Routing Protocols in Delay Tolerant Network (DTN): A Critical Study and Comparison

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ABSTRACT

Delay tolerant Network (DTN) became more popular in the research area recently, because of its application. It is a wireless network that communicate with the nodes by storing the message packets in the bundle temporally and whenever relay node or the intermediate node have the chance to send the message to the other node that just encountered by the relay node. The mechanism use for the DTN routing is the store-carry and forward approach. Main challenge for the DTN routing is that it discovers the route through the network without an end to end path so nodes in the network connect to the other nodes instantly. This paper review about DTN, types of routing techniques and its issues, some popular routing protocols and their performance in terms of Delay, message Delivery rate, Overhead, Controlling the number of replications of the node.

Keywords—DTN, Number of Replication, PRoPHET, Spray and wait

I. DELAY TOLERANT NETWORK

In today's world, Due to internet many of devices (computers, Mobiles) are communicating with each other in all around the world. For the humans better and easy life the technologies are increasing everyday communications so networks are emerging that are different and more Massive.The networks (MANETs VANETs, Wireless Sensor Networks (WSN)) have given new opportunities for the different types of applications. There are number of networks used in connecting and communicating with different devices and it is only possible by some set of protocols known as TCP/IP protocol suite. Principle on which TCP/IP works is based on end-to-end data transfer. However, there are many regions where the assumptions of the internet cannot be satisfied. If at any environment where there is no path between the sources to destination, then TCP/IP fails to work properly or might even stop working completely. Because of such circumstances, a newer network has evolved which is independent end to end connectivity between nodes. This network is called as Delay Tolerant Networks (DTN).DTN has different characteristics from the other wireless networks like intermittent connectivity, low error rates or link failure and large delay [1]. In the environments like disaster relief with limited range of radios, sensing the environment, military purpose, deep space communication, underwater sensing, inter vehicle communication.

In the wildlife monitoring the remote areas have to face low density of the nodes. By the type of networks the devices is not able to establish full connected network from source to the

destination for routing the data and due to this the thought of the new network DTN is emerging in the mobile network and vehicular network and others according to the application and environment.

Delay Tolerant Network (DTN) is a set of emerging networks that has extremely different characteristics from the other wireless network and internet. E.g. The intermittent connectivity, Large Delays, Low error rates [1] Mostly Large Delay and frequent partitions are there so may be up-to-date information for the stable network is not available so Data transmission is the main issue for the DTN. This is caused by the high mobility and the density of the nodes is very low. This kind of characteristics make the routing difficult in the DTN[1] exist solutions do not work in the environment like DTN networks because assumption is taken for the network is stable and the link failures are infrequent between the nodes. Therefore efficient routing is the still research area in DTN [1].Delay/ Disruption tolerant networks (DTN) also called as intermittently connected mobile networks (ICMN), are wireless networks where the high mobility and low density of the nodes in the network at any given time instance, the probability that there is an end-to-end path from a source to a destination is low[1][2] Delay (or disruption) tolerant networking, provides an alternative approach for a various wireless environments that challenge the limitations of the transport and routing layers in the TCP/IP model. TCP/IP based Internet routing [3] where end-to-end path exists between peers, end-to-end packet drop problem is small and Low delay path between source to destination. DTN routing usually follows store-carry-and-forward; i.e., after receiving some packets, a node stores and carries them around until it contacts another node and then forwards the packets. Since DTN routing relies on mobile nodes to forward packets for each other, the routing performance (e.g., the number of packets delivered to their destinations) depends on whether the nodes come in contact with each other or not.

DTN routing protocols application specific and lacks the support for dynamic situation. There by giving an opportunity to contribute towards building dynamic routing. This raises question:

1. How many copies to be replicated in network?
2. How the message replicate in the network?

An answer to above mentioned questions demands clearly place to efficiency in routing environment. Therefore, dynamic routing protocol is required to satisfy the need and routing objectives.

This paper is organized as follows: - Section II introduces the concept and architecture of DTN. Section III presents classification of routing protocol. Some important routing protocols of DTN are discussed in Section IV. Section V contains routing issues. Table 1analyzed and compared various routing technique proposed by the other researcher to solve routing issues in DTN.Finally, Section VI concludes the paper followed by future work.

