Performance Analysis of CSI:T Routing in a Delay Tolerant Networks

Hardika Kusuma Putri
Telkom University
Bandung, Indonesia
Dkusuma007@gmail.com

Leanna Vidya Yovita, and Ridha Muldina Negara
Telkom University
Bandung, Indonesia
{leanna, ridhanegara}@telkomuniversity.ac.id

***Abstract*—Delay Tolerant Network (DTN) is a network that allows nodes to move dynamically and doesn't always provide for end-to-end connection. The dynamically of nodes make the movement of the nodes becomes important. The movement model of nodes will record their behavior and this could be utilized to develop a new routing protocol in DTN. One of the DTN routing protocol that utilize it is CSI: T routing. CSI: T routing viewed a node based on their behavioral profile which is represent the mobility preference. Our study is measure the performance of CSI: T in terms of delivery probability, overhead ratio, and average latency by changing the buffer capacity, packet lifetime, and number of nodes. We used Opportunistic Network Environment (ONE) Simulator for the simulate the real-life scenario of a college-routines.**

Keywords—DTN; performance; analysis; routing; CSI: T

I. Introduction

DTN is a network that can be solution for dynamic network conditions with arbitrary topology. DTN is suitable for condition which doesn't always provide end-to-end connection. In DTN message will be sent from source to destination via intermediate nodes that perform the store, carry, and forward mechanism. Those intermediate nodes will store the data in buffer, keep them while mobile, and forward to the other node that belongs to its destination [2]. The characteristics of nodes to move dynamically make the movement of the node becomes important. A movement model will record the behavior of the nodes in a real scenario which is required to develop a new routing protocol in DTN [8]. A routing protocol implement a routing algorithm which is the mechanism of how to determine the best route to send messages. In DTN routing becomes interesting and challenging due to the DTN network connections between nodes are not always available causing the transmission path cannot be ascertained when starting the data transmission.

Recent years there has been discovered and developed a variety of routing protocol for data transmission. The routing related to how messages are forwarding in delivery process. Each routing protocol utilizing some information from nodes to get the best opportunities in forwarding the message to the destination. As has been mentioned that the movement model of the node associated with their behavior and significantly impact wireless link characteristics and network performances, while at the same time, network performances can potentially affect the node activity and behavior. Those were used to develop a new routing algorithm named CSI:T (CSI:Target mode) [8].

Our work is to analyze how the performances of this routing if this is implemented in the condition as section III. We observe the effect of changing the number of nodes accompanied by change the value of TTL and buffer capacity by using working day movement and shortest path map based movement for node movement that has not been studied in [8]. This paper is organized as follows. In II section, we review the DTN routing protocols. The simulation setup is described in section III. Next, we discuss the simulation results. And finally, in section V are the conclusion.

II. DTN Routing protocols

A. Routing in Delay Tolerant Network

Routing is one of the most important things in message transmission. Routing is a mechanism to determine the best path in deliver a message to its destination. In DTN we need a routing algorithm that is different from conventional network because DTN has the characteristics of long/variable delay as long as intermittent connectivity, where there may not be a continuous path between different nodes [2]. In conventional network the transmission path is definitely available [2] so the conventional network only considers where is the best path, while in DTN also considering how to find a node that relates to the destination node so the message can be delivered to the destination. Due to the characteristic of DTN nodes in DTN have the ability to carry the packet and do the store-carry-forward paradigm. Each node can carry a message keep it in buffer while mobile and exchange to others node.

There are several classifications of routing protocol in DTN based on forwarding, flooding, knowledge, and probability [3]. In forwarding based node will carries a message until it encounters the intended receiver. Flooding based is simply spread the message to nodes that belongs to connection range. Knowledge based routing use some information from past encounters history to do the message forwarding decision. While probability based use information of past encounter to get the delivery probability of other nodes.

