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A Cross-Layer Based Enhanced Handover Scheme Design in Vehicular Ad Hoc Networks

Nkoko S. Sehlabaka and Okuthe P. Kogeda

***Abstract*—Latest advances in wireless communication facilitated the establishment of vehicular ad-hoc networks (Vanets), which provide a platform to improve the life of passengers by delivering both comfort and safety applications. The mobile WiMAX standard provides a good communication framework for a Vanet due to the support of mobility. The standard defines handover process that consists of network topology acquisition and actual handover phases. However, the standard suffers from long handover delay due to unnecessary base-station scanning and association procedures, which result in severe degradation in system performance. This paper therefore presents the design of an enhanced cross-layer based handover algorithm, which solves the prolonged handover processing incurred when using mobile WiMAX by eliminating the scanning phase performed by mobile subscriber stations. The algorithm utilizes the currently connected vehicles to collect MAC and PHY layer information about target base-stations, and then broadcast the information to temporarily disconnected ones. The disconnected vehicles then adjust their WiMAX adapters and resume communication immediately after joining the transmission area. It is demonstrated by network simulator 2 (NS2) simulations that the proposed algorithm provides a reduced handover delay, increased network throughput and minimized number of lost packets at various speeds of vehicles and packet sizes.**

***Index Terms*—Cross-layer, enhanced handover algorithm, NS2 Simulator, Vanets, WiMAX.**

I. Introduction

TODAY vehicles constitute an important part in peoples' lives, and embedding software-based intelligence into vehicles has the potential to considerably improve the passengers' quality of life. Vehicular ad-hoc networks (vanets) provide a promising platform for a much broader range of large scale, highly mobile applications. Vanets are distributed, self-organized networks that utilize moving vehicles, road-side units (RSU) and base-stations (BSs) as nodes to create a mobile network thus turning every participating vehicle or base-station (BS) into a router, therefore permitting vehicles within coverage areas of each other to connect and in turn create a network with a wide range of applications.

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Nkoko S. Sehlabaka is with Tshwane University of Technology, Department of Computer Science, Private Bag X680, Pretoria 0001, South Africa. (e-mail: snsehlabaka@ gmail.com).

Okuthe P. Kogeda is with Tshwane University of Technology, Department of Computer Science, Private Bag X680, Pretoria 0001, South Africa. (Phone: +27(012) 382-9640; fax: +27(012) 382-0966; e-mail: kogedapo@ tut.ac.za).

Vanets facilitate coordination between drivers in order to avoid any critical situations such as road-side accidents, traffic jams, speed control and free passage of emergency vehicles. Besides that, they also provide comfort applications to passengers such as internet access, and thus mobile e-commerce. To facilitate access of these applications, vanets employ short range technologies such as Wireless Fidelity (Wi-Fi) and Wireless Access in Vehicular Environments (WAVE) to enable interaction among vehicles. On the other hand, vehicles can connect with infrastructure networks through Wi-Fi hotspots or wide range wireless technologies like Worldwide interoperability for Microwave Access (WiMAX) and cellular networks.

The mobile WiMAX (IEEE 802.16e) is designed to support mobility at vehicular speeds. Its physical layer has been modified to scalable orthogonal frequency division multiplexing access (SOFDMA) which supports multi-path propagation, and thus resulting in the ability to generate higher network throughput and improved coverage. However, handover delay in mobile WiMAX is still a problem which affects real-time continuity of applications. This is partly due to scanning process, as well as the network re-entry which results in delays of hundreds of milliseconds, surpassing the requirement of real-time services. This project therefore aims at addressing the issue of delay during handover processing in vanets in order to improve communication between vehicles and target BSs, and thus quality of service (QoS) and network reliability.

The remainder of this paper is organized as follows: In Section II, we provide technical background of mobile WiMAX handover process. In Section III, we present an overview of related work. In Section IV, we describe the proposed handover algorithm in detail. We provide the performance analysis in Section V and we finally conclude the paper in Section VI.

