Performance Analysis of Vehicular Delay Tolerant Network

Seema Jangra[1,2]
[1]Department of Electronics & Communication Engineering(Shri Mata Vaishno Devi University)
J&K, India
[2]Computer Science Dept,
I.P College for Women (University of Delhi)
Delhi, India
seema.mtech@gmail.com

Amit Kant Pandit
Department of Electronics & Communication Engineering (Shri Mata Vaishno Devi University)
J&K, India
amitkantpandit@gmail.com

Neha Gupta
Computer Science Dept,
I.P College for Women (University of Delhi)
Delhi, India
gupta.neha2599@gmail.com

Ritika Jain
Computer Science Dept,
I.P College for Women (University of Delhi)
Delhi, India
jainr6135@gmail.com

Rishita Rana
Computer Science Dept,
I.P College for Women (University of Delhi)
Delhi, India
rishitarana3010@gmail.com

***Abstract*—Traditional TCP/IP network model needs an end-to-end connection for data transmission. With this traditional network, it is difficult to communicate in those areas where intermittent connectivity exists. Delay Tolerant Network (DTN) offers an alternate solution for these challenged areas. In the DTN, end-to-end path between the starting and end node may not be available all the time, but the transfer of data takes place using store-carry-forward technique in which node can depot the data, hold it until another node comes in contact and then deliver it to the destination. DTN with vehicular nodes called Vehicular Delay Tolerant network (VDTN). Here, a comprehensive study of VDTN and comparative study of VDTN routing protocol's performance is done to analyze the effect of size of buffer. The simulation experiment is carried out using ONE simulator with Synthetic Traces and Real Contact Traces.**

Keywords— Real Contact Traces, Delay Tolerant Network, Vehicular Delay Tolerant Network, Buffer,.

I. Introduction

Delay Tolerant Network (DTN) is a wireless network possessing a very different approach as compared to traditional network architectures. DTN was first used for Interplanetary Networks (IPN) to communicate between earth and mars[1].

A. Delay Tolerant Network

DTN comes into function in the sparse areas with intermittent connectivity where the route may not subsist between end points. DTN uses Bundle Layer Protocol, which provides support in intermittent connection using store-carry-forward technique.

1) Store-Carry-Forward Approach: DTN has advantages over other wireless networks as it follows store-carry-forward technique [1] in which every node is provided with a buffer storage, enabling the nodes to store the information in that buffer, carries it along and forwards it further when another node comes in a range which does not allow data to get lost.

2) Custody Transfer: Custody transfer [2] is an assurance of receiving the bundle at the destination node. Custody is given by the sender nodes and accepted by the relay nodes, also known as custodians.

3) Contacts In DTN: DTN supports two types of contacts: Opportunistic Contacts and Scheduled Contacts. In Opportunistic contacts, no path, no aforesaid/former knowledge of future contacts is known. In Scheduled contacts, nodes are already aware of the coming in contacts.

B. MANET vs DTN

Wireless networks do not require any wired links for communication as the name suggests itself. Two devices come in communication range of each other and information is transferred, but here the devices (nodes) are static so the source device has to wait (may be longer) for another device to come in the range to make communication happen. So Mobile Ad-hoc Network (MANET) had been introduced with an additional function, .i.e., mobility to nodes Fig. 1. MANET [3] is a decentralized and an infrastructure-less wireless network in which nodes are free to move. Data is transferred through relay nodes, but an end-to-end connection is must otherwise link may get broken down in between and data will get lost. Further changes had been made to come up with a better wireless network so a new concept came i.e. Delay Tolerant Network(DTN) which seems to overcome most of these problems[4].

C. Why do we need DTN

Mobile Ad-hoc Network (MANET) has some cons due to which communication gets disturbed, especially in those areas where proper connectivity or a specified end-to end-connectivity for exchanging information is not available so here comes the need of a Delay Tolerant Network (DTN) [5]. Communication is not possible using TCP/IP protocols due to communication environments which are challenged by:

- *High Delays:* Long delays in delivery of messages between nodes lead to loss of data in TCP/IP protocol suite, but supported by DTN due to store-carry-forward approach.

