# A reliable proxy based vertical handover mechanism between WLAN and EVDO networks

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*Abstract*—***In the past decade, there was an enormous increase in the subscribers of Radio Access Networks (RANs) demanding ubiquitous quality of service (QoS), and continuous availability of connectivity. Therefore, Next Generation Networks (NGNs) are in high demand, which could imperatively combine multiple RANs to form a heterogeneous IP network. As mobile user moves across heterogeneous networks, there is a need of maintaining connectivity for continuous network availability. It is important to take seamless vertical handover as a fundamental step. In this research, we propose a Received Signal Strength (RSS)-controlled Vertical Handoff decision scheme. Moreover, for continuous connectivity, we have also presented a novel proxy based system architecture for end to end seamless mobility management during the handoff process. Using experimental setup, we have validated the efficacy of our scheme by analyzing TCP handoff behavior in different mobility scenarios.***

***Keywords- EVDO; Heterogeneous networks; Mobility; TCP; Vertical Handoff; WLAN***

## I. INTRODUCTION

Fourth Generation Networks (4G) ensure integration of multiple and diverse wireless access technologies to form an overlapping hybrid network. Accordingly, a mobile device is equipped with numerous network interfaces to shift between different radio access networks (RANs) while roaming. This type of inter-network mobility requires seamless handoff process between different air interfaces, called vertical handoff. However, horizontal handoff takes place between same access technologies [1] as shown in Figure 1. Seamless vertical handoff is one of the biggest challenges to be met for future networks. Mobile user on the move can utilize combined advantages of different RANs to enjoy continuous internet access and connectivity. TCP is a connection oriented protocol. Hence, due to migration of connection from one network to another, TCP applications suffer data loss due to handovers.In this paper, we discuss a application layer proxy based solution to resolve this issue. Moreover, we also present vertical handoff decision algorithm to select most favorable network on the basis of relative RSS values of access points (APs) and EVDO BS.

We have validated our proposed mechanism on various scenarios, and proved the efficacy of the proposed technique in terms of various performance evaluation measures such as throughput and latency.

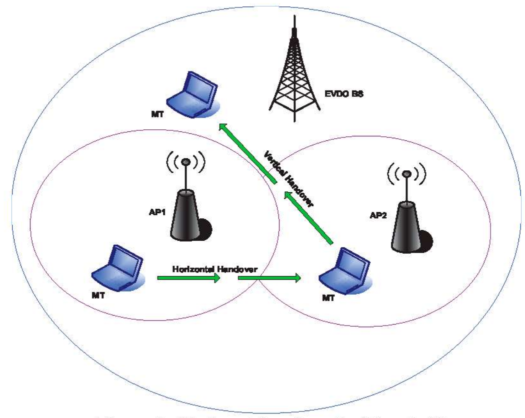


Figure 1: Horizontal and vertical handoff

## II. RELATED WORK

Almost every communication access technology has its own set of well-established horizontal handover protocols e.g. WiMax [2], LTE based networks [3], FMIPV6 [4] etc. These protocols are quite proficient for homogeneous networks.

Several mobility management mechanisms of mobile nodes for integrating wireless local area networks (WLANs) and cellular networks into heterogeneous wireless environment have been also introduced previously. These interworking mechanisms operate on different layers of network protocol suite, and are hence categorized accordingly [5].

Most widely used network layer solutions for mobility management are based on Mobile-IP. Multiple Mobile-IP approaches for handling mobility management problem of vertical handoff have been discussed in [6], [7],[8] and [9].These approaches solve the mobility problem by allowing mobile device to determine its current location and update home network for where to forward datagram received at home location. Although Mobile-IP solutions are among the most established mobility management solutions, they have certain limitations in wireless environment. Firstly, all of these approaches require inclusion of new supporting entities or modification to existing ones, which is an obstruction to deployment. Secondly, Mobile-IP maintains static IP address configuration of host, hence it is difficult to use with mobile, which is configured on Dynamic Host Configuration Protocol (DHCP). Moreover network layer solutions cannot provide all mobility services.

Numerous research has been carried out for supporting end-end mobility management, which operates at transport layer of

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network protocol stack. For instance, MSCTP [10], MPTCP [11], CWND-restore [12] and TCP mobility enhancement[13]. MPTCP, CWND-restore and TCP mobility enhancement techniques require enhancements in existing TCP implementation. MSCTP is a good extension of SCTP to support mobility management in an elegant way. But it does not support TCP applications. Session layer solutions to resolve mobility issue also exist. A majority of these solutions such as [14] and [15] revolve around variants of SIP protocol. But still SIP based approaches cannot handle TCP connections.