B. CSI:T routing

CSI: T (Target) [8] is a DTN routing protocol that develop based on user behavior in real life. This behavior considers the mobility preference. The mobility preference represents how

978-1-5386-0549-3/17/$31.00 ©2017 IEEE

much time spent by nodes at a given location. The value of mobility preference of nodes called behavioral profile. CSI: T selecting the relay node based on how their behavioral profile similarity. In CSI: T we called Target Profile (TP) to indicate the intended receiver. Target Profile has to be specified same as behavioral profile (i.e., the value of target profile also represent the mobility preference).

- Forwarding Decision [8]

In the CSI: T, the sender specifies the target profile (TP) and threshold similarity between BP to TP. Node decides to send the message to the other node that has the behavioral profile similarity closer to target profile. CSI: T use two phase in message forwarding: gradient ascend phase and group spread phase. To separate the using of these phases there is a threshold value which has been specified before. For example, given a user A. user A has a behavioral profile called BP(A). If Sim(BP(A), TP) > th_{sim}, BP(A) is more similar to TP than specified threshold then does the group spread phase. We also say that user A is belongs to intended receiver. If Sim(BP(A), TP) < th_{sim} we say that user A is not belongs to intended receiver and it works in gradient ascend phase. In gradient ascend phase there is only one copy of the message. The message holder asks the behavioral profile of every encountered node, if the encountered node has the behavioral profile similarity closer to TP so the holder will forward the message to that node. In group spread phase there are multiple copies of message because after a node reach the similarity to TP larger than th_{sim} and then encountered with other intended receivers then they continue to work in group spread phase.

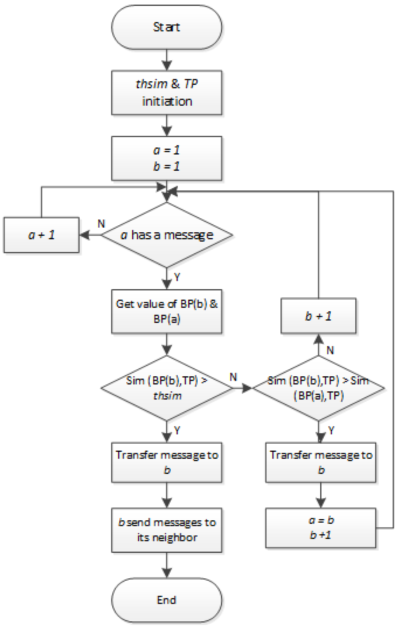

Fig. 1. Flowchart CSI:T forwarding scheme

III. Performance Metrics and Simulation Setup

A. Simulation Setup

In this study, we use ONE Simulator [5] to simulate the CSI: T routing. We conducted the simulation using the real-life scenario from a college routines in FTE, FRI, FIF faculty of Telkom University in 4 days with different number of nodes are 75, 180, 335 based on real data from schedule of every class that using the room of buildings in each faculty (Table I) by assuming that in each class has 5 student using device that support DTN, the total number of nodes shown in Table II. Those can represent the node density from three faculties. There are three classification of nodes divided by faculty and the location visiting of the nodes when they are in the campus area because each faculty has their own building, shown in Table I. Nodes act as a college student that move with the average speed of people walking is 0,8 – 1,4 m/s. We change the value of TTL from 2-10 hours, buffer capacity 2-10 MB, and packet size 500-1000k to analyze the impact of those parameters to the CSI: T routing performances. We set the value of threshold similarity 0.6. For the interface, we use 6 MB/s transmission speed with 10 m range. The performance that we analyzed is delivery ratio, overhead ratio, average latency, and buffer time average.

