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SECURE DATA FORWARDING IN MOBILE AD HOC NETWORK USING TRAJECTORY BASED FORWARDING

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Abstract: Trajectory based forwarding (TBF) is a novel paradigm that makes the transition from a discrete view of the paths to a continuous view of the paths in future dense networks. Its main advantages are that it provides cheap path diversity, decouples path naming from the path itself, and trades off communication for computation. When GPS is not available, TBF may make use of alternate techniques, such as global and local positioning algorithms. It is robust in front of adverse conditions, such as sparse networks, and imprecise positioning. This paper, TBF should be used as an essential layer in position centric ad hoc networks, as a support for basic services: routing (unicast, multicast, multipath), broadcasting and discovery.

Keywords: Mobile Ad Hoc Network, Routing, Trajectory based forwarding, Mobility, Broadcasting, Discovery

I.INTRODUCTION

In a mobile ad hoc network, all the nodes co-operate amongst each other to forward the packets in the network and hence, each node is effectively a router. Thus one of the most important issues is routing. Some of the other issues in ad hoc networks are described.

- **Distributed network:** A MANET can be considered as a distributed wireless network without any fixed infrastructure. By distributed, it is meant that there is no centralized server to maintain the state of the clients, similar to peer-to-peer (P2P) networks.
- **Dynamic topology:** The nodes are mobile and hence the network is self-organizing. Due to this, the topology of the network keeps changing with time. Hence the routing protocols designed for such networks must also be adaptive to the changes in the topology.
- **Power awareness:** Since the nodes in an ad hoc network typically run on batteries and deployed in hostile terrains, they have stringent power requirements. This implies that the underlying protocols must be designed to conserve battery life, or in other words, they must be power aware.
- **Addressing scheme:** The network topology keeps changing dynamically and hence the addressing scheme used is quite significant. A dynamic network topology entails a ubiquitous addressing scheme, which avoids any duplicate addresses. Mobile IP is currently being used in cellular networks where a base station handles all the node addressing. However, such a scheme doesn't apply to ad hoc networks due to their decentralized nature.
- **Security:** Security in an ad hoc network is of prime importance in scenarios of deployment such as battlefield. The three goals of security - confidentiality, integrity and authenticity are very difficult to achieve since every node in the network participates equally in the network.

Routing In MANETS: Unlike wired networks, routing in MANETs poses unique challenges. Designers of routing protocols for MANETs need to address several issues. In this chapter these issues are identified and the routing protocols available for MANETs are classified. Then working principle of a few protocols such as DSDV, DSR, AODV, etc. are explained. Their pros and cons are also identified. This chapter concludes with a summary of routing in MANETs.

II. DESIGN ISSUES

The following design issues must be considered before designing a routing protocol for MANETs [1]-

(a) *Dynamic Topology*: In a MANET, the network topology keeps changing with time due to the movement of the nodes, and hence the links between the nodes suffers frequent breaks. Thus the ordinary routing protocols for wired networks are not efficient since they are designed for static networks.

(b) *Bandwidth constraint*: The nodes in the network have a relatively low bandwidth when compared to traditional wired networks. This is an important issue to consider when designing routing protocols for MANETs since the utilization of bandwidth by the routing protocol in the network must be minimized.

(c) *Error prone broadcast channel*: The nodes in the MANET broadcast the information to all the neighboring nodes on the wireless channel. The channel itself is prone to several errors such as attenuation, multi-path fading, etc. Thus the routing protocol itself must be designed taking into consideration these issues.

(d) *Hidden and exposed terminal Problems*: The hidden terminal problem is shown in Figure 1.4.

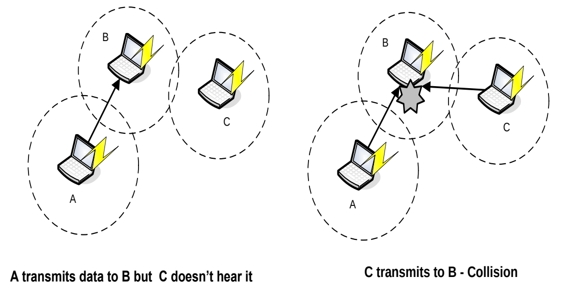


Figure 1: The Hidden Terminal Problem

This problem occurs in networks using contention based protocols such as ALOHA, CSMA/CD, etc. When two nodes which are out of range of each other send data frames to a node which is within their respective radio ranges, a collision of data frames occurs. As shown in Figure. 1, when both nodes A and C transmit data frames to node B a collision occurs. This problem can be resolved by using a mechanism called RTS/CTS handshake [2]. The exposed node problem is shown in Figure.2. An exposed node is one which is in the range of the transmitter, but out of the range of the receiver. In Figure.2, when node C is transmitting to node D, B overhears this and is blocked. Now if node B wants to transmit to node A, it cannot do so.

