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To Detect Attacks against High throughput Multicast Routing Protocol in Wireless Mesh Networks

G. Michael, R. Kavitha

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Abstract: Wireless mesh network (WMNs) emerged as a promising technology that offers low-cost high-bandwidth community wireless services. Discovering and maintaining routes between nodes are one of the biggest challenges in WMNs. The ultimate goal of the WMN community is to provide a set of standardized protocols that can be both robust and scalable. To improve the group oriented services a multicast stability scheme is to be used. This paper focused on metrics that estimate link quality to maximize throughput. The main objective of this system is to detect attacks against high throughput multicast routing protocol. This approach improves the robustness of the ODMRP multicast protocol with secured and high throughput metric form. The solution accommodates transient network variations and is resilient against attempts to exploit the defense mechanism itself. Link stability is computed by using the parameters such as received power, distance between neighboring nodes and the link quality assessed using bit errors in a packet. This scheme is expected to provide highly stable, reliable, robust paths. As the paths in this should be stable for longer time and does not break easily during data transfer so this can also give longer battery life. This work will be carried out using NS2.

Keywords: Multicast, S-ODMRP, High-throughput Metrics, Forwarding Node, Link Stability.

INTRODUCTION

A wireless mesh network (WMN) is a communication network made up of radio nodes organized in a mesh topology. Wireless mesh networks often consist of mesh clients, mesh routers and gateways. The mesh clients are often laptops, cell phones and other wireless devices while the mesh routers forward traffic to and from the gateways which may but need not connect to the Internet. Numerous applications envisioned to be deployed in WMNs, such as webcast, distance learning, online games, video conferencing, and multimedia broadcasting, follow a pattern where one or more sources disseminate data to a group of changing receivers. These applications can benefit from the service provided by multicast routing protocols. Multicast routing protocols deliver data from a source to multiple receivers organized in a multicast group. In the last few years, several protocols [4]–[6] were proposed to provide multicast services for multi-hop wireless networks. These protocols were proposed for mobile ad hoc networks (MANETs), focusing primarily on network connectivity and using the number of hops between the source and receivers as the route selection metric. Many of the applications that benefit from multicast services also have high-throughput requirements. Hop count does not maximize throughput [2] as it does not take into account link quality. Given the stationary nature and increased capabilities of nodes in mesh networks, recent protocols [3] focus on maximizing path throughput by selecting paths based on metrics that capture the quality of the wireless links [2], such metrics as link-quality metrics or high-throughput metrics, and to protocols using such metrics as high-throughput protocols

In a high-throughput multicast protocol, nodes periodically send probes to their neighbors to measure the quality of the links from their neighbors. During route discovery, a node estimates the cost of the path by combining its own measured metric of adjacent links with the route cost accumulated on the route

G. Michael, Associate Professor, Department of Computer Science and Engineering, BIST, BIHER, Bharath Institute of Higher Education & Research, Selaiyur, Chennai. E-mail: michaelcse@gmail.com

R. Kavitha, Associate Professor, Department of Computer Science and Engineering, BIST, BIHER, Bharath Institute of Higher Education & Research, Selaiyur, Chennai.

discovery packet. The path with the best metric is then selected. High-throughput metrics protocols require the nodes to collaborate in to derive the path metric, thus relying on the assumption that nodes are collaborative and behave correctly during metric computation and propagation. This assumption is difficult to guarantee in wireless networks that are vulnerable to attacks coming from both insiders and outsiders, due to the open and shared nature of the medium and the multi-hop characteristic of the communication. A path selection introduces new vulnerabilities and provides the attacker with an increased arsenal of attacks leading to unexpected consequences. For example, adversaries may manipulate the metrics in order to be selected on more paths and to draw more traffic, creating opportunities for attacks such as data dropping, mesh partitioning, or traffic analysis. This work provides the security implications of using high-throughput metrics. It focuses on multicast in a wireless mesh network environment because it is a representative environment in which high-throughput metrics will be beneficial.

RELATED WORKS

The problem of insider threats in unicast was studied in [11] detects adversarial nodes by having each node monitors if its neighbors forward packets to other destinations. Ariadne [11] uses multi-path routing to prevent a malicious node from selectively dropping data. ODSBR [14] provides resilience to colluding Byzantine attacks by detecting malicious links based on an acknowledgment-based feedback technique.

