ACHIEVING LOW END-TO-END LATENCY WITH A HANDOFF-BASED DETERMINISTIC ROUTING PROTOCOL (HDRP) IN DELAY-TOLERANT NETWORKING

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Abstract: DTN is able to adapt any mobility environment where any mobile routers and terminals are combined owing to the DTN's flexible hop-by-hop routing schemes. The existing DTN protocols like Epidemic, Prophet and Spray-and-Wait protocols rely on the message distribution mechanism where each DTN node produces one or more message copies. They can naturally adapt to the mobile situation where the destination node moves from an old connection endpoint to a new connection endpoint because any message copy may luckily be able to reach the new connection endpoint where the mobile node is newly connected. These protocols suffer from long latencies because message copies are not immediately forwarded until any suitable condition for forwarding is met. To solve these problems, we propose a Handoff–based Deterministic Routing Protocol (HDRP) that makes the best use of general handoff mechanisms intended for the IP network. This handoff mechanism includes the registration of locations by mobile nodes and backward propagation and caching of these locations over the experienced route. Our simulation results indicate that HDRP outperforms other existing protocols especially in terms of end-to-end latency.

1 INTRODUCTION

The architecture and protocols devised to be used in Delay and Disruption Tolerant Networking (DTN) are well suited for mobile and extreme environments lacking continuous connectivity (Ott, 2005). The DTN architecture is featured by dynamic hop-by-hop routing and the custody transfer mechanism. The Custody Transfer concept refers to the acknowledged delivery of a message from one DTN hop to the next and the corresponding passing of reliable delivery of the responsibility. A DTN node which has taken custody of a Bundle will buffer it until a suitable next hop is found (Fall, 2003). This also means that routing should dynamically be changed, depending on the ongoing situations. So, the re-routing function is equipped with the DTN architecture as hop-by-hop routing.

The existing DTN protocols like Epidemic, Prophet and Spray-and-Wait protocols (Vahdat and Becker, 2000), (Lindgren and Schelen, 2003), (Spyropoulos and Raghavendra, 2005) handle mobile situations, based on the message distribution mechanism where each DTN node produces one or more message copies, wait for a suitable condition for forwarding like meeting a node with higher delivery predictability in Prophet, then distributes them possibly on a hop-by-hop basis toward the destination node, and makes any lucky one of the copies reach the destination node. Therefore, the existing DTN protocols can naturally adapt to the mobile situation where the destination node moves from an old connection endpoint to a new connection endpoint because any message copy may luckily be able to reach the new connection endpoint where the mobile node is newly connected. However the existing DTN Protocols suffer from low delivery ratio because their routing decisions are based on the local knowledge given by the next hop node. The existing DTN protocols also suffer from long latencies because message copies are not immediately forwarded until any suitable condition for forwarding is met. These problems suggest that any global knowledge on end-to-end path from the source node to the destination node should be more

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exploited to enable immediate forwarding that eliminates any opportunistic waiting.

We assumed a practical environment with fixed routers and mobile or fixed terminals. Because when we project the future use of network, we find that more and more computer and network resources will be ubiquitously located in fixed locations just like the Wireless LAN environment. We propose a Handoff–based Deterministic Routing Protocol (HDRP) that makes the best use of general handoff mechanisms intended for the IP network. Here, the handoff refers to the dynamic event in which communications are maintained with the network by transferring the connection to a neighbouring network access point. The proposed handoff-based mechanism includes the registration of locations by mobile nodes and backward propagation and caching of these locations. When a mobile node moves to a new location, it registers its location (the name of the router it belongs to) with the DTN router and this location information is propagated to and cached in every DTN router over the experienced route to update the Proxy List (PL) at each router. As every DTN router maintains the connectivity information with adjacent DTN routers in the PL, the DTN router can select the best possible next hop for bundles destined to the mobile node in a deterministic way. Our simulation results indicate that HDRP outperforms other existing protocols like Epidemic, PROPHET and Spray-and-Wait especially in terms of end-to-end latency.

