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Recent trends in Social Aware Routing Scheme: Application and Routing Issues in Delay-Tolerant Social Network

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Abstract:- Access to information and digital services on the go has grown with the proliferation of mobile devices and various types of wireless networks. This trend brings an opportunity for individuals to access digital content, share resources, and communicate anywhere anytime facilities. However, the connectivity coverage rate did not go hand in hand with the trends of mobile phone penetration rate, and there is connectivity coverage disparity among developed countries and developing ones. This motivates that infrastructure-less networks such as Delay Tolerant Networks(DTNs) to play an alternative communication approach and to be leveraged in different application scenarios.

The characteristics of this kind of networks (i.e., intermittent connectivity and transient end to end path) create a challenging problem in routing data. For example, to deliver a given message towards destination node/groups of nodes, the routing scheme uses a store-carry- forward and utilizes different heuristics to select a potential forwarder node/intermediate node. This survey paper mainly focuses on presenting insights about recent trends in routing approaches in Delay Tolerant Social Network, and the performance of routing issues.It also provides a comprehensive overview of routing protocols in Delay Tolerant Social Network and examines the various routing taxonomies, and potential application use cases where DTSN suitable.

Keywords:- *Delay Tolerant Network; Forwarding; Routing Scheme; Opportunistic; Social-Aware ; Infrastructure-Less Network; Routing Taxonomies; Routing Issues.*

I. INTRODUCTION

Mobile devices(e.g., mobile phone, Smartphone, and personal digital assistance) penetration becomes a daily news event in the world. The number of individuals who access digital resources via mobile devices increases exponentially. For instance, in the world, the number of individuals in mobile cellular subscriptions has grown significantly [1]. This trend brings an opportunity for individuals to access digital content, share resources, and communicate anywhere anytime to ensure accessibility of facilities.

However, the connectivity coverage rate did not go hand in hand with the trends of mobile phone penetration rate, and affordability is also questioned in developing countries [2]. Moreover, Connectivity is concentrated in developed countries, and sparse in developing countries. Besides, in developing a country's perspective, addressing this huge gap with only an infrastructure-based network is not cost-effective in the area where the density of the population is sparse. Also, some digital contents and services are limited to a specific proximity of a given region, which is only required in that locality without highly dependent on the infrastructure-based network.

In general, ”Digital Divide” has been defined as the gap between those that have Internet access and those that do not. However, the ability to meaningfully participate in and benefit from the Internet is also dependent on the ability to use and have confidence in the technology, and it is mainly affected by various factors and barriers in including relevance and readiness barrier that hinder adoption of Inclusive Internet.

Therefore, infrastructure-less wireless networks, particularly opportunistic networks [3] are gaining huge attention from the research community to play an alternative communication approach and to be leveraged in different application scenarios. In this kind of network, nodes (e.g., people who carry the device) come into contact with each other opportunistically and communicate wirelessly using Wi-Fi and Bluetooth enabled mobile devices. Moreover, the underlying principle in this network is based on the human to human interaction via the mobile devices by exploiting the relationships and social features of the human, to design and build effective and efficient communication protocols (e.g., routing and forwarding algorithms).

Delay tolerant Social Networks(DTSN) is a kind of opportunistic networks based on communication mechanisms where communicating nodes in the networks has a transient end to end connectivity, because of the reason that social-aware intermittent connectivity occurred due to frequent mobility of the nodes. Communication between and/or among nodes in this kind of network is achieved using a store-carry-forward paradigm in a pair-wise fashion. This is a paradigm where nodes store the forwarded messages into the persistence storage space and carry and exchange upon encounter and/or contacts. Relying on this principle, an effective and efficient data routing and forwarding strategies is required. During data forwarding from source to the destination of node or group of nodes, different algorithms are devised for the relay node selection, when nodes encounter [4, 5, 6, 7].

Although, DTSN is being used in the aforementioned scenarios it has paramount challenges and problems that have to be addressed properly towards data forwarding operations. Due to the reason that it has a major role in the realization of this network in various application scenarios. And various solutions aiming to solve routing problems in specific scenarios to improve various network performance objectives. In this paper mainly focuses on presenting insights about recent trends on routing approaches in Delay Tolerant Social Network, and the performance of routing issues. It also provides a comprehensive overview of routing protocols in Delay Tolerant Social Network and examines the various routing taxonomies, and potential application use cases where DTSN suitable. The major contribution of these works are listed below:

- An outline and distill review of some potential applications scenario in DTSNs.
- A taxonomy of recent social-aware routing protocols into different categories.
- A condensed brief about the major characteristics of DTSNs.
- Sorted out open issues for an effective and efficient social-aware routing schemes performance for the realization of DTSNs in real-world applications

II. DELAY-TOLERANT SOCIAL NETWORKS

A. Routing Algorithms

Delay Tolerance social networks are an integration of features of Social aware network(social properties and relations) with delay tolerance Network characteristics. It is a network of self-organizing wireless nodes connected by multiple time-varying links, and where end-to-end connectivity is intermittent. In DTN mentioned characteristics associated with the problems are addressed by using a store-carry and forward paradigm [8,9,10]. This is a technique, where the message from the source node moved to the next node which is used as a hop to the destination node. When the message traverses along the path, there is a persistent storage place in each node which is used to hold the message in a definite time before it is forwarded to the next hop. The main concern of data routing strategies is to make a decision whether to forward the data to the counterpart when two nodes encounter. Different schemes are devised for the relay selection.