II. Background of Mobile WiMAX Handover

Handover is the process of changing the radio channel (frequency, time slot) associated with the current connection while a call is in progress. It is often caused either by the radio signal quality degradation in the current channel or by crossing cell boundary [1]. Handover in mobile WiMAX can be divided into two major phases: network topology acquisition phase and the actual handover process [2]. The network topology acquisition phase precedes the actual handover process. We provide details of each of these phases next, explaining their contribution in the overall MAC-layer handover delay.

A. *Network Topology Acquisition Phase (NTAP)*

During NTAP shown in Fig. 1, the mobile subscriber station (MS) and serving BS, together with the help of the backhaul network, continuously gather information about the underlying network topology before the actual handover decision is made. The serving BS periodically broadcasts this network topology information using the mobile neighbor advertisement (MOB_NBR-ADV) message, which includes channel information of neighboring BSs [3].

The MS starts scanning the advertised BSs within specific time frames, to choose the most suitable candidate for handover. The process is carried out with the help of mobile scanning interval allocation request and response messages (MOB_SCN-REQ and MOB_SCN-RSP), respectively. At the end, scanning result report (MOB_SCN-REP) summarizes all the scanning activities. Scanning is followed by ranging (contention or non-contention based) activities through which the MS gathers further information about PHY channel related to selected target BSs. Ranging request (RNG_REQ) and ranging response (RNG_RSP) messages are used for this purpose [4]. Ranging is then followed by association activities whereby the MS gets associated with the potential target BS candidates.

There are mainly two inefficiencies that are experienced at this stage of NTAP. Firstly, the MS redundantly scans and synchronizes with a number of neighboring BSs as potential target BSs candidates. Lastly, we encounter throughput degradation when the MS conducts neighboring BS scanning because the downlink data transmission is paused and interleaved.

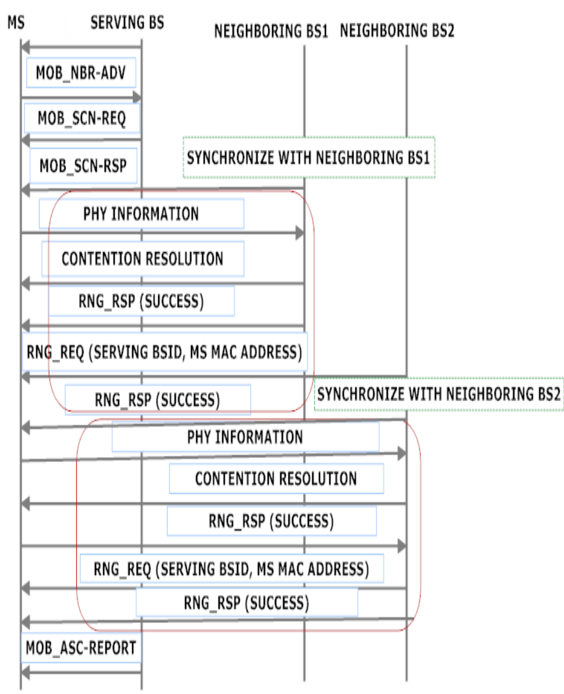

Fig. 1. Network topology acquisition phase

B. *Actual Handover Phase*

During the actual handover phase, the MS switches location from the serving BS to the selected target BS using information obtained from NTAP. The decision and initialization of a handover process may arise at the MS or serving BS. When the MS decides handover, it communicates the MOB_MSHO-REQ message containing the list of selected target BSs, and the serving BS replies back with the MOB_SHOP-RSP message. Alternatively, if the decision arises from the serving BS, the MOB_BSHO-REQ message is used. However, handover decision and initiation messages from the MS are always given preference [5]. Another ranging process is followed after handover initiation and the RNG_REQ/RSP messages are exchanged to complete the process. The RNG_REQ may contain the serving BS identity (BSID) to enable target BS to obtain MS information from the serving BS through backbone network, which happens only if the target BS is not associated with the MS from previous stage.

Once a final decision is made on the target BS, the MS informs the serving BS about the handover activity by sending a mobile handover indication (MOB_HO-IND) message as illustrated in Fig. 2. At this point, the MS terminates its association with the serving BS, and begins a new connection with the target BS.

