Performance Analysis of Epidemic, PROPHET, Spray and Wait, Binary Spray and Wait, and PRoPHETv2

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Abstract: The internet has been spreading its presence all across the globe. But there are still several locations where internet facilities are unknown. To illustrate, roads, sports complexes, parks and many other places that have scarcity of infrastructure. However, with the growing trend of smart devices such as Mobile Phones can solve this problem by providing internet access to such secluded places. Pocket Switched Network or PSN is a revolutionary network, which works on the concept of network. The Pocket Switched Network enables transmission of data from one place to another through the concept of roaming nodes. Through this study, we have investigated the overall performance of 5 different types of routing protocols[14] i.e. Epidemic[10], Protocol using History of Encounter and Transitivity (PRoPHET), Spray and Wait, Binary spray and wait, and PRoPHET version 2. The performance metrics of overhead ratio, average latency rate and probability have been evaluated in this.For this, ONE simulator has been taken into account. The output analyzed of this experiment demonstrates the 'Epidemic' protocol has better performance with regard to delivery of messages; however, this has higher overhead ratio. Similarly, the PRoPHETv2 has an upper edge as compared to PRoPHET in respect to overhead and delivery ratio. Lastly, Binary spray and wait performs better than spray and wait protocol with respect to delivery ratio.

Keywords: Pocket Switched Network, Epidemic, PRoPHET, Spray and wait, Binary spray and wait, PRoPHETv2.

1. Introduction

Wireless network are those computer networks that are not physical connected with the devices. It uses radio waves to transmit the data between devices. This enables not only quick installation of devices, but also reduces the need of the costlyequipment's. Apart from this, it provides scalability of the network and wider reachability. However, it has limited capacity of connected devices, and it does not provide high security. The typical examples of wireless network are Universal Mobile Telecommunication System (UMTS), Global System for Mobile Communication or GSM, Bluetooth and Wireless Local Area Network (WLAN).

One such wireless network technology is an Ad-hoc network or mobile Ad hoc network. It is basically a temporary network, which provides internet connectivity in metropolitan areas. One type of Ad hoc based network is Mobile Ad hoc Network or MANET. It does not have any infrastructure involved for connection, for example, Cellular Network or the Public Switched Telephone Network or better known as PSTN. These types of networks are robust, efficient and contains several mobile nodes. These days, internet connectivity through smart mobile phones has become quite the norm and become omnipresent as almost everybody has smart phone.Several social media sites or other internet applications can be accessed easily. Because the hotspots are readily available in several public places, the availability of internet has been increased. However, there are still lots of vicinities where access of internet services is quite difficult.

The Pocket Switched Network or PSN offers a solution to this issue. This works on the concept of roaming nodes from one place to another, which transmit the data and provide internet connectivity. Networks, for example, wildlife tracking system, defense network, nomadic community tracing network, underwater sensors and satellite-based network uses the concept of PSN.

Pocket Switched Network is an emerging Mobile Ad-hoc Network, which is known as MANET. PSN solves the issues of network accessing in a challenged atmosphere. Challenged network is a type of network which has limited infrastructure and frequent network disruption occurs. Due to the requirement of end-to-end network construction, protocols such as Ad hoc, On-Demand Distance Vector (AODV) or Dynamic Source Routing cannot be taken into account to forward the information across the network.

Epidemic routing protocol is one of the easiest routing protocols for data delivery in Pocket Switched Network. In this protocol, large quantity of packets is sent inside the network to find out the actual route from source node to destination node. If both the nodes find availability of radio signals, they will start transmitting the routing messages. The same process is being performed until each node gets the similar type of routing messages. The nodes in this algorithm perform as relay for other nodes, which have the ability to store the data and forward it. The primary benefit of this is that it is light-weight and offers less complexity of network. But it may require huge amount of storage space, bandwidth resources and power. Therefore, there is a loss of resources and thus performance of such system degrades. Epidemic routing protocol uses flooding technique to ensure the delivery of information.

Therefore, in order to resolve this issue Spray and wait[23] routing algorithm came into existence. Since Epidemic routing protocol sends several copies of messages to each node, the communication time gets increased. The Spray and [11] routing method transmits only small quantity of data to nodes in order to ensure the transmission is smooth and controllable. Consequently, performance of Spray and Wait is far better than Epidemic. As the name suggest, Spray and Wait has two phases i.e. Sprat and wait phase. In the Spray phase, source nodes send copy of messages to their neighbors until it gets full, whereas in wait phase, the nodes receivethe message and wait for direct transmission to occur. The next step in Spray and Wait is Binary Spray and Wait, which enhance the overall quality of forwarding the messages. In the Spray phase, source nodes transmit only limited quantity of messages copies to every node then the network gets transformed into wait phase. In this phase, network pushes the messages through direct transmission. Hence, the delay time in Binary Spray and Wait is less.

Similarly, Protocol using History of Encounter and Transitivity (PRoPHET)[20] has some characteristics that are helpful in routing. PRoPHET has the ability to predict the delivery and transitive properties as well. Transitive refers to the term when a node A which comes across node B, and node B is experiencing node C. Then node C is considered as a viable option for forwarding messages. This mechanism mitigates the wastage time and load of the node. Moreover, the chance of message dropping is quite less. The working of PRoPHET[22] is same as Epidemic. Once the nodes get connected, they transmit summary vectors along with delivery predictabilityP(a,b) ∈. The Delivery Predictability (DP) gets stored in delivery vector and gets updated whenever nodes communicate. PRoPHET routing uses Delivery Predictability (DP) of node along with transitivity to choose the messages and forwards them to another node without considering the distance.

2. Delay Tolerant Network

Delay Tolerant Network (DTN)[1] is another type of network, which enables communication in different types of network. It also fills in the communication gap which may occur during the transmission. It is used widely for connectivity between different plants and satellites. As the DTN[3] is a mobile wireless network, it does not provide guarantee for stable connection. Figure 1 demonstrates the concept of DTN network. It mainly uses for irregular networks.

