ANALYSIS OF SOCIAL NETWORK ALGORITHMS IN DELAY TOLERANT NETWORKS

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Certificate

This is to certify that project report entitled "**Analysis of Social Network Algorithms in Delay Tolerant Networks**", submitted by **DEEPAK PROCH** in partial fulfillment for the award of degree of Master of Technology in Computer Science & Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been carried out under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

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Abstract:

An existing social based routing protocol for opportunistic networks. SimBet uses similarity, betweenness centrality as its forwarding metrics. Although similarity shows how likely a pair of nodes belongs to the same community, it does not express how closely these nodes are connected. SimBet exhibits the direct link probability into the forwarding metrics, but it ignores the indirect link probability through neighbor nodes, so it doesn't applicable in real world scenario. To overcome this problem, we propose to incorporate Human opinion dynamics HOD with SimBet called SimBet-HOD. In this a trust of a node is based on the opinion of its neighbor nodes and also the previous interactions of the node with the concerned node. we have been calculate social rank, social influence, and the distance between nodes which are encountered randomly. This will always update a SimBet table of nodes in an random environment. Due to which an Average number of hops, Average delay and Total number of forwards in comparison with previous approaches are reduced.

Table of content

Page No.

Certificate…….i

Acknowledgement…….ii

Abstract……..…iii

1. Introduction…….. 1

1.1 Wireless sensor networks…….. 1

1.1.1 Over view of key issues…… 2

1.1.2 Types of wireless networks…… 6

1.1.3 Problems and Emerging issues in Wireless Sensor Networks……..... 8

1.1.4 Social Network Analysis in MANET…….. 15

2. Literature Survey..... … 19

3. Problem Formulation…… 36

3.1. Similarity and Betweenness Centrality calculation and its challenges….. 38

4. Proposed Methodology……. 40

4.1 Human Opinion Dynamics Model……. 40

4.2 Proposed Algorithm…… 43

5. Results and Discussion……. 44

6. Conclusion and Future Scope…… 49

References……..

List of Abbreviations

1. DTN (Delay Tolerant Networks)
2. SimBet (Similarity Betweenness)
3. QM (Queue Management)
5. FW (Forwarding)
6. WSN (Wireless Sensor Networks)
7. DSR (Dynamic Source Routing)
8. MANET (Mobile Ad-hoc Networks)
9. LAN (Local Area Network)
10. PR-Net (Packet Radio Network)
11. CSMA (Carrier Sense Multiple Access)
12. AODV (Ad-hoc on demand Distance Vector)
13. DSDV (Destination Sequence Distance Vector)
14. LAR (Location Aided Routing)
15. PSN (Packet Switch Networks)
16. HOD (Human Opinion Dynamics)

List of Figures:

1. Figure 1 (Broad Classification of multiple issues in a WSN)……. 5

2. Figure 2 (Overview of Mobile Ad-hoc Networks)……. 10

3. Figure 3(Hierarchy of Ad-hoc routing protocols)……... 11

4. Figure 4 (Disconnected Clusters)…… 16

5. Figure 5 (Random Deployment of nodes in the grid)……. 44

6. Figure 6 (Communication between Nodes)…… 45

7. Figure 7 (End to End Delay)…… 46

8. Figure 8 (Total number of forwards)…….. 47

9. Figure 9 (Average number of hops per message)…… 48

Chapter 1:

1. Introduction

1.1 Wireless sensor networks

Wireless sensor networks offer latest applications for military surveillance applications and environment monitoring. Lately, various developments in the hardware miniaturization correlated with less-cost mass production or advancement in wireless communications technologies which have created possibly various applications with high numbers of sensors. In other cases of ground access area of objectives has to be monitored is dangerous or difficult, so a solution to configure the sensors is to locate them from aircraft. Without locating the position, there is only a way to give adequate target coverage by sensors to use multiple sensors than the fixed number. Higher sensor density can enhance the possibility of targeted coverage, assigning the sensors can be randomly dispersed in the targets proximity. There is generally a basic issue in sensor networks is called network lifetime. According to the technology, the sensors are powered with battery. Due to cost and size constraints the available energy in the sensor to senses the communication and globally effect on the application lifetime. A general solution of energy problem is to apply the mechanisms for efficient energy management. This method is based on scheduling sensor activity so which for each sensor the active state, in it performs its monitoring alternate task with a less-energy idle state. The ratio of consumed energy has between active and the sleep state which has considerable or may be as high as 100. Other relevant result to this scheme is that batteries are discharging in some short bursts with the significant off-time that have twice approximately as well as lifetime comparing to continuous mode of the

operation. Thus, an operation mode alternates active or inactive the battery state extends of network lifetime.

One of the other problem of energy efficiency in the wireless sensor applications for the surveillance of various targets with known places. Consider large no. of sensors which are dispersed randomly in closed proximity to multiple objectives and transmit the monitoring information to central processing node. Every target has to be monitored in all the times with one sensor or each sensor has been able to monitor all the targets within operational range. One technique to extend the sensor network lifetime which is the division of sensor sets into disjoint sets like that each set totally covers all the targets. Consider a target that is covered if it is active sensor at operational range. Active the disjoint set successively, like that at any moment is active time only one set. The sensors of active set are into the active state and all sensors are in state of low-energy sleep. Monitored all the targets that are taken by every sensor set, the main goal are to determine a maximum number of disjoint sets, hence the interval time between two activations for sensor is longer. By reducing the fraction of time a sensor is active, the time overall until power turns out for all sensors that is increased and the application lifetime is expanded proportionally by equal factor to the disjoint sets. As a partial consequence, the density of active nodes has been lowered.

1.1.1 Overview of key issues

Present state-of-the-art sensor technology gives a solution to develop and design various types of wireless sensor applications. An existing summary of sensor technologies has provided in available sensors in market involving generic nodes and gateway nodes. A multi-purpose generic sensor node's task has been to take the measurements from monitored environment. It may be equipped with various devices

that can measure several physical attributes like as humidity, light, temperature, acceleration, acoustics, barometric pressure, velocity, magnetic field, etc. Gateway bridge nodes collect data from the generic sensors or relay them to base station. Gateway nodes contain higher processing battery power, capability, and transmission range. A combination of generic and gateway nodes are typically located to form a WSN. To enable the wireless sensor applications while using sensor technologies, the tasks range can be classified. Each sensor node has an individual system. To support different type of application software on sensor system, the development of newest platforms, storage schemes and operating systems are needed. The communication protocols enable the communication between sensors and application. They enable communication between sensor nodes. The services which are developed to increase the application of improve network efficiency and system performance. From network management perspectives and application requirements, it is crucial that sensor nodes are capable of self-arranging themselves. The sensor nodes can arrange themselves into a network and are able to control or efficiently manage themselves. Sensor nodes are limited in processing capacity, power, and storage, new communication protocols and management services are needed to fulfill these requirements.

The communication protocol has five protocol layers for packet switching: transport layer, application layer, data-link layer, network layer, and physical layer. In this, how protocols at different layers address network dynamics and energy efficiency. Functions like as storage, synchronization, localization, coverage, security, and data aggregation and compression are expressed as sensor network services. Implementation of protocols at distinct layers in protocol stack can significantly effect to energy consumption, system efficiency and end-to-end delay. It is crucial to optimize communication and minimize energy usage. The traditional networking protocols are not working well in WSN since are not designed to meet these requirements. Hence, new energy-efficient

protocols have been proposed for all layers of the protocol stack. These protocols employ cross-layer optimization by supporting interactions across the protocol layers. Specifically, protocol state information at a particular layer is shared across all the layers to meet the particular requirements of the WSN. As sensor nodes can operate on limited energy usage, battery power is a very important concern in aWSN; and which has been significant research focus that includes around harvesting and minimizing energy.

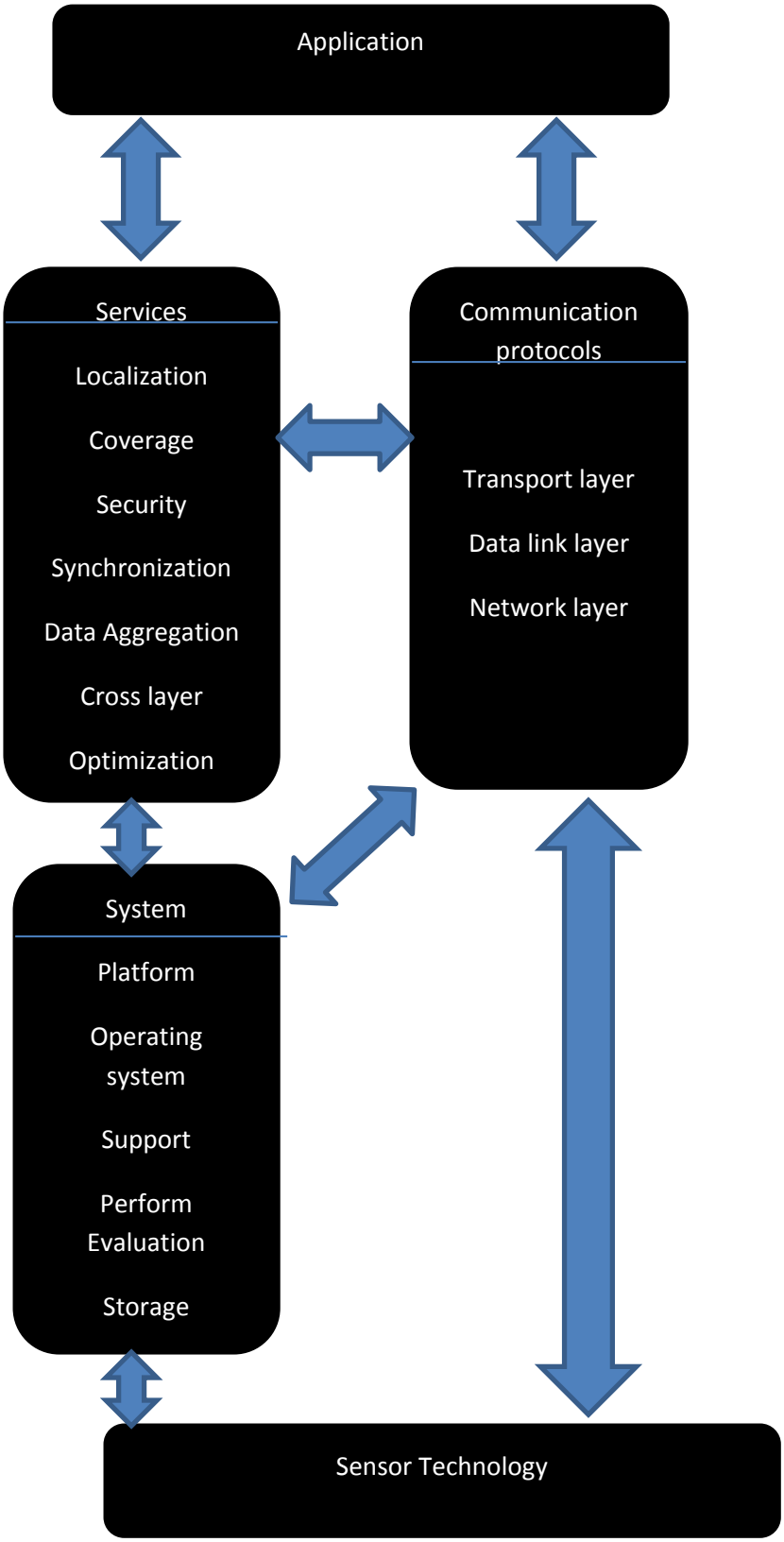


Figure: 1. Broad classification of multiple issues in a WSN

1.1.2 Types of wireless sensor networks

Current Wireless sensor networks are placed on land, underwater and underground. Depends upon the environment, a sensor network faces distinct challenges and constraints. There are 5 types of WSNs: terrestrial WSN, X underwater WSN, underground, and multi-media WSN, and mobile WSN.

