An Efficient Handover Prediction & Initiation Algorithm for Vehicular Communication in 4G Wireless Networks

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***Abstract*—The main motto behind the 4G wireless epoch is to provide a mobile ultra-broadband internet access with the help of a completely standardized Internet Protocol (IP) for video, Voice over IP (VoIP) and other multimedia services. It also requires the existing mobile services to pullulate into an open Mobile Cloud which can be used by all the providers. Vehicular networks can also be used to obtain information from the Internet which is not directly related to travelling. So numerous number of applications like surfing, email, gaming etc. can find its way into these wireless vehicular networks. In this paper we discuss the network mobility mechanism used to support the movement of nodes which changes its point of attachment to a fixed infrastructure from time to time, thus developing an efficient handover prediction and initiation algorithm for vehicular communication in 4G wireless networks. Here the handover is predicted using the route travelled (database) and it is initiated with the help of threshold values in both the scenarios. Until the threshold value is reached, the handover initiation can be postponed (made to sleep), without any need to check whether we are within the boundary of the current Access Router (AR) or not, thus saving a substantial amount of resource usage. By this way, the Mobile Router (MR) forebodes the handover, even if the current connection with the AR is still active.**

***Keywords*—4G, handover prediction & initiation, mobility characteristics, NEMO, vehicular networks.**

I. Introduction

The advent of wireless technologies has made a fiery impact in our lives in more ways than we can imagine. It provides a compact and collective broadband solution to wireless devices for providing ultra-broadband internet access and streamed multimedia. With the advancement in the technology where the world is today moving towards 4G, the usage of internet services for applications inside vehicles has become imperative. Currently vehicular communication makes use of Dedicated Short Range Communication (DSRC) devices for providing information related to safety warnings and traffic. The vehicular communication system is primarily used for accomplishing safety through Intelligent Transportation Systems (ITS) by enabling communication between mobile nodes and fixed nodes. As with many other communication networks, vehicular networks also need to evolve with time to provide the next generation multimedia support by integrating internet into it for obtaining content and services.

Though an IP-based WLAN can be configured to allow public access through mobile devices as discussed in [1], it is always tied to a single access point which deters the mobility factor in vehicles.

The advantage of using the concept called 4G connected car and the use of this technology in Russia has been discussed in [2]. In the vehicles that uses this concept, consumers would be able to access to internet and other applications putting an on-demand entertainment and other travel related information.

The compatibility (electromagnetic compatibility) of mobile communications equipment with the vehicle environment has also been a matter of discussion [3]. Communication gateway architecture has been proposed to enable services and applications within the car to transparently use different wireless communication systems [4].

The most common problems in such kind of vehicular communication is connectivity failure in case of contiguous cell scenario and considerable service disruption time in case of non-contiguous cell scenario. The other problems include fallible system which fails to perform faster prediction and re-association, increased usage of system resources, loss of packets due to handover, repeated handovers and overheads associated with packet forwarding.

We overcome these problems with the help of an efficient handover prediction and initiation algorithm for vehicular communication in 4G wireless networks which addresses efficient handovers in contiguous and non-contiguous cell scenarios. In this algorithm, we make use of the threshold values and the handover distance to predict the next AR, pre-route the packets to the next AR and initiate the handover thus providing seamless connectivity in case of contiguous cells and reduced service disruption time in case of non contiguous cells.

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Since the path is set to be a predefined one, the position of access routers is known well in advance, thus making the system even more reliable and robust for faster prediction and re-association if the connectivity fails.

The usages of resources are made optimal by making the probing system sleep once the next AR is predicted. Pre-routing the packets to the new AR obviates the overheads involved in packet forwarding when compared to forwarding packets from the cache of old AR to that of the new AR as discussed in Inter Access Point Protocol (IAPP) in [5].

Numerous other handover techniques have also been proposed to support mobile internet with the quality of service constraints within 4G [6]. A radio-locating Intelligent Mobile Data Networks (IMDN) which renders quick and precise information about the mobile user's location has been discussed in [7].