Due to intermittent connectivity, routing protocols based on the knowledge of end-to-end paths perform poorly, and several opportunistic routing algorithms have been proposed instead. To carefully use the available resources and reach short delays, many protocols perform forwarding decisions using locally collected knowledge about node behavior to predict which nodes are likely to deliver content or bring it closer to the destination, for instance, the forwarding process illustrates in figure 1.

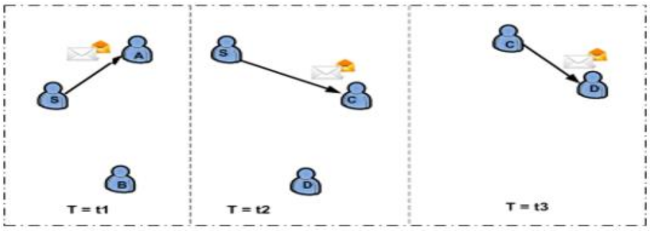

Figure 1 Example of opportunistic data forwarding processes. In the figure, ”S” indicates the source node of the messages and ”D” denotes its destination

Moreover, one of the fundamental goals of any communication network is to have the data or messages delivered to their corresponding destinations. Depending on the underlying network characteristics, the data or messages are required to be routed or relay along in the network with different routing approaches.

B. Characteristics of DTSNs

Delay tolerance social networks (DTSN) are a type of communication methods where there is a transient end to end connectivity between the sender nodes to the receiver, destination node. In this kind of network, intermittent connectivity, long or variable delay, asymmetric data rates, and error rate are common characteristics exhibited. Moreover, addressing the mentioned problems using the existing TCP/IP protocols stack is a very difficult and challenging task. However, in DTN the above-mentioned characteristics associated with the problems are addressed by using a story-and forward paradigm [11, 12]. In DTSN, routing and forwarding a message along with the nodes brings a challenging problem, since intermittent connectivity is common along with the nodes. The problem of selecting which contacts to carry messages and when represents an instance of the DTSN routing problem. As depicted in fig.2 in DTSNs, the main characteristics that exhibited and challenge the design of opportunistic message forwarding are transient end to end connectivity and limited node resource.

Each proposed forwarding solution has a limited expectation of the mention characteristics. And network application scenario in DTSNs is mainly characterized by the density of the network, where it influences the underlying network model, social graphs, which represent the structure of the network. For instance,if the density of the network is low or smaller enough, it is called a sparse network and/or development region network (type-1). Otherwise, if density is dense enough, it is called urban scenario (type-2), as shown in fig.2

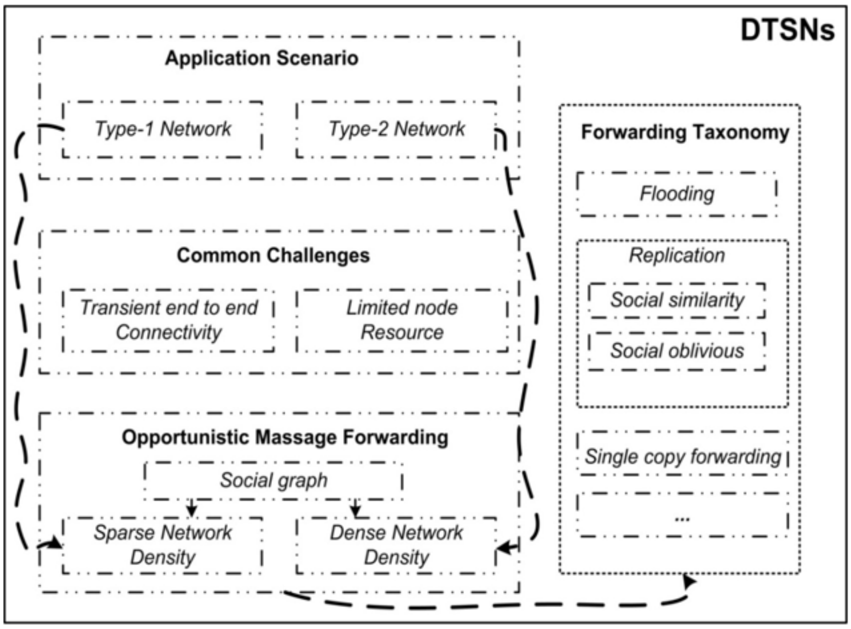

Fig 2 Characteristics of DTSNs and main operations

Moreover, the dotted arrow indicates that each application scenario requires a unique set of forwarding schemes. In other words, it attempts to show, which forwarding schemes are best suitable for each application scenario. And the proposed forwarding algorithms rely on the social properties(i.e.,Intercontact time, contract duration, and interest information) which can be inferred from the mobility pattern of the mobile user based on contacts among nodes. A contact between any two pairs of nodes is defined as an event that starts when nodes come within the transmission range of one another and continue until they get to reach out from each other's transmission coverage range. For example, the time duration for which two nodes stay in contact is the contract duration(or contact time). Besides, the dynamic nature of human behavior [13] has an impact on performance, and considering these features can also help to streamline the design of forwarding solutions either in the type-1 network or type-2 network application scenario.

