Jurnal
Teknologi

Full Paper

PERFORMANCE COMPARISON OF BASELINE ROUTING PROTOCOLS IN POCKET SWITCHED NETWORK

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Article history
Received
17 November 2015
Received in revised form
24 April 2016
Accepted
23 February 2016

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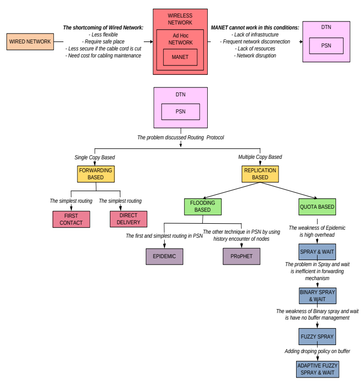
Graphical abstract



Abstract

Pocket Switched Network (PSN) is a branch of Delay Tolerant Network (DTN) which is intended to work in a challenged network. Challenged network is network with lack of infrastructure such as disaster area. As such, the network has intermittent connectivity. PSN provides a new paradigm to distribute messages in the network by taking advantage of roaming nodes from one place to another. In this paper, network performances of eight PSN routing protocols are investigated namely, First Contact, Direct Delivery, Epidemic, PRotocol using History of Encounter and Transitivity (PRoPHET), Spray and Wait, Binary Spray and Wait, Fuzzy Spray, Adaptive Fuzzy Spray and Wait. The performance metrics are packet delivery ratio, overhead ratio and average latency. Opportunistic Network Environment (ONE) simulator is used to evaluate the network performance. Experiments show that Epidemic has the best performance in term of message delivery ratio, but it has the highest overhead ratio. Direct Delivery has the lowest overhead ratio (zero overhead ratio) and PRoPHET has the lowest latency average.

Keywords: Pocket Switched Network, First Contact, Direct Delivery, Epidemic, PRoPHET, Spray and Wait, Binary Spray and Wait, Fuzzy Spray, Adaptive Fuzzy Spray and Wait.

Abstrak

Pocket Switched Network (PSN) adalah salah satu cabang dari *Delay Tolerant Network* (DTN) yang dimaksudkan untuk bekerja di *challenged network*. *Challenged network* adalah rangkaian dengan kekurangan infrastruktur seperti kawasan bencana. Oleh kerana itu, rangkaian mempunyai sambungan berkala. PSN menyediakan paradigma baru untuk mengedarkan mesej dalam rangkaian dengan mengambil keuntungan daripada perpindahan *node* dari satu tempat ke tempat lain. Dalam kertas ini, *network performance* dari delapan buah protokol *routing* PSN disiasat iaitu *First Contact, Direct Delivery, Epidemic, PRotocol using History of Encounter and Transitivity (PRoPHET), Spray and Wait, Binary Spray and Wait, Fuzzy Spray, Adaptive Fuzzy Spray and Wait*. Metrik prestasi adalah nisbah paket penghantaran, nisbah overhed dan rata-rata kependaman. Simulator *Opportunistic Network Environment* (ONE) digunakan untuk menilai prestasi rangkaian. Eksperimen menunjukkan bahawa *Epidemic* mempunyai prestasi yang terbaik dari segi nisbah penghantaran mesej, tetapi ia mempunyai nisbah overhed yang paling tinggi. *Direct Delivery* mempunyai nisbah overhed yang paling rendah (nisbah overhed sifar) dan *PRoPHET* mempunyai rata-rata kependaman terendah.

Kata kunci: Pocket Switched Network, First Contact, Direct Delivery, Epidemic, PRoPHET, Spray and Wait, Binary Spray and Wait, Fuzzy Spray, Adaptive Fuzzy Spray dan Wait

1.0 INTRODUCTION

Wireless network is a network that uses radio waves to work in certain frequency and it does not require any physical media to communicate. The advantages of this network are faster installation and expansion relatively easy, wide coverage area, support the mobile user, and it does not use any cable. Unfortunately, it has drawbacks such as expensive tools, no guarantee in safety, limited of network capacity and intermittent connection. Examples of wireless networks are Global System for Mobile Communications (GSM), General Packet Radio Services (GPRS), Exchanged Data rates for GSM Evolution (EDGE), Universal Mobile Telecommunications System (UMTS), High Speed Downlink Packet Access (HSDPA), High Speed Uplink Packet Access (HSUPA), Long Term Evolution (LTE), Worldwide Interoperability for Microwave Access (WiMAX), Wireless Local Area Networks (WLAN) and Bluetooth.

Pocket Switched Network (PSN) evolved from Mobile Ad hoc NETwork (MANET). PSN overcomes the difficulty of accessing network in a challenged environment. Challenged network is an environment which has lack of infrastructure, frequent network disconnection, network disruption, and lack of resource [1]. In the network, some popular routing protocols in MANET, such as Ad Hoc On-Demand Distance Vector (AODV) or Dynamic Source Routing (DSR), cannot be implemented due to end-to-end network construction is needed for forwarding the network messages. Some networks such as wildlife tracking sensor network, military network, inter-planetary network, nomadic community networks, underwater sensor networks, and satellite networks use similar concept as in PSN.