Terrestrial WSNs typically includes hundreds to thousands of wireless sensor nodes located in given area, either in pre-planned or in an ad hoc manner. In ad hoc placement, sensor nodes are bed ropped from a plane and particularly placed into target area. In pre-planned placement, there is grid deployment, optimal location, and 2-d and 3-d placement models. In a terrestrial Wireless sensor networks, reliable communication in an environment is vital. Terrestrial sensor nodes are able to communicate data back to base station. While power of battery is limited and it can not be rechargeable, terrestrial sensor nodes hence may be equipped with secondary power source like as solar cells. In such case, it is crucial for sensor nodes to reserve energy. For a WSN, energy can be saved with multi-hop fixed routing, in-network data aggregation, short transmission range, minimizing delays, eliminating data redundancy, and using low duty-cycle operations.

Underground Wireless sensor networks involve number of sensor nodes buried in a cave or used to monitor the underground conditions. In addition sink nodes are placed in the ground to relay the information from sensor nodes to base station. An underground Wireless sensor networks is expensive than a terrestrial in terms of deployment, equipment, and maintenance. These sensor nodes are very expensive because an appropriate equipment parts are selected to ensure the reliable communication via water, soil, rocks, and other mineral contents. The environment makes a challenge in wireless communication due to the signal losses and high levels of attenuation.

Underwater Wireless sensor networks involve number of vehicles and sensor nodes placed underwater. Opposite to the terrestrial WSNs, these sensor nodes are expensive and some sensor nodes are located. An autonomous underwater vehicle has been used for exploration or collecting data from sensor nodes. Comparatively to a fixed location of sensor nodes in terrestrial WSN, a placement of sensor nodes is located underwater. A typical underwater wireless communications has been established through transmission of acoustic waves. A challenge in underwater acoustic communication is the long propagation delay, limited bandwidth, and signal fading issue. Multi-media Wireless sensor networks have enabled to monitor and track the events in form of multimedia like as audio, video, and imaging. Multi-media Wireless sensor networks involve a number of less cost sensor nodes equipped with microphones and cameras. These sensor nodes can be interconnect with each other in wireless connection for process, data retrieval, correlation, and compression. These Multi-media sensor nodes are placed in pre-planned manner into an environment to the guarantee coverage. Challenges in the multi-media Wireless sensor networks include high energy consumption, high bandwidth demand, data processing, quality of service provisioning and compressing techniques, and cross-layer design. Multi-media content like as video stream needs high bandwidth for the content to be delivered. In the conclusion, high data rate are lead to the high energy consumption. Transmission method can support low energy consumption and high bandwidth to be developed.

Mobile Wireless sensor networks involve sensor nodes collection which can be moved to their own and connect with physical environment. Mobile nodes are the ability sense, communicate and compute like static nodes. The main difference is mobile node has an ability to organize and reposition itself in the network. A mobile Wireless sensor networks can start off with few initial placement and nodes can then spread out to gather information. Information gathered by a mobile node may be transmitted to other

mobile node when they are in range of each other. The key difference is a data distribution. In a static Wireless sensor networks, data has been distributed using fixed flooding during dynamic routing is used in a mobile WSN. Challenges in mobile WSN include localization, deployment, self-organization, navigation and control, coverage, energy, maintenance, and data process. Mobile WSN applications involve but are not limited to target tracking, environment monitoring, search and rescue, and real-time monitoring of hazardous material.

1.1.3 Problems and Energy Issues in Wireless Sensor Networks

As it mentioned before, deceasing energy consumption on different sensors in the network and attaining the standard of quality in solutions given by networks is a main challenge. In this thesis, we address a number of problems arising from several applications of Wireless sensor networks with a polynomial-time solution during emphasizing the energy minimization issue of networks. The problems are considered fall in wide categories of clustering, broadcasting, monitoring, and topology control of Wireless sensor networks. Mainly focuses on devising the distributed algorithms for problems, where different nodes are execute the algorithms to compute solutions of problem a global nature. A distributed algorithm where nodes are individually execute in that algorithm which make the decisions without knowing the global topology of network. Although, in distributed algorithms, it lets to nodes know a little global information.

Mobile Ad-hoc network (MANET)

Mobile Ad-hoc network is a set of wireless devices called wireless nodes, which dynamically connect and transfer information. Wireless nodes can be personal computers (desktops/laptops) with wireless LAN cards, Personal Digital Assistants (PDA), or other types of wireless or mobile communication devices. Ad-hoc networks are mobile wireless networks that have no fixed infrastructure. There are no fixed routers – instead each node acts as a router and forwards traffic from other nodes. Ad-hoc networks were first mainly used for military applications. There are currently two variations of mobile wireless networks infrastructure and Infrastructure less networks.

Infrastructure Networks

These are also known as Cellular network, have fixed and wired gateways. They have fixed base stations that are connected to other base stations through wires. The transmission range of a base station constitutes a cell. All the mobile nodes lying within this cell connects to and communicates with the nearest bridge (base station). A hand off occurs as mobile host travels out of range of one Base Station and into the range of another and thus, mobile host is able to continue communication seamlessly throughout the network. Example of this type includes office wireless local area networks (WLANs).

Infrastructure less Network

The other type of network is known as Mobile Ad NETwork (MANET). These networks have no fixed routers. All nodes are capable of movement and can be connected

dynamically in arbitrary manner. The responsibilities for organizing and controlling the network are distributed among the terminals themselves. The entire network is mobile, and the individual terminals are allowed to move at will relative to each other.

In MANET, a wireless node can be the source, the destination, or an intermediate node of data transmission. When a wireless node plays the role of intermediate node, it serves as a router that can receive and forward data packets to its neighbor closer to the destination node. Due to the nature of an ad-hoc network, wireless nodes tend to keep moving rather than stay still. Therefore the network topology changes from time to time. Wireless ad-hoc network have many advantages:

Low cost of deployment: Ad hoc networks can be deployed on the fly; hence no expensive infrastructure such as copper wires or data cables is required.

Fast deployment: Ad hoc networks are very convenient and easy to deploy since there are no cables involved. Deployment time is shortened.

Dynamic Configuration: Ad hoc network configuration can change dynamically over time.

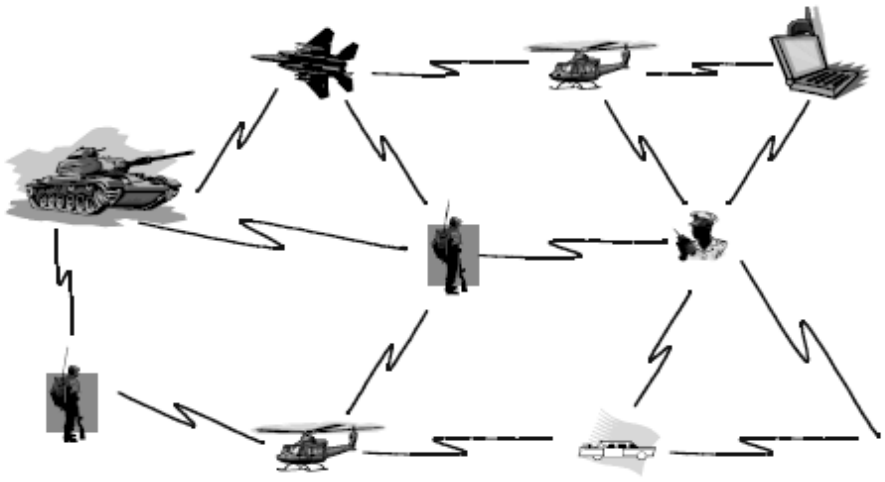


Fig 2 Overview of Mobile Ad-hoc Network

When compared to configurability of LANs, it is very easy to change the network topology of a wireless network. Routing protocols in ad hoc mobile wireless network can generally be divided into three groups [1]:

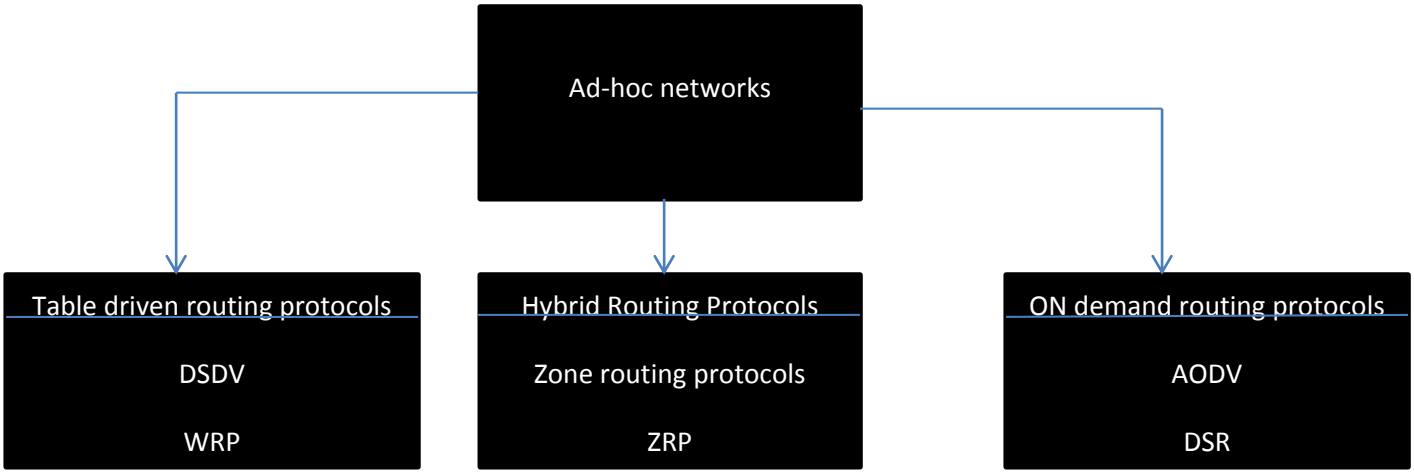


Fig 3 Hierarchy of ad-hoc routing protocols

Table driven: Table-driven routing protocols attempt to maintain consistent, up-to-date routing information from each node to every other node in the network. These protocols require each node to maintain one or more tables to store routing information, and they respond to changes in network topology by propagating updates throughout the network in order to maintain a consistent network view. The areas in which they differ are the number of necessary routing-related tables and the methods by which changes in network structure are broadcast.