This story-carry-and forward method,as shown in figure 3,it is used in this kind of networks, where the whole messages are moved (forwarded) from a storage place on one node to a storage place on another node along a path that in the end reaches the destinations. The storage places can hold messages in a finite amount of time, based on the properties of the message settings and the underlying buffer management approaches. These storage places are called persistence storage. Furthermore, by moving whole messages in a single transfer, the message-forwarding technique provides network nodes with immediate knowledge of the size of messages, and therefore the requirements for intermediate storage space and retransmissions bandwidth.

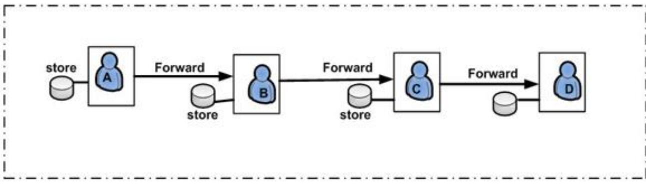

Fig 3 story-carry-and forward method

Moreover, in this kind of network, a message is not simply fragments of packets, rather it is a bundle of actual messages with its fields as we do say packet header in a conventional network. For example, some of the fields a given massage have: from, to, id, size, time Received, time Created, Content-Type, and other fields.

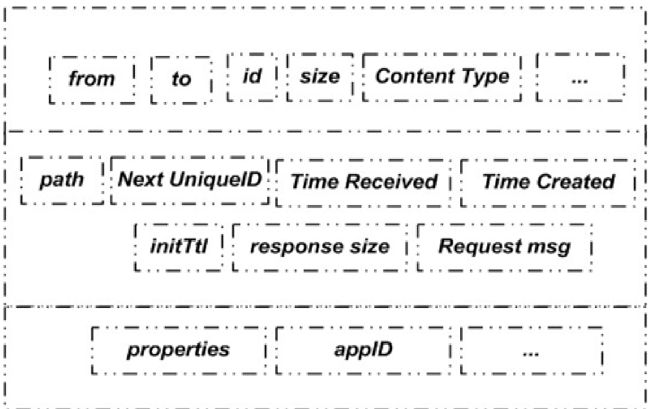

Fig 4 Message field in DTSNs

As shown in figure 4, id: field refers to the identifier of the message, size: indicates the size of the message in (bytes), path: field maintain a list of nodes this message has passed. And time Received: field the time this message was received and content Type: refers to type message (i.e.,interest of a given node towards a given content) properties: this field is a container for generic message properties. Note that all values stored in the properties should be immutable because only a shallow copy of the properties is made when replicating messages. And appID: indicates application id of the application that created the message.

III. APPLICATIONS

This section describes application scenarios where DTSNs can be used and a suitable application for opportunistic and delay tolerant networks [14,15]. And the application scenarios can be grouped into two categories. A) Developing region application scenarios B) Others Services and applications.

A. Developing Region Application Scenarios

In developing countries perspective because of economic factors (e.g., no fixed infrastructure networks in some part of remote village rural area) and addressing this gap via an infrastructure-based network(e.g., the expensiveness of large steel towers backhaul link) only is not cost-effective in the area where the density of the population is sparse. Also, some digital contents and services are limited to a specific proximity of a given region, which is only required in that locality without highly dependent on the infrastructure network. Therefore, DTSN like networks could be an alternative solution and enable various application use cases. For example, village communication, social message exchange application, and various services have paramount advantages. Mostly the messages are non-real-time and could be tolerable with some time interval in terms of hours or days.

Some of the representative village Communication Network proposed to rely on a delay-tolerant network that uses wireless technology to provide asynchronous digital connectivity services are daknet [16], kiosks[17]. In daknet for instance, the system consists of village Wi-Fi-enabled kiosks, mobile access point-equipped vehicles, and Internet access points, mostly far away towns from the village. These wireless devices transmit data via point-to-point short links. Local users who live around in the village sends a message into Wi-Fi enabled kiosk, and during mobile access points (e.g., Mounted on and powered by a bus, a motorcycle, or even a bicycle) reach within the range of village Wi-Fi enabled kiosk, it exchanges message (i.e., uploading and downloading). And carry the massages and transport with a physical means of transportation until it found an Internet access point, and then the message accessed from village Wi-Fi-enabled kiosks delivered to Internet access points. With this fashion daknet system provide delay-tolerant village communications to streamline message exchange services to provide last-mile access. Inspired by daknet, kiosks is a similar project that provides asynchronous village Communication Network.

In addition to the physical limitations of wireless infrastructure (mainly due to distance) to provide last mile access, there is also a growing disparity between those who can afford and not, because affordability and data plan cost add extra barriers for the average individual not to connect and consume data, let alone the people who are far from the connectivity coverage. Therefore, DTSN has attracted considerable attention, to employs social ties between nodes to offer data transmission services and used an alternative solution for the mention challenges. For instance, Social Network Service goose [40] and Social-based application D-Book [18] are some of the proposed applications in social message exchange services.

In Goose, it is a short message service-style social network service that enables users to send both text and voice messages for non-digital literate users (i.e., users having difficulties in understanding a complex user interface), and strengthens the daily life message exchanges within the local inhabitants.