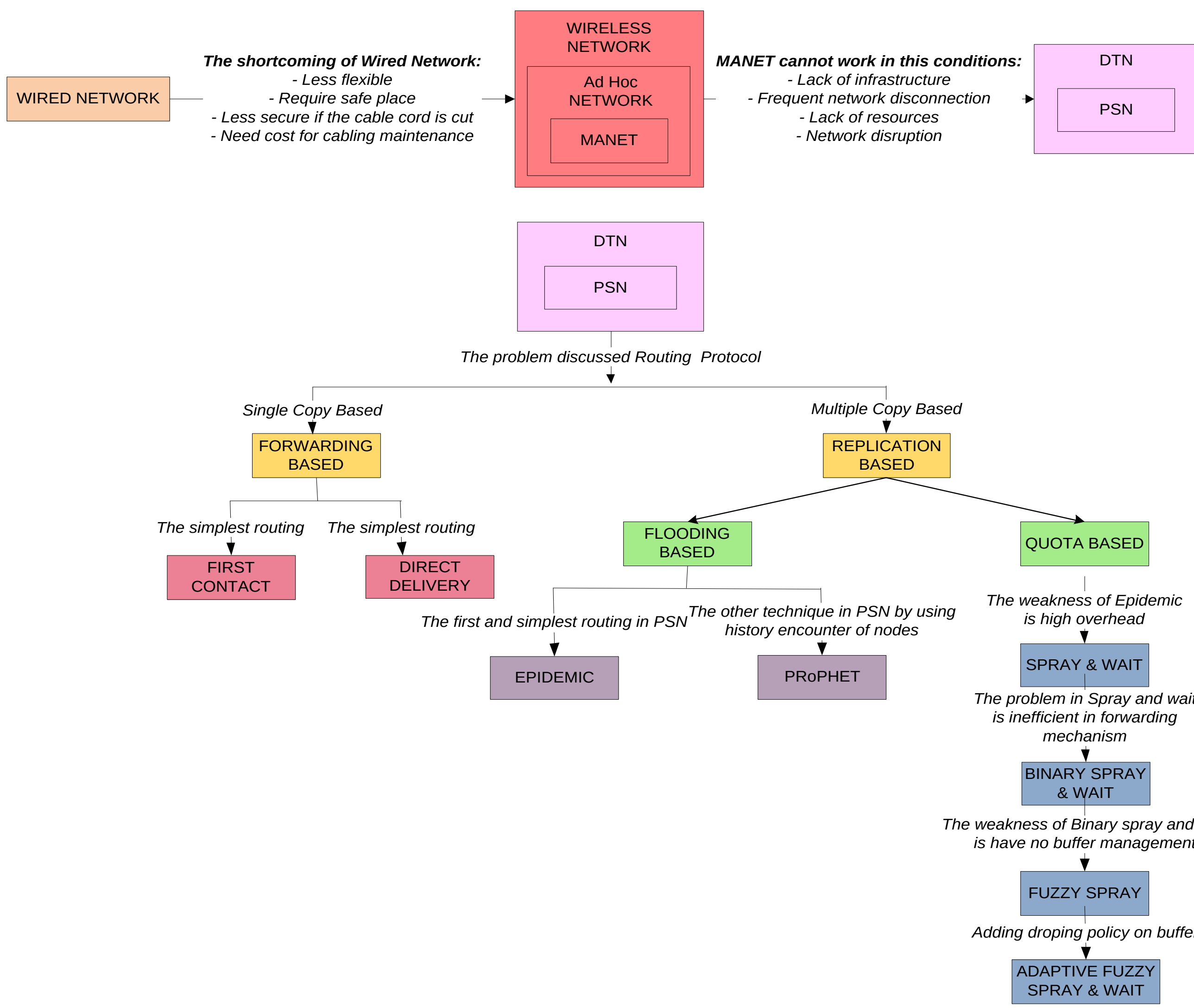


Figure 1. Development of Routing Protocols in Pocket Switched Network

Delay Tolerant Network (DTN) can work in communication gap since lack of infrastructures. It can also support communication between planets or satellites. In other word, DTN is mobile wireless network which can work in intermittent connection and it does not guarantee end to end connection. Figure 1 shows development of routing protocols in Pocket Switched Network. Figure 1 shows trend enhancement of routing protocols that refer to replication based. Replication based has multiple message copies in order to increase the successful probability of messages reaching the destination node compared to single-copy based. DTN is focused on extremely long delay of intermittent connection. The performance of DTN depends on human mobility pattern and their characteristics.

This paper is an extension of previous paper [15] that is more detailed analysis and more comprehensive information regarding another baseline routing protocols in PSN. The rest of this paper is organized as follows: Section I describes the overview of prominent routing protocols in Pocket Switched Network. Section II contains the process of simulation. Section III presents results and discussion. Conclusion is given in the final section namely, Section IV.

1.1 Pocket Switched Network

Pocket Switched Network (PSN) is application of DTN which exploits contact opportunities between mobile nodes and human mobility to transfer data in peer-to-peer connection [15,16,17]. PSN is also part of Opportunistic network where network contacts are intermittent or where link performance is highly variable or extreme [2]. This network can be applied in satellite network, nomadic community network, wildlife habitat tracking monitoring sensor network, military network and interplanetary network. Recently, PSN has been developed to enable mobile users in a social network to opportunistically exchange information by utilizing proximity-based connection capability, such as Bluetooth or Wireless Fidelity (WiFi) [3].

