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SCTPCD: A Cross Layer Transport Layer Protocol For Highly Dynamic Environment

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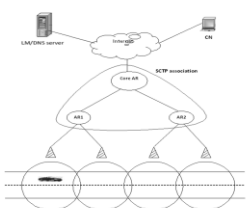
Graphical abstract



Abstract

Computer and wireless mobile communication need Internet accessibility at anytime and anywhere and this includes in high-speed wireless environment such as in high speed trains, fast moving cars as vehicle-to-infrastructure (V2I) communication. However, wireless qualities of service (QoS) provisioning in such environment are more challenging. This increases the development of numerous schemes concerning the need of smooth handoff of the mobile nodes. Transport layer protocols can support seamless handover in such high speed mobility. This paper highlights on the issues of moving users in WiMAX network. A cross-layer design of Transport Layer protocol which is called cross-layer design of Stream Control Transmission Protocol and BS handover messages (SCTPcd) is able to guarantee and maintain QoS for high-speed vehicle. The cross-layer allows information to be exchanged and shared across layer boundaries in order to enable efficient and robust mobility aware protocols.

Keywords: V2I; SIGMA; Cross-Layer; Handover; Mobility.

■1.0 INTRODUCTION

With more users moving around in need of Internet connection from their home to their office Vehicular ad hoc Network (VANETs) has increasingly becomes popular. Having infrastructure of 3G and 4G around VANET expanded its usage by attaching its users to the backbone infrastructure for additional support and applications. Thus in VANET there are two types of communication which are vehicle to-vehicle (V2V) and vehicle-to-infrastructure (V2I). V2V deals with communication among vehicles themselves, while in V2I it transmits information between vehicles and the fixed infrastructure which are installed at the sides of the road. This infrastructure includes gateways or base stations that provide services such as Internet access. VANET is very similar to MANETs (Mobile ad hoc network), however, the network topology in vehicular networks is highly dynamic and the topology is often constrained by the road structure.

Furthermore, V2I are likely to encounter a lot of obstacles such as poor channel quality and connectivity due to high moving speeds. Thus, there is a crucial need for effective protocols that take the specific characteristics of vehicular networks into account [16],[17].

Most of the existing transport layer techniques proposed for mobility cannot deal with mobility on their own since they depend on the network layer mobility management required by handovers. The main purpose is simply to minimize the degradation of transport layer performance caused by handovers. Some of the newly emerging protocols, such as Stream Control Protocol (SCTP) suggest the possibility of independent management of mobility by the transport layer. Multi-homing feature of SCTP provides a basis for mobility support since it allows a mobile user to add new IP address, while holding the old IP address already assigned to itself [5],[10],[11],[18]and[19].

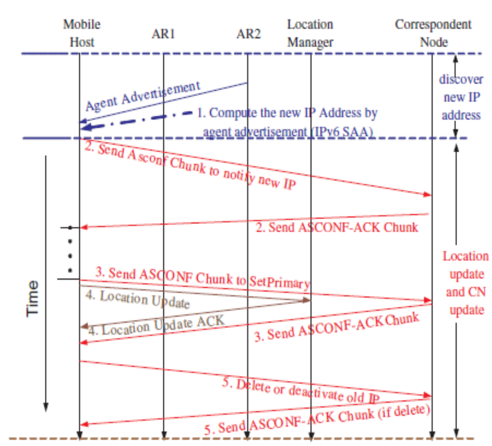


Figure 1 SIGMA handover procedure [7]

In V2I the vehicle moves fast from on base station to another; the current Internet session will need to perform handover. To reduce the delay time caused by handover, we proposed an enhancement over existing protocol known as Seamless IP diversity based Generalized Mobility Architecture (SIGMA). SIGMA uses location manager (LM) to reduce handover delay caused from diversity in the network as appear in figure 1. On other hand, it is experiences high handover delay packet loss rate when the speed of mobile user is high. A cross-layer design between transportation layer (L4) and data link layer (L2) is proposed in order to optimize the performance of SIGMA. This cross-layer design makes L4 aware about the movement of vehicle using signal strength indicator (RSSI).

The later parts of this paper are organized as follows. Section 2 mentions highly dynamic environments and related works. An overview of SIGMA and vehicular in terms of five requirements is mentioned in section 3. The cross-layer design of SIGMA to overcome the problem statement is well-defined in section 4. Section 5 describes simulation topology and parameters. Section 6 presents results of the protocol design mentioned and section 7 conclude the paper.

