Routing Protocol for Delay Tolerant Network: A Survey and Comparison

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Abstract— **Delay Tolerant Network (DTN) is evolved from Mobile Adhoc Network, MaNet. It is sparse and intermittently connected mobile adhoc network where reliable communication and end-to-end connectivity is not available for message transmission. The end to end connectivity is not ensured in Delay Tolerant Network. Only high latency applications are used in DTN. Latency may be in hours or days. The store and forward approach helps to increase message delivery probability in DTN irrespective of time taken to delivered message over normal MaNet. In DTN, the two or more nodes can exchange message when they move in transmission range of each other. Routing issue is very important due to limited resources for message storage and forwarding. This Routing issue is considered by many researchers which results in many routing protocol based on Flooding and Forwarding Approach. In this paper we try to summarize the routing protocols till date which are available in literature. We also try to compare the entire routing protocol. This paper gives right direction to researchers to proceed for designing a new routing protocol for Delay Tolerant Network.**

Keywords- Routing, Delay Tolerant Network, Flooding, Forwarding, MaNeT.

I. INTRODUCTION

Delay Tolerant Network (DTN) is evolved from Mobile Adhoc Network, MaNet. It is sparse and intermittently connected mobile adhoc network where reliable communication and end-to-end connectivity is not available for message transmission. In DTN, the main principal for routing message is "Store and Forward". Each node in DTN stores incoming message in the buffer and then delivered it to the other desirable node towards destination whenever contact is initiated. Intermediate node copies incoming message and work as relay node in order to increase the probability of message delivery. DTN is called opportunity network because the intermediate node always searches opportunity to relay message from source to destination. DTN has advantage over conventional MaNet with respect to data transmission probability. MaNet uses two phase approach to deliver data. First phase is used to setup route from source to destination and second phase is used to transmit data and maintain route information till data transmission over. This is not possible in case of DTN where nodes are sparsely deployed in the region and the two or more nodes can exchange message when they come in contact with each other. The store and forward approach helps to increase message delivery probability in DTN irrespective of time taken to delivered message over normal MaNet.

In DTN, the two or more nodes can exchange message when they move in transmission range of each other. This event is called "contact" in DTN [1]. As soon as they move out of transmission range of each other, communication link breaks. In conventional MaNet, a routing protocol has to establish end –to-end route to complete data transmission. This is not in case of DTN. In DTN, end-to-end path is very rare and unstable in nature and opportunity to establish complete route is negligible. DTN support those applications, whose time requirement is hours or even days or longer. So, it is necessary to delivered high priority message during "contact" phase. This problem of prioritize the message is discussed in Literature by many researchers.

Rest of paper is organized as follows: Section II gives brief summary of Routing Strategies exist in Delay Tolerant Network. Section III gives comparison of Routing Protocols and at last conclusion is given in Section IV.

II. ROUTING STRATEGIES IN DTN

Based on the strategies, routing in DTN is categorized in to two main categories, Flooding strategy and Forwarding strategy [6]. Flooding strategy is based on the principal of replicating messages to enough nodes so that destination nodes must receive it. Forwarding strategy uses knowledge about network to select best path to the destination. However there are some strategies that are not able to categorize strictly in to Forwarding or Flooding strategies.

A. Flooding Strategy

In this strategy, the multiple copies of same message will be created and these copies will be delivered to the set of nodes called relay nodes. Relay nodes stores the messages

until they come in contact with destination node [6]. As soon as the contact is made during "contact" phase, the messages are delivered by the relay nodes. Many of the strategies are workout by the researchers before this DTN get popular. These strategies are studied in the context of mobile adhoc network where random mobility is good chance of bringing the source in contact with destination. Message replication is then used to increase the probability that the message is successfully delivered to the intended node. These protocols do not require any prior global or local knowledge about network.

