Performance Evaluation of Flooding Based Routing Protocol for Delay Tolerant Networks

Shaurya Gupta, Ramesh Chandra Poonia, Xiao-Zhi Gao

Abstract*: *Delay Tolerant Network is one of the primarily considerable development of Mobile Ad Hoc Networks (MANET).These are a unique group of association of networks which supports infrastructure less MANET and do not require complete path in between source and destination nodes for the purpose of communication. This kind of networks allow sending of numerous copies of a single message which enhances the delivery ratio but significantly it decreases the delay of message transmission, though transmission of numerous copies of the identical message increases the message over head. This paper proposes DTN routing protocol i.e. Epidemic and Spray and Wait on the basis of number of messages delivered when compared to network overhead ratio.

Index Terms*: *VANET, DTN, Routing Protocol, Bundle Protocol, ONE-Simulator.

I. INTRODUCTION

Delay-Tolerant Network (DTN) [1] can be described as a collection of "interrelated networks" which ropes extensive wait, unstable affinity by means of "Store & Carry Forward" message mechanism. In this process the nodes are compliant with data packets originating from the source nodes in their buffers and distribute replica packets to adjacent nodes whenever they get nearer to broadcast range. DTN routing protocols are classified into Flooding based and Forwarding based [2]. Epidemic, Prophet comes under Flooding based category. Flooding mechanism creates more number of packets in a network which causes congestion in a network along with consumption of network resources. Keeping in mind the network resources, it's crucial to recognize what messages are to be delivered and what messages will be dropped. Here, nodes imitate their communication and broadcast them all to their adjoining nodes which are not having a replica or copy of that particular message. Each and every adjoining node will swap their message with other node they meet and acknowledge the only messages not possessed by those nodes. DTN primary purpose is to overcome flaws of varied system like network connection issues. These networks don't have accurate affinity due to enormous isolation, little density of node and active network topology. Delay Tolerant Network applications are very useful in vehicular, space and underwater communication attributed by the delay, liberal and continuous data passage. The correspondence in DTN is package specific which follows a method where a node buffer is storing data packet for a specific instant of time and forwards it whenever a connection is acknowledged.

Revised Manuscript Received on April 05, 2019.

Shaurya Gupta, AIIT, Amity University Rajasthan, Jaipur, India
Ramesh Chandra Poonia, AIIT, Amity University Rajasthan, Jaipur, India
Xiao-Zhi Gao, School of Computing, University of Eastern Finland, Finland.

II. RELATED WORK

In heterogeneous networks, priority is always on establishing best associations between start and end network nodes and these networks facilitate anywhere-anytime correspondence amongst the nodes [3]. DTN emerged to prevail over the drawback of varied networks like network affinity issues. Though these networks have high prospect of packet deliverance but there is a lot of wastage of resources which results in degradation of system [4] [5]. Epidemic routing strategy shows improved performance when compared with other occasionally associated networks like 2-hop and multi hop network [6]. To lessen the routing overhead, resources of the network should be consumed efficiently. Here, the source node is responsible for generating several replicas of the similar message to a set of nodes. These set of nodes saves the messages in their buffer till the association terminates [7]. As the nodes meet up they swap over the list of messages with each other so that both nodes have similar list of messages. Though this advance leads to faster delivery of messages as it maximizes the message deliverance rate and minimizes the message latency, number of resources used in message deliverance. Epidemic shows improved presentation in terms of other irregularly connected networks when 2 hop and multi hop networks are considered [8]. Multi hops are the networks in which a node takes two or more hops to get to the destination. To reduce the overhead in epidemic steering, the network resources should be used efficiently via priority rule [9]. The message with the top precedence hop count will be having first deliverance [10]. The performance of DTN is improved using forwarding queue plan which reduces the deliverance time of messages. DTN with sparse nodes are called opportunistic networks where their performance can be measured from time to time as they follow a particular pattern [11].