We use two mobility movements to specify the movement of the nodes those are Working Day Movement and Shortest Path Map Based Movement with POI (Point of Interest). Working day Movement combine several movements according to the daily routine for example went to the office in the morning, doing activities such as break time during the day, and returned home in the afternoon [6]. In addition to supporting the simulation to better fit the real conditions then we use *ShortestPathMapBased* with POI. In *ShortestPathMapBased* nodes will be looking for the shortest way based on map route to get the coordinates of a point of interest that has been determined then stay for a predetermined time and move to the other coordinates of POI. POIs are set based on the buildings used by each faculty, meeting points, and homes same as used by setting of Working Day Movement. The buildings also divide the movement range of nodes from each faculty. In Working Day Movement also provide the decision of how nodes will go to the work by vehicles or walk so we add 20 nodes act as vehicles with the speed 7 - 10 m/s, that amount has been included to number of nodes mentioned before. So, in this simulation nodes in each faculty will move to the coordinates of campus at working hours (8 hours) and stay for 1-2 hours in each coordinate. After working hours, nodes will go to the home coordinates for the rest of the day.

TABLE I. BUILDINGS USED BY EACH FACULTY

Faculty	Buildings
FTE	A 2nd floor, GKU 2nd floor, P, O, N 1st floor
FRI	A 2nd floor, GKU 2nd floor, B, C, P 1st floor
FIF	A 2nd floor, GKU 2nd floor, E, F, P 1st floor

Table 2 shows the total number of nodes based on the schedule of each class with the use of classrooms in each faculty in Table 1 with the assumption that each class there are 5 nodes that carry the DTN device.

TABLE II. TOTAL NUMBER OF NODES

Shift	Mon	Tue	Wed	Thu	Fri	Sat
06.30-10.30	220	285	335	250	170	190
08.30-12.30	180	225	250	180	75	130
10.30-14.30	195	220	275	190	120	95
12.30-16.30	245	250	290	210	225	95
14.30-18.30	130	100	130	95	120	30

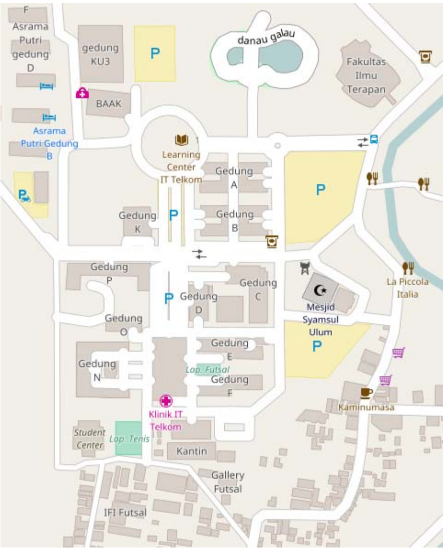

Fig. 2. School of Engineering Telkom University map

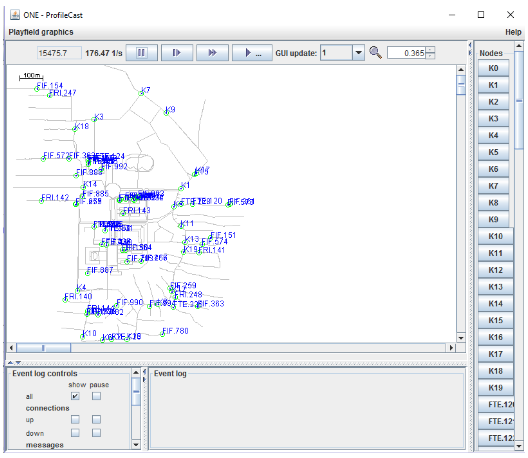

Fig. 3. Simulation in ONE Simulator

TABLE III. SIMULATION PARAMETERS AND VALUES

Parameter	Pedestrian	Vehicles
Simulator	ONE Simulator	
Location	School of Engineering Telkom University	
Simulation time	345600 sec	
Threshold similarity	0.6	
Node speed	0,8 – 1,4 m/s	7 – 10 m/s
Number of nodes	95, 200, 355	
Movement Model	Working Day Movement and Shortest Path Map Based with POI	
Transmission speed	6 MB/s	
Transmission range	10 meter	
Buffer capacity	2, 4, 6, 8, 10 MB	
Packet TTL	2, 4, 6, 8, 10 hours	
Packet size	512 KB	
Interval packet generation time	25-35 s/packet	

B. Performance Metrics

- Delivery Ratio is the ratio between the number of delivered message to the created message.
- Overhead Ratio is the number of replicas message per delivered message.
- Average Latency is the average time between message created and delivered.
- Buffer time Average is the average time a message in the buffer.