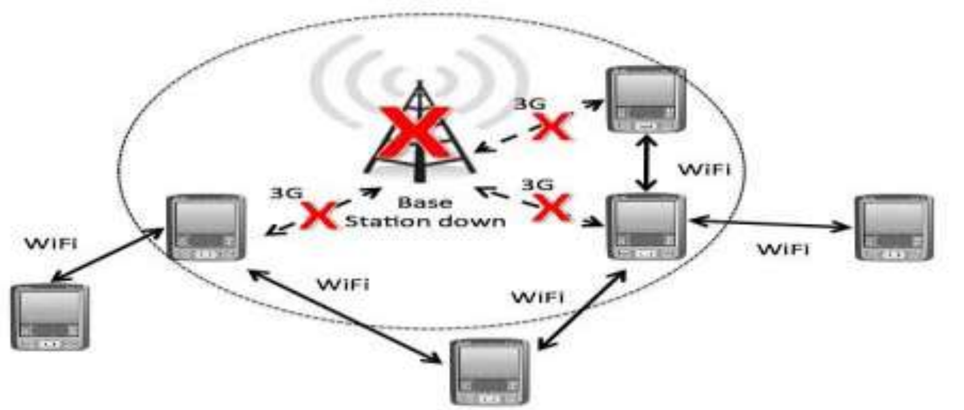

Figure 1. Mobile Nodes without Network Support

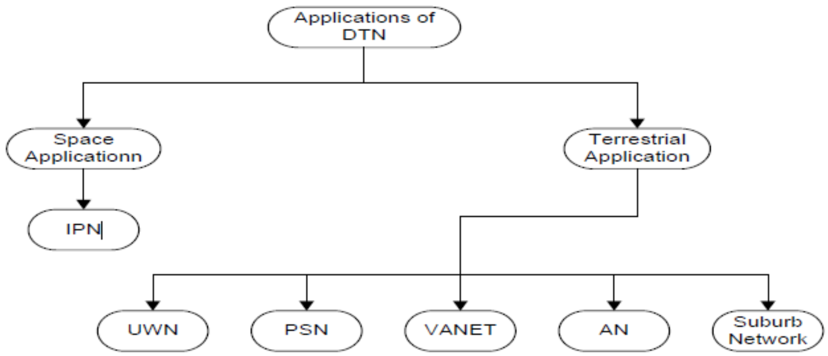

Figure 2. Application of DTN

The above-mentioned Figure 2 shows application of DTN network, including space application and terrestrial applications. The typical example of space application is IPN or Inter Planetary Network. On the other hand, VANET or Vehicular Ad Ho Network[24], Underwater Network (UWN), Airborne Network[25] or AN, PSN and suburb network are some samples of terrestrial applications.

Table 1 – DTN Layers

APPLICATION LAYER
BUNDLE LAYER
TRANSPORT LAYER
INTERNET LAYER
LINK LAYER

In Table 1, DTN architectural design is described. Bundle layer in the middle of transport layer and application layer is responsible for store-hold-and-forward method. The message is stored in the buffer space before forwarding it to another node, particularly for neighboring node. The data in the bundle layer is also known as bundle or message.

3. Pocket Switched Network

Pocket Switched Network or PSN is an application of DTN, which initiates the connection between mobile nodes and the mobility of human to transmit the data, usually in Peer-to-Peer method. PSN is a combination of header and payload, which is used in the situation where link is unstable. This network can be helpful in satellite-based networks, nomadic community and interplanetary networks. PSN also enables the communication to happen by asynchronously share or exchange the data in certain areas such as Bluetooth and Wi-Fi (wireless Fidelity).

PSN uses Store-Carry-and-Forward method to enhance the probability[15] of delivery of messages. In this, router node in PSN network holds the message in its buffer memory before transmitting to destination node. By doing this, message delivery ratio can be increased substantially. Apart from this, it reduces the delay and also utilize the resources properly. In contact mode or phase, two or more than two nodes share the messages. As a result, router nodes only deliver those messages which have highest priority rate and thus improves the performance. The duration of the connection relies on the mobility[16] factor of the nodes.

3.1 Routing in Pocket Switched Network

There are several routing protocols, which supposed to enhance the overall efficacy in PSN. Unlike, DTN, the PSN also contains two broad categories i.e. forwarding based and replication based. In the former one, single message is used to deliver the message to the destination node. This mechanism is suitable for those networks which have higher connectivity, and the network has the capability to take routing decisions. On the contrary, in replication, multiple copies of messages are used to ensure the delivery of the messages in association with destination nodes. This kind of mechanism is used in PSN network, which is an opportunistic network[4-6]. The main benefit of having this is that it offers lower latency rate and higher delivery ratio when compared with others. However, the downside is that it consumes lot of resources as there are multiple several copies of the same type of the messages. To illustrate this, Epidemic, PRoPHET, RAPID, PREP and so on are those routing protocols which works on this system. The other type of scheme is quota-based which saves the resources of the network by simply transferring fewer copies of the message inside the network. Spray and Wait[21], Binary spray and wait, EBR are the typical examples of this methodology.

3.2 Epidemic

Epidemic is a routing protocol which uses flooding technique to deliver the message across the destination node. In this, if two nodes experience same message within the radio coverage area, nodes exchange the messages required for routing. This method gets repeated until and unless each node receives the similar set of messages. The advantage of this is that it ensures the delivery of messages; however, it also has some down sides. It consumes the network resources such as bandwidth, storage and so on.

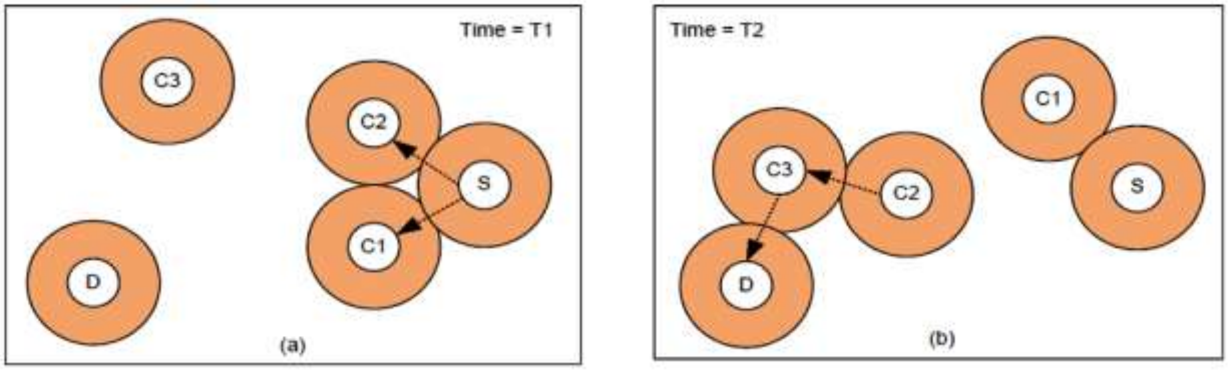

Figure 4. Working Scheme of Epidemic

The above mentioned, Figure 4, demonstrate the working of Epidemic routing. Here, S depicts source node, D refers to destination and c refers to carrier node. In the given diagram, node S initiates the communication by sending message to D node. Node S can send the data directly as there are no connection available. After this, S node sends messages to node C1 and C2. In figure(b), node C2 communicates directly with C3. In the meantime, C3 node comes in the range of Node D. Hence, the message can be delivered to node D.

