International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:10, No:6, 2016

A Hypercube Social Feature Extraction and Multipath Routing in Delay Tolerant Networks

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***Abstract*—**Delay Tolerant Networks (DTN) which have sufficient state information include trajectory and contact information, to protect routing efficiency. However, state information is dynamic and hard to obtain without a global and/or long-term collection process. To deal with these problems, the internal social features of each node are introduced in the network to perform the routing process. This type of application is motivated from several human contact networks where people contact each other more frequently if they have more social features in common. Two unique processes were developed for this process; social feature extraction and multipath routing. The routing method then becomes a hypercube–based feature matching process. Furthermore, the effectiveness of multipath routing is evaluated and compared to that of single-path routing.

***Keywords*—**Delay tolerant networks, entropy, human contact networks, hyper cubes, multipath Routing, social features.

I. Introduction

DTNs are interplanetary networks which have sporadic connectivity and limited amount of network capacity. The concept of DTN specifies a network of regional networks supporting interoperability among them. There exist many different applications such as connectivity of developing countries, transport communications and human contact networks (HCNs) [10].

Most of the approaches consider the trajectory and past contact information of mobile nodes. Here state information is dynamic and hard to obtain without a global or long assortment method. DARKNET provides a wireless network to provide digital connectivity and provides broadband connectivity; finally, it connects peoples in rural areas through internet [1]. It takes advantages to start and forward network and provides seamless scalability. Drawbacks of radio communication are that do not support real time functions [2]. Routing for Vehicle-Based Disruption-Tolerant Networks is a protocol for effective routing of messages with the prioritizing schedule of packets. It has the advantage of minimizing the transmissions and can increase the delivery rate. [3]. Haggle is specially designed for mobile users for packet switched networking and allows the users to transfer data with the ability to develop mobile applications easier. The main drawback is it does not maintain the security. Epidemic routing for wireless network provides random pair-wise exchanges of messages among the mobile hosts and ensures the ultimate message delivery. The main advantage is maximizing the message delivery and minimizing the message latency. It also has the drawback of slow message delivery process [4]. Mobility increases the capacity of the nodes in random pairs of multicast diversity. The advantage of node mobility will improve the throughput capacity of wireless networks [5]. A novel community method was proposed for biological networks with the nodes of the network in group of clusters are combined together in compact manner, then it has a clustering effect to detect unauthorized access in that network [6]. A variable and feature selection methodology is proposed to find the subset of features from a set of features. It maximizes the learner's ability to classify patterns. It ranks the node features and performs mapping functions [7].

A hypercube parallel computing model is proposed to construct an interactive model from the Bluetooth devices for rapidly organizing a hypercube computing environment; which establishes routing path from Bluetooth devices. The main drawback of this model is provided to disjoint path in a shorter routing path in the network [8]. A type of social based forwarding in DTNs is exploited with two social metrics such as centrality and similarity. It is used in both online and offline applications with low cast applications. More social feature related algorithms are used to compute the common element with fast feature matching process will increase the delivery rate by reducing the end-to-end delay and maximized throughput [12]. Here one group has multiple numbers of nodes. Proposed methods showed how the state information is to be matched with feature techniques and how the performances are to be improved in routing process [11].

To perform efficient multipath routing, node-disjoint routing is used to enhance a hypercube-based parallel feature matching method. Feature variations are resolved in a step-by-step manner till the destination is reached. We have a tendency to additionally propose a feature matching shortcut algorithm for fast searching, which also ensures node-disjoint-ness [48]. Another way to achieve efficient multipath routing is to extend delegation forwarding [9].

The major benefactions of our work are as follows: We convert the HCN routing problem from the mobile contact space into the social feature space, and use entropy to extract the most informative features to create a hypercube. Routing can be done in DTN by using the concept of group

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organization with A-SMART [57].

Two efficient multipath routing schemes are used under the hypercube structure: Node-disjoint based multipath routing scheme and delegation based multipath routing scheme. The extended method of multipath routing is used to implement hypercube model and compared with the cost effectiveness of multipath routing and the cost effectiveness of single-path routing based on different metrics for path construction [42]. It includes social-aware routing for comparison, which increases the performance level in real traces. The simulation results show the competitive performance of multipath routing [36].