■2.0 HIGHLY DYNAMIC ENVIRONMENTS

High-speed vehicles requiring network connection for interactive and real-time applications are becoming increasingly important. Therefore many seamless mobility approaches have been developed. To avoid service disruption and minimize the awareness of service degradation while mobile device is moving fast and changing the point of attachment from one access point to another, [2],[14] and [15] described various approaches that support seamless and lossless handover in high speed transportation system. Reference [2] exploits prediction technique to improve and optimize its performance in high-speed environment. Thus, there would be no problem regarding insufficient time in connection establishment as the speed increase. A study in [15] also suggest 802.21 centric approaches to exploit a prior knowledge method where network information is gathered from both mobile terminal and network infrastructure to establish an earlier connection with new subnet. In order to reduce the effect of service interruption in high movement speed environment, another research presented in [14] propose a packet forwarding control (PFC) scheme to select a common ahead point (CAP) as the tunnel source to forward packets. Using this method, packets can be sent through a shorter delivery path during handover. Reference [19] proposed Network Mobility (NEMO) Protocol for Vehicular Ad Hoc Networks VANET in highway. Since every car is moving in a fixed direction with high moving speed, the car adopting this protocol can acquire IP address from the VANET through V2V communications. In [19]they presents a cross-layer fast handover scheme, called vehicular fast handover scheme (VFHS), where the physical layer information is shared with the MAC layer, to reduce the handover delay. Using lower layers handovers, the transportation layer will not be aware of handover which may cause packet loss and degradation of the network QoS.

Transport layer based approach such as Mobile SCTP (mSCTP) influence the ability of SCTP to have multiple IP addresses per association. The mSCTP utilizes a feature of SCTP which allows a mobile node (MN) to dynamically switch between available access networks thus effecting seamless handovers. Reference [10] provides analysis that mSCTP can provide lower handover latency than Mobile IP and give much smaller handover latency for vertical handover. Hierarchical Transport layer Mobility protocol (HTM) which is a new proposed option deals with the local and global mobility and improves throughputs during the handoff period. This protocol exploits the dynamic address reconfiguration feature of SCTP and introduces an Anchor Mobility Unit (AMU) in order to complete more efficient handoff procedures. A novel error recovery mechanism associated with a handover was discussed in [21] where the error recovery time of this mechanism is analyzed and compared to that of the plain SCTP for handover cases.

The need to maintain a seamless communication in high speed environment is becoming highly attractive and is therefore becoming a critical and challenging issue that needs to be tackled. The increase in movement speed may give poor impact to the network performance due to insufficient time to prepare for the handover and thus results in high handover latency and high number of packet loss [2],[16],[17].

■3.0 VEHICULAR NETWORK MOBILITY MANAGEMENT

The mobility management in vehicular networks should guarantee the reachability to correspondent nodes (CN) in the Internet as well as the global reachability to mobile nodes in a vehicular network. For this purpose the mobility management has confined requirements such as seamless mobility, fast handover, IPv6 support high mobility speed and movement detection. VANET mobility requirements are summarized in the Table 1.

Table 1 The requirement for mobility management in high speed handover

Seamless mobility	Mobility of vehicles should be seamless regardless of vehicle's location and wireless technology. Moreover, accessibility and service continuity should be guaranteed
Fast Handover	Fast handover is needed for delay sensitive Intelligent Transportation System ITS applications (e.g., safety, internet access, etc.). Fast handover is also a crucial requirement for wireless networks with small coverage area (e.g., WiFi network), since the vehicle with high speed spends short period of time at each point of attachment (e.g., Base station), consequently high handover rate.
IPv6 support	The global reachability requires a globally reliableroutable IP address for each mobile node. IPv6 with large address space can support a unique address for each mobile device in the vehicles. In addition, IPv6 also has better support of security and quality of service (QoS) which are the necessary requirements of ITS applications
High mobility speed	The Internet access is expected to be constantly connected regardless of the movement speed. It is highly desirable to make these contents available and reliable regardless of time, place, fixed or mobile. As the speed of vehicle increases, the successful probability of handover decreases. Moreover, successful probability of handover is reduced by the same reason as the handover execution time is increased.
Movement detection	Vehicle needs to detect the availability of different types of access networks (e.g., WiMAX base station) known as data link layer handover (L2), and obtain addresses in these networks for communication.
Location management	Location management scheme, which deals with the storage, maintenance, and retrieval of mobile node location information, is needed in VANETs[23].

