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Tools and Architectural support for Mobile Phones based Crowd Control Systems

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Abstract

There is a vast body of research dealing with the development of middleware for Opportunistic and DTN networks. The development is mainly focused on developing mathematical models and designing routing protocol. These protocols are assumed to work on Pervasive computing systems that are inherently running on unstable networks and devices, subject to constant topology changes, network failures, and high churn. Merely protocol development and studies based on simulation are not able to handle these issues as part of their design. To address this, we propose a Crowd Control approach that explores the real technical challenges that face the developer of such systems and to move the handling of these volatile properties of pervasive environments to the protocol level. Through the development of two mobile applications, we discuss the underlying principles of message passing among crowds and present a set of visual tools that facilitate the adaptation process.

Keywords: Wireless networks, Data Dissemination, Message Routing Protocols, Delay Tolerant Networks, Bluetooth and WIFI Broadcast.

1. Introduction

Nowadays, the number of connected computing devices, such as, PDAs, laptops, mobile phones, GPSs, etc are increasing continuously. They form mobile ad-doc networks (MANET's), however they are not widely exploited yet because centralized infrastructures are not always available. This makes it challenging to use these new highly dynamic environments as an infrastructure to allow users to send alarm or notification messages to others nearby and they do the same. The services are offered for the users without internet connection or any centralized entity. During the recent revolutions in the arabic world, governments have shut down both Internet and Mobile phone services in an attempt to quell protests and control communication among demonstrators. In addition, during natural disasters, people have been left without means of finding out the latest news regarding emergency services.

Local connectivity among portable devices may be obtained by forming ad-hoc networks [1] since the mobile devices are more or less always turned on and have the necessary radio interfaces, processing power, storage capacity, and battery lifetime to act as routers. Such sparse ad-hoc networks generally cannot support the type of end-to-end connectivity required by large number of crowd spread widely in space beyond the individual's communication link, e.g. Bluetooth and WIFI.

Instead, new techniques are required to expand these connections to reach most of the people in the hot zone. Looping data between devices with one or more of these wireless interfaces to disseminate information can create new adventurous communication scenarios.

In this paper, we study and analyze the feasibility of message passing a fully distributed system based on short-link wireless communications which allow an ephemeral message to be spread to nearby nodes which in return connect to other nodes in epidemic manner. In short-time, a sharable message can float from one device to another and it's solely dependent on mobile devices and sensors in the vicinity using principles of opportunistic networking. Then we introduce our design of viral message passing system that is based on the application and architecture design using real smart phones.

This new framework doesn't just track and monitor people flow, it also sends saveable multimedia messages wirelessly which can alert to special announcements, emergency call, environmental condition, new chants or the number of people in a queue.

To protect privacy and to prevent spammers taking advantages of this system. Only authorized users may create messages, e.g. policemen or event managers. The initiator's device starts disseminating the message to its neighbours within range, as do other nodes, until the wireless range is extended from few meters to hundreds.

2. The need for crowd control based on short-link communications

There are billions of Bluetooth and WIFI chips embedded in portable and mobile device. However short-range radio is considered as underutilized and used by the least number of people [2]. The abundance of these devices in urban areas could open up new possibilities for community based applications. This has inspired many researchers to devise new concepts in order to utilise short range radio in the last few years. The Bluetooth specification [3] describes the concept of a ScatterNet. A ScatterNet is defined as two or more PICO-Nets joined together through the mechanism of a common node (i.e. bridging node). There is also a growing body of research being conducted with the goal of developing algorithms to efficiently form ScatterNets [4]. The MMPI library was created to allow for parallel computing across Bluetooth enabled mobile devices [5].

Bluetooth mobile advertising system is developed by [6] which used Bluetooth for delivering permission-based location- aware advertisements to mobile phones. More recent work, [7] described building a wireless information system by using the Bluetooth wireless technology. Another relating system is ZebraNet. ZebraNet is a mobile, wireless sensor network in which nodes carried by animals move throughout an environment working to gather and process information about their surroundings. Each node is equipped with a GPS unit in order to log position information. This information is then passed from zebra to zebra using peer-to-peer protocols until it reaches a base station where it can be processed and analyzed.

These systems suffer from similar limitations, as they are limited to the short range link and messages can't reach people in a large venue. What we propose here is a new light and affordable framework in order to utilize the short range radio in mobile and portable devices.