Source initiated (or *demand driven*): A different approach from table-driven routing is source-initiated on demand routing. This type of routing creates routes only when desired by the source node. When a node requires a route to a destination, it initiates a route discovery process within the network. This process is completed once a route is

found or all possible route permutations have been examined. Once a route has been established, it is maintained by a route maintenance procedure until either the destination becomes inaccessible along every path from the source or until the route is no longer desired.

Hybrid: This type of routing protocols combines features of the above two categories. Nodes belonging to a particular geographical region or within a certain distance from a concerned node are said to be in the routing zone and use table driven routing protocol. Communication between nodes in different zones will rely on the on-demand or source-initiated protocols.

MANET evolution

Historically, mobile ad hoc networks have primarily been used for tactical network related applications to improve battlefield communications/ survivability. The dynamic nature of military operations means that military cannot rely on access to a fixed pre-placed communication infrastructure in battlefield. Pure wireless communication also has limitation in that radio signals are subject to interference and radio frequency higher than 100 MHz rarely propagate beyond line of sight (LOS). Mobile ad hoc network creates a suitable framework to address these issues by providing a multi-hop wireless network without pre-placed infrastructure and connectivity beyond LOS. Early ad hoc networking applications can be traced back to the DARPA Packet Radio Network (PRNet) project in 1972 , which was primarily inspired by the efficiency of the packet switching technology, such as bandwidth sharing and store and- forward routing, and its possible application in mobile wireless environment. PRNet features a

distributed architecture consisting of network of broadcast radios with minimal central control; a combination of Aloha and CSMA channel access protocols are used to support the dynamic sharing of the broadcast radio channel. In addition, by using multi-hop store-and-forward routing techniques, the radio coverage limitation is removed, which effectively enables multi-user communication within a very large geographic area.

Ad hoc networking issues

In general, mobile ad hoc networks are formed dynamically by an autonomous system of mobile nodes that are connected via wireless links without using the existing network infrastructure or centralized administration. The nodes are free to move randomly and organize themselves arbitrarily; thus, the networks wireless topology may change rapidly and unpredictably. Such a network may operate in a standalone fashion, or may be connected to the larger Internet. Mobile ad hoc networks are infrastructure-less networks since they do not require any fixed infrastructure, such as a base station, for their operation. In general, routes between nodes in an ad hoc network may include multiple hops, and hence it is appropriate to call such networks as ''multi-hop wireless ad hoc networks''. Each node will be able to communicate directly with any other node that resides within its transmission range. For communicating with nodes that reside beyond this range, the node needs to use intermediate nodes to relay the messages hop by hop.

Autonomous and infrastructure-less MANET does not depend on any established infrastructure or centralized administration. Each node operates in distributed peer-to-peer mode, acts as an independent router and generates independent data. Network management has to be distributed across different nodes, which brings added difficulty

in fault detection and management. Multi-hop routing. No default router available, every node acts as a router and forwards each other's packets to enable information sharing between mobile hosts. Dynamically changing network topologies. In mobile ad hoc networks, because nodes can move arbitrarily, the network topology, which is typically multi-hop, can change frequently and unpredictably, resulting in route changes, frequent network partitions, and possibly packet losses. Variation in link and node capabilities. Each node may be equipped with one or more radio interfaces that have varying transmission/receiving capabilities and operate across different frequency bands. This heterogeneity in node radio capabilities can result in possibly asymmetric links. In addition, each mobile node might have a different software/hardware configuration, resulting in variability in processing capabilities. Designing network protocols and algorithms for this heterogeneous network can be complex, requiring dynamic adaptation to the changing conditions. Energy constrained operation. Because batteries carried by each mobile node have limited power supply, processing power is limited, which in turn limits services and applications that can be supported by each node. This becomes a bigger issue in mobile ad hoc networks because, as each node is acting as both an end system and a router at the same time, additional energy is required to forward packets from other nodes.

Network scalability: Currently, popular network management algorithms were mostly designed to work on fixed or relatively small wireless networks. Many mobile ad hoc network applications involve large networks with tens of thousands of nodes, as found for example, in sensor networks and tactical networks. Scalability is critical to the successful deployment of these networks. The steps toward a large network consisting of nodes with limited resources are not straightforward, and present many challenges that are still to be solved in areas such as: addressing, routing, location management,

configuration management, interoperability, security, high capacity wireless technologies, etc.

1.1.4 Social Network Analysis in MANET

A MANET is a wireless network which is dynamic in nature which is either fixed infrastructure or not. Nodes are organized arbitrary with free movement. There is a type of ad-hoc network is Sparse Network in which density of nodes are low and nodes doesn't come into contact frequently. In this the graph is rarely formed and the network should be delay tolerant. Traditional MANET routing protocols such as AODV, DSR, DSDV and LAR they assume that the fail to route messages if there is not a complete route from source to destination at the time of sending and the network graph is fully connected. Sparse networks don't use Ad-hoc network routing protocols because of the assumption of fully connected. Physically carry messages to the destination to avoid this issue. Store and carry method is used for the mobility. In this nodes takes their own decision for forwarding messages to its encounter node until it reaches its destination.

In this paper we propose the use of social network analysis techniques in order to forward data in a disconnected delay-tolerant MANET. Social networks exhibit the small world phenomenon which comes from the observation that individuals are often linked by a short chain of acquaintances. The classic example of a small world is Milgram's 1967 experiment, where 60 participants in Nebraska were asked to forward a letter to be delivered to a stockbroker in Boston [27].

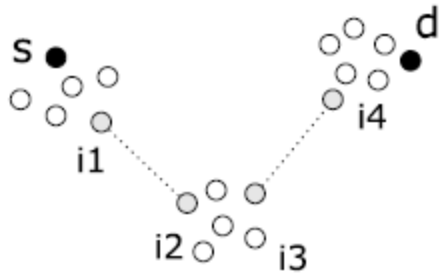


Fig 4 [1] Disconnected Clusters

Some networks may consist of cliques where metrics based on direct or indirect encounters may not find a suitable carrier for the message. Consider three disconnected clusters in figure 1. Source node s wishes to send a message to destination node d. However node s is involved in a highly cliquish cluster in which none of the nodes have directly or indirectly met destination node d. This makes the decision of selecting a node to forward data difficult. The three clusters are linked by bridging ties from i1 to i2 and from i3 to i4. A path exists between the three clusters using intermediate nodes i1, i2, i3 and i4 which form bridges between the three clusters. Weak acquaintance ties of i1-i2 and i3-i4, illustrated by the dashed lines, become a crucial bridge between the three tightly connected groups, and these groups would not be connected if not for the existence of these weak ties. We propose to forward data based on the identification of these 'bridges' and the identification of nodes that reside within the same cluster as the destination node. Our main contribution of this paper is a new forwarding metric based on ego network analysis to locally determine a node's centrality within the network and the node's social similarity to the destination node. To the best of our knowledge, this is the first work to exploit social analysis techniques in this manner.

Ad-hoc On-demand Distance Vector (AODV)

AODV is a combination of on-demand and distance vector i.e. hop-to-hop routing methodology [7]. When a node needs to know a route to a specific destination it creates a ROUTE REQUEST. By immediate nodes route request is forwarded which also create a reverse route for itself for destination. With route to destination when the request reaches a node it creates again a REPLY which contains the number of hops that are require to reach the destination. In forwarding where all nodes are participate in reply to the source node. From each node from source to destination this route is created and not the entire route as in routing of source.

Dynamic Source Routing (DSR)

DSR is a simple and efficient routing protocol designed specifically for use in multihop wireless adhoc networks of mobile nodes [10].In this the nodes discover a source route dynamically across multiple hops to any destination in the ad-hoc network. Data packets sent then completely carries in its header for ordered list of nodes which is used for message pass, allowing packet routing to be a trivially loop free and avoiding the need for up-to-date routing information in the intermediate nodes through which the packet is forwarded. With the inclusion of this source route in the header of each data packet, other nodes forwarding or overhearing any of the packets may easily cache this routing information for future use.

Destination Sequenced Distance Vector (DSDV)

DSDV is a hop-by-hop distance vector routing protocol requiring each node to periodically broadcast routing updates based on the idea of classical Bellman-Ford Routing algorithm [8]. Each node maintains a routing table listing the "next hop" for each reachable destination, number of hops to reach destination and the sequence number assigned by destination node. To avoid loop formation distinguish stale routs from new ones. Routing tables are periodically transmitted to their immediate neighbor by stations and also transmits if changes are occurred from the last update sent in a table. Because of that update is time-driven and event-driven. Full dump or an incremental update sent is the two ways of routing table updates.

Location aided routing (LAR)

To reduce overhead due to flooding LAR is an improvement and to decrease overhead LAR send the route request only to a particular area including destination. LAR uses two zones: Request zone and Expected zone. Expected zone includes the region where the destination is located. The request zone can be expanded covering entire network on unsuccessful path discoveries. The route request flooding is restricted to a request zone during route discovery procedure containing the location of the sender node and expected zone. Hence there should be a careful balance between reduced overhead and increased latency

Chapter 2:

2 Literature Survey

Daly, Elizabeth M. et al.[1] proposed the message delivers in Mobile Ad hoc Networks which is difficult causing the fact of rarely connected network graph. The main task is to find a route which provides best delivery performance and less delay in the disconnected graph network where the nodes are freely moved. The author proposed a multidisciplinary based solution to the consider the small world dynamics that can be proposed for social and economy studies and have lately revealed to be a powerful approach to be expressed for characterizing the propagation information in a wireless networks. For this purpose, some nodes of bridge are identified that based on the characteristics, e.g., the broker capability information exchanges among disconnected nodes. With the complexity of centrality metrics in well-known networks the main topic of ego networks are exploited, the nodes are not needed to interchange the information about whole network topology, but consider local available information only. In this, SimBet Routing is expressed that exploits the interchange of pre-estimated 'betweenness' locally determined and centrality metrics social 'similarity' to the end node. Moreover, displays simulations while using the dynamic trace data to define the Routing results of SimBet in the close delivery performance to the Epidemic Routing but significantly decreased overhead. In addition, it displays the Sim-Bet Routing performs PRoPHET Routing, specifically when the receiving and sending nodes have less connectivity.