4.0 PROPOSED CROSS-LAYER DESIGN FOR HIGH SPEED VEHICLE

Information from multiple layers can be effectively exchanged to improve performance of mobility management schemes. In our cross-layer design (SCTPcd) a scenario of vehicle move from serving BS (SBS) to the target BS (TBS), the current running Internet communication will switch from SBS to TBS with same technology (WiMAX BSs). Increasing in the movement speed may give adverse impact to the network performance when using SIGMA protocol due to insufficient time to prepare for handover and therefore high handover rate and packet loss. This cross-layer design handle these challenges much more efficiently using transport layer protocol SIGMA and available information from data link layer (RSSI). Figure.2 shows the state diagram of the cross-layer (SCTPcd) as vehicle moves from first state in SBS towards TBS, along this time signal strength become low. Then vehicle inter through handover area state 2 at that time L2 send to upper layers LinkStatusChange.ind message. State 3 the vehicle inside handover area and communication with SBS is stop so it sends L2 messages to upper layer asking the number of BSs, LinkConnect to TBS. Last is state 4 which is the finishing of handover, L2 receives LinkUp.ind to indicate signal strength going up and L3 message to inform of reaching network. Figure 3 shows the timing diagram of the proposed cross-layer to describe the flow of handover message between BS and vehicle (L2 handover) and vehicle and CN (L4 handover SCTP).

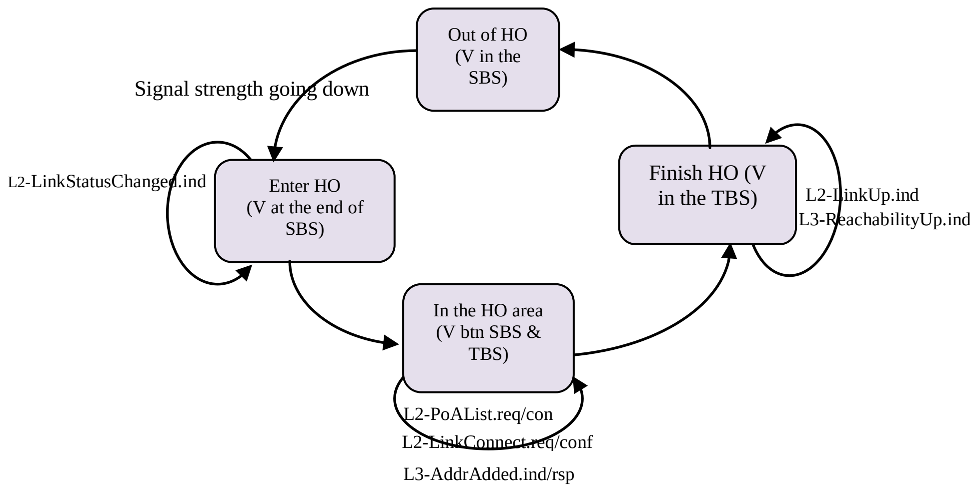


Figure 2 State diagram of the proposed cross layer design

4.1 Handover Procedure of SCTPCD

Handover procedure of the cross-layer design contains of data-link layer (L2) handover delay, network-layer handover delay (L3) and transportation layer handover delay (L4). L2 delay is mobile WiMAX BS signaling messages for handover. Most L3 delay is of duplication address detection (DAD). While using LM (location manager) in SIGMA protocol the MN address becomes global and known for other NAR. L4 delay of SCTP protocol used in SIGMA design is for ASCONF SET-PRIMARY/DEL-IP messages plus round trip time (RTT) between vehicle and CN (about 1-10ms). For LM, the link delay to update LM does affect handover delay for SIGMA so we neglect time of location registration request/response (REG.REQ/RSP), finally the total handover delay time of handover delay:

$$L2+L4\ (ASCONF\ SET\text{-}PRIMARY/DEL\text{-}IP)+RTT \quad (1)$$

Next the algorithm of the cross-layer design is provided to explain the proposed idea clearly.