PSN uses Store Carry Forward (SCF) approach to increase message delivery probability. Using this approach, a router node in PSN stores the incoming message into its buffer and then delivers the message towards destination node whenever the radio of the router node covers the destination node. This approach uses node mobility to deliver messages due to the lack of network-wide connection. It increases the message delivery ratio, reduces end-to-end delay and minimizes resource consumption, which is usually measured by bandwidth and buffer space [4]. According to [5], router nodes should deliver high priority message during contact phase. Contact phase is the time when two or more nodes exchange message. In other word, the time duration for two or more mobile nodes encountering each other within their radio transmission ranges and is able to transfer messages. The duration of the contact time depends on the mobility profile of participating nodes [6].

1.2 Routing in Pocket Switched Network

Many routing protocols have been proposed to improve the performance in PSN. As in DTN, the routing scheme in PSN consists of two groups; forwarding based and replication based [7]. Forwarding based uses single message to deliver it to destination node. This scheme works in good connectivity network and network with knowledge to decide the routing. Examples of such protocols are Direct delivery and First contact. While, replication based duplicates the message to ensure high delivery probability toward destination node. It is usually used in opportunistic network such as in PSN. It has higher delivery ratio and lower delay. Unfortunately, it has many redundant message copies in the network which consume many resources, such as buffer space, energy and bandwidth. The sample of routing protocol which uses these schemes namely, Epidemic, Protocol using History of Encounter and Transitivity **(**PRoPHET), MaxProp, Resource Allocation Protocol for Intentional DTN (RAPID), Prioritized Epidemic (PREP) and so on. Whereas, the other scheme is quota based which can save network resources by transmitting limited message copies in the network. Examples of such protocol adopting this scheme are, Spray and wait, Binary spray and wait, Opportunistic Routing with Windows-Aware Replication (ORWAR), spray and focus, Encounter Based Routing (EBR) and etc. The quotas based are best steward in using network resources.

1.3 First Contact

First Contact is a routing protocol which has no knowledge about the network in assistance to route the message from source node to destination node (zero-knowledge protocol). Hence, this protocol has no fixed configuration since it makes random decision in routing the message. In addition, this protocol never attempt to learn about topology and having the same routing performance for all time [8]. A message is forwarded randomly to the next contact. This protocol chooses the first available contact (first encountered node) when none that are connected at message arrival time. This protocol is regarded as a simple routing protocol of single-copy routing.

1.4 Direct Delivery

Direct Delivery is a routing protocol that waits the destination node and forwards the message directly to such destination. This protocol is also regarded as one of the simplest routing protocol of single-copy routing [9]. This protocol has zero overhead but it has long delivery delay. This protocol has zero information about the network in assistance to route the message toward destination node (zero-knowledge protocol).

1.5 Epidemic

Epidemic is a routing protocol which uses flooding approach to transfer message from source to destination node. In this protocol, if two nodes encounter within radio transmission coverage, a node exchanges all routing messages and it will repeat until all nodes in the network have the same set of routing messages. The advantage of this routing is it has high delivery probability. Unfortunately, this scheme has some drawbacks, it consumes unlimited storage, power and bandwidth recourses. Besides, it also has high overhead ratio.

1.6 Probabilistic Routing Protocol using History of Encounter and Transitivity (PRoPHET)

PRoPHET is a routing protocol for DTN and it has often been used as a benchmark to evaluate and compare to other DTN routing protocols [10]. PRoPHET uses the history of previous encounters with other nodes. PRoPHET has statistical properties namely, delivery predictability and transitive property which can help to choose the appropriate relay node for the next transmission. Transitive property is a condition when node A frequently encounters node B, node B frequently encounters node C, then node C probably is a good relay to forward messages are destined for node A. The benefits of transitive property scheme are low wasting time of signaling on the queue and less load pressure of node. Hence, the possibility of message dropping will be decreased. PRoPHET uses expected communication prediction which has three parts namely, updating delivery predictability whenever a node encounters other node, aging property and transitive property. $P(A,B) \in [0,1]$ describes the expected communication prediction between node A and node B. This algorithm assumes unlimited bandwidth therefore time is ignored during the transmission process to destination node.

1.7 Spray and Wait

Spray and wait is a routing protocol which is intended to improve the performance of Epidemic in terms of decreasing overhead ratio. The characteristics of spray and wait routing protocol are namely, performing fewer transmission than Epidemic and other flooding-based routings, having low contention in high traffic load and low latency in transferring messages, exhibiting good performances in large network size and node density, simple and requires a little knowledge about network. This protocol uses Store Carry Forward (SCF) scheme for messages transmission. A node stores messages, wait then travels to other places. Whenever a node meets the destination node afterward node directly delivers the messages. Spray and wait protocol has two phases namely, spray phase and wait phase. In spray phase, a source node sends a message copy to its neighbor node until only one message copy is left. Further, it switches to wait phase, a node sends a message copy to destination node by direct transmission. Finally, message reaches the destination node.