3.3 Spray and Wait

Spray and Wait is an opportunistic routing protocol. In this protocol, source node sends multiple copies of messages to several other nodes. The router has the capacity to store the message, wait and then transmit to another neighboring nodes. Once the router comes in the way of destination node, they will exchange the information directly.

The advantage of having Spray and wait protocol is that it requires fewer resources as compared to other routing protocols such as Epidemic and other which use flooding technique. Apart from this, it has a very low latency rate with higher delivery probability ratio. Hence, this protocol has better performance and efficacy, especially in large networks. As the Spray and Wait protocol transmits multiple copies in spray phase, direct transmission can be processed in wait stage. Consequently, it has fewer transmissions. Until the neighboring node does not reach to its limit, source node keeps on transmitting the messages. In Wait stage, message gets received and hold until the destination port is available for direct communication.

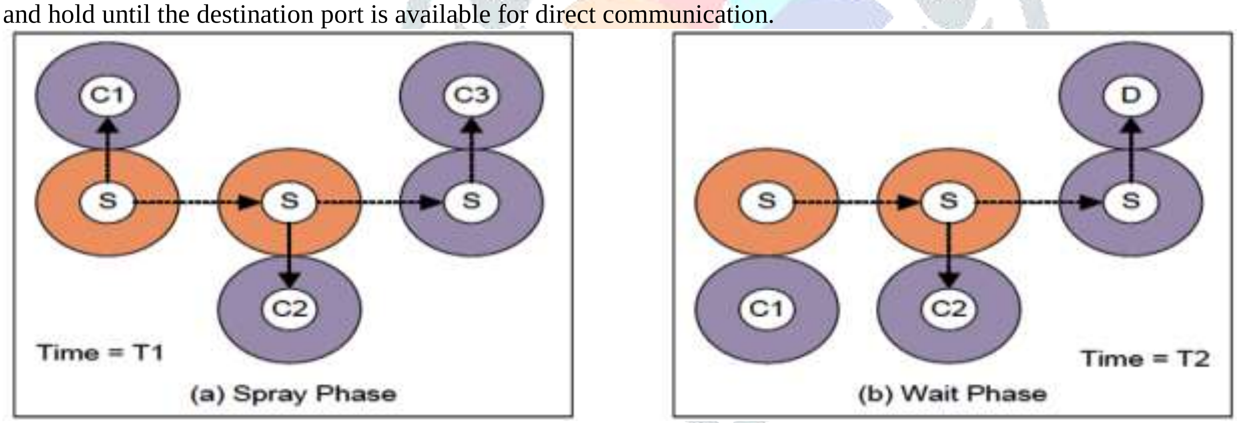

Figure 5. Working Scheme of Spray and Wait

In Figure 5, working mechanism of Spray and Wait routing Protocol has been presented. In this, The Source node is referenced with S, whereas D and C are Destination and Carrier nodes respectively. In Figure 1(a), Spray phase of routing has been shown. The node S has not initiated any route towards the node D. On the other hand, in Figure 1(b) represents the Wait stage or phase of the protocol. Source node S only initiate the connection and sends the traffic once node D is being encountered.

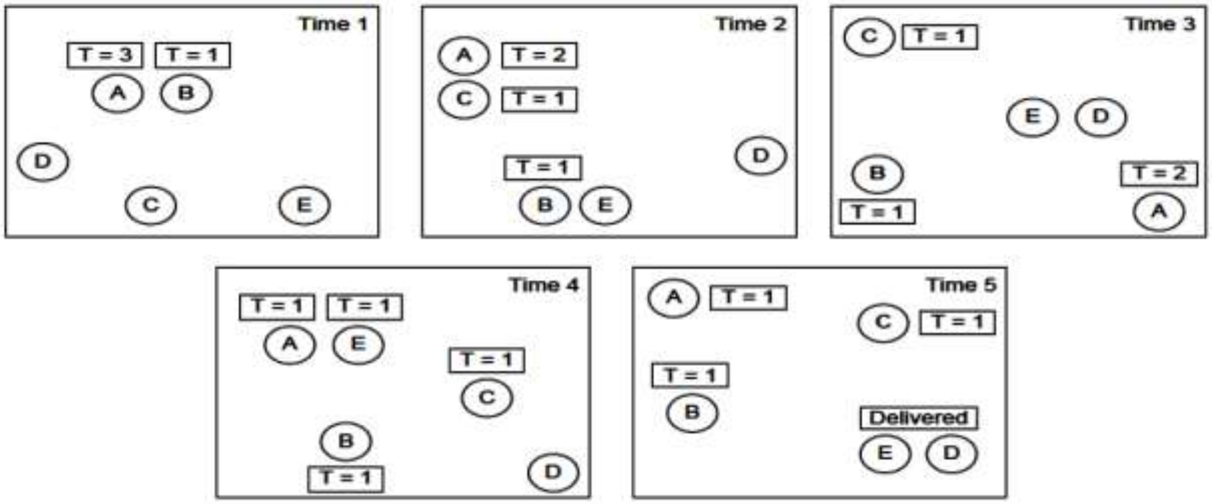

Figure 6. Spray and Wait Routing

In the above mentioned Figure 6, Working of Spray and Wait is elaborated. For the first time, Time 1 send total 4 messages M=4 From the node A. After this, since B is in proximity range of node A, node A delivers the message to node B.Second phase (Time 2), node C changes its position and receives the message from node A.In the Time 3, node A shifts its position and in Time 4, Node E shifts next to node A and receives the message from node A. Finally, E node gets shifted to node D and transmits the data to it.

3.4 Binary Spray and Wait

Binary Spray and Wait is meant for enhancing the overall performance of the Spray and Wait protocol. In this, Spray phase sends limited number of message data is transmitted from source node to every destination node until everyone has the copies. And, in the Wait stage, direct transmission happens between nodes. Binary Spray and Wait is far superior than this method and has lower latency rate.

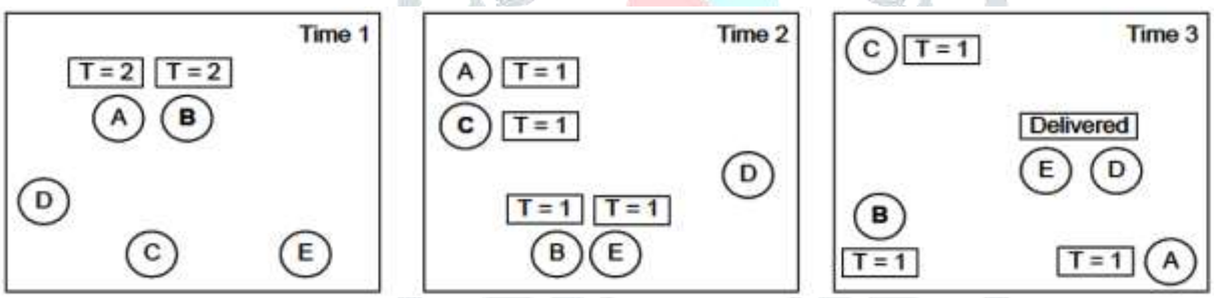

Figure 7. Binary Spray and Wait Routing

Figure 7 above, mentioned Binary Spray and Wait protocol. In Time 1 stage, there are total 4 messages M=4. Node A sends two messages to Node B because B is in the proximity range of node A. However, in Time 2, node C changes its position and receives half of the copies from Node A. Meanwhile, node B shifts to node E and receives half of the total copies. In the final stage, node E gets shifted to node D and provides the message M.

