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Intelligent WiMax Vertical Handovers

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1. Introduction

In next generation networks, tending to integrate different access technologies, the evolving WiMax 802.16 will play an important role in this integration for the purpose of offering the user the best possible service. WiMax will provide high bandwidth and high coverage, as opposed to current cellular systems providing high coverage and low bandwidth, and WiFi networks with limited coverage and high bandwidth. Hence, the vision of next generation networks is an all-IP network supporting heterogeneous access technologies such as WLAN, UMTS and WiMax. To enable inter- network access mobility known as vertical handover (VHO), a special mobility management is proposed in order for the handover to be performed with service continuity and minimum QoS degradation. The proposed intelligent vertical handover management consists of "guiding" the HO request to the best network capable of providing the required QoS and context parameters. The processing of the HO is based on an anticipated scenario where the HO decision parameters are compared to a pre-defined threshold in order for the HO to be guided accordingly. The handover could be guided to WiMax to benefit from high data rate and network availability to satisfy QoS requirements. The proposed handover management offers mobile users, roaming in next generation networks, service continuity by deciding on whether the handover is to be performed vertically or horizontally thus deciding on the destination network. In the context of the integration architecture, an Inter-Domain Management module IDM is introduced which is responsible of guiding the user to the next access network capable of offering the required QoS and context parameters. The mobility management is based on a "make-before-break" approach for a pre-network selection coupled with the Context Transfer Protocol CTP. In addition, when the horizontal handover could not be performed, it will be guided vertically. In this case, the user is guided to a different access technology, resulting in a vertical handover. This handover management will decrease the handover dropping probability and increase the HO performance in terms of less QoS degradation and best mapping of the HO requirements leading to "best" access network selection.

2. WiMax and Next Generation networks handovers

In the context of next generation networks enabling seamless handover for inter-technology access, a lot of work was conducted for wireless network integration architecture, mobility management and seamless handover. In [Wei, 2005], an overview of issues related to horizontal and vertical handoffs were addressed with the architecture of integrating WLAN and WAAN networks based on Mobile IPv6. Bandwidth measurements of WLAN were used as the decision parameter taking into account QoS and user service requirement. In [Les, 2008], IEEE802.21 was proposed to provide the seamless handovers between two radio systems supporting the challenging decision and pre-execution phases of inter-technology handovers. In what we propose, WiMax will be the destination network that will be used to provide not only seamless handover, based on the specified decision parameters, but also the stand-by network for horizontal handovers that could not be performed and should be guided vertically. The evolving WiMax 802.16 will play a key role in next generation networks integrating different access technologies. Worldwide Interoperability for Microwave Access, or WiMax, intended mainly for the exchange of data at home or in the office, has the potential to provide a significant improvement in cost and performance compared to existing wireless broadband access systems. IEEE 802.16e will enable a new set of high-speed nomadic and mobile data services over a wide metropolitan area with lower-cost solutions, higher performance and reliability. Coverage will be based on large cells interconnected to provide the user with high data rate. The ability to maintain connection while moving across cell borders is a prerequisite for mobility and will be included as a requirement in 802.16e system profile [Finneran, 2004]. WiMax will be considered as the destination access network capable of providing higher data rates and higher network coverage hence providing seamless handover with the required QoS. Instead of dropping the handover call in case WLAN/UMTS handover or degrading its performance, the handover is guided with respect to the context of the application, the user profile as well as the current network parameters.

