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A Review of current Routing Solutions for ad hoc Networks

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Abstract: Mobile Ad-hoc networks (MANETs) are self organizing, infrastructureless and multi-hop packet forwarding networks. There is no concept of fixed base station. So, each node in the network acts as a router to forward the packets to the next node. Ad-hoc networks are capable of handling of topology changes and malfunctions in nodes. Routing is one of the most important aspect of ad hoc networks. All operations and applications built around ad hoc networks, utilize the routing services of ad hoc networks in some way or the other. Considering the importance of routing techniques and their efficiency, in this paper we have taken a literature survey of different routing methods, their strengths and weaknesses. For this study we have classified different routing methods into some heads based on the characteristics they display. All methods under a given head display some common behavior and similarities in their functionalities. This paper helps to identify and understand different research areas in mobile ad hoc networks.

Keywords: MANET, routing protocols, Multi Path Routing, Literature Survey

I. Introduction

Mobile Ad-hoc networks (MANETs) are self organizing, infrastructureless and multi-hop packet forwarding networks. There is no concept of fixed base station. So, each node in the network acts as a router to forward the packets to the next node. Ad-hoc networks are capable of handling of topology changes and malfunctions in nodes. Routing plays an important role in MANETs. The routing decisions in MANETs face considerable challenges due to the characteristics and constraints in MANETs [13] [4]. In this section we will see the different types of MANET routing protocols, properties of MANET routing protocols and parameters that are used for the evaluation of routing protocols. MANET routing protocols are classified into three categories based on how routing information is acquired and maintained by the mobile nodes [37]. These are proactive routing, reactive routing and hybrid routing. Proactive routing protocol is also called table driven routing protocol. Using a proactive routing protocol, nodes in a mobile Ad-hoc network continuously evaluate routes to all reachable nodes and attempt to maintain consistent, up-to-date routing information. Therefore, a source node can get a routing path immediately if it needs one. Reactive routing protocols for mobile Ad-hoc networks are also called on-demand routing protocols. Reactive routing protocols do not update the routing tables periodically through advertisement messages. Routing in reactive protocols performed in two phases, route discovery phase and route maintenance phase. When a source node wants to communicate with destination node, firstly it checks for entry to the destination in its routing table. Then it starts sending data to the destination. If the source node is not able to find an entry to the destination in routing table, it starts the route discovery process by broadcasting a route request packet to its neighbors. Those Neighbors having route to the destination responds with sending a route reply to the source node. Routes may be disconnected due to the node mobility. In that case failure link's downstream node informs the failure notification to the source node. Hybrid routing protocols are proposed to combine the merits of both proactive and reactive routing protocols and overcome their shortcomings. Normally, hybrid routing protocols for mobile Ad-hoc networks exploit hierarchical network architectures. Proper proactive routing approach and reactive routing approach are exploited in different hierarchical levels, respectively.

II. Review of Research

When two nodes want to communicate to each other, two cases can occur: either they are neighbors, in which case they can communicate directly, or they are too distant, in which case messages must be routed. Routing is the problem of sending a packet from a source node to a destination one. Considering the broad aspect of issues in ad hoc networks, we classify various issues of ad hoc networks into the following categories:

A. Broadcasting and Multicasting

Broadcasting is defined to be a one-to-all communication, that is a mobile user sends a message that should be received by all other users in the network [32]. The most basic broadcasting protocol is known as the *blind flooding*, in which a source node transmits the message to all its neighbors, and then each node that receives it for the first time re-transmits it. Assuming an ideal MAC layer, every node in the network will receive at least

once the message. However, because of its simplicity, this protocol leads to a lot of duplicated packets and thus huge wastage of energy consumption. The problem of efficient broadcast therefore has always been a central topic of research.

Kumar et al. [18] evaluates the performance of mesh and tree-based multicast routing schemes relative to flooding and recommends protocols most suitable for specific MANET scenarios. He tries to characterize the performance of multicast protocols over a wide range of MANET scenarios. A more intelligent protocol, named *Neighbor Elimination Scheme (NES)* has been proposed in [33], [34]. Each node that receives the message for the first time does not retransmit it immediately, but waits for a given duration, which may be randomly generated. Then, the node starts monitoring its neighborhood and after each received copy of the broadcast message, it eliminates from its rebroadcast list those neighbors that are assumed to have correctly received it. If the list becomes empty before the node decides to relay the message, the re-transmission is canceled. This protocol allows some energy savings by canceling redundant emissions, while still insuring an entire coverage of the network.

A hybrid multicast routing protocol is proposed by Adel et al. It is able to change behavior in different situations in order to improve certain metrics like maximizing battery life, reducing communication delays, improving deliverability, etc. The protocol is augmented by an optimization scheme, adapted from the Optimized Link State Routing protocol (OLSR), in which only selected neighbor nodes propagate control packets to reduce the amount of control overhead.

