On the Impact of Network Dynamics on a Discovery Protocol for Ad-Hoc Networks

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ABSTRACT

A very promising approach to discovering services and context information in ad-hoc networks is based on the use of Attenuated Bloom filters. In this paper we analyze the impact of changes in the connectivity of an ad-hoc network on this approach. We evaluate the performance of the discovery protocol while nodes appear, disappear, and move, through analytical and simulative analysis. The analytical results are shown to be accurate when node density is high. We show that an almost linear relation exists between the density of the network and the number of update messages to be exchanged. Further, in case of nodes moving, the number of messages exchanged does not increase with the speed of movement. [Article copies are available for purchase from InfoSci-on-Demand.com]

Keywords: Ad-Hoc Networks; Mobility; Networking; Performance Evaluation; Wireless Technologies

INTRODUCTION

Context-aware ad-hoc networks adapt their behavior based on the context in which they operate. For this purpose, nodes use information from context sources. To discover these sources, a context discovery protocol is needed. Such a protocol disseminates information on context information that can be provided by nodes to nodes that might want to use the information. Ad-hoc networks are severely limited in resources, such as communication bandwidth, energy usage, and processing power. To save communication resources, we have proposed to perform context discovery using attenuated Bloom filters (ABFs) (Liu & Heijenk, 2007). We have proven that using ABFs our discovery protocol can provide discovery, while exchanging far less information than conventional approaches.

Another important feature of ad-hoc networks is dynamics in connectivity. In this paper, we present an investigation of the impact of network dynamics on our ABF-based discovery protocol through an analytical ap-
proach. In general, three categories of causes of network dynamics can be identified: nodes may be mobile; battery-supplied devices might exhaust their batteries; the quality of the wireless transmissions might be varying due to varying propagation conditions.

Because of the random position and movement of the nodes, it is not feasible to quantify the network traffic of our discovery protocol in a mobile environment mathematically. Thus, simulation is a good approach to study this problem. (Goering, Heijenk, Haverkort, & Haarman, 2007) has examined the network traffic generated by updating the ABFs while nodes are moving in a low density network, and the reachability of the required services through simulations. In this paper, we present an analytical modeling of the dynamics due to the limited battery-supply and unstable transmission quality in very high-density networks. First, we will consider node disappearance and appearance. When a node is powered off, it disappears from the network. After it switches on again, it joins the network again. We quantify the network load through analytical study and verify obtained results with simulations. Further, we observe a special case where the packets transmitted by a node get lost for certain time due to the poor propagation conditions. In this scenario, the node is considered as disappearing and reappearing in the network. We obtain simulation results for various packet loss periods. Finally, we study the effect of node movement on network traffic for various network densities using simulations.

This paper is structured as follows. Section 2 gives a brief introduction of the ABF-based context discovery protocol for ad-hoc networks. Section 3 discusses network structures, the assumptions we use in our analysis, and an approximation for the basic notion of i-hop node degree. Section 4 presents the analysis of network traffic when nodes appear and disappear in the network, when a series of consecutive advertisement packets are lost, or when nodes are moving. Section 5 concludes the study and discusses the future work.

A DISCOVERY PROTOCOL FOR AD-HOC NETWORKS

Attenuated Bloom Filters (ABF)

Bloom filters (Bloom, 1970) have been proposed in the 1970s to represent a set of information in a simple and efficient way. They use \( b \) independent hash functions to code the information. The hash results are over a range \( \{1...w\} \), where \( w \) denotes the width of the filter. In the filter, which has a length of \( w \) bits, every bit is set to 0 by default. Only the bit positions associated with the hash results will be set to 1. The resulting Bloom filter can be used to query the existence of certain information. If all the bit positions related to the hash results of the queried information are 1 in the filter, the information exists with small chance of false positive.

Attenuated Bloom filters (ABFs) are layers of basic Bloom filters. We use ABFs to represent information regarding the presence of context sources on a hop-distance basis (Liu & Heijenk, 2007). The \( i \)th layer of an ABF \( (0 \leq i < d - 1) \) aggregates all information about context sources \( i \) hops away. The depth of the ABF, \( d \), also stands for the total propagation range of the information. Note that context sources reachable in \( i \) hops may also be reachable via longer paths. As a result, hash results at layer \( i \) will often be repeated in lower layer \( j \) (\( j > i \)).

Figure 1 exemplifies the context aggregation operation for a node with two neighbors. In this example, each node has an ABF with 8 bits width \( (w=8) \) and a depth of 3 \( (d=3) \). The node uses two hash functions \( (b=2) \) to encode its local context sources “temperature” and “humidity” into \( \{2,8\} \) and \( \{2,5\} \) respectively. If we set the corresponding bit positions, we can obtain \( filter_{local} \) as shown in Figure 1. When the node receives the incoming filters \( filter_{in}[1...] \) and \( filter_{in}[2...] \) from its neighbors, it shifts the received filters one layer down and discards the last layer. Thus, \( filter_{in}[1...]’ \) and \( filter_{in}[2...]’ \) are obtained. We perform a logical OR operation on each set of corresponding bits of \( filter_{local}, filter_{in}[1...]’ \) and
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