MOBI-DIK: An Approach to querying Data in a Mobile Ad Hoc Network

Ouri Wolfson
University of Illinois
wolfson@uic.edu

1. Problem and Innovative Aspects of Solution

A Mobile Ad-hoc NETwork (MANET) is a set of mobile nodes (sensors, PDA's, Blackberry's, vehicles, etc.) that communicate with each other via short range wireless protocols, such as IEEE 802.11, Bluetooth, Zigbee, or Ultra Wide Band (UWB) (see Figure 1.1). Consider a database that is distributed among the nodes of the MANET. On each mobile node there is a local database that stores and manages a collection of sensor produced alerts (or tags). All the local databases maintained by the mobile nodes form the *MANET database*. The nodes communicate alerts to neighbors directly, and the alerts propagate by transitive multi-hop transmissions. Figure 1.2 below illustrates a MANET database. **The problem we address in this project is to develop a self-organizing, self-healing, low-bandwidth MANET database without a central point of failure or reliance on servers.** The database will be used to disseminate sensor produced alerts throughout the MANET. The heart of our invention is a distributed method that disseminates alerts intelligently in an adaptive manner. Using this method, each mobile node makes local decisions on when to disseminate alerts, how many to disseminate, and which alerts to disseminate. With the local decisions made by each individual node, the whole MANET database maximizes the number and timeliness of alerts disseminated to the mobile nodes, under the bandwidth, energy, and memory constraints. Specifically, the innovative aspects of our project include the following:

1. Store-and-forward (stateless) dissemination. There are two paradigms to conduct MANET data dissemination, namely state-full and stateless. In state-full dissemination, a routing structure is imposed and maintained among the mobile nodes. State-full dissemination may be ineffective in a large and highly mobile MANET, since the routing structure quickly becomes obsolete. In stateless dissemination, the intermediate nodes save alerts and later (as new neighbors are discovered) transfer these alerts. In the literature this paradigm is also called stateless gossiping, epidemic, or store-and-forward dissemination. In this project we will explore the stateless paradigm for alerts dissemination. Our invention does not rely on any infrastructure, central server, or routing data structures. Any subset of nodes will be able to separate from the network and share information by stateless dissemination. Broken connectivity will not automatically result in the loss of database capability for the war fighter. With these features, our invention provides high survivability of the MANET database in the presence of anomalies, failures, or threats.

The problem with the store-and-forward dissemination is that the alerts that need to be stored and forwarded by a node may exceed its storage, bandwidth, and energy capacities. Here is where the other two innovative aspects come into play.

2. Adaptive control of transmission size. We will evaluate a strategy by which a mobile node dynamically adjusts the number of alerts included in a transmission. The number depends on the period of time between two consecutive transmissions (the longer the period, the larger the number of alerts that the node is allowed to communicate), the available energy, the bandwidth, and the contact time between encountering neighbors.

With such adaptive control of transmission size, the number of collisions is minimized and the available bandwidth is optimally utilized.

3. Alerts prioritization. Given the bandwidth, energy, and memory constraints for the mobile nodes we target (sensors and PDA's), we believe that ranking of alerts is important in MANET databases, so that the most important alerts are transmitted and saved. Therefore we will explore a ranked store-and-forward (RANK-SF) method for alerts dissemination. The rank of an alert may depend on factors such as its demand (how important it is to the mobile nodes), its supply (how many mobile nodes have already received it), and its size.

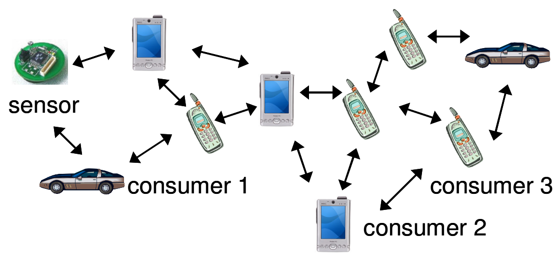

Figure 1.1: A mobile ad hoc network of sensors, PDA's, cell phones, vehicles.

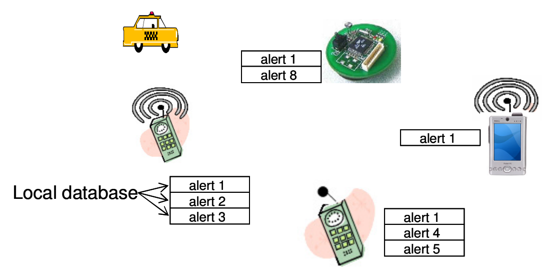

Figure 1.2: A MANET database

Our innovative aspects mentioned above are focused on scalability, self-healing, and self-organization. However, building the database will also require other components such as MANET source-to-destination routing, security, and reliability. For these we will adopt existing solutions.

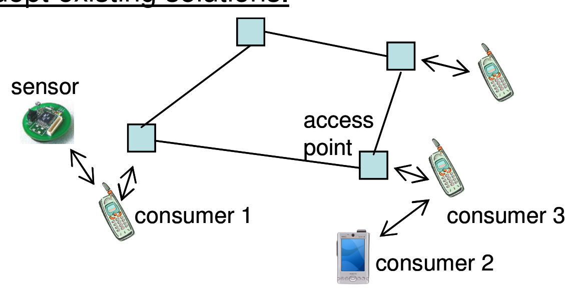

Figure 1.3: MANET database augments the infrastructure

The MANET database does not require a central server or a wireless infrastructure. However, when an infrastructure (such as a satellite, cellular or a helicopter-based network) is available, the MANET database can augment it to make the alert dissemination more efficient. The cellular and MANET approaches can be combined into an architecture in which dissemination of alerts in a MANET augments the infrastructure by covering the areas that are not covered by the infrastructure (e.g. elevators, subways, disaster areas), and it enhances and lowers the cost of alert dissemination where offered by the infrastructure. In other words, the MANET approach can also be used to communicate among the mobile devices in a hierarchical cellular architecture (see Figure 1.3), further enhancing the dissemination capability. In Figure 1.3, rectangles are access points of a (possibly fixed) hierarchical infrastructure, each of which controls an area called a "cell". For example, the squares may represent cellular controllers.

2. The MOBI-DIK System and Its Applications at DOD

In support of the MANET databases we propose to develop a Database Management System called *MOBI-DIK* (MOBIle DIscovery of local-resource Knowledge). The system consists of a set of software services, application programs and user interfaces (i.e. a software platform). The system will enable rapid development of MANET database applications that store information with complex spatial and/or temporal dynamics, in the same sense that a traditional Operating System does so for single-computer applications. MANET database applications will be embedded in computing and communication devices on board mobile nodes such as cell phones, PDA's, vehicles, and sensors. The system will relieve the developers of such applications from the burden of incorporating in the applications many complex issues related to data management, such as performance, memory, power, bandwidth, and security management. Basically, the system provides management (analogous to ORACLE for example) for databases that, instead of central servers, reside on mobile nodes that communicate via short-range wireless networks. Furthermore, such databases typically store spatial-temporal information, i.e. dynamic information that pertains to their geographic vicinity.

In a battlefield, MOBI-DIK can be used for short-range wireless dissemination of real-time battlefield intelligence, surveillance and reconnaissance (ISR) data. Possession of real-time, indeed instantaneous, information without having to wait for it to be posted is vital. Knowledge of the deployment and location of enemy forces will enable optimal tactical decisions to be made and executed. For example, a soldier driving a vehicle in a convoy needs to know about enemy engagements or other incidents in other parts of the convoy. The operation of the MANET database enabled by MOBI-DIK does not rely on any routing structure. This makes it self-healing since a structure is vulnerable to topology changes.