# A Handoff-based And Limited Flooding (HALF) Routing Protocol in Delay Tolerant Network (DTN)

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## ABSTRACT

*In a Delay Tolerant Network (DTN), routing protocols are developed to manage the disconnected mobile nodes. We propose a routing protocol named HALF (Handoff-based And Limited Flooding) in DTN that can work in both infra-structured and infra-structure less networking environment and hence it can improve the performance of the network significantly. In this paper, it is shown that HALF gives satisfactory delivery ratio and latency under almost all conditions and different network scenarios when compared to the other existing DTN routing protocols. As the traffic intensity of the network grows from low (.2) to high (.75) values, HALF shows about 5% decrease in the delivery ratio compare to much larger values showed by the other routing protocols and on the average takes same time to deliver all the messages to their destinations. As the radio range is increased over the range from 10m Bluetooth range to 250m WLAN range, due to the increased connectivity, the delivery ratio and the latency are increased by 4 times and decreased by 5 times respectively.*

## Keywords

*DTN, handoff, flooding, DTN routing protocols, infra-structured networking, infra-structure less networking, HALF.*

## 1. INTRODUCTION

Delay and Disruption Tolerant Networking (DTN) [1] equipped with advance features as custody transfer and hop-by-hop routing capabilities give a full potential of flexibility, adaptability and simplicity for wider range of different characteristics of network. The custody transfer capability allows messages or Bundles to be buffered in DTN nodes until Bundles are forwarded to the next hop DTN node and found to be unnecessary. The hop-by-hop routing capability enables routing decisions to be made dynamically during each hop [1]. HALF (Handoff-based And Limited Flooding) is an integrated routing scheme that combines an infrastructure-oriented DTN routing scheme with a flooding technique that works well for an infrastructure-less environment. The infrastructure-based routing scheme of HALF is a Handoff–based routing protocol that makes the best use of general handoff mechanisms intended for the IP network. In HALF, this handoff mechanism is implemented using the DTN features like hop-by-hop routing and custody transfer. For an infrastructure-less environment, HALF applies a flooding technique similar to Spray and Wait (SW) [2] protocol to spread message in the network but in a more controlled way.

Other existing DTN routing protocols like Epidemic [3], PRoPHET [4] and SW [2] are basically flooding based and mobility dependent routing protocols that simply utilize the local

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knowledge given by adjacent nodes but do not utilize the global connectivity knowledge on fixed network topology. These protocols are suitable for a network consisting mobile nodes only. On the other hand, HALF is suitable to be used in any type of networking environment whether it has only mobile nodes or both mobile and fixed nodes. In this paper, at first we explained our proposed HALF routing protocol and then the performance characteristics of HALF with the existing DTN routing protocols are intensively compared under a wide variety of network environments and conditions. The simulation results indicate that in most of the cases, HALF achieves higher delivery ratio and lower end-to-end latency under broad network environment in comparison to others.

The rest of the paper is organized as follows: Section 2 presents related work. Section 3 gives the basic mechanism and Protocol operation of HALF. Section 4 presents the Performance evaluation and analysis. Section 5 concludes the paper.

# 2. RELATED WORK

## 2.1. Related work on handoff technologies in TCP/IP protocol

Different methods were devised to overcome the problems associated with the TCP to handle mobility in the wireless environment [5], [6], [7] and [8] and to handle the handoff situations efficiently [9], [10], [11]. Protocols like Mobile IP[12] suffers from scalability problem and Cellular IP [13], [14] accompanies additional network load induced by forwarding packets on multiple paths and sometimes may cause packet loss due to the transient packet transfers to the old route. Also IP mobility-based techniques need explicit buffering instruction to the routers during handover to buffer packets at the router. Protocols like HALF in DTN does not have the end-to-end session management or connection state transfer problem during handoff and have lower handoff latency and overall latency than Mobile IP protocol. This is because handoff process in HALF implements handoff of the messages with minimum number of control message exchanges between the fixed nodes without transferring session state information that is necessary to keep an end-to-end TCP session. Furthermore, the custody transfer mechanism of DTN does not require any extra overhead of explicitly instructing to buffer packets during the handover process. Also the Custody Acceptance signalling [15] can control the burst packet transfers and so HALF does not suffer from the multiple consecutive packet loss problems which is unlike in TCP/IP-based forwarding and buffering scheme.