II. CONCEPT AND ARCHITECTURE OF DTN

A Delay Tolerant Network can be considered as an enhancement of the existing regional networks. This enhanced feature is called as the bundle layer. This layer is intended to function above the existing protocol layers and provide the function of a gateway when two nodes come

in contact with each other. The main advantage of this kind of protocol is flexibility. It can be easily linked with the already existing TCP/IP protocol networks or can be used to link two or more networks together [1-4]. The place of the bundle layer can be seen above the transport layer in the Fig. 1

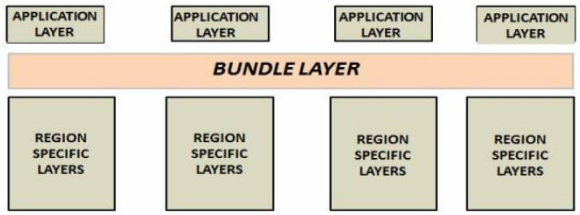

Fig.1The Position of the bundle layer [Thesis 1]

Bundles are the messages of nodes. By storing and forwarding entire bundles between nodes for the transfer of data from one node to another can be made reliable. The bundles contain source node ID and destination node ID, Time to Live-control information(TTL) and a bundle header. Whole bundles stores and transmit by the bundle layer between different nodes. The layers lower the bundle layers are selecting for their correctness to the communication environment of each filed.In DTNs at any given instant, there may not be any route to the next hop. In this case, the node must buffer the message in persistent storage, until a contact becomes available. Once the next hop stores the bundle in persistent storage, it is said to have taken custody of the bundle, and the node that have sent the message can delete its own copy of the bundle. Instead of waiting for the next hop to become available, the DTN gateways may themselves be mobile. Each node is associated with a persistent storage device like hard disk, where it can store the messages. It is called as persistent storage as it can store the message for amount of time. The persistent storage can be useful in situations when the next node is not available for a very long time, or when the rate of incoming messages is far higher than the rate of outgoing messages [4]

III. CLASSIFICATION OF ROUTING PROTOCOLS

The existing routing protocols in DTNs are classified with respect to their strategies for controlling message copies and forwarding decision of message to the destination [5]

Number of destination: According to the number of destinations nodes to forward messages and routing can be classified into the three categories:

1) Unicast Routing: Only one destination for the each message.
2) Multicast Routing: Destinations node could be one or group of destination nodes for the each message
3) Broadcast Routing: All the nodes are the destination for the each message.

Number of copy: Depending on the number of copies utilized in the routing process the routing protocol can be classified into the two categories:

1) Single-copy routing protocols: Only a single copy for each message exists in the network at any time.
2) Multiple-copy routing protocols: Multiple copies of same message can be generated and distributed into the network. Moreover, multiple copy routing protocols can be further divided into flooding-based and quota based.
a) Flooding-based routing protocol: Dissemination or broadcast a copies of each message to as many nodes as possible.
b) Quota-based routing protocol: It limits the number of message copies to flood in the network.

Available Network knowledge: Whether the forwarding decision is based on the knowledge derived from the nodes' encounters or not or from their history, protocols can as well be classified into two categories:

1) Deterministic routing protocol: Complete knowledge of node history encounter probability of nodes and node meeting times and period to make the forwarding decision
2) Non-deterministic routing protocols: Zero knowledge of pre-determined path between source and destination. These algorithms either forward the messages randomly or prediction based.

IV. POPULAR ROUTING PROTOCOL OF DTN

In this section, some important routing protocols and their strategies for their routing in DTN aredeliberated.

Earlier in 2000, Vahdat and Becker et al.proposedEpidemic Routing Protocol, a flooding-based forwarding algorithm [4].In this Routing, The node in the network which receives the message then it forward a copy of it to the all the node that node encounters so that the message is spread in the whole network by the moving or mobile nodes and in the all the nodes have the same data. Although, the guarantee of the delivery of the message is not provided. This routing is the best approach to reach to the destination. Each message has the unique identifier which stored in the buffer and list of them is called as the summary vector. When the two proximal nodes get contact with each other then they exchange and summarize the summary vector and compare which message they do not have and after that request for the message to the node. When the counter of the packet reaches to the zero then packet is discarded and other approach is to set the Time-to-live (TTL) for each packet in the routing. The packet would copy from one to the other node till the TTL expires. It is useful when there is lack of information regarding network topology and nodes mobility patterns [6]

Earlier in 2004, A. Lindgren, A. Doriaet.al. proposed probabilistic routing protocol using history of encounter and transitivity (PROPHET). In the routing it assumed that the mobile nodes used to pass to the some locations more than the others so passing through the previously visited location's probabilityare high than the other so this approach is implied in the routing scheme [7]. So from that approach the node will meet the other node more preferably in the future which they met each other in the past.

