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A Survey on Routing Schemes of Delay Tolerant Network for Internet of Things

Ruchi Chauhan[1], Shikha Malik[2], Susan Thomas[3], Pooja Sonawane[4], Jyoti Kolap[5]
[12345]*(Department of Electronics and telecommunication, Atharva college of engineering, India)*

Abstract: *Delay Tolerant Network (DTN) is meant to provide connectivity in heterogeneous networks which lack incessant connectivity due to disruptions or considerable delays ,one such network is Internet of Things (IoT). Internet of Things (IoT) is a domain which is being widely used by the industrial world and in daily human life. One of the most challenging constraint in IoT is prolonging network lifetime considering resource limitation and maintaining connectivity in order to deliver data all over the network to the final destination. These shortcoming of IoT devices motivated to study DTN routing algorithm which are based on Store Carry Forward Technique and seems to be an appropriate solution to handle intermittent connectivity, overcome resource constraint and network disconnection. Various DTN routing schemes are surveyed in this research and their advantages and limitations are discussed.*
Keywords: *Delay Tolerant Network, Internet of Things, routing schemes, ONE simulator, latency ,overhead ratio*

I. Introduction

Delay Tolerant Network (DTN) is meant to provide connectivity in heterogeneous networks which lack incessant connectivity due to disruptions or considerable delays like that of networks operating in mobile or extreme terrestrial environments or planned network in space. The DTN effectively improves network communications where the network connectivity is Periodic/Intermittent and are prone to disruptions. The Store, Carry and Forward technique via the Bundle Protocol (BP) of the Delay Tolerant Network facilitates the flow of data/information across any complex or intermittent network traffic. New emerging application domains are being created that also require delay tolerant support. Internet of Things (IoT) is a domain which is being widely used by the industrial world and in daily human life. Internet of Things (IoT) is a dynamic global ecosystem where billions of small devices with data capture and communication capabilities are seamlessly integrated into the information network. These devices have self-configuring capabilities based on interoperable communication protocols. These devices have physical and virtual identities, physical attributes, virtual personalities and use intelligent interfaces which facilitate interactions with smart things over the internet. IoT devices are a part of everyday living linking the real world data with the virtual world thus enabling anytime anyplace connectivity for anything like social processes, healthcare, automotive, security, manufacturing, services ,energy, agriculture and many other areas. However these devices have limited data storage and processing capabilities. To add the devices have limited power stored in tiny batteries. With such resource limitation prolonging network lifetime and maintaining connectivity in order to deliver data all over the network to the final destination is a major challenge. Enabling delay tolerant communication in IoT will allow smart objects to better communicate even with the presence of disruption in their connectivity. For example, in case of road traffic control applications with limited connectivity, vehicles recording important information on road status may need to store/carry data until they find an opportunity to forward. However, DTN routing algorithms have to be tailored to IoT applications to fit their specific requirements, such as: heterogeneity, huge amount of exchanged message, information centric based protocol, intermittent connection (ICN), etc.

II. Literature Review

The authors of [1] have stated the architecture, network characteristics and core applications of Delay Tolerant Network (DTN) which use the Store and Forward Technique via the Bundle Protocol (BP) of DTN in various applications like military operation, under water acoustic network and smart phone. Fatima Zohra Benhamida et.al [2] have surveyed the use DTN solution in IoT application to overcome connectivity problem considering the opportunities and challenges for each technology. The authors have given an overview of the DTN taxonomy which includes DTN classification categories and performance metrics along with interdependence of DTN performance metrics and IoT characteristics. Mari Carmen Domingo [3] has introduced Internet of Underwater Things (IoUT) and its main difference with respect to IoT have been outlined. The author also mentions the use of Underwater Convergence Layer (UCL) interconnect traditional IP-based and acoustic network using DTN Bundle Protocol. The authors of [4] have addressed the implementation of BP binding for Constrained Application Protocol (CoAP) as a means to enable delay tolerant IoT. The same has been illustrated by the author in regards to a smart city network. Ayman Radwan et.al [5] have proposed on-demand mobile small cells with caching capabilities for delay tolerant e-Health applications. The proposed networking architecture supports user mobile devices acting as small cells with caching capabilities for later transmission, when efficient high data rate communication conditions exist. Vahdat.A et.al [6] have proposed Epidermic routing algorithm for partially connected adhoc network which uses flooding technique to exchange messages between the nodes. The authors of [7] have proposed Spray and Wait routing algorithm for intermittently connected mobile network. Spray and Wait algorithm sprays a fixed no. of copies to the nodes it encounters and forwards the message copies to some distinct relay nodes. Spyropoulos .T et.al [8] have suggested Spray and Focus routing algorithm heterogeneous and correlated mobility which is based on forwarding strategy. A.Lindgren et.al [9] have implemented probabilistic routing protocol for intermittently connected network using history of past encounters and transitivity to predict future best. The authors of [10] have proposed a priority based scheduling policy for a hybrid routing algorithm in Delay tolerant Network and its applications.