The proposed ViralNet is more suitable for spreading messages between users on the move or in crowded zones. For example it can help people at the back of a crowd or queue to have a picture of their position of overall structure. This will stop them from contributing unknowingly to the forces which can build up, reaching crushing levels at the front of the crowd. It is completely Ad-hoc in the way the messages are spread between moving or stationary users without using any centralized base-station or fixed infrastructure.

The communication is at the application level and between individual devices which are preconfigured with the custom software. There is no need for PicoNets and all act both as a server and a client, and that the server and client parts share a persistent message pool between them.

3. Design concepts

In our deployments, ViralNet nodes use short-range wireless link. We have started with Bluetooth and WIFI primarily because of the ease of development and configuration. They are available on most modern mobile phones at a low cost.

Bluetooth capabilities of most mobile phones and similarly-powered devices are typically limited to a transmission range of approximately 10 meters while WIFI is limited to 100meters. Each device can be uniquely identified within the system; however we set the Bluetooth name to be the same on all the participating devices. If a user's Bluetooth device is in range, a message can be routed and pushed to this particular device. The message can then be accepted or rejected by the recipient. Mobile nodes only store messages temporarily, before it re-transmitted again to a new neighboring node which is within the range of the second device. A mobile node d_1 subscribed to the service will be able to obtain a copy of the message when it gets "in the wireless link range R_1", this turns the new device d_2 into data mule which in returns disseminates the message to other devices.

One of the main questions in implementation feasibility is that ViralNet capable of operating without user intervention. This implies three points divided in three parts: First, the transfer of messages must be allowed without needing the user to acknowledge each transfer. Second, there should be no need to pair or authenticate the devices to each other. Third, it should be possible to run the *ViralNet* application in the background.

The following are three additional design concepts that we have taken into consideration at the development stage:

- *Privacy and security control* – users need comprehensive control of their privacy and security settings by allowing them to reject a sender/service. *ViralNet* is NOT considered a spam as it is completely "*permission based*" so the mobile user will receive an invitation to accept the message, if the user chooses to accept it, it will then be viewed and downloaded to his/her phone. If the invitation is declined, the advert will NOT be sent. In this case, the mobile user is in complete control and will not be offered that same message to their mobiles again unless they choose to.

- *Fast and simple interface* - People are unlikely to be able to give their full attention to interacting with their mobile phones while walking. An easy and convenient method such as sound recording allows event managers to spend less time on creating their messages.
- *Free-of-charge* - People are concerned about the costs of sharing content such as access fees. Bluetooth-enabled mobile phones without additional equipments and service charge can encourage the use of the service of this type in the exuberant information context.

4. Message passing: high level description

Everything begins when a message is created. As far as *ViralNet* is concerned, there is no restriction of what kind of message is being delivered. The size of the message may be an issue, though, and the data types used partly dictate what kind of protocol can be used to deliver this message to the final recipient. The message is injected by a local system to the message pool. From this point onwards, the message is like just any other message in *ViralNet*. It does not receive any preferential treatment.

We consider the forwarding of the message m between k mobile nodes, which represent community members. Since the direct path between the sender s and the receiver r is not always available, our network belongs to the Delay Tolerant [8] and Opportunistic networks [9]. This means Messages can be sent in a one-way system due to the fact that routing is opportunistic and the message path cannot be guaranteed to be valid at any future point in time, bi-directionality is very hard to attain.

In message flooding scenario, a node n_2 will receive a copy of message m once in contact with node n_1 the current carrier of the message. Flooding [10] can potentially return the highest success rate in passing a message through the network, however the large amount of data generated by large number of nodes can lead to exorbitant demands for network bandwidth processing time and energy. Care would be needed to ensure that a given node was not saturated with connection requests from a series of nearby handsets. Therefore, we are working on a simple and intelligent protocol that selects nodes with higher delivery probability, i.e. nodes that meet large number of other nodes, or nodes at the edge of the current node range.

In other words, the number of connections should be reduced dramatically by inverting the connection criteria to furthest node in the range instead of the nearest as can be seen in Fig1. This will minimize the number of connection to one per each wireless zone. In this case the algorithm will be selective and only small percentage of users , who are evenly distributed, will receive the message which in turn can distribute this message verbally directly to the people right next to them.