Fig. 1. MANET

- *Intermittent connectivity*: Along with high delays, if there exists no path between source and destination then internet protocol will not work. Here, DTN is very useful.
- *Asymmetric bidirectional data rates:* Restrained asymmetries in data rates can be tolerated by conventional protocols but for large ones, DTN comes to use.

D. DTN Characteristics[6]

Absence of End To End Connectivity: DTN is based on network partitioning. End to end connectivity is not required to transfer data between the sender and the receiver.

- *High Latency:* When there is a delay in availability of next node, DTN stores the message in its buffer hence supporting high delays.
- *Asymmetric Data Rates:* Data is transferred even when the incoming and outgoing rate are different.
- *Prevent data loss upto a certain time limit:* The message is stored in the buffer of node and it is removed only when the custody of message has been transferred.
- *Intermittent Connectivity:* DTN supports sudden change of state as it provides buffer and custody transfer system.
- *Heterogeneous Environment:* DTN allows transfer of data between different types of nodes.

E. From DTN to VDTN

With the increase in applications of DTN, a new extension of DTN was found in vehicles and the term VDTN was coined. Vehicular Delay Tolerant Network (abbreviated as VDTN) is the exploited use of vehicles (such as cars, buses, tracks) to provide communication and network even in sparse regions as shown in Fig. 2. It is the strategic use of VANET's((i.e. Vehicular Ad Hoc Networks) characteristics along with the DTN's capabilities to provide low-cost, intermittent connectivity, in areas such as rural and mountainous where the necessary stable infrastructure is not available or is disconnected due to natural disaster, or emergency situations, etc. Unlike VANETs that believe in the end-to-end connectivity, VDTN nodes simply move in the network sending/receiving bundles from one another, following the store-carry-forward paradigm which adds up to its practical applications such as data collection in disaster affected areas, data transfer at remote locations, etc.

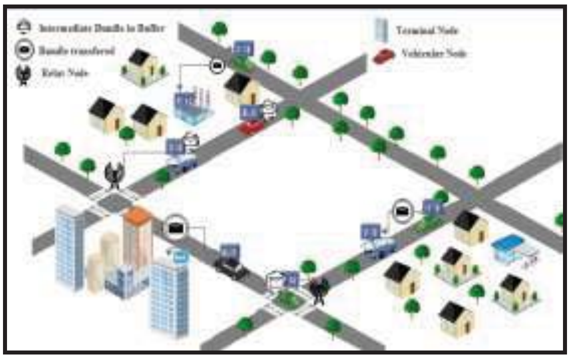

Fig. 2. VDTN Scenario

II. ARCHITECTURE OF DTN AND VDTN- COMPARATIVE STUDY

A. DTN Architecture

DTN architecture implements a store and carry mechanism by introducing a new layer, called bundle layer. The bundle layer lies between the Transport and Application layer as shown in Fig. 3. It forms a space on top and provide persistent storage which allows different network interruption and to succeed in exchanging information in heterogeneous networks. It uses naming mechanism and encapsulating messages. It uses Custody Transfer Mechanism, the node who is initially storing the message gives the custody of the message to next node to transfer it to the destination. First node will delete the message only after the next node takes the custody of the message (when the whole message is delivered to the next node).

All of the signaling as well as the data is contained in the form of packets called a bundle which is required to transit the transport layer, also known as the bundle convergence layer, the bundling equivalent addresses i.e End Point Identifiers (EPI), identify the DTN nodes. Routing of nodes is done in a store and forward manner between participating nodes over varied network transport technologies (including both IP and non-IP based transports) [7].

a) Application Layer: According to the needs of the user, Application layer provides the nature (environment) of the communication between the processes.

b) Bundle Layer: This layer ensures the end-to-end reliability i.e. the accurate message is transferred from source to destination by making use of the Custody Transfer mechanism. It has persistent storage, allowing heterogeneity in networks.

c) Transport Layer: This layer is responsible for congestion and transmission control protocol.

d) Network Layer: This layer is responsible for finding, making and maintenance of the route.

e) Data Link Layer: This layer is responsible for framing the data, checking the frame, error control and accessing media.