The rest of the paper is organized as follows. The second section describes the Network Mobility under 4G wireless networks. The third section describes the efficient handover prediction and initiation algorithm that is being proposed. A subsequent section consists of performance evaluation and advantages of the proposed scheme. Last section presents our conclusion.

II. Related Works

Various methods to reduce the unnecessary handovers in cellular systems and keep the quality of service intact have been presented in [8] and [9]. It initiates the handovers at fixed sampling intervals and also derives a mathematical formulation to determine the appropriate time for handover initiation by the mobile.

To achieve faster handovers, an improved handover scheme has been proposed to reduce the latency introduced in the handover process, by shortening the scanning and enhancing the network re-entry where scanning is required to find a suitable target BS, and network re-entry is needed to establish the new connection [10]. Here the scanning strategy reduces the delay by reducing the number of neighbor BSs to be scanned. This is done by approximating the rough location of the Mobile Station (MS) which enhances the network re-entry.

Even the efficiency of the handover prediction can be improved based on monitoring the frequency of previous handovers between pairs of base stations by investigating an efficiency of target base station prediction for several scenarios [11].

Improvement in handover prediction can be achieved by monitoring the signal quality between the mobile station and all the base stations in the neighborhood by using two thresholds for selection of the most likely target base station [12]. The prediction efficiency is strongly influenced by the number of neighboring BSs. The twice the increase of neighboring BSs leads to the drop of the prediction efficiency. A process has been defined for generating a link-local address, site-local and global addresses via stateless address auto-configuration, and the Duplicate Address Detection procedure [13]. It specifies the steps a host take, in deciding how to auto-configure its interfaces in IP version 6.

Many other extensions to mobile IPv6 and protocol enhancements have been proposed in [14] and [15] to minimize the handover latency and packet loss in addition to our proposed scheme as discussed in the previous section.

III. Network Mobility Under 4G Wireless Networks

Driven by the success of wireless technologies, mobility has canned its wired contemporaries. As the Internet has become more and more omnipresent, mobility will no longer be restricted to a single terminal anymore. So this should be supported with the help of a network that allows the mobile node to change its attachment point to a fixed base from time to time. This is known as network mobility in IP networks.

Network Mobility in which the attachment point of the node to the internet varies with time has been discussed in [16]. It also helps to maintain the session continuity in the mobile nodes.

In this scenario, there exists at least one MR that is connected to the fixed infrastructure and mobile devices are connected to the fixed infrastructure through this mobile router. Such a network whose attachment point to the internet varies with time is called mobile network. This is also known as NEMO (a network that moves).

The NEMO protocol creates a bidirectional tunnel between the MR and Home Agent (HA) to provide transparent mobility support to a complete network as shown in Fig. 1. The end of the bidirectional tunnel at the MR's side needs to be updated each time the mobile network moves to know the current location and also periodic updating to refresh the binding at the HA. This update is accomplished by exchanging the binding-update [17] and binding-acknowledgement messages between the MR and the HA.

There is only one exchange of information possible at a given time irrespective of the number of Mobile Network nodes (MNNs) attached to the MR.

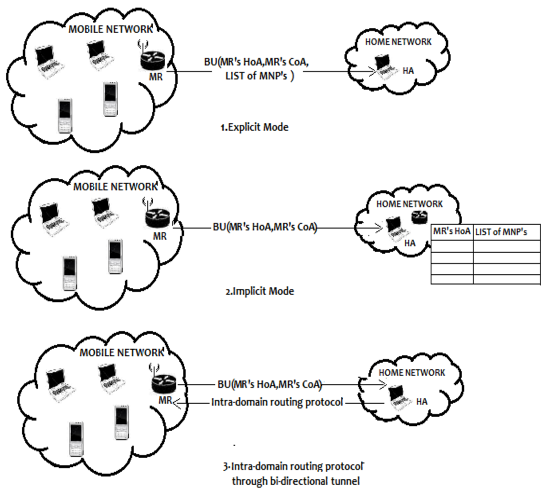

Figure 1. NEMO basic modes of operation

HA determines prefixes belonging to the MR in three different ways as shown in Fig. 1:

- *Explicit mode:* MR sends a binding update message to the HA which includes MR's home address, Care of Address (CoA) and the list of Mobile Network Prefixes (MNP) where MNP is the address which remain assigned to the NEMO when it is away from the home although it has a topological meaning only when the NEMO is at home.
- *Implicit mode:* MR sends a binding update message to the HA which includes only MR's home address and CoA but not the list of MNPs. Here the HA determines the MR's MNPs using a mechanism of its own.
- *Bidirectional tunneling:* MR and HA can run an intra-domain routing protocol between each other through a bidirectional tunnel and they can continue to run the same protocol that it ran at the time of connection with the HA.

IV. Efficient Handover Prediction and Initiation

This section introduces basic vehicular network mobility characteristics, the protocol architecture, constraints in implementation and the handover prediction and initiation algorithm.

A. Vehicular Network Mobility Characteristics

The unique high mobility characteristic of vehicular networks degrades the performance of Internet and Mobile ad hoc network (MANET) integration into vehicular networks because of the different transmission characteristics and penetration rates as discussed in [4]. Thus mobility management solutions are required specifically for vehicular networks.

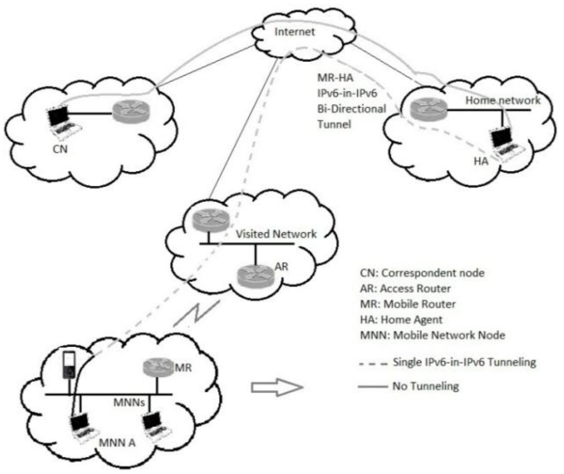

Figure 2. General model for vehicular networks

The requirements are identified and vehicular networks are classified into three scenarios namely Vehicle to Vehicle communication (V2V), Vehicle to Roadside communication (V2R) and Vehicle to Infrastructure communication (V2I) as shown in Fig. 2.

Vehicular Communication Systems are an acclivitous type of networking technology in which vehicles and roadside units act as the communicating nodes.

V2V and V2R communication techniques are suited for active-safety and real-time situation awareness as well as other applications.

As with many other communication types, Vehicular to Infrastructure communication (V2I) can be used for various purposes like web surfing, file downloads, Email, gaming and many more by integrating it with internet. Then virtually every application in internet will find its way through the vehicular networks.

B. NEMO Protocol Architecture

NEMO is a network that moves where the attachment point of the mobile nodes to the internet varies with respect to time.

The router within the NEMO that connects to the internet is called Mobile Router (MR). The place where a node resides when it's not moving is called Home Network and a Care-of-Address (CoA) is the one that is received from the visited network.

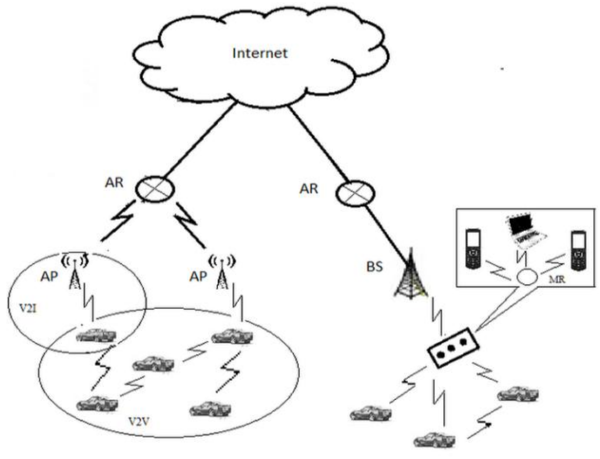

Figure 3. Example of basic NEMO operation

The packets addressed to a mobile node's home address are actually routed to its CoA. These Mobile IPv6 nodes [18] acquire their CoA through the address auto configuration technique discussed in [13]. Consider a Correspondent Node (CN) exchanging IP datagram with Mobile Network Node (MNN) A in Fig. 3. Then the following operations are involved in the communication:

- The correspondent node transmits an IP datagram destined for MNN.
- This IP datagram is encapsulated inside a new IP datagram by a special node located on the home network of the NEMO, called the Home Agent (HA).
- The new datagram is sent to the CoA of the mobile router, with the IP address of the home agent as source address. This encapsulation preserves mobility transparency (that is, neither MNN nor the CN are aware of the mobility of the NEMO) while maintaining the established Internet connections of the MNN.
- This encapsulated IP datagram is incurred by the MR, which in turn decapsulates the datagram and sends the original datagram to MNN.
- The operation is analogous in the opposite direction.

One of the main advantages of using the NEMO Basic Support Protocol, on the mobile router of every node of the mobile network, is that the signal generated by a complete moving network (consisting of a number of nodes) is the same as the one generated by a single moving node. Association of nodes from cell to cell as it moves has been discussed in [19].

C. Routing and Resource Constraints

The two particular mobility constraints in this proposed scheme for vehicle to infrastructure communication are as follows:

- The route or the pathway followed by the vehicle is considered to be a predefined path where it can't take any route other than the predefined one. This constraint is used for installation of Access Routers (ARs) at appropriate places.
- Public mobility is generally considered to be regular and iterative as it won't change from its allotted route (e.g. Buses, flights)

Information such as the path to be taken and the direction to be proceeded with can be known in advance with the help of database as the public vehicle is said to take only this predefined pathway.

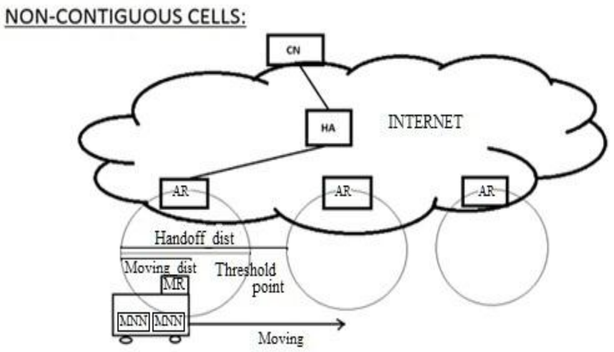

Figure 4. Non-contiguous cell scenario

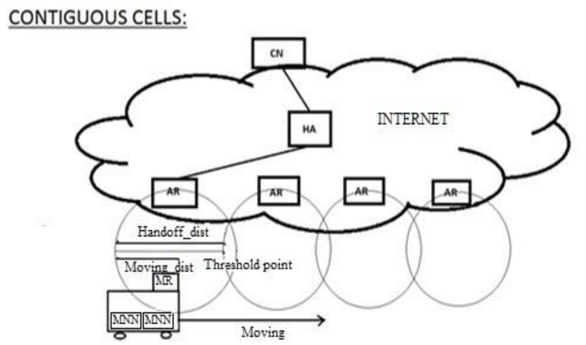

Figure 5. Contiguous cell scenario

D. Handover Prediction and Initiation

An efficient handover prediction and initiation algorithm for vehicle communication in 4G wireless networks is proposed for both contiguous and non-contiguous cell scenario as shown in Fig. 4 and Fig. 5. Let the distance at which the handover should take place from the beginning of the current cell be the handover distance. It is represented as handover_dist. Let the distance moved so far in the current cell be the moving distance. It is represented as moving dist and the location at which, a slightly stronger signal level or a zero signal strength is detected is considered to be the threshold point.

To set a pathway for the vehicle and to determine the position of the vehicle at various time intervals, we make use of a traffic mobility model named waypoint mobility model. It determines the sleep time for optimal resource usage during handover prediction and initiation mechanism where sleep time is the amount of time for which the probing system is made to sleep without any need of checking for the next AR.