1) Single Hop Transmission

The simplest strategy to transmit the data from source to destination in DTN is to transmit messages immediately as soon as the source and destination come in contact with each other directly. This is possible when the source and destination are one hop apart or immediate neighbor of each other. The strategy is very simple because source node sends only its own message. There are no relayed messages. Advantage is that very less resources are required. The main drawback of this approach is the large delay and less probability of message delivery. R. H. Frenkiel and B.R. Badrinath proposed infestation architecture using single hop transmission to increase wireless network throughput and decreasing cost [7]. M. Grosslauser and D. Tse proposed that the mobility of nodes in adhoc network increases the capacity by using single hop transmission strategy [8].

2) Two-Hop Relay

In this strategy source node along with the nodes which at the first instance come in contact with source node work in cooperative manner to increase message delivery probability to successfully deliver the message to the destination. This approach increases the message delivery probability. Also it increases the bandwidth and storage consumption. This strategy has same fundamental advantages and limitations as direct transmission. This approach was studied as routing strategy for sensor network [9] and for sensors with proactive mobility [10].

3) Tree Based Flooding

In tree based flooding, the task of making copies to other relay node is distributed to the next nodes which come in contact with the already discovered node. Message also carry one extra control field which carries the information about how many number of copies a relay node can make and forward. The relay nodes forms tree which is routed at source node [11].

4) Epidemic Routing

Epidemic routing [12] is an early sparse network routing protocol proposed for DTN. It assumes that each node has unlimited storage space and bandwidth [13]. Therefore every node can store all the messages transmitted during "contact" phase. This use the concept of database replication. Also, a relay node can exchange the entire message during "contact" phase. Each node maintains list of messages in the database called summary vector. This vector is exchanged first and then only those messages are exchanged that are absent in the other's summary vector. This epidemic strategy is practically possible In case of very sparse network and small size message. Epidemic routing is very simple and so it is proposed to work when no better method is available [14]. Main problem with epidemic strategy is that the message continues to propagate even the message is successfully delivered to the destination. Many researcher work on epidemic routing strategy to consume fewer resources [13], [14].

5) Prioritized epidemic routing

The main idea in prioritized epidemic routing [15] is to impose a partial ordering of message called bundles. The priority functions of transmission and deletion are used. The flooding of message based on some factor that is used to estimate priority of message. Some input parameters are used to evaluate priorities such as current cost to destination, current cost from source, the expiry time and the generation time.

6) Spray and Wait

Spray and wait [16] approach consists of two phase, spray phase and wait phase. During spray phase, each node will flood (spray) each message to L no. of relay nodes when they come in subsequent contact with each other. This L is initialized by source node. If destination is encounter, message transmission is successfully terminated. If not, wait phase started and then relay node can deliver message only during contact phase. This strategy is controlled by parameter L which is function of node density, there distribution and mobility profile.

7) Spray and Focus

Spray and Focus [17] is modification of spray and wait strategy. This is designed for specific application where the mobility of each node is localized. The nodes are assumed to move in small area for most of the time. Spray phase is similar to the spray and wait strategy [16]. The difference lies in second phase. In focus phase, single copy of message [18] is used to focus limited relay node to route the message to destination.

8) MaxProp strategy

In MaxProp [19] strategy, city environment are taken into consideration where nodes are city buses which has high probability to meet again. MaxProp approach exploits this behavior of city buses for exchanging messages in future.

Total cost is chosen as measure to select path to destination. MaxProp divides the buffer into two phases. First phase order stored messages based on hop count information of each message from low to high. Second phase is to order messages by cost from high to low. The buffer is utilized from both the end. Front end of buffer is used by first phase whereas back end is used by second phase.

9) Opportunistic Routing with Window-Aware Replication

ORWAR [20] is recently proposed. Its main goal is to reduce resource utilization and reduce partial and dropped messages during transmission. Partial messages are arises when node moves out of transmission range while transmission of message is going on. ORWAR estimate number of bytes that can be transferred during each contact time. This estimation helps to utilize bandwidth effectively. However, to deploy ORWAR, every node needs to be able to measure its speed and direction, which is possible when they are equipped with GPS like devices.

