Visualizing Uncertainty in Mobile Ad Hoc Networks

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Introduction

In mobile ad hoc networks, the use of queries is very important because applications need information from the network. Queries allow programmers to simply describe the kind of data they want without requiring them to know exactly where the data is located and how to get it from the network. Processing queries in the ad hoc network, however, has its challenges. With the mobility of nodes; nodes move in and out of communication range, causing links to break in the middle of query processing. Also, values change all the time during query processing. With traditional queries, the desired result is a snapshot of the state of the database at the time that the query is issued. It is not easy to get a snapshot of the network at the exact time the query is requested because of node movement and value changes. It is important that the fact that the query issued over the ad hoc network may not return a snapshot be exposed to the user who is requesting the query so they can see the degree of and reason for the inconsistency in the query result and make decisions based on that information. One way this can be done is to provide a visualization of the query result, as well as how and why it differs from the desired snapshot. The goal of this project is to come up with a software program that will collect all the information about nodes and values in the network and how they change over time, interpret it, and represent it in a visual way that can help users understand what is going on with the query and its results.

Background

A traditional query is issued over a single entity, a centrally controlled database, and you get a result. With a network query, the query is issued over multiple entities (nodes) and since the nodes move and links change over time they are different from traditional queries. Each entity receives the query over a wireless network link and also has to send back a result over the wireless network link. It takes time for this query to be passed on by the nodes in the network and it cannot be instantaneously distributed to all nodes. Since nodes can move at any time causing disconnection or new connections and values can change, there can be some changes in the network before the query can finish its execution. In Figure 1, this is described with the traditional query in the left as it sends in a query and gets back the result with no problems, and the network query that has to go through all of the nodes to get responses.

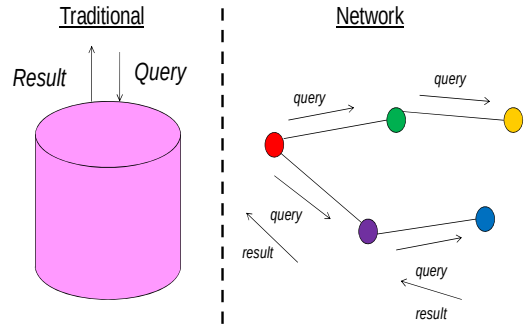

Figure 1.

Let's say that a query is issued over the ad-hoc network that says "tell me the number of tanks that are available". Let's pretend we issue the query over the network and ask some entity to watch the entire network as the query was executed and tell us what happened as well as the result. The entity might tell us "the result of the execution of the query protocol over the network is two tanks". Since we already know that there were three tanks available the instance the query was issued the results are invalid. Before the query could reach tank number 3, it moved away and disconnected from the network so and was not considered by the query. In other words, the query missed the tank, therefore there is some inaccuracy in the result and they are inconsistent.

Uncertainty in mobile ad hoc networks is an interesting topic and necessary to understand in order to allow applications to make decisions about their query results. Dr. Jamie Payton and other researchers wrote a paper on automatic consistency assessment of query results in dynamic environments [1], which explains the different semantics (meanings) of uncertainty in mobile networks. These semantics describe how well the results of a query reflect that state of the network at the instant a query is issued.

Research

We want to expose the uncertainty present in the query results for queries issued over mobile ad hoc networks. We do this so that users of queries can make decisions based on the accuracy of their query results. The goal of this project is to make it easy for query users to understand such information. Therefore, we want to develop a visualization that provides query users with information about the uncertainty that is present in their query results. Visualization is a technique which helps communicate a message from data it shows. It allows users understand what they are looking at. To provide a visualization for our project, we take the following steps:

- Step 1: Understand the reason for uncertainty
- Step 2: Represent the changing network over time
- Step 3: Produce a visualization

In Step 1, I had to understand what the meaning of uncertainty is. Dr. Payton's paper was a good start. It allowed me to think of other ways to show uncertainty for different query results. During my study, I found out the main causes of uncertainty in mobile ad hoc networks is the nodes connecting, disconnecting and the changes in their values that occur during a query's execution. Also, I learned about the simulator OMNeT++ which executes a protocol to get the simulation results of the network queries. It outputs the data so it can be analyzed to determine the causes of uncertainty. Step 2 is the huge part of the research: developing a data structure that can represent the changing network over time. We chose to use a tree class which has the constructor for the tree and the functions to add, delete and traverse the nodes in the network. The tree has nodes, so we also developed a node class that includes all of the node characteristics (node ID, parent ID, array of neighbors, and value). The final step is producing a visualization of the nodes in the network. Our initial ides are based on the concepts of blurring data that we are uncertain about, or using a "heat map" with a color system that shows cooler colors for locations of uncertainty in the query results.

Conclusions

This research offers a new outlook on how queries in a mobile ad hoc network can have uncertainty. It explains why the network is not always accurate with its query results, what can be done about it, and how to represent inconsistencies so the query issuer and application programmer can understand what they are viewing. Our goal is to represent the changing network over time and visualize the query results.

References

J. Payton and C. Julien and G.-C. Roman. Automatic Consistency for Query Results in Dynamic Environments*, Proceedings of the ACM SIGSOFT Symposium on Foundations of Software Engineering. 2007. (ESEC/FSE 2007 Distinguished Paper Award)*