Internet-based Information Flow in Mobile Systems and their Application in Traffic Monitoring Ad Hoc Networks

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***Abstract* - This paper presents various issues concerning mobile device–to-infrastructure information flow and emphasizes some specific features concerning the client-server model in Internet-based mobile telecommunications systems. Integration of such a system in an ad hoc traffic monitoring network is proposed and some practical aspects of its realization are also presented.**

***Keywords* - Information Flow; Mobile Systems; Traffic Monitoring Systems; Ad Hoc Networks; Client-server Model**

I. INTRODUCTION

The rapid growth and development in the telecommunications area in the past several years has led to enormous increase in use of mobile devices in everyday life and in business. Wide-spread use of cell phones and telecommunication networks for access to the Internet has its origins with the introduction of 2.5G (2.5 Generation) telecommunication networks [1, 2]. Characteristic of 2.5G networks is the use of packet-switched data transfer to connect to the Internet, which uses more efficiently the available radio spectrum than circuit-switched data transfer. Typical example of a popular 2.5G network is GPRS (General Packet Radio Service) over GSM (Global System for Mobile Communications).

Although 2.5G networks provide Internet access to mobile users, they don't meet their requirements for higher transfer rates and QoS (Quality of Service). 3G (Third Generation) telecommunication networks, which use completely different technological developments than 2.5G, offer broader band and thus higher transfer rates and are currently widespread [2, 3, 4]. 4G networks are also devised to meet even further requests for telecommunication services [2].

The access to Internet through mobile operators' networks and the appearance of highly sophisticated smart phone devices resulted in transition of many traditional desktop applications to mobile environment. Examples of such applications are audio and video streaming, VoIP (Voice over IP), access to social networks, etc. The new technological base, wrapped in familiar protocols of the TCP/IP stack, stimulated the development of new types of distributed applications such as mobile distributed systems. The areas in which these systems could be integrated vary from personal health care to environment monitoring. Existing distributed systems could also be easily adapted to include mobile devices.

The paper deals with the development of several models concerning the management of information flows between distributed mobile wireless computer devices. The models are based on the dialogue architecture implemented on the fundaments of the GSM wireless links between the devices. These models help the implementation of client-server architectures in respect to optimal flow management in practically realized mobile distributed systems.

II. MOBILE DISTRIBUTED SYSTEMS

Mobile distributed systems are distributed systems in which some of the elements are mobile and communicate with the rest of the system through the use of wireless infrastructure. The situation when mobile operators' networks are used as an underlying communication layer between the different elements of the system is examined in this paper.

The overall architecture of the considered distributed system is presented at Fig. 1. The core of the system is a communication and (possibly) application server which is responsible for the communication with the distributed nodes. The server receives data from the nodes and eventually sends back data or control information. The distributed nodes consist of a mobile device (MD) and one or more input devices, most often sensors.

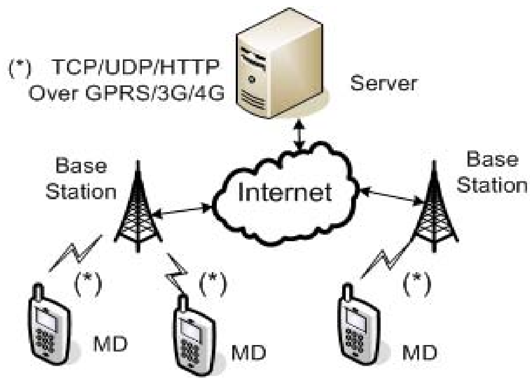

Figure 1. Architecture of mobile distributed system.

The communication between the server and the MDs is using the existing mobile operators' infrastructure, i.e. the MD sends data over the air to the nearest Base Station (BS) responsible for the home cell, which in turn sends the data to the server over the ground network infrastructure [4, 5].

The available protocols for communication between the MDs and the server include standard communication protocols over IP such as TCP (Transmission Control Protocol), UDP (User Datagram Protocol) and HTTP (Hypertext Transfer Protocol which is realized atop TCP). This means that developing applications for MDs is approximately the same as standard network programming from programmer's perspective. The underlying GSM wireless network protocols and technologies are unimportant from application point of view – they could be GPRS, 3G or 4G. Although this approach facilitates considerably the programmers, it also inherits existing problems in network, transport and application layers of the TCP/IP model.