3. Intelligent Vertical Handovers

In order to manage the mobility of the mobile nodes moving from one access technology to another, known as vertical handover, a special mobility and domain management are needed in order for the session to be resumed on the new data path with minimum delay, packet loss, and QoS degradation. This is why FMIPv6 is adopted in our proposition as the mobility protocol to take advantage of the "Make-before-break" scheme through the proposed IDM. The mobile node could be connected to the New access router (NAR) due to a prior a stateless auto-configuration of the address Care-of-Address (COA) before the handover is established through the **IDM interference.** Relying on Fast MIPv6 (FMIPv6) principle with the IDM interfering in the fast handover operation, has the advantage of not only preparing the handover in advance but also the handover will not occur unless the required settings with the New Access Network (NAN) are made. The handover delay is minimized since the handover settings are done in advance specially in the case of the HO guided vertically, where on-line packets will be directly forwarded to the New Access Router (NAR) once the Mobile Node (MN) acknowledges its neighborhood by sending Fast Neighborhood Acknowledgment (FNACK) which are done within the WiMax network. In addition, the QoS degradation is minimized based on the IDM selection process where resources are checked in advance in order to avoid QOS deterioration of an on-going session. The Context Transfer Protocol messages are exchanged in order to send the current context of a mobile node to the IDM capable of selecting the required NAR in the new access network. The Context Transfer Protocol will transfer the context data of the current mobile user through the IDM responsible of re-establishing the service with the same QoS parameters after the handover is performed. This transfer will eliminate the necessity of the MN to perform the AAA check and registration from scratch. Once the IDM is involved, re-authentication and re-establishment of the mobile host's authorization in the new network are transferred in the AAA context. This allows the mobile host to continue access in the new network once the handover is performed. In order for the IDM to select successfully the new access network, the main issue is that the handover should be performed after the context transfer messages are exchanged, so that the context data of the existing session will be transferred to the new network before the MN performs handover. In the proposed scenario, the mobile node "is guided" to the new access network capable of satisfying the required context parameters. Before describing the flow of messages as already briefly explained, figure 1 shows the WiMax vertical handover architecture with IDM interference.