2 MOTIVATION

The mobility environment supported by existing protocols in DTN is by having forwarding decision on the basis of local knowledge given by the next hop node and is done opportunistically depending on some condition to be fulfilled. These lead to degraded performances in terms of delivery ratio and end-to-end latency. The forwarding process can be improved by making use of the location information of the mobile node and back propagating and caching this information on the experienced route of the mobile node. As every DTN router maintains the connectivity information with adjacent DTN routers in the PL, the DTN router can select the best possible next hop for Bundles destined to the mobile node in a deterministic way. The novelty of the work lies in gathering the routing information through the Hand off process which provides the location information of the MH to the previous router as part of the process and hence helps to route the data more deterministically and quickly to the MH. Moreover the Back Propagation and caching of this location information at each of the routers in the experienced route of the MH provides option to choose the best route to reach the destination. This feature adds more dynamic and improved performance to the HDRP.

3 THE PROPOSED SCHEME

3.1 The System Model

Our system model assumes an environment of interconnected fixed DTN routers. We have considered the same network environment as the WLAN environment which is very practical if we project the future use of network.

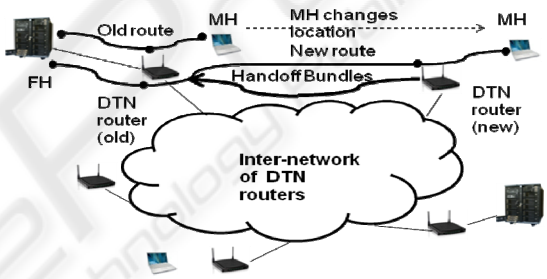

Figure 1: Handoff Bundles from one node to another after MH changes location.

There are two types of End nodes, Fixed Host (FH) and Mobile Host (MH) which are communicating with each other through these routers. The FHs are connected with DTN routers and the MHs are moving around following a map based movement model (Keränen and Kärkkäinen, March 2009). An MH can communicate directly with another MH if they come within each others' range.

If an MH move to a new location it registers its location to the new router and this location information is propagated back to the old router. The old router then hand off the data destined for the MH to the new router. Our main focus was to propose a routing protocol which is based on this handoff technique and at the same time to utilize the hop-by-hop routing and custody transfer mechanism of the DTN routers.

The DTN nodes communicate using the Bundle Protocol for DTN and the protocol data unit is known as Bundle which is the aggregated messages. Basically two types of Bundles are used -the data type and the Status Report (SR) type, latter of which is an administrative type of record for sending acknowledgement to a custody transfer request etc (Scott and Burleigh, November, 2007).

3.2 The Routing Protocol

Our proposed routing protocol named Handoff-based Deterministic Routing Protocol (HDRP) has some key conceptual features and technical features. This section explains each of these features in detail along with an example of a particular protocol sequence.

Every router has a **Proxy List (PL)** where it keeps record of all other routers in the network and the next hop to choose to reach each of the routers. When an MH moves to a new location it registers its location with the new router after receiving a beacon from that router. **The registration message, REG** contains [MH, Previous Master (PM)] addresses that is, the address of the MH and the old router. After registration is done the new router becomes the Current Master (CM) of this MH and forwards a **Handoff Message** containing (MH, CM) to the Previous Master.

In the mean time, when the old router senses (senses periodically whether the MH is within its range) that the MH has moved away it starts buffering the bundle destined for that MH. Upon contacted by the new router (through the handoff message), the old router handoff the buffered bundles to the new router and finally the bundles are forwarded to the MH. The old router also updates the **PL** with the (MH, CM) information so that it can forward the subsequent bundles destined for that particular MH using this route update. The process of handing over the buffered data from the old router to the new router is done through the **hop-by hop routing** method of DTN and the bundles are kept in the buffer of the old router until a new route is established to the destination with the help of the **custody transfer mechanism**.

Depending on the situation whether the direction of communication is from FH to MH or from MH to FH and whether the Bundle/SR has been lost during sending/ receiving process, there can be different protocol sequences for the handoff.

Figure 2 shows one of those protocol sequences between different DTN nodes in our model where MH fails to receive a Bundle due to its movement.

