Hybrid Routing Scheme for Vehicular Delay Tolerant Networks

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***Abstract*—In Vehicular Delay Tolerant Networks (VDTN) connection from source to destination at any required period is not necessarily available. Therefore, the node with the message, save it in its own buffer and carry it until an opportunity comes across for forwarding. Fix nodes enhances the performance of VDTN. It helps in message storage and relaying messages. Due to mobility the bit error rate is high in mobile nodes connection but it is not considered in any of the previous routing schemes for VDTN. The connection between fix nodes will always have low bit error rate as compared to connection involving mobile nodes. All the pervious schemes are one dimensional. Environmental hindrances are not taken under consideration as well. Its effect can be both negative and positive. In this paper, a scheme titled Hybrid routing scheme is suggested to overcome the above stated problems. Features of another vehicular network called Vehicular Ad Hoc Networks (VANETs) are added to Maximum Priority (MaxProp) routing scheme for VDTN. Different propagation models of VANETs are implemented for both with and without mobile node communication for VDTN. The concept of bit error rate is also featured in Hybrid routing scheme. This makes Hybrid routing scheme two dimensional and more intelligent. The implementation and performance assessment of the proposed scheme is evaluated via Opportunistic Network Environment (ONE) Simulator. The Hybrid routing scheme outperform MaxProp in terms of the delivery probability and delivery delay.**

***Keywords*- bit error rate; hybrid routing scheme; maximum priority; opportunistic network environment; vehicular ad hoc networks, vehicular delay tolerant networks**

I. Introduction

Internet is the key source of communication. Internet enables communication and data transfer with the help of protocol suites called Transmission Control Protocol/ Internet Protocol (TCP/IP). Communication with TCP/IP will be through some linkage i.e. wireless links or wired line or satellite, etc. TCP/IP assumes that end to end path between source and destination is available through some defined path. This type of communication have low error rate and symmetrical date rate but it cannot endure variable and high delay [1], [2].

If the situation is not ideal than end-to-end path is not available and network is having high error rates, high delay and asymmetrical data rate. In this type of situation TCP/IP based internet fails. Then there is a need of disruption, delay and disconnection tolerant network, which give rise to the concept of Delay Tolerant Networks (DTNs) [3]. DTN is a help where end to end connectivity is a problem. DTN is concern with *"How to address the architectural and protocol design principles arising from the need to provide interoperable communications with and among extreme and performance-challenged environments where continuous end-to-end connectivity cannot be assumed"* as defined by Delay Tolerant Networking Research Group (DTNRG) [4].

Communicating while moving is increased in last few years with the increase in portable devices like smart phones and laptops etc. Usually cars nowadays are equipped with devices for communication with other nodes and vehicles [1], [2]. Vehicular Ad Hoc Networks (VANETs) are used for communication involving vehicle [5], [6]. This network is based on the assumption of end to end path availability between source and destination. VANETs fail where the nodes are sparse, partially and intermittent connected. The unpredictable nature of the mobile nodes is also a problem which VANETs cannot address.

Vehicular Delay Tolerant Networks (VDTNs) is same as VANETs with having the store-carry and forward model of DTN [1]–[3]. It connects the heterogeneous networks. With this end to end connectivity is not assumed but is assumed to be available at some time. Due to mobility of vehicles the contact period is too small. If destination node is not in the range of source node, then the source node will take the help of intermediate nodes to reach destination node. Intermediate nodes can be any mobile node within range or/and fix nodes i.e., access points (APs) or Road Side Units (RSUs). Fix nodes boost the performance of VDTN [7], [8].

