# Community Aware Routing in Spray Technologies for Delay Tolerant Networks

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**Abstract**

Traditional routing algorithms require a definite path between source and destination. Many traditional algorithms fail in Intermittently connected network where there is no specific path to source and destination. Intermittently connected mobile networks are wireless networks where most of the time there does not exist a complete path from the source to the destination. There are many real networks that follow this model, for example, wildlife tracking sensor networks, military networks, vehicular ad hoc networks, Habitat monitoring sensor networks etc. Spray routing has been a good routing algorithm for Delay tolerant network. In this paper we will show community aware routing in spray technologies for Delay tolerant network. We also show the simulation results for Spray technologies using community aware routing as a mobility model.

## 1 Introduction

Wireless networks are proposed for the applications where mounting up a wired infrastructure is expensive (e.g. sensor networks) or simply not an option (e.g. disaster relief, deep space networks). Cellular access is expensive and low bandwidth, whereas WiFi access is available at a few places(hotspots) that the user has to locate and move to. Further, ad hoc networks have yet to find much application outside the research or military community, but scalability has been a major problem in ad-hoc networks .

The reason for these failures is that many of the assumptions made in the wired world, and which are largely responsible for the success of the Internet, do not hold in the wireless environment. The idea of a stable,connected network over which data can be sent reliably rarely holds there. Wireless signals are subject to multi-path propagation, fading, and interference making wireless links lossy and unstable. Additionally, frequent node mobility (e.g. VANETs [1]) significantly reduces the time a good link exists, and constantly changes the network connectivity graph. As a result, wireless connectivity is volatile and usually intermittent, as nodes move in and out of range from access points or from each other, and as signal quality fluctuates. In addition to the cases of wireless Internet access and ad hoc networks, the need to depart from the traditional networking practices has been recognized for a number of emerging wireless applications. Sensor networks can significantly increase their lifetime by powering down nodes often, or by using very low power radios. This implies that many links will be down frequently, and complete end-to end paths often wont exist. Tactical networks may also choose to operate in an intermittent fashion for LPI/LPD reasons (low probability of interception and low probability of detection) . Finally, deep space networks and underwater networks often have to deal with long propagation delays and/or intermittent connectivity, as well. These new networks are often referred to collectively as Delay Tolerant Networks (DTN). What they all share in common is that they can neither make any assumptions about the existence of a contemporaneous path to the destination nor assume accurate knowledge of the destinations location or even address, beforehand Under such intermittent connectivity many traditional protocols fail (e.g. TCP, DNS, etc.).

It is for this reason that novel networking architectures are being pursued that could provide mobile nodes with better service under such intermittent characteristics. Arguably though, the biggest challenge to enable networking in intermittently connected environments is that of routing. Conventional Internet routing 2 pro- tocols (e.g. RIP and OSPF), as well as routing schemes for mobile ad-hoc networks such as DSR, AODV, etc assume that a complete path exists between a source and a destination, and try to discover these paths before any useful data is sent. Thus, if no end-to-end paths exist most of the time, these protocols fail to deliver any data to all but the few connected nodes. However, this does not mean that packets can never be delivered in these networks. Over time, different links come up and down due to node mobility. If the sequence of connectiv- ity graphs over a time interval is overlapped, then an end to- end path might exist. This implies that a message could be sent over an existing link, get buffered at the next hop until the next link in the path comes up (e.g. a new node moves in range or an existing one wakes- up), and so on and so forth, until it reaches its destination. This model of routing constitutes a significant departure from existing routing practices. It is usually referred to as mobility-assisted [2] routing, because node mobility often needs to be exploited to deliver a message to its destination (other names include encounter-based forwarding or store-carry-and-forward). Routing here consists of independent, local forwarding decisions, based on current connectivity information and predictions of future connectivity information, and made in an opportunistic fashion. The crucial question any routing algorithm has to answer in this context is who makes a good next hop when no path to the destination currently exists and/or no other information about this destination might be available? Despite a number of existing proposals for opportunistic routing the answer to the previous question has usually been everyone or almost everyone. The majority of existing protocols are flooding-based that distribute duplicate copies to all nodes in the network or a subset of them (e.g. gossiping and utility-based flooding). We call schemes like these, which use more than one copy per message, multi-copy schemes.