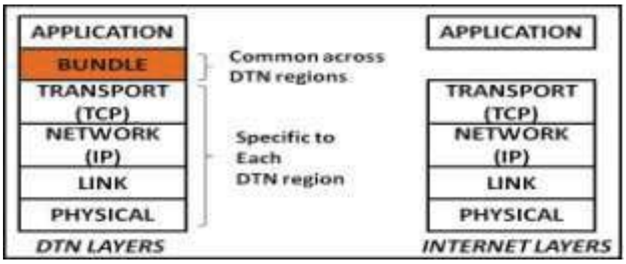

Fig. 3. TCP/IP Layer and DTN Layer [7]

B. DTN vs VDTN

In VDTN, nodes store and carry packets all along, and forward packets during their next interaction. VDTN has a layered structure with Data Link and Bundle layers being subcategorized as Control Plane and Data Plane, both having three distinct sub-layers. The Control Plane transmits the Control Bundles (CBs) while the Data Plane works on assembling and processing the data bundles (DBs), which is discussed in detail below.

1) Control Plane: In Control Plane, the Bundle Signaling Control (BSC) layer applies protocols at connection setup phase and exchanges control information between terminal nodes, relay nodes and mobile nodes. After knowing the characteristics such as node type, vehicles speed and localization, physical link, range, power constraints, storage, bundle size, bundle format, transmission data rate, expected contact time, delivery options, security requirements; DBs are finally transmitted between the nodes.

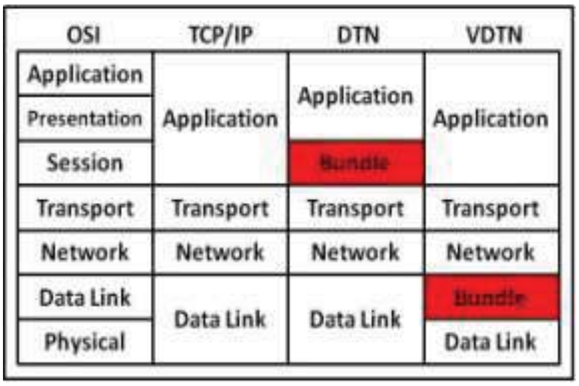

Fig. 4. Generic network architecture layers: Comparison of OSI, TCP/IP, DTN and VDTN [8]

2). Data Plane: In VDTN, the Bundle Aggregation and De-aggregation (BAD) layer is located below the network layer. Similar to the DTN architecture, it aggregates the arrived IP packets with similar properties (like, IP address of the destination terminal node) into DBs at the source terminal node, and de-aggregates the received DBs into individual IP packets at the destination terminal node. The aggregation can be done on many basis, such as application based aggregation (for IP packets with same destination application) or Quality of Service (QoS, for traffic prioritization).The arrival of an IP packet follows- Decoding, Properties Evaluation, and Data Plane. In VDTN, the Bundle Aggregation and De-aggregation (BAD) layer is located below the network layer.Similar to the DTN architecture, it aggregates the arrived IP packets with similar properties (like,IP address of the destination terminal node) into DBs at the source terminal node, and de-aggregates the received DBs into individual IP packets at the destination terminal node. The aggregation can be done on many basis, such as application based aggregation (for IP packets with same destination application) or Quality of Service (QoS, for traffic prioritization).The arrival of an IP packet follows- Decoding, Properties Evaluation, and the Translation of the destination address to a VDTN terminal node address. The Media Access Layer(MAC) and Physical Layer in either case provides the actual functional means for transmission of data between the various DTN nodes. Unlike DTN, Bundle Layer is located underneath the Network Layer in VDTN and the bundles are aggregated at the edge of the network, thus making its architecture network protocol independent. Also in comparison to the OSI model, as only two of its lower layers consists of what is termed as VDTN technology, VDTN is able to process the protocol data units in a more simple and quick manner. The existence of two different planes means a set of own distinct layers and protocols that allows them to work in an independent manner.