When we add fix nodes in the network then the VDTN networks have three types of communication i.e. vehicle to vehicle, vehicle to fix node and fix node to fix node. The existing VDTN routing schemes are one dimensional. The bit error rate (BER) is always different for stationary node and mobile node. The existing schemes do not consider the stationary node as a stationary node because it has the same BER for communication involving mobile node and the communication not involving mobile node. The BER of communication not involving mobile node will always be less than that of communication involving mobile node. This is the one dimensional nature of schemes which give rise to the problem that result in high BER and in return affects the performance of the network. Secondly, the environmental factors are also not considered in any of the VDTN routing schemes. In actual situations the stage is not always even. The surrounding does have obstructions such as buildings etc. which may entirely block the line of sight and obstetrics the data to be delivered. These do affect the communication and path loss occurs. This path loss factor is not considered in any of the schemes. Distances between the nodes which are communicating also affect the data rate and BER. Increasing the distance among communicating nodes, the received power do flow down in actual scenarios. The interference also affects the transmission in a negative manner but its effect can also be constructive as deflected signals can also reach destination node. Due to this the data can reach the destination on multiple paths which will have positive impact on network. All these factors are the problems when a communication will come through. Considering these issues in designing a routing scheme and testing its routine in software simulations may not give precise results and the outcome of the simulation results cannot indicate the real world scenarios. Therefore, a routing scheme is needed to overcome all these problems.

The Hybrid routing scheme is proposed in this paper to overcome these problems. The VDTN routing scheme is hybrid with the features of VANETs. The propagation models of VANETs are implemented for VDTN. The one dimensional nature of the all pervious schemes is enhanced by using two different propagation models for communication with model node and without mobile node.

The rest of the paper will follow the following pattern. The next Section will give a detailed overview of the background. Section III presents the proposed scheme namely Hybrid routing scheme. In Section IV the performance and impact of the proposed scheme and result will be analysed. Section V concludes the paper and gives future research directions

II. BACKGROUND

A. Delay Tolerant Networks

In Delay Tolerant Networks (DTN) there is no end-to-end connection between the nodes but it do exist over time. DTN works on store carry and forward mechanism [9]. Node stores the data in its buffer and forwards it when encounters another node and link is established. For this store and forward mechanism Bundle layer is introduced in the TCP/IP stack above the transport layer [5]. For Vehicular Delay Tolerant Networks (VDTN) this Bundle layer is above the data link layer in order to combine the incoming IP data packets into bundle messages [9]. This bundle packet has many IP packets of common features.

The Bundle protocol does not help in the routing of the data between the nodes [1], [2]. For this purpose we need to have routing schemes which can describe of how the data will be routed in the network. Direct Delivery scheme is the simplest of all. In this scheme the source node carries the data until it meets the destination node. It does not forward it to any other node accept the destination node itself. In First Contact routing protocol the source node forwards the data to the first node which it encounters in order to find destination node randomly. In Epidemic routing the data is forwarded to every node which does not have it and comes in contact with the node which has it. It maximizes the delivery ratio but at the cost of storage and bandwidth wastage. Surrounding routing is same as epidemic but the nodes which are in the surrounding of destination node will keep the data longer than other nodes [2], [3]. Spray and wait routing protocol [2] forward j copies of the message/data. In normal spray and wait source node give one copy to each other node it encounter and in binary spray and wait half of the copies are forwarded to contact node. When one copy is left then it is directly delivered to the destination node. This protocol limits the replication of data. Probabilistic Routing Protocol using History of Encounters and Transitivity (PRoPHET) scheme [10] depends upon the past encounter history of the nodes. The node X will only transfer the data to node Y if it estimates that node Y has higher probability to deliver the data to the destination node.

B. Vehicular Delay Tolerant Networks

Vehicles change their position, speed and direction frequently because of this the contact time between vehicles is too short, so whenever there is a contact opportunity, full opportunity should be taken to transfer larger packets of data. There may be longer delays because of a node carrying data might not meet another node for a longer time. The two nodes in contact may not have synchronized transmitter and receiver antennas. The existing Vehicular Ad Hoc Networks (VANETs) fails where the delay is long and frequent disconnection of end-to-end connectivity where node density is low. Vehicular Delay Tolerant Networks (VDTN) is vehicular networks which take the data routing to the next level, where VANETs fails to deliver. VANETs assume that end-to-end path exists while in VDTNs it is not, this is the basic difference between these two vehicular networks. VDTN is the subset of delay tolerant networks (DTNs). The concept of store, carry and forward model and bundle protocol are the main features of DTNs, which are also featured in VDTNs with some exceptions.

