one is 'link predictive change'. Link state change reports any change in MAC or PHY layers to MIHF. It includes events such as Link_Detected to report any newly detected access network, Link_Up and Link_Down to inform MIHF when the layer two connection is established or lost, respectively. On the other hand, Link_Going_Down is the only predictive event the standard provides. It corresponds to any connection degrading or loss that is about to happen.
- MIH events: which are the propagated events to the upper layers. The origin of these events can be either the MN or a remote entity and are dispatched by MIHF to different entities in the upper layers, which have to be subscribed to receive these asynchronous events.

Fig. 2 shows a multi-interfaced MN with MIH function enabled and positioned in the protocol stack. The MIHF obtains the information from lower layers through MIH_LINK_SAP and then provides them to MIH users in upper layers through the aforementioned services.

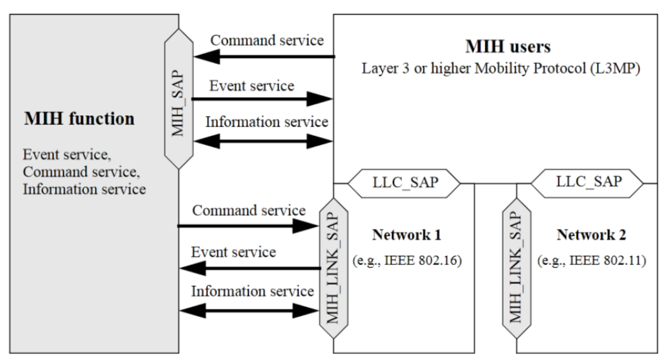

Figure 2. MIH Services [7]

3. IEEE 802.21 and LGD Event

Although the IEEE 802.21 standard defines the overall framework to optimize the handover process of MN between IEEE 802 family networks and non IEEE 802 networks, it does not provide a handover decision mechanism. Therefore many approaches are proposed to fill this gap. All of them aim to fulfill the following criteria:

- Avoiding any unnecessary handovers. Reducing the number of unnecessary handovers enhances the overall QoS.
- Minimising handover latency. Handover latency is the time that elapses between the moment the MN receives its last packet from the old point of attachment (PoA) and the moment that it receives its first packet in the new PoA [8], [9].
- Minimising handover failure. Any handover failure costs a significant quality degradation and may lead to a session disconnection.
- Reducing the packet loss ratio.

3.1. Vertical Handover Procedure

Seamless handover aims to maintain the ongoing sessions while the MN is moving. While the MN is moving, it experiences two types of handover. Horizontal Handover (HHO) when the MN changes its point of attachment, but keeps using the same wireless technology, while Vertical Handover (VHO) occurs when the new point of attachment has different data link layer technology. The VHO procedure could be divided into three phases [10]:

1) Handover information gathering: During this phase, MN is gathering all the required information to conduct a successful handover. MIH information server, in addition to other entities like user preferences (e.g., cost), network (e.g., latency), and MN (e.g., velocity), play a vital role in achieving the desirable handover.
2) Handover decision taking: In this phase, the handover decision is made based on the available information and the link conditions.
3) Handover Execution: In this phase, MN will connect to the new PoA without losing active sessions. Afterward, the old link will be released [11].

3.2. LGD Trigger

Link Going Down (LGD) is a predictive event generated by MIES to help higher layers timely initiate the handover procedure. To ensure seamless handover, defining a dynamic threshold for the LGD trigger is crucial because high thresholds increase the handover latency, whereas low thresholds cause unnecessary handovers. Three power thresholds are defined in order to generate the LGD event, as illustrated in Fig. 3:

- $CThresh\_$: Carrier Sense Threshold is the required power level to sense a received packet as well as to switch the MAC layer from idle to busy.
- $RxThresh\_$: Receiver Sensitivity Threshold is the minimum power required to receive a packet free of errors.

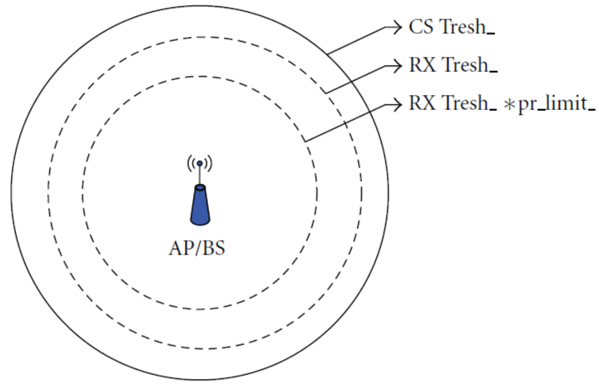

Figure 3. Power Thresholds [12]

- $RxThreshold\_\ X\ Pr\_Limit\_$: is the minimum power level used by MIHF to generate the LGD event and send it to upper layers. MIHF uses the coefficient $Pr\_Limit\_$ to generate both Link Down (LD) and LGD events. $Pr\_Limit\_$ is set to one in order to make MIHF generates the LD event; however, any value higher than one will lead to generating the event LGD. Therefore, estimating the value of the coefficient $Pr\_Limit\_$ is the key to generate the event LGD at a suitable time with a view to ensure a seamless handover.