Each object determines its velocity and position at a given time from a set of Waypoint objects which are assigned manually along a route. We can add up as many waypoints as we want to make the movement easier to predict (under the constraint that it does cause any overhead). For example, we can add waypoints at time t1, t2 and t3 so on at different position vectors (m1, m2, m3), (n1, n2, n3) and so on. We can assume the object to move with a constant velocity between the waypoints. As per the mobility model, waypoints can be added whenever necessary and it is also possible to stop the object for a given amount of time at any particular waypoint.

Determine the Source and the Destination for the vehicle. Source and destination are initialized as waypoints at first. Add waypoints between the source and the destination to set up a predefined path. Set 2 waypoints at same position with different times to make a node hold a certain position for a time interval so that the vehicle can stop for a while at these waypoints.

```
Pathway () {
    AddWaypoint (source, pos, time);
    AddWaypoint (dest, pos, time);
    AddWaypoint (Waypoint (Seconds (t1), Vector (m1, m2, m3)));
    AddWaypoint (Waypoint (Seconds (t2), Vector (n1, n2, n3)));
    SetPosition (Vector (n1, n2, n3), time (t1), time (t3));
    Discard past waypoints.
    Notify (Coursechange(dir,vel));
    CourseChange (direction,velocity);
    Determine the position at various time intervals
}
```

Figure 6. Setting up the pathway for the vehicular movement

Fig. 6 depicts the setting up the pathway between the source and the destination. Movement of the object between the waypoints is assumed to be at a constant velocity and the past waypoints are discarded. Notify the vehicle when there is a need to change the direction of the vehicle. Determine the position at various time intervals to keep track of vehicular movement.

When a MR enters into an AR's boundary, MR starts predicting the next AR. This is done by making use of the threshold values from the database.

Initially MR will check whether difference between the handover_dist and moving_dist is considerably lower than the threshold value. If it satisfies then next AR is predicted. Once predicted, the probing system is made to sleep for a time t2 which is little less than time t1, where t1 is the time taken to cover the distance between handover_dist and moving_dist. It needs to wake up the system earlier in order to perform the 3-way handshake for connection setup and also for pre-routing packets thus reducing the service disruption time involved in case of non-contiguous cells and increased seamless connectivity in case of contiguous cell scenario. When handover_distance is reached, association with the next AR is performed. In the association part, MR will pre-routes the packets to the predicted new AR and it's inform to the HA. Registering the MR with predicted AR to get CoA for MR. The association is calling recursively till we get a response because the response might get lost due to radio interference in the air. In Fig. 7, the prediction and initiation of the handover is described.

```
   Handover_predict()
{
   if ( (moving _dist) <= threshold value of the current  cell)
   {
      Predict the next AR ();
   }
   if (moving_dist< handover_dist)
   {
       Sleep (t2);
   }
   Handover_association (predicted AR);
 }
Handover_association (AR)
{
 Register MR (mobile router) with new predicted AR;
 if (response time >= advertise_time _interval)
 {
     Handover_association(AR);
 }
   Associate with the new AR;
   Inform the HA (home agent);
}
```

Figure 7. Handover prediction and initiation

After having done the required handover prediction and initiation steps, various applications like browsing and downloading can find its way into vehicular communication. This is done by the use of NEMO basic support protocol.

The Correspondent Node (CN) exchanges IP datagram with the MNN through the MR. the CN transmits the datagram destined for MNN to the HA, where it is encapsulated to preserve mobility transparency (that is, neither the MNN nor the CN are aware of the mobility of the NEMO).

```
CN_to_MNN_Transmit()
{
   Determine the destination MNN
   CN transmits IP datagram to HA;
   HA.encapsulate(IP datagram);
   MR.decapsulate(IP datagram);
   MR transmits IP datagram to MNN;
}
MNN_to_CN_transmit()
{
  MNN transmits IP datagram to MR;
  MR.encapsulate(IP datagram);
  MR transmits IP datagram to HA;
  HA.decapsulate(IP datagram);
  HA transmits IP datagram to CN;
}
```

Figure 8. Data transmission

This encapsulated datagram is then decapsulated at the MR by removing the outer IPv6 header and sent to MNN. The operation involved in transmission of IP datagram in the reverse direction (from MNN to CN) is similar in nature. Fig. 8 details the data transmission between the CN and the MNN.