Beside the above discussed routing schemes there are few other routing mechanisms specifically designed for VDTNs. As VDTN involves vehicles so their speed, mobility and their location has to be taken into account while designing a routing scheme. Maximum Priority (MaxProp) [11] work on the same principle as DTN networks: store-carry and forward. It floods the data to other nodes and once that data is received by the destination node the MaxProp protocol clears all the other copies of the same data. In MaxProp the data exchange between the nodes is in the specific order which depends upon the data hop counts and probability of the data delivery by that node to the destination node on the bases of their past encounters. Probabilistic Bundle Relaying Scheme (PBRS) [12] is a VDTN routing protocol which is infrastructure assisted i.e. Roadside Units (RSUs). Practically there are some blind areas between two RSUs. So if RSU_1 wants to send data to RSU_2 it must relay it through mobile node in order to carry that data through that blind area. The RSU_1 will calculate speed of the mobile node. If there are two mobile nodes it will forward data to the mobile node with a higher speed. Adaptive Carry-Store Froward (ASCF) routing protocol works on the same theme as PBRS but it overcome the outage time problem [2]. This work take the same example from above, when RSU_1 start forwarding data to mobile node M_1 and M_1 is leaving the coverage area of RSU_1 while the data transfer is not complete.

The RSU_1 will select another mobile node M_2 within its range to relay the remaining data to M_1. The selection of M_2 is based on that how long it can connect RSU_1 to M_1. In the Distance-Aware Routing with Copy Control (DARCC) routing protocol, if the location of the destination node is known then the data is transferred to that node which is nearer to the destination node [2]. If not then DARCC sprays data in different directions. Geographical Opportunistic Routing (GeOpps) [13] enhances the performance of the single copy routing in VDTN. GeOpps uses the geographical location of the node. It forwards data to the node which is going to the destination node or the point near to it; this point is called nearest point and is used to calculate the Minimum Estimated Time to Delivery (METD). It is defined as

$$METD = \text{Time to nearest point} + (\text{Remaining Time} / \text{Average Speed}) \quad (1)$$

The data will be forwarded to the node having lowest METD. Geographical Spray (GeoSpray) [14] in VDTN is the GeOpps with multi copy and multi path routing. It uses the theme of Spray and waits protocol to first find the destination path than it uses single copy scheme. Its delivery ratio is better than GeOpps but has high overhead than it but still less then epidemic.

III. Proposed Routing Scheme

In VDTN routing protocols the stationary nodes are also considered same as mobile nodes. Its data rate is same as mobile nodes communication. This in turn increases the BER in network and decreases the delivery probability. In real world scenarios the platform is not always smooth. It does have some obstacles which may completely block the line of sight and obstetrics the data to be delivered. Distances between the nodes which are communicating also affect the data rate. With the increase in distance between communicating nodes the transmission speed do flow down in real world scenarios. The interference also affects the transmission in a negative manner but its effect can also be positive as deflected signals can also reach destination node. Due to this the data can reach the destination on multiple paths which will have positive impact on overall network. All these factors are the real world problems which a communication will come across. So by not considering these factors while designing a routing protocol and testing its performance in software simulations may not give accurate results and the outcome of the simulation results cannot imply real world scenarios. So a routing scheme is necessary to address these problems.

All the VDTN routing protocols up till now have neglected the effect of obstacles, buildings blocking line of sights and distance between nodes in communication. The intention of this work is to find and have the effect of these factors. VANETs are another example of vehicular networks. Much research has been down to find the effect of obstructions in VANETs. But up till now none of these factors are consider in any of the VDTN routing protocol and VDTN simulators like Opportunistic Network Environment (ONE) simulator [15]–[16]. In this work we combine some features of VANETs routing protocols with the routing protocols of VDTN and implemented them in ONE simulator in order to have the effect of the above said problems. There are different types of propagation models for VANETs like Log-Normal Shadowing model, Rayleigh fading model, Nakagami Model etc. [5], [7], [17]. There can be three types of communication in VDTN i.e. vehicle to vehicle, vehicle to fix node and fix to fix node communication. The work has used VDTN routing scheme MaxProp and have changed some of its features. The Log-Normal Shadowing Model and Rayleigh Model are implemented in ONE simulator. For communication between fix nodes the propagation model used is Log-Normal Shadowing while for vehicle to vehicle and vehicle to fix node communication the propagation model used is Rayleigh Model.

