A study of the behaviour of vehicular delay tolerant network at the partial collaboration of Maxprop routing algorithm with Binary Spray and Wait

Sanjay Kumar†, Avijeet Singh Mandloi†, U Divya† and Sudhakar Pandey†

†Department of Information Technology, National Institute of Technology Raipur,492010 India

Summary
This paper analyses the performance of a modified routing protocol for delay tolerant networks. This routing protocol combines the routing strategies of MaxProp and Binary Spray and Wait. It utilizes a store-carry-and-forward mechanism, combining replication and routing decisions based on delivery likelihood, with explicit delivery acknowledgments to improve utilization of network resources. The performance of the proposed routing protocol is evaluated through simulations. The results have shown that proposed routing protocol achieves higher delivery ratio and lower average latency with a considerably low communication overhead, compared to well known routing protocols for delay tolerant networks

Keywords
Routing Protocol, MaxProp, Spray-and-Wait,DTN, VDTN, Simulation, Opportunistic Network Environment (ONE).

1. Introduction

Researchers have identified Delay Tolerant Networks (DTN) as an emerging field of research which consists of sparse and intermittently connected mobile nodes and is characterized by absence of reliable communication and end-to-end connectivity for message transmission most of the time. Asymmetric data rates and high error rates are some other characteristics of DTN. DTN accommodates different wireless technologies, disruption between networks, translation between communication protocols and mobility and limited power of wireless devices. It was originally used for interplanetary communication [1].

A DTN node can either perform the function of source or destination or forwarding function. Forwarding function implies that the node will forward packets to other nodes that implement same or different lower level protocols. The former case is referred to as routing equivalent forwarding and the latter as gateway equivalent forwarding [2].

The main principal for routing in DTN is Store, Carry and Forward, where each node stores incoming messages in the buffer and then delivers it to a desirable node. It can be viewed as transferring messages from one nodes storage to that of other node along a path that will end at destination node at some point[3].This mechanism resolves the main issues faced by DTN like intermittent connectivity where protocols like TCP will drop and re-transmit packets and result in failure of the application in case of high number of re-transmissions [4].

DTN has been found better than conventional MANET when it comes to probability of data transmission. The store, carry and forward approach helps to increase the probability that a message will be delivered regardless of the time taken to deliver the message over MANET [5].

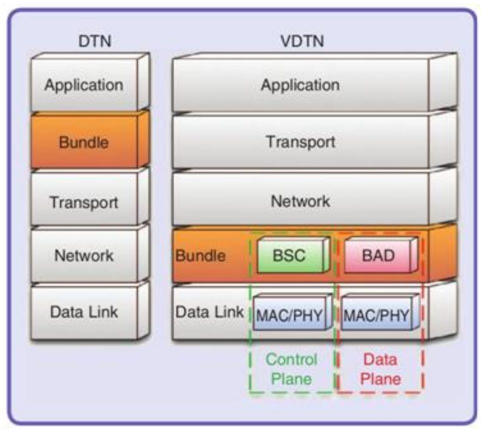

Figure 1: Network Layer Architecture of DTN and VDTN [7]

Vehicular Delay Tolerant Networks (VDTNs) supports applications that can be deployed on vehicular networks. Figure 1 shows the different layers in DTN and VDTN. We can see in the DTN architecture there exist a bundle layer protocol implemented over transport layer protocol. Bundles consist of a header, user data and a trailer. Classes of service provided by bundle protocol includes transfer of custody, assigning priority to delivery, acknowledgment and time-to-live. Characteristics of VDTN differs from DTN in terms of architecture as it favours Internet Protocol(IP) over VDTN approach and also separates the control and data planes with the help of out of band signaling [6].

Rest of the paper is organized as follows: Section 2 presents brief overview of MaxProp and Binary Spray and Wait protocol and some of the other routing protocols in DTN.Section 3 present explanation of the routing strategy.