III. Management of Information Flow in Mobile Systems

Information flow in mobile distributed systems is very important issue as efficiency of mobile applications depends on it. Characteristic for this type of systems is the use of mobile devices which have limited battery capacity and this parameter should be taken into account during design time [6]. Battery drainage is proportional to the time a MD is transmitting or receiving data as additional power is needed for management of the radio interface. Complementary factor to be considered is the financial equivalent of transferred data – mobile operators' schemes are devised to charge for sending or receiving data. As a consequence of both previously mentioned factors, the information flow should be efficiently managed and reduced to minimum.

Another issue is the model of the communication between the elements of the system. As mobile operators provide access to the Internet to potentially millions of subscribers and the communication protocol used at the network layer is IP, mobile operators cannot ensure public IP addresses to all their subscribers. A public (and static) IP address for a subscriber is seldom provided and often incurs additional surcharge. The vast majority of mobile subscribers use private networks addressing schemes which are hidden behind a NAT (Network Address Translation) box and IP addresses are distributed using DHCP (Dynamic Host Configuration Protocol) servers. The consequence of this situation is that MDs practically cannot be accessed from outside the mobile operator's network. Only MDs are in position to initiate connections but they are not in position to keep them alive for long periods because of battery drainage and financial reasons. This situation imposes the usage of client-server architectures for mobile distributed systems in which clients are MDs from the same or from different mobile operators' networks and the server resides on a public static IP address.

Different models for management of information flow are proposed and presented at Fig. 2.

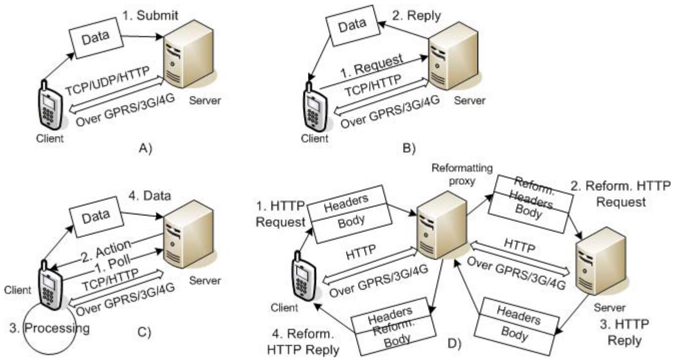

Figure 2. Client-server models for management of information flow.

A. Client-server model – submitting data

This model represents the simplest form of client-server interaction – the client (i.e. the MD) sends data to the server whenever this data is available or at the end of a predefined time period. This model provides most possibilities for usage of various transport and application layer protocols. As communication is one-way both TCP and UDP could be used depending on the requirements for security of the transmission. As UDP doesn't grant successful transfer, additional custom designed measures should be taken to ensure it. HTTP could be used as well – in this situation most overhead is generated but at the same time existing Web infrastructure and software could be used. Generally, least information flow is generated when UDP is used but the actual protocol choice depends entirely on the concrete solution.

B. Client-server model – requesting data

This model represents a simple two-way model of request-reply communication. It could be deployed if the MDs require any additional data from the server. In this situation a virtual channel is needed between the client and the server as the server should know where to send back the data. This leaves TCP and HTTP as candidates for protocol selection. HTTP generates more overhead than TCP but on the other hand facilitates programming as Web infrastructure and software could be used.

C. Polling

There are applications in which the server plays active role in modelling the client behaviour. In this situation the server is capable of calling certain functions at the client and controlling the client. The system in this case is a representation of a context-aware sensor network where the MDs correspond to sensors and some principles and issues already researched and developed in this area could be applied [7]. Another issue is that most often the MDs are behind a NAT box and dynamic IP addresses are leased to them, so it is impossible for the server to reach them, which means that the client should periodically check the server for control information. This polling mechanism should be designed in such a way as to ensure minimal information flow. The interval between two successive polls should be as long as possible. This length should be defined according to the nature of the problem whose solution is the distributed system. Lengths below 0.5 min are pointless as the propagation time for the signal could reach higher values. Briefly the model is as follows: the client polls the server; the server returns the action to be performed (if any); the client performs the action and returns the resulting data. The protocol selection concerns are as in the previous section.