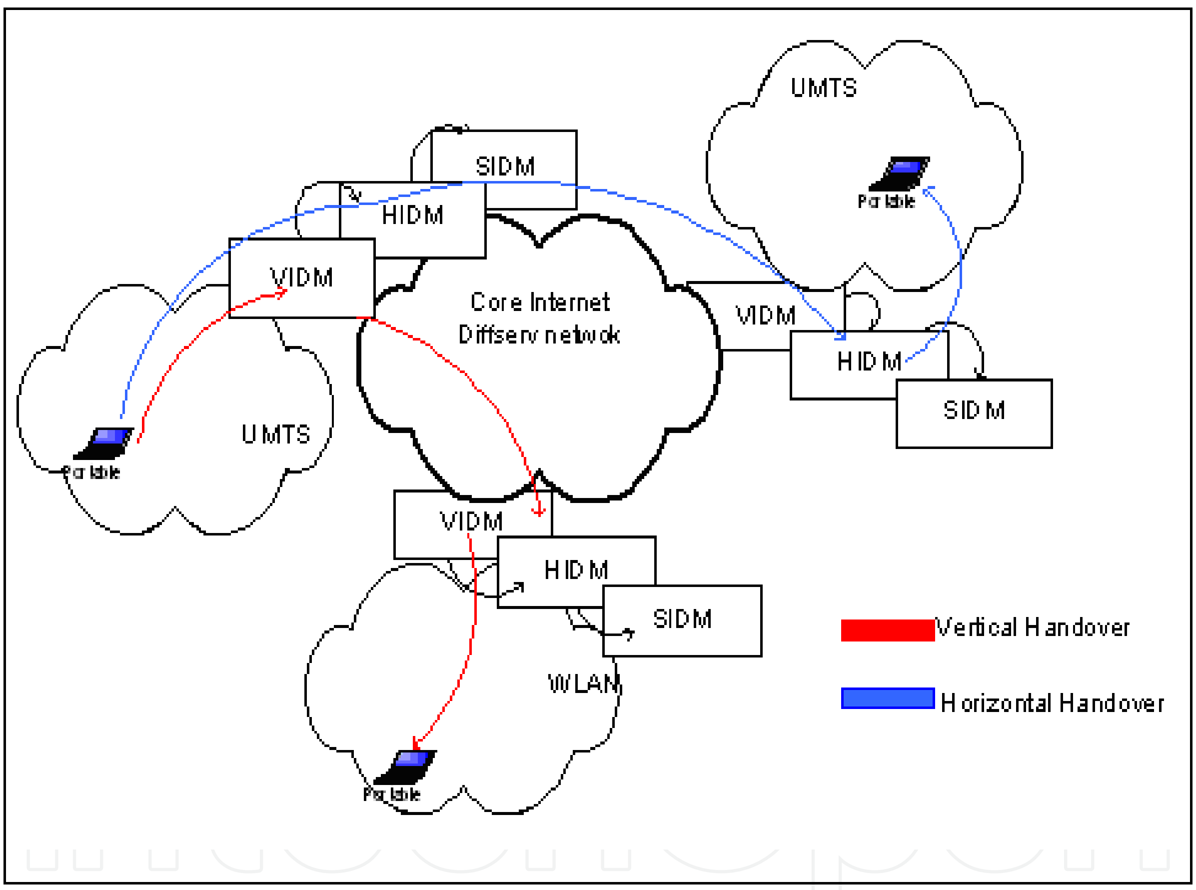

Fig. 1. WiMax Handovers Architecture

3.1 IDM Description

The Inter-Domain Management module IDM is responsible of mapping the mobile profile and the current context of a session to the Next IDM (NIDM) providing the necessary resources for the requested handover parameters. Each IDM keeps a table of the possible IDM's in the neighbored access network with their corresponding traffic load, network context and QoS parameters. The IDM will search accordingly for the available access routers: Each home-IDM scans its table to find the next IDM capable of providing the new data path with the required context parameters processing the handover based on FMIPv6, context transfer functionalities and the WiMax vertical handover algorithm. IDM will perform the following tasks:

- Stores the QoS attributes of a current session based on the context feature sent in the context data message.
- Stores the profile of the neighbored IDM and their corresponding traffic parameters (data rate, traffic load, resource availability…).
- Selects the next access network based on the previously collected data.
- Treats and accepts (accordingly) the handover request based on the "WHO'S NEXT" phase.

To support this handover management strategy, three types of IDM are proposed: Vertical IDM (VIDM), Horizontal IDM (HIDM), and Stand-by IDM (SIDM). VIDM role is to accomplish successfully vertical handovers between heterogeneous access network UMTS to WLAN, for example. HIDM is concerned with the inter handovers or the mobility belonging to the same access technologies. SIDM is to guide the handover to another network with high capacity and capable of satisfying the users QoS requirements from WLAN to WiMax, for example.

3.2 WiMax Vertical Handover Algorithm

The mobile node can perform handover from WLAN to WiMax or from UMTS to WiMax since WiMax will enable higher throughput and higher coverage compared to UMTS and WLAN. In the WiMax Vertical Handover Algorithm, the handover is considered for both network-initiated handover and user initiated-handover. These two cases will be managed by the vertical handover based on the proposed scenario:

Network-initiated handover: Consider the case where the mobile is in a WLAN hotspot. In the case of network-initiated handover, two thresholds T_1 and T_2 are chosen to initiate the handover. These two thresholds are set below the real threshold T which makes the user loose network coverage. Hence, if the Received Signal Strength Indicator (RSSI), or S for simplicity, falls below T_1, $S<T_1$, then the handover could still to be handled locally within the same access network. Thus the WLAN network will be the destination network and the HO is to be performed horizontally. On the other side, If $T_1<S<T_2$, then the handover is guided to the WiMax access network. Since, in this case, S is approaching the real threshold T and the HO should be performed smoothly with minimum delay, the handover is guided to the WiMax network providing high coverage and capable of providing service continuity. In this context, the handover dropping probability will be decreased sine WiMax network provides higher network capacity and coverage compared to WLAN. If $S >T_2$, which will not be considered unless the HO was not performed earlier, high priority WiMax HO should be requested to enable the HO to be performed with no additional delay.

In the case of **user initiated-handover**, the handover is decided according to the user profile and application parameters in order not for the application to degrade during HO. This could be done according to the user preferences with respect to a predefined threshold. The user initiates the HO based on the user profile (user preferences, charges, type of service, etc), network profile such as network bandwidth, and application profile such as traffic classes and types. The pre-defined degradation thresholds D_1 and D_2 are proposed based on accepted user profile and QoS requirements. Thus the handover is first initiated when the service degrades below the threshold D_1. If the degradation parameter D falls below D_1, then the handover is forwarded to another WLAN network capable of providing the required service. This could also be chosen if the service is tolerant to degradation according to the user profile and greater data rate is not required. The handover could be guided to another access network, WiMax network, if $D_1<D<D_2$. Thus, before reaching the real degradation threshold, the HO is guided to WiMax providing higher data rates and higher coverage. This could also be the case where the service could be no more served with the same QoS, and higher bandwidth is required according to the current application profile. The handover could also be guided to WiMax with higher priority request if $D>D_2$. In the last 2 cases, the handover is guided vertically to WiMax as a destination network. In all these cases, the IDM will exchange messages with the new IDM in the next selected network. These signaling messages are treated within the Diffserv core network as high priority traffic in order for the handover overhead to be minimized. The IDM traffic is mapped to the EF class providing low loss rate, low latency, assured bandwidth and low jitter [Mykoniati el al, 2003]. SIDM is responsible of scanning all the table entries to find the next IDM capable of providing the mobile with the required parameters ensuring a seamless handover to WiMax network. The flowchart of the proposed WiMax vertical handover scenario in case of user-initiated handovers as well as network-initiated handover is shown in figure 2.