Manuscript received August 5, 2016
Manuscript revised August 20, 2016

Section 4 presents comparison of the routing protocol with existing protocols. At last conclusion is presented in Section 5.

2. Related Work

The routing in DTN occurs in a store and forward mechanism. The objective of routing is to maximize the delivery probability of the messages while keeping minimum overhead ratio and delay [8]. Routing protocols in DTN are classified in two types: Flooding based and forwarding based [9].Many routing protocols for DTN and VDTN have been proposed by the researchers. Epidemic routing protocol is the example of protocols which do not require knowledge about the network. It passes the message to all the nodes which comes in contact with the node carrying the message[10].In PROPHET(Probabilistic routing protocol using history of encounters and transitivity) routing algorithm at each node a delivery predictability is estimated based on the historical encounters with other nodes in the network .This delivery predictability is used to forward a message at a node [11].VADD (Vehicle assisted data deliver) routing protocol uses vehicles for delivery of data toward the destination. At the junctions of streets based on the speed, distance of the main junction etc decision about the forwarding of a message is taken[12].GeOpps(Geographical Opportunistic)routing protocol uses opportunistic nature of vehicles and geographical location information to estimate the minimum time to the destination[13].GeoDTN+NAV(Geographic DTN with navigator) algorithm is able to estimate the network partition and then it uses store carry forward approach to send the message to the destination[14].

MaxProp routing protocol assumes nodes have no knowledge of network connectivity, no control over nodes' movement and no knowledge of location. It routes message effectively by assigning priorities to the dropped and transmitted packets [15].The priority is assigned on the basis of likelihood of paths, which can be determined by historical data or on the basis of hop count. Other features of MaxProp include using acknowledgments to clear the buffer, maintaining a list of previous encounters and favoring new packets that have not travelled far in the network. Message transmission using MaxProp is more effective than the protocols where meeting schedule of nodes is known owing to the use of an oracle. The protocol is explained as a sequence of steps executed when a node X detects a new contact opportunity with node Y:

First, all messages destined to Y are transferred. Second, a vector listing probability estimations of meeting other nodes is passed between X and Y. Third, acknowledgments for delivered data are transferred. Fourth, packets that have not traversed far in the network are given priority. For this, MaxProp logically divides the buffer in two on the basis of hop counts with respect to a threshold. Packets below the threshold are arranged by hop count while packets above are sorted by their delivery likelihood. MaxProp resolves the issue of efficient utilization of buffer space and packet scheduling problem. The performance is also efficient in varied DTN environments.

Spray and Wait is a routing protocol based on limited flooding principle [16]. It combines the benefits of both epidemic routing and direct delivery transmission and proceeds in the following manner:

Spray phase - Create L copies of a message M and forward it to L nodes or relays that makes contact with the source. There are various different mechanisms through which spray phase can be carried out.

Wait phase - It comes into effect only if the message has not been delivered to its destination during the previous phase.

The L nodes that now contain a copy of the message M will forward their copy only if they comes in contact with the destination of the message.

Binary Spray and Wait is a variation of Spray and Wait that defines the number of copies to be 'sprayed' as half the number of copies existing currently at the node performing the spray operation. The wait phase, that is switching to direct transmission mode, will take place if a node has only one copy of the message left after the spray phase and the message has not been delivered yet. Steps followed during routing can be summarized as:

1. Create limited number of copies per bundle.

2.Initially forward half the existing bundle copies to inter-mediate nodes

3.Wait until one of them meets the destination.

Performance of Binary Spray and Wait is efficient in terms of number of transmissions required and delivery delay and it is also scalable.

In this paper we have contributed by devising an algorithm by collaborating the concept of Maxprop routing protocol with binary spray and wait and studied the behaviour of resulting approach.

3. Proposed Routing Protocol

Let si is the source of message i and di is the destination of message i. An intermediate node is deonoted with ni.Each node n maintains a probability vector p(n,k) representing the meeting probability of node n with node k.This vector is updated whenever a node meets with some another node and get some information about other nodes or route. Ti is the time since a message has been created

Tli is the time to live of message I, numi is the number of copies of a message i.

