Efficient Mobile IP Location Update Mechanism for Idle Terminals in Optical Wireless Integrated Access Networks

[1&2]S.H. Shah Newaz*, [1]Raja Usman Akbar, [1]Youngmi Lim, [2]Gyu Myoung Lee**, [2]Noel Crespi, and [1]Jun Kyun Choi

[1]Korea Advanced Institute of Science and Technology (KAIST).
Daejeon, South Korea.
[2]Institut Telecom, Telecom SudParis.
Evry, France.
E-mail: *newaz@kaist.ac.kr, **gm.lee@it-sudparis.eu

***Abstract*— During an off-peak hour of a day, a Mobile Terminal (MT) can stay in idle mode for long time as there is no incoming or outgoing packet. An idle MT can move from one location to another and the wireless access network keeps tracking the idle MT. Idle MTs need to assist the wireless access network for location update; so that, on call arrival the network can route the call successfully. Mean while, Voice over IP (VoIP) got wide acceptance. To provide VoIP service in mobile environment or any IP packet based service, Mobile IP is very important protocol undeniably. However, Proxy Mobile IP was developed by IETF without considering the idle mode condition of MTs. Consequently, an idle MT needs to conduct Mobile IP binding (Layer 3 location update) whenever it moves to new area of a Foreign Agent although it does not have any incoming or outgoing packets during idle period. This phenomenon unnecessarily increases location update signaling cost. Here in this paper, based on optical wireless integrated access network we propose a mechanism that allows only Layer 2 location update when an MT is in idle mode and the Layer 3 location update is conducted after call arrives for an idle MT. Our numerical results show that proposed mechanism out performs than the existing solutions.**

Keywords- Mobile IP; Energy saving; Converged; Passive Optical Networks; Location Update .

I. INTRODUCTION

Energy consumed by network equipments is huge [4]. In the future, it can be anticipated that network will have more expansion, hence number of network node/equipment supposed to have an astronomical growth. To reduce amount for carbon footprint, energy saving in network has become an important research issue. Therefore, some researchers have considered idle mode condition in network devices/nodes. Authors in [5, 6] consider about idle mode in Optical Network Units (ONU). Adopting there mechanisms it is possible to reduce energy consumption in ONUs significantly. Similarly, it is also possible to reduce energy consumption by minimizing unnecessary signaling messages. It is because to produce signaling message one node needs to spend its computational power. Furthermore, by eliminating such unnecessary signaling message it is also possible to improve bandwidth utilization.

During idle period an MT needs to listen the paging signals periodically and updates its location [1]. All wireless access technologies (e.g., IEEE802.16e) require location update for idle MTs. So that, on call arrival they can be paged at the right location. Mean while Voice over IP (VoIP) got wide acceptance. To provide VoIP service in mobile environment, Mobile IP (MIP) is very important protocol undeniably. However, even the latest Proxy Mobile IP (PMIP) developed by IETF does not consider the idle mode situation MTs [2]. As a result, an idle MT needs to conduct PMIP binding (Layer 3 location update) whenever it moves to new area despite that it does not have any active session. Undeniably, this phenomenon increases location update signaling cost. Note that the location update signaling cost can be defined as amount of resources spent for managing mobility of an MT [2].

For convergence of optical and wireless network; for example, the integration of PON and WiMAX or WLAN, some possible cheap solutions have been proposed already by some researchers. Some of these solutions consider IP mobility in Optical Wireless Integrated Access Networks (OWIAN). Gangxiang Shen et al. in [3] proposed four access architectures for integrating Ethernet PON (EPON) and WiMAX. To support IP mobility, they suggest implementing a handover coordinator in the Optical Line Terminal (OLT). This handover coordinator communicates with a Wimax base station (BS), which is integrated with ONU, through a dedicated control channel. In [7], authors suggest PMIP for IP mobility among different ONUs. Besides, these days manufacturers are considering Layer 3 functionality in ONUs [19]. To reduce Layer 3 location update signaling cost, there are several existing solutions [2, 13-14]. However, they were not developed considering optical wireless integrated access network environment. To the best of our knowledge none of these existing works consider MTs' idle mode situation in OWAIN. Therefore, in OWIAN for an idle MT it is needed to conduct Layer 3 location update despite that there is no incoming or outgoing call for that idle MT.