In this diagram, a FH is sending Bundles to a MH through Router1 (old router). The MH changes its location and moved to Router2 (new router). The transfer of the data and SR bundles with specific functions are shown in the figure. To accomplish the

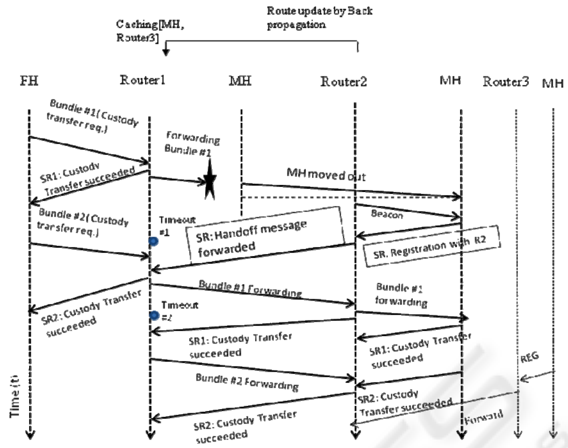

Figure 2: Protocol sequences showing a handoff situation and route update by Back propagation.

handoff process successfully, we extend the Bundle specified in the IRTF standardization in order to include the auxiliary addresses and its associated fields in the SR. The Handoff latency has been so far defined in different ways in different works that deal with the handoff problem (The ONE), (Manzoni et al.), (Yavatkar and Bhagawat, 1994). We have defined the Handoff latency as the time from “when the MH receives the beacon from the new router” to “the time when the MH receives the first Bundle through the newly established route”. Here we have assumed the best possible case for the arrival of the beacon that is we have assumed that as soon as the MH entered into the range of a router it receives a beacon from that router.

The above figure shows the simplest case when the old and new routers are only one hop away from each other. Our protocol also works efficiently even if the MH has moved far away that is even if there are one or more routers in between the old and new routers. In our system model, we have assumed that epidemic protocol is used for initial Bundle delivery to the router that will initiate the handoff. This is the situation before any MH in the network starts doing registration or any handoff has taken place. A very large sized buffer at the routers is assumed to cope with the situation of buffer overflow for the custody transfer.

As every DTN router in the HDRP maintains the connectivity information (through PL) with adjacent DTN routers, the DTN router can select the best possible next hop for Bundles destined to the MH in a deterministic way. The Forwarding mechanism also plays a vital role in achieving the deterministic routing: A router always look 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. A Flood List (FL) is maintained for each of the Bundles to be flooded through all the connections attached to a HDRP router. Bundles are sent according to the following priority: (1) Data from Buffer, (2) Data from Flood List (FL), (3) Handoff message, and (4) SR (Status Report). As shown, the data type always gets the priority over other types of Bundle.

3.3 The Bundle Protocol Extension

The features that we need to implement in our routing protocol required certain fields in the standard Bundle block format which is not specified in the present Bundle Protocol Specification (Scott and Burleigh, 2007). So, we propose some extension to the present Bundle Block format. To accomplish the Handoff process, the MH needs to do registration with the newly found router after receiving beacon from it:

- During registration the MH will inform the Current Master (CM) about its Previous Master (PM) and for this a field should carry the EID of the Previous Master.
- If When the CM will forward a Handoff message to the PM it needs to inform about the EID of the new MH that has just completed registration with it and used to reside with the old one.

We assume that this type of EID information can be carried as an auxiliary EID field in the payload block.

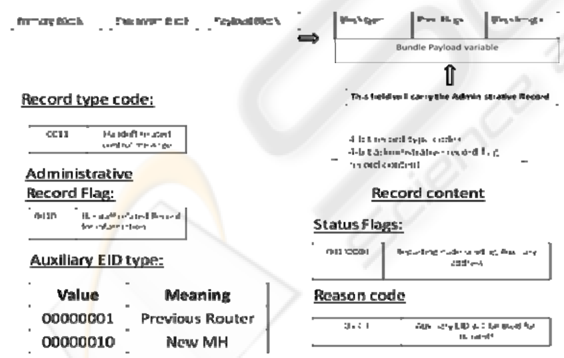

Figure 3: Extension to the Bundle block to support handoff mechanism in DTN.

As shown in Figure 3, A Bundle normally have the Primary Block and Payload Block, the extension Block is optional. The extension to the Bundle block is carried out in following steps:

- The 'Bundle payload variable' field normally carries Data but the field can also carry Administrative records like special Status Report.
- In this case, a flag in the Primary block indicates if it is carried in the Bundle payload field (Scott and Burleigh, 2007).
- The 'Record type code', 'Administrative record flag' and 'record content' field will indicate that the following information is carried to accomplish a handoff process.
- Finally the status flag and the reason code of the 'Record content' specifies about the auxiliary address and the auxiliary EID type is given with the value and meaning at the end of the Status Report.