Depend on the available underlies network infrastructure (e.g., GSM) or taking social encounters among the nodes in the network the application streamlines message exchange within the users. For example, in the unicast case, a user uses Goose to send a message to a given user over the GSM network. However, the application uses social encounters and epidemic algorithms for message dissemination (in the broadcast case) in a situation where no available network infrastructure exists.

Goose architecture is based on four components: the Network Manager, the Forwarding Manager, the Contracts Manager, and the User Interface. The overall structure of the Goose is shown in figure 5.

Similar to Goose, D-Book, it is a Social information-based application that provides social message exchange services(i.e., creating, modifying, and sharing profiles) among users in the network. In the application, each user maintains profile information that contains basic information, contact information, and interests. Based on the interest each user has, users can search for other users who have common interests. And enables users to send messages to other users and subscribe to the profile of other users based on interest.

B.Others Services and Applications

In various domains of applications (i.e., Wildlife tracking and monitoring, disaster area networks and vehicle Ad-hoc Network) digital contents and services are limited to a specific proximity of a given geographical region, which are only required in that locality without highly dependent on the infrastructure network (e.g., traffic information among Vehicle, local news feeds and notifications services). Therefore, with these classes of applications, opportunistic networking can utilize an alternative solution.

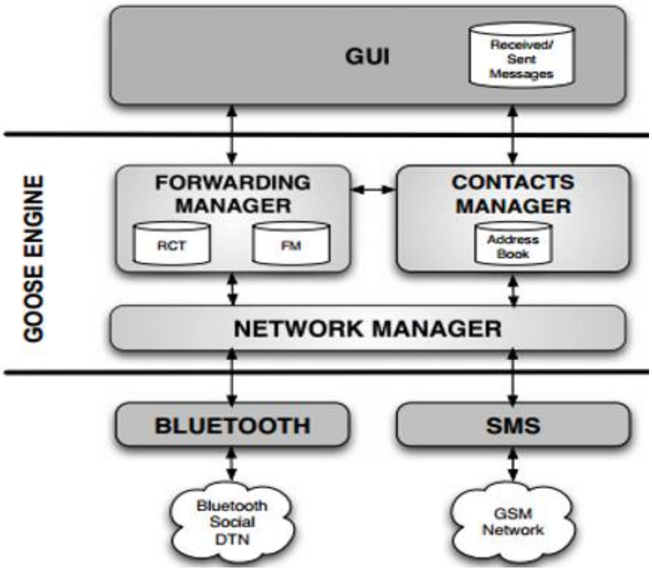

Fig 5 Goose architecture[19]

In Wildlife Tracking and monitoring applications scenario, for example, zebranet [20], is used to track movement patterns of zebra by relying on peer-to-peer wireless Ad-hoc Network approaches. In zebranet system, each zebra mounted on a tracking nodes, collars attached to the necks of zebras, and form network on large size of terrain under study. When two zebra encounters, the collars mounted on each zebra logs and exchanges information particularly tracks of locations information. And this kind of information keep exchanges among other zebras up on opportunistic encounters.

Moreover, Wildlife researchers drive across the area under study with a base station to collect tracks of locations information. The base stations received information from the nearby zebra when they came with proximity. With this, the researchers gained movement patterns of the zebra population over a specified period (e.g., three days). For the nodes to log location information and exchange with other nodes upon encounters, it has a positioning system (GPS), a flash memory, a wireless transceiver, and a low-power CPU to perform all the operations.

There is also a similar approach like Wildlife tracking and monitoring zebranet approaches in the underwater delay-tolerant communication network, SWIM [21], which is used to monitor the whales in the ocean. In this system, there is a radio tag implanted on the whale and a SWIM base station floating on the water. When a whale nearby to the radio frequency range of another whale upon encounters, it exchanges the data about whale and the information being diffused with another whale in this fashion. And finally, when a whale nearby to the surface of the water to the frequency range of the floating base station on the surface of the water, it delivers (i.e., offloading) the information being collected so far to the floating base station.

Moreover, the characteristics of the environment in which the network being used are challenging because it requires nodes to work longer periods without human intervention and needs to have a better power source. Therefore, there should be an effective solution from hardware to algorithms design to cope with the nature of the environment where these kinds of networks deployed.

IV. TAXONOMY OF ROUTING IN DTSNS

In delay tolerance social networks, for instance, there are different groups of routing approaches to achieve distinct goals. With this, as shown in figure 6 the routing approaches grouped into three major taxonomies.

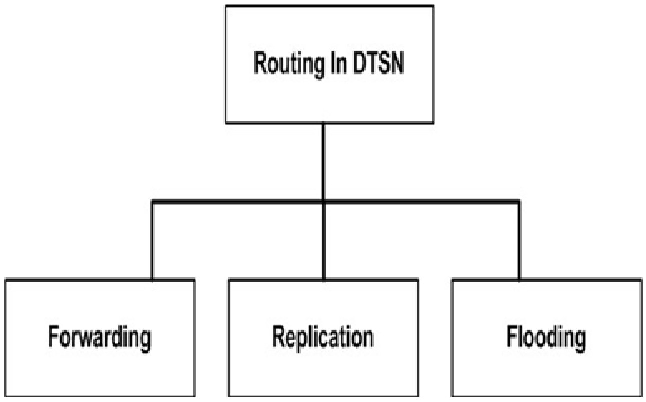

Fig 6 Common taxonomies of Routing Scheme in DTSNS[4]

A. Forwarding

In this category of forwarding approaches where only a single copy of a message exists in the network and the message is forwarded towards the intended destination. Some of the proposed schemes in these categories are Direct Delivery[22] and First Contact[23]. Direct Delivery, the node that carries a given message delivers directly to the destinations in other words the source node itself delivers its messages to the destination. Whereas in the case of First contact forwarding schemes, the node forwards a message to the first node that encounter and other node repeat the process until the message reaches its intended destination.