As up till now in VDTN, the routing schemes are one dimensional. So the mobile node data rate and BER and the fix node data rate and BER are the same. It considers all the nodes in the network, whether mobile node or fix node, as mobile node. This is reason for higher BER in VDTNs, which affects the overall network performance. Two different propagation models are used to check whether it is fix to fix node communication or mobile node is involved in it. If both communicating nodes are fix nodes the scheme will switch to the Log-Normal Shadowing propagation model and the BER will be low as compared to that of communication involving mobile nodes for which the scheme will switch to Rayleigh fading propagation model.

A. Algorithum

The main steps to implement the proposed routing scheme are as follows as well as shown in Fig. 1:

- It checks whether any nodes are within the range.
- If within the range then check that any node is mobile in this communication or not.
- Received signal power is calculated for every node *X* using propagation model, if it is within the communication range of another node.
- Bit energy (Eb) is found using received signal power.
- BER is calculated using modulation technique. Binary phase shift keying (BPSK) modulation technique is used.
- After having the BER value, it is multiplied with transmitted bits in that communication to find total error bits in that communication.
- Then randomly selected bits equal to the value of total error bits are retransmitted.
- This process is repeated every time when two nodes exchange data.

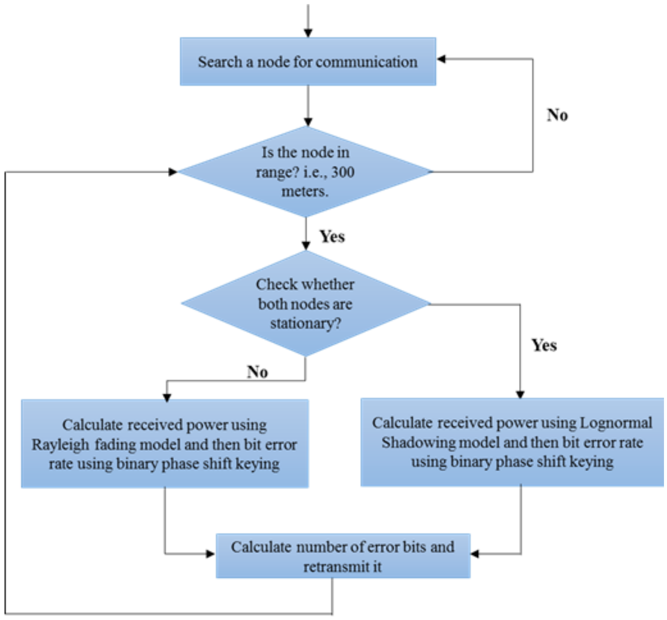

Figure 1. Flowchart of the proposed routing scheme.

TABLE I: SIMULATION FRAMEWORK

Simulation Parameter	**Value**
Scenario run time	43200 seconds
Area of map	10000 x 8000 meters
Number of groups	25
Number of nodes	74 (40 cars, 14 fix nodes, 20 buses)
Routing scheme	MaxProp, Hybrid Scheme
Wireless technology	WiFi (IEEE 802.11p)
WiFi range	300 meters
Velocity of mobile nodes	2.7 to 12 meter/ second
Mobility model	Car movement, bus movement, shortest path map based movement, map based movement
Time to live	50, 100, 150, 200, 300, 400 minutes
Buffer size	1 giga bytes

IV. SIMULATION RESULTS AND ANALYSIS

The ONE simulator is used to check the performance of the hybrid routing scheme. There are two kinds of simulation settings, one is simulator dependent settings and the other is external parameters values which are needed for simulation. Simulator dependent settings include mobility models, interface type, map size, transmission range, number of groups and nodes, etc (Table 1). The Map of the Helsinki city is used for the scenario. The Helsinki map is already available in ONE simulator. Total 25 different groups are defined in the simulation scenario with 74 nodes out of which 60 are mobile nodes and 14 are fix nodes (RSUs). Each group has some features of its own with some common features as well with other groups. Four different mobility models are used: car movement model, bus movement, shortest path map based movement and map based movement model. Buffer size is set to 1GB for the nodes in the scenario. WiFi interface is used with the transmission range of 300 meters. The speed range is 2.7 to 12 meter per second.