## 2.2. Related work on DTN routing protocols

In this section we present a brief overview of DTN routing techniques relevant to our proposed protocol. Existing protocols in DTN were designed to handle the challenging and opportunistic situations of sparsely connected Mobile nodes in a network. Epidemic routing protocol is solely based on the information exchanges between two encountering mobile nodes and thus distributing the messages throughout the network to reach the destination. The PRoPHET was devised to be more selective by being probabilistic while forwarding to the next node. The Spray and Wait (SW) protocol adds limited copy flooding feature to the mobile nodes while routing to the destination. These flooding based routing protocols do not make use of the global knowledge and hence suffers from reduced delivery ratio and large latencies. MaxProp prioritizes the scheduling of packets for the transmission and take the resource limitation into account. HALF assumes simple FIFO for scheduling the packets. Another DTN routing protocol, RAPID, deals with the problem of routing in DTN as a resource allocation problem and tries to solve it by calculating a routing metric per packet on the basis of available resources and then replicate the packet according to that. HALF does not have any replication method in its operation neither does it involves calculating the routing metric in the basis of resources available.

# 3. THE HANDOFF-BASED AND LIMITED FLOODING (HALF)

## 3.1. The basic mechanism

HALF makes use of the general handoff mechanisms intended for the IP network but uses DTN features like hop-by-hop routing and custody transfer. The knowledge of the location of the mobile node is utilized. The route update information during handoff and Back Propagation and caching of this location information over the experienced route helps to route the Bundle to the destination quickly and deterministically. A limited flooding technique is integrated to this mechanism, resulting in a much improved routing protocol that fits to a wide range of scenarios. To implement these concepts in our routing protocol, we extend the Bundle Protocol's message format given by the IRTF's Delay Tolerant Network Research Group (DTNRG) as BP specification [15]. The routing functions and handoff mechanism are included in the message format so that the routing and handoff can be implemented in a single unified layer. The unified BP layer stands between the Link layer and Application layer. It provides the reliable transfer and dynamic routing through hop-by-hop dynamic next hop selection and also efficient buffering mechanism during handoff through custody transfer.

## 3.2. The protocol operation

When a mobile node moves out from the coverage of a fixed router to another one, Handoff process takes place. Normally, every DTN router maintains the connectivity information with adjacent DTN routers in the Proxy List (PL). When a mobile node moves to a new location, it registers its location (the name of the DTN router it belongs to) with the new DTN router and this location information is propagated back to and cached in every DTN router over the experienced route to update the PL at each router. During this process, each of the DTN routers also maintains a Back List (BL) to keep the information of the old router of a mobile node to track the experienced route of that mobile node. So a router receiving a Bundle to be delivered to a mobile node for which it has cache route update information, can make use of the information to route the Bundle to the destination quickly and deterministically.

This improves the delivery ratio of the network, preserving the low overall latency. By increasing the cache time at each of the router it is also possible to increase the delivery ratio. Figure 1 shows the back propagation and caching with the PL and BL. If a node does not have information about the destination then it starts flooding but if any of the branch node has information in its PL about the destination then it need not to do the flooding. Instead, that node will forward the Bundle to the proxy found in the PL. That is why we termed it as Limited Flooding (LF).