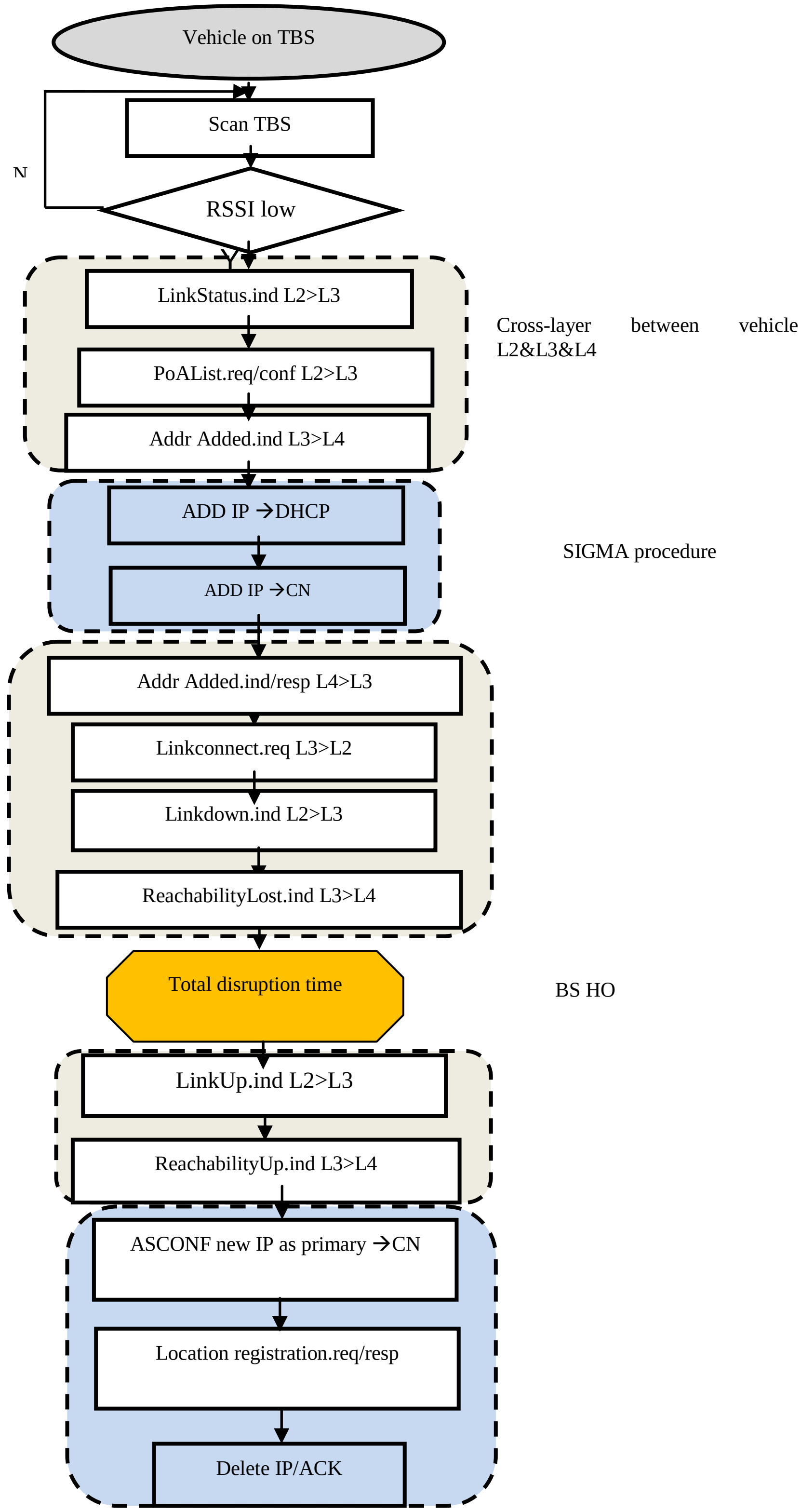
Algorithm 1 mentions the idea of cross-layer handover with L2 handover message of BS, L4 of SCTP protocol and high speed vehicle.

5.0 SIMULATION TOPOLOGY

As an illustration is shown in Figure 4, where the vehicle is multi-homed node moving with speed of 20-120km/hr and connected through four wireless access networks (WiMAX BS) with coverage area of 2000m each 2 BSs connected to AR. The overlapping region between two ARs is 200 meters. The correspondent node (CN) is a single-homed node sending traffic to vehicle, which corresponds to the services like file downloading or web browsing by mobile users and Location Manager (LM) uses by SIGMA.