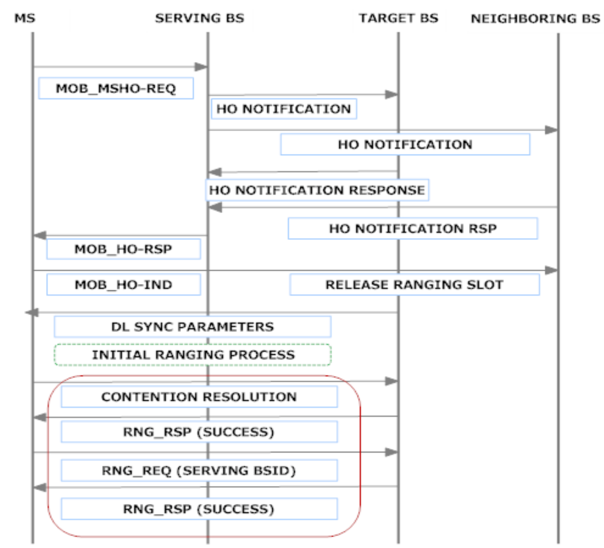

Fig. 2. Handover decision, initiation and ranging

The next phase after selecting the target BS is the network re-entry given in Fig. 3. It specifies the MS authorization and registration with the target BS. After successful registration, the MS sends MOB_HO-IND message and informs the serving BS that the handover process is completed.

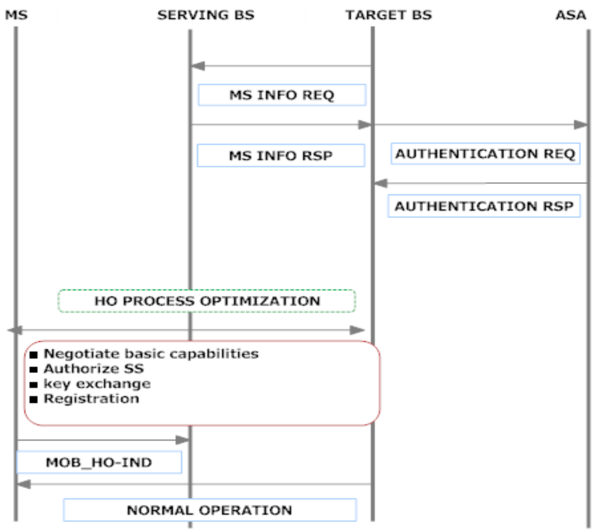

Fig. 3. Network re-entry in mobile WiMAX

algorithm minimizes scanning without the use of cross-layer design and does not consider dynamic topology of vanets due to high vehicular mobility, which is carefully considered in this design.

Doo Hwan, K. Kyamakya and J. P. Umondi [8] proposed fast handover algorithm to reduce unnecessary BS scanning. With this algorithm, the serving BS broadcast neighbor advertisement message to the MS, this then acquires mean carrier to interruption plus noise ratio (CINR) and arrival time difference (ATD) of each neighboring BS. The MS then selects the neighboring BS with bigger mean CINR and smaller ATD as the target BS. After selecting target BS, the MS requests synchronization and association from its serving BS, and conduct the processes only with the already selected target BS rather than to all other neighboring BSs. The authors claim that there is reduction in handover delay and there is significant increase in system throughput. The algorithm however does not consider the use of cross-layer design and the carry-store-forward capability present in vanets.

III. Related Work

Kuan-Lin Chiu, Ren-Huang and Yuh-Shayan Chen [6] proposed a vehicular fast handover scheme (VFHS) to reduce handover delay. VFHS utilizes oncoming side vehicles to accumulate PHY and MAC layers information of passing relay vehicles (RVs) and broadcast the information to the vehicles that are temporarily disconnected. The broadcasted network topology message (NTM) contains information about RVs' position and channel frequency, and about neighbors of RV. Upon receiving NTM a disconnected vehicle adjusts the frequency channel of its WiMAX adapter based on RV value. When a disconnected vehicle joins coverage area and thus approaching an RV, a rapid handover occurs. It is claimed that VFHS significantly decreases handover delay and packet loss. Their algorithm is similar to the one proposed in this project in that it considers almost the same traffic scenario and the use of cross-layer based network messages. However, the algorithm does not consider RVs' traffic during target selection. If the RV is too much involved in communication with nearby mobile subscriber stations (MSs), much of the available bandwidth is accumulated, and therefore the network throughput and quality degrade significantly. On the other hand, our algorithm performs target RVs selection based on the suitable bandwidth status and number of real-time flows per BS. Our algorithm also utilizes Proxy Mobility Internet Protocol version 6 (PMIPv6) to take care of MSs' mobility and IP layer communication.