After the scenario parameters are set. The simulation is run on ONE simulator to check the performance. It is found that the performance of the Hybrid routing scheme is better than that of simple MaxProp routing scheme. The results are shown in figures below. The analysis is done with respect to different time to live (TTL). The analysis results include delivery probability, average latency, overhead ratio and average buffer time.

A. Delivery Probability

Hybrid routing scheme has shown improvement as compared with MaxProp in terms of delivery probability (Figure 2). With TTL equal to 50 minutes the increase is 21.33%, with TTL of 100 minutes increase is 5.91%, with TTL equal to 150 minutes the improvement is 3.81%, with TTL equal to 200 minutes the improvement is 3.2% and with TTL of 300 and 400 minutes the improvement is 2.6%. It shows that the improvement in delivery probability is more if the message time to live is less.

The improvement in delivery probability is dropped to almost 3 times if the TTL value is doubled and by again doubling the TTL the improvement is further dropped to almost 45%. It is because when we increase the TTL of the message, it occupies the space in the buffer for longer time. Therefore, new messages do not have space for them, so that's why the delivery probability drops for higher values of TTL.

B. Average Latency

Figure 3 shows that Hybrid routing scheme showed percentage decrease in the average latency (delivery time). In Hybrid routing scheme message took lesser time to its final destination than that of MaxProp. There is a clear decrease in the average latency of the network. With TTL equal to 50 minutes the decrease in average latency is about 34.96%, with TTLs of 100, 150, 200, 300 and 400 the decreases are 42.78%, 45.38%, 46.54%, 48.17% and 48.17% respectively. With the increase in TTL, the average latency decreases. It is because with lesser TTLs the messages are discarded before their delivery and with longer TTL the messages are delivered faster than MaxProp.

C. Average Buffer Time

In the real world the buffer size is limited and it should be used wisely. If the routing scheme is unable to free the buffer from overburden messages, it is said to be underperforming. One way to free buffer is to forward the messages as quickly as possible towards the destination node. In Hybrid routing scheme a message bundle occupy the buffer for less time than that of MaxProp. The decrease in the average buffer time is even more than 50% in larger TTLs. Figure 4 shows the comparison of average buffer time taken by a message in Hybrid scheme with MaxProp scheme.