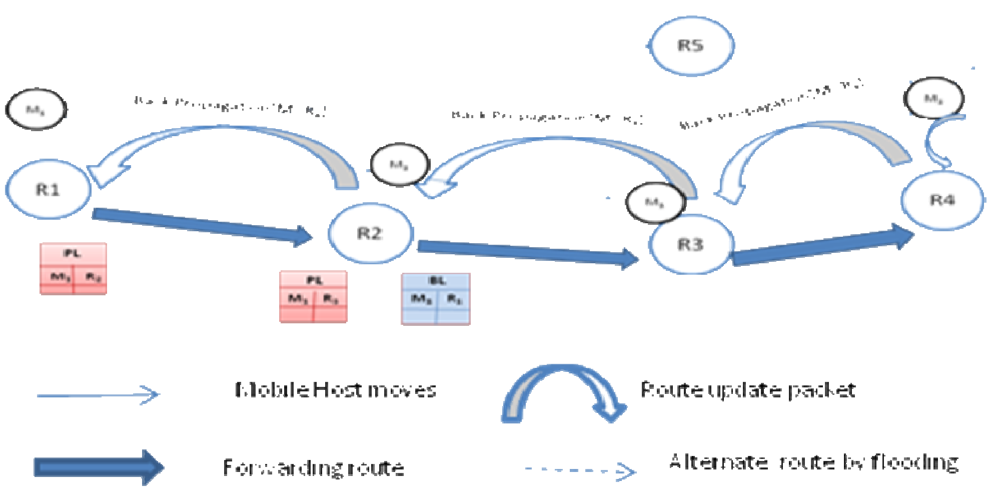



Figure1. Back propagation of routing updates using BL and caching at the Routers using PL

We give two examples in Table 1, from our simulation traces to show how the messages are transmitted through a network by selecting Proxy (PX) or Limited Flooding (LF) method depending upon the ongoing situation.

Table 1: Messages in an infrastructure-based and infrastructure-less network

| Message | Host | Transmission type | Time | Remarks |
|---|---|---|---|---|
| Message **M5** for Infrastructure-based network | W49 (Walker)<br>P5 (Pedestrian)<br>Fixed nodes :@116<br>@115<br>@107<br>@106<br>@103<br>@80<br>@79 | CT (Creation Time)<br>LF<br>LF<br>LF<br>PX<br>PX<br>PX<br>PX<br>DR (Direct Transmission) | 22<br>25.5<br>29.1<br>32.6<br>36.1<br>44.2<br>53.2<br>56.8<br>63.3 | In case of infrastructure-based network most of the messages find proxies on their way to the destination with few steps of flooding. |
| Message **M25** for Infrastructure-less network | @125<br>@66<br>@95<br>P1<br>t 63 (tram)<br>@101 | CT<br>LF<br>LF<br>LF<br>LF<br>DR | 82<br>85.9<br>89.9<br>93.7<br>97.8<br>185.8 | For an infrastructure-less environment most of the transmission from one hop to next hop is by Limited Flooding method. |

From Table 1, Message M5 was created at W49 at 22$^{nd}$ instant of time. It was delivered to P5 by SW flooding method at 25.5$^{th}$ sec. M5 was delivered to Fixed routers @116 and @115 by similar method. @115 found a proxy (PX) to the destination that is @107 and so M5 is delivered to @107 from @115 by proxy (PX) method. Finally fixed router @80 could send M5 by Direct Transmission to the final destination, @79. The second example of M44 has a similar explanation but there is no transmission by PX method.

The forwarding mechanism is such that a router always looks for a direct connection while forwarding a Bundle. If it is not found then the router consults the PL and lastly it goes for the flooding technique as shown in Fig. 2.

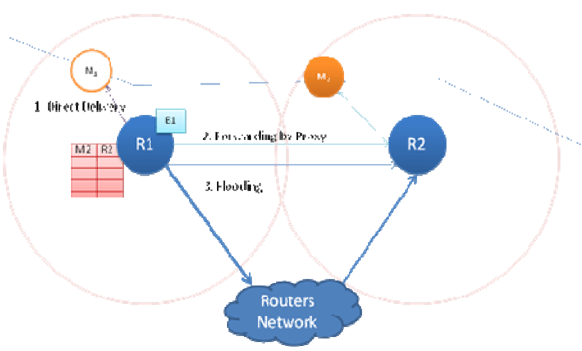



Figure 2. Basic forwarding mechanism in HALF

# 4. THE HANDOFF-BASED AND LIMITED FLOODING (HALF)

## 4.1. Network simulation model

Our network model, shown in Fig. 3, consists of Fixed and Mobile nodes. The mobile nodes such as Walkers, Pedestrians, Cars and Trams are plying along different routes in the Helsinki City map as featured in ONE simulator following a Map based Movement Model [16]. Real world aspects are added to the synthetic mobility models by adding real-world street maps, different classes of mobile nodes, realistic connectivity etc. [17]. HALF Routing protocol extends the Active Router module used in the ONE simulator. Fields and methods have been created to implement the Handoff mechanism which was not included in any DTN routing algorithm in ONE before. Special Reports have been generated by extending the Report module.