D. Reformatting proxy servers

Some network operators integrate in their networks reformatting proxy servers. The main purpose of these proxies is to optimize network traffic between clients and servers and particularly between smart phone browsers and non-WAP (Wireless Application Protocol) Web pages. Proxy servers reformat the header of the HTTP request and filter the body of the HTTP reply in such a way as to ensure only useful information to be transferred to the client. Proxy servers could be very useful with regard to minimise the information flow but could also present obstacles to applications which rely heavily on HTTP advanced features. Distributed mobile applications should be designed to be independent of the availability of proxy servers.

IV. Traffic Monitoring Ad Hoc Network

Mobile distributed systems have application in numerous areas. This section presents a novel practical realisation of a traffic monitoring system using mobile devices' cameras. Most traffic monitoring systems currently available make use of statically situated cameras which monitor traffic in points of interest. These systems aren't adaptable to changing traffic conditions. In contrast, this traffic monitoring system is mobile thus able to dynamically monitor traffic where needed [8]. The proposed architecture of such a system is illustrated at Fig. 3.

The system comprises of a server and MDs which are situated in vehicles. Mobile devices could be cell phones, smart phones or dedicated custom-designed devices with SIM (Subscriber Identity Model) cards. Every MD is connected to a camera, a GPS (Global Positioning System) receiver and a mobile operator's network. The application running on each MD has two modes of operation – automatic and user-driven. The application is started by the user and sends a snapshot of the current position of the vehicle along with the coordinates of this position to the server. After the initialization procedure is complete, the user could choose one of the two modes of operation.

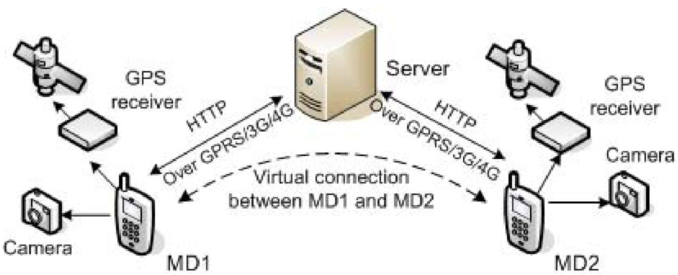

Figure 3. Architecture of mobile distributed traffic monitoring system.

A. User-driven mode

In this mode the user could choose when to make further snapshots of the surrounding area and to forward them along with the coordinates to the server. This corresponds to the first of the proposed information flow models. Another option for the user is to request snapshots from other close-by users. In this case the user first sends the current coordinates (taken from the GPS receiver) then the server searches its database and returns images from closely situated users. Closely situated users are considered to be several (up to 10-15) meters apart. This case corresponds to the second information flow model. The system could be regarded as an ad hoc network with central coordinator (the server) and mobile nodes (the MDs) [5]. Information is passed between the nodes through the coordinator. Once an MD is outside the range of the requesting MD, the communication is suspended.

B. Automatic mode

In the automatic mode the user passes the control of the application to the server. This approach uses the third information flow model (as described above) – the MD application polls the server to check if it is supposed to send a snapshot and coordinates of its current position. It has been decided that the polling interval should be 1 min as shorter time interval would lead to unacceptable financial consequences and longer time interval wouldn't provide detailed information of the traffic situation.

The architecture of the system allows for two groups of users to monitor traffic. First, traffic is monitored from a monitoring centre using the information stored in the server. Second, the traffic is monitored by the participants in the traffic who communicate with each other through the server.

HTTP has been selected as a communication protocol between the server and the MDs. It generates more traffic but allows existing software to be utilized, e.g. Web server. This improves scalability of the system as mechanisms for concurrency control of the server resources, which could be difficult to handle as more users join the system, has already been developed by the programmers of the Web server.

The system has been fully developed and functionally tested in Nottingham Trent University, Nottingham, UK.

V. Conclusions and Future Work

The paper presents various issues concerning Internet-based information flow in mobile distributed telecommunications systems. Four models for management of information flow and communication between clients and servers in such systems have been described. Use of these models has been illustrated by the presentation of a mobile distributed traffic monitoring system.

Future work should be directed towards further development of the system. One direction in which efforts should be concentrated is scaling the server to a cluster of servers which should be geographically dispersed so that propagation delays in communication between MDs and the server could be decreased. Another direction is scaling the system in terms of distribution – once the nearby users of a requesting user have been determined, communication between them could be realized through the use of short-range wireless interfaces such as Bluetooth or ZigBee without the intervention of the server. This would create a VANET (Vehicular Ad hoc NETwork) in which all nearby users could participate. Research in the area of VANET could be carried on and the developed system could be used as an experimental platform.

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