10) CEECR

Bulat and Z. Wang proposed CEECR [21] based on erasure based coding. This technique divides the original message into subsets called blocks. Then these blocks are individually transmitted. Decoding technique is used to obtain original message at the destination by receiving only subset of original message or fever blocks. The main advantage of erasure based coding is that there may be chances of recovery of original message even though the transmission failure occurs. They address several cost reduction schemes which are compared with other eraser techniques proposed in the literature.

11) CCQR

Tao Li, Chao Dong proposed CCQR [22] Routing Protocol to restrict the message flooding within only high quality nodes in DTN. CCQR solves the several nodal imbalance problems. The nodal cost is used as parameter which refers to the total number of messages received by a given node during the entire routing process. They used homogenous cost and heterogeneous cost to estimate nodal cost. These measures are used to identify the best quality nodes along the path to destination.

12) ASMART

J. Wu and N. Wang proposed ASMART [23] routing protocol, which is modified version of selective controlled-flooding scheme which utilizes travel companions of the destinations which improves the delivery opportunities, by controlling flooding overhead. The nodes called companion nodes are organized to form an ANYCAST group. These nodes broadcast its group identities and hop distance to build the routing table periodically. This protocol introduces extra phase to route the message to the companion nodes and second phase is same as SMART protocol.

B. Forwarding Strategy

Forwarding Approach makes use of the network topology and local or global knowledge to find best route along the path to destination. This best route is used to deliver the message. This approach does not replicate the message. Instead, A single path is used which is estimated by evaluating some of the network parameters. Following are the Forwarding strategies for DTN found in literature.

1) Location Based routing strategy

This is the simplest forwarding strategy which makes use of basic knowledge about location of a node. Each node in the network is assigned the coordinate. The coordinate may be physical such as GPS coordinate. Then distance formula is used to estimate the cost of delivering message from one node to another [24], [25]. The main advantage of location based routing is that it eliminates the need for storing routing tables as well as control information transfer management. Best path estimation is based on the coordinates of source, destination and intermediate node. Distance formula is used to calculate the minimum distance between source and destination. Finally message is transmitted through the best estimated path. The main drawback is that the location based routing suffers from obstacles even though the path is shortest. Also it is worst in case of mobility of a node which changes the physical coordinate.

2) Gradient Routing strategy

In this approach weights are assigned to the nodes in the network that represents it's suitability to deliver messages to a given destination. The relay nodes, which stores the messages temporarily contacts another node that has better metric for the message destination; it passes the message to it. This is called gradient strategy because it follows a gradient of improving utility function values towards the destination. This strategy is evaluated and found suitable for sensor network [25].

3) Label Based Forwarding Strategy

In this strategy first task is to create groups. These groups are labeled called labeled groups. These groups are then chosen as next node or next groups to forward message to the destination. This results in large improvements as the labeled nodes works in groups [26]. The group based routing efficiently utilizes bandwidth and consumption.

4) Bubble Rap Forwarding Strategy

The Bubble Rap [27] technique focus on two issues: community and centrality. These two issues are related with human beings. Community is used to divide the nodes in specific community or groups. Centrality is related with some person who always becomes centre of attraction. In the bubble Rap strategy, if a node has a message for destination node, this node bubble the message up to the hierarchical rankings tree using the global ranking, until it reaches a node which is in the same community as the destination node. Then local ranking is used to further bubble the message until the message is reached to destination or expires. This method does not require every node to know the ranking of all other nodes in the system, but it compares the ranking with the nodes encountered and sends the message using greedy approach.