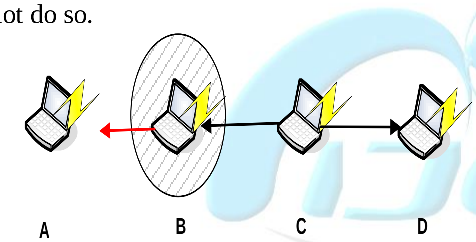


Figure 2: The Exposed Terminal Problem

This results in wasted bandwidth. The hidden and exposed terminal problems occur at the MAC layer and prevent successful transmission of data packets. This, in turn also affects the design of the routing protocol. In order to prevent this, the routing protocol must reduce the number of broadcast packets to minimize collisions [3].

(e) *Resource limitations*: MANETs consist of nodes such as PDA, laptops, etc. which have stringent power requirements. Further, some of these devices have limited processing power. Thus the routing protocols must be efficient in terms of power conservation.

(f) *QoS limitations*: For applications such as multimedia, QoS guarantees must be provided by the routing protocol. However, such guarantees come at the cost of higher latency and poor performance since multimedia applications require higher bandwidth and traffic rates.

(g) *Security*: Due to on open environment where MANETs are typically deployed, the routing protocols are prone to several attacks. Further, there is also the issue of secure key distribution.

III.LITERTURE REVIEW

S. Zhong, *et al.* [4] for mobile ad-hoc networks with selfish nodes, uses credit to provide incentive to cooperative nodes. When a node receives a message, it keeps a receipt of the message. Later, when the node has a fast connection to a Credit Clearance Service (CCS), it reports to the CCS the messages have been received/forwarded by uploading its receipts. The CCS then determines the charge and credit to each node involved in the transmission of a message, depending on the reported receipts of a message. There are some limitations of SPRITE system; firstly, there is an excessive burden on sender which loses credit for forwarding of its message. Secondly no punishment scheme is there for selfish nodes and also there is ambiguity between the nodes as to which one is selfish node.

Rekha Kaushik, *et al.* [5] proposed a credit based solution called MODSPIRIT to enforce cooperation among non cooperative nodes. This system is modification of SPIRITE system. The basic scheme of proposed algorithm is that when a node receives a message, it keeps a receipt of the message. It then communicates with the cluster head which is responsible for credit and debit of charges to nodes when they receive/forward messages to other nodes. Usage of cluster head reduces the burden of tamper proof hardware or CCS. Detection of selfish node is carried out by using neighbor monitoring mechanism. This mechanism is applied on limited number of intermediate nodes; hence reduces the computing overhead.

J. J. Garcia-Luna-Aceves, *et al.* [6] the STAR protocol is also based on the link state algorithm. Each router maintains a source tree, which is a set of links containing the preferred paths to destinations. This protocol has significantly reduced the amount of routing overhead disseminated into the network by using a least overhead routing approach (LORA), to exchange routing information. The optimum routing (ORA) approach obtains the shortest path to the destination while LORA minimizes the packet overhead. Garcia–Luna–Aceves and Spohn propose STAR where each node maintains a source tree which contains preferred links to all possible destinations. Nearby source trees exchange information to maintain up-to-date tables. The routes are maintained in a routing table containing entries for the destination node and the next hop neighbor. The link state update messages are used to update changes of the routes in the source trees. Since these packets do not time out, no periodic messages are required.

G.Pei, *et al*. [7] propose the FSR protocol which takes inspiration from the ''fisheye'' technique of graphic information compression proposed by Kleinrock and Stevens. When adapted to a routing table, this technique means that a node maintains accuracy distance and path quality information about its immediate vicinity, but the amount of detail retained decreases with the distance from the node. Each node considers a number of surrounding fish-eye scopes, areas which can be reached with 1, 2 ... hops. FSR reduces the size of the update messages by updating the network information for nearby nodes at a higher frequency than for there mote nodes, which lie outside the fisheye scope. This makes FSR more scalable to large networks than the protocols.

