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Time-optimized user grouping in Location Based Services

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ABSTRACT

We focus on Location Based Services (LBSs) which deliver information to groups of mobile users based on their spatial context. The existence (and non-trivial lifetime) of groups of mobile users can simplify the operation of LBS and reduce network overhead (due to location updates and application content flow). We propose an incremental group formation algorithm and an optimally scheduled, adaptive group validation mechanism which detects and further exploits spontaneous formation of groups of mobile users. The advantages of application simplification and network load reduction are pursued. Through the proposed mechanism the LBS server (back-end system) monitors representatives of formed groups, i.e., group leader, and, in turn, disseminates location-dependent application content to group members. We first introduce an incremental group formation algorithm for group partitioning and identification of group leaders. We elaborate on the mechanism which adopts the Optimal Stopping Theory in order to assess the group persistence through evaluation of compactness and coherency metrics. We compare the performance of the proposed scheme with that of existing mechanisms for moving objects clustering and quantify the benefits stemming for its adoption.

1. Introduction

We focus on the Location Based Services (LBS), which deliver information to groups of mobile users based on their surroundings, e.g., location information, nearby objects, spatially characterized content. In a typical scenario, mobile clients equipped with Global Positioning System (GPS) devices or other positioning technology send their locations to a central LBS server; hereafter referred to as the *system*, as shown in Fig. 1(a). The system collects such location information, establishes a connection with each mobile terminal and delivers (possibly personalized) content, e.g., advertisements to mobile users upon entrance to specific areas, like shopping malls, warnings when traffic conditions change, or tourist information when users approach a certain location [1,2]. However, as the number of users increases and they continuously change their position, the system and network load for location-based content delivery becomes quite significant [3].

Mobile users often form groups in daily life. The partition of moving objects into groups (clusters) has attracted increasing attention in the recent past [4–6]. A *group* is formally defined by a *Group Leader* (GL) and nodes that are within the GL's communication range. Such nodes are, hereafter, referred to as *members* of the group. Moving objects clustering results to groups of objects, which are not only close to each other at the current time but also

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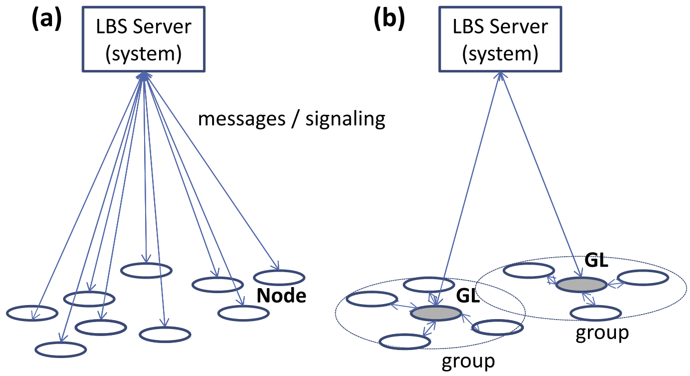

Fig. 1. (a) Typical scenario of location-dependent content and signalling between LBS server (system) and moving objects (nodes), and (b) Group-oriented communication among LBS server, group leaders (GLs) and nodes.

likely to move together for a certain time horizon. In Fig. 2, we can see an example of three group examples of moving objects Q_1, Q_2, Q_3 and their evolution over time starting from their creation time instance t_0. Evidently, the movement of objects that belong to a certain group is highly correlated.

The work presented in this paper deals with *time-optimized group monitoring*. Our motivation is to exploit moving object groups for minimizing location updates from mobile users to the system and application related messages from the system to mobile users as shown in Fig. 1(b). Specifically, the concept behind our model is that the system, instead of monitoring the location of all individuals (and thus transmitting location-dependent content to them), it (i) identifies persisting groups of users, (ii) discontinues monitoring individuals, and (iii) monitors only the representative (a single member) of a group i.e., GL. Based on this approach, the system pushes application content only to the GL and in turn the GL passes such content to group members. In terms of signalling, after the appointment of a member as GL, the GL notifies group members to stop reporting their locations to the system. Hence, the use of resources in the underlying network is highly rationalized and system's computation overhead is significantly reduced. As a result new group-oriented services can be introduced in back-end systems and dispatched easily through the supporting network.

Our model tries to handle problems arisen when groups are moving. A moving group should be observed over time since some members with different speeds or diverging behaviour over time may render the group not so compact, as shown in Fig. 2. In such case the system periodically checks whether the initial group retains its 'structure', i.e., the number and identity of members persists, in order to monitor its members through the GL. However, the large number of continuous location changes of users increases the system load (e.g., high frequency of location updates) resulting to increased network overhead. The decision of the system whether to communicate only with GL of an already identified group or with all members of the group should be validated. This decision depends significantly on the compactness and coherency of each group (to be introduced in the following paragraphs). It is deemed appropriate that the system be certain enough to decide whether group persists or not in a specific time horizon. This motivated us to define and propose a Group Validation System (GVS) to support a group-oriented system on taking such decisions.

Consider a formed group Q at time instance t. The GVS continuously monitors the persistence behaviour of Q before deciding to communicate only with the GL. Obviously, if the GVS delays on making a decision to monitor only the GL of the group other than monitoring all members then we obtain increased load of network and computational overhead due to (i) continuous location updates from all group members and (ii) delivery of location-dependent content from the system to all members. On the other hand as long as the GVS delays on making such decision, it becomes more confident on the persistence of the group. The problem for the GVS is to determine a time instance $t_* > t$ at which it stops monitoring and communicating with all group members. The time

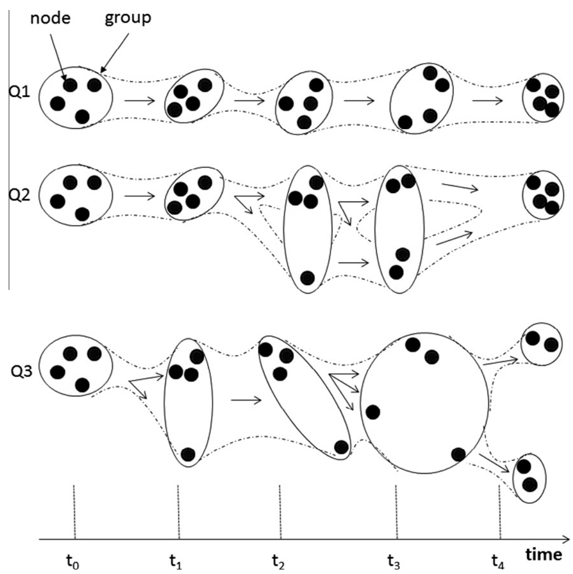

Fig. 2. Groups of moving objects (nodes), Q_1, Q_2, Q_3, along the time span.