Rouil R. and Golmie N. [7] developed an adaptive channel scanning (ACS) algorithm to facilitate the discovery of neighboring BSs. With this algorithm, the BS with the least scanning period for MSs is chosen. The serving base station receives configuration parameters of neighboring BSs and approximates the total scanning time of each neighbor BS, and reports this information to the MS. The MS then chooses a BS with the shortest scanning period as its target BS. It is stated that the approach functions very well to limit communication disruptions for all traffic. The

IV. Enhanced Handover (EH) Algorithm

The goal of EH algorithm is to reduce the handover latency in vehicular environment. The scheme considers a normal traffic scenario on highway in a four lane road, whereby some vehicles are within the transmission range of a relay vehicle (RV) and moving in opposite directions, while others are approaching the area of coverage and others moving out of the coverage as depicted in Fig. 4.

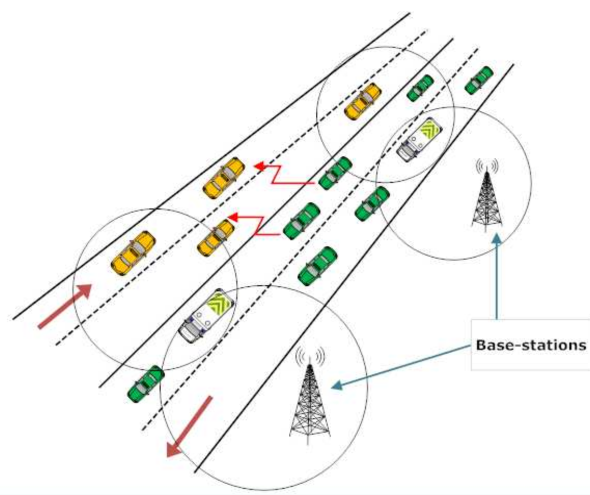

Fig. 4. System Architecture

The algorithm assumes that all vehicles are equipped with on-board units (OBUs), global positioning systems (GPSs) and application units (AUs) to permit and facilitate communication between vehicles. The OBU furnished with at least one short-range communication device. From Fig. 1, the RV periodically transmit MOB_NBR_ADV message to all vehicles within transmission range denoted by circles. Upon receiving this message, all vehicles accumulate and store the message in their in-built OBUs. This is a cross-layer message containing PHY layer information (i.e., available frequency channels, speed and location), and MAC

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layer information (i.e., number of real-time flows per RV and bandwidth status). When vehicles moving in the opposite direction disconnect or move out of transmission range of RV, they generate network topology message and broadcast to currently disconnected vehicles. Now with this information, the disconnected vehicles are able to select the appropriate target RV without scanning phase, based on the fact that they can easily tune their WiMAX adapters to suitable frequency channels of target RVs.

V. Performance Analysis

A. Simulation Environment

The simulations were done using a model of IEEE 802.16e developed in network simulator (NS-2.29) [9]. We have 40 vehicles in clusters at different speeds in the range 6-20 m/s labeled 6-45 on a multilane highway. We have considered 3 BSs each with 500 meters coverage area, and the distance between them was kept at 700 meters. The gap between RVs was kept constant and other parameters in the WiMAX module were set to default values. The simulations were run for 130 seconds. Both EH algorithm and standard mobile WiMAX were compared. Table I shows simulation parameter settings for the algorithm.

TABLE I
SYSTEM PARAMETERS

Experimental Parameters	
Routing Protocol	DSDV
Propagation Model	Two-ray Ground Reflection
Scan duration	50 sec
RXThresh	2.025e-12
Packet size	1000 bytes
Traffic Type	Constant Bit Rate (CBR)

Fig. 5. portrays the simulation topology used while conducting the experiments to evaluate EH algorithm. The BSs were located at (100, 200), (800, 200) and (1500, 200). Several OSVs and DVs were moving at constant velocities in opposite directions. Handover delay and packet loss were observed at the DV.