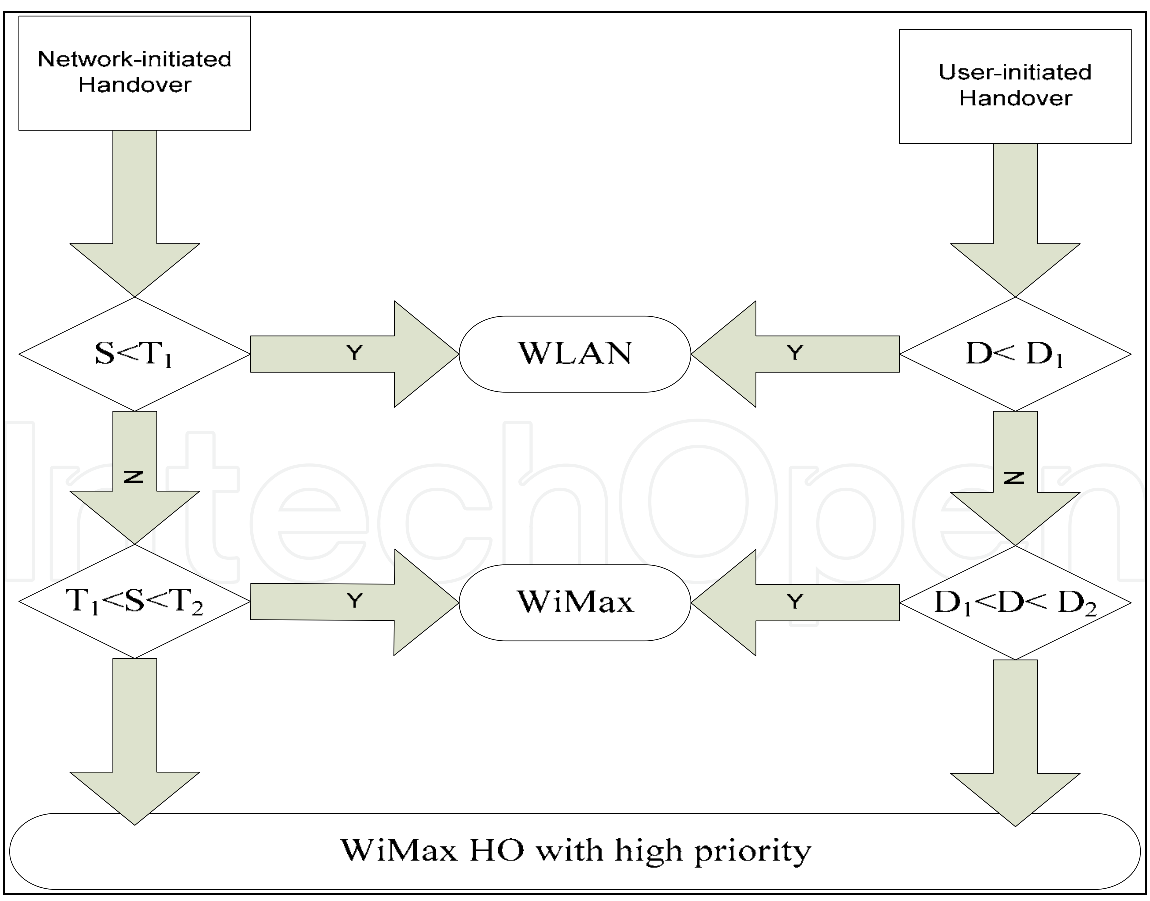

Fig. 2. WiMax Vertical Handovers

4. WiMax Vertical Handover processing

The main operations involved in the vertical handover from WLAN to WiMax are shown in figures 3 and 4. The context transfer messages used in the proposed scenario are similar to that described in [Kempf, 2002]. The transport of these messages is based on ICMPv6 protocol where the type and code are set to the specific type of CTP messages and the context data transfer is added in the data option field [Politis, 2004]. Contexts are identified by FPT (Feature Profile Type), which is a 16-bit unsigned integer. The context type numbers are assigned by IANA, and handled according to the message specifications [Politis, 2004]. FPT are transferred by data blocks used for transferring the actual feature context. Context Transfer Data (CTD) Message is sent from previous IDM (PIDM) to Previous Access Network (PAR) and includes feature data (CTP data). Once the required context parameters are mapped into the new IDM (NIDM) in the new network, the mobile user can perform handover without QoS degradation due to the appropriate selection of NIDM and accordingly the new access router in the new access network. The WiMax is composed of the Mobile Control Point (MCP) which provides the control and mobility anchor point for a mobile station (MS) as it moves between base stations (BSs) in the access network**.** Network Operations and Support Services (NOSS) includes functions required to operate and maintain the wireless access network such as authentication, authorization, and accounting (AAA) services; and configuration services. Figure 3 shows the WiMax network components role during the handover. The complete message exchange is done through the inter-Domain manager (IDM) which monitors and set the next access network within its domain based on FMIPv6 and context transfer protocol messages described in [Koodli, 2004; Kempf, 2002]. The scenario of the exchange is as follows:

- MN sends RTSOLPR to PAR to indicate HO initiation and to start the operation of acquiring a new address. The PAR will not reply directly (as in the normal FMIPv6 signaling flow) but it will wait for the IDM to select the appropriate NAR.
- MN sends Context Transfer Activation Request CTAR to PAR and PIDM prior to HO. this message contains MN IP address and PIDM IP address, and the entire context to be transferred. It also contains token to be used by NIDM for verification.
- Context Transfer Request CTREQ is sent from PIDM to PAR to update the context already available in the entry of the PIDM.
- PAR starts to send Context Transfer Data CTD to PIDM with the feature data context parameters.
- The "Who's next phase" is started. PIDM will start scanning (based on CTD) for a NIDM whose resources will satisfy the required context of MN asking for HO.
- Handover Initiation HI is sent from the PIDM to NIDM and NAR to configure the new CoA.
- All the FMIPv6 signaling flow will now proceed to perform the handover request to the selected access network.
- MN will finally send a Fast Neighbor Advertisement (FNA) to the NAR-MCP to notify it of its presence in the new access network.
- The packets destined to the old access router are no more buffered in PAR but in the PIDM which will forward these packets to the NIDM, as soon as the mobile node starts to communicate with the NAR.

The messages exchanged in the vertical handover scenario from WLAN to WiMax are shown in figure 3.