The proposed routing algorithm takes advantage of spray and wait algorithm to spread limited number of messages first and then enters into wait state to give the network some time to deliver the message to its destination. Taking inspiration from maxprop algorithm when a single copy of message is left at the node it transfer the message to a node with higher delivery probability toward the destination.These two phases work as under:

In first phase numi /2 copies of message i are forwarded to a node that comes in contact and do not having message i and are approaching towards di. Basic objective of spray phase is to cover all nodes of given area with minimum transmissions. Delivery likelihood is also updated in this phase.

When only one copy is left ,forward it to a node having higher delivery probability. The wait phase of proposed protocol ensures that copy of message i will be forwarded in promising direction only and increases the possibility of relay of messages between nodes that might never come in contact.

Calculation of delivery likelihood at node n involves maintaining probability of meeting node k. This probability is initially set as the reciprocal of one less than the total number of nodes in the network.When node k comes in contact this value is increased by 1. In this way the nodes that come into contact infrequently acquire a lower value over time. Every time any two nodes meet they exchange this value with each other.

3.1 Working of the algorithm

The algorithm has the following steps:

1) The vector containing the probabilities P(n,k) of a node n meeting another node k for calculating the cost of paths is used to check the meeting probability of the destination of the concerned message and the other node at the connection.
2) If the meeting probability of the other node and the destination of the message is greater than the meeting probability of the current node having the message and the destination node, then it will transfer half the number of existing copies to the other node.
3) If only one copy is left then the node having the message will wait until an opportunistic contact is made with a node having higher meeting probability and forward the one copy to that node.
4) The acknowledgment vector is also exchanged between the nodes so that proper buffer management can be done.
5) Also checking of the hop list which a particular message has passed is done which will prevent the traveling of the message to the same hop twice. The hop list also forms the basis for position of storage in buffer. In the left half of buffer messages with hop count less than a fixed threshold are stored and in the right half messages with hop count greater than the fixed threshold are stored on the basis of increasing priority which is calculated in terms of cost of path travelled by the messages.
6) Check if acknowledgement vector contains the message. Delivered messages are deleted from the buffer.

3.2 Pseudo code

The routing protocol is explained as a pseudo code in the form of sequence of steps executed at node n when nodes n and k come in contact:

1) Initial probability for a node = 1.0 / (initially known number of nodes)
2) For (connections : getConnections)
   Updated probability = (initial probability + alpha) / (1 + alpha)
3) For (connections : getConnections)
4) For (message : getMessageCollection)

If (binary mode == true)

   a) If (no of copies > 1) and if(other node doesn't have the message) and (Probability(n,d) < Probability(k,d))
      no of copies = (no of copies) / 2
   b) If connection is still available and If (no of copies) > 1 and
      Probability (n,d) = null, no of copies = (no of copies) / 2

Else

   a) If (no of copies > 1) and if(other node doesn't have the message) and (Probability(n,d) < Probability(k,d))
      no of copies = (no of copies) - 1
   b) If connection is still available and If (no of copies) > 1 and Probability (n,d) = null
      no of copies=(no of copies) - 1

4) Exchange acknowledgment vector.
5) Update acknowledgment vector.

Check if acknowledgment vector contains the message. Delivered messages are deleted from the buffer.

4. Performance Evaluation

Our routing algorithm is a hybrid approach of binary spray and wait and MaxProp. The performance of our algorithm was evaluated against MaxProp and Binary Spray and Wait so that the evaluation results represent the improvement in the original algorithms. The primary goal of any routing protocol is to maximize the delivery probability and minimizing the latency while keeping the minimum overhead ratio possible. We have evaluated our algorithm on the following two parameters:

Delivery Probability: This is defined as ratio of total number of messages delivered to the total number of messages created. It is also called as the delivery ratio.

Overhead Ratio: It is defined as the ratio of the total number of messages relayed to the number of messages delivered.