When the upper layers receive the LGD event, MN scans the media for a new PoA before leaving the current wireless coverage. Fig. 4 illustrates the layer two vertical handover process starting from the point when the LGD event is generated until completing the layer two handover process.

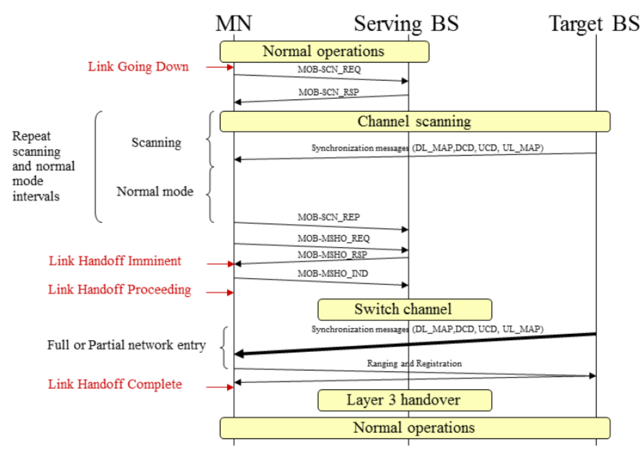

Figure 4. L2 Vertical Handover Process [13]

In [14], we have proposed a dynamic model for generating LGD events based on two factors, which are MN velocity and Round Trip Time (RTT), as follows.

$$LGD\_Factor\_ = 1 + \frac{MaxRTT}{ET} \qquad (1)$$

where MaxRTT is the Maximum Round-Trip Time that equals to estimated RTT plus a fluctuation RTT value, ET is the estimated time elapsed to leave the coverage area.

MaxRTT Evaluation: Round Trip Time (RTT) varies according to different factors; however, evaluating the maximum RTT (MaxRTT) is essential to ensure a seamless handover. Our prediction model in [14] adopts the single exponential weighting mechanism to evaluate the estimated RTT as in Eq. 2.

$$EstimatedRTT = (1 - \alpha).EstimatedRTT + \alpha.SampleRTT \quad (2)$$

where SampleRTT is the measured RTT and $0 \leq \alpha \leq 1$. Thereby, the MaxRTT can be evaluated as Estimated RTT with an acceptable margin as shown in Eq. 3 and 4.

$$DevRTT = (1-\beta).DevRTT + \beta.|SampleRTT - EstimnatedRTT| \quad (3)$$

where β is the coefficient of the exponential weighted moving average and its value is $0 \leq \beta \leq 1$

$$MaxRTT = EstimatedRTT + \gamma.DevRTT \quad (4)$$

where γ is the margin coefficient which depends on the type of application as well as the network parameters.

ET Evaluation: The Expected Time (ET) to leave the coverage area is another important factor in facilitating a seamless handover. ET is evaluated in our model using the Eq. 5

$$ET = \frac{D}{v} \quad (5)$$

where v is the MN speed, and D is the expected distance to leave the coverage area.
As IEEE 802.21 provides an information service, MN is able to know the coverage radius of the current PoA. Moreover, the Transmission Power (P_t) is also known. Therefore, the expected distance D to leave the coverage area is evaluated using the free space loss formula in Eq. 6 and Eq. 7

$$P_r = P_t.G_t.Gr(\frac{\lambda}{4\pi d})^2 \quad (6)$$

where G_t is the transmitting antenna gain, G_r is the receiving antenna gain, d is the distance between the AP border and the MN, and λ is the wavelength.

$$D = R - d \quad (7)$$

The Eq. 1, which is used to generate the LGD event, has two distinguished cases:

1) $MaxRTT > ET$: That means the time to leave coverage area is less than MaxRTT. Therefore, the value of LGD_Factor_ will be more than two, and this value will accelerate the generation of LGD event.
2) $MaxRTT \leq ET$: That means the time to leave coverage area is greater than MaxRTT. Therefore, triggering the LGD event will be postponed and be generated at a suitable time.