Hui, Pan et al. [2] proposed the social structures to prolong the understanding of human mobility to the use of structures in the design of sending algorithms to Pocket Switched Networks. In the real world, get the human mobility traces that discover the human interaction which is heterogeneous in hubs and communities or groups. More

so, author proposed a BUBBLE, which is a social based forwarding algorithm displayed empirically to increase the forwarding effectively significant comparing the oblivious forwarding schemes and to the PROPHET algorithm. It displays an algorithm which can be implemented in other distributed way that demonstrates in decentralized environment of the PSNs.

Lee, Kyunghan, et al. [3] proposed the combined optimization of link routing, scheduling for disruption-tolerant networks. In Delay Tolerant Networks, the optimization problems are typically solved for resource allocation in dynamic programming that needs the knowledge of future events like meeting durations and schedules. Author defines a newest notion optimality of Delay Tolerant Networks, called optimality snapshot where all the nodes has not clairvoyant, i.e., did not look ahead into events, and therefore decisions are created with the use of available contemporarily knowledge. Unfortunately, the accurate solution for snapshot are optimality stable which solves the problem of NP hard maximum weight set and a global information of presently owns a copy and what the probabilities of delivery are. A newest effective approximation algorithm, which is called Distributed Max-Contribution that perform greedy routing, scheduling based only on contemporarily and local available information. With the simulation real GPS trace tracks over four thousand taxies for 30 days in huge city; DMC performs the heuristically engineered existing resource allocation algorithms for Delay Tolerant Networks.

Liu, Jieyan et al.[4] proposed that routing process in Delay Tolerant Networks is a challenge causing the fact of network graph is intermittently connected. Although, the routing benefits are considered if gets the advantages of information concern nodes mobility, lately studies are shown location visiting of human preferences in daily mobility traces, considers a stable and common property of human, with the utilization design of routing algorithm for social-oriented. In this paper, author preference is

considered location-based routing strategy. Mainly focuses on three aspects, the long term behavior that offers the method of getting one's preference places, then the close metric that measures the degree of proximity of two nodes, on the basis of data forwarding algorithm. Some simulations are based on the real mobility traces which show the two relevant routing protocols in Delay Tolerant Networks, PLBR technique achieves good tradeoff between the delivery of data ratio/delay or delivery overhead.

Jacquet, Philippe et al.[5] proposed the understanding of fundamental concept of performance limits in mobile and DTNs, where multi-hop end-to-end paths are not exist and communication routes would be available through mobility and time. In this, use analytical tools to run generic theoretical upper bounds for information propagation speed in large scale intermittently connected networks. In other side, upper-bound may optimal performance, in terms of delay, that can be taken with the use of routing algorithm. Moreover, show the analysis that can be applied to particular mobility and graph models to attain particular analytical estimates. In specific, two-dimensional network nodes are moved at the highest speed v and density is small to prove the propagation information speed is upper which bounded by random way-point model, during it is upper bounded by O(pvv) for the other mobility models (random walk, Brownian motion). The simulations are confirmed the validity of bounds in some scenarios. At the end, generalize the results of one-dimensional and 3-dimensional networks.

Neely, Michael et al.[6] investigates the problem of allocated energy of renewable sources to the flexible consumers in electricity markets. There is a latest energy supplier that gives energy with time-varying supply process. The plant serves to the consumers within a particular delay window, and incurs a cost of drawing energy from another source if its supply has not sufficient to complete the deadlines. Formulate two stochastic optimization problems: firstly it minimizes the time average cost of other

sources. The second lets the latest source to uniformly set a price for service, and seems to increase the resulting time average profit. These problems have been solved via the Lyapunov optimization technique. Our algorithm does not need any knowledge of statistics of demand processes and time-varying supply and robust to arbitrary sample path variations.

Hui, Pan, [7] increases the penetration of smart devices with capability of networking form novel networks. Such networks, also referred as Pocket Switched Networks are intermittently connected and display a paradigm shift of transmitting the data in ad-hoc manner. The social interaction and structure of users like devices dictate performance of routing protocols in PSNs. At the end, social information is an important metric for designing forwarding algorithms for types of networks. Previous techniques relied on the building and updating the routing tables to cope with real network conditions. In the nutshell, it has been displayed the approaches have being cost ineffective with the partial capture of transient network behaviour. One more approach is to capture the intrinsic features of such networks and utilize the design of routing algorithms. In this, express the two structural and social metrics, namely community and centrality, with the use of real human mobility traces. The contributions are two-folded. First one is to design and include the BUBBLE, a social-based forwarding algorithm that utilizes the metrics to increase the delivery performance. Second technique shows the BUBBLE that can be substantially improve forwarding performance comparing to a number of algorithms containing the benchmarking history based on PROPHET algorithm, and social-based forwarding SimBet algorithm.

Zhu, Ying, et al.[8] DTNs lacks the continuous network connectivity. Routing in Delay tolerant networks is challenging that must handle network long delays, partitioning and dynamic topology in networks. In the recent years, social-based techniques that attempt to express social behaviours of Delay Tolerant Network nodes to take good

routing decision, have displayed better interests in Delay Tolerant Network the routing design. In this, the social properties in Delay Tolerant Networks, provides a survey of social-based DTN routing approaches. To prolong routing performance, these techniques take advantages of positive social characteristic like as community and friendship to assist packet transferring or consider the negative social characteristics like as selfishness. Some challenges are open challenging issues in social based schemes regarding the design of Delay Tolerant Network routing protocols.

Yao, Yuan, et al. [9] proposed stochastic based optimization approach to create server management decisions and distributed routing in context of large-scale that geographically distributed the data centres provides significant potential for expressing power cost reductions. An approach considers the decisions at distinct time scales and provides provable power cost and delay features. The utility of approach and robustness are illustrated via simulation-based experiments under the delay of tolerant workloads.

Li Yong, et al. [10] proposed the transmission approaches between the mobile nodes, delay-tolerant networks in routing that expresses the technique of opportunistic forwarding. Effective policies and algorithms for opportunistic transferring are important for increasing the message delivery probability during reduces of delivery cost. In this, the energy opportunistic to forward the Delay Tolerant Networks has been discussed. Firstly, the message model which is dissemination by time of Markov framework. The approach based on framework to solve the optimization problem of opportunistic forwarding, while some constraints of energy are consumed by message delivery for both epidemic forwarding and two-hop. It based on the solution of optimization problem that design the distinct kinds of forwarding policies like dynamic and static policies. These policies find the dynamic policy threshold which is relevant for both epidemic and two-hop forwarding. By results of simulation, shows the

correctness of continuous-time Markov analysis model. Moreover, through extensive numerical results, to demonstrate the performance of threshold dynamic policy is static and continuous dynamic policies, and dynamic policies may negative-power policy offers relatively better performance.

Sollazzo, Giuseppe et al. [11] proposed the content dissemination applications which are becoming more popular in the fixed infrastructure. TACO-DTN is a content dissemination system by virtue of time-aware in the terms of events and subscriptions, which is appropriate for delay tolerant networks, where the number of nodes are act as an info stations, keeping the form of connectivity to backbone, and some nodes are mobile devices, reachable or sometimes they through the intermittent connectivity of carriers. These applications are benefiting such as system could to be travel information systems in huge cities or on highways, information dissemination to the remote villages, and advertisements dissemination at specific times. The technique is based on the novel concept of temporal utility of events and subscriptions. The temporal utility has been used to govern the routing of events to right info station, to avoid the unwanted information transfers on the buffer management and slow links, in case buffer limitations. The description of protocol has been described and discussed the validation of simulation.

Li, Qinghua, et al. [12] proposed the current routing algorithms for DTNs nodes are used to forward the packets for others. In real world most people are selfish socially; i.e., they forward the packets for nodes to them with they are social ties but not to others, and this willingness can be varied with the strength of social tie. The philosophy of design has been followed for user which a Social Selfishness Aware Routing algorithm to cope the user selfishness and give better routing performance in an effective way. To choose an efficient forwarding node, SSAR may consider the both users contact opportunity and willingness to forward, and runs a metric with

mathematical modeling and techniques of machine learning to measure the forwarding capability of mobile nodes. More so, Social Selfishness Aware Routing formulates data forwarding process to the Multiple Knapsack Problem with Assignment Restrictions to complete the user demands of performance and selfishness. Trace-driven simulations display that Social Selfishness Aware Routing lets users to maintain selfishness and takes better routing performance with less transmission cost.

Lindgren, Anders et al. [13] proposed the Delay Tolerant Networking has a lot of attention from research community in later years. The work has been done of network architectures and algorithms for forwarding and routing in networks. In the same time of many enthusiasms are displayed for new research area which has many skeptics and usefulness of research area. Other research areas have become over-hyped and die out there has no any killer app for them that it made them helpful in real scenarios. Real deployments of Delay Tolerant Networking systems have so far commonly been limited to some niche scenarios, where they have done as proof-of-concept field tests in the research projects. In this, embark a question to find out the characteristics of potential killer application for Delay Tolerant Networking. There are various applications and situations of Delay Tolerant Networking that provides the services that has not be taken otherwise, or have potential to do it in a good way than other techniques. Moreover, some of the main challenges that require solving the applications and make Delay Tolerant Networking a part of the mainstream of network landscape.

Conan, Vaniaet al. [14] proposed multi-hop or a single copy opportunistic routing approach for sparse DTNs. The approach uses only input estimates of average contact times between the nodes in the network. It defines as fixed point of a recursive process and aims at less delivery time in independent exponential pair-wise inter-contacts. The properties of loop-free sending and polynomial convergence create the approach workable for routing in Delay Tolerant Networks. The routing performances of this

approach are included on three publicly available reference data sets. Comparisons with popular single-copy schemes, containing MED and consistently demonstrate improvements, the two hop relay strategy for both delivery ratio and delay.

Karlsson, Gunnar, et al.[15] proposed several asynchronous communication conditions for the prevalent continuous connectivity circuit is not needed. Communication with less delay tolerance can be provided by intermittent store-and-transferring between nodes. This proposes a created design for an open broadcasting system that connects to delay-tolerant transferring of data chunks via mobility of wireless nodes. The system gives public broadcast channels that may be used openly for both reception and transmission. It displayed the simulation and analysis under benchmark mobility models which delay-tolerant broadcast channel has sufficiently high throughput and arrives to be interesting as a competitive alternative to regulated wireless broadcast channel. The analysis scheme is depends on queuing model to the interactions among multiple mobile nodes in a street. The analysis of simulations complement for mobile nodes moved to square according to the benchmark mobility models. Finally, displays a design of, and experiences with, a proof-of-concept prototype.