Single copy schemes [3] that only route one copy per message can considerably reduce resource waste. Yet, they can often be orders of magnitude slower than multi-copy algorithms[4] and are inherently less reliable. These latter characteristics might make single-copy schemes very undesirable for some applications (e.g. in disaster recovery networks or tactical networks beyond enemy lines; even if communication must be intermittent, minimizing delay or message loss is a priority). Summarizing, no routing scheme for intermittently connected environments currently exists that can achieve both small delays and prudent usage of the network and node resources. For this reason, a family of multi-copy protocols called Spray routing, which can achieve both good delays and low transmissions. Spray routing algorithms generate only a small, carefully chosen number of copies to ensure that the total number of transmissions is small and controlled. From the perspective of functionality, spray routing can be viewed as a tradeoff between single and multiple copy techniques. Despite this, theory and simulations show that spray routing: (i) achieves an order of magnitude reduction in transmissions compared to flooding- based schemes, and even fewer transmissions than some single-copy schemes; (ii) can at the same time achieve better delays than all existing schemes in most scenarios, if carefully designed; and (iii) has very desirable scalability characteristics, with its relative performance improving as the network size increases. Additionally performance depends upon the mobility model used for analysis. Specifically, we provide an efficient algorithm that each node can use to locally choose the number of copies to generate in a given scenario, and also show how to optimally distribute these copies.

## 2 Modules

We proposed the following modules for the analysis of efficient node utilization and time delays based on the mobility model.

1. Epidemic Routing
2. Spray and wait
3. Spray and focus

### 2.1 Epidemic routing

It is flooding-based in nature, as nodes continuously replicate and transmit messages to newly discovered contacts that do not already possess a copy of the message. In the simplest case, epidemic routing is flooding; however, more sophisticated techniques can be used to limit the number of message transfers. Epidemic routing has its roots in ensuring distributed databases remain synchronized, and many of these techniques, such as rumor mongering, can be directly applied to routing.

### 2.2 Spray and Wait Routing

Since too many transmissions are detrimental on performance, especially as the network size increases. Our first protocol, Spray and Wait, distributes only a small number of copies each to a different relay. Each copy is then carried all the way to the destination by the designated relay. Spray and Wait routing consists of the following two phases:

**Spray phase:** For every message originating at a source node, L message copies are initially spread forwarded by the source and possibly other nodes receiving a copy to L distinct relays.

**Wait phase:** If the destination is not found in the spraying phase, each of the L nodes carrying a message copy performs Direct Transmission (i.e. will forward the message only to its destination). Spray and Wait decouples the number of transmissions per message from the total number of nodes. Thus, transmissions can be kept small and essentially fixed for a large range of scenarios. Additionally, its mechanism combines the speed of epidemic routing with the simplicity and thriftiness of direct transmission. Initially, it jump-starts spreading message copies quickly in a manner similar to epidemic routing. However, it stops when enough copies have been sprayed to guarantee that at least one of them will reach the destination, with high probability. If nodes move quickly enough around the network or cover a sizeable part of the network area in a given trip, we will show that only a small number of copies can create enough diversity to achieve close-to-optimal delays. Some examples of applications with such favorable mobility characteristics would be Vehicular Ad hoc Networks [6] for real-time traffic reports and accident prevention, or a wireless mesh network over city buses equipped with radios.