III. Delay Tolerant Routing

Routing means to facilitate the successful message delivery from source to destination. Traditional routing protocols like DSDV (Destination sequenced Distance Vector), DSR (Dynamic Source Routing) forward message to destination only after forming an end to end path between source and destination but in DTN end to end path may never be there so DTN has to store , carry and forward messages in order to reach the destination. DTN uses two types of scheme for routing messages: 1. **Forwarding Strategy**: In this scheme the message generated by source remains in the network until it reach the destination or its dropped from the network. In this scheme the sender node discards the message after forwarding it to next node. 2**. Flooding Strategy**: In this number of copies are generated and nodes replicate the messages among them. Controlled flooding uses combination of flooding and forwarding strategy by having limited number of copies being circulated.

Forwarding Strategy Routing Algorithm

1**. First Contact**: In this algorithm the copy of message generated by source is forward to node which it comes in first contact with and this keeps repeating till message is delivered to destination

2. **Spray and Focus**: It uses controlled flooding where a limited number of copies are forwarded. It works in two phases in the Spray phase each node forward a limited number of copies to the relay nodes and in the Wait phase each relay node carries the copy of message till it reach the destination. Advantages: The above mentioned algorithm uses least resources in terms of energy, bandwidth and buffer space. Disadvantages: The message delivery ratio is low, have high average delivery latency and large overhead ratio

3. **Prophet routing**: Probabilistic Routing Protocol using History of Past Encounters and Transitivity uses past encounters to predict future best. The source node will for ward the copy of message to the node which has better probability of meeting the destination as it does that by seeing the history of forwarding nodes and it chances of meeting the destination. Advantage: Less resource consumption. Disadvantage: No guarantee to meet the destination node in message lifetime which affects the delivery ratio.

Flooding Strategy routing Algorithm

1. **Epidermic Routing**: In this algorithm node forwards the copy of message to each and every node it comes in contact with. They exchange their summary of vectors and forward only those messages which are not in common. Advantage: It has very high delivery ratio as messages are flooded in the system. Disadvantage: High resource consumption and network congestion as number of copies are circulated in the network.

2. **Spray and Focus**: This algorithm uses controlled flooding where L number of messages is generated. In the Spray phase the source forward the limited copies to relay nodes and in the Focus phase the relay nodes transfer the message to other relay nodes which are closer to destination. Advantage: Less Overhead ratio as compared to fully flooding algorithm. Disadvantage: Moderate Delivery ratio as compared to fully flooding algorithm.

Priority Based Scheduling policy for a Hybrid routing algorithm[10]: To overcome the pros and cons of existing routing schemes , priority based scheduling algorithm has been proposed which priorities the message into high priority message like accident messages, medium priority like traffic related messages and general purpose messages like finding parking lot in a mall or office. The algorithm starts by setting the message types and assigning the message priorities. When the nodes come in contact each other, at every node the messages are ordered according to the descending message priorities. When it is the time to transmit a message, nodes make use of flooding, controlled flooding, or forwarding strategy based on the high or medium or low message priorities respectively . The threshold for message copies has been decided empirically. Finally when the buffer gets full, the messages are deleted based on their time-to-live and on the basis of low-to-high message priorities.

IV. Simulation

Opportunistic Network Environment (ONE) Simulator is used as a platform for simulation which is developed especially for DTN Networks. ONE Simulator is capable of generating node movement using different movement models, routing messages between nodes with various DTN routing algorithm, visualizing both mobility and message in real time in its graphical user interface, can import mobility data from real world traces and produces a variety of reports from node movement to message passing and general statistic. Simulator is written in JAVA. In the simulation three routing algorithm have been simulated using ONE simulator epidermic, prophet and spray and wait with different number of nodes and graph have been plotted for average latency and overhead ratio using the reports generated during different simulation.