Fall, Kevin et al. [16]proposed the well-designed successful architecture or several protocols of today's Internet which may operate slowly in environments characterized by long delay paths and frequent partitions of network. These problems are discussed by end nodes with limited memory resources and power. Often take it in the extreme and mobile environments lacks of continuous connectivity, several networks have their specialized protocols, and doesn't utilize IP. To get the interoperability between them, a network application and architecture interface structured with optionally-reliable of asynchronous message forwarding, with the limited expectations of connectivity and node resources. This architecture can operate as an overlay to transport layers of networks if it interconnects, and give main services like interoperable naming, auth as

in-network data storage and retransmission, enticated forwarding and a coarse-grained class of service.

Fischer, Daniel, et al.[17] proposed the simulation that means evaluating the mobile applications which are depends on the ad-hoc networks. It has been kept to design the large mobility models for changing the realistic movement of user under the physically constraints. In the later years, the newest model of social mobility has risen. These SMMs model are the social aspects of human mobility, e.g. users meet, when or how often. This information can be indispensable for simulation of a large range of socially-aware protocols mostly that based on the delay-tolerant networks, including the opportunistic data dissemination and adhoc routing systems. Each SMM requires a model of relations between the set of relevant people in order to explain their mobility. The existing SMM lacks the flexibility when each one has been specific implicitly restricted, simplifying SNM. It displays the GeSoMo, a newest SMM which differentiate the base model of mobility from structural description of social network underlying the simulation. This elegant design principle provides GeSoMo generalizing power: Arbitrary including and future SNMs has been used without the changes of GeSoMo itself. Our evaluation results display the GeSoMo that generates the simulations that are coherent with large range of fixed data defining in the real-world mobility and human social behaviour.

Bulut, Eyuphan et al.[18] proposed the routing in DTNs have a great interest recently. Increasing the well-known type of delay tolerant networks are mobile social networks, which are called pocket switched networks. However, analyzing correct social network properties which have become a vital issue in design the efficient routing protocols for mobile social networks. In this, firstly discuss a metric for detecting quality of

friendships accurately. Using the discussed metric, each node has defined its friendship community for the set of nodes which have closest friendship with either indirectly or directly. Friendship Based Routing in temporally differentiated friendships which are used to create the forwarding decisions of messages. The real trace-driven simulation results displayed the algorithm achieves which has better delivery rate during forwarding fewer messages than the existing algorithms.

Zakhary, Sameh, et al.[19] proposed the improved position of privacy for users those are accessing the location-based services in opportunistic DTNs. The designed protocol offers position privacy through request location obfuscation technique that uses the nodes' to own social network to run the forwarding heuristic. A fully distributed SLPD utilizes social ties between the nodes to make K-Anonymity, i.e. the requesting node's location has not defined by least k-1 from the other nodes in the social network. Social based place privacy protocol has been used with real connectivity data traces and extended simulations. Compare a benchmark protocol which is required by the centralized trusted server. In the distributed protocol Delay Tolerant Network is applicable with several mobility patterns, or gives the required privacy which is 30% less than the defined privacy range. Social based location privacy protocol achieves success ratios same as the ones attained using centralized benchmark solutions up to fifteen percent privacy requirements.

Zhuo, Xuejun, et al.[20] proposed the popularization of handset mobile devices, like smartphone, that enables to inter-connectivity with mobile users without getting the infrastructure support of Internet. When users are moved and contacted to each other opportunistically, they get (DTN) Delay Tolerant Network that can be expressed to share the data among them. Data replication is a common technique for data sharing. Although, the unstable network topology and contact limited duration in Delay Tolerant Networks make it difficult to directly apply data replication schemes.

Although there are some studies on data replication in Delay Tolerant Networks, they normally ignore the contact duration limits. In this, arrange the deficiency of current data replication approaches that treat the complete data item of replication unit, and report the replicate data at packet level. Moreover, it analytically describes the contact duration to aware the data replication problem and centralized solution for better storage buffers and contact opportunities. Furthermore, it proposed a practical contact Aware Replication Algorithm that operates in fully distributed manner and decreases the computational complexity. Extended simulations are realistic and synthetic traces display distributed approach achieves close-to-optimal performance, and performs existing replication schemes.

Soares, Vasco et al.[21] proposed the vehicular networks that are used by highly disruptive and intermittent dynamic network topology connectivity. In these network environments, a comprehensive path from the source to destination that does not exists on part of the time. VDTN architecture used to deal with connectivity constraints. Vehicular delay-tolerant network assumes bundle-oriented communication, asynchronous and a routing paradigm of store-carry-and-forward. A protocol for Vehicular delay-tolerant networks should create the best use of the tight resources in network nodes to make a path that exists over time. This proposes a Vehicular delay-tolerant network routing protocol, known GeoSpray that takes routing decisions which based on the geographical location data, and adds a hybrid and efficient approach between single copy and multiple-copy approaches. Firstly starts a multiple-copy scheme, spreading a limited no. of bundle copies to express alternative paths. Then, it switches to a transferring approach that gets the advantages of contact opportunities. It keeps improving the resources utilization of delivered bundles of network node. It is displayed the GeoSpray increases significantly the delivery probability and decreases

the delivery delay, comparing to the traditional multiple-copy routing protocols and single-copy non location-based

Walker, Brenton et al.[22] proposed the Mobile Wireless Delay-Tolerant Networks which are the wireless networks that effects from intermittent connectivity, but the enjoy benefit of these mobile nodes are not carried, stored and forwarded messages or packets, brings closer to the destinations with selective forwarded policy. The evaluation of Delay-Tolerant Network routing protocols are relied on the simulation because several theoretical mobility models are unable to display the mobility patterns that such protocols seek to get advantage of. In this analyses a mobility model that known as Localized Random Walk. This model is simple and incorporated into mathematical models, but it spatially localized to other mobility models makes possible to show properties of the heuristic-based Delay-Tolerant Network routing protocols. The spatial stationary distribution of mobility model, approximate call its spatial cross section, estimates the properties of interaction with following nodes other mobility models, and use the model some relatively simple Delay-Tolerant Network scenarios.

Bulut, Eyuphan et al.[23] In a delay tolerant network), nodes are intermittently connected and the future unknown node have their connections. In these type networks, a connected path from one place to other place has been unlike to exist, and message delivery opportunistic routing. However, effective forwarding based limited knowledge of contact behaviour of nodes is challenging. Most of previous studies are looked at only relations based on the pair wise node to decide the routing. On the other side, analysis of correlation meetings in the each node that focuses on utilization of correlation for effective and efficient messages routing. Moreover a new metric has been defined called that based on the conditional inter-meeting time that calculates an average time between two relative nodes with third node using the knowledge of past contacts. Then, display the utilization of proposed metric on the current Delay-Tolerant

Network routing protocols to prolong their performance. For the shortest-path routing protocols in Delay-Tolerant Networks to route the messages over shortest paths in link cost between nodes which are defined by conditional inter-meeting times. More so, for metric-based forwarding protocols to uses the conditional inter-meeting time additional delivery metric during forwarding the decisions of message. Our trace-driven simulations on three distinct datasets show that the modified algorithms perform the better and original ones.

Bulut, Eyuphan et al. [24] proposed Delay tolerant networks are the wireless mobile network that lacks the continuous network connectivity. The multicast compatibles with distribution of data to group of users, a service needs for several potential Delay tolerant networks applications. During multicasting in Internet and mobile ad hoc networks has studied extensively, due to the unique characteristic of frequent partitioning in Delay tolerant networks, multicasting in Delay tolerant networks which is considerably challenging and different problem. It does not require newest destinations of multicast semantics, but also brings issues to the design of routing algorithms. In this, newest forwarding models for Delay tolerant networks multicast and develop various multicast forwarding algorithms. We use delegation forwarding in Delay tolerant networks multicast and compares it with multiple copy multicast models that are designed by us. The effectiveness of approach is verified with extensive simulation.

Liu, Cong et al.[25] proposed the introduction of DTNs that based on the nondeterministic connectivity and mobility. The message routing in Delay Tolerant Networks mainly employs a multi-copy approach. To reduce the cost associated with flooding, much effort focused on opportunistic forwarding to decrease the cost of

transferring while obtaining large routing performance to forward the messages to other nodes which have large delivery probabilities. This displays two multi-copy forwarding protocols, known optimal opportunistic forwarding and OOF-, which increases the expected delivery rate and less expected delay, while getting the number of sending per message does not increase a certain threshold. All contributions are summarized as follows: apply the stopping rule in the multi-copy forwarding protocol. Specifically, two optimal opportunistic forwarding metrics to increase delivery probability and less delay, respectively, with a fix number of copies and within given time-to-live. Then implement and evaluate OOF as well as various representative forwarding protocols, i.e., Spray-and-wait, Epidemic, MaxProp, and Delegation. The trace-driven simulations are using synthetic and real trace. Simulation results display that, in traces where nodes have regular inter-meeting times, the delivery rates of OOF can be Thirty percent larger than the compared routing protocols.

Wu, Jie, et al.[26] proposed that several routing protocols for delay tolerant networks to sufficient state information, with trajectory and information, to ensure routing efficiency. Although the state information tend to be real and hard to attain without taking global or collection processes of long terms. The internal social features of node in network to perform routing process. This is motivated from various social networks, such as the Infocom 2006 trace, where the people contact to each other frequently if they have social features in common. It includes two processes: multi-path routing and social feature extraction. In this social feature extraction, entropy to extend the informative social features to makes a feature space, where the Fi corresponds to features. The routing technique becomes a hypercube based matching process where routing process is step-by-step and feature resolving process. They two special multi-path routing techniques: node-disjoint- routing and delegation routing. Extended simulations to both

synthetic and real traces are conducted in the comparison of several existing schemes, spray and- focus routing and spray-and-wait routing.

Daly, Elizabeth M.[27] proposed a sparse mobile ad hoc network that is difficult to fact the network graph which is rarely connected. The main challenge is to search a route with good delivery performance and less end-to-end delay in disconnected network graph where the nodes are moved freely. An information flow problem has been followed in a social network. This social network analysis the metrics that can be uses to support forwarding solution to efficient message delivery in the disconnected delay-tolerant mobile ad hoc networks. These metrics are based on past interactions node's of social analysis and adds three local executed components: a "betweenness" node's centrality node's social "similarity" to destination node, and node's tie strength relationship with destination node. It simulations with the use of three real trace data sets to describe the metrics delivery performance that get close to Epidemic Routing with significantly decreased overhead. In addition, it improves the performance when compares to the PRoPHET Routing.

