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Resource reservation with mobile hosts using fuzzy matrices

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Abstract

To provide high QoS (Quality of Service) with mobile hosts, service managers must first make resource reservations at subsequent locations to which mobile hosts may visit during the lifetime of the connection. In this paper, we propose a mechanism based on Fuzzy Matrices with movement directions and mobility specifications to predict the locations that a mobile host will visit. Through the fuzzification, defuzzification, and inference procedures, a resource reservation scheduling was performed. Our study indicates that the proposed strategy may significantly reduce the mean inefficiency (miss rate) and operating cost at 27 and 32%, respectively, compared with other approaches at the expense of a small blocking rate.

Keywords: Mobile computing; Resource reservation; Fuzzy matrices; Mobility specification; Quality of service

1. Introduction

To meet market demand and world trends, mobile phone services have been growing rapidly in Taiwan. As of January 2000, there are approximately 8 million subscribers to AMPS, GSM, and DCS systems at a penetration rate of 40% [1]. Today, subscribers require a significant number of real-time multimedia services such as video conferencing and video on demand. In order to support these multimedia applications, it is important that service networks must be able to provide QoS guarantees. The network architectures and mechanisms to provide real-time applications for stationary hosts are inadequate to accommodate mobile hosts that may frequently change their locations. Mobility and radio properties make the QoS guarantee more difficult in a cellular system [2].

Many mechanisms, based on resource reservation have recently been proposed to guarantee high QoS for real-time multimedia services in a mobile environment [3–5]. Most of these authors assumed that subscriber mobility could be known in advance using a mobility specification which is a database that records the historical calling tracks for a mobile user. However, because of the mobility features of mobile hosts, traces cannot be performed easily and thus the aforementioned assumption is impractical in the real world. In view of this, a mechanism based on the uncertainty analysis to predict the locations that a mobile host will visit is proposed here.

2. Background knowledge

To provide a high QoS guarantee for real-time multimedia services, many mechanisms based on resource reservations have recently been proposed for both stationary and mobile environments [6–8]. In this section, we provide an overview of these mechanisms.

2.1. RSVP and MRSVP protocols

RSVP, a resource ReSerVation Protocol that sets up resource reservations for real-time traffic is designed for existing networks [9]. A host requesting a specific QoS from the network for particular application data streams uses RSVP. Two types of flows have been defined. These are as follows.

- *Active:* a flow is active at a switch along a data path if resources are reserved for the flow at these switches along the data path and data is being transmitted to a receiver along that path.
- *Passive:* a flow is passive at a switch along a data path if resources are reserved for the flow at these switches along the data path but the data is not currently passing through that switch.

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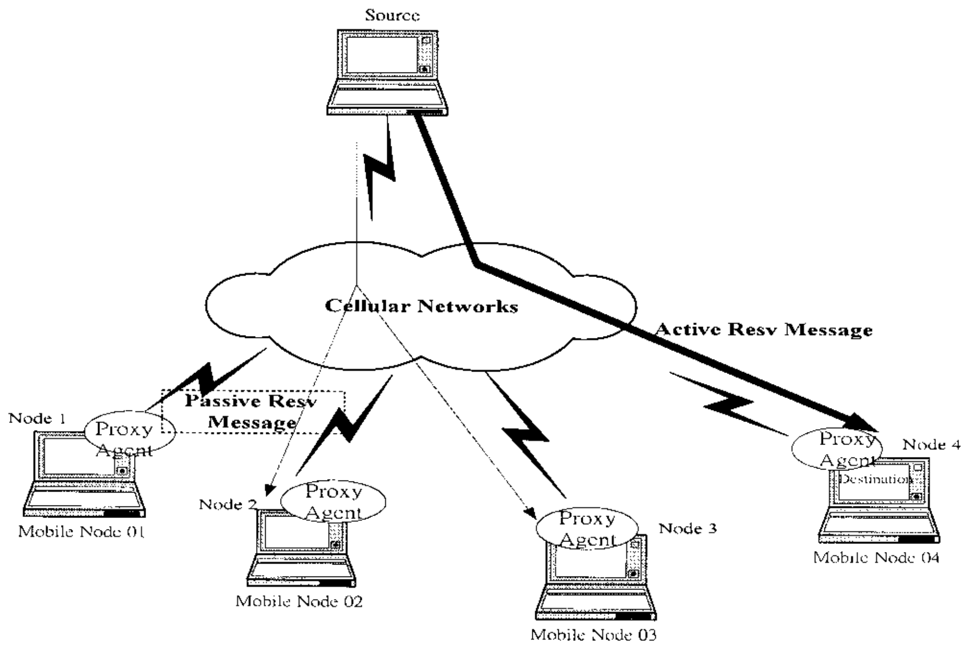

Fig. 1. The concept of MRSVP protocol.