There is no permanent transportation in DWSN [13]. All nodes haphazardly share out in a convinced monitoring section and a smaller quantity of nodes can transfer. These nodes, which shape the network in self-organized approach, congregate and rearrange routinely based on the changing the assignment and network topology requirements will produce an impermanent network. This methodology can be acclimated by the node collapse. Every node is capable of accumulating and supervising the information using the built-in network workstation, and then they will broadcast the connected information to every routing manager node by using the representation of multi hop communication [14].

The interleaving development generates the rearranging process in the order of information symbols to be broadcasted based on an implementation rule [16]. At the recipient, the unique information symbols are regenerated based on the indirect rule [61], [62].

Sensor Protocols for Information via Negotiation [17] is a periodic-based data-transmission routing protocol which has the metadata of related information in order to use the innovative information to ascertain the active paths over a smooth Wireless Sensor Networks (WSNs). Initially, every beginning node sends the data indication message to its adjacent nodes using one-hop transmission. Every adjacent node is used to generate that it is in busy in data generating, optimizing and creating reports with acknowledgement to requesting packets. Ultimately, the beginning node sends the innovative information packet to any of its adjacent node who already sent a request for the particular packet. The middle nodes can generate an equivalent method to forward information packets while the sink node will receive the data packets. Moreover, the Protocol is unable to give guarantee for data delivery process because there will be a network disconnection or requested data packets lost. However, a new protocol [33] can be used to minimize the energy consumption as the middle sensor nodes which has been wasted the energy sources to reside the data in longer amount of time [63].

Directed Diffusion [19] is a query related routing protocol that generates data mining learning methodologies to transmit the data from the beginning node to the destination node with active data gathering [39]. The queries are intermittently generated by the sink node to confirm and energize the possible available path in the network. Upon accepting the aggregated packets, middle nodes store the updated active path of routing information of data packets in their confined tables to ascertain and reserve the possible arrival paths from the source nodes to the sink node. The updated routing confined table information is used for data aggregation process; then, the data packets will be broadcasted from the source nodes through the possible arrival paths in the Network [15]. The query aggregation process is replicated by middle node in expectation of the process acceptance by the source nodes that have aggregated data from the arrival paths. Since source nodes collect a quantity of comparable queries that are forwarded throughout alternative paths, they require to choose the most favourable path to describe data packets in the Network [18]. The optimized path is generated to forward the data packets through the sink node. All the other possible middle nodes are created as alternative paths when the selected possible paths are failed to send the data packet [21]. The middle nodes are responsible for aggregating and forwarding the data packets through the selected possible paths. Energy consumption is the key factor to broadcast the data packets [24]. The bottleneck problem will be reduced by this type of Directed Diffusion Methods. Power control strategies are used in collaborative networks for utilizing the network capacity [30]. Distributed Self-Healing Protocol is used to reduce the bottleneck problem in WSNs [51].

Minimum Cost Forwarding Algorithm [20] launches several routing paths from data regions to the sink node in which the routing path with the minimized cost and hop count is picked to send data packets. Using the modified algorithm of minimum cost forwarding algorithm, the recipient will likely to aggregate a quantity of incoming cost based packets before re-broadcasting them. It will reduce the traffic and subsequently minimize the energy consumption [22]. In the end, this has directed in the precedent to the abundance of repeated WSN exploitations [23]. Virtual Sensor Networks (VSNs) [25] or Software Defined Sensor Networks (SDSN) [26] are used to improve the efficiently with the limited amount of resource utilization, minimized cost, maximized flexibility and manageability in WSN deployments [28]. Network virtualization technologies are used in numerous synchronized applications [29].

Tree Based Opportunistic Routing (TBOR) is used to generate multipath threshold possibility of link scalability in MANET [27]. SenSHare [31] generates numerous superimpose sensor networks which are used by a distributed physical communications. UMADE [32] is an incorporated network for distributing and organizing real-time applications in distributed sensor networks with the conception of Quality of Monitoring. Middleware systems can represent multiple real-time applications [34]; a service-oriented middleware system is represented in [35]. A model of Software Defined WSN is proposed in [37] with the objective of supplementing limited energy resources. In [38], an optimization structure is used to increase the Quality of Monitoring in distributed sensor networks. The application assignment problem is solved by using game-theoretic tools [40]. The periodic applications have been used to distributed sensor nodes with the definitive target of increasing the lifetime of the sensor network [41], [45]. An optimization structure is developed to lengthen network lifetime by properly utilizing the network tasks in a distributed sensor network [43].