Hence, we develop a protocol considering the characteristics of shared network like EPON. In the OWIAN, we consider EPON and WiMaX integration similar to [3, 18]. Here, our objective is to introduce a mechanism using

 ISBN: 978-1-61208-133-5

which Layer 3 location update becomes obsolete for an idle MT in OWIAN.

In our work, the terms ‘Layer 3 location update’ and ‘PMIP binding’ are used interchangeably.

In this paper, Section II discusses related work. In Section III, we present proposed mechanism. Numerical analysis is presented in Section IV. Finally, Section V draws the conclusion and states future research direction.

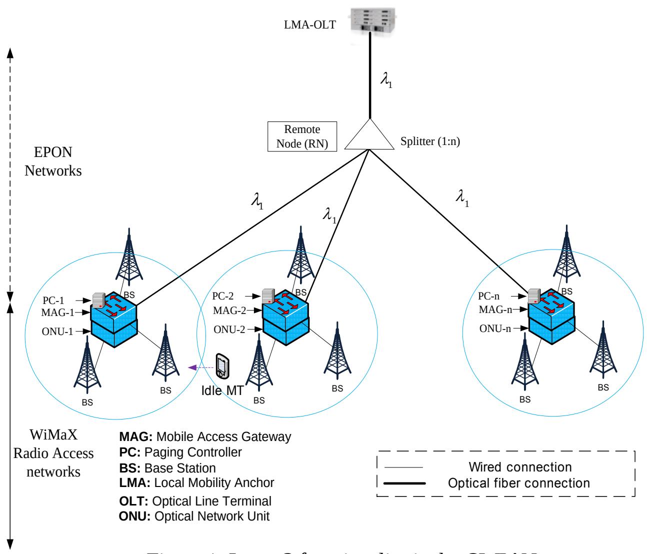

Figure 1. Layer 3 functionality in the OWIAN.

II. RELATED WORK

In this part, we first discuss some possible solutions that can be used in OWIAN to manage the IP mobility for the idle MTs and their limitations. Then we briefly explain how PMIP location update works. We also summarize MTs’ idle mode consideration in wireless access networks. Finally, we present the existing works that put effort for reducing Layer 3 location update signaling cost when an MT is in idle Mode.

A. *Discussion:*

Fig. 1 states how the PON network topology looks when Layer 3 functionality for IP mobility management is considered on top of the Layer 2 based PON networks.

Note that the behavior of a particular protocol of an OSI Layer can have significant impact on other OSI Layers’ protocols. Let’s consider the Fig. 1 where PMIP mobility agents are considered in OWIAN similar to [3, 7]. Now, if an idle MT moves from one MA to another MA, the PMIP binding is needed to be conducted [8]. To conduct the PMIP binding, collocated MAG needs to send proxy binding update (PBU) message to the OLT and OLT needs to pass this message to the LMA (see Fig. 1). Now, if during that time ONU is idle mode, the PBU cannot be transmitted to the LMA which is collocated with the OLT. Question might be raised on why does not the MAG trigger the ONU to wakeup. Even the MAG does so, an ONU cannot transmit. The reason comes from the fact that PON is a shared media where ONUs can transmit during a dedicated uplink transmission slot only.