III. APPLICATIONS OF DTN

DTNs is one of the emerging networks whose various practical applications have been put to use. Some of them are:

1) Rural Area Development: One of the most concerned issues of a nation is to find a way to establish a communication link with the farthest remote area possible. Researchers have found a solution to this problem in DTN. One of such projects is KioskNet Project [9] that aims to provide the Internet facilities, like E-Mails, Web Access, Telemedicine, in the villages through the use of the Kiosk.

2) Wildlife Data Collection: The projects like DataMule [10] or ZebraNet [10] based on DTN can be proved effective even in the collection of data related to wildlife such as animals at a national park or even aquatic animals.

3) Disaster Affected Places: The DTN network can be used even in the areas affected by natural disasters to establish communication between the Government and the region because of its properties such as Intermittent Connectivity.

4) Environment Monitoring System: DTN techniques can be used to easily collect environment related data and current level pollution, humidity levels, by attaching sensors on the vehicles. One of its examples is the Environmental Monitoring in Metropolitan Areas (EMMA) project [11] that monitors the pollution level using public transport.

5) *Interplanetary Communication:* It was primarily aimed to be used in Interplanetary Communication [12] by the Space Agencies find ample practical usage in this field.

IV. ROUTING IN DTN

The routing paths in DTN are chosen in such a way to maintain its efficiency even when end-to-end connectivity is absent. The main characteristics taken into consideration while routing is Custody Transfer, Time Synchronization, Security and Privacy etc. Different types of routing schemes are First Contact Routing, Direct Delivery Routing, PRoPHET Routing and Spray and Wait. In First Contact Routing, sender node sends the message to the first node which comes in a range and this process continues till message reaches its destination [13]. In direct delivery routing, a node that generates the data forwards the message directly to the destination node [14]. In Epidemic Routing each node creates a copy of the message and forwards it to each node met so far, continuing this till destination node receives the message [15]. In the Prophet routing protocol, delivery probability was evaluated between two nodes on the basis of contacts in the past. If the delivery probability of contact node is more than the sender node then only the node forwards the copy of the message [16]. Spray and Wait routing algorithm is parted into two phases- Spray and Wait. In spray phase, the root node replicates the data to a limited number of nodes (say m) which further relay the message to m nodes. If the data do not reach to its destination in this phase ,then data is stored and direct delivery routing is followed [17]. A secure routing in VDTN using social skeleton is also discussed in [20].

V. PERFORMANCE MATRICES IN DTN

Performance metric considered to evaluate the VDTN performance are:

1) Delivery Ratio: The number of messages that have been delivered divided by the total messages created.

2) Delivery Delay(Latency): The delay occurred in the delivery of the message that is delivered first among its multiple copies.

3) Overhead Ratio: The number of messages which get connected to get relayed divided by the number of messages delivered.

VI. EFFECT OF BUFFER SIZE IN DTN

A. Simulation Tool

Opportunistic Network Environment (ONE) is used to simulate VDTN. The purpose is to see the realistic approach of DTN. Other DTN simulators mainly focus on routing simulation which is not the case with the ONE, as it combines mobility modeling, DTN routing and visualization in one package [18].

In this, we have studied how the three parameters are affected by varying buffer size in different routing protocols ,i.e., First Contact, Direct Delivery, Epidemic, Prophet, Spray and Wait. And we have also compared its effects on Synthetic trace buffer and Real trace buffer.