In [44], an overturn mathematical model is introduced in which the sensor nodes act as senders. In [46], the system performance has been evaluated using heuristic algorithm.

In [47], the optimization concept has been developed. The implementation of signal-to-interference-and-noise-ratio model was incorporated in [49]. By introducing a cognitive radio graph-theory based model, the system performance is categorized in terms of connectivity [50]. The hurdles of signal-to interference-ratio (SIR) model were categorized in [52]. The disseminated topology control algorithm is proposed so as to preserve the connectivity of derived networks [53]. In [55]. An improved approach is incorporated in physical models to utilize the network connectivity in cooperative cognitive networks [56], Optical Communication [58], satellite communication [59]. Security is established in MANET using SIPTAN [60] and EUDIS [54].

II. Social Feature Extraction

In social feature freeing we use entropy to extricate the m most instructive social characteristics to make a feature space (F-Space): (F_1, F_2, …….,F_i), where F_i compares to a feature.

A. Social features

Expect that there are N individuals in the framework. Each individual can be represented by a social feature profile, a representation of his/her social features inside a peculiarity space, likewise called the F-space. The social features represent either real features, such as contact details in a social group. In this paper, we convert the mobile and unstructured contact space (M-space) with N individuals into a static and structured feature space (F-space) with M groups (or simply nodes), each consisting of a set of individuals in M-space with the same features. Therefore, there is no one-to-one correspondence between an individual in the M-space and a group (node) in the F-space.

B. Feature Extraction with Entropy

The individuals are characterized by a high dimensional feature formation. However, generally only a small subset of features is important, extracted by the set of features by feature extraction method from data mining. There are N individuals with m' features, which are represented as F_1, F_2, … Fm'.

The goal of our social feature extraction process is to extract the most informative subset (MIS) with m (<m') key features. We use Shannon entropy, which filter the expected value of the information contained in the feature, to point the key features:

$$E(F_i)=-\sum P(x_k)\log_2 p(x_k), \quad (1)$$

where $\sum$ ranges from K=1 to N_i and (i=1,2,…..,m')

$$F_i=\{x_1,x_2,\ldots\ldots\ldots x_{ni}\} \quad (2)$$

where i=1,2,……..m', K={1,2,3,…….n}. Similarly, K= length and m=most informative features.

By selecting the most informative features:

Overall entropy function is:

$$E(F_i) = \frac{E(F_i)}{\Sigma\, E(F_i)} \quad (3)$$

where $E(F_i)$ represents the entropy of the feature F_i, p represents the probability mass function of the data F_i. $\{x_1, \ldots, x_{ni}\}$ are the possible values of F_i. Feature Selection parameters values are shown in Table I. We will extend this routing scheme by adding shortcuts for fast feature matching in multipath routing.

TABLE I
Feature Selection Parameters and Their Values

Feature Contacts	INFOCOM trace	MIT trace
0	51200	224500
1	6500	82300
2	4200	40100
3	2310	23200
4	1420	14100

III. Multipath Routing Scheme

Multipath routing is performed by node disjoint based and delegation based routing. Here node disjoint based routing performs highest delivery rate and low latency. Delegation based routing reduces the number of forwarding's.

A. Node Disjoint Based Routing

Here the copies are distributed to numerous node-disjoint paths to determine the characteristic dissimilarity between the source and destination. The source has m copies of the packet to send to the destination in k feature distances. In an m-D binary cube, there are k shortest paths of length k and m k non-shortest paths of length k þ 2, which are all node-disjoint.

In Algorithm 1, for the source node, the source sends (seq; mode) to a matching neighbor, where mode is 0 for a shortest path or 1 for a non-shortest path. seq is the result of a circular left shift of C0 for mode=0. D is the destination. The source also maintains two sets, d and d'. d is initialized as {1, 2, …, k), which are different features between the source and destination. d' is $\{k_i, k_{i+1}, \ldots, k_m\}$.

B. Algorithm 1. Node-Disjoint-Based Routing on Source Node

Source node contacts D or neighbor B in dimension i.

1. If B and D are in the same group then
2. Forward the packet to D.
3. else
4. case i € d: d = d/{i} and send (Ci,0) to B.
5. case i € d':d'=d'/{i} and send (C||I,1) to B.
6. case i €/ d U d': do nothing.