4.1 Simulation Environment

We simulated our proposed protocol on the ONE (Opportunistic Network Environment) simulator developed by Helsinki University [17].Some modules were added in ONE to accommodate features of VDTN following the methods given in [7]. In the simulation we have considered a city environment and the entire nodes move on paths restricted to the map of Helsinki which is provided in the ONE simulator. We assumed six groups of nodes representing pedestrians, vehicles and trams. We assumed pedestrians and vehicles follow ShortestPathMapBasedMovement and trams follow MapRouteMovement mobility model [18]. Table shows the parameters of each group.

Table 1. Simulation Parameters

Group	No. of nodes	Speed(m/s)	Buffer Size	Transmission Bandwidth	No. of interfaces
1(p)	40	0.5-1.5	5M	250kBps	1
2(v)	40	2.7-13.9	5M	250kBps	1
3(p)	40	0.5-15	5M	250kBps	1
4(t)	2	7-10	50M	250kBps, 10mBps	2
5(t)	2	7-10	50M	250kBps	1
6(t)	2	7-10	50M	250kBps	1

(p):pedestrain (v):vehicle (t):tram

Our proposed algorithm starts with a certain number of copies of the packets. Increasing the number of copies should increase the delivery probability but will also increase the overhead. To find out the optimum number of copies, we simulated our protocol at different number of copies while keeping the time to live of each packet constant at 300 minutes.

4.2 Simulation Results

Figure 3 shows the delivery probability and Figure 4 shows the overhead ratio at different initial number of copies respectively. The result shows a gradual increase up to 30 number of copies. The maximum values are obtained at 48 (0.5721) and 30 (0.5714). Delivery Probability decreases after further increasing the number of copies. This decrease is due to limited buffer size of nodes resulting in packet drop when more packets compete for the buffer. Figure 4 shows an increase in overhead ratio on increasing the initial number of packets. At points of maximum delivery, the overhead ratios are 18.0766 (30) and 20.4026 (48). Both 30 and 48 result in comparable delivery probability while overhead ratio at 30 is 11.4% less than that of 48. Therefore, we proceed our simulations with initial number of copies to be 30. We also kept initial number of copies for Binary Spray and Wait at 30 so that both the protocols are compared at the same parameters.