Although single-copy forwarding approaches aiming to optimize the utilization of network resources (i.e., storage space, overhead, and battery life), forwarding performance objectives, the delivery ratio is very small and average latency becomes very long. Due to this performance drawback, these kinds of forwarding approaches are uncommon in DTSNs.

B. Flooding

In this forwarding and routing scheme category where a node carries a message and replicates/copies the messages to all encountered nodes, without taking into account any kind of heuristic to select a node to replicate the message towards the destination. Epidemic[24] is one of the most common proposed flooding based routing scheme which model message replication similar to the spreading of epidemic diseases in real life. Due to unlimited message coping behaviors, the scheme has both advantages and disadvantages. Forwarding performance objectives, for instance, delivery ratio maximized and average latency is reduced during sending a message towards a destination, because, out of the replicated messages the chance that one of the message reaches to the destination is higher. However, a lot of network resource is consumed, for example, the overall storage requirements become high in such networks.

C. Replication based

Compared to flooding approaches, a replication-based scheme either use by limiting the number of message copies being generated by each node through some configurable limits during message exchanging, to control the replication process or nodes taking into account some kind of heuristic to select among encounters node to replicate the message towards the destination. Due to this characteristic, this approach maintains optimal forwarding performance objectives without incurring extra consumption of various network resources.

Spray-and-wait[25] is a proposed scheme that controls the number of messages copies created. It sets a maximum limit on the number of possible replications of a message. And the scheme follows different techniques to deliver the message towards the destination with spray and waiting phases. In the spray phase, a message is forward to at most some fixed number of different relay nodes. And if the given messages do not deliver at the spray phase, the waiting phase continues and some relay nodes deliver the message to the destination using a direct delivery approach.

PRoPHET[26] a proposed scheme that tries to estimate which node has the highest chances of being able to deliver a message to the final destination based on a heuristic, node past encounter history. In summary, both flooding and replication refer to the process where a transmitting node sends a copy of the message to the receiving node and itself keeps the original message. And there are multiple copies of a message that can exist in the network. Such approaches are used to enhance the chances of message delivery because of a transient end to end path appear in the network. On the one hand, single-copy forwarding approaches aiming to optimize the utilization of network resources. On the other hand, flooding and replication-based approaches aim to optimize delivery probability. Both flooding and replication are multi-copy forwarding but the former has unlimited in coping data or message, and the latter uses some kind of heuristics to which node a given message should be copied or replicated or sets maximum limits on the number of the message being replicated.

The heuristics that guide (i.e., selecting a node and replicate the message to) replication of message during the forwarding process mainly rely on network behavior in which each node exhibits in the network. The behavior of the network is described in stochastic terms, based on the user's mobility and social behavior, to better represent the dynamics of networks (i.e., how networks evolve) [13, 28].

Moreover, single-copy forwarding has the advantage of using network resources(i.e., storage space, overhead, and battery life) properly, but may end up taking too long to deliver the messages. Whereas flooding approaches have advantages of granting to deliver the messages fast, but may end up taking too much network resources. Replication based approaches, placed in between the two to optimize network performance goals and network resources.

As it is depicted in figure 6, the routing approaches grouped into three major taxonomies. However, replication-based approaches can be further subdivided into social similarity and social oblivious, based on the characteristics of each node in the network (e.g., users mobility pattern and social behavior). And this social similarity metrics can be represented through user interest, community, and node popularity features. The overall routing taxonomies are depicted in figure 7.

The static network information, for instance, social information of the nodes in the network has gained much attention to design routing and forwarding algorithms in DTSNs. Since this kind of information tends to stable over time, and do not highly coupled with the underlying topology in the network, routing and forwarding algorithms relying on this information do not highly influenced by the dynamic nature of DTSN (i.e., mobility), and has a better performance result compared to dynamic network information.

Moreover, forwarding schemes rely on Social similarity approaches to improve the performance of different operations of data forwarding in DTSN. And in papers[6, 28], explained that social aware routing and forwarding algorithms are performed better than social oblivious routing algorithms. Due to the reason that forwarding schemes based on social relationships which are represented through social similarity are less volatile than forwarding schemes rely on mobility behavior of nodes where mobility patterns of nodes in the network changes now and then in the network and cause different operations of data forwarding computation unstable.

Moreover, in another aspect of the social features in the literature that streamline forwarding algorithms design is a community structure, when a group of users with social links, common interests, and similarities tend to interact with each other more frequently than those in other groups. These groups are called communities. In this community-based forwarding algorithms, since nodes in the same community members frequently meet than different community, the forwarding strategies follows two distinct approaches to forward the data. These are intracommunity and inter-community approaches.