III. DELAY TOLERANT NETWORK

Delay Tolerant Network is a wireless asymmetrical, broken set of links admitting the extended delay in broadcasting the data. It utilizes bundle process and chains delay binding of data in varied situations like armed and remote section correspondence. DTN aids in unbalanced affinity and promises the delivery of ideal data, which resides in dispatcher's buffer area rather than being misplaced [12]. Bundle protocol permits DTN to cover numerous diverse networks and permits the differentiation of DTN protocols on the basis of naming and addressing pattern.

Multiple replicas of data are created before being forwarded. The option of the selection of the premium node to which data will be forwarded exclusively depends on type of routing strategy being used. DTN is a move ahead to networking which arranges the functional concerns in varied system which lacks invariable network affinity, though they maintain connectivity in between nodes to guarantee the effective and efficient delivery of packets from source node to destination node. The nodes accountable for transporting the data packets are called relay nodes. Nodes are transmitting duplicate packets to other nodes as they get in touch with other nodes, while the duplication of messages causes issues like congestion of network or resource wastage. Therefore, DTN uses flooding and forwarding strategy for transmission of packets in a network. Flooding uses duplication of messages whereas forwarding follows the best selection of path for transmission based on information about network. Delay Tolerant Network is a wireless asymmetrical or irregular set of associations which admits elongated delays in data relay transmission. DTN aids in irregular connectivity and promises ideal data deliverance, as data is stored in the buffer of correspondent or receiver node rather than being misplaced. Data is replicated to other nodes prior being forwarded. The option of selecting the best transmit node exclusively relies on kind of method being used. DTN is a progress to networking which arranges the concerns in delay of data deliverance in a network which is lacking network affinity constantly. In a DTN, nodes do not have end to end even association i.e. the connection gets disrupted many a times. Therefore, the topology of these networks changes frequently. Along with, the nodes have very limited energy which is being used in movement in a network and appropriate path detection and selection.

IV. EPIDEMIC ROUTING PROTOCOL

Epidemic routing protocol comes under the category of flooding based scheme [22]-[24]. In this flooding method, pair wise exchange of message amongst mobile nodes ensure deliverance of messages, which increases the messages deliverance rate and reduces message latency as well as number of resources consumed in deliverance of messages [13]. It focuses on forwarding of messages which depends on the least possibility of network topology and connectivity. Every node has a buffer which is being used for storage of messages received from other hosts nodes in a network [23]. To attain the capable administration of communication, the messages are listed in a hash table. Every node has a collection of bits which is called the summary vector which depicts the number of entries which are saved in a hash table. Whenever two nodes are communicating, the node with the lowest id initiates an anti entropy gathering with the node with the highest id through which communication is forwarded. Every node has a record of nodes with which connection has taken place in recent times so as to shun unnecessary sessions [14]. As this process is completed, it produces a huge quantity of redundancy in a network which requires good bandwidth and buffer capacity and at the same time the network should be strong enough to handle network congestion failure as the network overhead is extremely high in this case. Though, epidemic routing promises broadcasting of data in a network immaterial of delivery delay. The pseudo-code for the binary Epidemic is depicted in Algorithm 1 below.

Algorithm 1: **Pseudo code for Epidemic Routing Protocol**
Procedure Name: On Contact_Epidemic

```
Procedure Name: On Contact_Epidemic

Step 1: Input: node a, node b, integer ContactDuration
Step 2: Drop_Expired_Packets (a, b) /* Packets with expired lifetime at both ends to be dropped */
Step 3: ExchangeSummary_Vector (a, b)
Step 4: if Contact_Duration > 0 then
Step 5: pkt=Get_Packet (a)
Step 6: if pkt then
Step 7: if NotReceived_Before (pkt, b) then
Step 8: if Is_Destination (pkt, b) then
Step 9: Send_Packet (pkt, a)
Step 10: Consume_Packet (pkt, b)
Step 11: else
Step 12: Send_Packet (pkt, a)
Step 13: Store_Packet (pkt, b)
Step 14: end if
Step 15: Contact_Duration=Contact_Duration-size (pkt)
Step 16: end if
Step 17: end if
Step 18: end if
```