IV. SIMULATION RESULTS

A. Impact of Varying the Buffer Capacity

TABLE IV. IMPACT OF VARYING BUFFER CAPACITY TO DELIVERY RATIO

Number of Nodes	Delivery Ratio				
	Buffer Capacity (MB)				
	2	4	6	8	10
95	0.2965	0.5277	0.5871	0.6027	0.6189
200	0.3107	0.5214	0.5302	0.5345	0.5723
355	0.3787	0.5184	0.5296	0.5345	0.5437

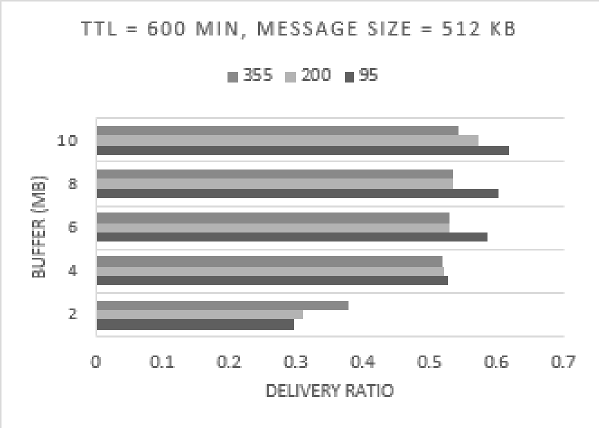

Fig. 4. Impact of varying buffer capacity to delivery ratio

From Fig. 4, it can be observed that increasing the buffer capacity increases delivery ratio in generally because with a certain packet size, the larger buffer capacity the more message can be stored in buffer so, the opportunities of message can be delivered to their destination is higher. From these results indicate that the number of nodes is not linear to the value of the delivery ratio because in this scenario the node will move to the building which are different for each faculty so this will affect the location distribution of the nodes. Meanwhile, the CSI: T routing utilize information in the form of mobility preference in message forwarding process and affect the value of delivery ratio.

TABLE V. IMPACT OF VARYING BUFFER CAPACITY TO OVERHEAD RATIO

Number of Nodes	Overhead Ratio				
	Buffer Capacity (MB)				
	2	4	6	8	10
95	0.8026	0.5744	0.5377	0.5082	0.4850
200	1.0908	0.7740	0.6905	0.6855	0.6452
355	1.1335	0.8253	0.8194	0.8167	0.7865

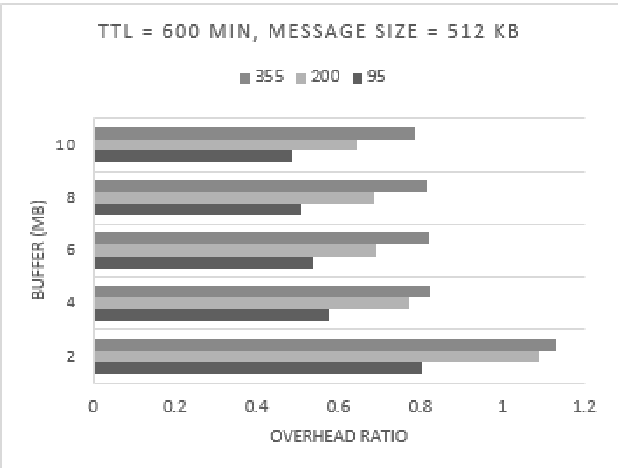

Fig. 5. Impact of varying buffer capacity to overhead ratio

In Fig. 5 shows that increasing buffer capacity can potentially decrease the overhead ratio because the larger buffer capacity the more messages that can be stored in the buffer and the probability messages are sent to the destination is larger it means the ratio between the appropriate and inappropriate message in overhead ratio equation is larger. That is why the value of overhead ratio is decrease. Impact of Varying Buffer Capacity to average latency