The major concern of this routing protocol is to improve the delivery predictability and reduce the wastage of the resources in the epidemic routing. In this scenario, initially in the network it will estimate the probabilistic metric for each known node. Delivery predictability (a,b) ∈ [0,1] for the node A for the each known destination B. whenever the nodes a node encounters with the other nodes then they exchange summary vectors as same as the epidemic routing .This summary vector contain the delivery predictability values for the destinations for the each node. The calculations of delivery predictabilities of nodes have three parts. Nodes update their delivery predictability metrics whenever meet each other. Visiting more nodes would be that high delivery predictability values. The calculation for that is shown in the equation 1.

$$P(a,b) = P(a,b)old + (1 - P(a,b)old) \times Pinit. \quad \text{Eq. 1}$$

(Where Pinit is initialization constant)

In the conventional routing protocols that discover the route and forward the packet to the destination on the basis of the shortest path or the lower cost, on the other hand, in the PROPHET whenever the node receives the message there no path to the destination and node carry the message in the buffer and forward it to the encountered node. The limitation of the PROPHET routing is that whenever node meets with the low delivery predictability then there is no guarantee that it would meet the other with higher predictability value during the message life time. The basic difference of Prophet than Epidemic Routing is its forwarding strategy, when two nodes meet, Prophet allows the transfer of a message to the other node only if the delivery predictability of the destination of the message is higher at the other node

Earlier in 2005, T. Spyropoulos, K. Psouniset.al. proposed Spray and Wait (SW) Routing Protocol. This is the replication based routing proposed which control the spreading of messages in the network. The spray and wait protocol assume to have no knowledge of the network topology and mobility of the nodes whether it is random or the repetitive behavior. It just forward the multiple copies of the messages using the flooding [8] The difference between epidemic routing and spray and wait is just that it only spreads the limited number of copy (L)message. This routing consists of two routing:

1) **Spray Phase:** In this phase according to the network limited number of copy (L) of messages are spread over the network by the source and other nodes will receive the copy of the message.
2) **Wait Phase:** After the spreading the copies the all copies of the message is done and the destination node is not encountered with the copy of the message in the spray phase then each of nodes carrying the copies try to send their own copy to destination via direct transmission.

To enhance form of spray and wait is the binary S&W. According to binary spray and wait, the source node creates L copies of the original message and then, whenever the node is encountered, communicate half of them to it and keeping the remained copies. This process is continued with other relay nodes until only one copy of the message is left. When this happens the source node waits to meet the destination directly to carry out the direct transmission.

Different methods limiting the number of distributed messages and reduce resource consumption in intermediate nodes but often better performance result compared to the epidemic routing protocol.

V. ROUTING ISSUES IN DTN

In this section some of the important routing issues of DTN are discussed.

Buffer space: Due to Intermittent connectivity, messages must be buffered for long periods and next node in the communication require enough buffer space to store all the messages that are waiting for future communication opportunities. Hence, intermediate nodes require sufficient buffer space to store all pending messages as per opportunities.

Energy: In DTN, due to the mobility of nodes, energy of the nodes kept wasting this leads to low level of energy. During sending, receiving and storing of messages, nodes required sufficient energy. Therefore, designing energy-efficient routing protocols is one of the challenging issue important to carry our research work.

Processing Power: One of the goals of delay-tolerant networking is to connect devices that overcome the limitation of the traditional networks. These devices may be very small having small processing capability, in terms of CPU and memory. These nodes will not be working for the some routing protocols because of power consumption.

Reliability: Some acknowledgment should be there for reliable delivery of data. If any routing protocol this ensures successful and stable delivery of data. For example, when a message correctly reaches to a destination, some acknowledgement messages should be sent back from destination to sources for confirmation.

Security: Security is always a significant issue. A message may pass through intermediate nodes randomly before reaching its final destination. Depending on the security requirements of applications, users may require secure guarantees about the authenticity of a message. The cryptographic techniques may be beneficial for secure intermediate routing.

Different researchers have come up with different approaches to solve the issues of routing in DTN, but none of the existing approaches offers a concrete solution against these issues. Due to resource limitation, proposed system drawback there is a need for a new routing proposal that provides higher message delivery rate and with minimum resources used and processing overhead.

Table 1.*Comparisons analysis of various technique proposed by the researcher to solve Routing Issues in DTN*