### 2.3 Spray and Focus Routing

Although Spray and Wait combines simplicity and efficiency, there are some situations where it might fall short. As, it requires the existence of enough nodes that roam around the network often, which could potentially carry a message to a destination that lies far. Usually, Spray and Wait spreads all its copies quickly to the nodes immediate neighborhood. Hence, if the mobility of each node is restricted to a small local area, then none of the nodes carrying a copy might ever see the destination. An example where such localized mobility might arise could be, for example, a university campus, where most people tend to stay or move locally within their buildings for long stretches of time. In such situations, partial paths may exist over which a message copy could be quickly transmitted closer to the destination. Yet, in Spray and Wait a relay with a copy will naively wait until it moves within range of the destination itself. This problem could be solved if some other single-copy scheme is used to route a copy after its handed over to a relay, a scheme that takes advantage of transmissions (unlike Direct Transmission). We propose the use of the single-copy utility-based scheme from for this purpose. Each node maintains a timer for every other node in the network, which records the time elapsed since the two nodes last encountered each other 2 (i.e. came within transmission range). These timers are similar to the age of last encounter in, and are useful, because they contain indirect (relative) location information.

Specifically, for a large number of mobility models, it can be shown that a smaller timer value on average implies a smaller distance from the node in question. Further, we use a transitivity function for timer values (see details in), in order to diffuse this indirect location information much faster than regular last encounter based schemes . The basic intuition behind this is the following: in most situations, if node B has a small timer value for node D, and another node A (with no info about D) encounters node B, then A could safely assume that its also probably close to node D. We assume that these timers are the only information available to a node regarding the network (i.e. no location info, etc.). We have seen in that appropriately designed utility based schemes, based on these timer values, have very good performance in scenarios were mobility is low and localized. This is the exact situation were Spray and Wait loses its performance advantage. Therefore, we propose a scheme were a fixed number of copies are spread initially exactly as in Spray and Wait, but then each copy is routed independently according to the single-copy utility- based scheme with transitivity. We call our second scheme Spray and Focus.

**Spray and Focus:** Spray and Focus routing consists of the following two phases:

**Spray Phase:** for every message originating at a source node, L message copies are initially spread forwarded by the source and possibly other nodes receiving a copy to L distinct relays.

**Focus Phase:** let UX(Y ) denote the utility of node X for destination Y; a node A, carrying a copy for destination D, forwards its copy to a new node B it encounters, if and only if UB(D) > UA(D) + Uth, where Uth (utility threshold) is a parameter of the algorithm.

# 3 Mobility Models

Mobility model represents the movement of the mobile users, and how their location, velocity and acceleration change over time. Mobility models are of four types. They are:

- spatial Dependency mobility model
- Temporal Dependency mobility model
- Random-based mobility model
- Geographic restriction mobility model

**Spatial Dependency Mobility Model** Mobility of mobile node could be influenced by other neighboring nodes. Since the velocities of different nodes are 'correlated' in space, thus we call this characteristic as the Spatial Dependency of velocity.

**Temporal Dependency Mobility Model** Mobility of a node may be constrained and limited by the physical laws of acceleration, velocity and rate of change of direction. Hence, the current velocity of a mobile node may depend on its previous velocity. Thus the velocities of single node at different time slots are correlated'. We call this mobility characteristic the Temporal Dependency of velocity.

**Random Based Mobility Model** In this model the mobile nodes move randomly and freely without re- strictions. To be more specific, the destination, speed and direction are all chosen randomly and independently of other nodes.

**Geographical Restriction Mobility Model** Nodes may move in a pseudo-random way on predefined path- ways because of geographic obstacles, this type of mobility is called mobility model with geographic restriction.

## 3.1 Random Waypoint Model

In this model the mobile nodes move randomly and freely without restrictions. To be more specific, the destination, speed and direction are all chosen randomly and independently of other nodes. In the Random Waypoint model, each node moves as follows

Choose a point X in the network uniformly at random. Choose a speed v uniformly in [vmin, vmax] with vmin = 0. Let v denote the average speed of a node. Move towards X with speed v along the shortest path to X. When at X, pause for Tstop time slots where Tstop is chosen from a geometric distribution with mean Tstop. After this duration it again chooses another random destination in the simulation field and moves towards it. The whole process is repeated again and again until the simulation ends. If Tstop=0, it leads to continuous mobility .