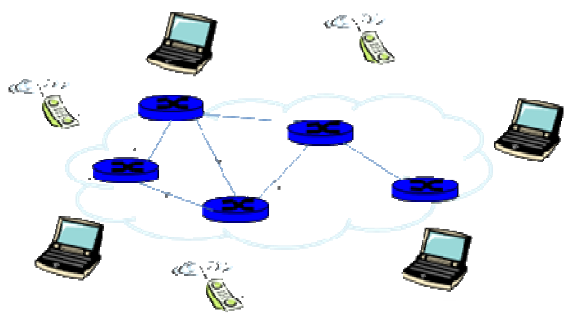


Figure 3. A General network model with fixed and mobile routers

Fixed nodes are connected with each other through communication link of 250 kBps (kilo Bytes per second). To test the wider applicability of our routing protocol we have simulated it and made comparison with other existing routing protocols in different types of network models: Mostly Fixed, Mixed, Mostly Mobile and All-Mobile where the number of fixed nodes with respect to the number of the mobile nodes are kept higher, equal, smaller and nil respectively. Both types of nodes are varied for 35, 50 and 65 numbers among 100 nodes in total within (4500 x 3400) m simulation area. The TTL of the message is 40mins (for discarding messages). The simulation time was for 12 hours. For every simulation case, we have chosen five runs using different random seeds and report the average value. As a performance metrics for evaluation, we have used delivery ratio and average latency.

It is very important to study how a protocol can handle different types of networks, different traffic load conditions of the network and different message sizes. The buffer size at different nodes of a network influences the perfromances of a routing protocol for a particular traffic and message size conditions. It is also required to see how the different radio ranges affect the number of delivered bundle and time to be delivered to their destinations. While the existing routing protocols were developed for sparse mobile environment only, in this paper we would like to study the perfromance of the routing protocols where the number of fixed nodes are kept constant but mobile nodes are varied in a network. How a random and a more realistic Mobility model along with the variation in the different mobility speed contributes to the performance of HALF and other protocols are also worthwhile to study as these also give a insight to how much message size the routing protocol can handle under different Mobility conditions.

Table 2 shows the different scenarios that we have simulated.

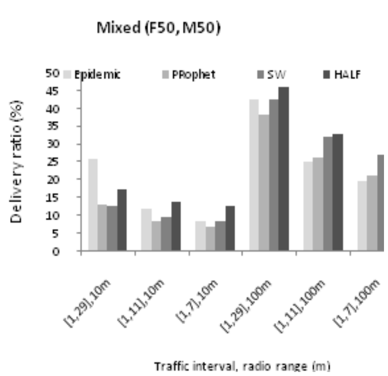
Table 2. Different scenarios simulated for our model

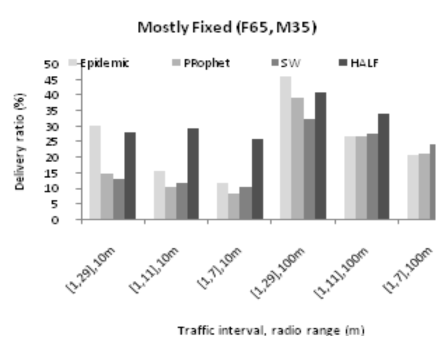
| Scenarios | Parameters | Details |
|---|---|---|
| Mostly Fixed Routers<br>Fixed=Mobile Routers<br>Mostly Mobile Routers<br>All Mobile Routers | Traffic Load of the network | Message generation interval of [1, 29], [1, 11] and [1, 7] corresponds to Traffic intensity (ρ) value of low (0.2), medium (0.5) and high (0.75) respectively. |
| | Message sizes | Varied as [100KB - 2MB], [500KB - 4MB], [500KB - 8MB] and [1MB - 100MB] with [1, 29] interval. |
| | Buffer sizes | Pedestrians, Walkers and Cars have 5Mbytes, Fixed nodes have 20Mbytes and the Trams have 50Mbytes each. These values are increased to 10M, 100M and 100M respectively. |
| All Mobile Routers | Radio ranges | 10m~250m |
| | Mobility model | RWP, SPMBM |
| | Mobility speed | Varying the speed of the different mobile carriers in the simulation model |