3.5 PRotocol using History of Encounter and Transitivity (PRoPHET)

PRoPHET[9] is another routing protocol for DTN[8] networks. Unlike PSN, PRoPHET is standardized protocol. It works on the history of the previous nodes. Also, it offers high predictability of delivery along with the other transitory characteristics. Transitive property refers to the term when node A often experience node B and Node B experience the presence of node C then C node is considered as perfect option to deliver packets. By doing so, we can increase the efficiency along with overall executional time. Furthermore, it reduces the load on each node and increase the probability of message delivery. The formula of ($P(a,b) \in [0,1]$) is used to predict the communication between nodes. The issue with this protocol is that it consumes lot of bandwidth because it frequently delivers the messages to newly experienced nodes.

For the calculation of communication prediction, we have three portions available which are as follows.

1. To Updatethe delivery predictability once anode detectsa new node.

$Pa, b = Pa, bold + 1 - Pa, boldxPinit$

Where Pinit is initializing constant with value $Pinit \in [0,1]$. The recommended value of Pinit is 0.75.

2. If a pair of nodes fail to detectanother node, it means that they are likely to be good options for forwarders of messages. Hence, delivery predictability value gets decreasedwhile processing. $P(a,b) = P(a,b)old \times \gamma k$

Where the value of $\gamma \in [0,1]$ is constant. The recommended value of γ is 0.998 (constant). While, k is the number of timesit has been elapsed in association with the metric gets expired.

3. Transitive property

$Pa, c = Pa, cold + 1 - Pa, coldxPa, bxPb, cx\beta$**(2.3)**

Where β ∈ [0,1] is scaling constant which decidestheeffect,a transitivity property should have on delivery predictability. In this, 0.25 is the recommended value of β.

3.6 Protocol using History of Encounter and Transitivity Version 2 (PRoPHETv2)

PRoPHETv2 routing protocol is a hybrid version of Epidemic protocol and PRoPHET Systems. The primary aim of having this protocol is to improve the performance of message delivery. PRoPHETv2 is considered on the basis of N4C system for distinctive regions, particularly in mountainous regions of Sweden when data was failed to transmit over heights. The problem was encountered as the transitive equation of PRoPHET has unusual and unpredictive behavior as mentioned in the 2.3 equation. If we set the value of β to zero, PRoPHET delivers extremely well performance because it has the ability to disengage the transitive property. The issue was being faced during the routing informational exchange. Routing information along with the traffic flow was gathered to examine the problem. As PRoPHET works on the history of encountering nodes, it seems as infeasible option. Therefore, DP failed to meet the requirements and the protocol remains in the assessment phase.

PRoPHETv2 was taken into account to resolve the problem encountered previously. If the value of β > 0, DP will increase for every known node. In the heterogenous type of network, this protocol has very promising results. Although transitive property has an incremented value, which is still tiny, the impact of DP is minimalistic in the event of much higher frequencies for several other nodes in addition to K node. This may provide the fake value inside the network. Hence, in order to tackle this issue, new type of transitive properties has been incorporated in 2.4 equation. Here, the suggested β value is 0.9

$PA, i = \max\,(PA, iold, PB, iPA, Bx\beta$

$PA, B = PA, Bold + 1 - PA, BoldxPenc$

The value of $Penc$ has been discussed below:

$$Penc = Pmax\ x\,\frac{IntvlB}{Ityp}\ ;\ \text{if } 0 \leq IntvlB \leq Ityp$$

$Penc = Pmax$;

The Epidemic protocol is reliable where applications have much larger buffer[17] space along with the bandwidth. Whereas, PRoPHET is used where accuracy is utmost priority. Spray and Wait[18] and Binary Spray and Wait[19] can be taken into consideration where there are exigencies, especially in Spray phase. PRoPHETv2 protocol on the other hand, is used to make self-reliant networks such as heterogenous mobility scenarios.

4. Simulation Setup

All the aforementioned routing protocols were based on Opportunistic Network Environment i.e. ONE simulator[2]. These simulators were designed for performance analyzing in DTN-based networks. ONE simulator works on JAVA[12] programming language to perform its task. Generally, the movement and interconnected nodes can be analyzed using ONE simulator[7].The range of the Bluetooth interfaces is up to 10 meters with the connection speed of approximately 2Mbps. There are 2 types of wireless technologies which provide Ad-hoc based connectivity, i.e. Wireless Fidelity (Wi-Fi) and Bluetooth.

A. Simulation Parameters

The simulated data has been described in the following tables. Table 1 represent the simulation of the configuration of the buffered size and table 2 depicts simulation configuration of message size. The final table i.e. table 3 represents configuration simulation of time. The size of the map is 4500 meters with 3400 meters of height. The experiment contains 6 groups with 126 nodes. Group 1 involves roughly 40 pedestrians having the velocity of 0.5 m/s-1.5 m/s. In the second group, there are 40 vehicles having the velocity rate of 2.7 m/s-13.9 m/s. In the next group, 40 additional pedestrians have been involved with the velocity rate f 0.5 m/s-1.5 m/s. And, in the group 4, there are two cable cars with approximately 7-10 m/s velocity rate and the buffer size is 50 Megabyte. Group 5contains 1tram with 6-10m/s velocity rate and 40MB of buffer size. Finally, in the group 6, 3 trams cars are involved with 50MB of buffer memory. The average time is 12hours along with 10meters of range and 2Mbps of transmission speed.

Table 2– Simulation Parameters of Different Buffer Sizes

SIMULATION PARAMETER	SIMULATION VALUE
Msg Size	500-1000KB
Time to Live	300 mins
Buffer Size	5 – 35MB

Table 3 – Simulation Parameters of Different Message Size

SIMULATION PARAMETER	SIMULATION VALUE
Msg Size	500-1000KB, 1.5-2MB, 2.5-3MB, 3.5-4MB, 4.5-5MB, 5.5-6MB, 6.5-7MB
Time to Live	300 mins
Buffer Size	500 MB

Table 4 – Simulation Parameters of Varying TTL Value

SIMULATION PARAMETER	SIMULATION VALUE
Msg Size	500-1000KB
Time to Live	60, 120, 180, 240, 300, 360, 420
Buffer Size	500

B. Performance Metrics

For analyzing the performance of delivery probability, ratio of overheads, and average latency, 3 metrics have been incorporated. The outcome of theses metrics generated by ONE has been discussed further.