**Random Walk Model** The Random Walk model was originally proposed to emulate the unpredictable movement of particles in physics. Because some mobile nodes are believed to move in an unexpected way, Random Walk mobility model is proposed to mimic their movement behaviour. The Random Walk model has similarities with the Random Waypoint model because the node movement has strong randomness in both models. We can think the Random Walk model as the specific Random Waypoint model with zero pause time. The Random Walk model is a memory less mobility process where the information about the previous status is not used for the future decision. That is to say, the current velocity is independent with its previous velocity and the future velocity is also independent with its current velocity. In the Random Walk mobility model, each node moves as follows Choose one of the four neighboring grid points uniformly at random. Move towards the chosen grid point during that time slot. Continue the process until the simulation ends.

## 3.2 Random Direction Model

This model is able to overcome the non- uniform spatial distribution and density wave problems. Instead of selecting a random destination within the simulation field, in the Random Direction model the node randomly and uniformly chooses a direction by which to move along until it reaches the boundary. After the node reaches the boundary of the simulation field and stops with a pause time Tpause, it then randomly and uniformly chooses another direction to travel. This way, the nodes are uniformly distributed within the simulation field.

In the Random Direction model, each node moves as follows

- Choose a direction uniformly in [0, 2).
- Choose a speed v uniformly in [vmin, vmax] with vmin = 0 and vmax = . Let v denote the average speed of a node.
- Choose a duration T of movement from a geometric distribution with mean T. The average distance traveled in a duration L is equal to Tv.
- Move towards with speed v for T time slots. After T time slots, pause for Tstop time slots where Tstop is chosen from a geometric distribution with mean Tstop.
- The process continues until the simulation ends.

## 3.3 Community Aware Routing

In community aware routing[5] the nodes are divided into communites. Each nde in the community is aware of the nodes in his community. when a node wants to transmit data it first checks the destination is in his community or not. If the destination and source are in the same community then it is called intra community routing. In the intra community routing the nodes wil transfer data to only to the nodes in its community. When source and destination are in different communities then it is called inter community routing. In inter community network the source will transfer data to the nodes in the community of the destination. Community aware routing is explained in Figure 1.

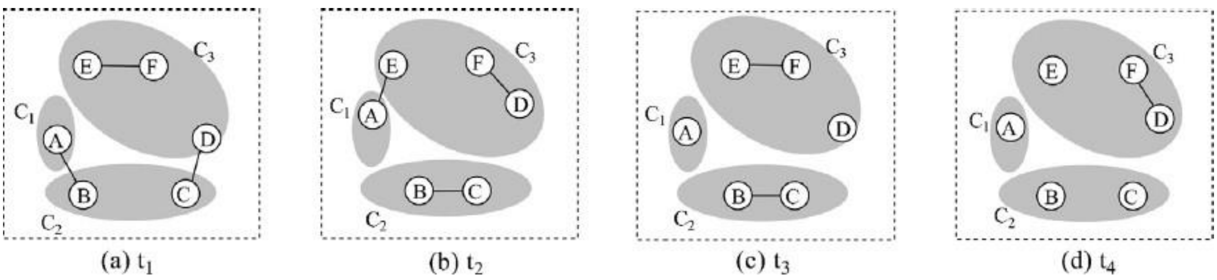


Figure 1: A sample community aware delay tolerant network with six intermittently connected nodes at different time. C1, C2 and C3 denote three different communities in the network, node A belongs to C1, nodes B and C belong to C2, nodes D, E and F belong to C3

# 4 Algorithm

In this section we will show our Community aware routing. For every message int he source buffer if the destination is in the same community as source, it will trigger intra community routing algorithm and if otherwise it will trigger intra community routing algorithm. Algorithm is presented in algorithm 1. In step 1 source $v_i$ has $M$ messages in it's local buffer. Now in step 2 $v_i$ checks its reachable nodes and updates its contact history. For every message in step4, $v_i$ checks whether the destination is in same group as $v_j$, if yes then an Intra community routing algorithm is invoked otherwise an inter community routing is invoked.