This means that not all nodes need to be connected to. Instead, coming to contact with fewer nodes might be enough.

At the time *t* of the forwarding process, assuming that *m* is carried by a mobile n_1 which meets n_2 and n_3, if $P^{n1-2}t > P^{n1-3}t$, then n_1 transmits *m* to n_3 by the delivery deadline D_m.

And since our objective is to route the message *m* between *k* mobile nodes from *s* to *r*, we will be developing our message forwarding algorithm as the optimization solution, which maximizes the delivery probability $P^{n}t$ of the message *m* from *s* to *r* and meets the delivery deadline D_m as follows:

$$\max P^{n}t \text{ s.t. } T_m < D_m \tag{1}$$

By using one or more of wireless metric such as *RSSI* (*Signal Strength Indicator*) it will be possible to determine the mobility of the nodes, direction of the mobility and hence forecast which node to send the message to. RSSI also helps in predicting link break. When the link breaks are predictable, then weaker links along the active path can be substituted with a stronger one. *RSSI* measurement does not involve sending extra data wirelessly and so it does not consume power at the mobile device [11].

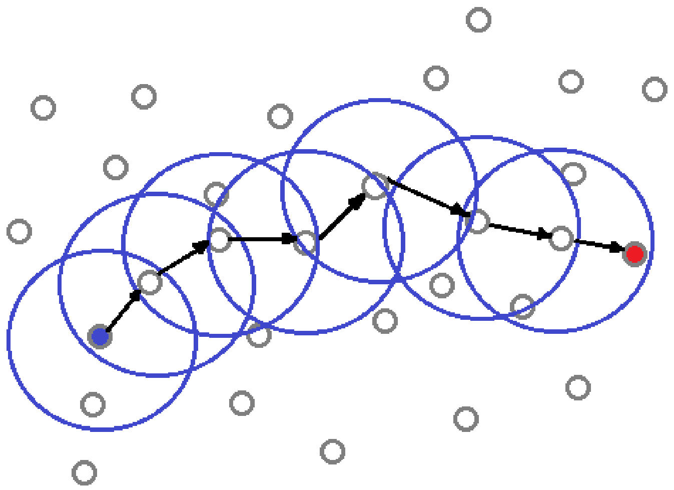

Figure 1. *ViralNet* Message Passing Topology.

The proposed protocol also uses *RSSI* values to determine the mobility of the nodes, direction of the mobility and hence forecast the link breaks.

The floating message should be forwarded only to new devices; cross-sending (i.e. sending the message twice or more to the same recipient) is not permitted. As long as there are enough mobile devices around to receive and disseminate a piece of content, it floats. When the node density becomes too low (even temporarily—longer than the expiry threshold), the content disappears, unless it was reactivated by the initiator.

A robust forwarding algorithm is needed to make ViralNet functional, since any algorithm that requires keeping global information is not suitable since the wireless nodes are resource constrained and there is a large number of nodes which can add to quickly to the message overhead. To avoid a situation where a message is passed back and forth between two devices, the receiving party stores the sending device's MAC address with the message when it is put in the pool. This is checked before sending the message. The address is deleted immediately after the message has been forwarded. Also, the sender of the message should retain the MAC address of the last device it communicated with and avoid sending messages to it again. This way, all messages are not sent through the same route, also the sizes of packet overhead when forwarding the message between nodes are kept to minimum.

5. Technical framework

Mobile Application based on Bluetooth: In this work, we developed ViralNet as custom mobile application written in Java targeting Android Mobile phones platform 2.1 onward. However, mobile platforms with API higher than 10 (a.k.a.2.3.3 or Gingerbread), are preferred since it allows insecure Bluetooth socket connection over RECOMM Serial Protocol, which effectively can establish a connection without explicit pairing.

Our system runs at the application layer in the Bluetooth stack which consists of the protocols that are run over the host protocol layers. We currently use serial port emulation through RFCOMM protocol to transfer data. Also we are interested in TCP/IP networking over BlueTooth which can be done using Point to Point Protocol (PPP), and the object exchange protocol, OBEX, which is also run over RFCOMM.

The Viral network formation is initiated by a single node 'the initiator' that searches for other nodes in its vicinity to acquire a connection in order to send the message. This in turn pages its nearest neighbour to pass the floating message to it and so on. In this case the Bluetooth range can be extended to wider geographical area.