Delivery probability[13]refers to the ratio of successful messages and number of messages delivered. If the delivery probability of the network is high, its efficiency improves significantly.

$$Delivery\ Probability = \frac{number\ of\ message\ received}{number\ of\ message\ sent}$$

Overhead ratio refers to the metric which is required to ensure the delivery of the actual messages.In this case, performance is directly proportional to less overhead.

$$Overhead\ Ratio = \frac{number\ of\ messages\ forwarded - number\ of\ message\ received}{number\ of\ message\ received}$$

Latency average refers to the average time taken between messages to generate and received by the receiver or destination node. The latency rate of an opportunistic networks are high.

$$Latency\ Average = \sum_{i=1}^{n}\left(\frac{time\ when\ message\ received - time\ when\ message\ produced}{number\ of\ messages\ received}\right)$$

5. Results and Discussion

In this section, we will discuss the performance and efficiency of different algorithms such as Epidemic, Spray and Wait, Binary Spray and Wait, PRoPHET, and PRoPHETv2 in context of delivery probability, overhead ratio, latency rate and so on. This experiment has variable buffer size, message size and live time. The outcomes of these have been gathered from the ONE simulator and it is discussed in the upcoming paragraphs.

A. Varied Buffer Size

It represents the performance of different networks if they are provided with variable length of buffer memory. The sizes of the buffers are ranging from 5MB, 10MB, 15MB, and so on up to 35 MB.

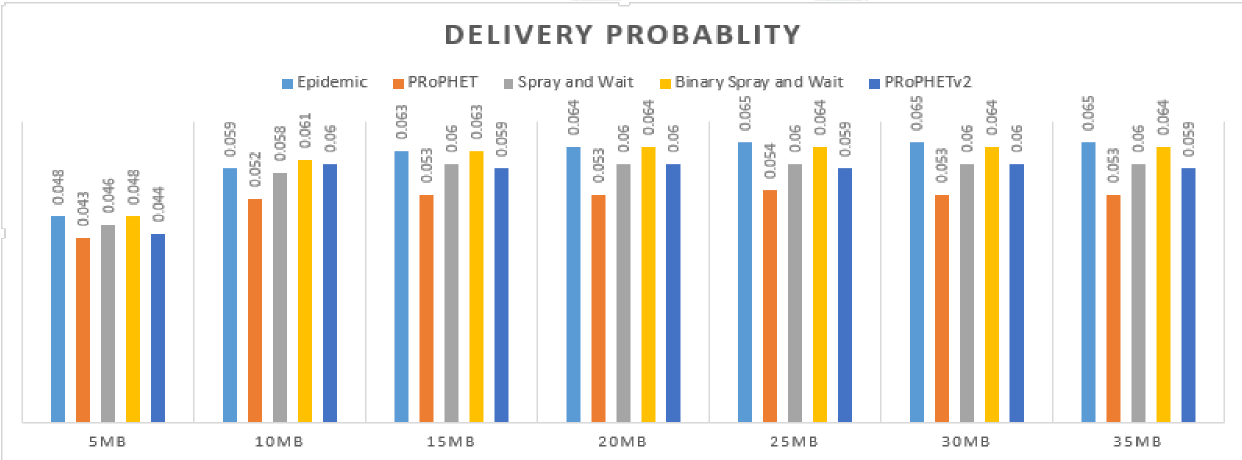

Figure 8. Buffer Sizes are Varied

In the Figure 8, represents the delivery probability of different buffer sizes. The 0 represents to the minimum value of delivery probability, whereas 1 refers to the maximum value. From the results of the experiment, it can be clearly seen that the Epidemic protocol has the highest delivery probability, whereas Binary Spray and Wait is at the second, Spray and Wait is at third along with PRoPHETv2 being at the fourth position in terms of delivery probability.

Apart from this, incremented value of buffer has the great impact on delivery probability, which means with higher buffer size on the network, several messages can be hold on that. Hence, the possibility of connection drop is far less. The Table 4.2, represents the overhead ratio value in association with prior algorithms because the sizes of the buffers are variable.

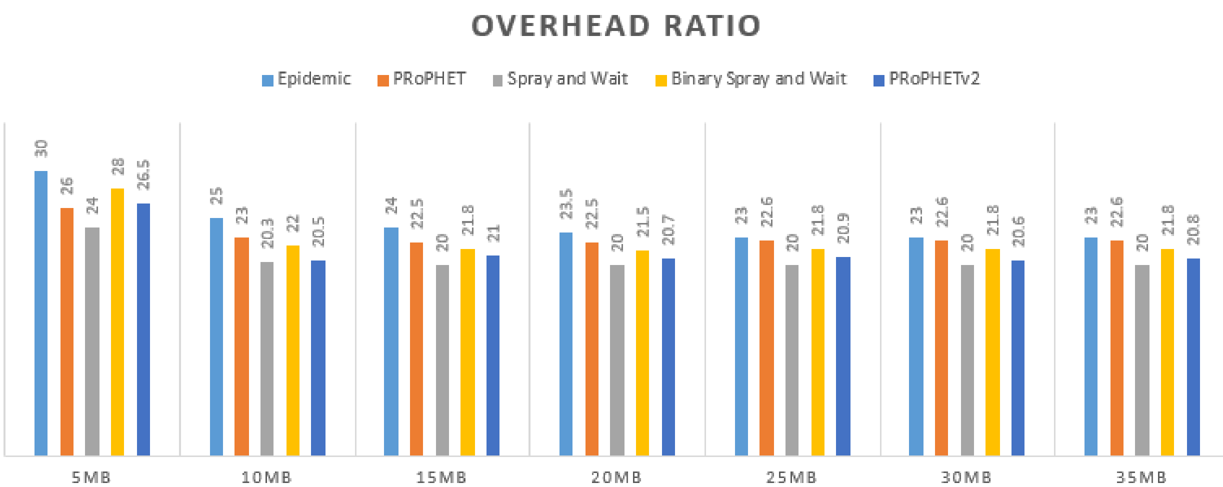

Figure 9. Overhead Ratio in terms of variable Buffer Sizes

During the experiment, it is found that Epidemic has the greatest overhead ratio in comparison with other algorithms. Whereas PRoPHET has the second highest value of overhead, Binary Spray and Wait has the third position and PRoPHETv2 are at the fourth position. And, at the last position there is Spray and Wait. One thing to be noticed, PRoPHET and PRoPHETv2 have the least overhead ratio value than Epidemic. This is due to the fact that both nodes send data only to reliable destination nodes. Binary Spray and Wait and Spray and Wait have the slightly least value than Epidemic as there are limit in number of messages being transmitted. Moreover, the increased buffer size value allows decrease in ratio value of overheads. In the following table 4.3, average latency rate of algorithms has been described.