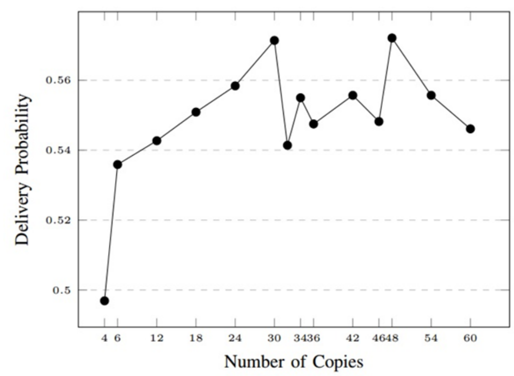

Figure 3 : Delivery Probability at different number of copies

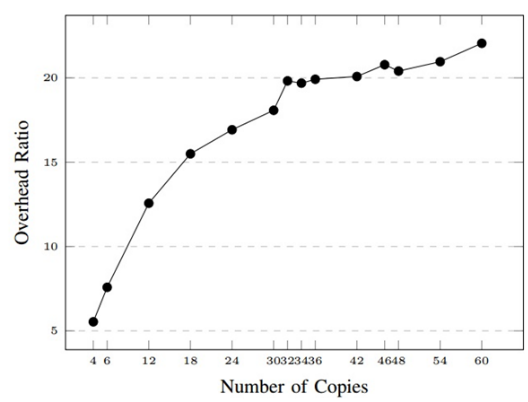

Figure 4 : Overhead ratio v/s number of copies

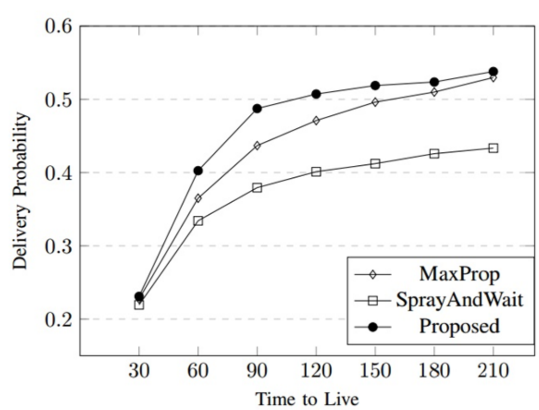

Figure 5 : Delivery probability v/s Time to live

We evaluated the protocols by varying Time to live of the packets. Figure 5 show variation of delivery probability at different values of Time-to-live. Delivery probability of all routing protocols increase with increase in time- to-live of the packet. This is because packets get more time to stay on the network before getting dropped and thus have a greater chance of getting delivered.

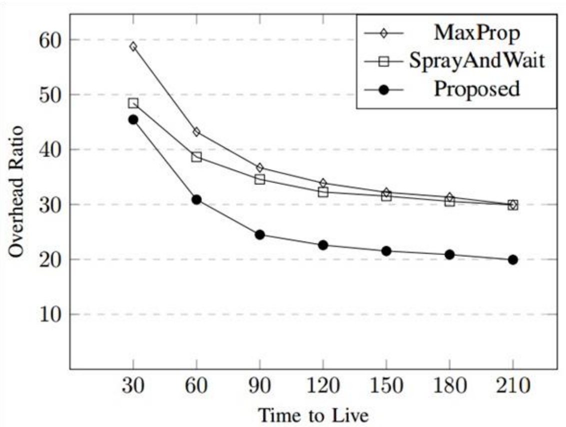

Figure 6 : Overhead ratio v/s Time to Live

Our proposed algorithm has the high delivery probability irrespective of Time to Live. The increase in delivery probability in Modified protocol than MaxProp is attributed to the use of multiple copies of packets. Modified MaxProp forwards the packets to nodes which have a higher delivery probability which is better than spray phase of Binary Spray and Wait. This results in better delivery probability than Binary Spray and Wait.
Overhead Ratio measure the bandwidth efficiency of the network. It is a measure of number of packet transfer needed for each packet delivery. Figure 6 shows the overhead ratio at different values of Time to Live. Our Modified MaxProp algorithm has lower overhead ratio than both MaxProp and Binary Spray and Wait. Figure 6 show a significant decrease in overhead ratio and is lower than both MaxProp and Binary Spray and Wait.

5. Conclusion

In the paper, we study the behavior of a modified routing protocol which we get after the collaboration of Maxprop with Binary spray and wait routing protocol. It uses the same procedure for metric calculation as that of MaxProp on the basis of which packets are forwarded but incorporates the replication and forwarding policy of Binary Spray and Wait. We evaluated the proposed algorithm in an urban scenario using ONE simulator and compared our results to MaxProp and Binary Spray and Wait. Our proposed algorithm shows an improvement in Delivery Probability and a significant decrease in Overhead Ratio.

Acknowledgments

Authors would like to thank administration of department of IT and NIT Raipur for their support.