Work studying multicast routing specific security problems in wireless networks is scarce with the notable exception of the authentication framework by Roy [5] and BSMR [7] which focus on outsider and insider attacks for the well known tree-based MAODV multicast protocol. Significant work focused on the security of unicast wireless routing protocols. Several secure routing protocols resilient to outside attacks were proposed in the last few years such as Ariadne [11] and the work in [13].

PROBLEM AND PROBLEM SOLVING APPROACHES

A. High-Throughput Metrics

Initially, routing protocols have used hop count as a path selection metric. In static networks, this metric was shown to achieve sub-optimal throughput because paths tend to include lossy wireless links [2].Now the focus has shifted toward high-throughput metrics that seek to maximize throughput by selecting paths based on the quality of wireless links (e.g., ETX [2]). In such metrics, the quality of the links to/from a node’s neighbors is measured by periodic probing.

ETX Metric - The ETX metric [2] was proposed for unicast and estimates the expected number of transmissions needed to successfully deliver a unicast packet over a link, including retransmissions. Each node periodically broadcasts probe packets which include the number of probe packets received from each of its neighbors over a time interval.

SPP Metric - ETX was adapted to the multicast setting by Roy et al. in the form of the SPP metric [3]. The value of SPP for a path of k links between a source S and a receiver R is the metric for each link on the path. The reason for defining SPP as above is twofold:

- Unlike in unicast, where a successful transmission over a link depends on the quality of both directions of that link, in multicast only the quality of the forward direction matters because there are no link layer acknowledgments.
- Unlike unicast, in which the individual link metrics are summed, in multicast they are multiplied. This reflects the fact that for SPP the probability of a packet being delivered over a path from a source to a receiver is the product of the probabilities that the packet is successfully delivered to each of the intermediate link. In particular, SPP = 1 denotes perfect reliability, while SPP = 0 denotes complete unreliability.

B. High-Throughput Multicast Routing

ODMRP overview: ODMRP is an on-demand multicast routing protocol for multi-hop wireless networks, which uses a mesh of nodes for each multicast group. Nodes are added to the mesh through a route selection and activation protocol. The source periodically recreates the mesh by flooding a Join Query message in the network in order to refresh the membership information and update the routes. We use the term round to denote the interval between two consecutive mesh creation events. Join Query messages are flooded using a basic flood suppression mechanism, in which nodes only process the first received copy of a flooded message.

When a receiver node gets a Join Query message, it activates the path from itself to the source by constructing and broadcasting a Join Reply message that contains entries for each multicast group it wants to join; each entry has a next hop field filled with the corresponding upstream node. When an intermediate node receives a Join Reply message, it knows whether it is on the path to the source or not, by checking if the next hop field of any of the entries in the message matches its own identifier. It makes itself a node part of the mesh (the Forwarding Group) and creates and broadcasts a new Join Reply built upon the matched entries. Once the Join Reply messages reach the source, the multicast receivers become connected to the source through a mesh of nodes (the Forwarding Group) which ensures the delivery of multicast data. While a node is in the Forwarding Group, it rebroadcasts any non-duplicate multicast data packets that it receives.

ODMRP with high-throughput metrics: The main differences between ODMRP-HT and ODMRP are: (1) instead of selecting routes based on minimum delay (which results in choosing the fastest routes), ODMRP-HT selects routes based on a link-quality metric, and (2) ODMRPHT uses a weighted flood suppression mechanism to flood Join Query messages instead of basic flood suppression as required by the link-quality metric each node measures the quality of the link from its neighbors to itself, based on the periodic probes sent by its neighbors. The Join Query message is flooded periodically by a source S and contains a route cost field which accumulates the metric for the route on which the message travelled. Upon receiving a Join Query updates the route cost field by accumulating the metric of the last link travelled by the message. Because different paths may have different metrics, Join Query messages are flooded using a weighted flood suppression mechanism, in which a node processes flood duplicates for a fixed interval of time and rebroadcasts flood messages that advertise a better metric. Each node also records the node from which it received the Join Query with the best quality metric as its upstream node for the source S.

After waiting for a fixed interval of time, during which it may receive several Join Query packets that contain different route metrics, a multicast receiver records as it's upstream for source S the neighbor that advertised the Join Query with the best metric. Just like in ODMRP, the receiver then constructs a Join Reply packet, which will be forwarded towards the source on the optimal path as defined by the metric and will activate the nodes on this path as part of the Forwarding Group. In Fig 1 gives an example of how ODMRP-HT selects the mesh of nodes in the Forwarding Group based on the SPP link-quality metric.

