Management of Information Sharing in Wireless Environments

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Abstract

We present a strategy for sharing Intelligent Transportation Systems (ITS) information in a wireless, two-way automatic communications environment such as digital cellular and personal communications services (networks). It is assumed that communications can be initiated by the mobile or the service, with or without user intervention. Based on the demand of information, the availability of data channels, the server can dynamically move the clients from channel to channel in order to achieve better use of both network resources and information.

1 Introduction

In the Phase I summary report of the ITS Architecture Development Program, 29 ITS user services are identified, as shown in Table 1.

Many of these ITS user services provide information that can be shared among users. En-route driver information, route guidance, and traveler services information, for example, should be made available to all interested users. Dynamic ride matching information, on the other hand, can only be shared by the *registered* users of the service for safety and security reasons. In addition, some services require two-way interactions between the user or user agent and the system. Most of the information services, especially the en-route and dynamic services, will be provided mainly through wireless rather than wire-line media.

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Currently, there are many proposed technologies and techniques for the request and delivery of sharable information for ITS services. Some wireless technologies are:

- RBDS Broadcast [2] and/or SCA [3].
- Cellular Voice Call-in [4].
- Localized Short Range Broadcast, e.g., AHAR and LPHAR [4].
- Localized Short Range Two-Way Vehicle-Roadside Communications (VRC), e.g., Ali-Scout [5] and Hughes VRC [6].

The broadcast methods mentioned above are inherently a one-way medium where the user needs to continuously monitor the appropriate medium for information. While it is possible to use some sort of control messages and a user-specified profile to filter the information flow so that the human user is only made aware of certain events [6], these methods require different devices for different media. In addition, they do not allow the user to feed back, report, or request information to the system. Localized short range

Travel and Transportation Management	Commercial Vehicle Operations
▶ En-Route Driver Information	▶ Commercial Vehicle Electronic Clearance
▶ Route Guidance	▶ Automated Roadside Safety Inspection
▶ Traveler Services Information	▶ On-Board Safety Monitoring
▶ Traffic Control	▶ Commercial Vehicle Administrative Processes
▶ Incident Management	▶ Hazardous Materials Incident Response
▶ Emissions Testing and Mitigation	▶ Commercial Fleet Management
Travel Demand Management	Emergency Management
▶ Pre-Trip Travel Information	▶ Emergency Notification and Personal Security
▶ Ride Matching and Reservation	▶ Emergency Vehicle Management
▶ Demand Management and Operations	Advanced Vehicle Control and Safety Systems
Public Transportation Operations	▶ Longitudinal Collision Avoidance
▶ Public Transportation Management	▶ Lateral Collision Avoidance
▶ En-Route Transit Information	▶ Intersection Collision Avoidance
▶ Personalized Public Transit	▶ Vision Enhancement for Crash Avoidance
▶ Public Travel Security	▶ Safety Readiness
Electronic Payment	▶ Pre-Crash Restraint Deployment
▶ Electronic Payment Services	▶ Automated Highway Systems

Table 1: ITS User Services [1]

two-way VRC provides information exchange capability. However, because of their limited placement at strategic intersections or points on highways the method lacks coverage. Users at other locations will not be able to obtain the services. Cellular voice call-in provides both the coverage and two-way information exchange, but it is slow (requires human intervention) and provides no interface to other on-board subsystems (e.g., navigation, route-guidance, remote automatic transaction systems) for further processing. It is also inefficient since the information can only be delivered to one user, over one exclusive channel at a time.

With the recent dramatic increase in mobile computing power and the (r-)evolution in wireless communications, mobile computing and communications devices/equipment are becoming more powerful and intelligent. We envision the following scenario for mobile information services: upon instruction by the user or a predetermined schedule, the mobile device will initiate the information exchange process — to request information or to submit information. It will then present the result to the user in a suitable form (voice, text or graphics), or to pass the information to other on-board subsystems. On the other hand, the service the user subscribes to will initiate the exchange to provide important updates (e.g., automatic incident interruption) or to poll the user (for automatic vehicle location management, for example).

The rest of the paper is organized as follows. The problem statement is presented in Section 2. We discuss the services and memberships in Section 3. Resource allocation and client management is discussed in Section 4. The paper concludes with Section 5.

2 Problem Statement

In any wireless communications environment, channels are a scarce resource. Sharing is important in both conserving the resource and serving more users better and more efficiently. Digital cellular and PCS have many advantages over other technologies: multi-functionalities (one device can be used for voice and data), wide-area and potentially seamless coverage, allowing automatic two-way information exchange, information/channel sharing and potential support for a large number of ITS and other information services. The problem of comparatively higher cost of cellular and PCS is deminishing as their price continues to decrease. In [7], we presented a medium access control protocol for shared channels in such environments.