V. SPRAY AND WAIT ROUTING PROTOCOL

DTNs generally engross devices which are energy-sensitive where saving of energy is one of the prime purposes. Energy is mostly consumed during the communication procedure which involves transmission and reception of data by nodes in a network. To conserve energy of nodes, the number of transmissions and receptions should be trimmed down. Therefore, the authors in [24] projected the SnW routing protocol. The thought behind SnW is to set the amount of replica of packets in the network. A copy of node packet which is being transferred from one node to other is linked with the amount of replicas which are allowed for the second node to distribute further. This number decreases by the amount of transfer for this packet at every node. When this permissible magnitude of copies reaches one, the carrying node will stop generating further more copies of the packet and keeps its single copy till it reaches the destination or the packet is dropped because of buffer overflow or life span termination. A binary edition of SnW is proposed by authors in [22], where every node is permitted to utilize half of copies allowed for the packet, whereas the rest half is left for the receiving node.

The pseudo-code for the binary SnW is shown in Algorithm 2 below.

Algorithm 2: Pseudo code for Spray and Wait Routing Protocol
Procedure Name: On Contact_SnW

```
Step 1: Input node a, node b, integer Contact_Duration
Step 2: Drop_Expired_Packets (a, b) /* Packets with expired lifetime at both ends to be dropped */
Step 3: ExchangeSummary_Vector (a, b)
Step 4: if Contact_Duration > 0 then
Step 5: pkt=Get_Packet (a)
Step 6: if pkt then
Step 7: if NotReceived_Before (pkt, b) then
Step 8: if Is_Destination (pkt, b) then
Step 9: Send_Packet (pkt, a)
Step 10: Consume_Packet (pkt, b)
Step 11: else
Step 12: NrOf_Copies=GetNrOfCopies (pkt, a)
Step 13: if NrOf_Copies > 1 then
Step 14: Send_Packet (pkt, b)
Step 15: Store_Packet (pkt, b)
Step 16: GetNrOf_Copies (pkt, a, NrOfCopies/2)
Step 17: GetNrOf_Copies (pkt, b, NrOfCopies/2)
Step 18: endif
Step 19: endif
Step 20: ContactDuration=ContactDuration-size (pkt)
Step 21: endif
Step 22: endif
Step 24: endif
```

The editions of SnW protocol i.e. regular and binary have better performance than full flooding protocol i.e. EPIDEMIC in conditions of average packet delay and energy consumption. Though, SnW still undergo from the feature of unsighted choice of next-hop nodes which demean the packet delivery ratio. It comprises of two stages i.e. spray and wait stage. As and when a new correspondence is initiated in the network, a number N is linked to that correspondence which depicts the number of message copies that can be transmitted in a system. When spray phase is dynamic, N messages are transported to relay nodes. As relay node receives a replica of message it gets into a wait phase where it is responsible for only holding that message till an appropriate target is met.

VI. SIMULATION SYSTEM DESIGN & RESULTS

As the simulation of Epidemic and Spray and Wait protocols is done in batch mode and using ONE simulator also [15], [16]. We compared the Epidemic and Spray and Wait protocols in terms of network overhead ratio and number of packets delivered. ONE focuses on simulating routing protocols and mobility modeling. It also combines DTN routing and visualization as a single package which is quiet extensible and provides a blend of reporting and analyzing components [17]. Open JUMP [18] is a GIS program which is Java based and is used for editing and converting the maps in our experiments. Node progress is implemented using movement models. Connectivity amongst the nodes depends on their position, message range and the bit-rate. The simulation parameters are described below in Table I.

Table I. Simulation Parameters

Parameters	Values
Simulation Scenario	Helsinki Downtown
Simulation Time	12 Hours
Number of Nodes	100
Node Movement	Shortest Path Based Map Model
Transmission range	10m
Message size	250kb
Transmission speed	2Mbps

Apart from simulation parameters there are performance metrics on which the performance of a network is evaluated. The following metrics were used for performance comparison:

Network Overhead: It is defined as the quantity of messages copied in a network compared to the number of messages which are in fact delivered to the destination.

$$Overhead = \frac{No.\ of\ relayed\ message - No.\ of\ delivered\ message}{No.\ of\ delivered\ message}$$

Packets Delivered: It is defined as the total number of message delivered per unit time.

$$Packets\ Delivered = \frac{No.\ of\ message\ delivered}{Unit\ of\ Time}$$

Here, in this simulation an urban scenario is considered. The real data map of Helsinki city in Finland has been imported from Open Street Map [19].When the simulation is run for twelve hours, nodes travel on mapped paths with speed in the range of 0.5~13 m/s . Every node has 1MB buffer.