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V. PROMINENT EXAMPLES

PRoPHET (a probabilistic replication-based routing and forwarding scheme), Bubblerap (a social aware replication routing and forwarding scheme), and Epidemic (flooding based routing) are the most well-known routing and forwarding algorithms that inspire most proposed routing and forwarding schemes in DTSNs. These schemes are used as benchmark routing algorithms to compare and evaluate different proposed forwarding scheme. Moreover, each benchmark scheme represents a group of the proposed scheme is given taxonomy(see, fig.7) to which it was designed; to achieve a given objective.

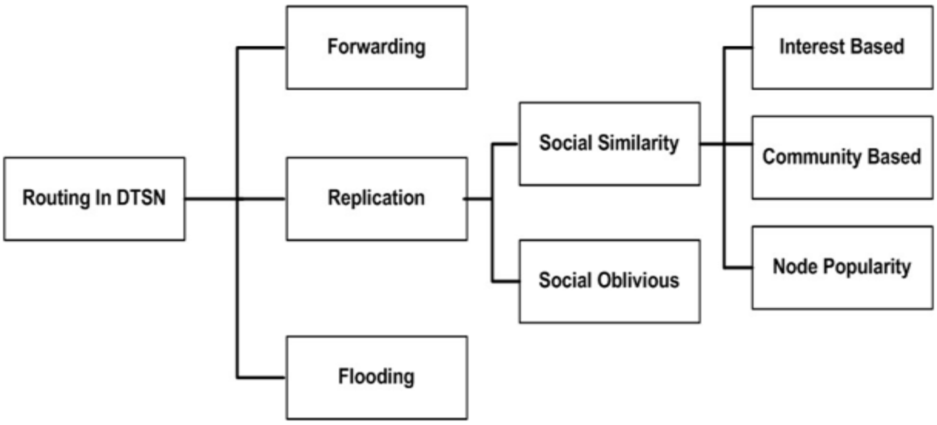

Fig 7 Our Taxonomy of Routing in DTSNs

A. PRoPHET

In social oblivious categories, for example, encounter-based forwarding algorithms use encounter information of nodes in the network upon direct contact for data routing strategies. This kind of scheme forward messages according to node contacts frequency, and choose the node with higher contact probability as the relay for data delivery. For instance, a work that inspires most of the schemes in DTSN is Prophet [26], the Probabilistic Routing Protocol using History of Encounters, and Transitivity used predictability for data delivery as the metric for relay selection. It has a probabilistic metric that is calculated based on the encounter pattern of a node(e.g., frequency of contacts between nodes). This probabilistic metric, delivery predictability is a strong signal to deliver a message to a destination based on its past contact patterns and computed by the following equations from eq.1 to eq.3

$$P_{(AB)} = P_{(AB)old} + (1 - P_{(AB)old}) \times P_{init} \quad (1)$$

$$P_{(AB)} = P_{(AB)old} \times \gamma^{\kappa} \quad (2)$$

$$P_{(AC)} = P_{(AC)old} + (1 - P_{(AC)old}) \times P_{(AB)} \times P_{(BC)} \times \beta \quad (3)$$

And these equations used to compute and update delivery predictability utility, its aging factor, and the property of transitivity among the encounter nodes.

Moreover, $P_{(AB)}$ and $P_{(AB)old}$ are the current and previous delivery predictabilities respectively of node A towards node B over some contact patterns. And P_{init} is initialization constant. κ and γ are parameters aging constant and the number of time units expired since the last update of this predictability respectively. And β is a scale constant to what extent transitivity property affects delivery predictabilities utilities.

In summary, the scheme uses the delivery predictability utility of a node to send a message towards a destination by selecting a node that has a higher utility value as a relay node. Besides, transitivity property used to select a relay node towards the destination in the condition where contact patterns among nodes have transitivity. However, there is a high communication overhead due to an exchange of encounter information between the nodes.

B. Bubblerap

In bubblerap[27], a community based routing algorithms that forward a message in a packet switch network. By using k-clique community detection algorithms, the schemes find the node to which community they belong. To forward the message from source to destination at any given point in time, the schemes compute the centrality value (i.e., betweenness centrality, it is metrics which qualify the level of relevance of the node in the network for message routing. For each node which it comprises of local value and the global value and their rank compared to the neighbor node. As shown in fig 8 once the messages bubble from the source node, it traverses from one node to another node based on the global ranked centrality value of each node which has higher rank chosen to rely on until a node which belongs to the same community where the destination node is found and then, using local centrality value, and hence once a member of the desired community receives the message, it uses local ranking of the other nodes in the community to further disseminate it until the message reaches to its corresponding destination node.

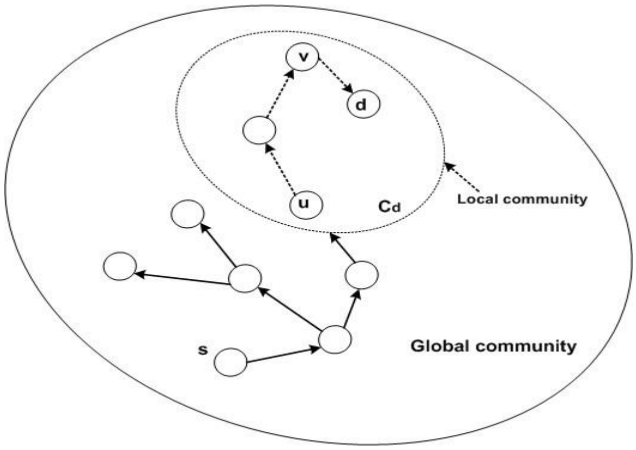

Fig 8 Message forwarding process in the Bubble Rap[27]