The remainder of the paper is organized as follows. Section II describes vertical handoff decision-making algorithm. Section III explains system architecture and handover procedure. In section IV, we analyze the results of real time scenario for the validation of our scheme. Section V, finally, provides comments, conclusion and future work.

## III. VERTICAL HANDOVER DECISION ALGORITHM

WiFi and EVDO cellular network exhibits different link characteristics. WiFi covers hotspots, campuses, offices, etc, at high data transmission rates whilst cellular network provides wider area coverage at lower data transmission rates but at higher price levels. Therefore, it is essential to remain connected with WLAN for as long as possible unless Mobile Terminal (MT) while moving goes out of its coverage area or RSS value becomes unacceptable. In case of WLAN it is very difficult to find the best orientation of antenna to receive strongest possible signal strength .In order to resolve this issue, multiple APs should be deployed to cover all dimensions of working area. Moreover, these APs overlap cellular networks coverage area to form a heterogeneous network.

Despite the explosion of RSS-based vertical handover decision algorithms, there seems to be a little research with respect to TCP performance in real-time environment. Secondly, achieving high throughput value is the major concern for vertical handover scenario. In [16], researchers believe that there is a direct relationship between throughput and RSS. This relationship is shown in Table 1. Thirdly, RSS-controlled algorithms eliminate unnecessary handoff decisions. Moreover, conventionally each AP takes handoff decision solely based on its own characteristics.

TABLE I. RELATIONSHIP BETWEEN RSS AND THROUGHPUT

| RSS (dBm) | Throughput (Mbps) |
|---|---|
| -63 | 1.28 |
| -75 | 1.20 |
| -93 | 1.08 |
| -111 | .32 |
| < -111 | 0 |

In this research, we suggest RSS-controlled seamless vertical handover decision algorithm (VHDA). This paper tries to address the above mentioned gap in research by analyzing the throughput achieved as a result of this decision algorithm. Algorithm uses several variables to make a decision.

TABLE II. SEVERAL VARIABLES OF THE ALGORITHM

| Variable | Description |
|---|---|
| $S_{thres}$ | Standard threshold value for both networks |
| $R_h$ | Highest signal strength of WLAN Access Point |
| $R_{evdo}$ | Measured signal strength of EVDO network |
| AP1 | Access Point with highest signal strength |
| AP | Currently serving AP |

Computational procedure for vertical handover decision algorithm is shown in Figure 2. To initiate a vertical and horizontal handover, eq (1) and (2) should be satisfied respectively:

$$R_{evdo} > R_h < S_{thres} \quad (1)$$

$$AP_1 \neq AP \text{ and } R_h > S_{thres} \quad (2)$$

Proposed VHDA is basically terminal based i.e. handover module is deployed on mobile host rather than on a network. Handover module queries the physical layer to ensure existence of both EVDO cellular device and WLAN Network Interface Card (NIC). NIC and EVDO cellular modem are configured properly to scan for RSS values of all installed APs and EVDO BS periodically with interval of only 10ms. The highest computed RSS ($R_h$) for AP is evaluated against a certain threshold value ($S_{thres}$) which is experimentally defined. If measured $R_h$ for AP is below $S_{thres}$ and $R_{evdo}$, the handoff is triggered. MT switched to overlay EVDO cellular network to enjoy ubiquitous connectivity and pervasive coverage of cellular network. While working in EVDO, MT will continuously scan for WLAN access and $R_h$ value .If $R_h$ value exceeds $S_{thres}$, mobile host will switch back to WLAN network due to its low cost and high data transmission rates.

The above mentioned steps endeavor to provide MT continuous connectivity while roaming.