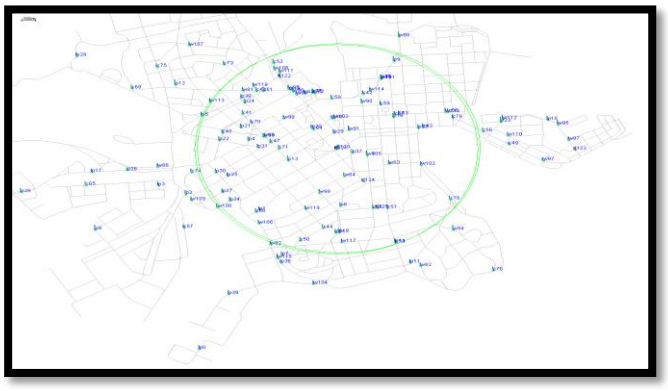

Fig. 1 Nodes position in Epidemic Routing in playfield graphics

All the nodes are connected by Wi-Fi bond with a propagation data rate of 2mbps. Here, Shortest Map Based Movement Model is utilized in this simulation. Here, movement of nodes is random but it always follows a path which is described by map data.

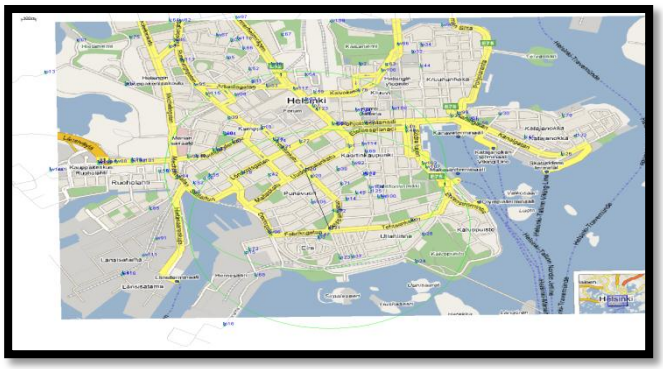

Fig. 2 Nodes position in Epidemic Routing in underlay image

Here, epidemic routing is considered. The maps in Fig. 1, 2 are simulation observed of epidemic routing in playfield graphics type and underlying image type correspondingly. The primary illustration form is an alternative choice in ONE simulator to exhibit map imagery in diverse type, while the images can be introduced from Open Street Map also [19].