We, in this paper, focus on how to manage information sharing among various service providers, the communications network, and the users. However, we will not discuss the detailed message transport protocols for individual services.

3 Services and Memberships

The services under our consideration include all suitable ITS user services and other value-added information services such as near real-time stock quotes. The services are loosely-coupled with the rest of the network as shown in Figure 1. This allows the communication between an information service provider and the cellular network components.

3.1 Service Look-up Server

A service look-up server (SLUS), which has a well-known directory number, is established for each local/metropolitan-wide area. All the information services connected to the network in the area are registered with SLUS as (ServiceType, DirectoryNumber). An internal protocol, which behaves like the Address Resolution Protocol (ARP), allows the SLUS from all areas to collaborate in locating services not available in a particular area. In this sense, SLUS serves as a referral service. A potential client will be able to interrogate the SLUS for services availability or for the directory number of a particular service in the local area or a remote area in another cellular network.

3.2 Service Membership

One client can subscribe to multiple services, and hence obtain multiple memberships. Permanent membership for a service is negotiated between the user and the service provider. For a user who wishes to access the service on a short-term basis, dynamic or temporary membership can be obtained with (possibly) restricted privileges. The charges to a temporary member of a service can be collected against his/her cellular account, using arrangements between the service and the network. The membership of SLUS service can be managed as permanent or temporary. For the rest of the paper, the term *server* is used to denote an entity that represents the service interface with the members. The term *user* is used interchangeably with *client* or *member*, and denotes the device that communicates directly with the server.

4 Resource Allocation and Client Management

The management of channel resources and clients requires the coordination of the cellular/PCS network and the information services. This includes channel allocation, consolidation, client migration, etc. The network provides the communications channel to the client-server sessions, while the server provides "hints" for channel management. This selected division of labor is advantageous because (1) the server helps to group the users to conserve resources and improve efficiency, and (2) the network is rid of the details of client management. New servers can be added but the complexity of the network management is not increased, thus improving the scalability.

4.1 Client Access and Session Termination

The client connects himself/herself to the services by dialing a well-known directory number of the service. The network sends the MIN (Mobile Identification Number) or the universal personal number of the client to the server. The server looks for the user in its user database and grants/denies the service. If the service is denied because of nonexistence or expired membership of the user, the user has the option of obtaining a temporary membership that is valid through the session.

Once the service is granted, the server records

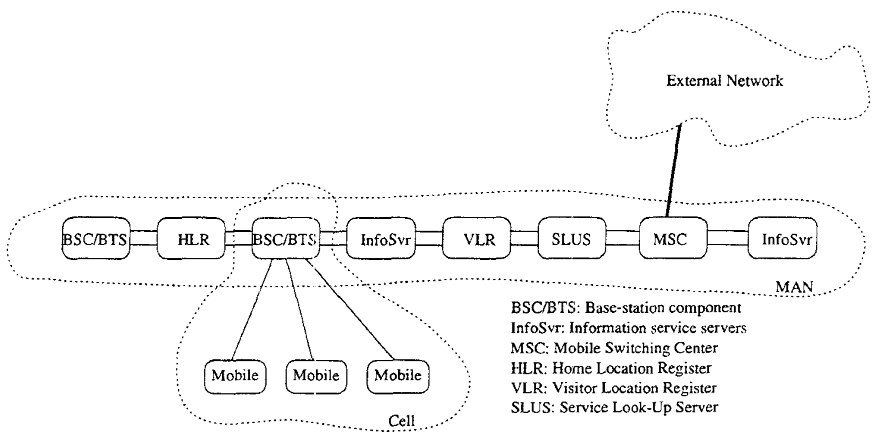

Figure 1: Information Service Network

the base station that currently accommodates the user. If the requested service is sharable, the server examines the record to see whether a channel has been allocated for that service in the cell or not. Then it asks the cellular network to assign the new user to the existing channel if the channel is not yet "over-crowded", or to a new channel if it is over-crowded (see Section 4.2 for more details) or if it does not exist. A new channel may or may not be available in the cell. Any of the channel reallocation schemes discussed in the literature, such as those in [8–10], can be used. If the requested service is not sharable, the server may still request to place the user in a channel assigned to one or more users of non-shared services managed by the same server. It could also simply request that a new channel be allocated for the user. Under no conditions will more than one server concurrently manage the same shared channel.