Number of Nodes	Average Latency (second)				
	Buffer Capacity (MB)				
	2	4	6	8	10
95	4808.7	9915.2	12865.8	14903.3	15694.5
200	8951.4	15049.2	15555.6	15777.8	15936.7
355	11020.5	15558.7	15975.7	16076.9	16091.8

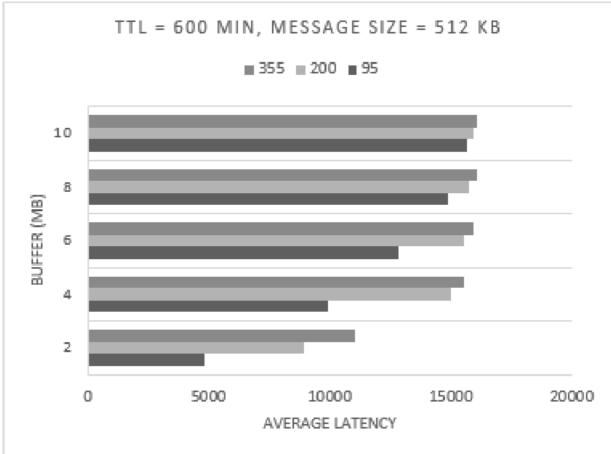

Fig. 6. Impact of varying buffer capacity to average latency

From Fig. 6 shows the increasing buffer capacity also increase the value of average latency. The larger buffer capacity the more message can be stored so the process time in buffer also increase because a node needs more time to select the message that will be forwarded to its intended receiver. This has correlation with Fig. 7.

TABLE VI. IMPACT OF VARYING BUFFER CAPACITY TO AVERAGE BUFFERTIME

Number of Nodes	Average Buffer Time				
	Buffer Capacity (MB)				
	2	4	6	8	10
95	4323.4	7072.9	8894.7	10468.5	11437.5
200	7435.1	11203.2	13067.2	15245.7	15650.5
355	10191.9	13515.7	14709.8	15173.2	15701.2

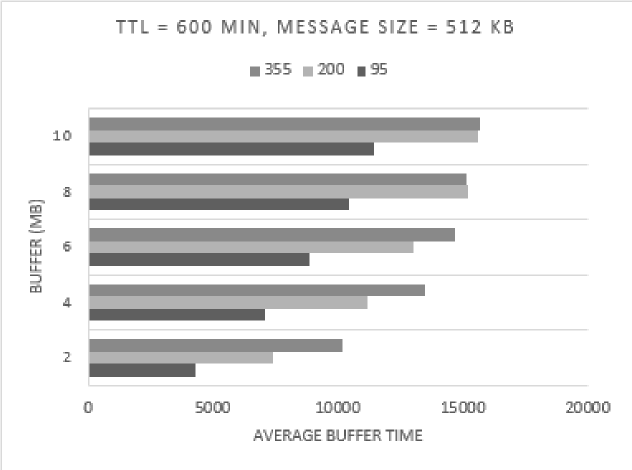

Fig. 7. Impact of varying buffer capacity to buffertime average

B. Impact of Varying Packet Lifetime

TABLE VII. IMPACT OF VARYING TTL TO DELIVERY RATIO

Number of nodes	Delivery Ratio				
	TTL (minutes)				
	120	240	360	480	600
95	0.25982	0.343	0.41834	0.50936	0.5924
200	0.22718	0.32558	0.39404	0.44584	0.5048
355	0.21606	0.3516	0.41968	0.48976	0.5252