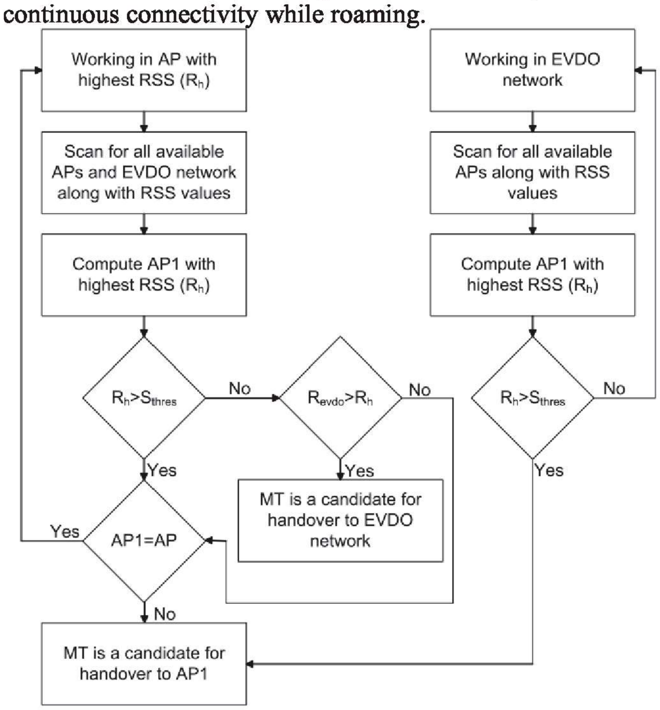


Figure 2: RSS based vertical handover decision algorithm

## IV. SYSTEM ARCHITECTURE AND HANDOFF PROCEDURE

In early ages, internet was designed on simple principle of fixed network edges. This simplicity allowed internet to evolve as a smash hit of the century. With the advent of new communication technologies, user demands QoS and continuous connectivity while moving. To fulfill such requirements of this era, researchers and network engineers are integrating artificial intelligence in computer networks.

It evolved as a burning issue that whether to incorporate intelligence in network layers or in end hosts. Despite of waiting for the solution of this issue, we proposed a handoff architecture, which provides enough intelligence to end hosts to initiate and complete handoff procedure based on RSS without service disruption.

In this work, we propose a complete vertical handover solution between wireless local area networks (WLAN) and evolution, data optimized (EVDO) networks. We tackle the issue of mobility management by developing an application layer based solution, which neither requires additional entities like Mobile IP nor TCP adaptation. Though proposed scheme is proxy based but proxy is deployed on MT, thereby eliminating the need of additional entity in the network.

Proposed architecture mainly consists of two modules: 1) handover module 2) embedded proxy. Handover module implements decision algorithm and makes a connection with most appropriate network on the basis of RSS value. Embedded proxy can handle multiple TCP connections and responsible of migrating all connection to new interface on handover .Our main focus is on the reliable delivery of data rather than preserving TCP connection. Though connection might be affected during handover but it is the responsibility of proxy to initiate a new TCP connection and maintain sequence of data for reliable delivery. PBHA is suitable for supporting horizontal handover as well as vertical handover scenarios.

Whenever PBHA client requests a TCP connection , the request is sent through embedded proxy server. For data transfer proxy makes a tunnel through selected network. When handover module initiates handover on the basis of decision algorithm, proxy buffers inbound and outbound packets, thus prevents them from dropping. Therefore proxy hides the effect of handover from user. Handover module associates the MT to the most appropriate network according to decision algorithm. Proxy creates a new TCP tunnel through new network interface and resumes data flow.

Detailed handover procedure between WLAN and EVDO network is shown in Figure 3.

Here we assumed that MT is initially connected to WLAN. WLAN has a shorter coverage area, but high bandwidth whereas EVDO supports wider area coverage with low data rates. Therefore, PBHA considered WLAN as preferred radio access network over EVDO. While roaming, when mobile user moves away from coverage area of WLAN, received beacon signal strength gradually weakens and ultimately dropped below specified threshold value. At this point, handover is initiated by MT and EVDO network gets activated. During handoff, proxy buffers all inbound and outbound packets, thus prevents them from getting dropped. Proxy creates an active tunnel with new network interface to which MT is handed over and resumes traffic flow, hence achieves minimal packet loss and smooth data transmission. Finally MT dissociates itself from WLAN radio interface and removes associated tunnel.