REFERENCES

[1] K Fall. A delay-tolerant network architecture for challenged internets. In: Proceedings of the 2003 conference on Applications, technologies, architectures, and protocols for computer communications;2003: ACM. pp. 27–34.
[2] F. Warthman et al. Delay-and disruption-tolerant networks (dtns),A Tutorial.V.. 0, Interplanetary Internet Special Interest Group, 2012.
[3] V. N. Soares, J. J. Rodrigues, J. A. Dias, and J. N. Isento. Performance analysis of routing protocols for vehicular delay-tolerant networks. In: Software, Telecommunications and Computer Networks (SoftCOM), 2012 20th International Conference : IEEE. pp. 1–5.
[4] R. C. Durst, P. D. Feighery, and K. L. Scott, “Why not use the standard internet suite for the interplanetary internet,” InterPlanetary Internet (IPN) Technical Information, 2000.
[5] R. Mangrulkar and M. Atique, “Routing protocol for delay tolerant network: A survey and comparison,” in Communication Control and Computing Technologies (ICCCCT), 2010 IEEE International Confer-ence : IEEE. pp. 210–215
[6] V. N. Soares, J. J. Rodrigues, and F. Farahmand. Geospray: A geo-graphic routing protocol for vehicular delay-tolerant networks. Information Fusion, 2014, vol. 15. pp. 102–113.
[7] J. N. Isento, J. J. Rodrigues, J. A. Dias, M. C. Paula, and A. Vinel. Vehicular delay-tolerant networks a novel solution for vehicular communications. Intelligent Transportation Systems Magazine, IEEE, vol. 5, no. 4, pp. 10–19, 2013.
[8] S. Jain, K. Fall, and R. Patra, Routing in a delay tolerant network. ACM, 2004, vol. 34, no. 4.
[9] E. P. Jones and P. A. Ward. Routing strategies for delay-tolerant networks. Submitted to ACM Computer Communication Review (CCR), 2006.
[10] Zhang, X., Neglia, G., Kurose, J., & Towsley, D. (2007). Performance modeling of epidemic routing. Computer Networks, 51(10): 2867-2891.
[11] Lindgren, A., Doria, A., & Schelén, O. (2003). Probabilistic routing in intermittently connected networks. ACM SIGMOBILE mobile computing and communications review, 7(3), 19-20.
[12] Zhao, J., & Cao, G. (2008). VADD: Vehicle-assisted data delivery in vehicular ad hoc networks. Vehicular Technology, IEEE Transactions on, 57(3): 1910-1922
[13] Lee, Kevin C., Uichin Lee, and Mario Gerla. "Geo-opportunistic routing for vehicular networks [topics in automotive networking]." Communications Magazine, IEEE 48.5 (2010): 164-170.
[14] Cheng, P. C., Lee, K. C., Gerla, M., & Härri, J. (2010). GeoDTN+ Nav: geographic DTN routing with navigator prediction for urban vehicular environments. Mobile Networks and Applications, 15(1), 61-82.

[15] J. Burgess, B. Gallagher, D. Jensen, and B. N. Levine. Maxprop: Routing for vehicle-based disruption-tolerant networks. In: INFOCOM, vol. 6, 2006. pp. 1–11.
[16] T. Spyropoulos, K. Psounis, and C. S. Raghavendra. Spray and wait: an efficient routing scheme for intermittently connected mobile networks. In: Proceedings of the 2005 ACM SIGCOMM workshop on Delay-tolerant networking: ACM. pp. 252–259.
[17] A. Keranen,¨ J. Ott, and T. Karkk¨ainen.¨ The one simulator for dtn protocol evaluation. In: Proceedings of the 2nd international conference on simulation tools and techniques. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2009.pp. 55.
[18] A. Keranen¨ and J. Ott. Increasing reality for dtn protocol simulations.Helsinki University of Technology, Tech. Rep, 2007.

Sanjay Kumar is working as Assistant Professor in National Institute of Technology, Raipur (India). He received B.E.(CSE) in 2002from MNREC Allahabad and M.Tech.(CSE) in 2007 from RGPV Bhopal,India.He is life member of IETE and CSI. His research focuses on wireless ad-hoc networks and Delay Tolerant Networks.

Avijeet Singh Mandloi received B.Tech(IT) from National Institute of Technology Raipur in 2016.His area of interest for research is ad-hoc networks.

U Divya received B.Tech.(IT) from National Institute of Technology Raipur in 2016.Her area of interest for research is ad-hoc networks.

Sudhakar Pandey received D.Phil. from University of Allahabad, India in 2012.He is currently working as Assistant Professor and Head of Information Technology department in NIT Raipur, India. His research focuses on wireless networks, Delay Tolerant Networks and Wireless sensor networks.