In Algorithm 2, for a non-source node, source routing is used when the routing path is determined by the packet header seq. Step 4 represents shortest-path routing, where a strict coordinate sequence order is followed through extracting the first dimension in C'. Step 5 corresponds to non-shortest path routing, where any permutation of dimension differences can be used.

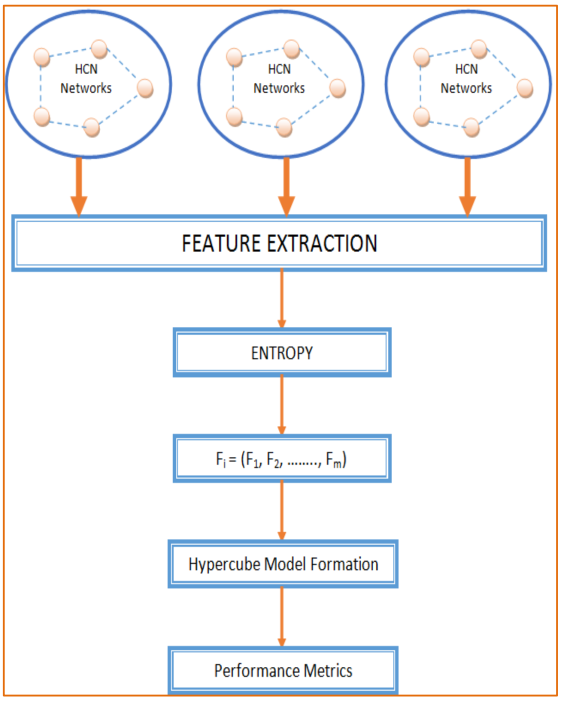

Fig. 1 Architecture Design

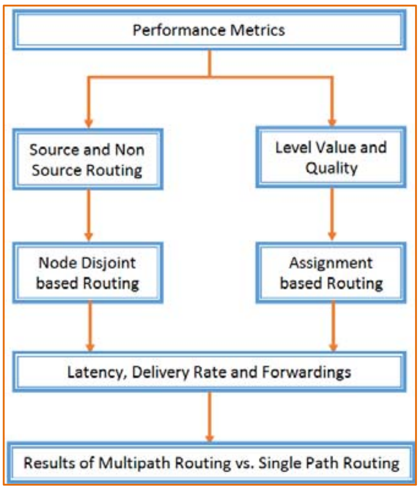

Fig. 2 Model of Performance Metrics

C. Algorithm 2. Node-Disjoint-Based Routing Non-Source Node

Non-source node contacts D or Neighbor B in i with (seq: C'. mode:m).

1. If B and D are in the same group then
2. Forward the packet to D.
3. else
4. case m = 0 ^ i = first (C'): send (C'/{i},0) to B
5. case m =1^ i€ C': send (C'/{i},1) to B.

D. Algorithm 3 - Assignment Based Routing

1. Individual *A* meets *B*, *A* has a packet with C copies and *B* has no copy for destination *D.*
2. Initialize L_A & Q_A
3. If $L_B > L_A$ then
4. Forward L_A/L_B
5. Then $L_A/L_B = B$
6. $L_A = L_B$.

In Algorithm 3, when A, with c copies of the packet, meets B, who has no copy but has a higher quality level LB (note that $L_B = Q_B$ in this case) than A's level LA, A will forward $(1-L_A/L_B)$. C copies of the packet to B and update its level value to L_B. The proposed work is demonstrated in Fig. 3.

The distribution of copies is based on the feature distance to the destination. We use the features of the destination to partition nodes into groups. This approach is called destination-based partitioning.

Assignment based routing forwards the copies of a packet only to the individual that has a smaller feature distance to the destination. The number of copies to be forwarded is proportional to the feature distance to the destination. In assignment-based routing, there are two values to determine packet forwarding: quality value and level value (i.e.) feature distance as the quality value.

By using the above feature contacts with INFOCOM and MIT reality trace the selection feature forms a Hypercube model. This model is performed by multipath routing schemes: Node disjoint based and assignment based routing algorithms. The resulting hypercube social feature matching in HCNs delivers three performance metrics delivery rate, latency, number of forwarding nodes. Fig. 4 shows the hypercube Model formation for feature matching process with the parameters of x-axis and y-axis model.

```
Calculate Hr = a θ b
if (Hr = = 0) then
        finish
else
    begin
        Let P be the location of the top significant 1 in the n-bit attribute, Hr;
        Bit from the location (x-1) through 0, Msg
        Route the msg through P;
        Hypercube node is different from their P-bit address location
        P connection the two adjacent nodes in the network
    end
endif
```

Input: n information objects and amount of clusters

Output: Association value of every entity in all the clusters

Step1. Select the original position for the cluster centre.