IV.TRAJECTORY BASED FORWARDING (TBF)

Describe a new forwarding paradigm, trajectory based forwarding (TBF) which addresses the issue of scalability and dynamic network topology. This fundamentally new approach to routing in "dense matter" where the route path is specified and treated as a continuous function as opposed to a discrete set of points. The transition from a discrete view of route paths to a continuous view of route paths is only natural as we move from dealing with sparse networks to dealing with dense networks. The key idea in the approach is to embed a trajectory in the packet and then let the intermediate nodes forward packets to those nodes that lie more or less on the trajectory. Representing route paths as trajectories is an efficient scalable encoding technique for dense networks. Since a trajectory does not explicitly encode the nodes in the path, it is to a large extent impervious to changes in specific nodes that make up the topology. Trajectories are a natural namespace to describe route paths when the topology of the network matches the topography of the physical surroundings in which it is deployed, which by very definition is embedded computing. Here, the physical paths traversed by packets mirror the underlying shape of the physical space that is being queried. Further, forwarding packets along trajectories can be very effective in implementing many networking functions when standard bootstrapping or configuration services are not available, as will be the case in disposable networks, where nodes are thrown or dropped to form a one-time use network.

Although Cartesian routing [8] offers the possibility of routing packets based on positions, it does so only on straight lines between source and destination. There are many practical network services that require routing along routes possibly other than the shortest path. One such example is multipath routing, which may be employed by a source to increase bandwidth, or resilience of communication. Routing along the shortest path is not always the best option in wired networks [9]. In sensor networks the same problem manifests itself as potential network partitioning due to battery overuse along popular shortest paths. Communication over alternate paths must be therefore used as a load balancing method in order to achieve more uniform battery depletion. Finally, non straight trajectories are necessary to describe unicast routes in a network where straight line forwarding is not possible due to obstacles, holes in connectivity, or other criteria, such as security requirements. TBF has a number of features that make it an ideal candidate for a low level primitive in any ad hoc network.

- It decouples the path name from the path itself. This is the most critical aspect in a dense network, where intermediate nodes between source and destination might move, go into doze mode or fail, thereby rendering useless a discrete source based path.
- The specification of the trajectory is independent of the name of the destination. This makes TBF usable as a routing support, when the destination is indicated, as a discovery support primitive, when the destination is not known, or as a flooding replacement.
- It provides cheap path diversity, when compared to flooding based traditional methods of finding alternate paths.
- It trades off communication for computation, by declaring paths instead of searching them. This is a desirable tradeoff, considering the four orders of magnitude difference between the cost of sending a wireless packet and executing an instruction [1].
- It may be assisted by various functionalities available in the nodes. Ideally, each node would be equipped with a GPS receiver, case in which nodes closest to the indicated trajectory will forward the packet. If, however, GPS is not available (such as non line of sight scenarios, or lack of sufficient precision) TBF may use approximate positions given by positioning algorithms [10,11] that are based on nodes' other abilities to sense their neighbors (ranging, angle of arrival, compass).

Besides simple unicast, trajectory routing and forwarding have significant advantages for many other important network functions such as broadcasting, discovery, multipath, multicast and broadcast, path resilience. In this chapter, I focus on issues related to trajectory forwarding in networks with availability of node positions, and identify a number of research challenges related to trajectories in ad hoc networks.

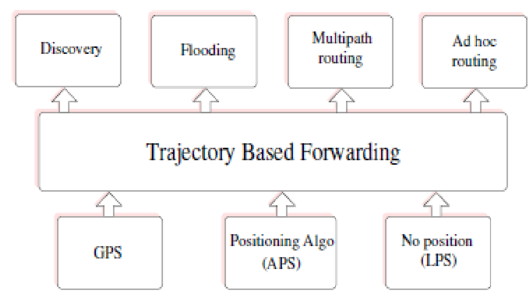


Figure 3: TBF layer

A) TBF description:

TBF is a hybrid technique combining source based routing [12] and Cartesian forwarding [13], but uses a continuous representation of the route. Like in source based routing, the path is indicated by the source, but without actually specifying all the intermediate nodes. Like in Cartesian forwarding, decisions taken at each node are greedy, but are not based on distance to destination - the measure is the distance to the desired trajectory. Source based routing has the advantage that intermediate nodes are relieved of using and maintaining large forwarding tables, but it has the disadvantage of the packet overhead increasing with the path length. Cartesian routing uses positions to get rid of the routing tables, but defines one single forwarding policy: greedy, along a straight line. TBF gets the better of the two methods: packets follow a trajectory established at the source, but each forwarding node takes a greedy decision to infer the next hop based on local position information, while the overhead of representing the trajectory does not depend on path length. In a network where node positions are known, the packet may be forwarded to the neighbor that is geographically closest to the desired trajectory indicated by the source node. If the destination node is known, the trajectory followed by the packet might be a line, and the method reduces to Cartesian forwarding. Trajectory based forwarding (TBF) requires that nodes be positioned relative to a global coordinate system or a relative coordinate system. The strength of TBF lies in the edibility of being able to work over a wide variety of positioning systems. In fact, TBF can be seen as a middle layer between global , ad hoc and local position providing services, and many network management services (Figure 3).