Each floating message is timed by its originator according to the content of the message. For example, a message sent to *fan* in sport event might be relevant only for few minutes. All nodes are given the same Bluetooth friendly name, e.g. "ViralNet". As mentioned above, mobile phones with API higher than 10 can be paired automatically. Unfortunately the latest android platforms impose security restrictions on Bluetooth connections which is governed by the ability of the device to find other nodes with their discoverability manually turned on every five minutes. The discovery process usually involves an inquiry scan of about 12 seconds, followed by a page scan of each found device to retrieve its Bluetooth name. However, Pre-paired devices or connection using MAC address doesn't require the target node to be visible. In addition, we believe advanced development platforms for mobile devices are emerging and these will hopefully enable developers to set Bluetooth discovery visibility as required (this was possible with Nokia S60 series).

Also, ultimately, we look for Bluetooth 4.0 to combine low-power rendezvous and WIFI (802.11) speed of communication.

Mobile Software based on WIFI: Due to these unavoidable obstacles with Bluetooth we opt to use WIFI. WIFI is also available in most of smart phones and its range can go up to 100m with higher speed.

In the WIFI version of the software we also used location tracking in order to limit the message spread to a predefined range. Also location tracking allows the message to be spread away from the initiator node and not toward it. Fig. 1-b shows a screenshot of the software with WIFI in usage.

Since the floating messages could be audio files, sensor readings, text messages, images, video or even sequence of vibrations, a dedicated interface is built to allow message initiators to broadcast their messages on the go. ViraNet interface includes simple tools to help users to create and edit their text or media files such as voice recorder, and image editor, text editor and paintbrush type of applications, (see Fig.2, (a) is the original Bluetooth based interface ,(b) is the new interface with WIFI link).

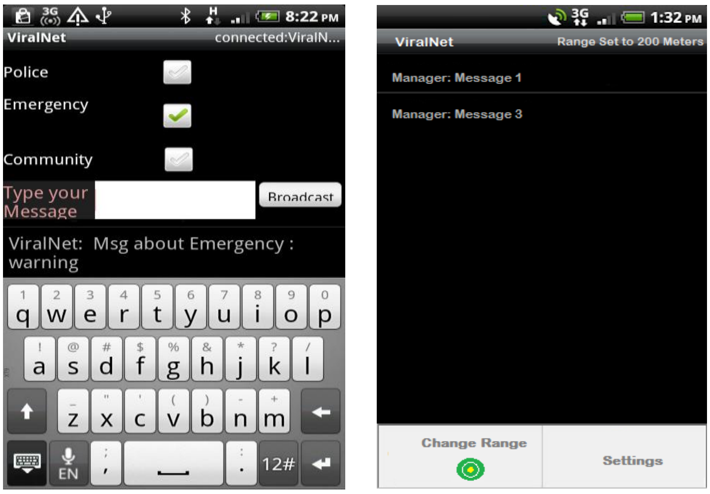

Figure 2. *A screenshot of mobile interface.*

(a) Based on Bluetooth, (b) based on WIFI

In addition, a dedicated service is being implemented in order to allow the software to work in the background without UI or with bind service method which allows simple widget to appear on the screen to provide communication with it through simplified interface exposed by the service.

Environment Setup and Evaluation

To fully test the domino effect of the system in passing messages, we have utilized 20 smart phones number of mobile devices to cover a 400 square meter zone at the Square of expositions in Riyadh as shown in the map in Fig 3., which is exported from GoogeMaps.