B. Effect of Buffer Size on DTN Performance with Synthetic Contact Traces

As seen in Fig. 5 , increase in buffer size, delivery ratio increases where prophet routing protocol performs better as compared to others. Epidemic and spray and wait routing protocols shows comparable value of delivery ratio.

Effect of buffer size on delivery delay is depicted in Fig. 6, which shows with that with the increase in buffer size the delivery delay increases, but it is also observed that the first contact routing protocol shows lowest delivery delay than others with poor delivery ratio.

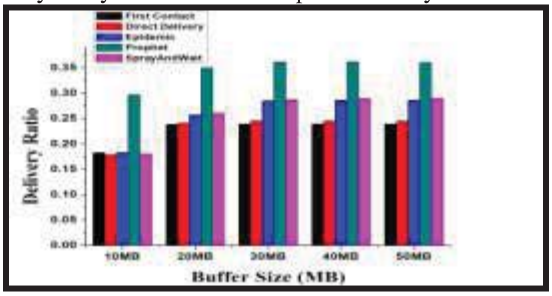

Fig. 5. Delivery Ratio Vs Buffer Size

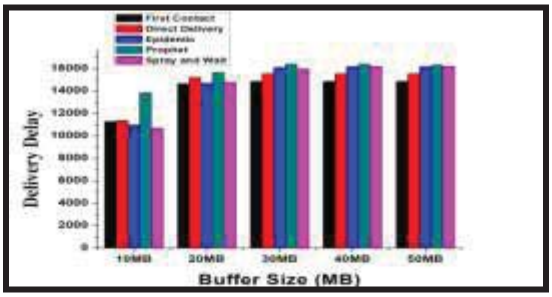

Fig. 6. Delivery Delay(Latency) Vs Buffer Size

Prophet routing protocols perform better in order to get higher delivery ratio and low delivery delay as compare to other routing schemes.

As we have seen above that by increasing buffer size, the overhead ratio decreases. Epidemic and spray and wait show comparable results.

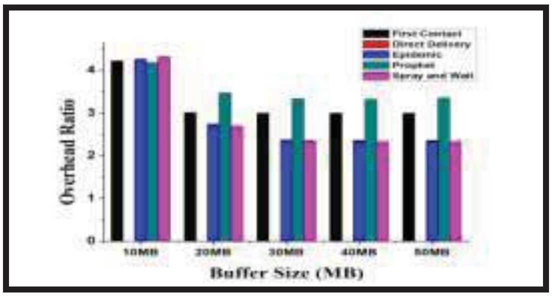

Fig. 7. Overhead Ratio Vs Buffer Size

C. Effect of Buffer Size on DTN Performance with Real Contact Traces

Real contact traces, INFOCOM'05 data set are considered to study the effect of buffer size in VDTN scenario. The INFOCOM'05 dataset is downloaded from CRAWDAD [19] and converted in ONE Standard Events Reader format after some post processing. The characteristics of INFOCOM'05 are listed in TABLE II.

TABLE I INFOCOM'05 CHARACTERISTICS

Characteristics	Infocom'05
Year	2005
Days	3 Days
Devices used	iMote
No. of Nodes	41
Environment	Conference
Type of Network used	Bluetooth
Granularity used	120 per sec

Internal Contacts Number	22,459
Average Contact/Day	4.6

With real contact traces it has been observed from Fig. 8 that with the increase in buffer size changes the delivery ratio, delivery delay and overhead ratio. The delivery ratio increases with increase in buffer size and prophet routing protocol exhibit the highest delivery ratio. Epidemic routing protocol performs better in terms of delivery delay with increase of buffer size in real contact traces as shown in Fig. 9.