The extension in the Bundle block format that we have proposed will not have any influence on the operation of the current Bundle protocol.

In Back propagation, the route update information of a particular MH is propagated back in its experienced route. The concept is implemented in the routing protocol. We do not need to make any change in the Bundle block format to support this mechanism. The route update propagation and caching at each of the routers in the experienced route involve the Handoff message and REG which is supported by the Bundle extension that we have proposed earlier.

Our protocol is also suitable to work in an environment where mobile routers are used. After receiving the Handoff Message, the Previous Router (PM) of the MH sends Bundles destined for that MH to its Current master (CM). If the CM changes its position by this time due to mobility, the Bundles can still reach the destination because if the PM fails to reach the CM by direct connection or PL it will ultimately go for the flooding technique as the last resort to reach the CM of the MH. As a result, even if the CM is a mobile router it will eventually get the Bundles to be delivered to the MH.

On the other hand, if it happens that the PM changes its position while the MH is going through the registration process to its CM, the scenario will be handled in a similar way as the case when the PM is multi hop away from the CM.

4 PERFORMANCE EVALUATION AND ANALYSIS

4.1 Simulation Network Model

Our network model consists of Fixed routers connected in a certain topology, Fixed end nodes connected to some of these routers and different type of mobile nodes moving around this fixed infrastructure network to communicate with other

Table 1: Parameters used in the simulation.

Parameter	Description (Values)
Node type	Fixed Routers: scenario 1 for 26 Routers; scenario2 for 65 Routers. End nodes: The numbers were varied from 124 to 1000.
Connections & movement model	Most of the Routers are connected with each other; Map based movement model (Keränen and Kärkkäinen, March 2009)
Mobile node types	Pedestrians, cars, trams
Transmitting speed of the Routers & End nodes	20M,250k Bytes per second
Transmitting range of the Routers & End nodes	300m
Message interval& Message size	Message interval of (1,2000), (25,35), (10,20) and (1,5) (per second) with random distribution; Message size is randomly varied between 500KB and 1MB
Buffer size	Varied from 10Mbytes to 300Mbytes
Mobility speed(M)	∑(Minimum speed, maximum speed) in m/s of each type of mobile node groups × no. of hosts in that group/total no. of nodes; M1,M2,M3 and M4 are calculated by varying the range of the speed for each mobile node types and finally by varying all together.
Simulation time	43K ~= 12 hours
Message TTL	40mins (for discarding messages)
Alive time/Back Propagated (BP) Routing update expired time/cache time	We varied the value for 5 sec, 30 sec, 160 sec, 600 sec and 3000 sec.

end nodes. Communication is possible between any pair of end nodes through one or more routers. The mobile nodes can communicate directly with each other if they are within the communication range. Different parameters used in the simulation are listed in Table 1. We have used the ONE simulator (Keränen and Kärkkäinen, 2009), (The ONE) to build and simulate our network model.

We made some modification and do some extension in the ONE simulator in order to implement our protocol. Our HDRP 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. Handoff Reports have been generated by extending the Report module.

4.2 Simulation Results

4.2.1 Performance at Different Traffic Intensity

In ONE simulator we can set different Message interval values within a minimum and maximum range. We varied this interval for (1, 2000), (25, 35), (10, 20) and (1, 5) per second. For each of these ranges, messages are generated randomly within the limits which actually indicate how much densely the messages are generated within our specified simulation time. That is why here we refer the different Message interval as the different traffic intensity of the network.

The basic HDRP is enhanced by us by combining the Back Propagation technique and hence we also have simulation results for HDRP (BP) which gave better performance. Our devised protocol has been compared with Epidemic, PRoPHET and Spray & Wait routing protocol in DTN. These protocols are renamed as FixedEpi, FixedPro and FixedSnW respectively as they are applied to a network which has fixed infrastructure that is fixed DTN routers.

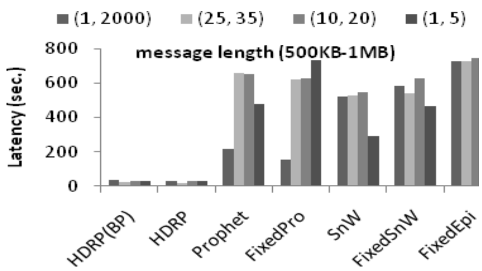

Figure 4: Latency at different traffic intensity.