Cao, Yue,[28] proposed the intelligent devices with minimum range of wireless communication schemes which are motivated development of Mobile Ad hoc networks from the last few years. However, the traditional end-to-end routing algorithms designed for Mobile Ad hoc networks with much strong in challenged networks suffer from disruption, device capability and sparse network density. Such challenged networks, also known as Intermittently Connected Networks adopt the Store-Carry-Forward behaviour arise the mobility of mobile nodes for the message relaying. In this ICNs as Delay/Disruption Tolerant Networks for generalization, since Delay Tolerant Networks are envisioned for different applications with a large number of proposed routing algorithms. It is motivated by great interest from research community, the existing uni-casting issue of Delay Tolerant Networks because of its extensive research

stages. It addresses the multicasting and any casting issues in the Delay Tolerant Networks considering their perspectives. A detail survey has based on the taxonomy over period from 2006 to 2010 which is not only given comparison is given. Furthermore identifies the remaining challenges and open issues which have been followed by an evaluation framework for routing in Delay Tolerant Networks. Finally summarize the contribution with three future research topics highlighted.

Bulut, Eyuphan[29] proposed the routing in delay tolerant networks which is a big challenge due to intermittent connectivity between resulting nodes in frequent absence of end path for any source-destination pair at provided time. Lately, this problem is attracted a good deal of interest and various schemes have been proposed. Since the mobile social networks are popular type of Delay Tolerant Networks, creating correct analysis of social network properties of networks which is important for designing with efficient routing protocols. In this, a new metric detects the high quality of friendship between the accurate nodes. Then, utilizes the metric, each node has defined the community of set of nodes having closest friendship relations with itself directly or indirectly. Then, Friendship Based Routing in periodically differentiated friendship relations used in forwarding of messages. Extensive simulations on synthetic and real traces that show algorithm is efficient than existing algorithms.

Ahmed, Shabbir proposed that delay tolerant networks have been displayed to the exhibit power-law behaviour. Analysis of temporal connectivity graph of networks reveals to the existence of hubs, a fraction of nodes that are connected to the rest of nodes. In this, a forwarding novel strategy called Hub Code that seeks to get the hubs as message relays. These hubs used as random linear network coding for multiple messages addressed to same destination, thus decreasing the forwarding overheads. Furthermore, the use of hubs as relays ensures that multiple messages are delivered to destinations. Two versions of Hub Code are displayed with this method exhibiting

contrasting behaviour in terms of routing overheads and computational costs. A mathematical model for the message delivery delays and displays a closed-form expression for the same. It validates the model and demonstrate the efficacy of solutions in the comparison with forwarding approaches by simulating a large-scale vehicular DNA using empirically collected movement traces of a city-wide public transport network. Under the pragmatic assumptions that account for short contact durations between the nodes, our schemes are out perform comparable strategies by more.

Zhang et al. [30] proposed the benefits of random linear coding for uni-cast transmissions in DTN. The RLC has been used as a simple flooding to transmit the messages in the network. Hence, the transmitting native messages or a node combines with these messages to the form which has encoded the message and forward to encoded message to neighbours. These coefficients are used in encoding process are transmitted with the message. These messages are decoded at end place, when it receives a sufficient number of encoded messages. The proposed method uses network coding for the forwarding messages. Although there are two main differences, first one is the flooding encoded messages in network, the power-law leverage properties of network and chooses a less fraction of nodes that have large connectivity, the relay nodes. Second one, only the hubs are mainly responsible for these coded messages.

Chapter 3:

3.1 PROBLEM FORMULATION

In a sparse network the links between nodes are very fewer, so the problem of routing arises. In a network the data from one node to the other is routed through different intermediate nodes. In sparse networks the node density of the network is less so it is difficult to route the data efficiently.

Link density of a network is calculated, which is the measure of the successful transmissions of data from one node to another in a network. The link density is calculated using the formula

$$d = \frac{2m}{N(N-1)}$$

Where, d is the link density of a network having m links and the total number of nodes in the network are N.

Centrality is the measure of the importance of a node compared to other nodes in the network. It is perhaps the measure of the social power of a node and the influential abilities of the given node in the network. Network thinking has also contributed immensely in order to measure the social power. Network thinking approach also emphasizes on the inherent relatedness of the nodes. For a network which is loosely coupled i.e having less number of nodes, the amount of power exerted by the *node of importance* is also less while in high density networks the power is greater. So amount of power can vary largely and based on the number of nodes. Power in social network can be seen as both systematic means the power in the network is equally divides among

nodes and relational means it is unequally distributed. In social network power can be viewed as both systematic and relational, in former one node is believed to describe the entire population and later describes the relation between different nodes.

The Degree Centrality is the measure of the ties of a node with other nodes. The node with the higher degree of centrality is always in advantageous position when it comes to data routing from one node to another.

The degree centrality is given by the formula

$$C(ni) = \sum_{k=1}^{N} a(ni, nk)$$

Here $a(ni, nk)$ is a binary value, if a link exists between node i and node k the value of C (ni) is '1' otherwise '0' and also $i \neq k$.

Closeness is described as the shortest distance between the concerned nodes with every other node in the network. If a node is within reach to many other nodes in the network then the node concerned is more powerful as compared to other nodes in the network. Closeness Centrality measures the shortest path between the nodes. It can be regarded as the time elapsed in spreading the information in the network by the concerned node.

$$C_c(ni) = \frac{N-1}{\sum_{k=1}^{N} d(ni, nk)}$$

Where, $d(ni, nk)$ is the distance between the nodes $ni\ and\ nk$.

Betweenness means the extent to which a node lies between the two nodes in the path and the data is routed through that node. It shows that the middle node has the control over data which is flowing between the source and the destination node. A node with high value of betweenness means that how well that node provides the link between the two nodes. Betweenness Centrality is calculated as

$$C_B(ni) = \sum_{j=1}^{N} \sum_{k=1}^{j-1} \frac{g_{jk}(ni)}{g_{jk}}$$

Here g_{jk} is the number of geodesic paths between nj and nk and $g_{jk}(ni)$ the number of paths which includes ni .

3.1.1 Similarity and Betweenness Centrality Calculation and its challenges

Similarity is calculated using the $n \times n$ matrix and the common neighbour between nodes $i \; and \; j$ is the simple count of the non-zero values of the of rows in the matrix.

Betweenness Centrality is calculated using an ego network matrix representation with which this node comes in contact with the number of nodes.

SimBet Utility Function

SimBet Utility function is a combination of Similarity Utility function and Betweenness Utility function and its value varies between 0 and 1. Similarity Utility function is given by

$$SimUtil_n(d) = \frac{Sim_m(d)}{Sim_m(d) + \; Sim_n(d)}$$

And Betweenness Utility function is given by

$$BetUtil_n = \frac{Bet_n}{Bet_n + \; Bet_m}$$

So the SimBet Utility $SimBetUtil_n(d)$ Function can be calculated as

$$SimBetUtil_n(d) = \alpha SimUtil_n(d) + \; \beta BetUtil_n$$

Where $\alpha + \beta = 1$ are the tunable parameters.

The major challenges related to the thesis work are

- To reduce the packet data loss as there are very fewer nodes in the network the packet data loss during communication is high.
- To make the decision for the node which is selected to carry the packets in the network, the parameter of foremost importance related to the decision is trust.
- An Opinion Dynamics based model is used to calculate the trust of the node based on recommendations of the other nodes.
- The developed algorithm is analyzed on the basis of packet data loss and stability in the network.

Chapter 4:

4.1 Proposed Methodology

In this work, we propose a method of data transfer and communication in sparse network. As the number of nodes in a sparse network is fewer, the data transfer between the nodes is difficult. So we must be careful while selecting the nodes for the routing and data transfer. The decision for the selection of nodes for data transfer is based on few parameters. These parameters include the trust of the node which is calculated using the Opinion Dynamics model discussed later in the chapter. According to this model, the trust of a node is based on the opinion of its neighbour nodes and also the previous interactions of the node with the concerned node.

The nodes with the high trust value and the minimum number of retransmissions are selected as the retransmitted node for the concerned node. If there is no node present which is used to retransmit or satisfy the above criteria of trusted node then the node concerned will take its data forward until it find the trusted node.

The main advantage of the selection of trusted node as the retransmission node is that the data which we want to retransmit does not require any encoding technique to secure the data, as we can directly retransmit the data to the next node until it reaches the destination.

4.1.1 Human Opinion Dynamics Model

Modeling human behaviour has been an interesting area of research for quite a time now and a lot of theories have been put forward to emulate the real life dynamics into a mathematical model. HOD is one such recent area which has been recently claimed to solve complex optimization problem. Although roots of this approach lies in SITO, they

are found to have limited utility in high dimensionality problems and are based on discrete opinion formation. HOD model is utilized to develop an optimizer referred as Continuous Opinion Dynamics Optimizer (CODO).

The model is based on the opinion formation mechanism of a group of individuals during a discussion and has four basic elements- social structure, opinion space, social influence and update rule. Social structure forms the platform for different individuals to interact with each other where each individual are placed on the nodes of the social graph. A cellular automata model is employed with a modified form of Moore's neighborhood where all the individuals are included as neighbours of each other rather than immediate orthogonal members as in Van Neumann topology or all immediate eight neighbours as in simplistic Moore's topology. Opinion space is different from the social space and refers to a hyperspace, where the opinions of each individual affects each other and is modified under a certain update rule. An important difference of HOD based optimization from PSO is that, in opinion space, collision is possible, i.e. two individuals can have same opinion at a time while two insects cannot have the same position in the swarm at a time. Opinions are considered to be continuous here to suit our problem of optimization where optimizing parameters can have any value within a finite range. Opinions are influenced by the opinions of its neighbours depending on their social influence which is defined here as the ratio of social rank of any individual to the distance between them and is given by:

$$w_{ij} = \frac{SR_j(t)}{d_{ij}(t)}.$$

Here, SR is determined by the inverse of the fitness value of an individual, where fitness value is the error which needs to be minimized. Each individual's opinion is updated by the following rule given as:

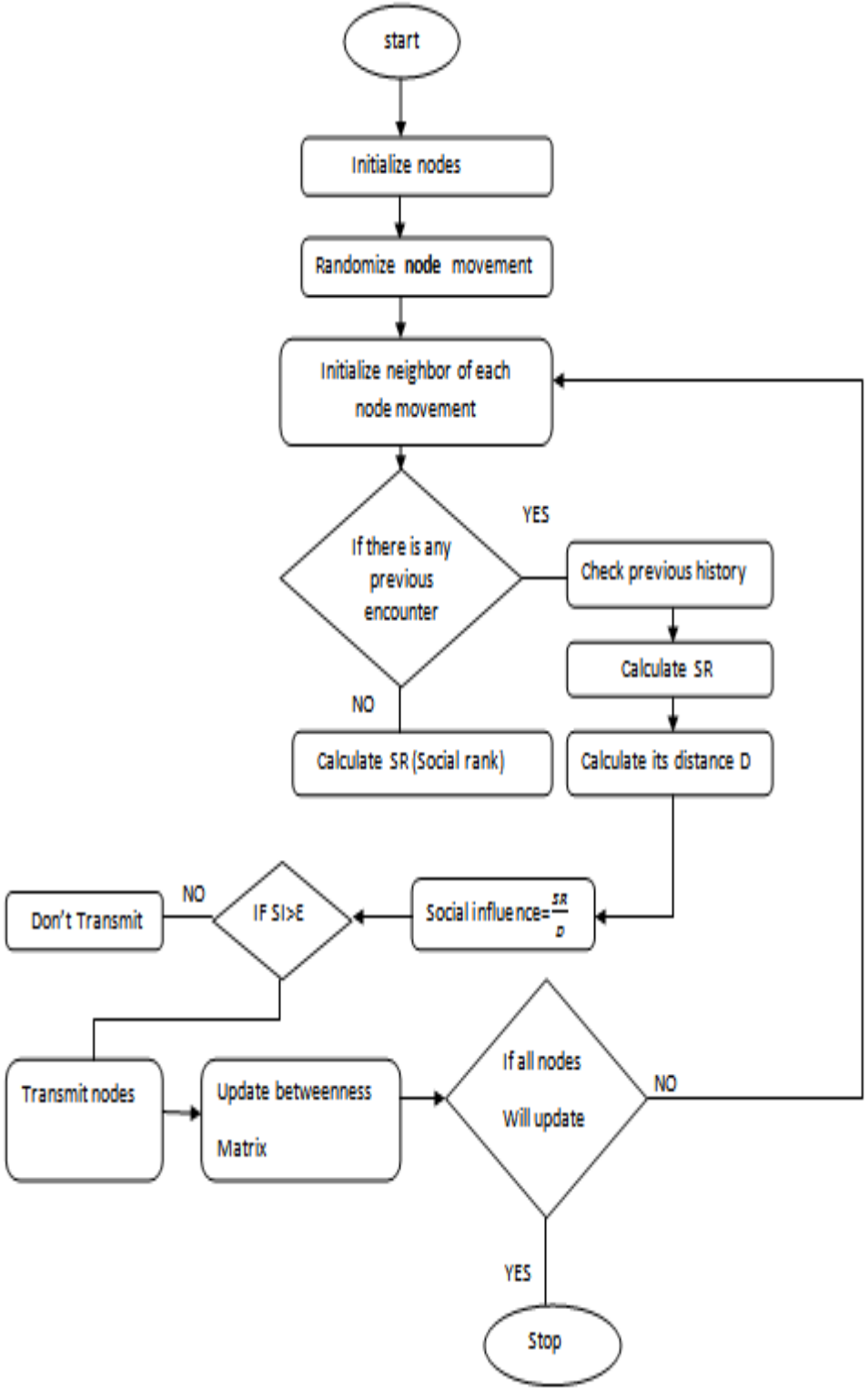
$$\Delta o_i = \frac{\sum_{j=1}^{N} (o_j(t) - o_i(t)) w_{ij}(t)}{\sum_{j=1}^{N} w_{ij}(t)} + \eta_i(t), j \neq i,$$

Where oj(t) is the opinion of neighbours of individual i, wij is the social influence factor, and η is adaptive noise introduced to justify individualization in society after a certain consensus limit is reached. Individualizations phenomena are inspired by Durkheim's theory of division of labor in society which was used by(Mäs et al., 2010)to simulate a model where individualization co-exists along with integration in society. Similar context meaning was given by (Kennedy, 2010)to explain craziness factor introduced during development of PSO. The inclusion of this term makes the optimization algorithm more robust and increases its exploration capabilities, preventing it from being trapped in local extemum while encountering complex optimization problems. H is a normally distributed random noise with mean zero and standard deviation 'σ' and is given by:

$$\sigma_i(t) = S \sum_{j=1}^{N} e^{-f_{ij}(t)},$$

Where 'f' is the difference in fitness factor between ith and jth opinion and S denotes the strength of disintegrating force. S needs to be adjusted as a compromise between individualisation and integration i.e. as more number of individuals attains similar fitness, individualisation increases. This increases the robustness of the algorithm at the cost of convergence rate.

4.1.2 PROPOSED ALGORITHM



Chapter 5:

5.1 Results and Discussions

The above problem is simulated for a condition of 30 nodes distributed randomly in a 1000x1000 unit area. The nodes are given initial set of energies as specified above. Radio model of transmission has been considered. All the simulations are done on a PC of 4 GB RAM, 2.7 GHz processor on Network Simulator 2.35 in Ubuntu 14.04. The simulation results are shown below.

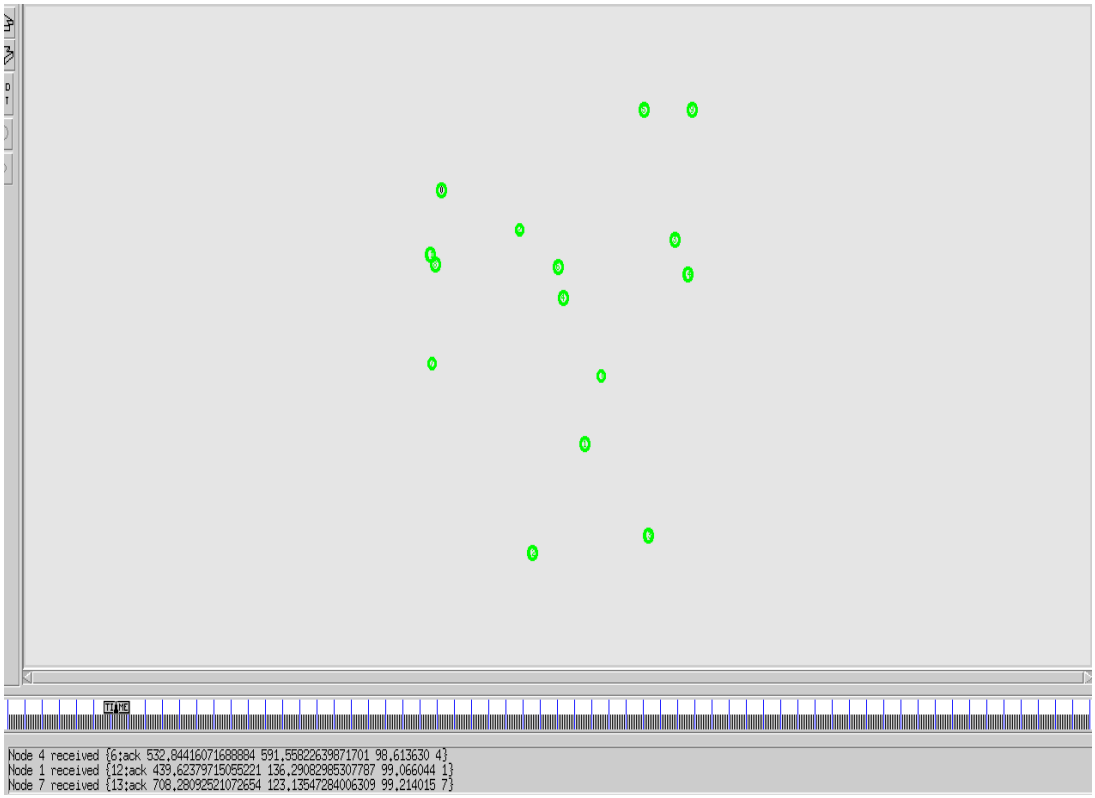


Figure 5 Random Deployment of Nodes in the Grid

Figure 5 shows the random deployment of nodes in a 1000x1000 Network Animator window. The simulation runs for 100 seconds.

Figure 6 shows the communication between the nodes in the grid. Here the nodes sending or receiving information at a particular time instant is also shown in the trace annotate monitor portion in the figure5 and figure6.

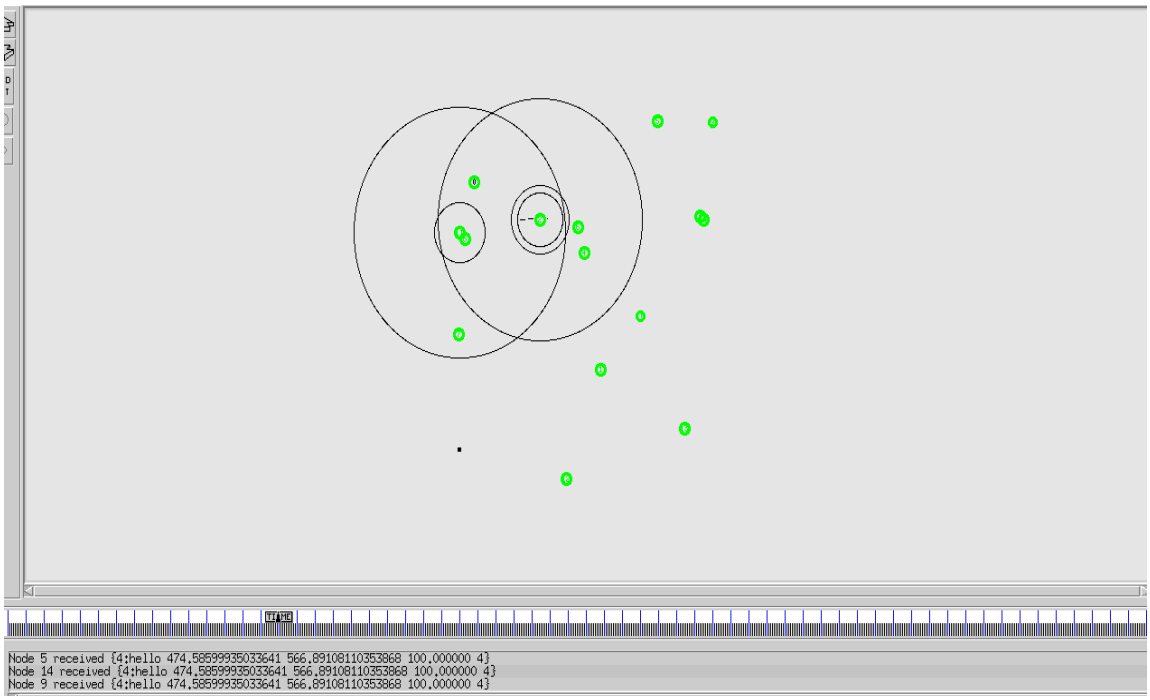


Figure 6 Communication between Nodes

Figure 7 shows the graph between the Average End to End Delay and the number of interactions. As it is shown in the graph that average end to end delay is less as compared to the value calculated using SimBet utility function. The graph shows a good difference between the output of the SimBet Function with or without applying the recommendations from other nodes. The lower value of average end to end delay is desirable and proves the efficacy of our algorithm. The decrease in a delay as compare to previous approach is approximately 5%.