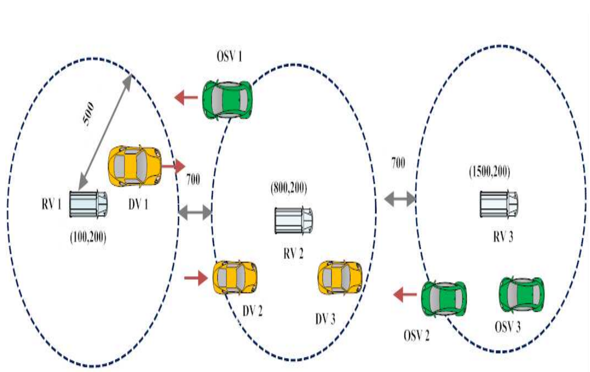

Fig. 5. Simulation scenario

B. Experimental Results and Analysis

The performance metrics include:

1) Handover delay - the time interval from when a disconnected vehicle lost its communication with previous RV until it establishes a new connection with target RV.
2) Network throughput - measure of the amount of packets that can be transmitted over a given time interval to desired destinations.
3) Packet loss - number of packets lost during handover processing.

Handover Delay

The impact of vehicle speed on handoff latency for both EH algorithm and standard WiMAX as the DV performs handover from RV1 to RV2 is shown in Fig. 6. As the vehicle speed increases from 10.01 m/s to 10.07 m/s, the handoff latency slightly decreases due to the fact that the time period to pass through the distance between RVs is reduced. Now looking at Fig. 6, our scheme performs much better with the average handover delay of 2.026e-5 seconds, which is 19.9% below that observed in mobile WiMAX. The improvement basically emanates from the elimination of scanning phase, which is mainly enabled by the sharing of RVs' cross-layer information between MSs.

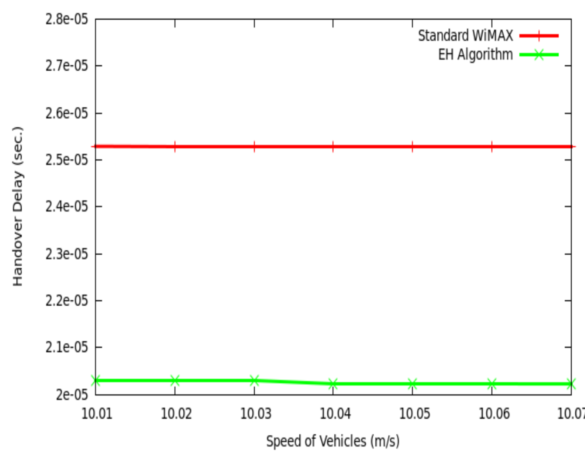

Fig. 6. Handover delay under various speeds

Network throughput

To calculate the average network throughput, we used the algorithm and awk program given in Fig. 7. Firstly, the overall downlink throughput comparison for EH algorithm and mobile WiMAX is presented under various CBR packet sizes: 1000, 1500, 2000, 2500 and 3000 bytes. The effect of packet sizes over throughput of the network can be observed in graphical format in Fig. 8. Notice that the throughput increases exponentially with the size of the CBR packets. It is clear from Fig. 8 that our algorithm presents an improved network throughput compared to mobile WiMAX.

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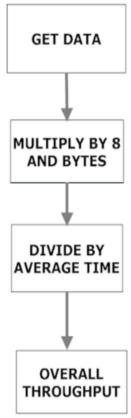


```
Begin {
send = 0;
recv = 0;
startTime = 0;
stopTime = 0;

}
if ($19 == "AGT" && $1 == "s")
    if (send == 0)
       startTime = $3;
    stopTime = $3;
    startTime[$41] = $3;
    send++;
}
if ($19 == "AGT" && $1 == "r")
{
if(recv == 0)
{
   last_pkt_recv = $3;
}
else
{
   last_pkt_recv = $3;
}
  recv++;
  bytes += $37;
  stopTime[$41] = $3;
}
END {
      print("Average Throughput [kbps] =" bytes*8/(stopTime-startTime))
}
```

Fig. 7. Algorithm and awk program for throughput

On the other hand, Fig. 9 shows the result of the impact of vehicles' speed on network throughput. As the speed increases, there is slight decrease in throughput because the packet delivery ratio also decreases. It can be concluded from Fig. 9 that the EH algorithm provides better performance in terms of throughput.