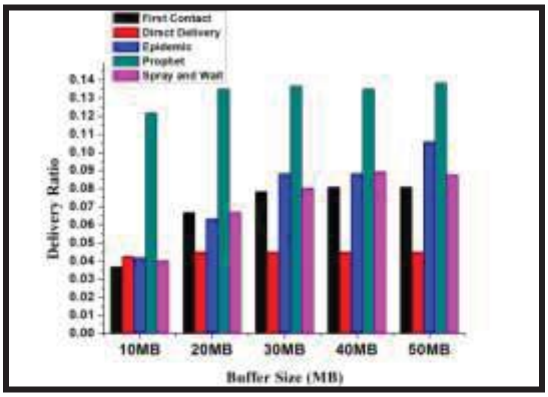

Fig. 8. Delivery Ratio Vs Buffer Size

Fig. 10 depicts the better performance of epidemic routing protocol with moderate value of overhead ratio.

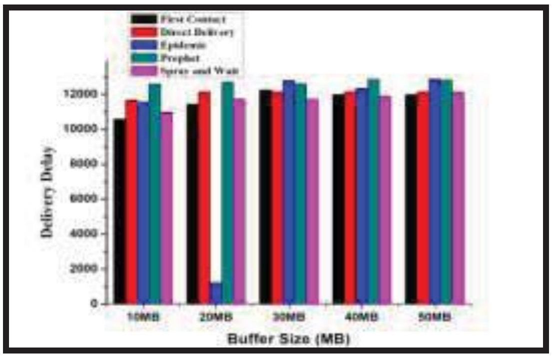

Fig. 9. Delivery Delay(Latency) Vs Buffer Size

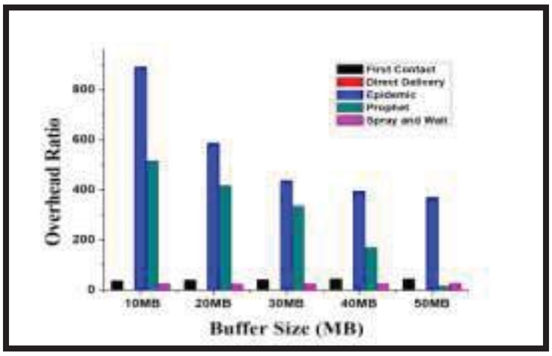

Fig. 10. Overhead Ratio vs Buffer Size

VII. CONCLUSION AND FUTURE WORK

After studying the effect of buffer size on VDTN performance it is observed that delivery ratio and delivery delay both are increasing while the overhead ratio is decreasing but sometimes it show anonymous increase and decrease. The maximum delivery ratio is observed in Prophet protocol in both Synthetic Contact Traces and Real Contact Traces. Delivery delay is minimum for First Contact protocol in Synthetic Contact Traces and minimum but somewhat similar for First Contact protocol and Spray and Wait protocol in Real Contact Traces. The minimum overhead ratio is observed for Direct Delivery protocol in both Synthetic Contact Traces and Real Contact Traces. Changes are more prominent in Synthetic Contact Traces than in Real Contact Traces. But if the buffer size is increased , the cost required for the setup increases too . In future work, new Buffer Management Scheme can be proposed in order to decrease the delivery delay and overhead ratio.

REFERENCES

[1] IP, Yin-Ki, Wing-Cheong Lau, and On-Ching Yue. "Forwarding and replication strategies for dtn with resource constraints." Vehicular Technology Conference, 2007. VTC2007-Spring. IEEE 65th. IEEE, 2007.Zhang Z. Routing in intermittently connected mobile ad hoc networks and delay-tolerant networks: overview and challenges. Common Surveys Tuts 2006; 8: 24-37.

[2] K. Fall, W. Hong and S. Madden, "Custody Transfer for Reliable Delivery in Delay Tolerant Networks," Technical Report, Intel Research, Berkeley, 2003.

[3] Freebersyser and B. Leiner, "A DoD Perspective on Mobile Ad Hoc Networks," Ad Hoc Networking, Ed. C. E. Perkins, Addison-Wesley, 2001, pp. 29-51.