Figure 5 depicts that that the HDRP outperforms all other protocol in terms of the end-to-end average latency of the network. Whereas each of the PRoPHET, SnW and Epidemic has latency in the range of 700 sec the latency for the HDRP is less than 50 sec. The reason behind HDRP performing so much better than other protocols are mentioned below:

- The efficient Forwarding mechanism of HDRP: In HDRP when a router has a message it looks for whether a connection is available: at first the router tries whether a direct connection can be found to the destination. If it is not there then the router consults its Proxy List (PL) to see if there is some information about the next hop to reach the destination for the message. If this second attempt also fails then the router tries to send out the message by flooding it to the available outgoing connections. The router uses the flooding method as the last resort to forward the message to its destination. In most of the cases it can found a direct route or a suitable next hop from its PL. Using HDRP a router does not need to wait for a suitable condition for forwarding to meet as in PRoPHET a node with higher delivery predictability has to be found or in a Spray and Wait protocol the destination itself should be there if the sparying phase is finished.

- In our system model we consider the fixed DTN routers interconnected with each other and the end nodes, that is the FH and the MH are communicating through this routers. During this communication in between the fixed routers there is no waiting time because of the fixed links. The only waiting time is between the Source and the router next and the Destination and the router next. This logical time is also very minimal. This contributes to the low end-to-end latency of the network.
- The existing DTN routing protocols deals with only the mobile nodes and it is required to wait until the next hop mobile node physically moves to the wireless range of the previous hop node and also the forwarding condition needs to be satisfied before the routing takes place. This leads to the larger value of overall end-to-end latency.

HDRP (BP) gives slightly worse performance (avg. 38 sec.) than that of HDRP (avg. 32 sec.) because of the fact that now more bundles can reach the destination from the distant routers using the cached route update information of the Back Propagation technique.

Figure 5 also depicts how the other protocols will perform in the same environment. It is found that PRoPHET performs well when the traffic density is low but the performance overall deteriorates as the traffic density increases. Since this protocol works based on finding a suitable node to forward with higher delivery predictability than the previous one, it can be concluded that increasing the traffic density does not help much in finding that suitable next hop. On the other hand the Spray and Wait (SnW) protocol shows overall same performance for all types of traffic density and the latency is larger than the PRoPHET. Epidemic presents quite a low profile than all other protocols.

Figure 6 presents the comparative situations of the end-to-end latency for all the delivered messages in the above mentioned protocols. This figure clearly shows the lower latency range for the HDRP where about 90% of the messages contribute between 5 to 15 sec latency whereas in case of PRoPHET and SnW protocols most of the messages have latency between 256 to 1025 sec range. This reveals that in HDRP most of the messages are delivered to the destination very quickly but in other protocols majority of the messages takes longer time toreach the destination and hence the end-to-end latency increases. In this chart the HDRP (1, 5) gives more end-to-end average latency than the HDRP (1, 500) owing to the heavy traffic intensity which causes more delay for the Bundles to reach the destinations. We have plotted the PRoPHET (1,5) and SnW (1,5) to show the comparison between the protocols when the network traffic is very high.

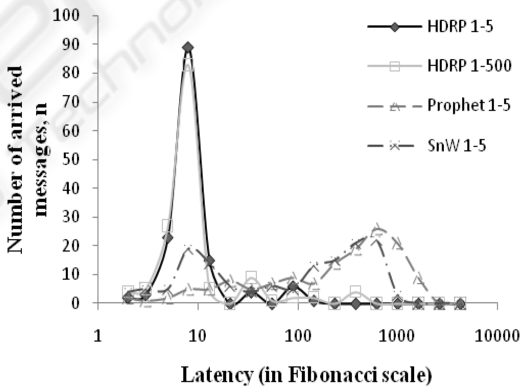

Figure 5: Latency values of different number of messages.