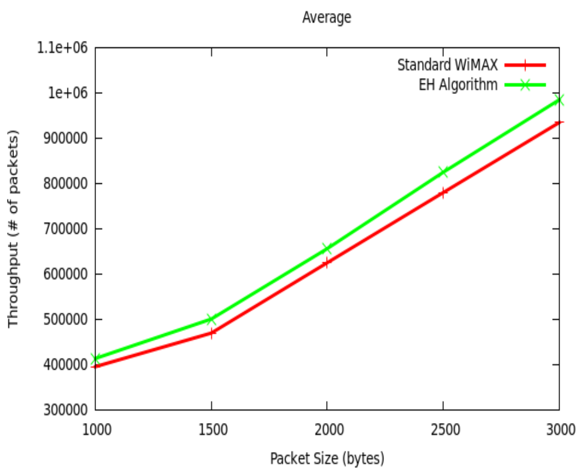

Fig. 8. Average throughput under various packet sizes

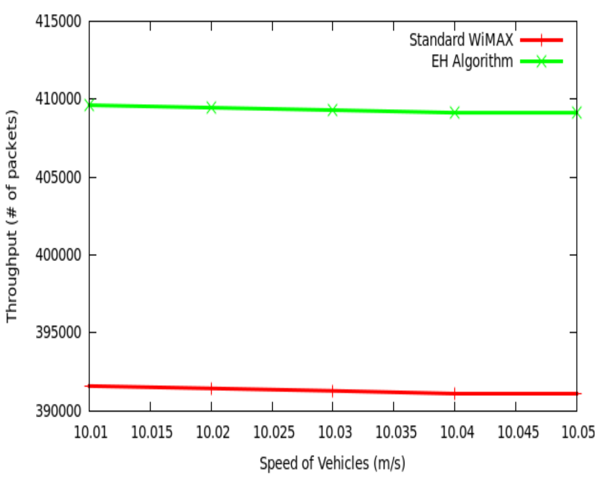

Fig. 9. Throughput under various vehicle speeds

Packet loss

Fig. 10 presents the number of lost packets during handover processing with the CBR packet size held constant at 1000 bytes. The speed of vehicles was also set steadily at 10 m/sec. We notice from Fig. 10 that the number of lost packets increases as the number of vehicles increases because actually the more there are vehicles doing handover the more packets are sent and increased probability of dropped packets. Moreover, it is worth noting that when the length of disconnection period increases, the amount of lost packets also increases.

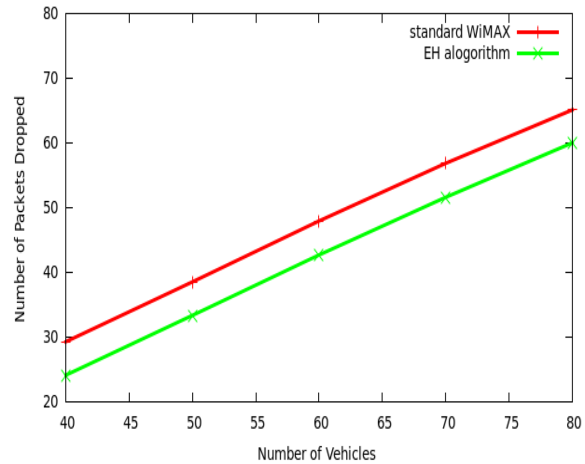

Fig. 10. Number of packets lost during handover

VI. Conclusion

In this paper, we presented a cross-layer based EH algorithm to minimize handover latency experienced in vehicular environments. This algorithm relies on sharing network parameters among vehicles in order to minimize the network re-entry procedure by eliminating the scanning phase. The article also presented system architecture and its implementation in NS2. The results show that latency and number of lost packets during handover are significantly reduced as compared to standard mobile WiMAX. In addition, our proposed solution presented an improved network throughput, which in turn resulted in improved QoS and network reliability.

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