**Algorithm 1** Community Aware Routing - CAR

1: Let $M_1, M_2, ..., M_M$ be the messages in $v_i$s local buffer.
2: **if** $v_i$ meets $v_j$ at $t$ **then**
3: $v_i$ and $v_j$ update their contact history and calculate the up-to-date average meeting interval.
4: **for** $k = 1, 2, ..., M$ **do**
5: $v_d \leftarrow mk.destination$
6: **if** $S_{v_i}$ $S_{v_j} = \varphi$ **then**
7: Trigger the Inter-Community Routing.
8: **else**
9: Trigger the Intra-Community Routing.

# 5 Experimental results

In this section we show simulation results of our algorithm. Figure 5 shows simulation results of epidemic routing and spray and wait routing in random way point model. Figure 5 shows Spray and wait and spray and focus in community aware routing. The first picture in Figure 5 shows intra community routing where source and destination belong to the same group. The second picture in 5 shows inter community routing where the source and destination are in different groups.

# 6 Conclusion

In this paper we shown a new routing protocol know as community aware routing and implemented it in routing using spray technologies. We also shown simulation results for epidemic, spray and wait in random waypoint mobility model and also simulation results of our community aware routing in spray technologies.


Figure 2: Epidemic routing and spary and wait routing

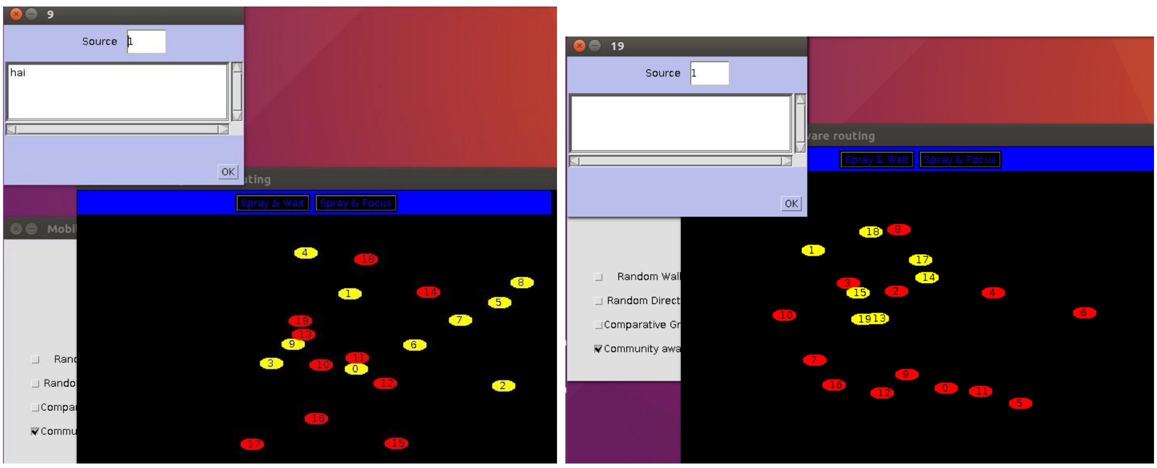


Figure 3: Inter community routing and intra community routing

# Refernces


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[2] Mobility models.

[3] Thrasyvoulos Spyropoulos, Konstantinos Psounis, and Cauligi S Raghavendra. Efficient routing in intermit- tently connected mobile networks: The single-copy case. *IEEE/ACM Transactions on Networking (ToN)*, 16(1):63–76, 2008.

[4] Thrasyvoulos Spyropoulos, Konstantinos Psounis, and Cauligi S Raghavendra. Efficient routing in intermit- tently connected mobile networks: The multiple-copy case. *IEEE/ACM Transactions on Networking (ToN)*, 16(1):77–90, 2008.

[5] Honglong Chen and Wei Lou. Contact expectation based routing for delay tolerant networks. *Ad Hoc Networks*, 36:244–257, 2016.