## 4.2. Simulation Results

### 4.2.1. Performance at different traffic intensity

It is shown in Fig. 6 and Fig. 7 that increase in traffic intensity decreases the Delivery ratio and increases the latency for both 10m and 100m radio range. Because the nodes cannot deliver the increased traffic due to overburden causes, delivery ratio decreases. On the other hand, as the traffic intensity increases the average time to reach the destination for the messages increases due to increased waiting time but this increase in the latency is a gradual increase rather than having a sharp profile. This behavior is because of the contribution from the encountering delay between two nodes out of the total delay. As we go from the Mostly fixed to the All mobile network, the delivery ratio decreases because of less contribution from the interconnected fixed nodes and the latency increases as the bundles can reach to their destination only by the movement of the mobile nodes. It is noteworthy that HALF gives higher delivery ratio and lower latency than all other protocols under almost all above mentioned conditions and scenarios. It is found that HALF is suitable for 100m wireless range than 10 m wireless range due to wider coverage of moving nodes.



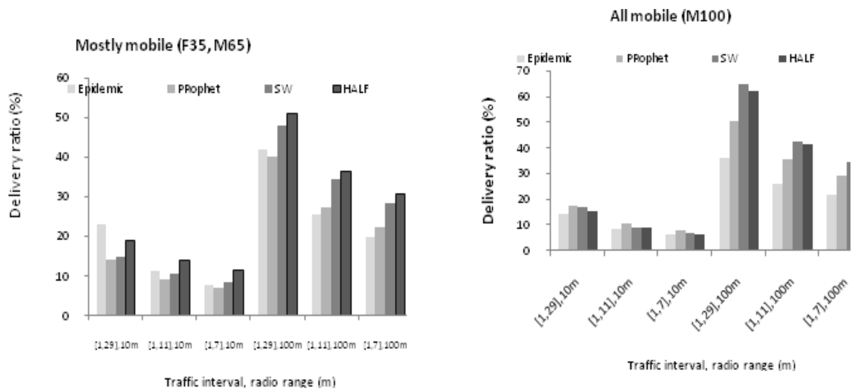



Figure 6. Delivery ratio with different number of Fixed and Mobile nodes

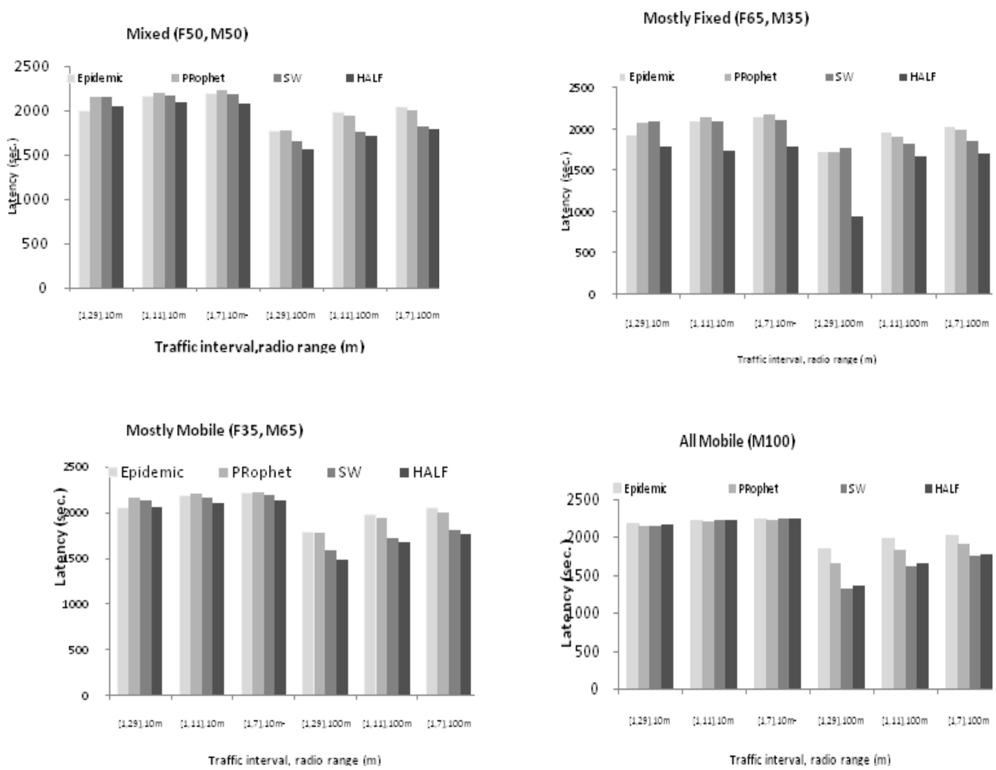



Figure 7. Latency with different number of Fixed and Mobile nodes