B) Forwarding methods

In the TBF framework, routing a packet requires the specification of the trajectory along which a packet can be forwarded. The trajectory is usually decided by the source - assume that it is expressed in parametric form X(t); Y (t). For example, to route along a line with slope _ passing through the source with coordinates x_1; y_1, the trajectory would be described by $X(t) = x_1 + t \cos(\alpha)$; $Y(t) = y_1 + t \sin(\alpha)$. α; x_1; y_1 are constants, and the parameter t actually describes Euclidean distance traveled along the line. It is convenient, for the simplicity of the explanation to assume that t indicates the distance on the curve, but it need not be so in the general case. The neighborhood of a node N_0 (Figure 4) is defined as the portion of the curve and the nodes that are within a certain distance form N_0, shown by a dashed line in the figure. In the simplest case, the neighborhood could be the smallest circle enclosing all N_0's one hop neighbors.

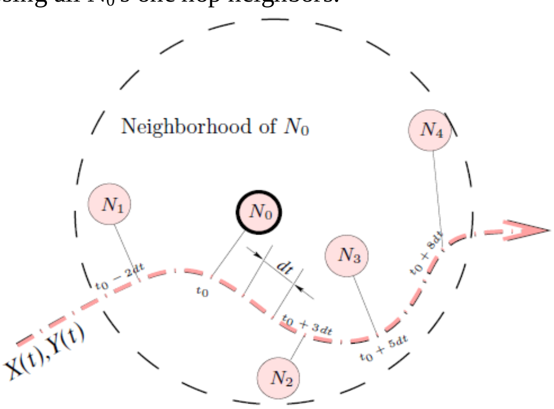


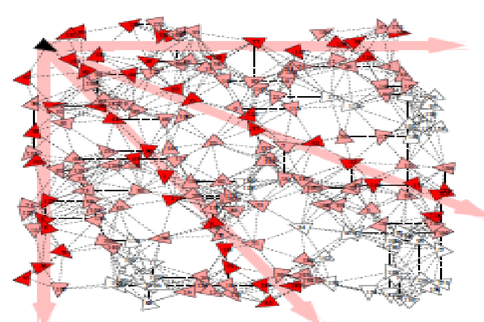
Figure 4: Forwarding on a curve

In a network in which node positions are known, the main question is how to choose a next hop that best approximates the trajectory. Assume node N_0 receives a packet with the trajectory indicated by the curve X(t); Y (t) and the value t_0 that corresponds to the point on the curve that is closest to N0. Using sampling of the curve at dt spaced intervals, indicated by dots in the dashed trajectory curve, N0 can compute all the points of the curve that reside inside its neighborhood. For all neighbors N_1::N_4, their corresponding closest points on the curve are t_0; t_0+3dt; t_0+5dt; t_0+8dt. When referring to curve fitting, these distances are called residuals. In fact, the mentioned method computes an estimation of the residuals, instead of the true ones, which would require either infinite resolution ($dt \rightarrow 0$), or usage of higher derivatives of X(t) and Y (t): Since choosing a next hop for the packet should be towards advancement on the trajectory, only the portion of the curve with t > t0 is considered. For this reason, node N1 receives t0 as the closest point, instead of $t_0 \rightarrow 2dt$, which would be closer to the perpendicular from N1 onto the curve. Several policies of choosing a next hop are possible:

- "Minimum deviation": choose the node closest to the curve, with the minimum residual. This policy would favor node N_2 and would tend to produce a lower deviation from the ideal trajectory;
- Most forwarding within radius (MFR),choosing N_4. This policy should also be controlled by a threshold of a maximum acceptable residual, in order to limit the drifting of the achieved trajectory. It would produce paths with fewer hops than the previous policy, but with higher deviation from the ideal trajectory;
- Centroid of the feasible set, favoring N_3: the centroid is a way to uniformly designate clusters along the trajectory, and a quick way to determine the state of highly dense networks;
- The node with most battery left;
- Randomly choose between best three: useful when node positions are imperfect, or when it may be necessary to route around obstacles;
- In mobile networks a forwarding policy that might provide better results would be to choose the next hop which promises to advance along the trajectory, or one that is expected to have the least mobility in the future.