B. QoS Routing

The United Nations Consultative Committee for International Telephony and Telegraphy (CCITT) Recommendation E.800, has defined QoS as: "The collective effect of service performance which determines the degree of satisfaction of a user of the service". Takahiro Hara [43] aims to quantify the influences of mobility on data availability from various perspectives. He proposes and quantifies several metrics that affect data availability.

Colin et al. [7] proposes a scheme for bandwidth allocation in wireless ad hoc networks. The quality-of-service (QoS) levels for each end-to-end flow are expressed using a resource-utility function. The shared channel is modeled as a bandwidth resource and the allocation algorithm employs an auction mechanism in which flows are bidding for resources. Fairness and quality of service (QoS) are two imperative issues in allocating wireless channels [11]. It proposes a fair QoS agent to simultaneously provide per-class QoS enhancement and per-station fair channel sharing in WLAN access networks. While QoS is implemented through scheduling and queue management algorithms, fairness is achieved by estimating the fair share for each station and dynamically adjusting the service levels of packets. [17] proposes a price-based resource allocation framework in wireless ad hoc networks to achieve optimal resource utilization and fairness among competing end-to-end flows. A study was conducted by Sooksan et al. [13] to study the effects of route reservation in MANETs. It was found that these schemes can indeed yield better delay performance than Non-reservation schemes. This advantage, however, comes at the expense of lower throughput. An important aspect for QoS routing is fulfillment of QoS requirement. In this aspect [15] analyses whether a packet sent by source satisfies the QoS requirements to the destination. It provides protocols that enable verification of delivered QoS for individual packets, as well as verification of statistical QoS for groups of packets.

Chilukuri et al. [42] presents an integrated MAC and routing protocol called Delay Guaranteed Routing and MAC for delay-sensitive wireless sensor network applications. DGRAM is a TDMA-based protocol designed to provide deterministic delay guarantee in an energy-efficient manner. The design is based on slot reuse to reduce latency of a node in accessing the medium, while ensuring that the medium access is contention-free. The transmission and reception slots of nodes are carefully computed so that data is transported from the source toward the sink while the nodes could sleep at the other times to conserve energy. Thus, routes of data packets are integrated into DGRAM, i.e., there is no need for a separate routing protocol in a DGRAM network. The Bluetooth MAC protocol is based on a strict master/slave concept wherein any communication between slave devices has to go through the master. While this model is simple, the use of such a non-optimal packet forwarding scheme incurs much longer delays between any two slave-devices as double the bandwidth is used by the master. As a solution, [14] proposes Dynamic Slot Assignment, where the piconet master dynamically assigns slots to slaves so that they can communicate directly with each other without any intervention from the master.

C. Multipath Routing

Multipath routing is essentially a routing technique where multiple routes to destination are explored. Initially, multipath routing was proposed to provide fault tolerance [19], [20]. Multiple paths are discovered and if one path becomes inaccessible, alternate path is explored, thereby providing fault tolerance. Multipath routing is used as tool to guarantee differentiated treatment to priority traffic in [21]. Because of the availability of multiple paths, each with its different QoS levels that it can provide, it becomes possible to offer differentiated services to different users. Multipath routing is applied in [22] as a means for minimizing the overhead resulting

from route disruptions and consequent flooding of route requests. [40] proposes a new routing protocol named CHAMP which uses cooperative packet caching and shortest multipath routing to reduce packet loss due to frequent route failures. Wang *et al.* [23], Zhang *et al.* [24], and Yin and Lin [25] explore multipath routing from load balancing perspective.

Multipath routing is regarded as appealing for ad hoc networking because it can provide fault tolerance. Use of back-up routes leads to less packet loss, longer duration of the communication sessions and robustness. Moreover, sending the data packets of each flow along different paths can lead to better distribution of the traffic load. Although multipath routing can be effectively used to increase reliability and robustness of established sessions, there are some overheads which cannot be ignored. Determining multiple routes itself is quite complicated with respect to unicasting routing. Often these multiple routes have to be established with variable factors, which makes the task more challenging. An important question to be answered here is that exploring these alternate paths means spending more resources such as bandwidth, power, etc. to find and evaluate them in the already constrained ad hoc networks. This calls for a trade-off between the benefits and its associated cost and we have to limit the overheads to some maximum level. Another question in Multipath routing is whether route maintenance should be centralized or distributed [22].