### 4.2.2. Different Message sizes

The Pedestrians, Walkers and Cars have the Buffer size of 5Mbytes, the Fixed nodes having buffer of 20Mbytes and the Trams are having 50Mbytes each. Because of the opportunistic contacts, larger messages cannot be always successfully delivered. So, the Delivery ratio decreases as the Message size increases for all the protocols, for both types of scenario as shown in Fig. 8. Thanks to the support for the fixed infrastructure, the delivered bundles take less overall time for Mostly Fixed environment but in an All Mobile scenario the latency is higher. With the increase of the Message size the latency decreases as less number of bundles takes less time to be delivered to their destination. Interestingly, HALF gives much better performance than the other protocols in a Mostly fixed environment but in an All mobile scenario its performance is a bit lower than other protocols.

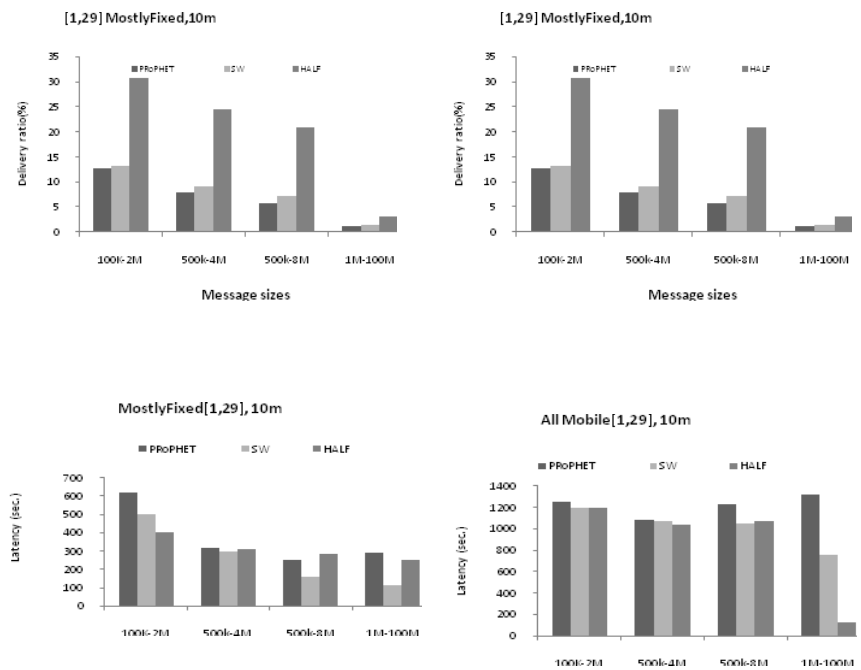



Figure 8. Performance for different Message sizes

### 4.2.3. Different Buffer sizes at the nodes

The buffers at the nodes (as mentioned previously) are increased to 10M, 100M and 100M respectively, for a particular Message size of [500k, 1M] and for low traffic [1, 29] and high traffic [1, 7] conditions under the Mostly Fixed scenario. As shown in Fig. 9, the increased Buffer size at each node causes the delivery ratio to be increased by 50% because now more bundles can be buffered at the nodes to wait for the next opportunity to be delivered instead of getting dropped. At the same time, the bundles now take longer to get delivered to their destination because of increased buffering time which leads to reduced value of overall latency.