When the user wishes to terminate a session, either manually or according to a predetermined schedule, the server is first notified by the controlling base station. It could in turn send back a session termination message to the user. The message can contain the accounting information for the session, among other things. The server will then request the de-allocation of the channel used if no other users occupy the channel at that time.

4.2 Sharing Management

Based on the demand of information, the availability of channels, and the type of the service and the client, a server can dynamically move the clients from channel to channel in order to achieve better use of both network resources and information.

4.2.1 Information Sharing

For a sharable information service, the server maintains a record of the channels/cells of the same type under its control. For each piece of information to send to the users, the server asks the base station(s) to broadcast in all such channels so that all users receive the same information at the same time. A user with a pending request for that information may discard its request after receiving the information. This should reduce the contention on the reverse channel.

4.2.2 Channel Sharing

Channel sharing is a concept slightly different from information sharing. Users on a shared channel may use different, non-sharable services of the same server. Each request/response contains specific sender and receiver information. The unintended users on the same channel should discard the messages. The information transmitted can be protected by using an encryption scheme provided by the cellular/PCS network or one that is agreed upon by the user and the service.

4.2.3 Channel Spilt-Over

When a shared channel becomes *over-crowded*, some users need to be moved to a new channel. Over-crowdedness is a condition determined by the information server. It can be characterized by excessive portion of corrupted messages from the reverse channel, even when a MAC protocol such as MUF [7] is being used. Once the server decides that an over-crowdedness has occurred, it asks the cellular network to migrate some arbitrarily-chosen users into a new channel, if such a channel is available. Alternatively, the server can instruct the users to use a deterministic medium access protocol such as round-robin, within the channel. The order of transmission is determined arbitrarily according to a server-chosen criterion.

4.2.4 Handoffs

When a user moves from one cell to another, a handoff occurs. Before a handoff can be exercised in either user-assisted (e.g., GSM) or soft-handoff (e.g., Qualcomm CDMA) manner, the old and the new base stations need to coordinate with the information server such that the server will have the correct user record. For the more complicated soft-handoff case, the process is as follows: (1) the user announces its intended move into the new cell to both base stations; (2) the new base station informs the server of the arrival of the user with service requirements; (3) the server decides whether a new channel in the new cell is needed. If it is needed, it asks the base station to allocate it and place the new user in the channel. Otherwise, the server asks the base station to assign the newcomer to a certain channel shared by some existing users. At the same time, the server records a second entry for the user in its database. At this time, all information intended for the user will be delivered through two paths. The user will discard one of them at this stage (by matching sequence number, for example); (4) after the user has established its session in the new cell, the server orders the old base station to stop managing the user and de-allocate the old channel if no other user is assigned to it. Once the handoff is completed, the server deletes the entry that associates the user to the old base station so that the user only receives one copy of each server-originated message.

4.2.5 Roaming Users

A roaming user who crosses the cellular/PCS system boundaries should still be able to access the services s/he registered for. This can be achieved in different ways. If the user enters the new system when s/he is in a session, the handoff procedure described above can be used. If the user enters the new system and then tries to initiate a session, s/he will need to contact the local SLUS first. The SLUS, recognizing the user's roaming status, will contact the user's home SLUS to obtain the correct server number. If the user requested a local service, it can be managed as described in Section 3. On the other hand, the user's home service can negotiate to have a point of presence (PoP) at the cellular networks other than its home network. The local SLUS simply returns the PoP as the server number to the user. The PoP acts as a cache for information from the home server and serves the user as if s/he is in the home network.

4.2.6 User Profile

A profile of each user with the eligible services is maintained at each server. The profile contains detailed service descriptions, including the definitions of any automatic conditional triggers. The triggers can be some predetermined specific events or flags associated with a set of actions. Once a trigger is fired, the server calls upon the cellular network(s) to locate the user and initiate the session. It can be used as event reminders, automatic incident reports, emergency notification, etc.

5 Conclusions

This paper describes an on-going effort on the management of resource sharing in wireless environments. Using communications architecture support, digital cellular and the emerging personal communications services (networks) exhibit many desirable qualities. They may not replace the services provided by RBDS, SCA, and other technologies, but they provide the types of services that compliment or enhance those available. The concepts of information and channel sharing in this environment are introduced. Issues of user access, migration and roaming, channel spilt-over, automatic interrupts, etc. are then discussed. The management strategy we describe here is especially suitable for information and services that can be shared among many registered users. It also accommodates the need for private data communications in the wireless environment. The strategy represents a possible first step towards the evolution and deployment of ITS and other user services for next generation wireless networks.

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