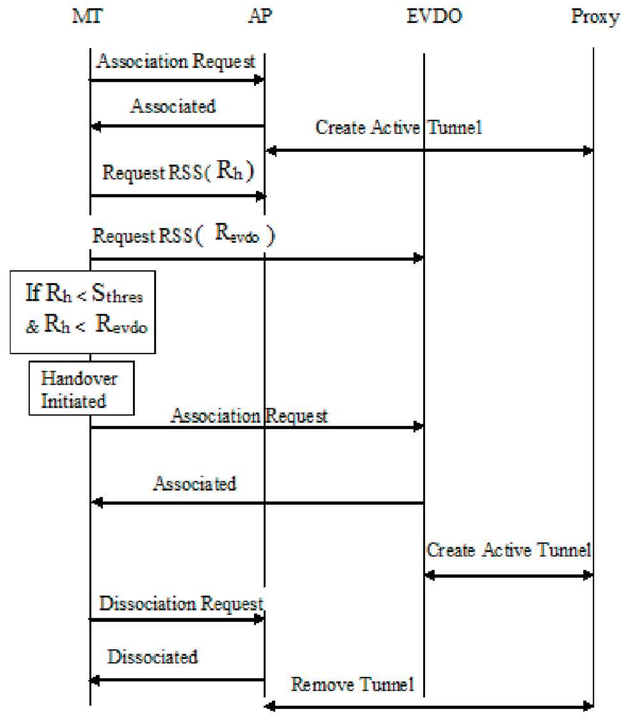


Figure 3: Sequence of vertical handoff procedure

## V. PERFORMANCE EVALUATION MEASURES

We have validated the performance of our proposed hand over algorithm using well-known performance measure of throughput and latency.

### A. *Throughput*

Throughput is the amount of data transferred in one unit of time. It is measured in Kilo bits per second (*Kbps*). Throughput is measured using the following equation.

$$Throughput = \frac{Total\ data\ transfered}{Total\ time} \quad (3)$$

### B. *Latency*

Latency is the time delay involved in handover process i.e. the time taken by the mobile terminal in leaving one network and successfully joining another network. It is measured in seconds (*s*).

## VI. EXPERIMENTAL ENVIRONMENT AND RESULTS

We presented simulations for a wireless coverage area that is occupied by two overlying radio access technologies i.e. WLAN with various hotspots and EVDO. To show that our proposed algorithm in fact achieves seamless horizontal as well as vertical hand off under various network environments, we performed experiments under three test scenarios. MT move around for whole experimental period of around 1 minute with random mobility model and at random speed. In this experimental research, we practically analyzed TCP throughput during handover. Measurements are taken at intervals of 5 sec and average throughput result of various independent readings is shown. For real time simulation of our scheme, we started TCP bulk downloads from remote server to MT. MT starts file downloading while serving in one radio access technology and move to coverage area of another access technology with better signal strength compared to previous network for initiating a vertical handover.

Our three test case scenarios are:

- MT roams from WLAN to EVDO
- MT roams from EVDO to WLAN
- MT switches between various APs covering large area.

These cases are discussed in detail in the following text.

### *A. MT roams from WLAN->EVDO and EVDO->WLAN*

Figure 4 and Figure 5 shows vertical handoff for WLAN-EVDO and EVDO-WLAN respectively. Graphical results show that TCP traffic flow is maintained successfully during both handover scenarios. However throughput is affected only for a negligible short time at 38.5$^{th}$ -39$^{th}$ and 38$^{th}$-39$^{th}$ second , respectively, in Figure 4 and Figure 5.

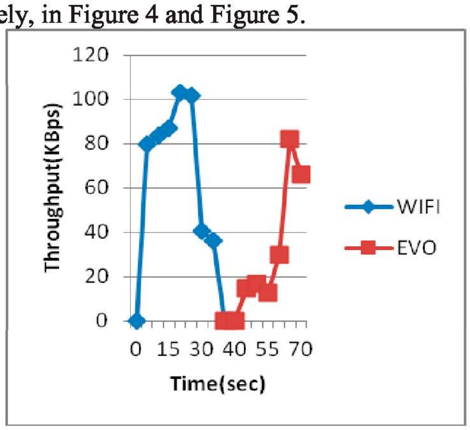


Figure 4: Throughput analysis for WLAN-EVDO handover

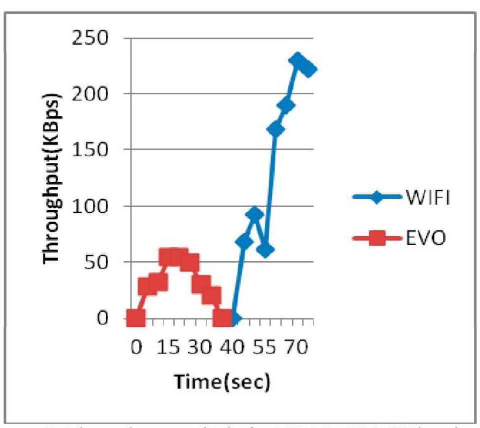


Figure 5: Throughput analysis for EVDO- WLAN handover

### *B. MT switches between various APs covering large area.*

When RSS of existing AP falls below certain threshold, we firstly prefer to switch to another AP offering acceptable RSS value. Figure 6 shows MT performance during horizontal handover between 3 APs. Figure 6 shows the TCP throughput of MT that is stable but falls sharply only for 2 sec during handoff.