In a similar way community- based epidemic forwarding, Localcom[29], which used an extended clique distributed approaches that only use local information of the nodes to form and detect the community structure. And exploiting the virtual link between a pair of neighbor nodes to represent the relationships and finds at least one path with the maximum of k-hop distance between them. During message forwarding between nodes in the same community, also called intracommunity forwarding strategies, LocalCom, used similarity metrics, which composed of closeness relationship between nodes that represent the minimum average separation period in terms of a given time, and some irregularity of separation period during at the same time reflected by the variance of separation period. The minimum average separation period is deduced from the frequency of contacts between neighbor nodes and the duration of contacts, which helps to formulate similarity metrics. And messages forwarding operation done, based on high similarity metrics value and short hop count distance.

In the case of inter-community forwarding strategies, the scheme used flooding based approaches via bridge (i.e., these are kind of nodes which have a direct neighbor relationship between different communities.) nodes, where two or more communities are connected. Moreover, selecting which bridge nodes to facilitate forwarding between communities requires static and dynamic pruning mechanism to reduce redundancy because of flooding, and to limit the number of bridge nodes used. And message forwarding proceeds by using betweenness centrality value of the bridge node, from the current community where the message is originated to other neighbor community bridge node. Using the virtual link, the bridge node forwards the message to all local community members nodes where the bridge node belongs.

LABEL[30], community-based routing algorithms that apply social properties to forward messages. In this approach, nodes in the network assigned labels that help to identify the affiliations. When Nodes encounter each other, exchange labels, and compare it towards the label of the destination nodes. And the messages forwarded if the destination nodes belong within the same community of the encountered node. However, this kind of forwarding strategies has a difficulty when the destination node is not within the same community. And this brings low network performance (i.e., delivery ratio, average delay). However, these approaches suffer from the overhead of community formation and a drawback in regards to average delay since to form and have a table view of the community, takes more time.

C. Epidemic

Epidemic[24] is one of the most common proposed flooding based routing scheme which model message replication similar to the spreading of epidemic diseases in real life. Due to unlimited message coping behaviors, the scheme has both advantages and disadvantages. Forwarding performance objectives, for instance, delivery ratio maximized and average latency is reduced during sending a message towards a destination, because, out of the replicated messages the chance that one of the message reaches to the destination is higher. However, a lot of network resource is consumed, for example, the overall storage requirements become high in such networks.

D. Social aware based Routing Scheme

In social aware based forwarding algorithms, the forwarding strategies rely on and examine the social properties of the nodes in the network when they encounter. Several schemes have been investigating the exploitation of social relationships as well as individual interests through social similarity to improve network performance.

In this categories, Mei et al. [31], based on the observation that peoples movement is affected by their interests, and thus propose social-aware and stateless routing(SANE) which represent interest profile of a node by K-dimension vector space and the angle between two vectors (e.g., two encounter nodes in this case and K- indicates the number of interest profile) is used as a measure of divergence between the vectors by using cosine similarity metric (i.e., identical vectors value is 1.0, and 0.0 for orthogonal) to measure the social tie of nodes to predict future contact opportunities. And message will only be forwarded to the node if the cosine similarity between encountering nodes is larger than a threshold.

However, people's movement would not be always reflected through interests, therefore, more node properties and characteristics utilized to measure social tie strength to predict contact opportunities among nodes in the various network application scenario.

For instance, in BEEINFO[32], community structure is formed based on the user interest, and data forwarding strategies in the intracommunity case are done using the social tie metric and community density metric is used for inter- community case. Moreover, the scheme inspired by food forging of bee, also called bee colony algorithm. It uses this algorithm to have an awareness capability to the context of the environment by taking into account the social properties of nodes in the network, similar to the nectars forging of bees. A similar work Int-tree[33], examined the relationship between interests of mobile node users and its impact on the performance of the data forwarding schemes since relay selection and forwarding decisions are critical to be made by current node based on certain routing strategies. It categorizes the relation among users interests into three types. Those are inclusion, cross-layer, and intersection via layer- based concepts.

However, they focused only on the inclusion relationship type, and community-based forwarding strategies using community density and social tie metrics. And for intracommunity (inside the community) forwarding strategies, a given node measures social tie between the encountered node, and a node that has higher value is selected for a better relay. However, both these schemes have drawbacks in average latency.

In Dlife[34], a weighted contact graph represents the dynamics of the social structure. The scheme relying on the social properties and its dynamics nature over certain periods for a specified number of nodes. By using a weighted contact graph that represents the social structure and its dynamics behaviors, they study how does the social structure evolves over some amount of period. Moreover, they formulate TEDC(time-evolving contact duration) that captures the evolution of social interaction among pairs of users; and TEDCi(time- evolving contact duration importance) that captures the evolution of users' importance, based on its node degree and the social strength towards its neighbors. Both utility functions measure and quantify contact duration and the importance of a node towards its neighbors. And the forwarding algorithm as follows when nodes encounter and comparing with its social strength towards the destination, nodes which have a higher relationship to the destination receives the message, due to the assumption that there is a greater chance for the encountered node to meet the destination in subsequent contacts. If the relationship to the destination is less or unknown, the scheme replicates the message to the encountered node which has a higher importance than the carrier.