Step2. Produce an innovative separation of the data by transmissions to identify its nearby centre.

Step3. Approximate the Association value of every entity in all the clusters.

Step4. Estimate innovative cluster centers.

Step5. If the cluster separation is constant then conclude, or go to step 2.

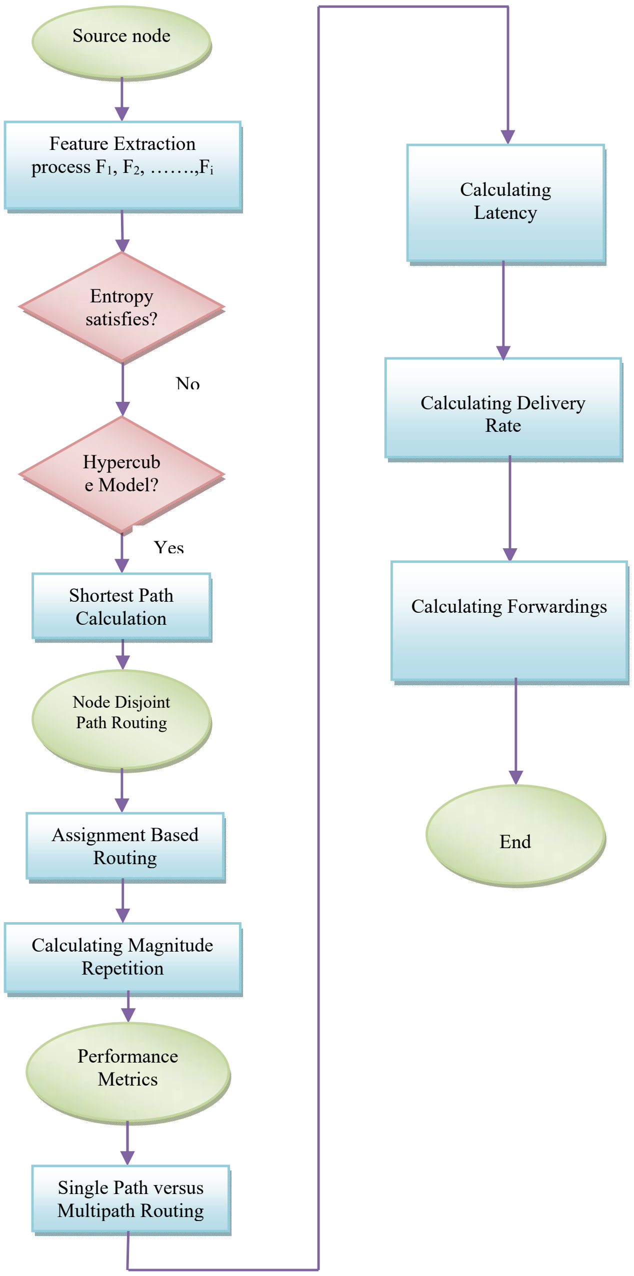

Fig. 3 Flowchart for Proposed Work

E. Algorithm – Magnitude Repetition

procedure magnitude_Repetition()
if M_t > 3 x normal Repetition time-span **then**
if M_s = Disjoint_Path **then**
return Finish
else if M_s = Non_Disjoint_Path **then**
wait for non disjoint path to finish, then accept one as new Path
return finished
else if M_s = Not_Connected **then**