1.8 Binary Spray and Wait

Binary spray and wait is an enhanced of Spray and Wait protocol. This protocol is intended to improve the performance of spray and wait in forwarding mechanism [14]. In spray phase, a source node sends half of message copies to each distinct node until node have only one message copy then the network switches to wait phase. Meanwhile, in wait phase, the network sends a message copy to destination node by direct transmission. This protocol is more efficient than Spray and wait protocol since Binary spray and wait has less delay.

1.9 Fuzzy Spray

Fuzzy spray proposed by [6] is another enhancement of Spray and wait protocol in spray phase. It improves the efficiency of message copies transfer and reduce overall latency in the network. This protocol uses Forward Transmission Count (FTC) and message size parameters for prioritizing messages stored in buffer for next transmission. FTC is instead of hop count to measure the number of messages copies. The initial value of FTC is 1. Using FTC is better than hop count since this protocol uses replication strategy to increase delivery ratio and it works in limited bandwidth so node cannot transmit all message copies to relay nodes within contact phase. Here, contact phase has short time so that sequence message is very important. This protocol works well in all scenarios with various node densities and distribution. Fuzzy decision is used to classify messages into levels in buffer and promoting high priority within contact phase.

1.10 Adaptive Fuzzy Spray and Wait

Adaptive Fuzzy Spray and Wait is an extension of Fuzzy spray proposed by [11] that addresses the drawbacks of Fuzzy spray. Similar to Epidemic protocol which has no limitation of message copies per message during message transmission. As a result, Fuzzy spray has high overhead. In order to solve the problem, AFSnW calculates the average of message size locally. Similar to estimation of Round-Trip-Time (RTT) value did in Transmission Control Protocol (TCP). AFSnW also estimates number of nodes by counting unique ID of message source which have been forwarded. The additional feature of AFSnW is having dropping policy to determine message to be dropped in case of buffer overflow. Priority scheme determines which messages are transmitted first within contact phase. This protocol is more effective in ensuring fairness while maintaining high delivery probability. Meanwhile, dropping policy is used to get fairness during contention. During transmission process, smaller messages have high priority within contact phase. AFSnW performs better than Fuzzy spray protocol in delivery probability, latency and overhead.

2.0 SIMULATION

This section contains the simulation parameters such as number of groups, number of node, movement model, map size, transmit speed, transmit range and so on. The experiments are deployed to measure the network performance of First Contact, Direct Delivery, Epidemic, PRoPHET, Spray and wait, Binary spray and wait, Fuzzy Spray and Adaptive Fuzzy spray and wait.

The above mentioned routing protocols are analyzed on Opportunistic Network Environment (ONE) simulator. This simulator is designed to evaluate the performance of Delay Tolerant Network (DTN) protocol. ONE simulator uses Java language programming. The main functions of ONE are modeling the node movement and inter node contacts.

The network interface is Bluetooth interface which can transmit within range of 10 meters and transmission speed 2 Mbps (250 Kbps). There are two wireless technologies available for Ad Hoc connectivity on mobile phones namely, Wireless Fidelity (WiFi) and Bluetooth. This paper considers Bluetooth connection due to only one with a reference implementation supporting the deployment of DTN protocols.

This experiment has four scenarios consists of varying number of nodes, varying periods of time to live, varying buffer sizes and varying message sizes. The map sizes are 4500 meters width and 3400 meters height. The time simulation is 24 hours. The simulation parameters are shown in table 1 and table 2. Table 1 summarizes the simulation configuration for number of nodes analysis. While, table 2 shows the simulation configuration for time to live analysis. Scenario 1 consists of 100 nodes (pedestrians) and divided into 4 groups namely, 40 pedestrians, 30 bicycles, 20 cars and 10 trams. The velocity of pedestrian is 0.5 m/s – 1.5 m/s, velocity of car is 1.4 m/s – 4.0 m/s, velocity of car is 2.7 m/s – 13.9 m/s and velocity of tram is 7.0 m/s – 10 m/s. The node movement is Random Waypoint.

Table 1. Simulation Parameters of Varying Number of Nodes

Simulation Parameter	Simulation Value
Message size	10 kB - 1 MB
TTL	360 Minutes (6 Hours)
Buffer Size	100 MB for each pedestrian
Number of Nodes	50, 60, 70, 80, 90, 100, 110 Nodes

Table 2. Simulation Parameters of Varying Time to Live

Simulation Parameter	Simulation Value
Message size	10 kB - 1 MB
TTL	20, 40, 60, 80, 100, 120, 140 Minutes
Buffer Size	100 MB for each pedestrian, bicycle and car, 50 MB for each tram
Number of Nodes	100 Nodes (40 Pedestrians, 30 Bicycles, 20 Cars, 10 Trams)

2.1 Performance Comparison

There are three metrics are used to measure the network performance namely, delivery probability, overhead ratio and average latency. The description of performance metrics are shown below.

1. *Delivery probability* is ratio between successful messages arrives at destination node and number of delivered messages [12]. The network has good performance if delivery probability is high. It means more messages are received in destination node.

