Environment-Aware Reputation Management for Ad hoc Networks

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***Abstract*— Reputation management is a mechanism that has been proposed to mitigate against internal node misbehavior with respect to the packet forwarding functionality in ad hoc networks [1]. Their goal is to promote cooperation among nodes by building a reputation for each and utilizing that reputation in offering differentiated services to different nodes (e.g. prioritizing packet relaying based on the reputation of the source). It has been customary to carry out the functions of reputation management (evaluation of node behavior, detection of misbehaving nodes, and reaction to nodes according to their behavior) homogeneously across time and space. However, the dynamic, resource-constrained, and infrastructureless nature of ad hoc networks suggest that node behavior can be spatially and temporally affected by the network environment. For a reputation management system to operate properly, it must distinguish between a node's willful decision not to forward packets (i.e. misbehavior) and its inability to do so due to adverse network environment. In this paper, we define and provide motivation for environment-awareness of reputation management systems in ad hoc networks. We highlight the requirements to yield reputation management environment-aware and introduce EARMAHOC (Environment-Aware Reputation Management system for Ad HOC networks), a reputation management system that partially honors a subset of the requirements defined for environment-awareness. We also discuss open research issues towards realizing a fully environment-aware reputation management system.**

I. Introduction

Reputation management is an effective mechanism in discouraging misbehavior and in mitigating the effects of misbehavior if it occurs. Reputation management systems can target security concerns related to internal misbehavior attacks in decentralized and unstructured networks such as ad hoc networks. However, a major shortcoming in most reputation management systems proposed is the assumption that reputation management systems at different nodes carry out the reputation management functions (node behavior evaluation, detection of misbehaving nodes, and appropriately reacting to each node according to its behavior) homogeneously across time and space. In other words, the evaluation criteria, detection decision factors, and reactive measures are the same at all nodes at all times. The homogeneous application of reputation decisions often results in sub-optimal performance, as it restricts adaptation [2]. Ad hoc networks operate in a dynamic environment where network conditions change from time to time and may be perceived differently from one node to another. This includes channel condition, traffic intensity, as well as the node available resources (e.g. battery power, bandwidth, etc.). It also includes the topology dynamics. A node may fail to relay traffic routed through it due to adverse channel conditions, congestion at the network layer, the inability of the routing protocol to converge due to rapid node mobility, or shortage of its battery power. For a reputation management system to operate properly, it must distinguish between a node's willful decision not to forward packets and its inability to do so due to adverse network environment. In this paper we describe the requirements of an environment-aware

reputation management system: one that is accounts for the dynamics of the network environment when evaluating node behavior (Section II). We also introduce EARMAHOC, a step towards environment-awareness in reputation management systems (Section II). We then discuss in Section III the challenges and open research issues in realizing environment-awareness in reputation management systems.

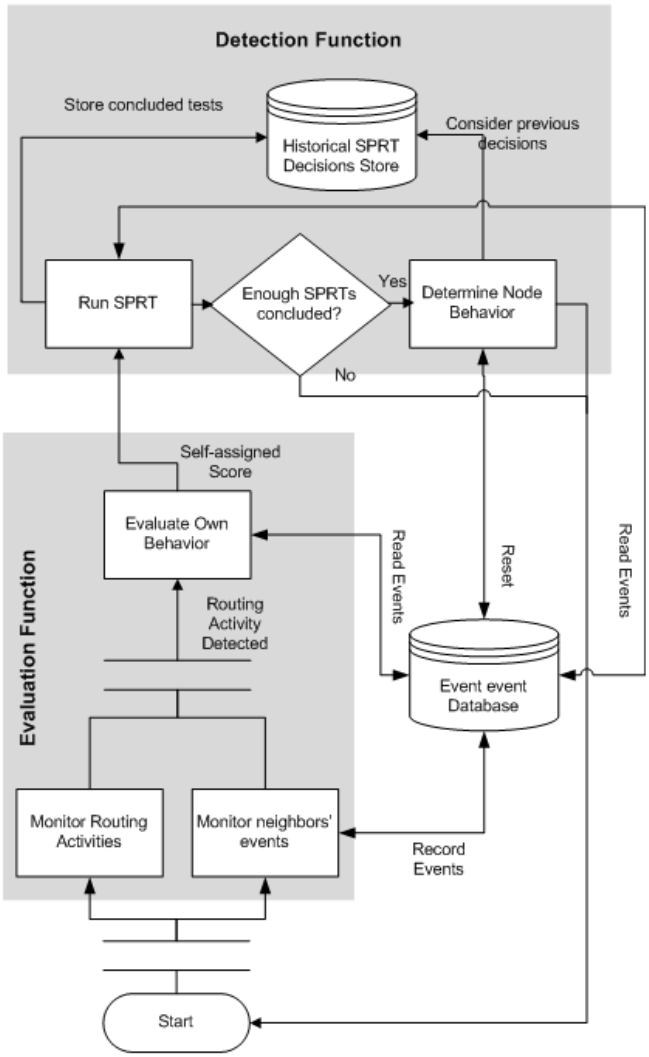

Figure 1. EARMAHOC System

II. ENVIRONMENT-AWARE REPUTATION MANAGEMENT SYSTEM

An environment-aware reputation management system is one that is aware of its surrounding conditions and their effect on node behavior. We consider the following to be requirements for environment-awareness in a reputation management system:

1) It must be aware of the network environment factors that may affect node behavior. This includes congestion at the network layer, contention at the data link layer, and physical communication impairments such as shadowing and path loss. Such conditions should be accounted for when evaluating node behavior.
2) It must be aware of any shortage in resources that may affect other nodes' willful decisions to forward packets. Shortage in battery power of some nodes for example should be taken into consideration when evaluating their behavior. Since such nodes are not necessarily cooperative (they lack the resources to relay traffic) but cannot be labeled misbehaving (since they do not have a malicious intent), a third category of nodes can be created (where the first and second categories being cooperative and misbehaving nodes) that distinguishes such nodes as disadvantaged. Routing through disadvantaged nodes may be limited to avoid further drainage of their already limited resources.
3) It must be aware of the topology dynamics and their impact on packet forwarding. Our earlier and on-going work has shown that the inability of routing protocols to converge in a rapidly changing topology affects the perception of node behavior (as a consequence of the inability of nodes to correctly relay packets) [3]. This should also be taken into consideration when evaluating node behavior.

We introduce EARMAHOC, our on-going research towards realizing environment-awareness in reputation management system for ad hoc networks (Figure 1). EARMAHOC is aware of the temporal and spatial network environment factors that affect node behavior. EARMAHOC consists of two main modules: behavior evaluation function and behavior detection function.

The node behavior evaluation function uses a metric to assign each node a score, which is a quantification of the node's behavior with respect to packet forwarding. The metric is based on the ratio of packets relayed to those routed through the node. In EARMAHOC, we utilize a self-behavior assessment mechanism to measure the impact of network environment factors on node behavior. Behavior evaluation is done in timeslots to capture temporal changes in network conditions. Each time-slot, cooperative nodes independently evaluate their own behavior with respect to packet forwarding and use

that to deduce the impact of network environment factors on node behavior within its neighborhood. If for instance the cooperative node is able to forward only 80% of traffic routed through it, then network environment factors around the node at the time of the evaluation account for 20% of all packet forwarding failures. Other nodes within the node's neighborhood are judged accordingly. The process is repeated every time-slot [3].

The detection function uses the scores assigned to nodes by the evaluation function and the sequence of events that led to each score to distinguish between cooperative and misbehaving nodes. EARMAHOC utilizes the Sequential Probability Ratio Test (SPRT) [4] at the detection function. In a SPRT, the number of observations required to evaluate node behavior need not be determined in advance and observations may be weighted differently depending on their significance. These properties of SPRTs suit well the dynamic nature of ad hoc networks where the rate and the significance of a given observation may change spatially and temporally. As previously mentioned, the behavior evaluation function of a node passes to the detection function at the end of each evaluation slot the list of scores assigned to each neighbor, the sequence of events (i.e. observations) that led to each score, and the node's self-assigned score. The detection function analyzes the list of events related to each node and uses a SPRT as a judgment function. If after *n* events the judgment function reaches either the SPRT threshold that marks misbehaving or the threshold that marks cooperative behavior, the test concludes with evidence about the node's behavior during the last *n* events, i.e., either misbehavior or cooperative behavior. The outcome of the test is recorded and the test is restarted for another evaluation round starting at the *n + 1* event [3].

EARMAHOC also considers topology dynamics. In a dynamically changing topology, node interactions are short and intermittent. Also, packet forwarding may fail due to the instability of routes and at times due to the inability of the routing protocol to converge (particularly in scenarios with high mobility). Therefore, EARMAHOC accumulates evidence of node behavior over longer periods of time so as to capture longer-term patterns of node behavior. Decisions about node behavior are done only when enough evidence is collected to make an accurate assessment of the long-term node behavior.

III. Challenges And Open Research Issues

In this section, we summarize the main challenges that need to be address for developing environmental awareness for reputation management systems in ad hoc networks:

1) Mechanisms are needed to identify and accurately measure resources that may affect nodes' willful decisions to forward packets and to account for their effect when evaluating node behavior.
2) Mechanisms are needed to assess and account for the impact of topology changes on the ability of nodes to forward packets routed through them.
3) Increased awareness comes at the cost of increased complexity. The more the nodes become aware of their surroundings, the more resources they have to consume in the process. This includes energy and computational resources. Mechanisms are needed to weigh in the need for awareness against the consumption of resources needed to be aware and to adapt node awareness temporally and spatially as needed and as can be tolerated.

IV. Conclusion

In this paper, we made the case for environment-awareness in reputation management systems. Ad hoc network environments are too dynamic and require applications that are adaptive rather than statically configured. We introduced EARMAHOC, an on-going research towards realizing environment-awareness in reputation management system for ad hoc networks. We also discuss open research issues and challenges towards realizing a fully environmental-aware reputation management system.

References

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