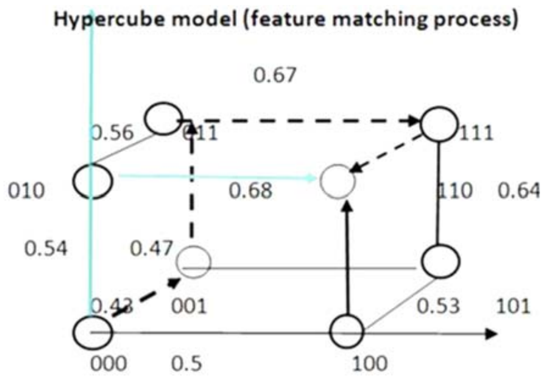

Fig. 4 Hypercube Model

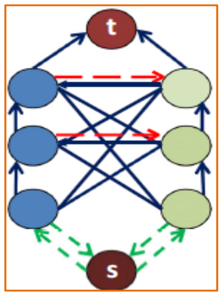

Fig. 5 Routing Model

pick a random connected node to act as alternative after it concludes
wait for it to finish, then **return** completed
end if
else if M_s = Connected
and Followers() < $f_{min}(M_t)$ **then**
C_ID generate New arbitrary ID ()
nearby transmit(conscript, *M_ID*, *C_ID*)
else if M_s = Disjoint_Path **then**
best_organizer ← *M_ID*
Count_follower > Followers
for all n where n is a probable new disjoint_path **do**
Count_follower = survey designed for Num Followers(n, *C_ID*)
if *Count_follower* > *best threshold* **then**
best_organizer ← n
end if
end for
if *best_organizer* **is not** *M_ID* **then**
send(*best_organizer*, encourage, *C_ID*)
Wait for *best_organizer* to transmit it's conscript communication
Locally transmit (relinquish, *M_ID*, *C_ID*)
end if
end if
end procedure

IV. Performance Evaluation

In this experimental set up we randomly select the common features from the HCNs by using entropy. The selecting feature matching process forms a hypercube model by using social feature extraction and multipath routing. Finally, the performance of this process (delivery rate, latency, number of forwardings) is compared to several existing social aware routing schemes. The delivery rate of a packet ranges from 20, 40, 60, 100, 120 and the allowed packets are 100. The packet rate is used for the performance metrics. Fig. 11 illustrates the delivery ratio, Fig. 12 describes the latency and Fig. 13 describes number of forwardings. It increases the 80% of the delivery rate even comparing to the existing approaches of spray and wait, spray and focus techniques.

The node disjoint based routing can cut latency by 14.6%. This will increase our performance within the generation time and the arrival time of a packet.

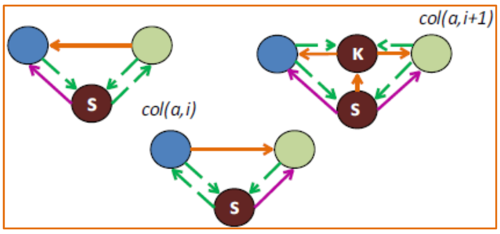

Fig. 6 Magnitude Repetition Model

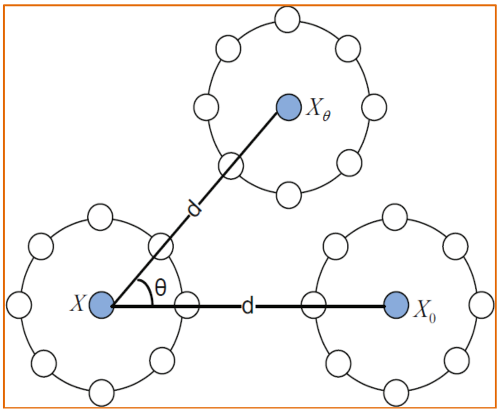

Fig. 7 Co-occurrence Model

Several existing social aware routing schemes perform high level of forwardings; when compared to multipath routing schemes, it will reduce the number of forwardings by 5%.

Although multipath routing increases the number of forwardings, it can increase the delivery rate and reduce the latency in both the real and synthetic traces. The multipath routing schemes and their performances are compared to single path routing.