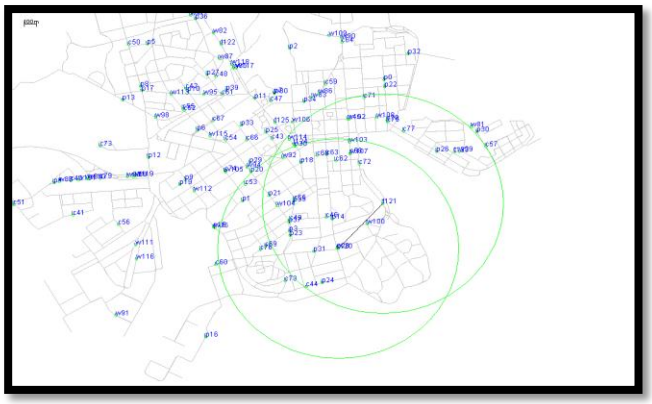

Fig. 3: Nodes position in Spray and Wait Routing in playfield graphics

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

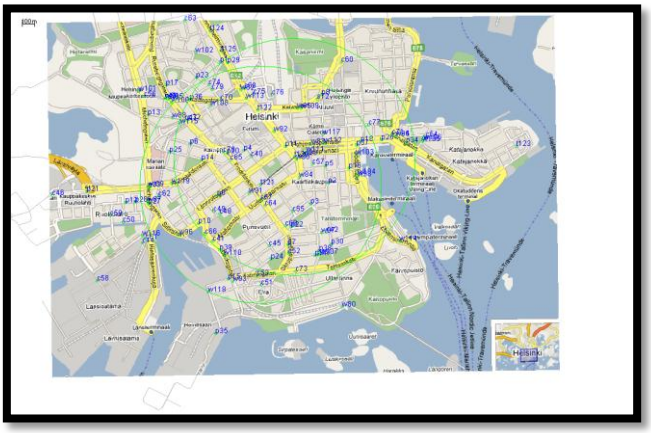

Fig. 4: Nodes position in Spray and Wait Routing in underlay image

Here, Spray and Wait routing is taken in thought. The above maps are situation cases taken of Spray and Wait routing in playfield graphics form and underlying image form correspondingly. The underlying image form is an option in ONE simulator to exhibit map images in diverse type, while the images can be imported from Open Street Map also [19].

VII. SIMULATION OUTCOME

When the simulation is done in observance of parameters, the subsequent consequences are obtained. The simulation can be considered for various movement models and for diverse routing protocols by varying certain parameters under different scenarios [12]. When Epidemic, Spray and Wait routing protocol are being simulated using batch mode in command mode environment using the following commands:

- *one.bat -2 epidemic_settings.txt*
- *one.bat -2 snw_settings.txt*

Here 2, specifies the no. of times per simulation would be running. The trace file of the simulation is stored in the folder "Report" in the ONE simulator setup folder. The snapshot has been shown below, which shows the trace files of Epidemic, and Spray and Wait protocol.

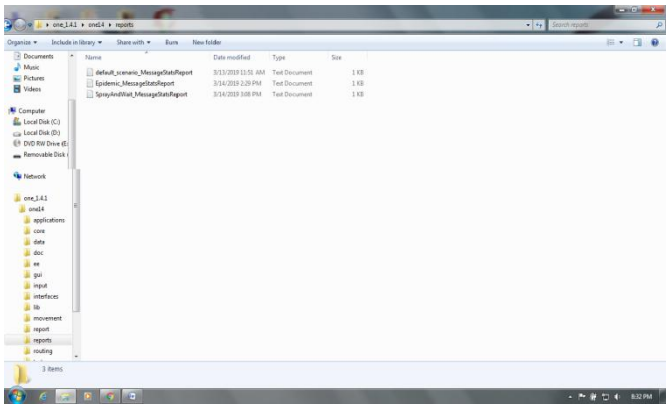

Fig.5 Location of Trace File while Simulation

The trace file of Epidemic and Spray and Wait routing protocols are having the following parameters of evaluation.

Message parameters for Epidemic Routing Protocol

```
sim_time: 43200.1000
created: 1461
started: 58268
relayed: 31006
aborted: 27261
dropped: 30948
removed: 0
delivered: 343
delivery_prob: 0.2348
response_prob: 0.0000
overhead_ratio: 89.3965
latency_avg: 4775.2942
latency_med: 3352.6000
hopcount_avg: 4.5190
hopcount_med: 4
buffertime_avg: 1407.0311
buffertime_med: 889.8000
rtt_avg: NaN
rtt_med: NaN
```

Message parameters for Spray and Wait Protocol

```
sim_time: 43200.1000
created: 1461
started: 31520
relayed: 12266
aborted: 19254
dropped: 12106
removed: 0
delivered: 664
delivery_prob: 0.4545
response_prob: 0.0000
overhead_ratio: 17.4729
latency_avg: 2937.3557
latency_med: 2127.7000
hopcount_avg: 2.8072
hopcount_med: 3
buffertime_avg: 2744.3308
buffertime_med: 2115.3000
rtt_avg: NaN
rtt_med: NaN
```

Below are the results of the trace files discussed above and are compared through graphs.