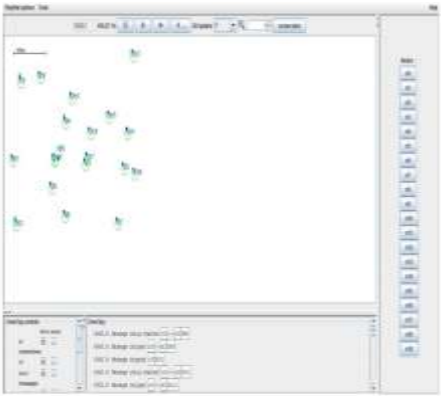


Fig 1. Epidermic routing for 20 nodes

RandomWalk_EpidemicRouter_2M_MessageStatsReport.txt - Notepad
File Edit Format View Help
Message stats for scenario RandomWalk_EpidemicRouter_2Msim_time: 5000.0000
created: 170
started: 193
relayed: 174
aborted: 18
dropped: 296
removed: 0
delivered: 7
delivery_prob: 0.0412
response_prob: 0.0000
overhead_ratio: 23.8571
latency_avg: 1984.0000
latency_med: 1896.0000
hopcount_avg: 2.7143
hopcount_med: 3
buffertime_avg: 447.9155
buffertime_med: 240.0000
rtt_avg: NaNrtt_med: NaN

Fig2. Epidemics routing Report for 20 nodes

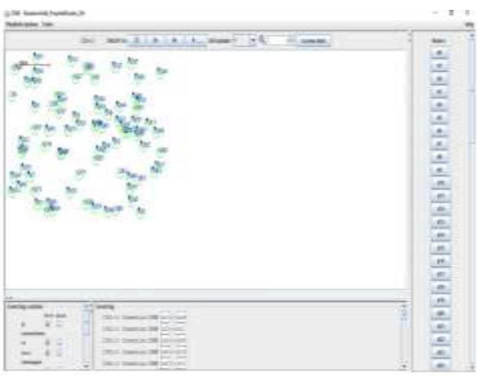
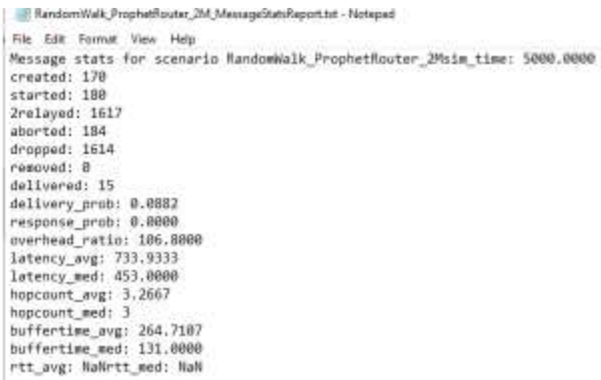


Fig.3 Prophet routing for 80 nodes



RandomWalk_ProphetRouter_2M_MessageStatsReport.txt - Notepad
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started: 180
2relayed: 1617
aborted: 184
dropped: 1614
removed: 0
delivered: 15
delivery_prob: 0.0882
response_prob: 0.0000
overhead_ratio: 106.8000
latency_avg: 733.9333
latency_med: 453.0000
hopcount_avg: 3.2667
hopcount_med: 3
buffertime_avg: 264.7107
buffertime_med: 131.0000
rtt_avg: NaNrtt_med: NaN