C) Mobility

Mobile networks are a case in which TBF provides a desirable solution due to its decoupling of path name from the path itself. In a mobile ad hoc network, route maintenance for trajectory based routing comes for free since all that is needed is the position of the destination. This is especially true when only the intermediate nodes or the source are moving, and the destination of the packet remains fixed. When the destination is moving, a location service [14] may be used, or the source may quantify its uncertainty about the destination by using a localized flooding around the destination (Figure 5).



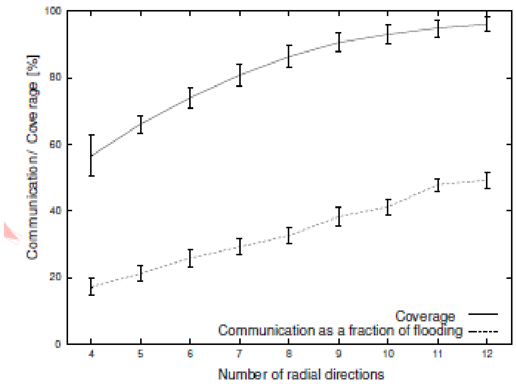


Figure 5: Naive TBF based broadcasting

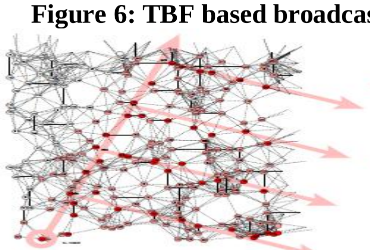
D) Discovery

One of the areas in which TBF is particularly appropriate is quick and dirty implementation of services without the support of preset infrastructure. Such is the case of discovery - of topology, or of some resource. Many algorithms use initial discovery phases based on flooding [11] in order to find a resource or a destination. A replacement scheme using trajectories is as follows: possible destinations (servers S) advertise their position along arbitrary lines and clients C will replace their flooding phase with a query along another arbitrary line which will eventually intersect the desired destination's line. The intersection node then notifies the client about the angle correction needed to contact the server directly. In order to guarantee that the server and client lines intersect inside the circle with diameter CS, it is in fact necessary for the nodes each to send in four cardinal directions.

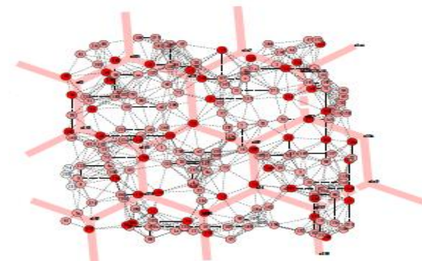
F) Broadcasting

Broadcasting is one of the most used primitives in any network, used for tasks ranging from route discovery at the network layer, to querying and resource discovery at the application layer. Its most frequent implementation is under the form of suppressed flooding, which entails each node of the network broadcasting the message exactly once. It is a stateful method, since it requires bits to mark the status of a node - covered or uncovered.

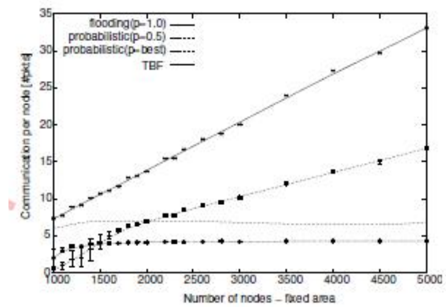
Figure 6: TBF based broadcasting



(a) parallel (stateless)



(b) honeycomb (stateful)



(c) Performance

The problem with the marking bits is that they have to be provisioned on a per broadcast basis, if several broadcasts are to be supported simultaneously. If only O(1) marking bits are used, some global serialization is necessary. For example if one bit is used, one broadcast is supported in the network, and after the settling time (time at which last copy of a message is broadcast), the bit has to be cleared to allow for another broadcast. Suppressed flooding also incurs several other problems: increased communication, increased settling time, poor scalability and delivery ratio in congested networks. Probabilistic flooding addresses some of these problems by flipping a coin each time a node has to rebroadcast the message. This reduces the number of duplicates a node receives, but the method exhibits a bimodal behavior, meaning that either the broadcast is successful in covering most of the network, or it dies very early, covering only a small portion around the source. While broadcasting is not the main application, TBF can provide solutions that address most short coming of traditional flooding and of probabilistic flooding. The broadcast achieved by TBF also has an approximate nature, just like probabilistic flooding, meaning that there may be nodes which do not receive the message even under ideal collision free conditions.

V.CONCLUSION

The parallel structure of the spokes proves to be quite economical in terms of overhead because spokes spaced at about twice the communication range tend to reduce the number of duplicate packets, while providing high coverage. Both stateless schemes - the radial and the parallel spokes -

have a lower predictability since large portions of the network may remain uncovered due to a break in the trajectory.

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