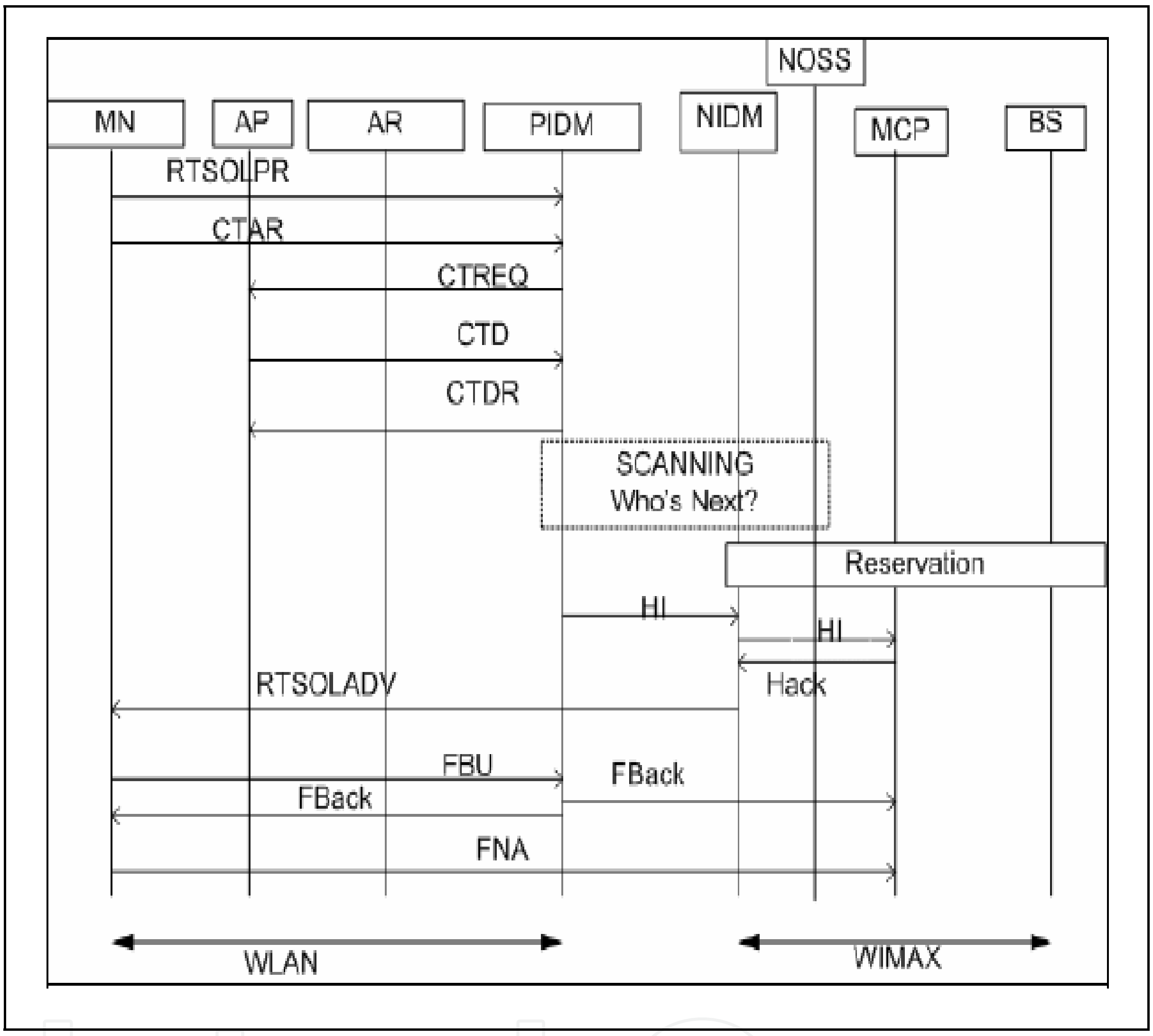

Fig. 3. WLAN to WiMax Handover

In the case of vertical handover, before the MN is out of coverage in the current network or before application degradation occurs, the handover operation is initiated. The handover could be requested by the user to satisfy the user policies and preferences. The handover could also be requested to benefit from a faster and high coverage network as from WLAN networks to WiMax. The handover is first requested before the real threshold is reached in order not to be disconnected. Once initiated, the HO request is treated by starting the context transfer exchange and mapping the requested QoS parameters into the next selected network. The request is classified into horizontal or vertical handover. If the application is tolerant to degradation, the HIDM will perform horizontal HO. On the other hand, if the application is of high sensitivity and not tolerant to degradation, the HO call will be guided to a SIDM which will perform vertical HO. This is done in the "WHO'S NEXT" phase. The mobility management will take place and the CoA is configured and updates to the IDM and AR are done. Next, the mobile node will start to communicate with the New access router (NAR) on the new access network.

5. WiMax Vertical Handover Evaluation

The handover from WLAN to WiMax is modeled on the following basis: Since WiMax has more bandwidth and can accommodate more calls; the following Markovien model is used figure 4. In this model, the HO calls are privileged over the local calls. The local calls are accepted until the threshold T is reached. When the number of calls is greater then T, then the only the HO calls (vertical calls from WLAN) are accepted.
SIDM admission Model (UMTS, WLAN to WiMax)The following assumptions were made:

- The IDM is modeled as M/M/C/C queuing system.
- C-T interval channels are the guard band channels used only for handover calls.
- The local traffic is a poisson process of rate λ_l and the handoff request is a poisson process of rate λ_h.
- The time of stay in IDM is exponentially distributed of rate $1/\mu$.

The blocking and dropping probabilities P_B and P_D in function of the threshold T are as shown in figures 5 and 6. The choice of the threshold will highly affects the handover dropping probability as well as the blocking probability of the incoming local calls. The variation of these two probabilities with respect to the threshold is given in figures 5 and 6. The maximum allowed threshold is when T=C. As T increases, the blocking probability decreases, since the calls (local requests) are accepted until T is reached; whereas, the dropping probability is increased since the probability of dropping the handover calls is increased with no priority scheme. Figure 4 shows the results with T and C difference from 0 to 50.