V. Performance Evaluation and Advantages

Performance is evaluated by means of seamless connectivity, reduced service disruption time, robustness, optimal resource usage, reduced packet loss and overhead elimination. By reducing the handover delay, we can guarantee the connection continuity.

A. Performance Factors

1). Seamless connectivity: Reduced packet loss can be ensured by the seamless connectivity of the vehicle in case of contiguous cell scenario. And this can be done by fast re-association with new AR. The proposed scheme predicts the next AR, initiates the handover, and associates the MR with the next AR through binding and thus performing faster registration to get seamless connectivity.

2). Reduced service disruption time: In case of non-contiguous cells scenario, this proposed scheme reduces the service disruption time generated due to the handover between two different cell ranges of the ARs.

3). Robustness: Robustness can be ensured by faster prediction and re-association with the AR in case of failure in connection or disconnected network.

4). Optimal resource usage: Usage of resources can be made optimal by putting the probing system to sleep for a given amount of time as mentioned before.

5). Eliminates overhead: Overheads can be removed by pre-routing the packets to the new predicted AR instead of forwarding the entire packet from the old AR to the new AR at once.

6). Reduced handover delay: In normal schemes, the MR has to wait for the acknowledgement for its Router Solicitation message which when may not get transmitted due to transmission errors. In that case Router Solicitation message is sent at regular intervals to get the response. This increases the handover delay.

In the proposed scheme, there is no need for the MR to wait as it operates mainly on the basis of distance traversed so far in the given path and thus making faster prediction and association and reducing the handover delay involved in it.

B. Results and Discussions

The path to be taken by the vehicles has been designed with waypoint mobility model using ns3 simulator. Sleep time required to put the probing system into sleep is calculated from this mobility model using the graph derived from the simulation results as tabulated in Table I.

The simulation values are plotted to get a graph as shown in Fig. 9, from which we can determine the position of the vehicle at different time stamps which is in turn used to determine the appropriate sleep time and time of handover prediction.

Similarly a graph is plotted for depicting the vehicular mobility when the movement is irregular (not along one direction) as shown in Fig. 10.

TABLE I. SIMULATION RESULTS FOR VEHICULAR MOVEMENT ALONG THE XZ PLANE FOR 16 DIFFERENT WAYPOINTS (ALONG ONE DIRECTION) BETWEEN SOURCE AND DESTINATION

X Coordinate (position)	Y Coordinate (sec)	Z Coordinate (position)
0	0	0
0.5	3	-1
1.16667	7	-2.3333
1.83333	11	-3.6667
2.5	15	-5
3.16667	19	-6.3333
3.83333	23	-7.6667
4.5	27	-9
5.16667	31	-10.3333
5.83333	35	-11.6667
6.5	39	-13
7.16667	43	-14.3333
7.83333	47	-15.6667
8.5	51	-17
9.16667	55	-18.3333
9.83333	59	-19.6667
10	60	-20

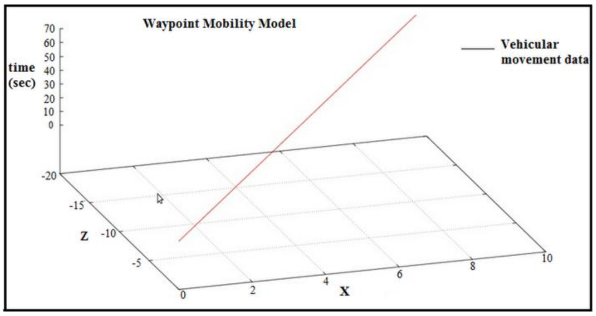

Figure 9. Graph depicting vehicular movement in XZ plane with respect to time stamps along y axis which is used to determine the sleep time for probing system