It is also possible that an ONU can buffer that PBU message and then transmit to the OLT when dedicated uplink time slot comes. However, this solution can bring another problem. As the downstream of PON is broadcast and select mechanism, OLT needs to mark the link Layer frames with Logical Link Identifier (LLID), so that destination ONUs can recognize their frames after reading the LLID. Therefore, when the PBU is buffered inside the ONU, in the mean time OLT might starts sending packets on call arrival for an idle MT to the previous serving MAG as the Layer 3 binding table has not been updated yet at the LMA. Consequently, it can cause long startup latency because in such case LMA needs to retransmit those packets for that idle MT through the PON network. Otherwise, the ONU of that MA somehow needs to forward to the serving ONU (collocated MAG). An ONU can forward those packets when architecture like [7] is deployed.

B. *Proxy Mobile IP (PMIP) Location Update:*

In PMIP, there are two important functional units: LMA and MAG. Any packet for an MT must come first at the LMA. A LMA knows the serving MAG for that MT.

① *LMA Working Description:*

Packets send by other nodes to the destination MT are received at the LMA within and beyond the PMIP’s domain [8]. LMA creates and maintains a binding table, which keeps the record of each MT and the corresponding MAG. On packets arrival for an MT, the LMA encapsulates the incoming packets with Proxy-CoA of the serving MAG and then forwards them towards the MAG. LMA also decapsulates the outgoing packets from MT by removing LMA address (LMAA) and forwarding the packet towards its destination. It is important to mention that PMIP standard does not consider the status of an MT in LMA (idle or active).

② *MAG Working Description:*

Any incoming and outgoing packet of an MT should pass through MAG. MAG plays the role of the router on point-to-point link [8]. MAG encapsulates the packets with LMAA before sending it to LMA and also decapsulates the packet when it receives from the LMA.

C. *Ethernet Passive Optical Network in Brief:*

In EPON, an OLT is the centralized intelligence. It receives the packets from core network and then delivers to the destination ONU through optical fiber. OLT marks the frames with LLID so that ONUs can recognize their corresponding frames [15, 16, 18]. If the LLID matches, an ONU retrieves the frames and then processes. While it discards if the LLID does not match. For unicasting point of view, each ONU used to have single unique LLID, however, for broadcasting or multicasting they can have common LLIDs. In EPON, when an OLT transmits a frame conveyed by a wavelength λ_1 it is splitted by a passive splitter which

 ISBN: 978-1-61208-133-5

situates at a remote node as shown in Fig. 1. And then the same frame is directed to the all ONUs through fiber. Usually the splitting ration is *1: n*, where *n* can be 16 or 32 or 64.

D. Idle Mode Operation in WiMaX:

When there is no incoming or outgoing packet for a certain amount of time T_{th}, an MT moves from active mode to idle mode to save battery power. Fig. 2 states the state transition diagram. WiMAX (e.g., IEEE 802.16e) has three mobility entities for managing idle mode and paging operation [1, 17]. These include: paging agent (PA), paging controller (PC), and paging grouping (PG). PC can be collocated in a MAG or in a BS [1]. PC performs the task of observing the activities of all MTs located in particular Paging Group. An idle MT periodically wakes up and listens whether it has any downlink packet or not.

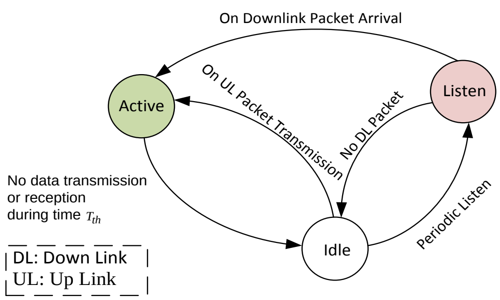

Figure 2: MT's mode (active/idle) transition diagram.

E. Existing Solutions for Location Update:

Many of the researchers have considered idle-mode condition of MTs in Mobile IP environment. They propose to reduce Layer 3 location update cost when an MT is in idle mode by adopting different approaches.

For example, in [13], the authors suggest to delay the PMIP location update till a call arrives for an idle MT. And when a packet arrives, LMA forwards it to new-MAG via old-MAG. It is because this scheme does not allow Layer 3 location update as long as the MT is in idle mode. However, when the distance between the old-MAG and the new-MAG is long, MT experiences a long startup latency and additional signaling burden at MAGs.