4.2.2 Performance at Different Router Density

We have simulated our network model for two different topologies: i) Few Routers (FR):26 routers ii) Many Routers (MR): 65. The routers are not fully connected but they are well connected. They are placed at different positions of the map of our model so that the mobile nodes plying around the city map can fall within the range of one or other to accomplish their communication. It can be intuitively guessed that increasing the router density will certainly improve the delay performance in our system. But we wanted to show how much would be the difference if the number of the routers are more than double.

Figure 7 depicts that HDRP and HDRP (BP) have lower latency when Many Routers are present than the Few Routers. This amount is substantially lower than other protocols. As the number of router increases more routers can be used to reach the destination quickly. We found very low latency values especially in case of MR. When the router number increases from 26 to 65, the latency decreases from 50sec (avg) to 25 sec (avg.) in case of HDRP and from 60 sec (avg.) to 30 (avg.) sec in case of HDRP (BP).

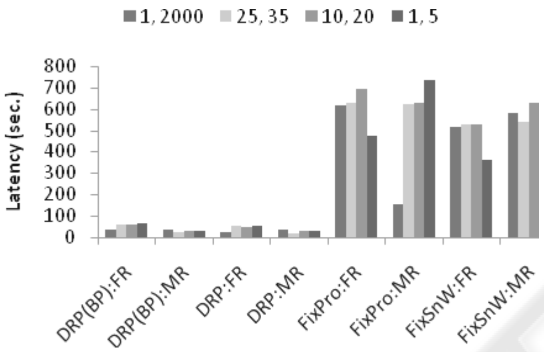

Figure 6: Latency values of different number of routers.

Another point worth mentioning here is the transmitting range of the routers. We have used the 300 m transmitting range. With lower transmitting range the performance degrades. And with higher transmitting range we got same performances as with the 300m range.

4.2.3 Performance for Different Node Density

We wanted to show what will happen if the number of end nodes communicating in our working environment increases keeping the fixed router numbers at 26. We tried with different end node numbers from 124 to approximately 1000 nodes. For the wide range of (120 to 1000 numbers of nodes), both HDRP and HDRP (BP) gave much lower latency value than others. Figure 8 shows that the HDRP is scalable for the different node density.

4.2.4 Effect of Different Mobility Speed

To show how the mobility of the MHs affects our protocol and others we have chosen different values of Mobility speed, M by varying the speed of each type of mobile nodes (pedestrians, cars, trams etc.),

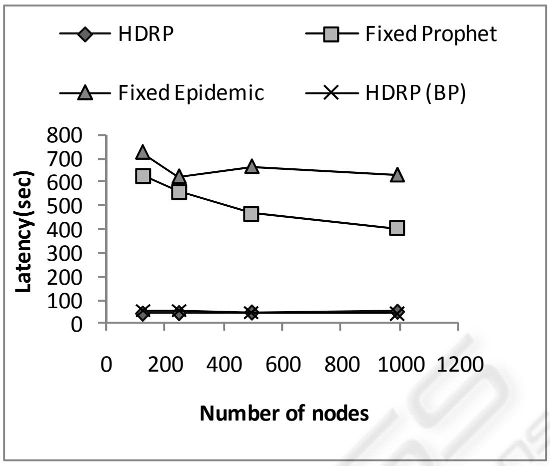

Figure 7: Latency at different node density.

as explained in Table 1 For example, M1= [(.5, 1.5) x40+ (2.7, 13.9) x40+ (7, 10) x2+ (7, 10) x2]/84=4.833. Here the pedestrians speed has the distribution of (.5, 1.5), no of pedestrians is 40; speed distribution for the cars are (2.7, 13.9), no of cars is also 40; trums1 and trums2 both have the distribution as (7, 10) and the total number of mobile nodes are 84. Finally, the total speed is divided by the total number of nodes that is 84 and we get the M1 value as 4.833.We varied the speed range of the different type of mobile nodes and calculated the M2, M3 and M4 respectively.

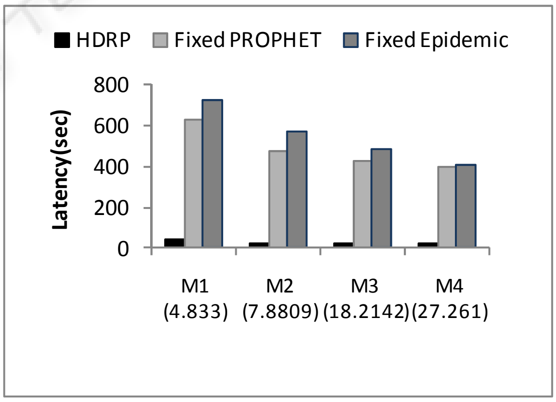

Figure 8: Latency for different mobility speed.