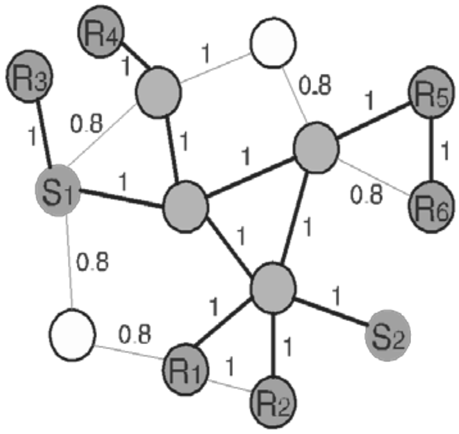

Fig. 1: ODMRP-HT Mesh Creation

ATTACKS AGAINST ODMRP-HT

This paper identifies several attacks against high-throughput multicast protocols. The attacks exploit vulnerabilities introduced by the use of high-throughput metrics. They require little resource from the attacker, but can cause severe damage to the performance of the multicast protocol. The attacker can achieve the goal of disrupting the multicast data delivery by either exhausting network resource (resource consumption attacks), by causing incorrect mesh establishment (mesh structure attacks), or by dropping packets (data forwarding attacks).

Types of Attacks

A. Resource Consumption Attacks
B. Mesh Structure Attacks
C. Data Forwarding Attacks
D. Metric Manipulation Attacks

A. Resource Consumption Attacks

The attacker can also activate many unnecessary data paths by sending many JOIN REPLY messages to cause unnecessary data packet forwarding. Finally, the attacker can inject invalid data packets to be forwarded in the network.

B. Mesh Structure Attacks

Mesh structure attacks disrupt the correct establishment of the mesh structure in order to disrupt the data delivery paths. The attacker can spoof the source node and inject invalid JOIN QUERY messages, which can cause paths to be built toward the attacker node instead of the correct source node.

C. Metric Manipulation Attacks

Multicast protocols using high throughput metrics prefer paths to the source that are perceived as having high quality, while trying to avoid low quality paths. A good strategy for an attacker to increase its chances of being selected in the FORWARDING GROUP is to advertise artificially good metrics for routes to the source.

The use of high-throughput metrics requires each node to collect local information about its adjacent links based on periodic probes from its neighbors. This local information is accumulated in JOIN QUERY packets and propagated in the network, allowing nodes to obtain global information about the quality of the routes from the source.

Attackers can execute two types of metric manipulation attacks:

1. Local Metric Manipulation (LMM)
2. Global Metric Manipulation (GMM)

LMM Attacks

An adversarial node artificially increases the quality of its adjacent links, distorting the neighbor's perception about these links. The falsely advertised high quality links will be preferred and malicious nodes have better chances to be included on routes.

GMM Attacks

In a GMM attack, a malicious node arbitrarily changes the value of the route metric accumulated in the flood packet, before rebroadcasting this packet. A GMM attack allows a node to manipulate not only its own contribution to the path metric, but also the contributions of previous nodes that were accumulated in the path metric.

D. Data Forwarding Attacks

The attacker node on the data delivery path simply drops data packets instead of forwarding them.

SECURE HIGH-THROUGHPUT MULTICAST ROUTING

This section presents secure multicast routing protocol that accommodates high-throughput metrics. It also describes about authentication framework and methodologies are involved in this paper.

A. Authentication Framework

Assume that each user authorized to be part of the mesh network has a pair of public and private keys and a client certificate that binds its public key to a unique user identifier. This defends against external attacks from users that are not part of the network. Assume source data is authenticated, so that receivers can distinguish authentic data from spurious data. Efficient source data authentication can be achieved with existing schemes such as TESLA [9].