[4] Ott, Jrg, Dirk Kutscher, and Christoph Dwertmann. "Integrating DTN and MANET routing." Proceedings of the 2006 SIGCOMM workshop on Challenged networks.(pp. 221-228). ACM, 2006.

[5] Pravin Ghosekar, Girish Katkar Dr. Pradip Ghorpade "Mobile Ad Hoc Networking: Imperatives and Challenges" IJCA Special Issue on "Mobile Ad-hoc Networks" MANETs, 2010.

[6] Research Scholar, Dr. Mahalingam Centre for Research & Development, NGM College, Pollachi. 2Associate Professor, Dr. Mahalingam Centre for Research & Development, NGM College, Pollachi, "DELAY Disruption Tolerant Network (DTN), its Network Characteristics and Core Applications ".

[7] K. Fall, "A delay-tolerant network architecture for challenging internets," presented at the Proceedings of the 2003 conference on Applications, technologies, architectures, and protocols for computer communications, Karlsruhe, Germany, 2003.

[8] Soares, Vasco & Farahmand, Farid & Rodrigues, Joel. (2009). A layered architecture for Vehicular Delay-Tolerant Networks.. 122-127.

[9] S. Guo, M. H. Falaki, E. A. Oliver, S. Rahman, A. Seth, M. A. Zaharia and S. Keshav, "Very Low-Cost Internet Access Using KioskNet", ACM Computer Communication Review, Oct. 2007.

[10] P. Juang, H. Oki, Y. Wang, M. Maronosi, L. Peh, D. Rubenstein, "Energy-Efficient Computing for Wildlife Tracking: Design Tradeoffs and Early Experiences with ZebraNet", Proc. ASPLOS, Oct 2002.

[11] S. Lahde, M. Doering, W. Pottner, G. Lammert and L. Wolf,"A practical analysis of communication characteristics for mobile and distributed pollution measurements on the road", Wireless Communications and Mobile Computing, vol. 7, no. 10, pp. 1209-1218, Dec. 2007.

[12] V. Cerf et. al., "Interplanetary Internet (IPN): Architectural Definition", http://www.ipnsig.org/reports/memo-ipnrg-arch-00.pdf

[13] S. Jain, K. Fall, R. Patra., "Routing in a Delay Tolerant Network".Proc. of ACM SIGCOMM, pp. 145–2008.

[14] Spyropoulos, Thrasyvoulos, Konstantinos Psounis, and Cauligi S. Raghavendra. "Single-copy routing in intermittently connected mobile networks." Sensor and Ad Hoc Communications and Networks, 2004. IEEE SECON 2004. 2004 First Annual IEEE Communications Society Conference on IEEE, 2004.

[15] Vahdat, Amin, and David Becker. Epidemic routing for partially con-nected ad hoc networks. Technical Report CS-200006, Duke University, 2000.

[16] Lindgren, A. Doria, and O. Scheln. "Probabilistic Routing in Intermittently Connected Networks." LNCS, Springer, vol. 3126, pp.239-254, 2004.

[17] Spyropoulos, Thrasyvoulos, Konstantinos Psounis, and Cauligi S. Raghavendra."Efficient routing in intermittently connected mobile networks: the multiple-copy case." Networking, IEEE/ACM Transactions on 16.1 (2008): 77-90.

[18] Helsinki University of Technology – Networking Laboratory, "The Opportunistic Network Environment simulator," [Online].

[19] Kotz, D., & Henderson, T. (2005). CRAWDAD: a community resource for archiving wireless data at Dartmouth. IEEE Pervasive Computing, 4(4), 12–14.

[20] R. Amla, S. Jangra and A. Pandit, "Improving Security and Performance Parameter using Social Skeleton in heterogeneous VDTN," *2018 3rd International Conference On Internet of Things: Smart Innovation and Usages (IoT-SIU)*, Bhimtal, 2018, pp.1-7. doi: 10.1109/IoT-SIU.2018.8519857