Researchers	**Based on/Approach**	**Objective**	**Replication Control**	**Advantages**	**Disadvantages**
Eung-Hyup Kim et al. *ICOIN 2014* [9]	Based on spray and wait	Copies messages to a node with high probability of data delivery using data delivery probability with PROPHET protocol	Yes	Prevent any unnecessary spray in an existing spray and wait so buffer space is not wasted and message arrival rate is increased	Delay is more than the S&W
TomoakiMiyakawa et al. *2015 29th International Conference on Advanced Information Networking and Applications Workshops*[10]	Based S&W and PRoPHET	Combines S&W and PRoPHET so that S&W restricts the number of replications and PROPHET compare the delivery predictability of the replicated node and destination node	Yes	High message delivery rate can be achieved which raise the performance of the network	Overhead is more than the S&W
PriyankaDaset al. *2012 2nd IEEE International Conference on Parallel, Distributed and Grid Computing*[11]	Based on the credit , a value assigned to a node each time it gets connected to another node	Anodethat receives the message earlier will have greater probability of reaching the destination in time with low cost	Yes	-Message delivery rate is greater than the single message method and at the same time reduces the number of replications. -Less costly than other protocols	Delivery capability is less than the EPR.
PhearinSok, KeecheonKim. *Distance-based PRoPHET Routing Protocol in DTN ICTC 2013*[13]	Based on PRoPHET with distance metric	When delivery predictability is equal for the two nodes. It computes the distance of the node from the physical layer and store value in the share registry	No	Bundle delivery ratio is increased and the bundle delay is decreased during delivery	Delay will be more than PRoPHET

Lee and Nam et al. *ICOIN 2015*[14]	Based on PRoPHET, PRoPHETv2 with contact duration	If two nodes are encountering frequently then the probability of that nodes increases in the short period of time. PROPHETV2 is there with contact duration consideration.	No	Higher delivery ratio and low overhead then PRoPHET in terms of bandwidth and the average message size.	Number of replication to be is not considered
Samuel C. Nelsonet al. *Encounter–Based Routing in DTNsIEEE INFOCOM 2009*[15]	Encounter-based Routing (EBR), a quota-based DTN routing protocol	Predicts the future rate of node that encounters can be roughly predicted by past data	Yes	Minimize the delay and overhead and message delivery rate is increased also battery consumption is less	Analysis of parameter for variance number of replicas for all nodes is not considered
Wang and Shuet al. *2009 Fifth International Conference on Mobile Ad-hoc and Sensor Networks*[16]	Based on Epidemic Routing	ARER counts the forwarding predictability according to the metrics Replication Density based on the quantity of the replications Also assigns the weight function to the message Replication Density ,TTLof the message and delivery predictability	Yes	Message copies send is less and message delivery rate is more than EPR and other routing protocol	Delay would be more than S&W if the number of copies are less
Shou-Chih Lo et al. *2012 9th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD 2012)* [17]	Replication routing technique and a message moving technique to provide good Congestion control	Information about Buffer occupancy and delivery probability of node exchange to all nodes to control congestion	Yes	Used in all routing protocols for congestion control	It does not consider the parameter of delivery ratio and delay other than the congestion control and depends upon the integrated protocol

Liu and Tang et al. *2012 International Conference on Computer Science and Service System* [18]	Based on S&W with relay probability (R-ASW)defines from energy and probability of nodes.	If the forwarding probability of the relay node is greater than the current node so relay node carry more packets	Yes	Improves the delivery ratio and reduces the delay and overhead	Compared only with S&W
Xiang FaGuo et al. *2013 IEEE International Conference on Sensing, Communications and Networking (SECON)* [19]	Based on link transmission of connection is quality strong or weak	If message sent to the strong link is more deliverable than the weak link. Replication control can substitute over the strong link and how the strong and weak link is defined.	Yes	Much lower overhead is there compared to S&W Transmission latencies is low	Weak links are defined by the assumption that contacts are independent and identically distributed which does not fits in the real world scenario
XinWanget al. *Mobile Tendency Based Hybrid Routing for Partially Connected Networks* [21]	Based on mutli-hop neighbor discovery mechanism. Find end-to-end path and the partial path in the network.	If end to end path is not found then data will be stored in the buffer and it will replicate the message and send it to the relay according to the opportunities	No	Packet delay and delivery outperforms then the EPR,S&W and DFR	It is not highly modular for DTN system and geographical routing is not considered
Xue and Fan et al. *2009 International Conference on Networks Security, Wireless Communications and Trusted Computing* [22]	Based on S&w and Binary S&W	It counts the average delivery of the nodes and according to that it will send the replication to the n nodes using BSW routing	No	It have slight higher average delivery rate and short average delay	There is not major difference between BSW and if number of copies less

VI. CONCLUSIONAND FUTURE WORKS

Several existing routing protocols of DTN and their important issues are studied in this paper. Due to the unique characteristics of DTN, it creates a number of consequential challenges to its efficient routing design. To overcome the challenges, there is a need to design a new routing protocol that can control the number of replication of the message to the encountered node and give better performance than the existing protocols in terms of delay, overhead and increasing the message delivery rate.

Our immediate future plan is to evaluate the existing routing protocols of DTN and then propose a new routing technique which can control the number of replication of the message to the encountered node and give better performance.

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