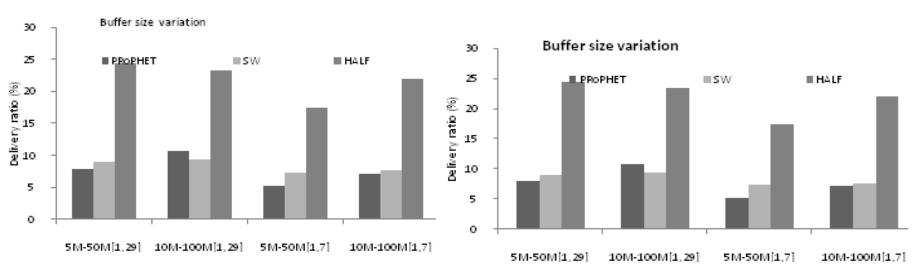



Figure 9. Performance for different Buffer sizes at the nodes

### 4.2.4. Different Radio ranges

We showed in Fig. 10 how HALF and other protocol behaves for different radio ranges starting from Bluetooth (10m) range to Wireless LAN range (100m) and even larger ranges like 200/250m, considering the futuristic probability of using higher wireless range devices for communication. As the communication range increases the connectivity among the nodes increases. As a result of this, the delivery ratio and the latency at 250m wireless range is increased by 4 times and decreased by 5 times respectively than their value at 10m wireless range. When the buffer size is increased to [10/100/100] M at different nodes, for 10m, 100m and 250m ranges, it is found in Fig. 10 that more bundles are delivered because of the increased Buffers but are taking longer time to reach their destination

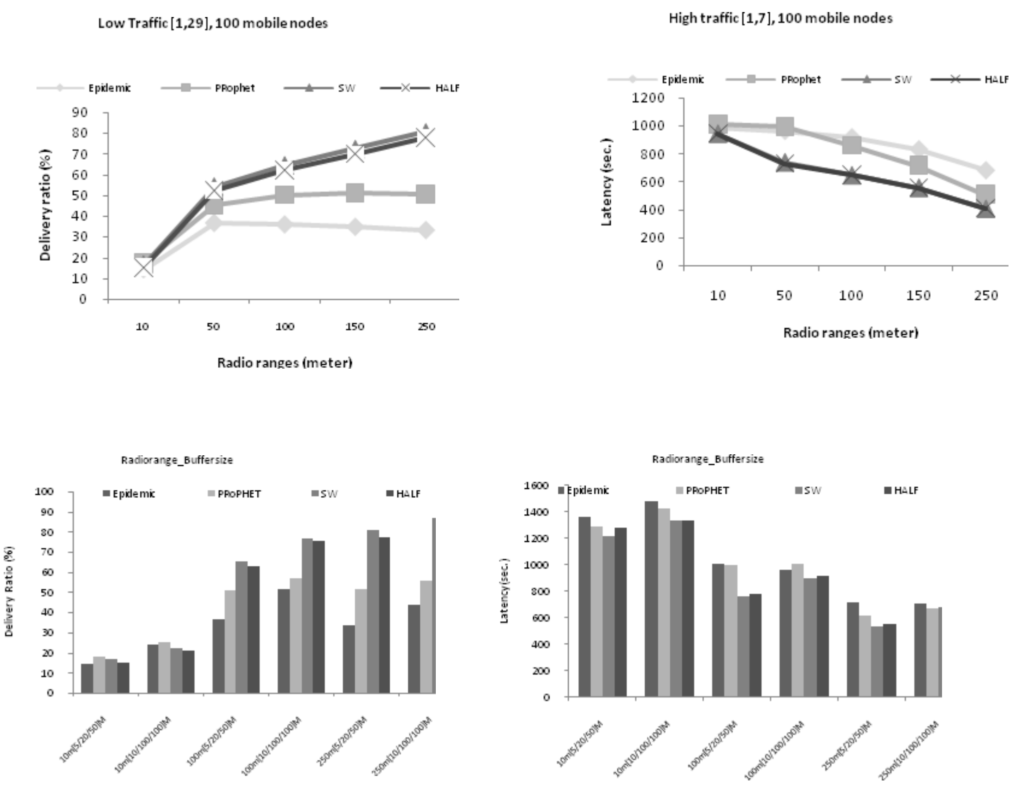



Figure 10. Performance at different Radio ranges and with different Buffer sizes at the nodes

### 4.2.5. Different Mobility model

To study how the Mobility models can affect the different protocol performances for the All Mobile network environment, we try with one random model like Random Way Point (RWP) and another more realistic model like Shortest Path Map Based Mobility Model (SPMBM). As shown in Fig. 11, with SPMBM the delivery ratio is higher than with RWP. The latency is best with HALF compared to other protocols. We also observed the performances by varying the number of different type of Mobile nodes. The number of cars influences the delivery performances very much because of the increased contact frequency. The number of trams has less influence on this as we found that with no trams but 40 cars the delivery ratio is better than with no Cars (but trams and others). In summary, SPMBM mobility model with high speed vehicle improves the performance of the protocol.