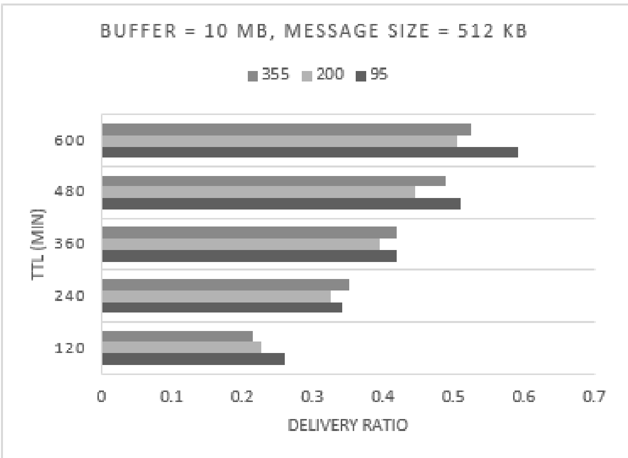

Fig. 8. Impact of varying TTL to delivery ratio

In this experiments, we can see that increasing the packet lifetime (TTL) will increase the delivery ratio due to the length of the message TTL then the possibility to drop the message in the network is smaller so the opportunities of corresponding message sent to the appropriate recipient can be even greater. But this only can be the advantage for guided routing protocol and will bad in blind routing due to full flooding that can cause overload in buffer.

TABLE VIII. IMPACT OF VARYING TTL TO OVERHEAD RATIO

Number of nodes	Overhead Ratio				
	TTL (minutes)				
	120	240	360	480	600
95	1.64926	1.36152	1.06238	0.77044	0.58134
200	1.91626	1.44154	1.21040	1.03404	0.82484
355	2.42796	1.48048	1.28548	0.98376	0.8851

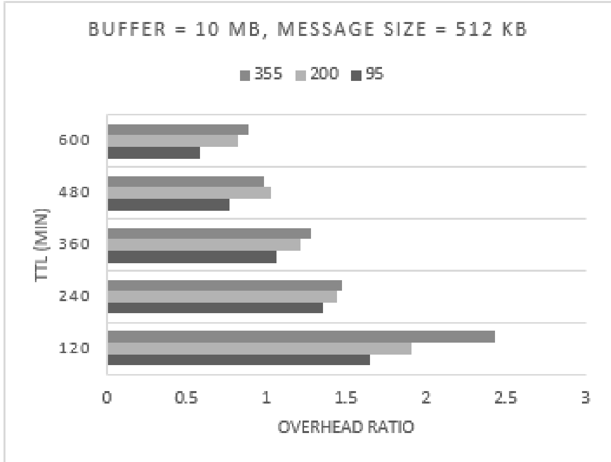

Fig. 9. Impact of varying TTL to overhead ratio

From Fig. 9 presents the impact of increasing TTL to the value of overhead ratio. Based on graph, by the increasing TTL the overhead ratio for all number of node will decrease. The smaller overhead ratio means the less energy consumption during transmission dan reception message. The small value of overhead ratio due to the characteristic of CSI:T routing. In CSI:T the message is not always sent in multiple but also single copies and supported by CSI:T routing capabilities to select the appropriate intended receiver.

TABLE IX. IMPACT OF VARYING TTL TO AVERAGE LATENCY

Number of nodes	Average Latency				
	TTL (minutes)				
	120	240	360	480	600
95	2712.2	5482.1	8765.5	12357.5	15261.7
200	3248.0	6804.1	9890.6	12387.6	15369.6
355	3482.1	7198.9	10090.7	12826.8	15616.6