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

2. *Overhead ratio* is measurement used to estimate how many redundant messages are forwarded to deliver one message. Lesser overhead ratio denotes good network performance.

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

3. *Average latency* is average time between messages produced and messages received by destination node [13]. Opportunistic network has high average latency due to nature of its network. Network is considered good performance if it has less average latency.

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

3.0 RESULT AND DISCUSSION

This section discusses the network performances of First Contact, Direct Delivery, Epidemic, PRoPHET, Spray and wait, Binary spray and wait, Fuzzy Spray and Adaptive Fuzzy spray and wait according to the value of delivery probability, overhead ratio and latency average. The experiment consists of varying number of nodes and varying value of time-to-live.

3.1 Varying Number of Nodes

This section discusses the network performance in varying number of nodes. The numbers of nodes are 50, 60, 70, 80, 90, 100 and 110 nodes. Figure 2, Figure 3 and Figure 4 show delivery ratio vs number of nodes, overhead ratio vs number of nodes and latency average vs number of nodes respectively.

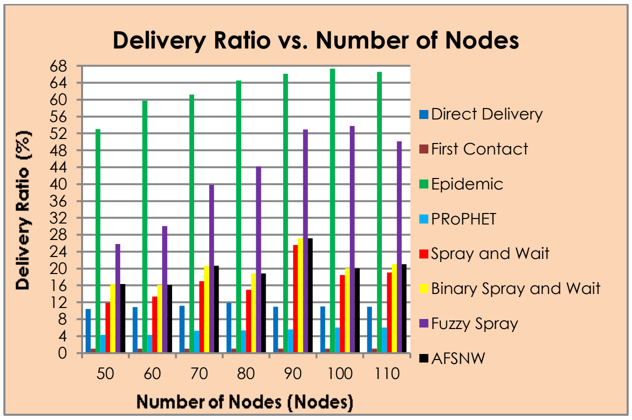


Figure 2. Delivery Ratio as Number of Nodes are Varied

Table 3. Delivery Ratio as Number of Nodes are Varied

Number of Nodes	Direct Delivery	First Contact	Epidemic	PRoPHET	Spray and Wait	Binary Spray and Wait	Fuzzy Spray	AFSNW
50	10.4	9.89	53.05	4.28	11.86	16.33	25.81	16.33
60	10.87	12..4	59.76	4.26	13.36	16.13	30.05	16.13
70	11.18	10.5	61.22	5.3	17.05	20.62	39.81	20.62
80	11.88	11.36	64.51	5.34	15.01	18.84	44.17	18.84
90	10.98	10.02	66.16	5.61	25.58	27.16	52.94	27.16
100	11.01	11.38	67.32	6.02	18.49	20.03	53.79	20.03
110	10.96	11.47	66.59	6.01	19.05	21.04	50.15	21.04

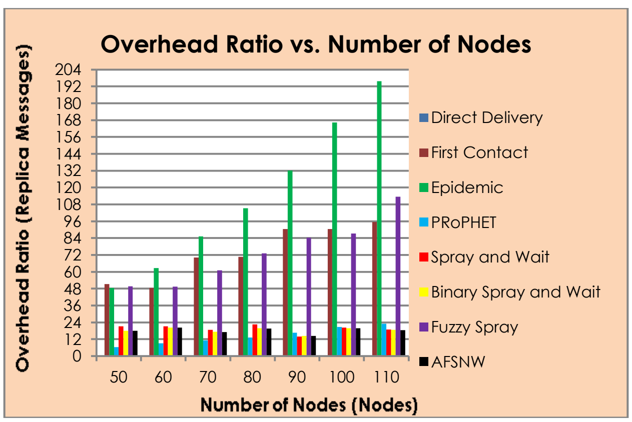


Figure 3. Overhead Ratio as Number of Nodes are Varied

Table 4. Overhead Ratio as Number of Nodes are Varied

Number of Nodes	Direct Delivery	First Contact	Epidemic	PRoPHET	Spray and Wait	Binary Spray and Wait	Fuzzy Spray	AFSNW
50	0	51.3702	48.4974	6.448	21.2597	18.1321	49.6347	18.0094
60	0	48.4588	62.6174	9.112	21.2874	20.3143	49.5487	20.2
70	0	70.2866	85.2564	11.0903	18.7091	17.3985	61.1992	17.2331
80	0	70.7289	105.279	13.1667	22.4796	19.7886	73.184	19.626
90	0	90.5119	132.1008	16.6829	13.9819	14.4773	84.3216	14.3068
100	0	90.4835	166.3225	20.6932	20.35	19.9077	87.2155	19.8385
110	0	95.4077	195.734	23.1591	19.0242	18.6715	113.531	18.4891