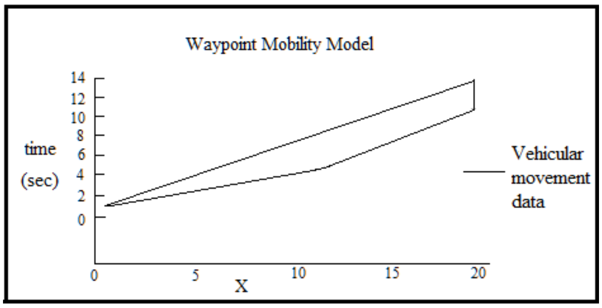

Figure 10. Graphical representation of irregular vehicular mobility (not along one direction)

C. Performance Measure

The performance of this handover prediction and initiation scheme is almost twice as compared to the performance of any other normal scheme that is currently under use. This is shown in Table II.

The values are plotted as a graph as shown in Fig. 11 to depict the variation in curves in terms of connectivity against delay time for both the proposed and existing scheme.

This is because there will be no need for the router advertisement messages to wait for the detection of ARs in the neighborhood as we use a prediction scheme and hence the entire time taken for re-association will also be half the time taken for re-association in normal schemes. Connection continuity decreases with the increase in delay time.

The delay time referred here mostly includes the advertisement time interval, service disruption time, time taken to recover from probing system failure and time taken to route the packets to next AR for achieving session continuity and reliable communication.

TABLE II. COMPARISON OF THE PERFORMANCES

Delay time (sec)		Connectivity (proposed scheme) (kbps)	Connectivity (existing scheme) (kbps)
5.5		21.5	10
5		25	12.5
4.5		27.5	14
4		30	15.25
3.5		32.5	20
3		38	22.5
2.5		43	25
2		50	32.5

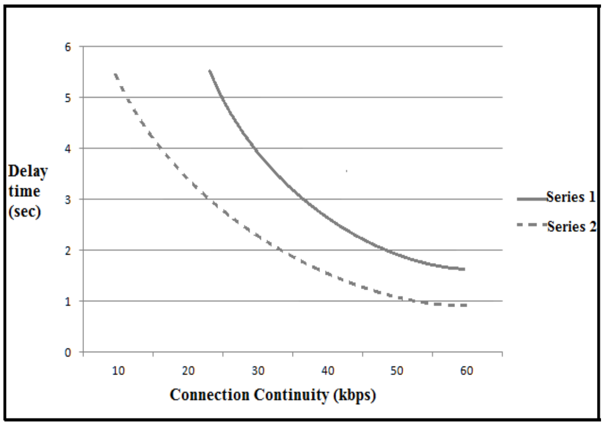

Figure 11. Performance comparison of the proposed scheme (Series with that of the present day (Series 2) mobility schemes (Theoretical analysis)

D. Advantages

In addition to the features mentioned above, the proposed scheme also performs the 3-way handshake mechanism at some time t before the entry of the MR into the new predicted AR. In discontinuous cell scenario, since the next AR is predicted in advance, the packets are routed to the new predicted AR when the MR is in the area of no coverage. So when the MR enters the cell region of the predicted AR, all the packets are routed from this AR to the MR. Pre-routing the packets also reduce the overhead involved in forwarding the packets.

VI. CONCLUSION

This paper proposes an efficient handover prediction and initiation algorithm in 4G wireless networks and evaluated to use in vehicular communication. It is used for transmitting large volumes data to the mobile network nodes in public vehicles. Since the direction and path to be taken for the predicted AR can be known in advance, the location and the position at which the handover should be initiated are known. In this way it enables fast re-association to the new AR, thus providing uninterrupted connectivity, shortened service disruption period and optimal resource usage with reliable communication. The future work can be focused on the analysis and optimization of prediction techniques utilizing the signal parameters [19]. This proposed work can also be extended to the usage of vehicles which keep changing routes dynamically instead of taking a predefined route.

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