In [14], the authors indicate that Layer 3 location update should be performed at every MAG. We named this scheme in this paper as per-MAG location update (PML). This scheme reduces startup latency because Layer 3 routing information is refreshed whenever an MT visit a new MA. However, it also increases location update signaling cost.

In [2], a distance based approach is mentioned. After crossing a predefined distance (*d*) PC, which is the Layer 2 mobility agent of IEEE 802.16e, invokes the MAG to conduct Layer 3 location update. This mechanism can reduce the number of Layer 3 location update significantly. However, it has some drawbacks. For example, with the increase of predefined *d*, startup latency also increases. This is because the startup latency is a function of distance between o-MAG and n-MAG [2].

As a matter of fact, existing solutions proposed in [2, 13, 14] cannot be used for reducing Layer 3 location update signaling cost for idle MTs in OWIAN. This is because those solutions were made considering a wired network architecture. Adopting those in OWIAN, there might be improper operation. For example, solution in [2] needs retunneling between old-MAG and new-MAG. In fact, it is not possible in typical PON architecture as an ONU here communicates with other ONUs through the OLT. Therefore, if aforementioned procedure is followed startup latency supposed to be increased.

III. PROPOSED LOCATION UPDATE MECHANSIM IN THE OWIAN

In this paper, our objective is to develop a protocol in such a way that can eliminate Layer 3 location update during the inter-call arrival time (MT's idle period) and can forward the packets of an idle MT on call arrival properly in the OWIAN.

We consider that when time between two call arrivals for an MT crosses T_{th}, OLT assumes that the MT is in idle mode. We further assume that in that EPON network domain another kind of LLID is used for only the idle MTs' packets. In other words it can said that the OLT marks all the idle MTs' frame with a special LLID (SLLID) and this SLLID is known to all ONUs in the OWIAN. Therefore, whenever an ONU receives any frame marked with that SLLID, it opens that frame. Note that the reason behind the SLLID is if the OLT marks the packets based on serving MAG, OLT might forward to the wrong ONU. The reason is that after Layer 3 location update an MT may not stay in the same MA.

On the other hand, in the proposed solution an idle MT only performs Layer 2 location update in the wireless access network domain with the PC, which is collocated with the MAG, through the serving BS as shown in Fig. 1. And Layer 3 location update at LMA is postponed as long as the MT is in idle mode. So that signaling cost for Layer 3 location update can be saved. The following paragraphs explain how proposed mechanism works.

(i) The idle MT moves from one MA to another MA, without performing any Layer 3 location update.

(ii) When call comes for any MT at the OLT, OLT resolves status of the MT (idle/active) from T_{th}. If the MT is in idle mode OLT sends those packets after marking with that SLLID. Otherwise, OLT assumes that MT is active and it is in the same MA from where last Layer 3 location update was conducted. In fact, there is still chance that active MT might move to another MA within that t_{move}, where $t_{move} < T_{th}$. However, we avoid such scenario in this paper.

(iii) If the MT is active, the OLT resolves the corresponding LLID of that ONU from the Proxy-CoA of the serving MAG and then forwards the packets after marking with that LLID. The following algorithm states how the OLT makes decision on arrival of a call.

(iv) On the other hand, when an ONU receives a frame marked with SLLID, it extracts the packets inside. Then, it invokes collocated PC asking all the idle MTs' lists of its MA. PC provides the list in reply. If the ONU finds any packet which is destined for any one of these idle MTs, it requests PC to page that MT to wakeup. After successful paging, idle MT switches from idle mode to active mode. Then, those destined packets are forwarded through the serving BS to that MT.