4. Simulation Model

In this section, the simulation scenario and the obtained results will be presented. The simulation results are obtained using the Network Simulator NS-2 [15], MIH mobility add-on package, which has been developed by the National Institute of Standards and Technology (NIST) to support MIH functions [16], and WiMAX patch [13]. The simulator NS-2 has been chosen to evaluate our model because it is the only option available to simulate IEEE 802.21. However, it needs some debugging works to incorporate the aforementioned packages into it.

4.1. Proposed Scenario

To evaluate the vertical handover in a heterogeneous network, NIST supports the concept of multi-interfaced MN. The simulation environment, shown in Fig. 5 consists of one BS 802.16e, AP 802.11b, and an MN moving from WiFi towards WiMax.

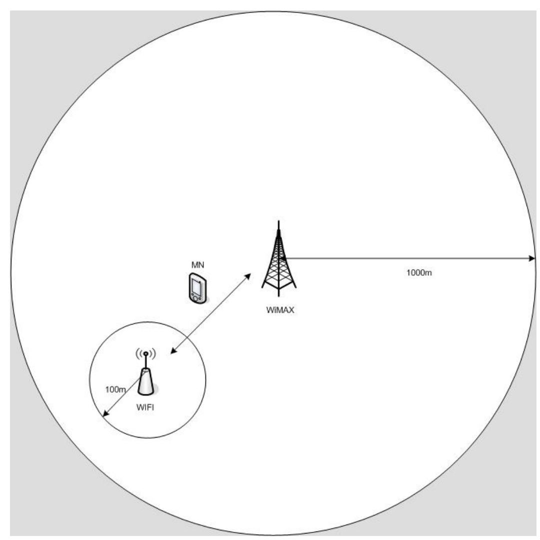

Figure 5. Simulation Scenario

802.11b and 802.16e parameters are shown in table 1, and table 2, respectively, while table 3 shows the simulated traffic parameters:

TABLE 1. 802.11B AP PARAMETERS

IEEE 802.11b	Parameters
Coverage Radius	100m
Radio Propagation Model	Two-Ray Ground
Frequency	2.4 GHz
Transmission Power (Pt_)	0.0027 W
RXThresh	$2.64504e^{-10}W$

TABLE 2. 802.16E BS PARAMETERS

IEEE 802.16e	Parameters
Coverage Radius	1000m
Radio Propagation Model	Two-Ray Ground
Frequency	3.5 GHz
Transmission Power (Pt_)	15 W
RXThresh	$7.59375e^{-10}W$

Results are obtained for three kinds of traffic between the MN and the Correspondent Node (CN):

- File Transfer Protocol (FTP).
- Voice over Internet Protocol (VOIP).
- Video Streaming.

TABLE 3. SIMULATION TRAFFIC PARAMETERS

Traffic Type	Packet Size	Delay Interval	Data Rate
FTP	1500 B	100 ms	120 kbps
Streaming	1500 B	100 ms	160 kbps
VOIP	160 B	20 ms	64 kbps

During the simulation, the MN moves outside the WiFi coverage with a speed of 1 m/s, as illustrated in Fig. 6. Consequently, the LGD event is triggered based on Eq. 1 to initialize the handover process. The simulation experiments show that our predication model can save up to 53% of the handover latency.

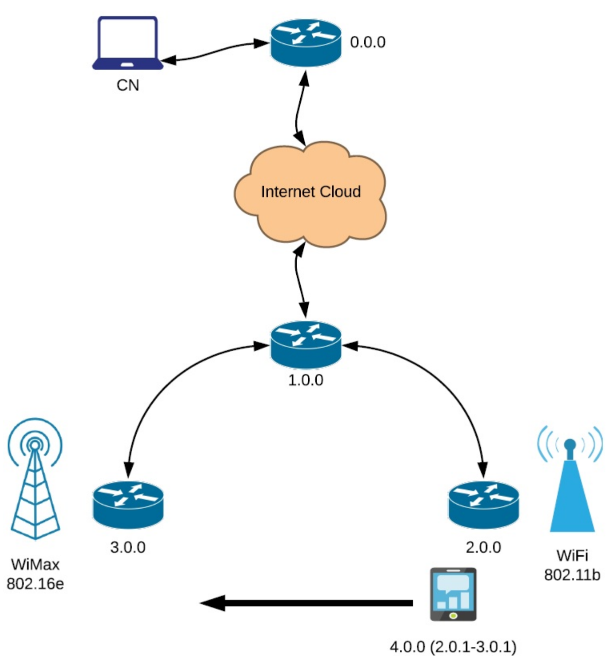

Figure 6. The topology of the simulation scenario

4.2. Simulation Results

In this subsection, our prediction method to trigger the handover process is evaluated using different performance metrics.