Figure 9 shows that the latency of HDRP decreases to about 50% of its value at M4 than M1. As the moblity of the nodes increases from 4.833 to 27.261 that is more than 6 times, now more Bundles can reach their destination faster than before. Thus the latency of HDRP decreases to 21 sec from 43 sec which is almost half. As we know that in Epidemic protocol the message can spread faster in the network if the speed of the mobile nodes increases and thus can reach the destination within small time. So the latency for Epidemic decreases to 403 sec to 724 sec as mobility goes from M1 to M4. But PRoPHET is less effeced by mobility than Epidemic and ofcourse from HDRP as its operation is guided by the suitable forwarding condition to be made.

4.2.5 Effect of Route-cache Time Variation

In the HDRP with Back Propagation technique we varied the Alive time or route- cache time at each of the routers from 5 sec to 3000 sec value range. Because of the increased cache time at the routers, few more Bundles get their way to the destination deterministically using the cached route information. The latency increases to 31.27 sec from 22.82 sec which shows that now Bundles from the far away routers are now contributing in the latency values and so there is a increase in the overall latency.

5 RELATED WORK

5.1 Related Work on Handoff Technologies in TCP/IP Protocol

There have been ample research works going on the Mobility issues particularly Handover techniques in Mobile Wireless environment. After wireless networking technology became popular people tried to develop mechanism that will deal with both the wired and wireless part of a network efficiently. Different methods were devised to overcome the problems associated with the TCP to handle mobility in the wireless environment (Manzoni et al., 1995), (Yavatkar and Bhagawat, 1994), (Balakrishnan et al.), (Caceres and Iftode, 1994). In spite of many improvements these methods have the drawback of end-to-end session management, TCP slow start mechanism etc. I-TCP, Snoop-TCP, M-TCP and few other protocols were developed to handle the handoff situations efficiently through the use of mediation by the Mobility Support Router (MSR) (Bakre and Badrinath, 1997). But these methods also suffer from the problem of large Handoff Latency due to the connection states transfer between the old and new MSR. In HDRP the rerouting during the Handoff is done with the help of the hop-by-hop reliability mechanism and custody transfer of the DTN technology. This protocol does not have the end-to-end session management or connection state transfer problem during handoff. When handoff takes place, the MH registers its location to the new router and this location information is propagated back to the experienced route and cached there so that any Bundle destined to that MH can be deterministically delivered to the destination.

The handoff latency is reduced in HDRP in comparison to I-TCP in terms of number of message exchanges:

Between MH and its CM it is similar because in case of I-TCP we have Beacon/Greet/Grack and in case of HDRP we have Beacon/REG/ SR correspondingly. But between the CM and the PM the number of message exchanges is not same because I-TCP has Fwd Ptr/Fwd Ack/MHState/ACK and HDRP has HO message/Data forwarding/SR.

Within the CM and PM routers, in case of I-TCP, there are number of internal message exchanges between the components of the router to accomplish the handoff process but HDRP does not require any internal message exchanges for the handoff to take place.

Mobile IP, the mobility extension to the Internet Protocol devises all the techniques to handle mobility related and hence handover situations at the network layer. But it also suffers from many problems regarding the duration of handover and the scalability of the registration procedure (Schiller). If we consider a large number of mobile nodes changing networks quite frequently, a high load on the home agents as well as on the networks is generated by registration and binding update messages. The message delivery in HDRP does not involve going through any home agent and update messages do not need to travel so far. The old router simply consults the PL and forwards the messages destined for that particular mobile node. This process is a very simple one and takes reasonably less amount of time.