6.0 RESULTS AND DISCUSSION

The simulation platform is built to evaluate the performance of the proposed handover scheme. The simulation is done with MS speeds between 1 and 40 m/s. The 40 m/s equals to 144km/h, which is above the 100 km/h limit described in IEEE 802.16e for a seamless handover. When the MS is moving to the border of one BS in a certain speed, the signal quality of the SBS begins to degrade, if the signal strength becomes low, initial handover process would be performed as handover initiation messages send, and if the signal strength is below threshold (standard 2dB) the HO process would be executed.



Algorithm 1 Cross-layer design

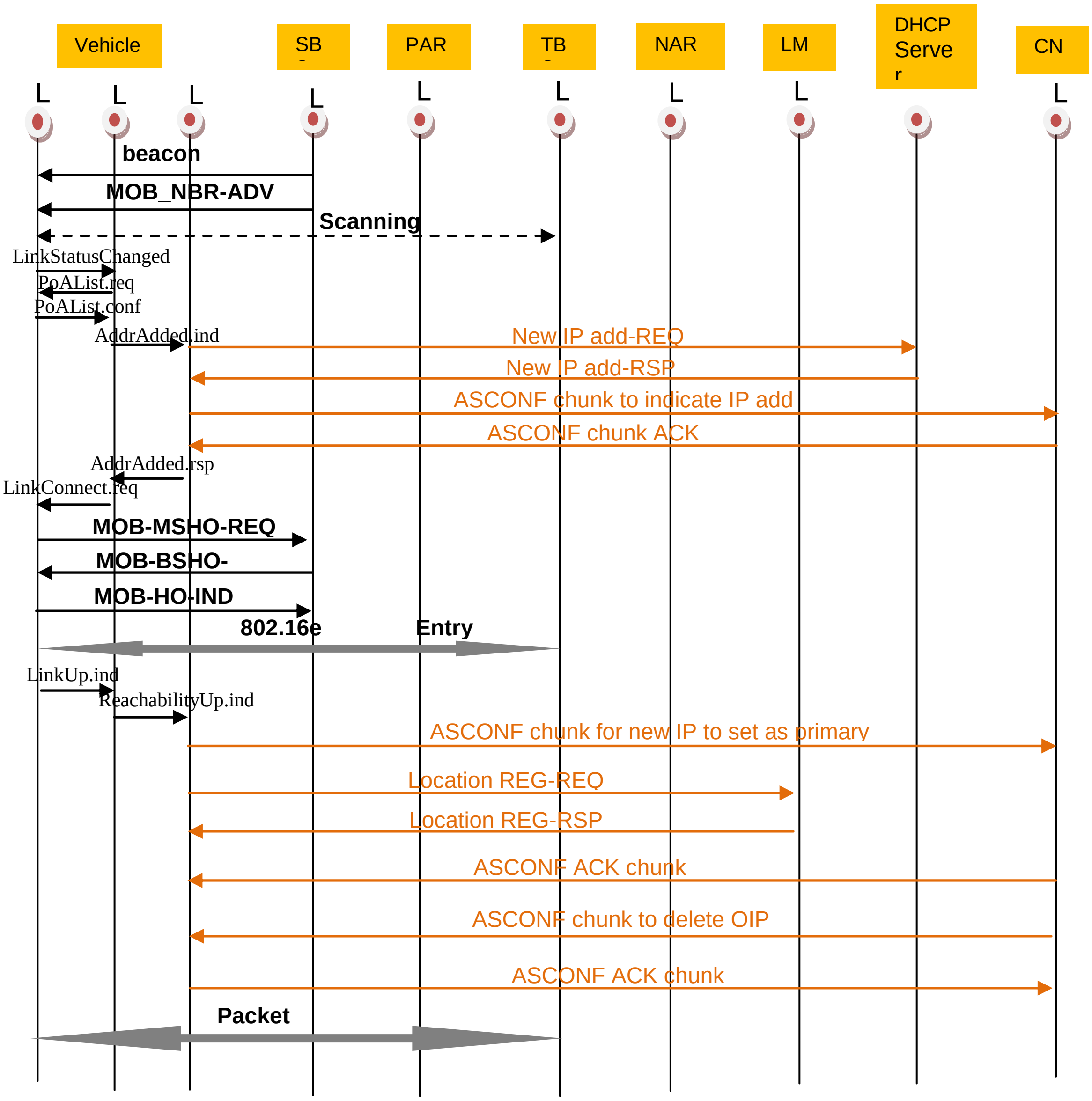


Figure 3 Timing diagram of the proposed cross-layer design

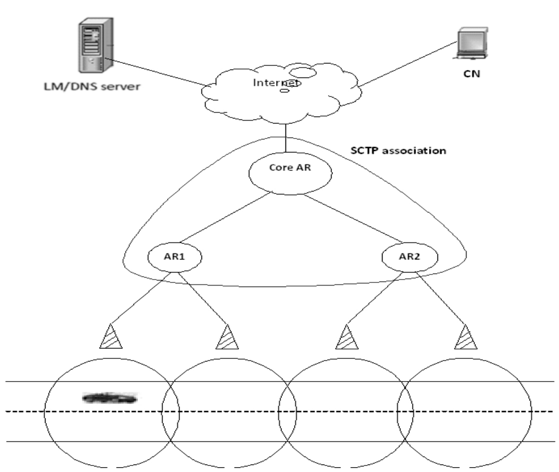


Figure 4 Network scenario

6.1 Handover Latency

Handover latency of SIGMA is very low at 15ms L2 delay [6],[7],[8]. Moreover, in high speeds vehicle SIGMA experiences more handover delay as shown in figure 5. In contrast, this proposed cross-layer design employs the selective background scan during data communication and L3 can decide next BS without waiting L2 channel scans. Figure 5 shows the difference.

This cross-layer design uses SIGMA protocol to drop DAD delay by using LM as mentioned earlier and there is not much delay to update LM. On the other hand, triangle routing problem of the packets that routing between CN and vehicle along a triangular path longer than the optimal one especially in higher speed vehicle [14], which definitely introduces higher latency and high network load. In SIGMA there are no triangle routing causes by high speeds because the CN always sends the packets directly to the vehicle's current IP address through LM.