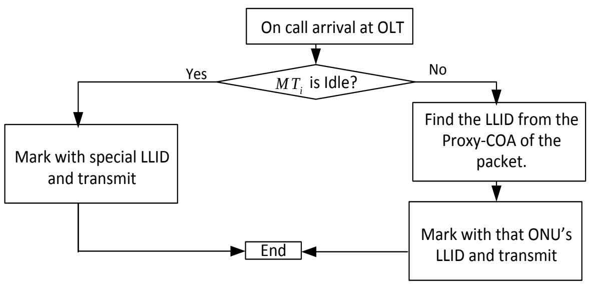

Figure 3: LLID selection and forwarding procedures in OLT.

(v) When the idle MTs wakeup and start receiving packets, ONU can collect all the PBU messages for Layer 3 location update from the collocated MAG, and then can transmit to the OLT during dedicated uplink transmission slot.

(vi) On arrival of PBUs at OLT, OLT sends those to collocated LMA. And finally LMA updates its binding table (Layer 3 location update is performed).

IV. Numerical Modeling and Performance Analysis

In this part, we are interested to know how these location update protocols proposed in [2, 14] perform between two call arrivals when they are dispensed in an OWIAN. Similar to [2, 10], we consider that location update cost is the amount of resources spent for managing mobility of an MT. It might be possible that network operators can consider relative cost spent at a mobility agent (e.g., LMA, MAGs, OLT) for tracking an MT. For example, resources spent for processing a signaling message, amount of bandwidth consumes for transiting that signaling message.

We draw the previous OWIAN architecture depicted in Fig. 1 again in Fig. 4, for numerical modeling. Similar to [10-12], the parameters are defined as follows for numerical analysis:

- λ : Call arrival rate follows Poisson process.
- a_l : Location update processing cost at the LMA.
- a_o : Location update processing cost at the OLT.
- a_m : Location update processing cost at the MAG node (the node where MAG and PC exists) with the collocated PC.
- $l_{OLT,ONU}$: Distance between the OLT and an ONU.
- $l_{m,mt}$: Average hops between the MAG and MT via a BS.
- D: Diameter of an MA.
- η_m^{-1} : Is the mean residence time follows exponential distribution, of an MT in an MA.

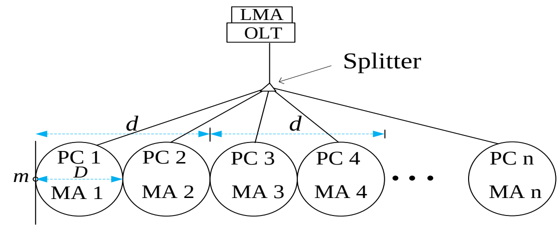

Figure 4: OWIAN architecture for numerical modeling.

We assume that trip of an idle MT starts from the point *m* as shown Fig. 4. Similar to [10], it is also considered here that signaling cost for transmitting a signaling message is proportional to the distance between source and destination node. And the proportional is δ_u. The time between two call arrivals or inter-call arrival time can be presented as $T_c = 1/\lambda$. And then number of MA crossed by an MT during that T_c is $x = \lambda^{-1}\eta_m$. Based on the parameters defined earlier, the equation (1) and (2) shown below are developed for measuring location update cost at the LMA and MAG respectively. Note that LMA location update should include location update processing cost at LMA and OLT.

$$C_l = a_l + a_o + 2(l_{OLT,ONU} + l_{m,mt})\delta_u. \quad (1)$$

$$C_m = a_m + 2l_{m,mt}\delta_u. \quad (2)$$

Using (1) and (2), location update signaling cost between two call arrivals can be expressed as follows for PML [14].

$$L_{\cos t}^{PML} = \lambda^{-1}\eta_m(C_m + C_l). \quad (3)$$

As mentioned before DBLU does not suggest Layer 3 location update always, rather it makes Layer 3 location update after crossing a predefined distance *d*. Therefore, based on the inter call arrival time, DBLU can have three different location update signaling cost. First, if a call comes at every MA, then DBLU must do Layer 3 location update at all MAs [(a)]. Second, calls come at the time when idle MT crosses predefined distance [(b)]. And finally, a call comes in MA where DBLU does not suggest performing Layer 3 location update as the predefined distance has not been crossed by that idle MT [(c)].