B. Methodologies

The implementation work can be divided into

- Mesh Creation
- Attack Detection
- Attack Reaction
- Fallback Recovery

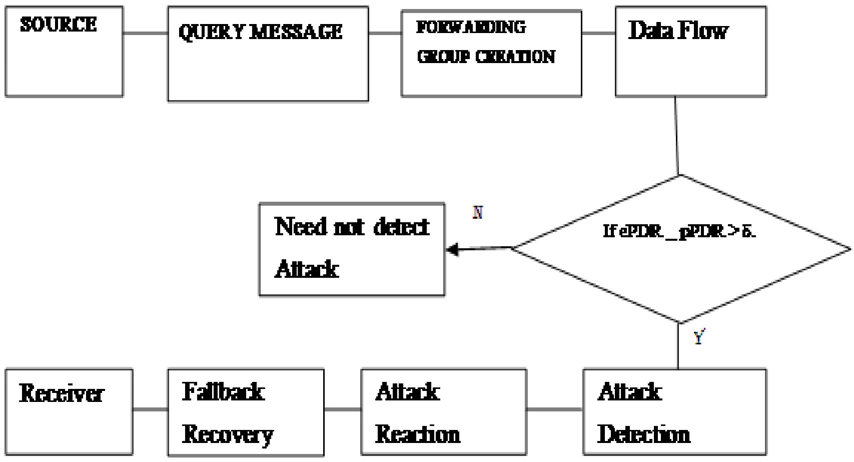

Fig. 2: Overall Flow Diagram

Mesh Creation

Join Query message is signed by S and then it is propagated. Nodes only process Join Query messages that have valid signatures and that are received from nodes not currently accused. Nodes record the upstream node and the metric correspond to the route with the best metric as best upstream and best metric.

The Join Reply massages are then sent from receivers back to S along optimal paths as defined by the high-throughput metric.

It leads to the creation of the Forwarding Group (the multicast mesh). After sending a Join Reply to its best upstream, a node starts to monitor the PDR from it's from its best_upstream in order to measure its perceived PDR (pPDR).

Attack Detection

It detects attacks using a measurement-based mechanism. Each forwarding group and receiver node continuously monitors the differences between expected packet delivery ratio (ePDR) and perceived packet delivery ratio (pPDR).pPDR calculated as pPDR=m / n ,where m is the number of packets received and n is the number of packets sent by the source. Flags an attack if ePDR _ pPDR > δ, where δ is the estimated PDR discrepancy under normal network conditions.

Attack Reaction

To isolate attackers, S-ODMRP protocol uses a controlled accusation mechanism. An accusation message in the network contains N's identity (the accuser node) and the identity of N's best_upstream node (the accused node). It also contains a value accusation_time, indicating the amount of time the accusation lasts. Recovery messages are activating the fallback procedure at the receiver.

Fallback Recovery

When an attack is detected, receiver nodes need to find alternative routes During Join Query flooding, besides recording the best upstream node, each node also record fastest upstream route. To recover from an attack a receiver sends a Join Reply message to fastest upstream node.

SCHEME EVALUATION

A. Simulation Analysis

In our Simulation Analysis, nodes are randomly placed. Then randomly select two receiver and its corresponding multicast group members. Group members join the group at the beginning of the experiment. At second 100, the source starts to multicast data packets for 400 seconds at a rate of 20 packets per second. When attackers are present, they are randomly selected among nodes that are not group members.

S – ODMRP use RSA signatures with 1024 – bit keys. This work tunes the threshold δ=20% to accommodate random network variations.

B. Performance Analysis

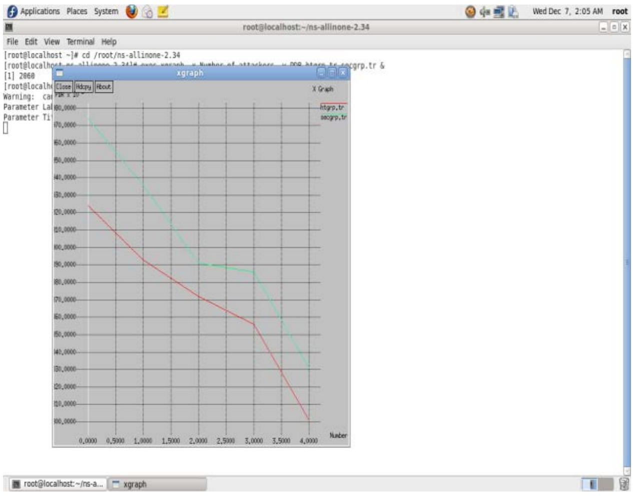

Fig. 3: The effectiveness of S-ODMRP compared to ODMRP-HT

The above figure shows the effectiveness of S-ODMRP defense scheme against number of attackers, compared to the insecure ODMRP-HT protocol. S-ODMRP suffers only a small PDR decrease relative to the baseline no- attack case. The PDR decrease for S-ODMRP as number of attackers increased. This outcome reflects the design of defense mechanism in which ODMRP-HT accusations last proportional to the discrepancy between ePDR and pPDR

CONCLUSION AND FUTURE WORK

This work identified metric manipulation attacks and security implications of using high-throughput metrics in multicast protocols in wireless mesh networks. Here, a node is detected as an attacker only if the PDR drop caused by the node exceeds the threshold δ.

In future work will carry out quality of the link using link stability scheme. This scheme is expected to provide highly stable, reliable, robust paths.

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