Handover delay for this cross-layer design calculated from vehicle to CN, the disruption time due L2 is about 0.01s and it negligible for L3. For L4 it takes about 0.045 ms for ASCONF SET-PRIMARY/DEL-IP, then total disruption time:

$$T_{HO} = L2+L4 = 10ms + 0.045ms+RTT = 10.045+10 = 20 \text{ ms}$$

And the handover delay between vehicle and CN depend on RTT between both, is about 0.2s.

6.2 Throughput

We calculated the throughput of vehicle communicating to IEEE802.16e with high speed. The SCTPCD handover latency is about 25 ms as mentioned earlier. In this scenario the communication time in one coverage area of BS with high speed of 30 m/s (120km/hr) about 67 s. Thus for high speed vehicle with consecutive handover the vehicle cannot receive packets for 0.2s due to handover, and then receives packets for 66.8 s. Therefore, the throughput of SCTPCD is much better than other SCTP in the environment of highly dynamic handover, as mentioned in figure.6.

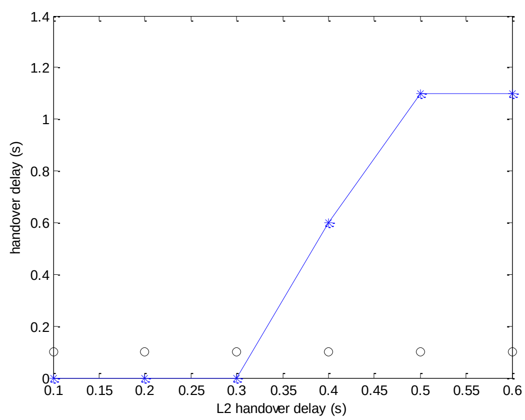


Figure 5 SIGMA & cross-layer handover latency for L2 handover latency

Table 2 Comparison of cross-layer and SIGMA throughputs for different speeds (15-40m/s)

speeds	15	40
protocols	Throughput (Mpbs)	
SIGMA	6	0.9
cross-layer	9	9

7.0 CONCLUSION

Internet accessibility in high speed vehicles as V2I has widened the use of computer and wireless communications. The QoS in such speeds is more challenging and raises the need of smaller latency. In this paper we have proposed an algorithm in order to provide seamless handover in high speed vehicles. The cross-layer is simulated in a scenario of fast moving vehicle along highway connected to the Internet. This cross-layer uses SIGMA protocol for global reachability and L2 information to L3 and L4 to support high moving speeds. The results show that the design achieves better performance when speed is high if compared to conventional SIGMA protocol.

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