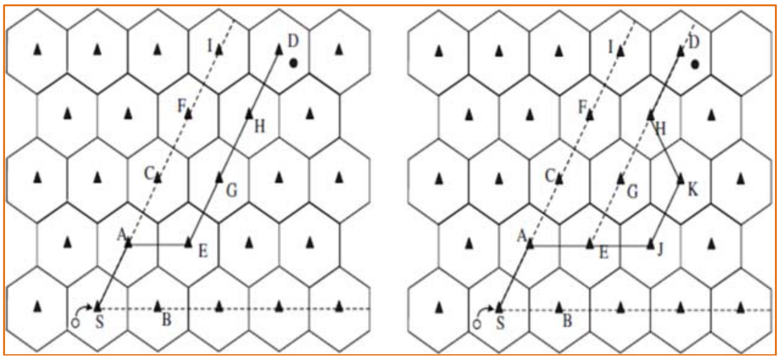

Fig. 8 Transferring data in HCN

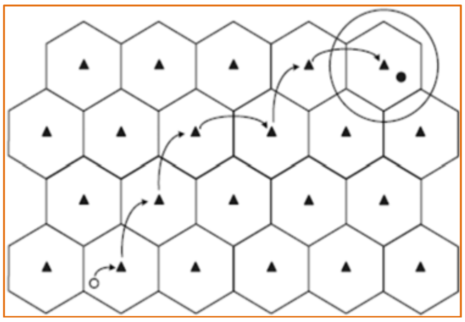

Fig. 9 Geographical Hexagon

International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:10, No:6, 2016