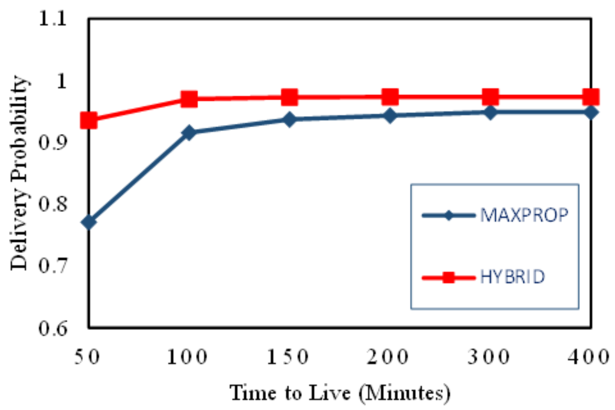

Figure 2. Comparison of delivery probabilities of hybrid and maxprop

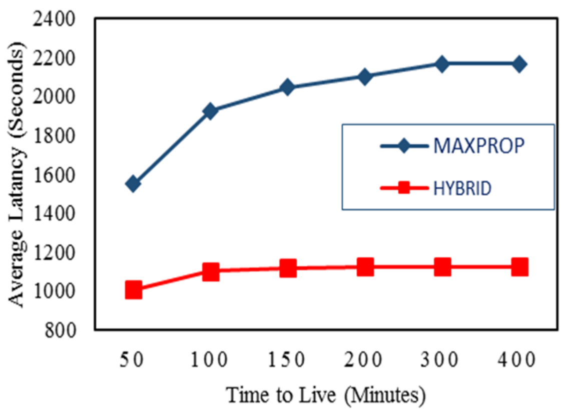

Figure 3. Comparison of average latencies of hybrid and maxprop

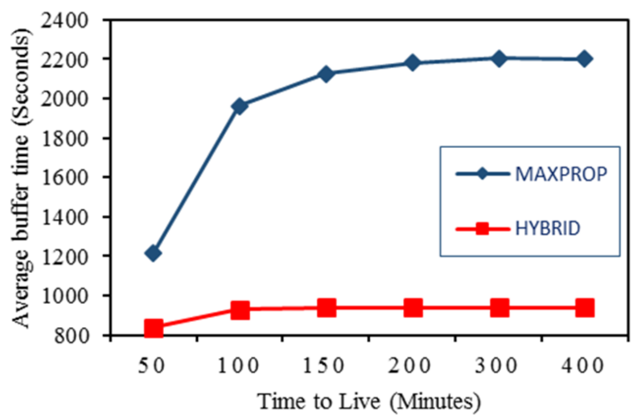

Figure 4. Average time taken by a message in the buffer

D. Overhead Ratio

As far as overhead ratio is concerned, it is clear from Figure 5 that the MaxProp routing scheme showed better performance than that of Hybrid routing scheme. For TTLs of 50, 100, 150, 200, 300 and 400 minutes the percentage increase in the overhead ratio of the Hybrid routing scheme with respect to MaxProp were 28.9%, 40.32%, 42.16%, 42.6%, 43.17% and 43.17% respectively. This is because that there is a lot of retransmission in the network due to noise and obstructions, which is taken under consideration in Hybrid scheme but not in MaxProp. Due to bit errors the packets are retransmitted so this increases the number of packets in the buffer and thus cause increase in the overhead ratio of the network. In all the pervious routing schemes the BER was not considered. So in case of errors there was no retransmission and after forwarding the message it was deleted from the buffer but in hybrid routing scheme it waits for acknowledgment from receiver about any error before clearing buffer.

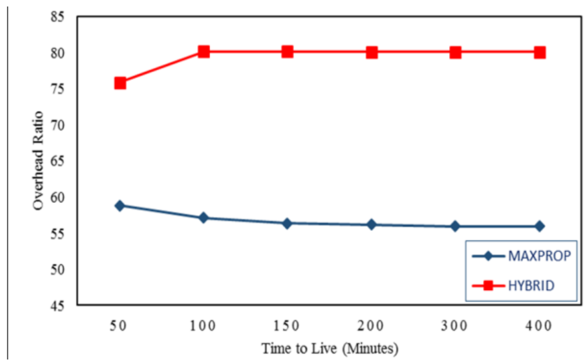

Figure 5. Comparison of overhead ratios of the hybrid and maxprop

V. CONCLUSION

In existing routing schemes of VDTN the area was considered to be uniform. Same data rate was considered as the schemeswere one dimensional and were unable to differentiate between mobile node and stationary node. The data was always considered to be 100% right with absolutely no errors which is not realistic. This paper presented a Hybrid routing scheme. With the inclusion of the two propagation models, the problems in the existing routing schemesd were overcomed. The Hybrid routing scheme uses two different propagation models for the communication involving mobile node and for communication without mobile node. This two dimension nature of Hybrid routing decreases the overall network BER because the BER for communication between fix to fix nodes is always less than that of communication involving mobile node. In addition, the environmental obstacles are all added and the environmental effect can easily be added by including its path loss and sigma value. It is then concluded that the Hybrid routing scheme performed better as compared with its counterpart. The overall delivery probability is increased and the average latency and the average buffer time are decreased, which improves the performance of the network.

Further research can be done to decrease the overhead ratio. The energy issues can also be taken into account in future work as the real world devices have limited energy. The willingness of the node to accept messages can also be taken in to consideration. The real world implementation of this research can also be taken into consideration as future work.

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