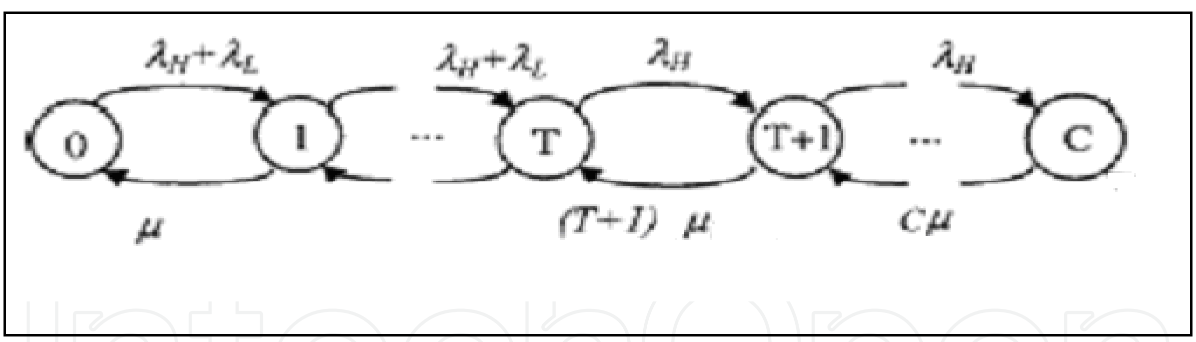

Fig. 4. SIDM model for WiMax Handovers

6. Conclusion

The horizontal and vertical handover considered are a complementary solution for a seamless handover. We considered that VHO could occur when the HHO could not be performed successfully or seamlessly. Thus, when no available resources are possible to perform the required parameters of the HHO, the VHO will take place. The proposed solution provides QoS provisioning and seamless handover between different access technologies. Integrating the emerging WiMax in the all-IP architecture is a vertical handover solution that decreases the Handover dropping probability and profits from high data rates provided by WiMax networks thus guiding the handover request to WiMax.