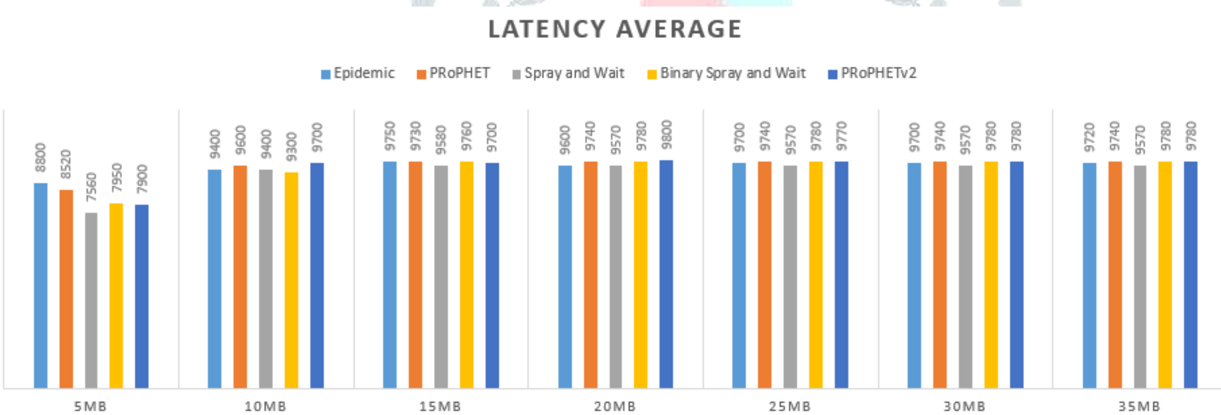

Figure 10. Latency Average Latency with variable Buffer

The Figure shows the average latency in comparison to other existing algorithms along with variable sized buffer space available. In this, Spray and Wait algorithm has very promising results as compared to others. If we increase the value of buffer memory, latency average will also escalate.

B. Variable Message Size

This section is all about the performance of network of variable messages size.

The typical message sizes are ranging from 500 kB to 1 MB, 1.5 MB to 2 MB, 2.5 MB to 3 MB, 3.5 MB to 4 MB, 4.5 MB to 5 MB,5.5 MB to 6 MB, and 6.5 MB to 7 MB.

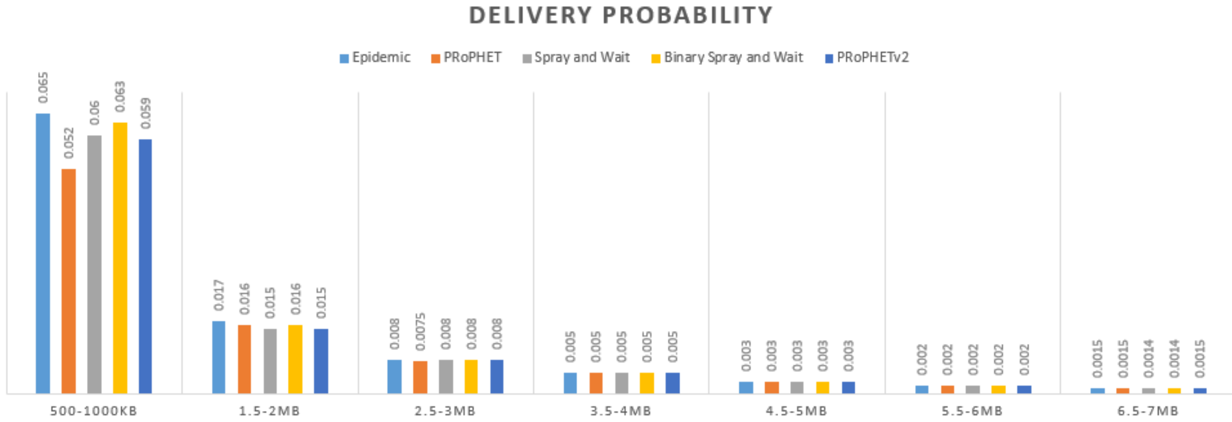

Figure 11. Delivery Probability

The above-mentioned chart represents the delivery probability in association with other algorithms. It shows that the delivery probability remains the same if the size of the message is between 1.5Mb and 2Mb to 6.5Mb and 7Mb. On the flip side, when the message is between 500KBto 1Mb, Binary Spray and Epidemic protocols have the highest delivery probability. Spray and Wait and PRoPHETv2 have the similar DP. And, at the lowest delivery probability, there is PRoPHET. The incremented value of message size decreases the delivery probability.

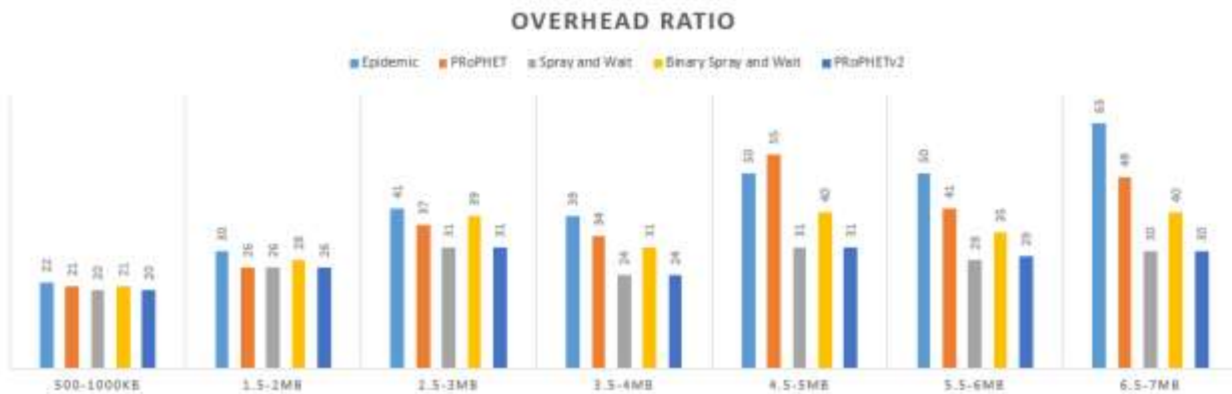

Figure 12. Variable Message Sizes

Above mentioned figure illustrates the ratio of overhead message sized in association with algorithms. It shows Epidemic has the greater overhead value because of the random and blindfolded message forwarding technique. PRoPHET is at second position and Binary Spray and Wait being at the 3rd level. PRoPHETv2 and Spray and Wait have the lowest overhead ratio. The main benefit of having PRoPHET and PRoPHETv2 is that they examine and access the probability of message before sending it to destination nodes. This is the reason they have lesser value of overhead ration in comparison to Epidemic. In Spray and Wait and Binary Spray and Wait there is limit in sending message copies to destination nodes, which is why they also have less ratio of overhead than Epidemic. Apart from this, increment in message size tend to rise the ratio of the overhead.