Fig.4 Prophet routing report for 80 nodes

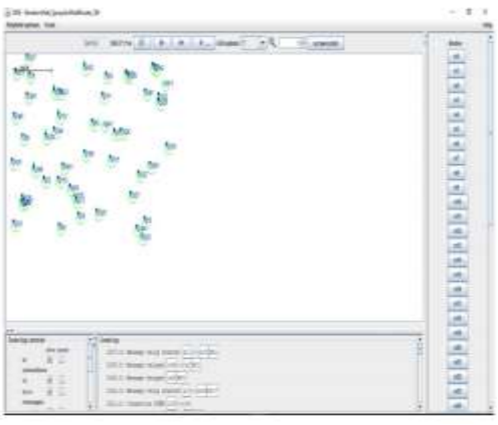
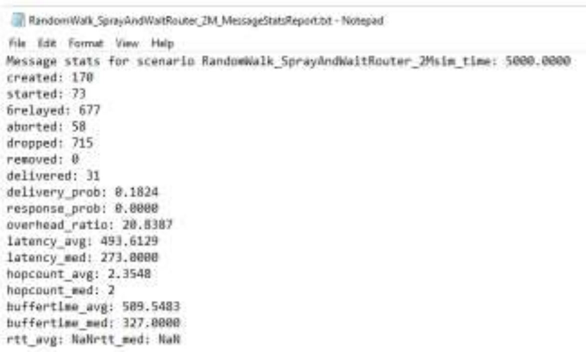


Fig5. Spray and Wait routing for 50 nodes



RandomWalk_SprayAndWaitRouter_2M_MessageStatsReport.txt - Notepad
File Edit Format View Help
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6relayed: 677
aborted: 58
dropped: 715
removed: 0
delivered: 31
delivery_prob: 0.1824
response_prob: 0.0000
overhead_ratio: 20.8387
latency_avg: 493.6129
latency_med: 273.0000
hopcount_avg: 2.3548
hopcount_med: 2
buffertime_avg: 589.5483
buffertime_med: 327.0000
rtt_avg: NaNrtt_med: NaN

Fig6. Spray and Wait routing report for 50 nodes

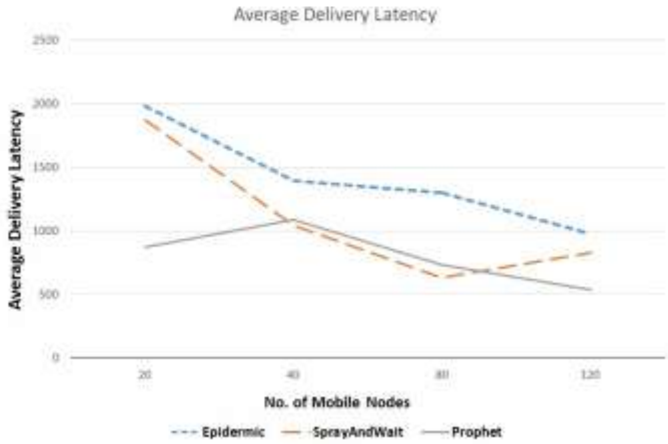

Fig.7 Average Delivery Latency graph

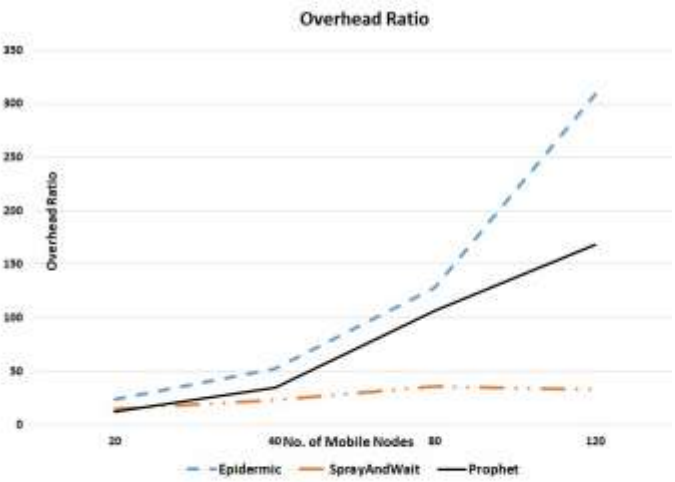

Fig.8 Overhead Ratio Graph

V. Conclusion

The analysis of the Average Delivery Latency Graph shows that Delivery Latency increases as the number of nodes increases as there would be congestion in the network and information processing at every node takes time. The average latency of Spray and Wait was found to be better than other two algorithms .The analysis of the Overhead Ratio Graph shows that Overhead Ratio increases as the no. of nodes increases as there would be a large number of messages that will be relayed as compared to delivered messages. The Overhead Ratio of Spray and Wait was found to be better than other two algorithms.

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