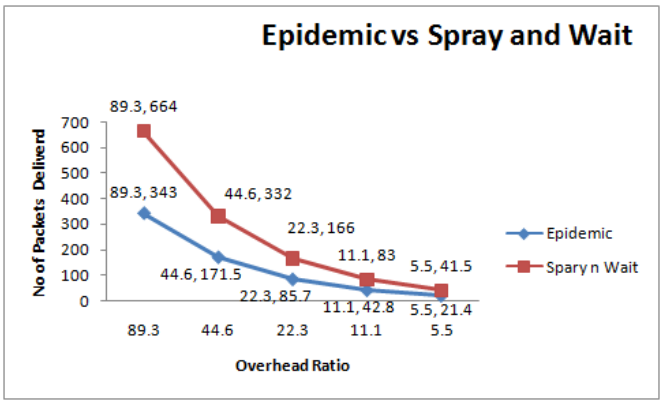

Fig.6 Network Overhead Ratio vs. No. of Packets Delivered

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Fig. 6 clearly shows the network overhead ratio as compared to the number of packets delivered in Epidemic and Spray and Wait routing protocol. Here, we can clearly see that network overhead ratio is quite high in Epidemic and number of packets delivered is quite less when compared to Spray and Wait routing protocol. In Epidemic routing protocol the number of packets delivered is 343 while the network overhead ratio is 89.3% whereas in case of Spray and Wait protocol the number of packets delivered is 664 while the network overhead ratio is 17.47. Therefore we can clearly conclude that Spay and Wait routing protocol is far better than Epidemic routing protocol.

VIII. CONCLUSION AND FUTURE WORK

From the simulations, it can be accomplished that as and when the overhead ratio of packets being delivered in Spray and Wait protocol is quite less as compared to that of Epidemic and when considering the case of number of packets being delivered Spray and Wait protocol again has an edge over Epidemic protocol. These simulations were carried for Shortest Path Based Map Model. Simulations can be carried out keeping a parameter fixed and testing the behavior of other parameters under certain network movement model scenario. The network scenarios can be Map Based Movement Model or Working Day Movement Model. The results of parameters like packets delivered and network overhead ratio would be different in case of different network movement model scenarios. Upcoming work may be done in optimizing these protocols using cross approach so as to attain optimized consequences in circumstances of buffer management, average latency and TTL i.e. time of node existence in a network.