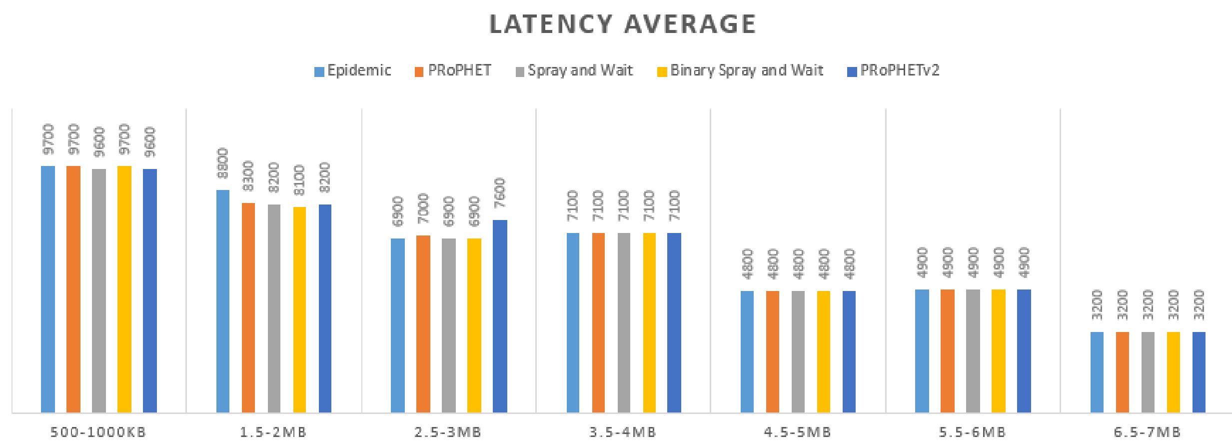

Figure 13 Average Latency with Variable Message Sizes

The aforementioned Figure 13 states average latency with variable sizes of messages along with different algorithms. It can be seen that if the message size escalates, latency average drops. This is because of the lower consumption of resources by the source node.

C. Variable length of Time To Live (TTL)

In this section, performance of network has been elaborated. The given time tolive are 1 hour, 2 hours, 3 hours, and so on upto 7 hours.

Figure 14. TTL Delivery Ratio

In Figure 14, the delivery probability of time to live (TTL) has been discussed. It shows that the Binary Spray and Wait has the highest value of DP, whereas PRoPHET algorithm has the least value. If the value of TTL rises, delivery ratio will also escalate. The TTL enables the network to transmit limited number of message copies. Consequently, performance of the network improves significantly.

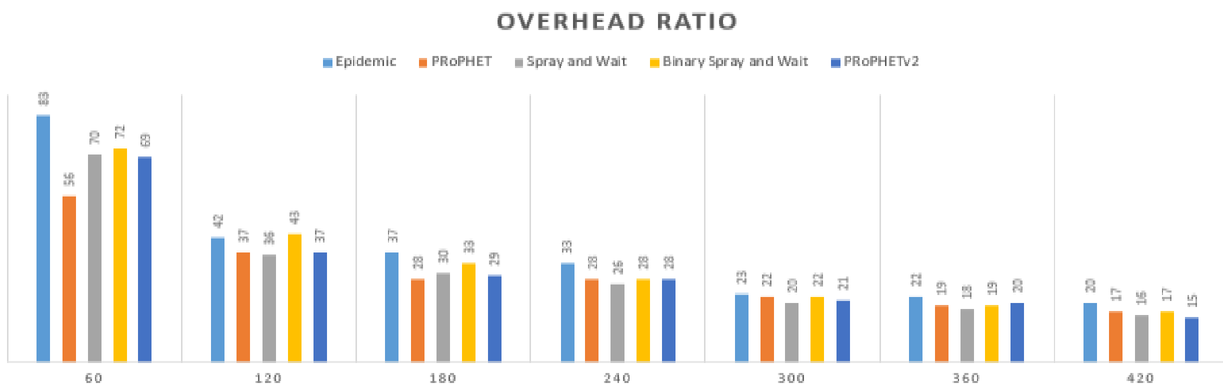

Figure 15. Variable Overhead Ratio of TTL

In this Figure 15, the overhead ratio of TTL in comparison to other algorithms have been shown. Epidemic has the highest ratio of overhead. If the TTL value gets increased, overhead ratio will de-escalate. Therefore, highest value of TTL seems a good preference for the network.

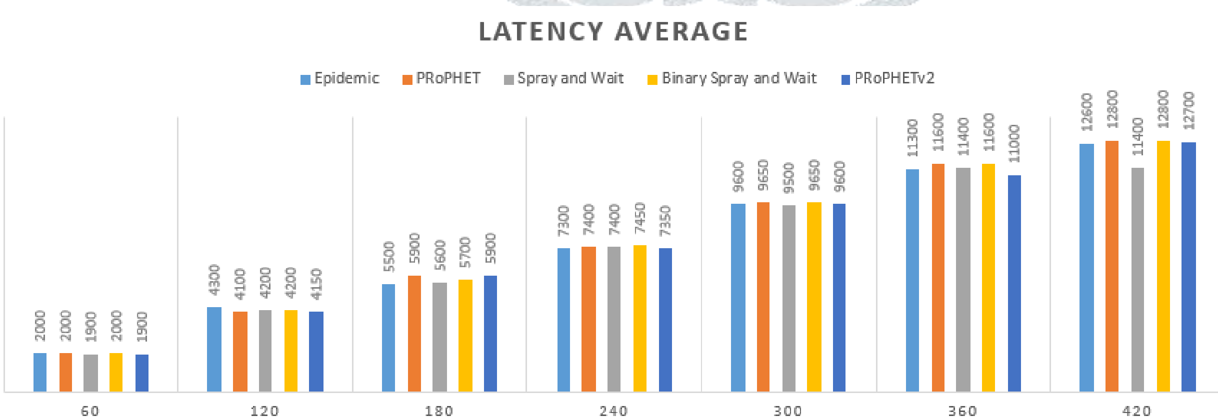

Figure 16. Latency Average of TTL

In figure 16 it is mentioned that the Binary Spray and Wait and Epidemic have the highest value of DP. The more is the value of TTL, the greater is the latency average. This is because of the fact that message has to wait in the buffer memory before it gets transmitted over the network or gets dropped.