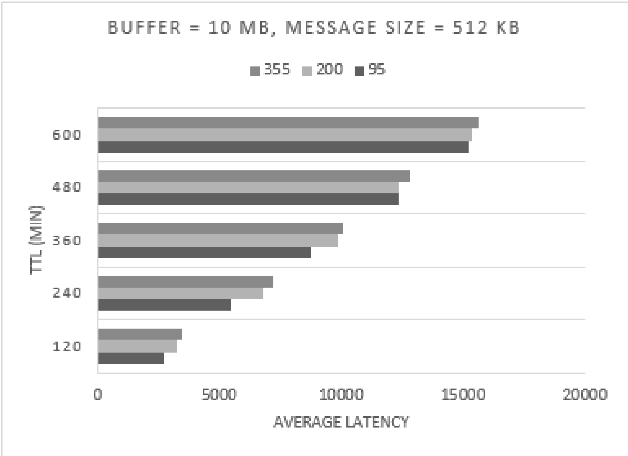

Fig. 10. Impact of varying TTL to average latency

In Fig. 10 we can observed that the larger value of TTL decrease the variety of the messages in the network. That caused the process time of a message to find the intended destination is longer so the time required by a message to transmit from the sender to the destination is much longer. The longer average latency usually accompanied by the high value of buffertime average. Because when a message can be delivered to its destination for long time it still be in the buffer until their lifetime end. We can see this in Fig. 11.

TABLE X. IMPACT OF VARYING TTL TO AVERAGE BUFFERTIME

Number of nodes	Average Buffertime				
	TTL (minutes)				
	120	240	360	480	600
95	6224.5	9274.5	11604.8	11947.9	12187.5
200	6224.8	9235.8	11923.9	14020.2	15096.4
355	5385.5	8438.7	11129.5	13879.6	15872.6

Fig. 11. Impact of varying TTL to buffertime average

V. CONCLUSION

In this study, we analyzed the impact of changing buffer capacity and packet lifetime to the delivery ratio, overhead ratio, average latency, and buffer time average of CSI: T routing protocol in DTN. From the simulation results we get some conclusions as follows:

- Increasing buffer capacity will increase the delivery ratio in generally accompanied by the increasing of overhead ratio. It is because with a certain value of message size, the larger buffer capacity the more space for the message to be stored. While not all of them are the intended message for the receivers.
- Buffer time average and average latency show the increasing value as the buffer capacity increase. It is related with the increasing value of overhead ratio as mentioned before. It means there are unintended messages that stored in buffer. So, it will take more time to process forwarding messages.
- Increasing the TTL value is the best way to get the good results in delivery ratio and overhead ratio. Increasing TTL value also increase the delivery ratio but decrease the overhead ratio. In performance measurement the best results are when the delivery ratio is high with the smallest delivery cost (overhead). But increasing TTL can't be a solution to a problem in DTN i.e. very long delay.

REFERENCES

[1] M. S. Hossen, M. T. Ahmed and M. S. Rahim, "Effects of Buffer Size and Mobility Models on the Optimization of Number of Message Copies for Multi-Copy Routing Protocols in Scalable DelayTolerant Networks," *International Conference on Innovations in Science, Engineering and Technology (ICISET)* , 2016.

[2] Y. Mawad and S. Fischer, "Infrastructure-based Delay Tolerant Network Communication," in *ICOIN*, 2016.

[3] V. Juyal, N. Pandey and R. Saggar, "Impact of Varying Buffer Space for Routing Protocols in Delay Tolerant Networks," in *International Conference on Communication and Signal Processing*, India, 2016.

[4] Z. H. Kurniawan, L. V. Yovita and T. A. Wibowo, "Analisis Performansi Routing dLife pada Delay Tolerant Network," 2016.

[5] A. Keranen, J. Ott and T. Karkkainen, "The ONE Simulator for DTN Protocol Evaluation," in *Proc. SIMUTools '09*, 2009.

[6] F. Ekman, A. Keranen, J. Karvo and J. Ott, "Working day movement model," in *ACM SIGMOBILE*, 2008.

[7] T. Abdelkader, K. Naik, A. Nayak, N. Goel and V. Srivastava, "A Performance Comparasion of Delay-Tolerant Network Routing Protocols," in *IEEE*, 2016.

[8] W.-j. Hsu, D. Dutta and A. Helmy, "CSI: A Paradigm for Behavior-oriented Delivery Services in Mobile Human Networks," *ACM Transactions On Networking,* 2008.