D. Energy-aware Routing

Some initial works tried to minimize power consumption by minimizing the maximum power of nodes or minimizing the total power consumption of all nodes [1], [2]. Some other works about energy-efficient broadcast have focused on routing protocols as a solution. These routing protocols are distributed routing algorithms that select routes with less energy cost. Most of the works on energy efficient broadcast/multicast are focused on configuring energy power of each node. That is, given the geometry position of a set of nodes in a plane, find the transmitting power of each node such that the energy cost of the broadcast/multicast tree is minimized [3], [4], [5]. Hassan *et al.* [6], proposes building a broadcast tree and by applying some heuristics, tries to minimize energy cost of the broadcast tree. The issues of QoS provision and energy conservation have been addressed in [8]. Jiun-Long *et al.* [8] discuss a QoS-aware and energy-conserving algorithm utilizing on-demand broadcasting technique. M. Cui *et al.* [44] uses a modification of back-off algorithm for wireless networks. To achieve node throughput fairness, the back-off is explored both in terms of time & space. The spatial back-off algorithms which back-off in space as an alternate to time back-off algorithms, though conserve energy, they have a negative effect on node's throughput fairness. Here throughput is related to both transmission power level & back-off window size and incorporated into CSMA protocol as CSMA/TS. The paper shows that this approach can achieve higher node throughput fairness even in situations known to be unfair, while still attaining high throughput.

E. Security Issues in Ad Hoc Networks

A covert channel is a concealed communication path whose very existence is not planned in the design of these channels [48]. Covert communication happens when a user intentionally manipulates and embeds information into some properties of the system in such a way that the extra information can be detected by specific users in the system. A low transmission rate is generally sufficient to satisfy the requirements of covert channels. Existence of covert channels violates both secrecy and integrity properties of trusted systems. A covert channel can be used to communicate sensitive information. A covert channel is very difficult to detect. This paper investigates ad-hoc wireless networks' susceptibility to covert channels that can be formed through manipulating the network protocols. In Mobile Ad-Hoc Networks, establishing trust relationships between the nodes is a challenging task. the sender nodes accurately identify the legitimate nodes in the network, a robust routing can be provided while mitigating the effects of malicious nodes. [49] Proposes a secure and robust routing scheme in which the interaction between the sender and receiver nodes is modeled using a dynamic Bayesian game model. A repeated game is considered and opinions of a node about the types of other nodes are established using an acknowledgement mechanism from the destination. The scheme guarantees the availability of message as long as a legitimate path exists.

Denial-of-Service (DoS) attacks can cause serious problems in mobile multi-hop networks [50]. Attacker traceback in mobile multi-hop networks is a challenging problem, due to its limited network/host resources. Existing IP traceback schemes developed for the fixed networks cannot be directly applied to mobile multi-hop networks due to its peculiar characteristics. This paper proposes a protocol framework for attacker traceback called CATCH for mobile multi-hop networks. CATCH tracks down attacker under diverse mobile multi-hop network environment with low communication, computation, and memory overhead. [51] describes a two-stage intrusion detection system (IDS) for use with mobile ad-hoc networks which works by analyzing the context from the application-level interactions of networked nodes. In the first stage global and local maxima in the probability density functions of the behaviors are identified to isolate deviance at the level of a single node. During the second stage, a cross-correlative component is used to detect multiple threats simultaneously.

III. Limitations of current routing protocols

Most of these protocols try to discover the route on-demand by flooding route request messages, which results in increased end-to-end latency and also consumes considerable amount of network bandwidth. These limitations make protocols not suitable for real-time multimedia communication. Most of the current protocols have limited support for QoS. QoS is either not supported at all or limited support is provided. Though many protocols try to find an efficient path based on prioritizing certain aspects over other, not much has been done in reliably measuring the QoS parameters and providing a guaranteed QoS connection. The available level of QoS support in ad hoc network is often arbitrary. Further, concepts of resource reservation such as Bandwidth reservation are still not much developed. All these make the current routing protocols for MANETs unfit for real-time and multimedia applications. Reliability is another issue which needs to be addressed to for ad hoc networks. Reliability of ad hoc networks is often almost questionable.

IV. Conclusion

The applications and domain of ad hoc networks are unlimited. Many current applications demand some minimum QoS requirements to be met. A bidding algorithm proposed by Colin et al uses bandwidth allocation to provide required QoS on a per flow basis. When it comes to providing QoS, it is to be seen that some nodes are not starved of network resources. For this Park et al proposes a fair QoS agent to simultaneously provide per-class QoS enhancement and per-station fair channel sharing.

Multipath routing is regarded as appealing for ad hoc networking because it can provide fault tolerance. Use of back-up routes leads to less packet loss, longer duration of the communication sessions and robustness. Moreover, sending the data packets of each flow along different paths can lead to better distribution of the traffic load. Although multipath routing can be effectively used to increase reliability and robustness of established sessions, there are some overheads which cannot be ignored. An important question to be answered here is that exploring these alternate paths means spending more resources such as bandwidth, power, etc. to find and evaluate them in the already constrained ad hoc networks. This calls for a trade-off between the benefits and its associated cost and we have to limit the overheads to some maximum level.

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