Sr No	Name of RP	MSN	# Copy	Whose Resources	Tab-le	MDR	LT
1	Direct Transmission	S, D	No Copy	S, D	No	M	L
2	Two-Hop Relay	S, D, R=1	Single Copy	S, D,R	No	Lw	L
3	Tree Based Routing	S, D, R= Log(N/2)	S, D, R= Log(N/2)	S, D, R= Log(N/2)	No	Lw	L
4	Epidemic	All EN	All EN	S, D, R= #EN	MV	N	N
5	Prioritize epidemic routing	All EVC	All EVC	S, D, R= #EVC	MPV	G	N
6	Probabilistic Routing	All HPN	All HPN	S, D, R= #HPN	DPV	G	N
7	Spray and Wait	L	L or >L	L or >L	No	G	N
8	Spray and Focus	L	L or >L	L or >L	No	G	N
9	MaxProp	All NC	All NC	All NC	No	G	N
10	ORWAR	All DPN	All DPN	All DPN	No	G	N
11	CEECR	All EN	All EN	All EN	No	G	N
12	CCQR	All QN	All QN	All QN	All QN	G	N
13	A-SMART	All TCN	All TCN	All TCN	All TCN	G	N

Table 1: Comparison between Flooding Based Routing Protocols.

5) NECTAR

Etienne CR. And C'elio V. N. proposed the protocol called NECTAR [28] which based on the contacts history in order to create a Neighborhood Index and then determine the most appropriated route used for routing message in DTNs. This protocol use heuristic knowledge based on mobility. It considers that the nodes which meet recently have more chances of meeting again. NECTAR allows sending message by relay in controlled manner to limit the traffic in the network. This protocol significantly improves the number of delivered messages, consuming fewer resources, in limited resources networks.

6) CREST

Srinivasa and Krishnamurthy proposed distributed CREST [29] protocol based only on a limited knowledge of the contact behavior of the nodes in the network. This protocol use 'conditional residual time' as the parameter which accurately estimates the time remaining for a pair of nodes to meet using only the local knowledge of their past contacts. CREAST has a lower end-to-end delay compared to other protocols that depend on future contact schedules and global knowledge of the contact behavior across the network. CREST achieves a better delivery ratio as compared to other flooding protocols.

7) CSPR

Eyuphan Bulat, Sahim Cem. G. and B. K. Szymanski proposed CSPR [30] protocol based on human mobility traces and some findings of previous work. This protocol use 'conditional intermeeting time' as the parameters which computer the average intermeeting time between two nodes relative to a meeting with third node using local knowledge of the past contacts. This 'conditional intermeeting time' is used to estimate best path towards destination in shortest path routing algorithm. CSPR achieve high delivery rate as well as lower end-to-end delay compared shortest path routing protocols.

8) QoNSW

G.Wang, B. Wang, Y. Gao proposed QoNSW[31] protocol which used the Quality of Node (QoN). QoN refers to the activity of node, or the number a node meets other different nodes within given interval of time. Node meeting many more nodes in the network for given interval has greater QoN. This measure is used to find the best suitable relay node to route message. This QoNSW protocol has significant improvements on Binary Spray and Wait and Simple Spray and Wait [16].

9) SCR

L.Yin, Hui-Mei Lu and Y. Cao proposed Single Copy Replication Routing Protocol(SCR)[32], which duplicate the message to the node selected as best relay node. They use 'Time Interval' as parameter to select the node with the least time interval among neighbors as the next hop.SCR allows to start message transmission in Critical Transmission Rang(CTR) and stopping transferring out of communication range which reduces the overhead by decreasing message delivery failure that occurs due to node's movement out of transmission range of another node.

10) CRHC

D. Hua and X. Du proposed a DTN routing protocol based on Hierarchical forwarding and cluster control mechanism, CRHC [33]. This protocol control routing in

same cluster efficiently using Cluster-Head and reduces messages transmission by allowing transmission permission to Cluster Head. The only drawback of CRHC is that it needs to maintain the information regarding partial nodes of the network. This protocol has higher delivery rate and lower delay.