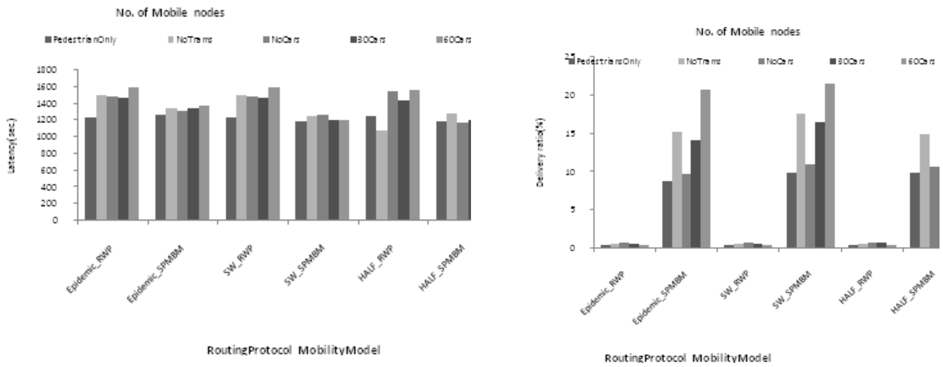



Figure 11. Performance for different Mobility models

### 4.2.6. Different Mobility speed

Further sub-sectioning, if required, is indicated

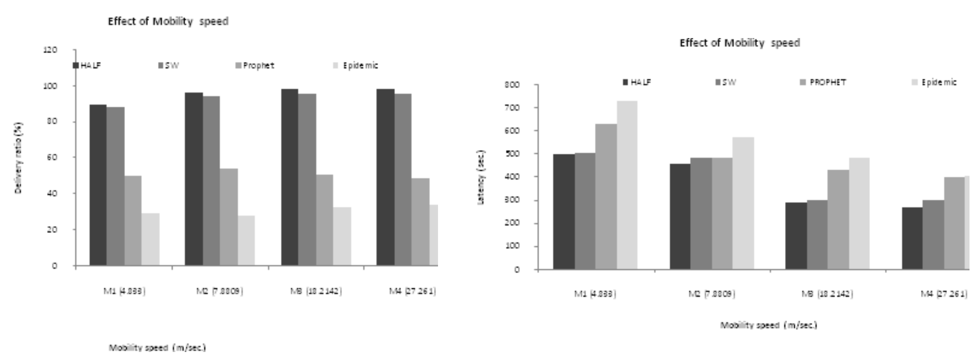



Figure 12. Effect of different Mobility speed on the

We calculated different Mobility speed M1, M2, M3 and M4 using the following relation :

∑(minimum speed, maximum speed) in m/s of each type of mobile node groups × no. of hosts in that group/total no. of nodes; the range of the speed for each mobile node types were varied to calculate the values of different M.

Fig. 12 presents that as the mobility increases, the delivery ratio increases and the latency decreases. The latency of HALF decreases to about 60% of its value at M4 than at M1 because due to the moblity of the nodes more Bundles can reach their destination faster than before.

### 4.2.7. Different route-cache time variation

By varying the Route-Cache time of the update message at each of the routers from 5 sec to 3000 sec value range we get increased delivery ratio and decreased latency value. Because of the increased cache time, more Bundles can get their way to the destination using the route information and Bundles from the far away routers are now contributing in the latency values.

## 5. CONCLUSION

Our main achievement is that HALF gives satisfactory performances over a wide range of network types. Considering the latency, HALF is better than all other existing routing protocols for low to high traffic intensity conditions in the network. This protocol could also achieve higher delivery ratio than others except at low traffic intensity. HALF can work over the radio range from 10m to 250m with improved performance as the range increases. We also showed that HALF is suitable for small message sizes. The SPMBM mobility model with high speed vehicle improves the performance of the protocol and with the increase of the Mobility speed the delivery ratio increases and delay decreases to a substantial amount.

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