In work[35], this proposed routing algorithm relying on the observations that nodes in the networks having common interest have more contact opportunities than nodes having disjoints interest. And have a higher more connection in the social graph in opportunities network. The scheme proposed to address congestion problems and to reduce message overhead and average delay during forwarding, occurred in the network that impacts the performance. However, grouping nodes based on the number of common interest it has limit the membership of nodes to a few interest social groups, which affects the scalability of the scheme.

In summary, replication refers to the process where a transmitting node sends a copy of the message to the receiving node and itself keeps the original message. And there are multiple copies of a message that can exist in the network. Such approaches are used to enhance the chances of message delivery because of a transient end to end path appear in the network. It is indeed both a multi-copy forwarding approaches (flooding and replication-based approaches) aim to optimize delivery probability. However, in the case of flooding, there is an unlimited message coping, and a replication-based approach uses some kind of heuristics to select a given node to replicate the message for.

The heuristics that guide (i.e., selecting a node and replicate the message to) replication of message during the forwarding process mainly rely on network behavior in which each node exhibits in the network. Forwarding schemes which based social properties and relation as a heuristics achieves statistically significant performance results, but still, there is room for further performance enhancement by incorporating some additional social metrics. It belongs to this category of forwarding schemes. Summary of Routing schemes in respective taxonomies are depicted in table 1.

Table 1: Summary of Routing schemes in respective Taxonomy

Routing Schemes	**Taxonomy**	**Interest Based**	**Community**	**Node popularity features**
Epidemic[24]	Flooding	×	×	×
PRoPHET[26]	Social oblivious with replication	×	×	×
BubbleRap[27]	Social aware with replication	×	✓	✓
LABEL[30]	Social aware with replication	×	✓	×
BEEINFO[32]	Social aware with replication	✓	✓	✓
Dlife[34]	Social aware with Replication	×	×	✓
Local com[29]	Social aware with Replication	×	✓	✓
Int-tree[33]	Social aware with Replication	✓	✓	×
SANE[31]	Social aware with Replication	✓	×	×
ONSIDE[35]	Social aware with Replication	✓	✓	×

Note: - Satisfies the condition × - not satisfies the conditions

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VI. OPEN ISSUES

One of the fundamental goals of a communication network is to have the data or messages delivered to their corresponding destination or group of destinations. Depending on the underlying network characteristics, the data or messages are required to be routed or relay along in the network with different routing approaches. However, delivering the data itself is not worthy enough, if the underlying communication protocols (e,g., Routing and Forwarding scheme) perform its operations without aims to achieve effectiveness and various performance objectives.

In delay tolerance social network, for instance, there are different groups of routing approaches to achieve distinct goals towards performance enhancement. However, the performance of the routing and forwarding algorithm highly depends on different design considerations and assumptions that one can take into account. Let alone the common Characteristics (see fig.2) that challenge the underlying communication protocols operation and performance. Due to this, there are open issues that require further exploration and investigation. These are:

- Improvement of performance and efficiency towards the routing and forwarding scheme by exploring the comprehensive use of social metrics.
- Exploring an effective approach to collect, and store routing information (i.e., social information to be used for routing decisions) to design forwarding scheme with an optimal and acceptable network resource conservations (e.g., reducing energy usage and minimal buffer occupancy) for the mobile node.
- Forwarding and routing performance may be affected when the selfish behavior of nodes is considered. Because a node may discard the message received from due to resource constraints (i.e., energy, buffer space, and bandwidth) or malicious property. Exploring novel cooperative schemes and mitigation techniques with various approaches is a key component for the realization of DTSN in the real world. Moreover, most Proposed routing and forwarding schemes are designed for considering only in infrastructure-less network, but it has paramount benefits if the scheme can work in both network environments (infrastructure-less and infrastructure) such as dense city situations. Designing a forwarding scheme that considers both network mode can bring an extra realism for the realization of an opportunistic network into reality.
- In regards to contract duration, one aspect we look in to further investigation is modeling the size of contact duration between encounter nodes, to better predict and streamline an effective message forwarding scheme, to aware and identify better bandwidth capacity between encounter nodes, to reduce recurring message drops, due to short contact duration or low bandwidth constraints in the heterogeneous network application scenario, where different kind of nodes characteristics included.
- Another area which requires further investigation is the impact of different mobility model[36] and various real human connection traces on forwarding performance, since different mobility model reflects various application scenario or use cases, and affects where nodes should move next. Therefore, it determines the underlying assumption to design an effective forwarding scheme to achieve better network performance objectives.

VII. CONCLUSION

DTSNs is a promising communication paradigm where the social properties of the mobile nodes exploited to design effective and efficient data routing schemes. In this kind of network, intermittent connectivity, long or variable delay, asymmetric data rates, and error rate are common characteristics exhibited.

This paper mainly presents insights about recent trends in routing approaches in Delay Tolerant Social Network and the performance of routing issues. It also provides a comprehensive overview of routing protocols in Delay Tolerant Social Network and examines the various routing taxonomies, and potential application use cases where DTSN suitable. Besides, a wide range of intriguing open issues that are tied to the performance of routing protocols for the effective and utilization of DTSNs in various potential application scenarios. It assists to open up further exploration in the enhancement of routing protocols in DTSNs.

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