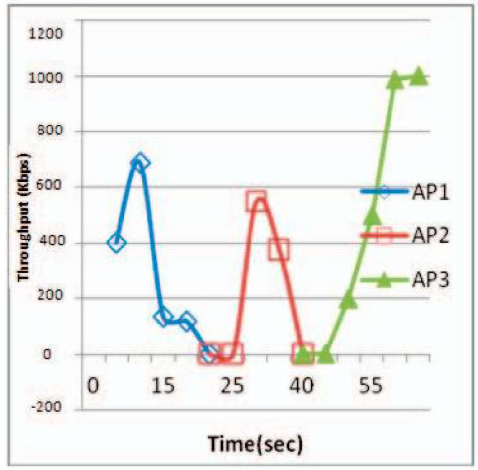


Figure 6: Handoff between various APs

In order to validate the effectives of our proposed handover algorithm, we have compared our proposed PBHA algorithm with previously published MIPv6, DAD-Less MIPv6 and TCP mobility enhancement technique[16]. Figure 7 depicts the handover latency during vertical handover initiated by movement of MT. According to results, we can reasonably conclude that our proposed PBHA algorithm has better handoff performance as compared to MIPv6 and DAD-Less MIPv6 . The reason behind the fact is that MIPv6 requires a complex registration and location update procedures. Contrary, our proposed PBHA algorithm is computationally less expensive, and does not require complex location update mechanism. On the other hand TCP enhancement technique has low latency as compared to PBHA but it requires change in TCP protocol. In our opinion, comprehensive mobility management solution neither requires support from network nor change in TCP with acceptable handover delays.

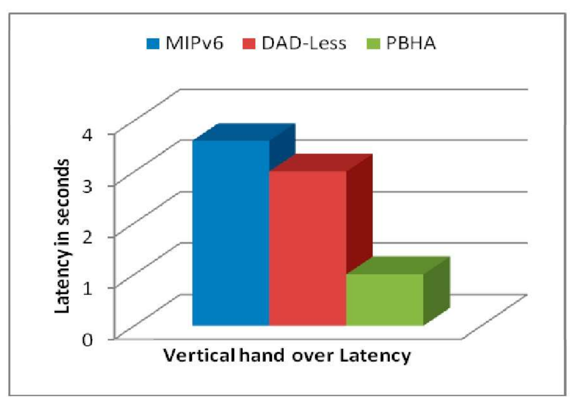


Figure 7: Latency involved in vertical handover process

Tabular comparison of different vertical handover techniques on the basis of various parameters is shown in Table III.

TABLE III. COMPARISON OF DIFFERENT VERTICAL HANDOVER TECHNIQUES

| Parameters | MIPv6 | DAD-Less MIPv6 | TCP mobility enhancement | PBHA |
|---|---|---|---|---|
| TCP adaptation | N | N | Y | N |
| Require support from network | Y | Y | N | N |
| Application layer | N | N | N | Y |
| Handover delay (sec) | 3.6 app | 3 app | Negligible | 1 app |
| TCP adaptation | N | N | Y | N |

Results in Table III shows that percentage decrease in latency when the proposed PBHA is used instead of previously published MIPv6 or DAD-Less MIPv6 algorithm handover is more than 55% .This fact validates the efficacy of the proposed PBHA algorithm.

## VII. CONCLUSION

In this research article, we proposed an end-end system design for mobility management of mobile terminals and a RSS-controlled vertical handover decision algorithm. This architecture allows mobile hosts to continue their services ubiquitously while moving across homogeneous as well as heterogeneous networks. Proposed scheme works at application layer and neither requires insertion of any supporting entity nor enhancements in existing TCP implementation. Moreover, unlike other Vertical Handover (VHO) algorithms, our proposed decision algorithm connects to alternate network only when needed thus decreases power consumption of mobile station. Using experiments, we evaluated our scheme. It is observed that proposed PBHA model along with VHDA is capable of maintaining continuous connectivity while roaming.

Up till now, we have investigated VHO procedure between WLAN and EVDO networks only. Future work is planned to expand this research to incorporate other radio access technologies in PBHA i-e. Wimax, GSM/ GPRS, UMTS etc. Furthermore, in future we will consider application of VHO scheme to VOIP applications with the goal of achieving seamless mobility during video conferencing.

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