4.2.1. Throughput. Throughput is the number of messages successfully delivered per unit time, and it is measured in kbps [17]. The simulation is run for 50s, and it includes one vertical handover from WiFi to WiMax. The throughput rates during the simulation for the three types of traffic are shown in Fig. 7.

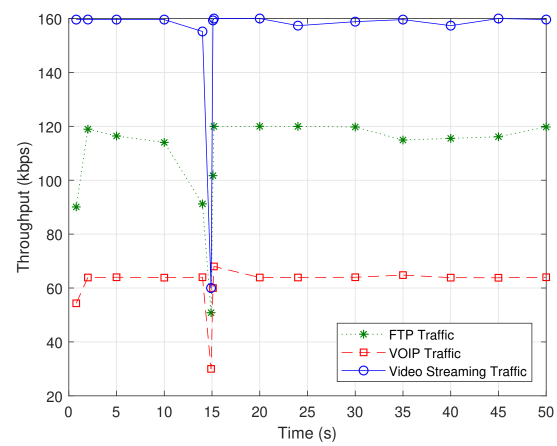

Figure 7. Throughput

It is obvious that the throughput is decreased dramatically for all the traffic types. An average drop of approximately 57% is noticeable on all types of traffic (around 58% for FTP, 53% for VOIP, and just over 62% for video streaming). Moreover, video streaming is the most affected traffic during the handover process, while VOIP traffic is the least one. With regards to the packet size of the three types of traffic shown in table 3, it is obvious that increasing the packet size affects the throughput rate negatively during the handover period.

4.2.2. Packet Loss Rate. Packet loss is measured as the percentage of the packets lost to the packets sent. Fig. 8 shows the packet loss rates for the three types of simulated traffic.

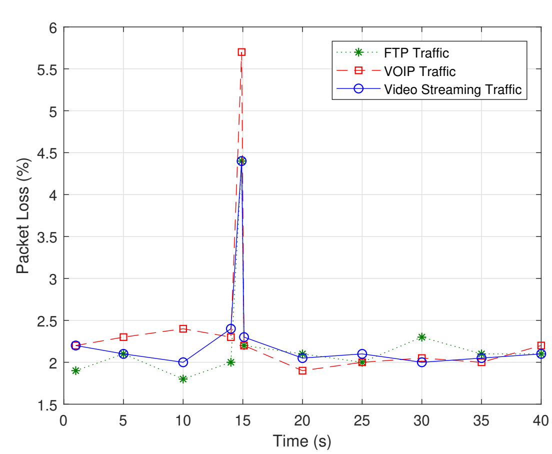

Figure 8. Packet Loss Rate (%)

The line graph shows that the packet loss rate during the handover period increased significantly. Just over 200% is the packet loss of both FTP and video streaming, while the packet loss rate for VOIP traffic is 285%. Moreover, smaller packet sizes tend to experience more packet loss during the handover process. In contrast with throughput, bigger packet sizes affect the packet loss rate positively.

4.2.3. End-to-End Delay. End-to-end delay is the amount of time taken by a packet to be transmitted from the source to the destination. It includes processing delay, propagation delay, transmission delay, and queuing delay. The same parameters are used in this experiment to evaluate the overall end-to-end delay. An approximately 2% rise is shown in Fig. 9 for all types of traffic. On the other hand, obviously, end-to-end delay in the WiMax network is better than that offered by the WiFi network. Moreover, results show a slight rise in end-to-end delay for the lower date rate. It is increased by around 1.1 ms when the data rate decreased around 50% to 64 kbps.

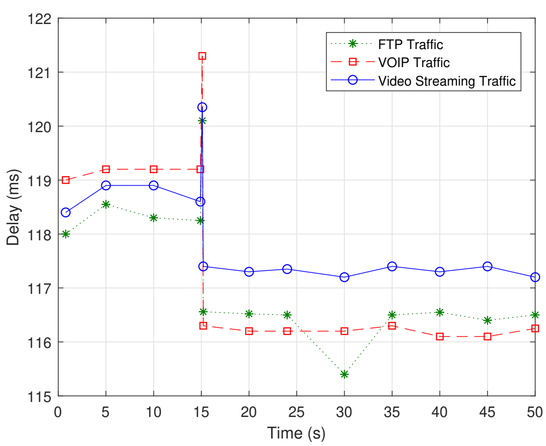

Figure 9. End-to-End Delay

5. Conclusion

In this paper, we have evaluated the network performance of the vertical handover of our predictable LGD triggering mechanism. The simulations are run between WiFi and WiMax networks for three types of network traffic: FTP, VOIP, and video streaming using the NS2 simulator. Although the service quality is decreased during the handover process, it still acceptable as the overall latency of the handover process is significantly reduced by using our predictable LGD triggering model; moreover, different influences are shown for different packet sizes and data rates for throughput, packet loss rate, and end-to-end delay.