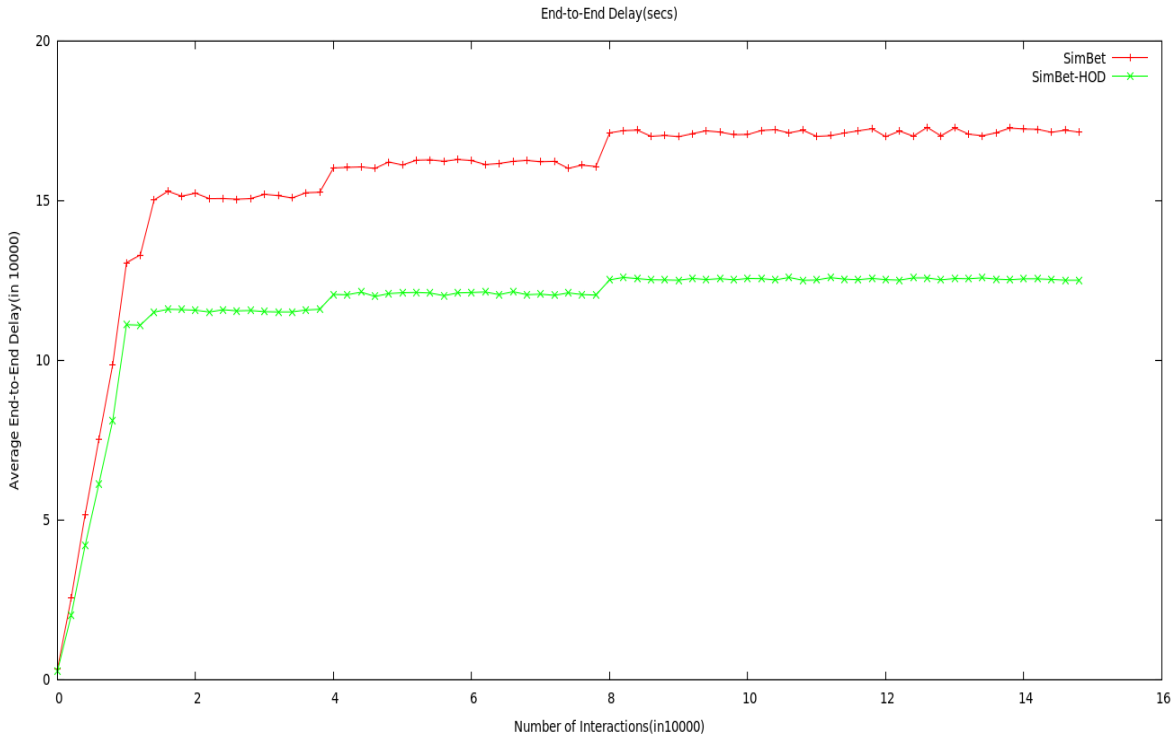


Figure 7 End-To-End Delay

Figure 8 shows the total number of forwards of message from each concerned node. The graph shows that after applying Human Opinion Dynamics Algorithm the total number of forwards of message from the node is reduced. The difference between both the techniques is not significant but the result shows that the number of forwards is reduced which in turn shows that the data is forwarded by the trusted nodes only.

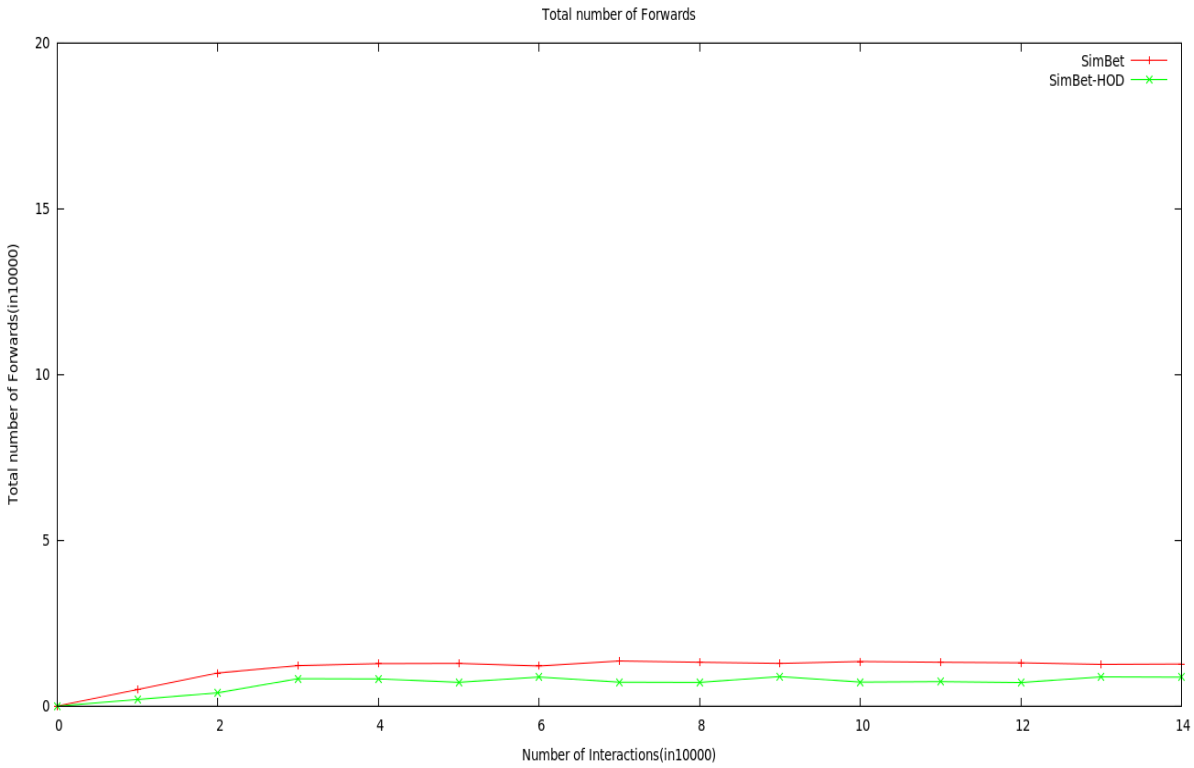


Figure 8 Total Number of Forwards

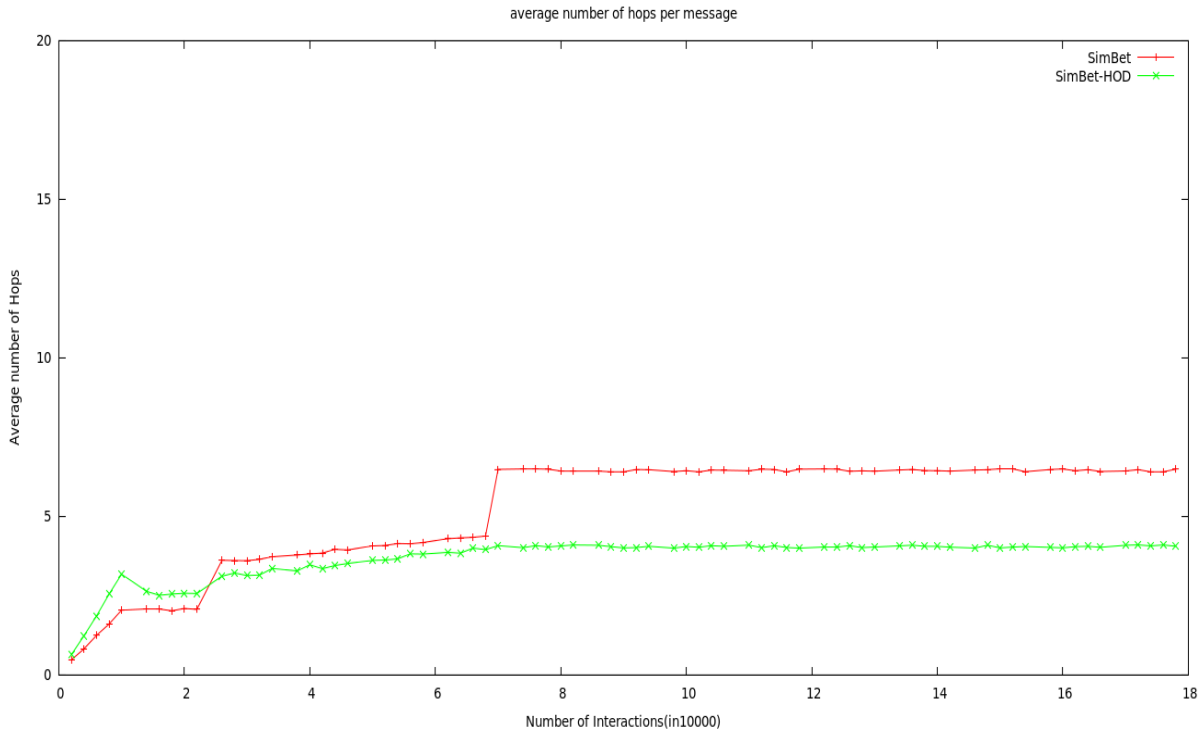


Figure 9 Average Number of Hops per Message

Figure 9 represents average number of hops per message in case of SimBet and SimBet HOD. The average number of hops is initially higher in case of our proposed algorithm as compared to that of the SimBet algorithm but decreases slowly as the number of iterations is increased. This is due to the fact that initially there is no opinion about the other nodes which starts accumulating over time and the social rank of each node starts updating. As it is updated, the average number of hops starts decreasing as there is optimal decision making due to HOD. The decrease in average number of hops per message is approximately 3%.

Chapter 6:

6.1 Conclusion and Future Scope

Human Opinion Dynamics Algorithm is used in order to solve the problem of data routing and communication in sparse network. There are very fewer nodes in a sparse network and there is a need to efficiently route the data in the sparse network via the trusted nodes. HOD algorithm is used to calculate the SimBet Utility function which is simply the similarity and betweenness function and a decision is taken according to the value returned by the algorithm. The opinion dynamics modeling includes optimization based on a model which selects on the basis of discussion taking place in a group. Social Rank and Social Influence Factor has been calculated. The opinions are updated based on the social influence factors.

It is shown that the average number of Hops per message is reduced and the total number of forwards from the concerned node and the average end to end delay is also reduced. In future, the scenario can be extended to higher levels. Also more experiments involving different number of nodes can be performed and analyzed.

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