REFERENCES

1. Delay Tolerant Networking Research Group. Available: “http://www.dtnrg.org”.
2. Shen, Jian, Sangman Moh, and Ilyong Chung, "Routing protocols in delay tolerant networks: A comparative survey." The 23rd International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC 2008). 2008.
3. Assouma, Abdoul Djalil, Ronald Beaubrun and Samuel Pierre. "Mobility Management in heterogeneous wireless networks.", IEEE journal on selected areas in communications 24.3 (2006): 638-648.
4. Spyropoulos, Thrasyvoulos, Konstantinos Psounis, and Cauligi S. Raghavendra. "Efficient routing in intermittently connected mobile networks: The multiple-copy case." IEEE/ACM Transactions on Networking (ToN) 16.1 (2008): 77-90.
5. Guan, Xin, Min Chen, and Tomoaki Ohtsuki. "Epidemic theory based H+ 1 hop forwarding for intermittently connected mobile ad hoc networks." EURASIP Journal on Wireless Communications and Networking 2012.1 (2012): 76.
6. Maheswari, B. Uma, and T. S. B. Sudarshan. "Error resilient multipath video delivery on wireless overlay networks." Telecommunication, Computing, Electronics and Control (TELKOMNIKA), Vol. 14, No. 3, 2016.
7. Boudguig, Mohammad, and Abdelmounaïm Abdali. "New predictability concept for routing in DTN”, International Conference on Multimedia Computing and Systems, IEEE, 2012.
8. Xin Guan, and Tomoaki Ohtsuki, “Epidemic theory based H + 1 hop forwarding for intermittently connected mobile Ad Hoc networks”, EURASIP Journal on Wireless Communications and Networking, June 2012.
9. Guan, Xin, Min Chen, and Tomoaki Ohtsuki. "Epidemic theory based H+ 1 hop forwarding for intermittently connected mobile ad hoc networks." EURASIP Journal on Wireless Communications and Networking 2012.1 (2012): 76.
10. Sindhuja, M., et al. "Delay Tolerance in Wireless Networks through Optimal Path Routing Algorithm." Procedia Computer Science 48 (2015): 401-407.
11. Neena, V. V., and V. Mary Anita Rajam., "Performance analysis of epidemic routing protocol for opportunistic networks in different mobility patterns.”, International Conference on Computer Communication and Informatics, IEEE, 2013.
12. Gupta, Shaurya, and Ramesh C. Poonia., "Performance Evaluation of Direction-Finding Protocols in Vehicular Delay Tolerant Network." (2018).
13. Lu, Xiaofeng, and Pan Hui. "An energy-efficient n-epidemic routing protocol for delay tolerant networks." 2010 IEEE Fifth International Conference on Networking, Architecture, and Storage, IEEE, 2010.
14. De Rango, Floriano and Salvatore Amelio., "Performance evaluation of scalable and energy efficient dynamic n-epidemic routing in delay tolerant networks.” International Symposium on Performance Evaluation of Computer and Telecommunication Systems (SPECTS). IEEE, 2013.
15. Keränen, Ari, Jörg Ott, and Teemu Kärkkäinen., "The ONE simulator for DTN protocol evaluation. “Proceedings of the 2nd international conference on simulation tools and techniques. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2009.
16. The ONE. Available: “https://akeranen.github.io/the-one/”
17. Keranen, Ari. "Opportunistic network environment simulator." Special Assignment report, Helsinki University of Technology, Department of Communications and Networking (2008).
18. Open JUMP - The free, Java based and open source Geographic Information System for the World. Available: “http://www.openjump.org” .
19. Open Street Map, Available: “http://www.openstreetmap.org”.
20. Almeida, Rodrigo, et al. "Forwarding Strategies for Future Mobile Smart City Networks." 2018 IEEE 87th Vehicular Technology Conference (VTC Spring), IEEE, 2018.
21. Kimura, Tomotaka, and Masahiro Muraguchi. "Buffer management policy based on message rarity for store-carry-forward routing." 2017 23rd Asia-Pacific Conference on Communications (APCC), IEEE, 2017.
22. Spyropoulos, Thrasyvoulos, Konstantinos Psounis, and Cauligi S. Raghavendra. "Efficient routing in intermittently connected mobile networks: The multiple-copy case." IEEE/ACM Transactions on Networking (ToN) 16.1 (2008): 77-90.
23. Dhaka, V. S., Ramesh C. Poonia, and Linesh Raja. "The Realistic Mobility Evaluation of Vehicular Ad-Hoc Network for Indian Automotive Networks." International Journal of Ad hoc, Sensor & Ubiquitous Computing 5.2 (2014): 1.
24. Shastri, A., R. Dadhich, and Ramesh C. Poonia. "Performance analysis of on-demand Routing protocols for vehicular ad-hoc Networks." International Journal of Wireless & Mobile Networks (IJWMN) 3.4 (2011): 103-111.

AUTHORS PROFILE

Shaurya Gupta is working in the capacity of Assistant Professor from past 3.5 years with Amity University, Rajasthan. He is pursuing PhD from Amity University, Rajasthan. He has done M.Tech (CS) in the year 2014 from Jagannath University Jaipur and has over 9.5 years of experience in Teaching, Administration, Liaison & Coordination, Student Management and Research & Analysis. He has published three papers in reputed research journals and attended four national and International conferences. His areas of interest are Delay Tolerant Network, Wireless Sensor Network, Ad Hoc Network.

Dr. Ramesh Chandra Poonia has rich experience of 15 + years as an academician. At present he is an Associate Professor of Computer science at Amity Institute of Information Technology, Amity University Rajasthan, India. He has received his PhD in Computer science from Banasthali University Rajasthan , India. His Research interest include IOT for sustainable agriculture, ITS and WSN Protocol, Simulation and modeling.

Dr. Xiao.-Zhi Gao is working in the capacity of Professor in University of Eastern Finland from April 2018 till present. Prior to that he has worked as a Docent with Aalto University, Finland for about 15 years. His research interest includes Soft Computing, Machine Learning, Data Mining and Networks.