References

[1] IEEE, "Ieee standard for local and metropolitan area networks–part 21: Media independent services framework–corrigendum 1: Clarification of parameter definition in group session key derivation," *IEEE Std 802.21-2017/Cor 1-2017 (Corrigendum to IEEE Std 802.21-2017)*, pp. 1–13, Jan 2018.

[2] S.-J. Yoo, D. Cypher, and N. Golmie, "Timely effective handover mechanism in heterogeneous wireless networks," *Wireless Personal Communications*, vol. 52, no. 3, pp. 449–475, 2010.

[3] S.-J. Yoo, D. Cypher, and Golmie, "Lms predictive link triggering for seamless handovers in heterogeneous wireless networks," in *MILCOM 2007-IEEE Military Communications Conference*. IEEE, 2007, pp. 1–7.

[4] M. Yousaf, S. Bhatti, M. Rehan, A. Qayyum, and S. A. Malik, "An intelligent prediction model for generating lgd trigger of ieee 802.21 mih," in *International Conference on Intelligent Computing*. Springer, 2009, pp. 413–422.

[5] A. De La Oliva, A. Banchs, I. Soto, T. Melia, and A. Vidal, "An overview of ieee 802.21: media-independent handover services," *IEEE Wireless Communications*, vol. 15, no. 4, pp. 96–103, 2008.

[6] J. Iqbal, M. Khan, M. Afaq, and A. Ali, "Performance analysis of vertical handover techniques based on ieee 802.21: Media independent handover standard," *Transactions on Emerging Telecommunications Technologies*, p. e3695, 2019.

[7] "Media independent handover services," *IEEE Std 802.21-2008*, 2009.

[8] G. Nie and X. Qing, "Comparison and handover performance evaluation of the macro-mobility protocol," *Journal of Networks*, vol. 8, no. 1, p. 100, 2013.

[9] D. Pandey, B. Kim, H.-S. Gang, G.-R. Kwon, and J.-Y. Pyun, "Maximizing network utilization in ieee 802.21 assisted vertical handover over wireless heterogeneous networks," *Journal of Information Processing Systems*, vol. 14, no. 3, pp. 771–789, 2018.

[10] O. Khattab and O. Alani, "A survey on media independent handover (mih) and ip multimedia subsystem (ims) in heterogeneous wireless networks," *International journal of wireless information networks*, vol. 20, no. 3, pp. 215–228, 2013.

[11] M. Zekri, B. Jouaber, and D. Zeghlache, "Context aware vertical handover decision making in heterogeneous wireless networks," in *IEEE Local Computer Network Conference*. IEEE, 2010, pp. 764–768.

[12] M. Hugo, R. José, M. Paulo, R. Jonathan *et al.*, "Simulation of 802.21 handovers using ns-2," *Journal of Computer Systems, Networks, and Communications*, vol. 2010, 2010.

[13] "The network simulator ns-2, nist add-on ieee 802.16 model (mac+phy),2009, draft 1.2.1," accessed: 11-10-2019. [Online]. Available: http://www-x.antd.nist.gov/seamlessandsecure/req_80216.html

[14] M. S. Hajar, M. K. Chahine, and R. Hamdan, "An effective prediction model for generating link going down event of ieee802.21," *Asian Journal of Information Technology*, vol. 14, no. 5, pp. 187–191, 2015. [Online]. Available: www.scopus.com

[15] "The network simulator ns-2," accessed: 25-04-2019. [Online]. Available: https://www.isi.edu/nsnam/ns/

[16] "The network simulator ns-2 nist add-on, ieee 802.21 model (based on ieee p802.21/d03.00), 2007," accessed: 11-10-2019. [Online]. Available: http://www-x.antd.nist.gov/seamlessandsecure/req_mobility.html

[17] H. Khalil and M. Hamarsheh, "Speed effect on the performance of vertical handover in wifi-3g network," *International Journal of Simulation–Systems, Science & Technology*, vol. 19, no. 3, 2018.