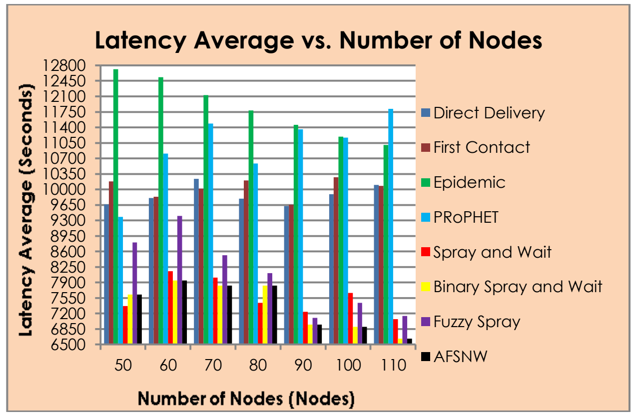


Figure 4. Latency Average as Number of Nodes are Varied

Table 5. Latency Average as Number of Nodes are Varied

Number of Nodes	Direct Delivery	First Contact	Epidemic	PRoPHET	Spray and Wait	Binary Spray and Wait	Fuzzy Spray	AFSNW
50	9662.84	10180.14	12716.33	9379.687	7367.934	7630.52	8800.52	7630.5123
60	9803.27	9832.466	12535.82	10807.2	8153.338	7949.05	9401.14	7949.0486
70	10241.6	10015.12	12130.31	11489.86	8012.454	7831.19	8518.91	7831.191
80	9795.71	10206.03	11784.25	10587.96	7444.005	7833.25	8108.51	7833.2512
90	9625.9	9652.13	11458.92	11357.6	7235.571	6948.76	7104.57	6948.7591
100	9891.11	10273.61	11190.47	11167.06	7666.98	6897.32	7438.52	6897.32
110	10102	10083.76	11001.01	11820.69	7070.055	6635.96	7144.32	6635.9584

Figure 2 and Figure 5 shows comparison of delivery ratio among routing protocols. It shows Epidemic protocol has the highest delivery ratio than other protocols since Epidemic sends message to all possible nodes. Meanwhile, PRoPHET has the lowest delivery ratio because PRoPHET chooses the appropriate relay nodes before transferring messages by using Delivery Predictability (DP) property. Besides, the number of node also gives impact to delivery ratio. The increasing number of nodes makes the delivery ratio higher. It means, more nodes in the network contribute to higher opportunity of message copies to reach destination node.

Figure 3 and Figure 6 describes comparison of overhead ratio among routing protocols. It shows that Direct delivery protocol has the lowest overhead ratio (zero overhead ratio) because the message is sent only to the destination node. While, Epidemic has the highest overhead ratio than other routing protocols since transferring message in Epidemic is flooding-based. The value of overhead ratio can be influenced by number of nodes. Increasing number of nodes contributes to higher overhead ratio because more contact opportunity between nodes and more transmission take place.

Meanwhile, Figure 4 and Figure 7 illustrates PRoPHET has the highest latency average among other routing algorithms since this protocol need longer time to decide the appropriate relay node in transferring message toward destination node. Increasing the number of nodes lowers latency average since more nodes contributes to faster message transfer from source node to destination node.

B Varying Values of Time-To_live

This section describes the performance of network with varying time to live values. The values of time to lives are 20, 40, 60, 80, 100, 120 and 140 minutes. Figure 5, Figure 6 and Figure 7 show delivery ratio vs time to live, overhead ratio vs time to live, latency average vs time to live respectively.

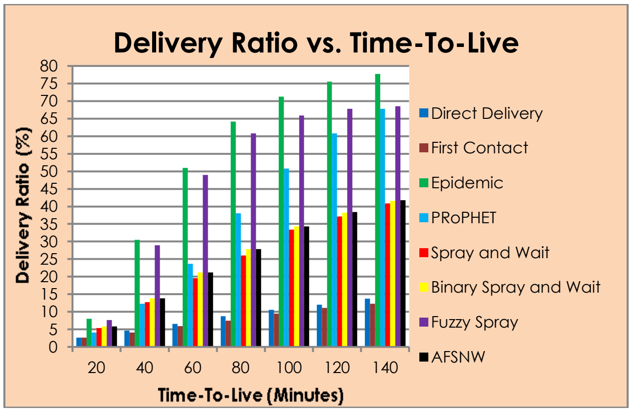


Figure 5. Delivery Ratio vs. Time-To-Live

Table 6. Delivery Ratio vs. Time-To-Live

TTL (Minutes)	Direct Delivery	First Contact	Epidemic	PRoPHET	Spray and Wait	Binary Spray and Wait	Fuzzy Spray	AFSNW
20	2.7	2.63	8	4.14	5.39	5.86	7.63	5.86
40	4.62	4.14	30.46	12.27	12.79	13.87	28.97	13.87
60	6.56	5.95	50.97	23.69	19.57	21.26	49	21.26
80	8.72	7.52	64.17	38.02	26.04	27.89	60.8	27.89
100	10.53	9.44	71.28	50.77	33.44	34.36	65.9	34.36
120	12.03	11.15	75.52	60.82	37.13	38.21	67.75	38.37
140	13.74	12.31	77.71	67.76	40.83	41.6	68.52	41.76