$$L_{cost}^{DBLU} = \begin{cases} x(C_m + C_l) & (\lambda^{-1}\eta_m = x) < 1 \quad \text{(a)} \\ xC_m + xDd^{-1}C_l & (\lambda^{-1}\eta_m = x)\ when\ x \in \text{integer} \quad \text{(b)} \\ xC_m + xDd^{-1}C_l + C_l. & (\lambda^{-1}\eta_m = x) > 1, when\ x \notin \text{integer} \quad \text{(c)} \end{cases} \quad (4)$$

In the proposed mechanism, it is mentioned earlier that there would not be any Layer 3 location update with the LMA for an idle MT as long as any call arrives. And during

T_c an idle MT must conduct Layer 2 location update with a PC through a serving BS. Then location update signaling cost in proposed scheme can be presented as:

$$L_{\cos t}^{\text{Proposed}} = \lambda^{-1}\eta_m C_m + C_l. \quad (5)$$

Between an MT and a MAG, an intermediate hop can be a BS [1]. So we assume $l_{m,mt}$ = 1Km. Besides, similar to [10, 12] we assign values for the parameters in table 1. We vary the T_c from 0 to 4000 sec. while the $1/\eta_m$ is kept 640 sec [11].

TABLE I. PARAMETER VALUES FOR LOCATION UPDATE COST EVALUATION

Parameter	Value	Parameter	Value
a_l	25	δ_u	0.1
a_m	10	$l_{OLT,ONU}$	20 Km
a_o	25	D	3Km
d	6 Km	r	9 Km

Fig. 5 states that as T_c increases the location update signaling cost, which encompasses Layer 2 and Layer 3 location update signaling, increases gradually in all three schemes: PML, DBLU, and proposed. However, among those proposed solution performs best. It is because this scheme can successfully ignore Layer 3 location update during the T_c (time between two call arrivals) without increasing the startup-latency.

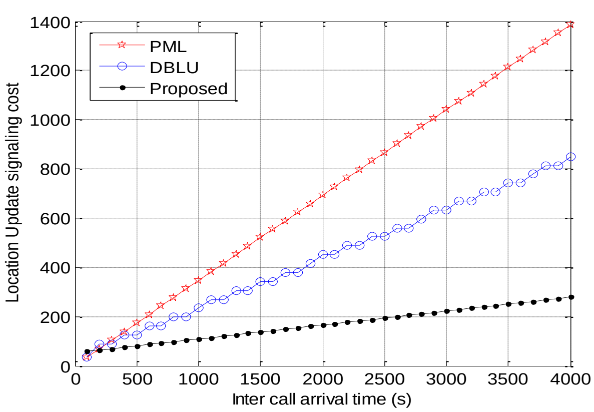

Figure 5: Location update signaling cost between two call arrivals in an OWIAN.

V. CONCLUSION AND FUTURE WORKS

Our proposed mechanism helps to fully utilize the advantage of idle mode. In this mechanism, an idle MT does not need to wakeup for conducting Layer 3 location update; therefore they can stay in idle mode only by performing Layer 2 location update in the wireless access network domain. Besides, mainly it contributes a great deal of reduction of Layer 3 location update signaling messages in OWIAN. In our future work, we would like to evaluate the performance of proposed mechanism at different residence time of an idle MT.

ACKNOWLEDGMENT

This work was supported by the IT R&D program of MKE/KEIT (KI001822, Research on Ubiquitous Mobility Management Methods for Higher Service Availability; and A1100-0801-3015Development of Open-IPTV Technologies for Wired and Wireless Networks).

REFERENCES

[1] Y. Zhang and H.-H. Chen, "Mobile WiMAX: toward Broadband Wireless Metropolitan Area Networks," Auerbach Publication, 2008.

