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Some observations on using meta-heuristics for efficient location management in mobile computing networks

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Abstract

With the increase in global wireless communication, there is a need for efficient network management strategies. Location management in a mobile network involves keeping track of mobile host (MH) cell locations. MHs perform location updates to inform the network of their location. When a call arrives for an MH, the network uses its last known cell location and a paging strategy to find that host. Current location management techniques do not consider host-mobility patterns or call arrival rates. This paper describes a selective update strategy that is modeled on the characteristics of a network, such as, topology, host mobility patterns and connection request rates. Then, a genetic algorithm is used to solve the location management problem that involves the search of a large solution space. The aim of the work is to determine whether genetic algorithms can be applied successfully to solve this problem, and to evaluate their efficiency in solving this class of optimization problems. Results from the selective update strategy show improvements over alternative algorithms. The location management optimization problem is shown to be well adapted to the workings of the genetic algorithm. The proposed solution also saves power, processing time, and network bandwidth.

Keywords: Genetic algorithms; Location management; Mobile computing; Wireless networks

1. Introduction

Wireless communication using radiated electromagnetic waves, is becoming one of the most popular and practical ways of communicating across land, sea, and space. The ability to communicate without wires has provided the basis for new technologies from simple cell phones to sophisticated military systems.

Mobile devices can be divided into four major application areas: one-way messaging, two-way dispatch, two-way mobile telephone, and two-way data or messaging. One-way messaging uses a radio signal to simply forward an alert to the wireless device (often referred to as a "pager"). The device may have the functionality to output a message, or just a beep tone.

Two-way dispatch is basically a "command-and-control" system for coordination of portable units by a central dispatch. Messages are typically short and distributed to multiple receivers (one-to-many communication). Two-way mobile telephone includes the ability of mobile devices to engage in extended full-duplex calls or exchanges.

Finally, two-way data messaging has evolved most recently, and represents the current and future model for wireless communication. It facilitates varied forms of data communication such as electronic messaging, computer communication, and telemetry.

Location management in a wireless network deals with the tracking of each mobile host (MH) as it moves through communication-linked regions called cells. Each cell is defined in size and geometry by base stations that allow two-way communication from MHs to a main switching centre. MHs notify the system of

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their position "location update". Location updates have an associated cost composed of several factors such as bandwidth usage, power dissipation, and processing time.

When a call arrives for an MH, the last known cell location is paged (paging also has an associated cost). If the MH performs location update at a high rate, a low number of pages is required to locate that MH when needed. A balance may be found between location update and paging so that the wireless network has a lower overall cost of location management.

With the dramatic increase in wireless availability and use, the need for efficient location management has become more important. The current technology has not yet evolved to a stage where location-tracking overhead is negligible. That is, the costs of location management are high enough to warrant investigation of new paradigms in this area.

Few existing location management techniques consider the composition and state of the network they oversee. There are four common update schemes that can use time, movement, distance, and zones to determine when to update. These and other methods of location management suffer from the following drawbacks:

- generalized assumption of cell geometry and topology,
- inaccurate host mobility models,
- insensitive to paging costs and call arrival rates,
- global tracking schemes for large networks are inefficient and cause stress on the high-level wire-line network.

The goal of the paper is to determine whether a genetic algorithm is capable to generate efficient solutions that reduce Location management costs (LMCs). This can be achieved by the following process: implement a flexible and extensible wireless network model, design a genetic algorithm, generate solutions that may be practically implemented in a wireless network, incorporate network state and topology (among other factors) into the optimization problem, calculate the average LMC given a suitable user mobility model, compare the results and performance of the genetic algorithm to other location management techniques, and finally, draw conclusions as to whether genetic algorithms are useful in delivering cost effective location management solutions.

The location management problem is introduced in Section 2. Section 3 provides a brief discussion of genetic algorithms. The proposed genetic algorithm-based approach is presented in Sections 4 and 5 that describe how the mobile network was designed and implemented. This is followed by results and conclusions in Sections 6 and 7.

2. Location management in mobile networks

A cell is the most atomic unit in network topology. It is defined as a physical area where an MH may reside. Cells size and location is generally governed by a mobile service station (MSS). An MSS acts as a stationary transmitter and receiver for communication between MHS and a large central message exchange.

Traditional network models employ hexagonal cell geometry. This paper uses a different representation. A network can be represented as a bounded and connected graph. This enables us to concentrate on network topology, rather than cellular geometry. It also provides a level of abstraction over the irrelevant physical aspects of the system, such as areas where cells overlap and frequency assignments.

Formally, the graph is represented as $G = (V, E)$. The set of vertices V represents all the MSSs in the system, and the set of edges E represents the arcs or possible transitions between cells. Each arc has an associated probability and direction. The probability of all outgoing arcs (plus "no move" probability) for a node should add up to 1 (Fig. 1).

2.1. Mobile hosts

MHs are assumed to be passive, and in this paper, do little more than roam cells performing location update and receiving paging requests. In practice, they would represent electronic devices that accept and request data communications (an example would be a vehicle-based computer or mobile phone). MHs are used in this work to demonstrate the efficiency of network algorithms. An assumption is made that required statistics about the network (such as transition probabilities) can be attained by observing MH movements in the network over a period of time.

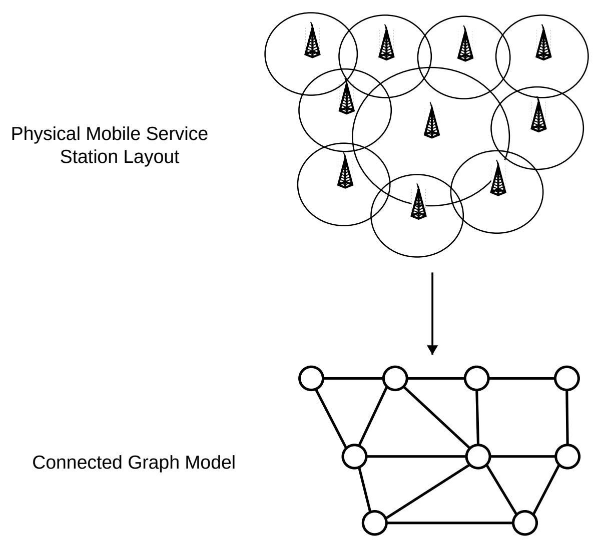

Fig. 1. Network model translation.