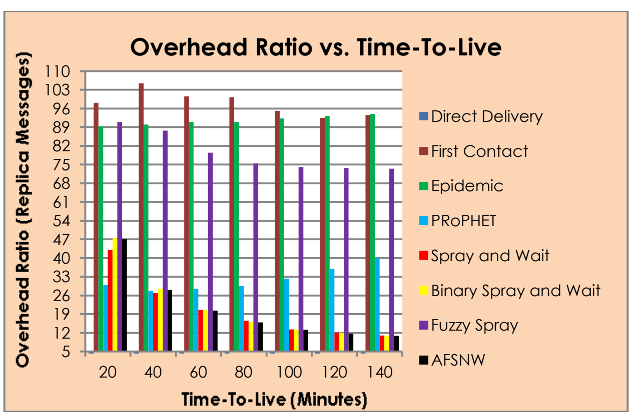


Figure 6. Overhead Ratio vs. Time-To-Live

Table 7. Overhead Ratio vs. Time-To-Live

TTL (Minutes)	Direct Delivery	First Contact	Epidemic	PRoPHET	Spray and Wait	Binary Spray and Wait	Fuzzy Spray	AFSNW
20	0	98.1169	89.2479	29.876	43.0286	47.4211	90.964	46.9737
40	0	105.405	90.0202	27.6797	26.9639	28.4667	87.686	28.1556
60	0	100.5287	90.9819	28.4978	20.5984	20.5435	79.443	20.2971
80	0	100.1955	90.9366	29.5773	16.5503	16.1547	75.401	15.9448
100	0	95.1377	92.3074	32.3077	13.2488	13.2915	74.042	13.1121
120	0	92.5061	93.2861	35.9719	12.0539	11.9839	73.677	11.7711
140	0	93.6	93.9613	40.2134	11.0113	11.0333	73.451	10.8376

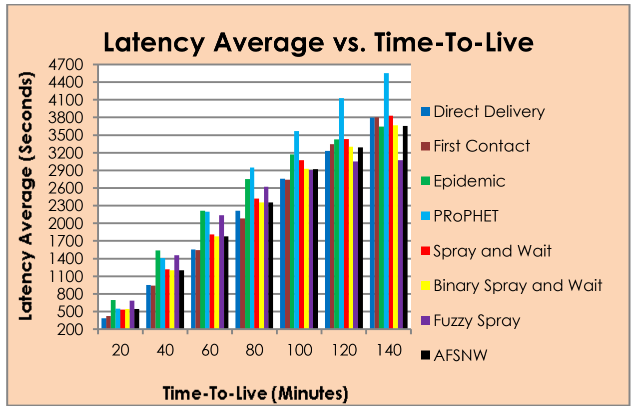


Figure 7. Latency Average vs. Time-To-Live

Table 8. Latency Average vs. Time-To-Live

TTL (Minutes)	Direct Delivery	First Contact	Epidemic	PRoPHET	Spray and Wait	Binary Spray and Wait	Fuzzy Spray	AFSNW
20	386.8506	426.3312	696.1141	546.7281	531.2086	546.3211	685.56	546.321
40	952.3185	939.0264	1536.75	1410.451	1220.113	1199.6444	1459.5	1199.64
60	1556.669	1542.106	2216.179	2195.09	1813.175	1778.3833	2138.4	1778.38
80	2213.883	2081.304	2753.787	2950.731	2420.086	2355.0541	2622.5	2355.05
100	2759.601	2743.387	3171.42	3570.248	3074.538	2925.1193	2905.1	2920.47
120	3232.977	3343.287	3429.232	4127.483	3433.323	3299.3202	3051.6	3291.63
140	3794.46	3802.614	3644.617	4555.535	3831.876	3664.5248	3074.9	3656.11

Figure 5 illustrates that increasing Time To Live (TTL) value contributes to increase the delivery probability. TTL helps limiting number of message copies in network since TTL denotes how long a message exists in the network. Regarding PSN has intermittent connection, hence, higher of TTL value then delivery probability performance is improved. In longer time to live, there are quite high chances that messages can be delivered to destination node. Figure 6 shows overhead ratio can be influenced by the value of time to live. Increasing TTL value contributes to decrease the overhead ratio. As such, it is better for network if it has higher time to live. Figure 7 describes latency average can be influenced by TTL value. Increasing TTL values can increase the latency average. It is due to the increment of TTL value influences messages must wait longer in buffer before the message either is delivered to destination node or dropped when lifetime expired.

4.0 CONCLUSION

The evaluation was done using ONE simulator. Two scenarios were investigated namely, the variation number of nodes and variation of time-to-live (TTL). The performance metrics investigated are delivery probability, overhead ratio and average latency. The experiment shows that Epidemic has the highest delivery probability. Unfortunately, Epidemic has the highest overhead ratio than others since it uses flooding-based. PRoPHET has the lowest delivery ratio due to PRoPHET chooses the appropriate relay nodes before transferring messages. Direct delivery protocol has the lowest overhead ratio (zero overhead ratio) due to the message only sends to the destination node. PRoPHET has the highest latency average among other routing algorithms since this protocol need longer time to decide the appropriate relay node in transferring message toward destination node.

The increasing numbers of nodes make the delivery ratio higher because more nodes in the network contribute higher opportunity message copies to reach destination node. Increasing numbers of nodes contributes higher overhead ratio because more contact opportunity between nodes and more transmission take place. Increasing the number of nodes lowers of average latency since more nodes contributes to be faster in transferring message from source node to destination node.