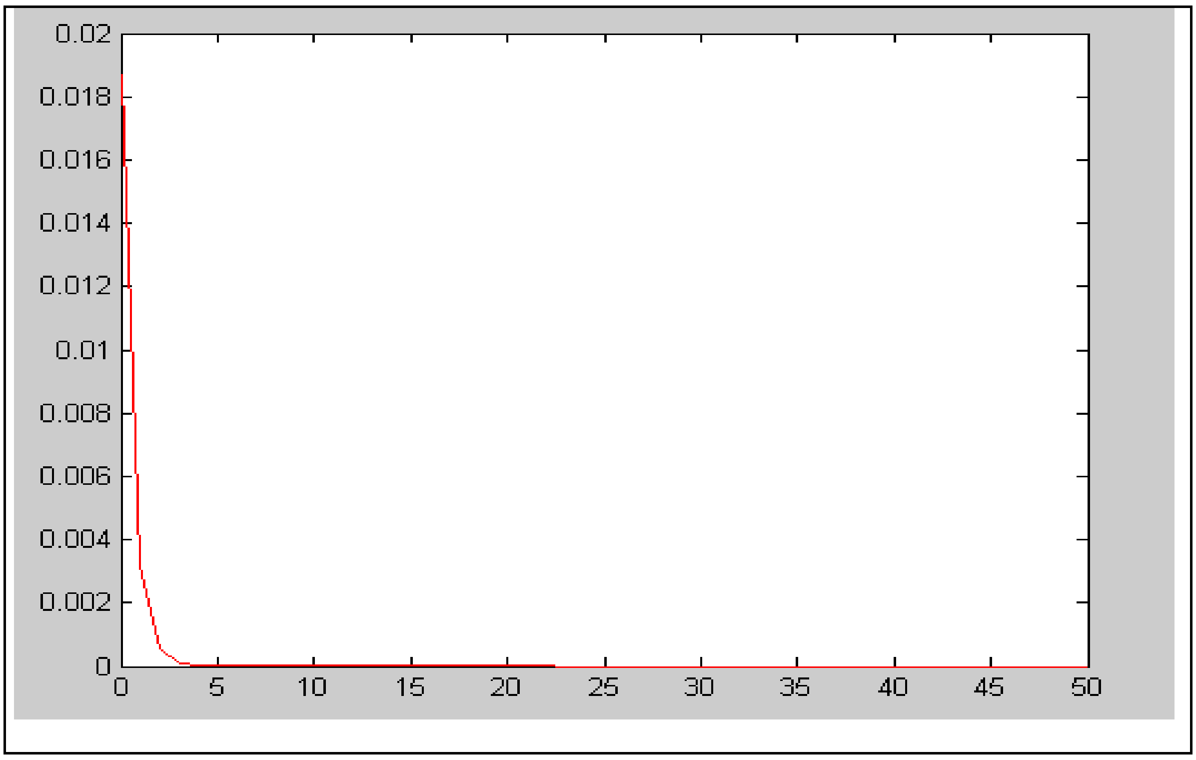

Fig. 5. Blocking Probability for WiMax Handovers

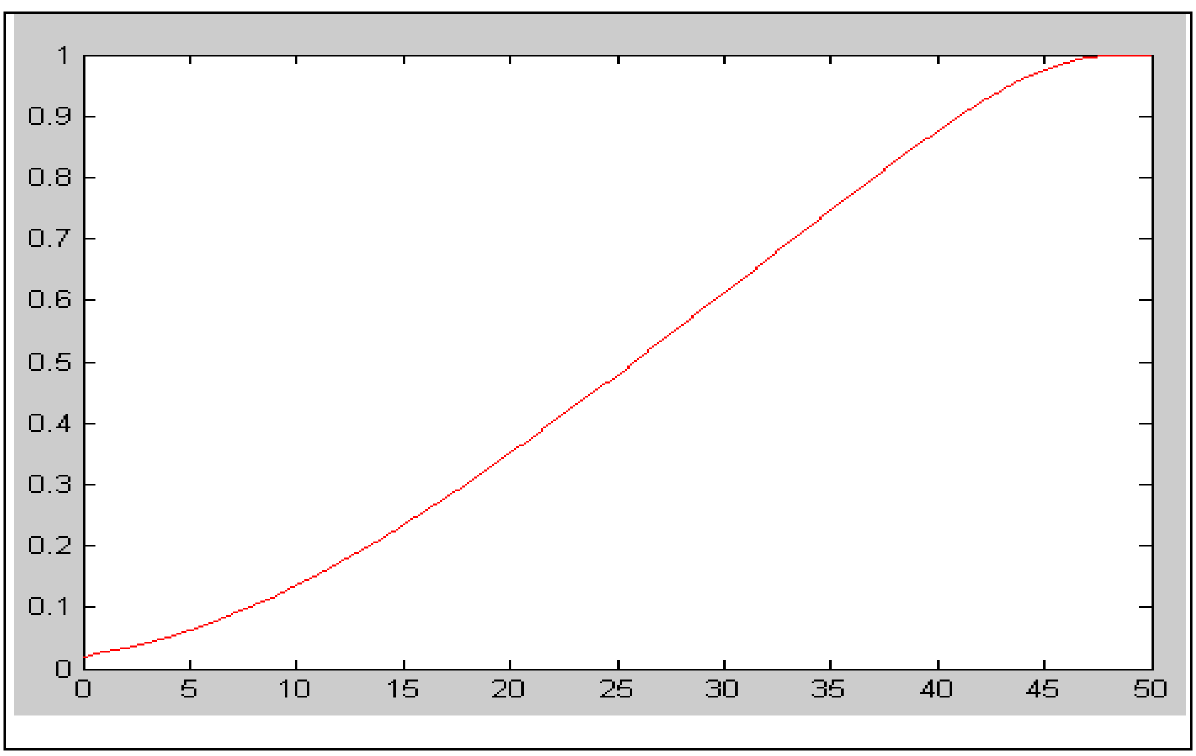

Fig. 6. Dropping Probability for WiMax Handovers

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WiMAX (Worldwide Interoperability for Microwave Access) is a wireless broadband access network named by industry group called the WiMAX forum formed in June 2001. It is Wireless MAN with IEEE 802.16 family standards. Loosely, WiMAX is a standardized wireless version of Ethernet that enables the last mile, intended primarily as an alternative to wire technologies (such as Cable Modems, DSL and T1/E1 links) to provide broadband access to customer premises. Mission of the WiMAX forum is to promote and certify compatibility and interoperability of broadband wireless products. This book touches most of the above issues in form of 22 individuals' papers containing research work in WiMAX domain in particular. WiMAX has two important standards/usage models: a fixed usage model IEEE 802.16-2004 for Fixed Wireless Broadband Access (FWBA) and a portable usage model IEEE 802.16e-2005, which is mainly concentrated on Mobile Wireless Broadband Access (MWBA). Both are released as standards and amendments are available in form of drafts. Higher data rate transmissions (@ 100 Mbps) are achieved in IEEE 802.16-2004 WiMAX through LOS communications which incorporate a stationary transmitter and receiver but IEEE 802.16e supporting NLOS communication is much complicated and little less bit rate is achieved. 2-11 GHz licensed band is the range of frequencies with TDD and FDD supports. The book will provide a wide horizon to visualize the WiMAX technology and its developments leading towards 4G systems. It will provide a good platform to the researchers with clues to the innovative ideas in WiMAX domain. I wish all the best to the authors and readers of this book in their successful research of WiMAX technology.