In the RSVP protocol, a flow is identified by the destination address. This protocol uses seven types of messages such as *Path*, *Resv*, etc. Each datagram periodically sends a *Path* message that sets up the path state at these switches along the path from the sender to the receiver. Each receiver periodically sends a *Resv* message that sets up a reservation state at these switches along the reverse path from the receiver to the sender.

However, this is not suitable for mobile computing because the usual periodic reservation refreshing mechanism may not be able to adequately respond when mobile hosts move. Therefore, Talukdar extended the RSVP concept and proposed a new protocol MRSVP (Mobility-RSVP) to support mobile hosts [10].

MRSVP requires proxy agents to make reservations along the paths from the sender to the locations in the mobility specification, which is the set of locations the mobile host is expected to visit during the lifetime of the connection. The proxy agent of a subnet supporting mobile nodes is a special MRSVP capable router in the subnet, which has the ability to deliver all datagrams to the mobile nodes and make passive reservations on behalf of the mobile hosts, which are not currently present in the subnet. The proxy agent at the current mobile node location is called the local proxy agent. The proxy agents at the other locations in the mobility specification of a given mobile node are called remote proxy agents. The remote proxy agents will make passive reservations on behalf of the mobile nodes. The local proxy agent of a mobile node acts as a normal router for the mobile node and an active reservation is setup from the sender to the mobile node via the local proxy agent.

A mobile node, requesting a mobility independent service guarantee, makes an active reservation from the sender to its current location and a passive reservation is made from the sender to all other locations in the mobility specification where it may move later. When the mobile node moves from one location to another, according to its mobility specification, the active reservation to its old location is turned into a passive reservation and the passive reservation to its new location is turned into an active reservation. The MRSVP concept is illustrated in Fig. 1.

This scheme assumes that the mobility of a subscriber can be known in advance according to the mobility specification.

2.2. Linear resource reservation scheme

Based on the behavior that people usually exhibit along roads or highways, the Linear Resource Reservation (LRR) mechanism is proposed in Ref. [11]. This strategy is based on the assumption that the probability a mobile host will move in a straight line will be greater than any other direction and is illustrated in Fig. 2.

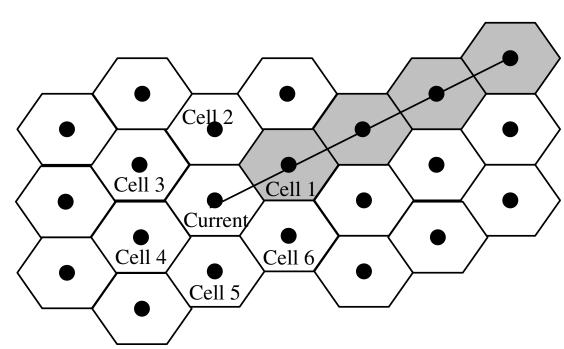

Fig. 2. The strategy of LRR.

LRR assumes that every base station has a unique global coordinate, say (x, y). When a mobile node moves to another cell, two coordinates are produced. We therefore have a linear equation and can make resource reservations in advance along this straight line. However, this strategy will not take the “inexact structure” into consideration.

2.3. Other schemes

Levine proposed a resource allocation and admission control scheme based on the Shadow Cluster concept [12]. In this scheme, mobile hosts inform the base stations in neighboring cells of their bandwidth requirements, position, and movement parameters at the call setup time. Based on this information, base stations predict future demands, and then reserve resources accordingly. This improves the QoS of mobile calls by reducing the number of dropped calls in a mobile environment.