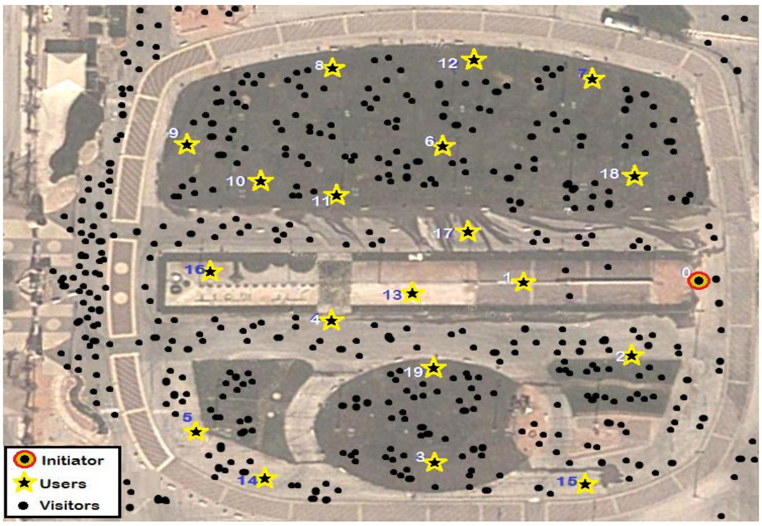

Figure 3. Square of expositions with 20 mobile nodes located in random locations and ready to receive the first set of messages.

Twenty users with Android devices including HTC Desire HD, HTC Desire, Nexus S, LG Optimus, LG Optimus 3D and HTC Young have been asked to spread around the venue randomly as seen in (Fig.3) and to wait for messages. The tracking radius on each mobile is set by the users to 200meters. Any users beyond this range do not receive messages. Messages were text based and are generated every 30 seconds by the Initiator.

One of the users played the role of Initiator who sent 200 experimental messages in total. The users have moved only two places during the experiment. The initiator sent 100 messages while the receiving users were in the first positions and the second 100 messages were sent after the users moved to the second positions. Fig4. shows message delivery rate at each node during the two phases of the experiment. Every value shows the number of received messages at this particular mobile node. The first column represents the number of messages received

In real world situations, many objects, still and moving ones, produce reflections, diffraction and scattering. Attenuation of the signal is not only a factor of distance, but also of the obstacles between the sender and receiver -even when position is not changed, the signal strength can drop 2 to3 dB. We have noticed that, as we sent the messages to the farthest in the range, close nodes don't have higher delivery rate than the others.

We also observed that many messages are not received by its recipients not because of link breakage, but because some of the devices can stop sending messages for few seconds while they carry on receiving messages.

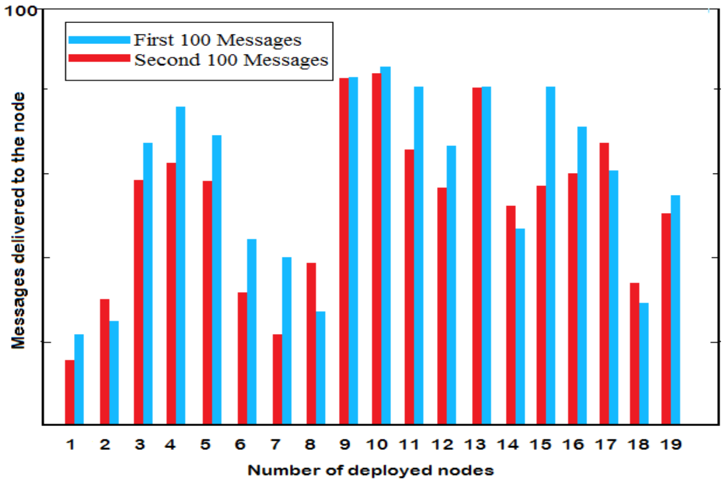

Figure 4. Message Delivery during the pilot study

To fully test the domino effect of the system in passing messages, we will repeat the experiments with larger number of devices for extensive evaluation process which will be reported in a future publication.

6. Conclusions and outlook

This paper discusses the design tradeoffs and early experiences in developing a framework for message passing in crowded places. Messages are passed as quickly as possible toward the end of the range in order to maximize message spreading around the crowd.

We concluded that there is a potential for ViralNet approach. We intend to develop our message passing algorithm further and evaluate the functionality system through a set of experiments at the user and device levels. We will also evaluate the system using a Network simulator using a realistic settings in order to test the scalability of our framework.

We also plan to take message priority into consideration, since designing an optimal routing protocol with a delivery probability of 100% under all conditions is difficult, prioritizing messages becomes a necessity.

We also have a plan to minimize battery consumption while using the application and improving the security and privacy of information are on the list. A leading principle should be that the creator owns the data and decides how the data can be used by others.

Looking forward, we believe that advanced development platforms for mobile devices are emerging and these will hopefully provide low level access to handset subsystems such as Bluetooth. This in turn will permit handsets to be more active in the viral short range message passing process since APIs and behaviors will standardize and applications will be easier to deploy.

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