Higher Time-To-Live (TTL) value increases the delivery probability because it helps limiting number of message copies in network. In addition, increasing TTL value contributes to decrease the overhead ratio. Lastly, increasing TTL values can increase the latency average.

The networks are said to have good performances if they have high delivery probability, less overhead ratio and less average latency. There are some suggestions for future work in this area. Firstly, deploying other movement models such as map based movement, shortest path map based movement, map route movement and external movement in order to compare the network performance among different movement models. This paper uses Random Waypoint movement model. Other research contributions consider other soft computing for the evaluation such as genetic algorithm, neural network and so on since this paper uses Fuzzy logic.

References

[1] G. Wang, H. Lu, and L. Xu, "Nested Spray And Wait Routing algorithm Based on Core Nodes Assisted", *IEE International Conference on Computational Intelligence and Software Engineering, pp. 1-4,* 2009.

[2] C.-M. Huang, K.-c. Lan, and C.-Z. Tsai, "A Survey of Opportunistic Networks", *IEEE 22nd International Conference on Advanced Information Networking and Applications* pp. 1672-1677, 2008.

[3] K. C.-J. Lin, W.-T. Lin, and C.-F. Chou, "Social-Based Content Diffusion in Pocket Switched Networks", *IEEE Transactions on Vehicular Technology, Vol. 60, No. 9,* pp. 4539-4548, 2011.

[4] S. Yang, C. K. Yeo, and F. B. S. Lee, "Cooperative Duty Cycling For Energy-Efficient Contact Discovery in Pocket Switched Networks", *IEEE Transactions on Vehicular Technology, Vol. 62, No. 4,* pp. 1815-1826, 2013.

[5] G. Wang, B. Wang, and Y. Gao, "Dynamic Spray and Wait Routing algorithm with Quality of Node in Delay Tolerant Network", *IEEE International Conference on Communications and Mobile Computing,* pp. 452-456, 2010.

[6] A. Mathurapoj, C. Pornavalai, and G. Chakraborty, "Fuzzy-Spray: Efficient Routing in Delay Tolerant Ad-hoc Network Based on Fuzzy Decision Mechanism", *FUZZ-IEEE 2009, Korea, August 20-22, 2009,* pp. 104-109, 2009.

[7] S. M. A. Iqbal and A. K. Chowdhury, "Adaptation of Spray Phase to Improve the Binary Spray and Wait Routing in Delay Tolerant Networks", *IEEE,* pp. 261-266, 2012.

[8] E. P. C. Jones, L. Li, J. K. Schmidtke, and P. A. S. Ward, "Practical Routing in Delay-Tolerant Networks", *IEEE Transactions on Mobile Computing, Vol. 6, No. 8, August 2007,* pp. 943 - 959, 2007.

[9] V. N. G. J. Soares, J. J. P. C. Rodrigues, J. A. Dias, and J. N. Isento, "Performance Analysis of Routing Protocols for Vehicular Delay-Tolerant Networks", IEEE 20th International Conference on Software, Telecommunications and Computer Networks (SoftCOM), pp. 1-5, 2012.

[10] S. Grasic, E. Davies, A. Lindgren, and A. Doria, "The Evolution of a DTN Routing Protocol – PRoPHETv2", *ACM Workshop on Challenged Networks, pp. 27-30,* 2011.

[11] J. Makhlouta, H. Harkous, F. Hutayt, and H. Artail, "Adaptive Fuzzy Spray and Wait: Efficient Routing for Opportunistic Networks", *IEEE International Conference on Selected Topics in Mobile and Wireless Networking (iCOST),* pp. 64-69, 2011

[12] Q. Ayub, S. Rashid, M. S. M. Zahid, and A. H. Abdullah, "The optimization of Spray and Wait routing Protocol by prioritizing the message forwarding order", *International Journal of Innovation and Applied Studies* pp. . 794-801, 2013.

[13] M. Abbas, N. H. M. Yusof, and N. Fisal, "Performance Evaluation of Binary Spray and Wait OppNet Protocol in the Context of Emergency Scenario", *IEEE Third International Workshop on Pervasive Networks for Emergency Management 2013, San Diego,* pp. 517-522, 2013.

[14] D. Yulianti, S. Mandala, D. Nasien, M. Sunar, A.H. Abdullah and A.S. Ismail, "A Survey of Spray-and-Wait Routing Protocol in Pocket Switched Network", Advanced Science Letters, Vol. 20, No. 10-12, pp. 2162-2165, October 2014.

[15] D. Yulianti, S. Mandala, D. Nasien, Md. A. Ngadi and C. Yahaya, "Performance Comparison of Popular Routing Algorithms in Pocket Switched Networks", IOS Press, Vol. 265, pp. 964-978, 2014.

[16] E. Wang, Y. Yang, J. Wu and W. Liu, " Phone-to-Phone Communication Utilizing WiFi Hotspot in Energy-Constrained Pocket Switched Network", IEEE Transactions on Vehicular Technology, 2016.

[17] J. Huang, X. Cheng, J. Bi and B. Chen, " Wireless Relay Selection in Pocket swicthed Networks Based on Spatial Regularity of Human Mobility", Sensors, Vol. 16, No. 1, pp. 94, 2016.