Fujita also proposed IP roaming in which mobile hosts can maintain communication before and after moving towards a neighboring network segment by getting a new IP address through a Dynamic Host Configuration Protocol (DHCP) before moving [13].

Choi proposed an efficient strategy for a Wireless Local Area Network (WLAN) that provides quality of service guarantees for heterogeneous traffic within a cell [3]. This strategy categorized the traffic into two classes, real-time and non-real-time, according to the required QoS. The Time Division Duplexed transmission was used with classes for the reservation scheme.

In Ref. [5], channel reservation is based on the handoff probability of a call arriving at an adjacent cell. This proposed method is a more flexible and dynamic means of providing handoff priority in a mobile pico-cell environment, in which frequent handoff events are expected.

In Ref. [6], a new admission control scheme based on adaptive bandwidth reservation to provide QoS guarantees was proposed. This scheme uses both local and remote information to determine connection acceptance or rejection and reduce the assigned bandwidth to non-real-time calls. This method provides high QoS to real-time calls. This scheme can also adjust the amount of reserved bandwidth based on network conditions.

There are additional works on resource allocation in a multicast environment. Legout investigated three bandwidth allocation policies for multicast flows and evaluated their impact on the bandwidth received by the individual receivers [14]. These policies can achieve the best trade-off between maximizing receiver satisfaction and maintaining a high degree of fairness. Kodialam and Low researched resource allocation methods [15]. They focused on how to allocate bandwidth in a multicast tree and solve the problem of allocating bandwidth such that the sum of link costs is minimized.

The drawbacks of these schemes are that they require detailed knowledge regarding the mobile hosts’ movement patterns, such as the probability that a mobile host will arrive at a given cell at a given time. Moreover, the admission control policy portion of these schemes is only suitable for scheduling a slow-motion environment. However, the problem of providing QoS guarantees in a mobile environment and the associated reservation protocol design has been not addressed. The mechanisms presented in these works may suffer significant QoS degradation due to the high mobility rate.

3. Proposed reservation schemes

In this section, some basic fuzzy set theory concepts are reviewed for the development of our mechanism. Following that, we will explain our approach in detail.

3.1. Fuzzy sets and linguistic variables

In 1973, Professor L.A. Zadeh proposed the concept of linguistic variables [16,17]. Linguistic variables can be thought of as linguistic objects or words, rather than numbers. In a non-fuzzy set, an element of the universe of discourse either belongs to or does not belong to that set. That is, the membership of an element in the set is binary (yes or no). A fuzzy set can be viewed as the generalization of a crisp set in that it allows a degree of membership for each element to range over the unit interval [0,1] instead of only 0 or 1. Therefore, the membership function of a fuzzy set maps each element of the universe to its interval range, [0,1]. A fuzzy set F in U may be represented as the set of ordered pairs of a generic u and its grade of membership function: $F = \{(u, u_F(u)) | u \in U\}$.

The notion central to a fuzzy system is that the membership value, which is indicated by a value in the range [0.0, 1.0], with 0.0 representing absolute Falseness and 1.0 representing absolute Truth. It is important to note that two operations, UNION (OR) and INTERSECTION (AND), which represents the clearest point of departure from a probabilistic theory for sets to fuzzy sets. These two operations are utilized to support our approach.

$$\mathrm{C} = \mathrm{A\ UNION\ B},\ \text{where}: \mu_{\mathrm{C}}(x) = \mathrm{MAX}(\mu_{\mathrm{A}}(x),\ \mu_{\mathrm{B}}(x))$$

$$\mathrm{C} = \mathrm{A\ INTERSECTION\ B}\ \text{where}: \mu_{\mathrm{C}}(x) = \mathrm{MIN}(\mu_{\mathrm{A}}(x),\ \mu_{\mathrm{B}}(x))$$

3.2. Concepts of fuzzy logic controller

Fuzzy Logic is a departure from classical two-value sets, that uses “soft” linguistic (e.g. large, hot, tall) system variables and a continuous range of truth-values in the interval [0,1], rather than strict binary (True or False) decisions. Simple, plain-language **IF** *X* **AND** *Y* **THEN** *Z* rules are used to describe the desired system response in terms of linguistic variables rather than mathematical formulas.