[2] S. Jin, C. Yoon, and S. Choi, "A Simple Remedy for Idle Mode via Proxy MIP," *IEEE Comm. Lett.*, pp. 423-425, June 2008.

[3] G. Shen et al., "Fixed Mobile Convergence Architectures for Broadband Access: Integration of EPON and WiMAX," *IEEE Communications Magazine*, Vol. 45, Issue 8, pp. 44-50, Aug. 2007.

[4] M. Gruber, O. Blume, D. Ferling, D. Zeller, M.A. Imran, and E.C. Strinati, "EARTH — Energy Aware Radio and Network Technologies,"2009 IEEE 20th International Symposium on Personal, Indoor and Mobile Radio Communications, pp. 1-5, Sept. 2009.

[5] S. Wong, L. Valcarenghi, S. Yen, D.R. Campelo, S. Yamashita, and L. Kazovsky, "Sleep Mode for Energy Saving PONs: Advantages and Drawbacks," *IEEE GLOBECOM* Workshops, pp. 1-6, Nov. 2009.

[6] P. Chowdhury, M. Tornatore, S. Sarkar, and B. Mukherjee, "Building a Green Wireless-Optical Broadband Access Network (WOBAN)," *Journal of Lightwave Technology*, pp. 2219-2229, Aug. 2010.

[7] S. Lee, J. Kim, and M. Kang, "Route optimization for proxy mobile IPv6 using local customer internetworking in PONs," *Optical Internet (COIN)*, pp. 1-2, Oct. 2008.

[8] S. Gundavelli, "Proxy Mobile IPv6," RFC 5213, IETF, August 2008.

[9] S.H.S. Newaz, S. H. Jeon, J. H. Lee, J. Lee, J.K. Choi, and M. H. Kang, "An approach of multipath transmission from intelligent OLT in optical-wireless converged networks," *Optical Internet (COIN)*, 9th International Conference on , pp. 1-3, July 2010.

[10] J. Xie and I.F. Akyildiz, "A Novel Distributed Dynamic Location Management Scheme for Minimizing Signaling Costs in Mobile IP," *IEEE TMC*, pp. 163- 175, Sep. 2002.

[11] S. Jin, K. Han, and S. Choi, "Idle Mode for Deep Power Save in IEEE 802.11 WLANs," *JCN*, Oct. 2010.

[12] Y. Li, Y. Jiang, H. Su, D. Jin, Li Su, and L. Zeng, "A Group-Based Handoff Scheme for Correlated Mobile Nodes in Proxy Mobile IPv6," in *Proc. IEEE GLOBECOM'09*, pp. 1-6, Dec. 2009.

[13] S. Jin, K. Han, and S. Choi, "A novel idle mode operation in IEEE 802.11 WLANs," in Proc. *IEEE ICC'06*, pp. 4824-4829, June 2006.

[14] J. Na, Y. Chung, H. Noh, S. Lee, and S. Kim, "Two Alternative Registration and Paging Schemes for Supporting Idle Mode in IEEE 802.16e Wireless MAN," *IEEE VTC'06 Fall*, pp. 1-5, Sep. 2006.

[15] G. Kramer and B. Mukherjee, "Supporting differentiated classes of service in Ethernet passive optical networks," *Journal of Opt. Netw.*, vol. 1, no. 8/9, pp. 280–298, Aug. 2002.

[16] IEEE Std. 802.3ah-2004, "Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications," *Institute Computer Society*, Sep. 2004.

[17] IEEE Std. 802.16-2009, May 2009.

[18] S.H.S. Newaz, Y. Bae, M.S. Ahsan, and J. K. Choi, "A study on PMIP deployment over EPON," *Optical Internet (COIN)*, 9th International Conference on , pp. 1-3, July 2010.

[19] <http://www.madisontech.com.au/fibre-optics/product/ftth-onu> 06.05.2011.