IP micro mobility-protocols like Cellular IP (Campbell and Gomez-Castellanos, 2000), (Campbell et al., 2000) or others are developed to complement mobile IP by offering fast and almost seamless handover control in limited geographical areas. But they accompanies additional network load induced by forwarding packets on multiple paths. An additional cost of these schemes is that communication, signaling and information state exchange are required between the base stations for these approach to work. On the other hand the Handoff protocol in HDRP implements handover of the messages with minimum number of control message exchanges and no additional cost of overhead. In case of Cellular IP, the back propagation of route update packet takes place between the MH and the crossover gateway of the cellular network. In case of HDRP, the back propagation takes place along the experienced route of the MH that is through all the Previous Masters of the MH. The distance between the MH and the crossover Gateway is very important in case of Cellular IP because while considering the Hard handoff, the notification time from the new base station to the old base station should be less than the round trip time from the MH to the crossover Gateway. This reduces the packet loss. On the other hand, in HDRP (BP) the route update propagates until sometime defined by the Alive time of the route update Bundle at each of the router.

Another technique used in Cellular IP to reduce the packet loss is the use of soft handoff technique where the semisoft packet creates new routing cache mappings between the crossover and the new base stations, beforehand. In case of HDRP we didn't use any kind of route cache mapping creation before the actual handoff takes place.

Many schemes have been developed considering cross layer approach that is considering the Link Layer triggering to the Network layer and how they jointly reacts to handle the handover problems (Blondia et al..,2003). In HDRP the handling of both routing and handoff is done in a single bundle layer which reduce cross layer interaction and synchronization overhead and thus makes the handoff latency smaller. An interaction between the Bundle layer and the Physical layer is present during the registration process by receiving the Beacon.

There are methods like Daelalus Implementation (Seshan et al., 1996) that anticipates a handoff using the received signal strength and multicast data destined for the MH to nearby base stations in advance. Combined with intelligent buffering techniques at the base station, this provides good performance without explicit data forwarding. But this method has the inefficiency in handling the routing of packets to the base station and the overhead of buffering packets at several base stations. During handoff in HDRP, we do not need to consider any multicasting technique neither do we need to apply any routing in advance. Hop by hop routing decision is taken dynamically and buffering is accomplished through custody transfer mechanism efficiently.

5.2 Related Work on DTN Routing Protocols

A number of routing protocols have been targeted towards the context of intermittently connected mobile networks with opportunistic connectivity. Many of these protocols assume that all nodes are mobile and have developed algorithms to transfer message between these nodes. Flooding is one of the popular techniques among these. Epidemic Routing (Vahdat and Becker, 2000) is the protocol that extends the concept of flooding in intermittently connected mobile networks. It shows good performance in a DTN environment where random pair-wise exchanges of messages among MHs ensure eventual message delivery and performs well in terms of maximizing message delivery rate and minimizing message latency until other protocols were devised. PRoPHET (Lindgren and Schelen, 2003), a probabilistic routing protocol for such networks assumes non-random mobility of nodes to improve the delivery rate of messages while keeping buffer usage and communication overhead at a low level. The Spray and Wait routing protocol (Spyropoulos and Raghavendra, 2005) manages to significantly reduce the transmission overhead of flooding-based schemes and have better performance with respect to delivery delay especially when the wireless channel has high contention. These flooding based routing protocols do not make use of the global knowledge and hence suffers large latencies. We wanted to make use of the knowledge of the location of the mobile node and propose a handoff based routing protocol which can route Bundles in a deterministic way. The route update information during handoff and Back Propagation and caching of this location information over the experienced route improves the performances.

In comparison to Epidemic, PRoPHET and Spray & Wait protocols HDRP is deterministic in nature and this is a more logic based routing protocol. With carefully designed forwarding mechanism and message prioritizing technique, under different scenarios, it is possible to achieve better delivery delay than the other protocols mentioned above.

6 CONCLUSIONS

The HDRP protocol is a simple but efficient handoff-oriented protocol that integrates the DTN features with Custody Transfer and hop-by-hop routing and the existing Internet-based handoff schemes like mobile-IP, cellular-IP and I-TCP. This integration is not a simple result that simply combines the two different technologies but a sophisticated and well-considered result because DTN architecture is based on hop-by-hop routing and fundamentally different from the end-to-end routing of the Internet architecture. Therefore we have devised a unique integration that fully utilizes the DTN features.

HDRP gives better performance than the already existing DTN protocols in terms of Delivery ratio and end-to-end latency by making use of the location information of the MH and applying the Back Propagation of the route update information technique efficiently. The protocol shows superior performance even for high traffic loads and it is possible to achieve very low end-to-end latency with the help of this protocol.

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