Conclusion

In this paper, we analyzed that the different aspects of algorithms as the experiment has been conducted through ONE simulator. For the experiment, we took variable length buffer size along with message size and TTL. The efficiency has been analyzed with respect to delivery probability, latency and ratio of overhead. Also, it has been analyzed that the Epidemic has greater value of delivery probability. On the other hand, Binary Spray and wait performs better than Spray and Wait with respect to delivery probability. However, Spray and Wait has the capacity to perform well if we consider overhead ratio and latency average. Similarly, PRoPHETv2 is far better option than PRoPHET. But the PRoPHET delivers good performance in association withlatency. The performance of the network is optimal when there is lower in overhead values and lest latency average. From the experiment, it has been found that if we apply another movement model such as map-based, shortest path map, external movement or map route, the performance will increase. Furthermore, from the security point of view, improvement in the network seems necessity.

References

[1] A. Chauhan and A. Aggarwal, "Buffer Adaptive Epidemic Protocols for DTN," *2019 Global Conference for Advancement in Technology (GCAT)*, BANGALURU, India, 2019, pp. 1-4, doi: 10.1109/GCAT47503.2019.8978412.
[2] Ari Keränen, Jörg Ott and Teemu Kärkkäinen, "The ONE simulator for DTN protocol evaluation", *Proceedings of the 2nd international conference on simulation tools and techniques*, pp. 55, 2009.
[3] Jones, PC Evan, Li Lily, Jakub K. Schmidtke and Paul AS Ward, "Practical routing in delay-tolerant networks", *IEEE Transactions on Mobile Computing*, vol. 6, pp. 943-959, 2007
[4] Gandhi J., Narmawala Z. (2020) Fair Comparative Analysis of Opportunistic Routing Protocols: An Empirical Study. In: Jain L., Tsihrintzis G., Balas V., Sharma D. (eds) Data Communication and Networks. Advances in Intelligent Systems and Computing, vol 1049. Springer, Singapore
[5] J. Dede,A. Förster, E.Hernández-Orallo, J.Herrera-Tapia,K.Kuladinithi,V.Kuppusamy et al., Simulating opportunistic networks: survey and future directions. IEEE Commun. Surv. Tutor. **20**, 1547–1573 (2018)
[6] S. Bharamagoudar, S. Saboji, Routing in opportunistic networks: taxonomy, survey, in *2017 International Conference on Electrical, Electronics,Communication, Computer, and Optimization Techniques (ICEECCOT)* (2017), pp. 300–305
[7] A. Keränen, E. Hyytiä, J. Ott, M. Desta, T. Kärkkäinen, Evaluating (Geo) content sharing with the one simulator, in *11th ACM International Symposium on Mobility Management and Wireless Access (MobiWac'13)* (2013)
[8] R. Cavallari, S. Toumpis, R.Verdone,Analysis of hybrid geographic/delay-tolerant routing protocols for wireless mobile networks, in *IEEE INFOCOM 2018-IEEE Conference on Computer Communications* (2018), pp. 2321–2329
[9] V.F.S. Mota, F.D. Cunha, D.F. Macedo, J.M.S. Nogueira, A.A.F. Loureiro, Protocols, mobility models and tools in opportunistic networks: a survey. Comput. Commun. **48**, 5–19 (2014)
[10] A. Vahdat, D. Becker, *Epidemic Routing for Partially Connected Ad hoc Networks* (2000)
[11] T. Spyropoulos, K. Psounis, C.S. Raghavendra, Spray and wait: an efficient routing scheme for intermittently connected mobile networks, in *Proceedings of the 2005 ACM SIGCOMM Workshop on Delay-Tolerant Networking* (2005), pp. 252–259
[12] A. Keränen, J. Ott, T. Kärkkäinen, The ONE simulator for DTN protocol evaluation, in *Proceedings of the 2nd International Conference on Simulation Tools and Techniques* (2009), p. 55
[13] A. Lindgren, A. Doria, O. Schel, #233, Probabilistic routing in intermittently connected networks.SIGMOBILE Mob. Comput. Commun. Rev. **7**, 19–20 (2003)
[14] J. Burgess, B. Gallagher, D. Jensen, B.N. Levine, Maxprop: Routing for vehicle-based disruption-tolerant networks, in *25th IEEE International Conference on Computer Communications. Proceedings INFOCOM* (2006), pp. 1–11
[15] Y. Cao, Z. Sun, and N. Wang, "Spraying the Replication Probability With Geographic Assistance for Delay TolerantNetworks," *IEEE ICC 2012 - Next-Generation Networking Symposium*, 2012.
[16] L. F. Xie, P. H. J. Chong, Y. L. Guan, and B. Chong Ng, "Routing for Group Mobility in Mobile Ad Hoc Networkswith Delay-Tolerant Approach," *IEEE Wireless and Mobile Networking Conference (WMNC)*, pp. 1-6, 2010.
[17] Z. Guo, Z. Peng, B. Wang, J.-H. Cui, and J. Wu, "Adaptive Routing in Underwater Delay Tolerant SensorNetworks," *IEEE Communications and Networking in China (CHINACOM)*, 2011.
[18] A. Derry, "Spray and Wait an Efficient Routing Method for Intermittently Connected Mobile Networks," *AmericanJournal of Mechanical Systems*, vol. Vol.2 No.3 2012.
[19] S. M. A. Iqbal and A. K. Chowdhury, "Adaptation of Spray Phase to Improve the Binary Spray and Wait Routing inDelay Tolerant Networks," *IEEE*, 2012.
[20] X. Wang, L. Qian, P. Wei, F. Dai, and F. Miao, "Probabilistic Route Mechanism of Considering CommunicationTime—PROPHETCCT," *IEEE International Conference on Computer Science and Software Engineering*, 2008.
[21] D. Pan, M. Lin, L. Chen, and J. Sun, "An Improved Spray and Wait with Probability Choice Routing forOpportunistic Networks," *Journal of Networks*, vol. 7, 2012.

[22] P. Sok and K. Kim, "Distance-based PRoPHET Routing Protocol in Disruption Tolerant Network," *IEEE* 2013.
[23] M. Abbas, N. H. M. Yusof, and N. Fisal, "Performance Evaluation of Binary Spray and Wait OppNet Protocol in theContext of Emergency Scenario," *IEEE Third International Workshop on Pervasive Networks for EmergencyManagement* 2013.
[24] Y. Cao and Z. Sun, "Routing in Delay/Disruption Tolerant Networks: A Taxonomy, Survey and Challenges," *IEEECommunications Surveys & Tutorials* 2012.
[25] P. Puri and M. P. Singh, "A Survey Paper on Routing in Delay-tolerant Networks," *IEEE* 2013.