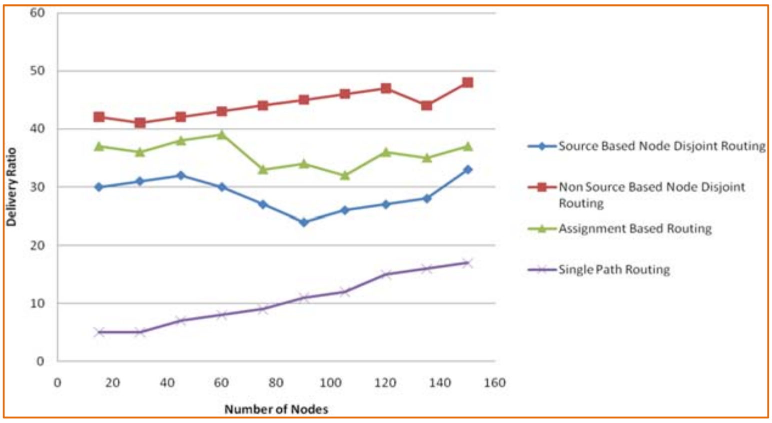

Fig. 10 Delivery Ratio

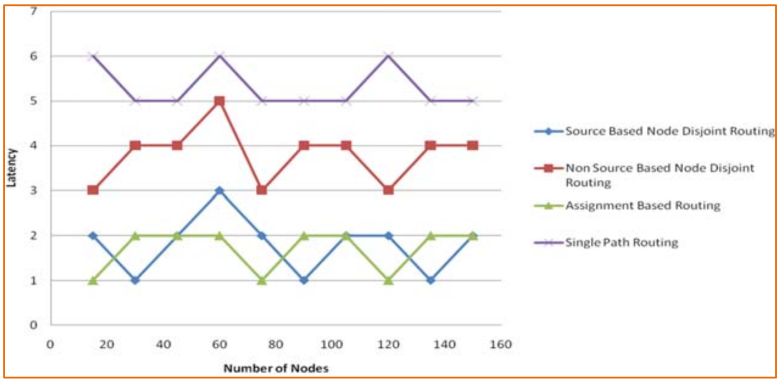

Fig. 11 Latency

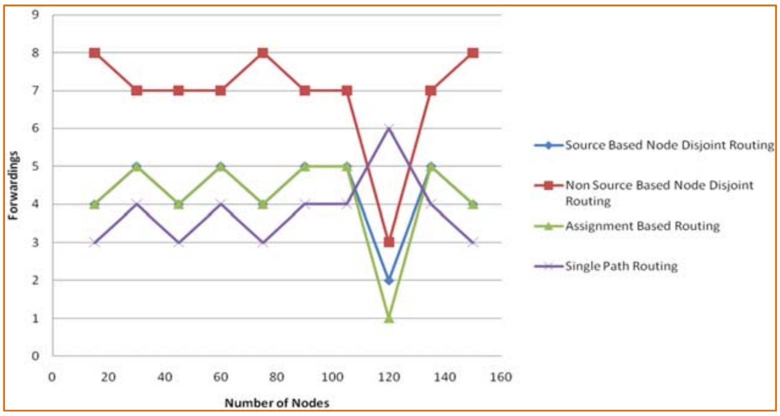

Fig. 12 Number of Forwardings

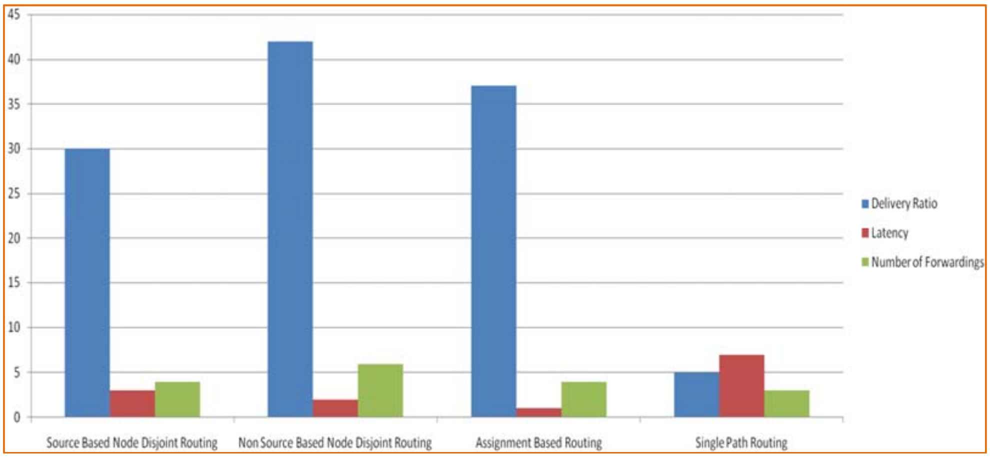

Fig. 13 Performance Metrics

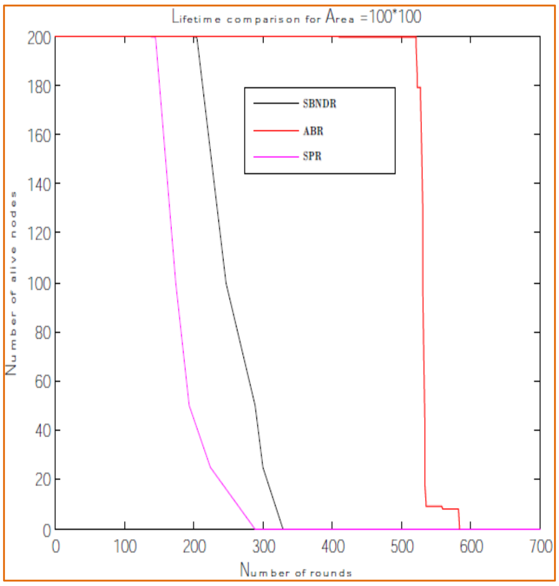

Fig. 14 Lifetime Comparison for Area = 100 x 100

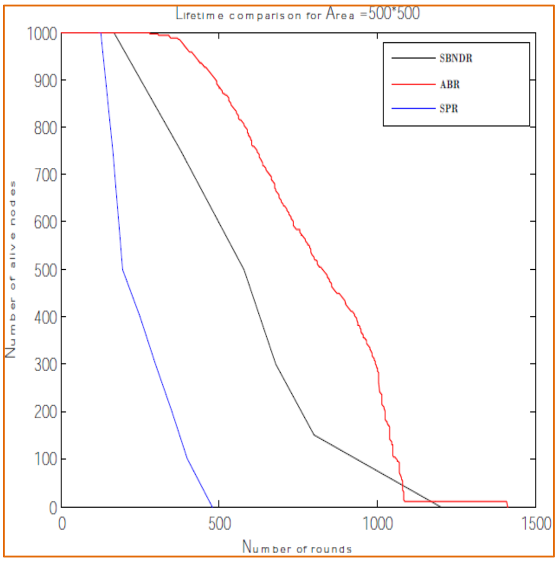

Fig. 15 Lifetime Comparison for Area = 500 x 500

Our simulation concludes that, although multipath routing increases the number of forwarding compared to spray- and-wait, spray-and-focus, and social-aware routing based on connecting less centrality and similarity, it has a significantly higher delivery rate and reduces the latency, especially under node-disjoint-based routing. Node-disjoint-based routing has multiple node-disjoint paths, which help to improve search efficiency. In node-disjoint-based routing, shortcuts also can increase the delivery rate, lower the latency, and reduce the number of forwardings, at the same time. By comparing the performance between multipath and single-path routing, we find that multipath routing has multiple paths to search for the destination simultaneously, which performs better than single-path routing.

V. Conclusion

In this paper, the routing process is performed by hypercube model (HCN), a special form of DTNs. The hypercube model has two methods: Social feature extraction and multipath routing. Selections of features are extracted by using entropy and the common features forms an M-dimensional hypercube. The results of multipath routing are far better than the single path routing.

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