11) PROCCS

R. Jathar and A. Gupta proposed PROCCS [34] based on repetitive contact patterns and their time sequencing to improve routing. Greedy path probabilistic approach is used to calculate probability of path and then best path is selected as the path for routing message. Contact graph is used for particular time issued by PROCCS to calculate best path. The results achieve high message delivery ratio with no message replication as compared to PROPHET and Epidemic.

III. COMPARISON OF ROUTING PROTOCOLS

In this section we compare the routing protocol based on flooding and forwarding strategy.

A. Comparison between Flooding Based Routing Protocols

In this section we try to compare the routing protocols based on Flooding strategies by considering the message storing nodes, resources required, # of copy of message generated, Routing information storage and retrieval, Message Probability Ratio, Latency etc. The comparison is summarized in the Table 1. For this following abbreviations are used

S: Source Node, D: Destination Node, R: Relay Nodes, EN: Encountered Nodes, EVC: Evolution nodes satisfying evolution criteria, L: Specified nodes in Message. NC: Nodes Encountered during contact, EN: Nodes storing encoded message, QN: Quality Nodes, TCN: Travel Companion Nodes. MDR: Message Delivery Ratio, Lw-Low, N-Normal, G-Good. Latency: L-Low, N-Normal, HPN: High Probability Nodes, DPN: Direction and Byte Predicted Nodes. RP: Routing Protocol, MV: Message Vector, MPV: Message Probability Vector, Delivery Probability Vector,

A. Comparison between Forwarding Based Routing Protocols

In this section we try to compare the routing protocols based on Forwarding strategies by considering the Parameter used to estimate best path, The nodes whose resources are required, Message Delivery Ratio and Latency. The comparison is summarized in the Table 2. For this following abbreviations are used

S: Source Node, D: Destination Node, R: Relay Nodes, RP: Routing Protocol, DN: Distance between Neighboring nodes, SM: Suitability to deliver message, SLN: Nodes with same Label, SCN: Nodes in Same Community, PCH: Previous Contact History, CRT: Conditional Residual Time, CIT: Conditional Intermeeting Time, QoN: Quality of Nodes, TI: Time Interval, CH: Cluster Head, CPTS: Contact Pattern and Time Sequencing, HGP: High Greedy Probability Value Nodes, MDR: Message Delivery Ratio, LT: Latency: G: Good, N: Normal.

Table 2: Comparison between Forwarding Based Routing Protocols.

Sr. No.	Name of RP	Parameter	Whose Resources	MDR	LT
1	LBR	DN	S, D, R=Min(Dist)	G	N
2	GR	SM	S, D, R=NGP	G	N
3	LbBR	SLN	S, D, R=SLN	G	N
4	BRR	SCN	S, D, R=SCN	G	N
5	NECTAR	PCH	S, D, R=PCH	G	N
6	CREST	CRT	S, D, R=CRT	N	N
7	CSPR	CIT	S, D, R=CIT	N	N
8	QoNSW	QoN	S, D, R=QoN	G	N
9	SCR	TI	S, D, R=TI	G	N
10	CRHC	CH	S, D, R=CH	G	N
11	PROCCS	CPTS	S, D, R=HGP	G	N

IV. CONCLUSION

In this paper, we elaborate the routing issues and objectives. This paper also gives brief summary of Routing protocols present in the literature. These protocols are classified in to two broad categories: Flooding and Forwarding. Each protocol has its own advantages and disadvantage. Comparison of Flooding and Forwarding based routing protocols are given in tabular forms. The DTN based applications suffered from less resources as well as bandwidth. We effectively identified the nodes whose resources are consumed while transmitting message in Delay Tolerant Network. Some of them follow the objectives as described in the previous sections. Thus conclusion is that the suitability of routing protocol in DTN based on the application for which Delay tolerant Network is configured. The Large delay results in low latency.

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