إدارة الجموع من خلال تمرير الرسائل عن طريق وسائل الاتصال اللاسلكية قصيرة المدى

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Crowd Management using message passing over short link connections

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ABSTRACT

Disasters like stampedes in religious and sport events have made management of large crowd more critical than ever before. Managing large crowds is a very complex, challenging and costly exercise. Most people carry a wireless device in their pocket. There are already thousands of millions of these devices around the world. Any modern device has several wireless interfaces, such as GSM, 3G, WiFi, Zigbee, Bluetooth, and increasingly powerful computing capabilities. 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 other nearby users and offer them services without any centralized entity. The collected messages can be then processed and analyzed it in real-time, to respond to events and to the appropriate actions.

Looping data between devices via short-link connections to disseminate information can create new adventurous communication scenarios. To understand the importance of this type of systems, we will apply our proposed framework to one particular scenario which is the Hajj, the pilgrimage to Mecca, Saudi Arabia. About three million pilgrims participate in this annual pilgrimage. For this reason, there are many incidents during the Hajj, as pilgrims are trampled in a crush. In this type of scenario crowd-control techniques as the one proposed here are absolutely critical. The objective of the project proposed is two fold: First we plan to study the mobility model of large crowd and design an ad hoc forwarding algorithms in order to minimize network overload, delivery ratio, average delay, data loss and energy consumption. These protocols will be evaluated based on synthetic traces. The second is to setup a series of field experiments using off-the-shelf miniature motes such as TinyNodes to send and receive short messages to neighbor nodes over short-link connections using minimum processing and battery power.

ملخص البحث

شهد المناسبات الرياضية والدينية المزدحمة كثيرا من المخاطر والحوادث بسبب التدافع والتزاحم مم يلقي الضوء ويؤكد علي اهمية وجود حلول فورية لإدارة الحشود و معالجة التجمهر، الا ان ايجاد مثل هذه الحلول ليست عملية بسيطة بل هي عملية معقدة وتواجه الكثير من التحديات والتكاليف.

علي الجانب الاخر فلقد انتشرت الأجهزة اللاسلكية بدرجة كبيرة فمعظم الناس يحمل في جيبه جهاز لاسلكي وهناك الاف الملايين من هذه الأجهزة متوفرة في العالم، بل لقد اصبح كل جهاز يحتوي علي عدة وسائط لشبكات الاتصالات مثل الجي اس ام (GSM) و الجيل الثالث (٣G) والواي فاي (WiFi) والبلوتوث (Bluetooth) وازدادت قدرات هذه الأجهزة بدرجة كبيرة. علي الرغم من توافر هذه الأجهزة كوسائل اتصل متاحة ورخيصة الا ان استغلالها لا يزال ضعيفا، و يرجع ذلك لعدم وجود البنية التحتية التي تربط هذه الأجهزة ببعضها. كل ذلك يدعونا لنفكر في طريقة لأستخدام هذه الأجهزة كبديل للبنية التحتية لتوفر طريقة لإنتقال المعلومات والرسائل والانذارات بين المستخدمين دون الاحتياج الي اي وحدة مركزية او بنية تحتية. هذه المعلومات يمكن تحليلها ومعالجتها بطريقة فورية لإتخاذ القرارات والإجراءات المناسبة بناءا علي الأحداث.

يمكن تقليل وتفادي العديد من المشاكل والتحديات لإدارة الحشود ومعالجة التجمهر بإستخدام تقنية البلوتوث والتقنيات اللاسلكية الأخري. الهدف من المشروع دراسة النماذج الممثلة لحركة الأجهزة ونقاط الإتصال في الأجواء شديدة الإزدحام و تصميم نظام جديد وبروتوكول فعال لإنتقال المعلومات بين الأجهزة والنقاط المختلفة يأخذ بعين الأعتبار قدرة التحميل

للشبكة و نسبة وصول المعلومات سليمة ومعدل التأخير او فقدان المعلومات والطاقة المستهلكة. هذا البروتوكول المقترح تم تقييمه بأستخدام سيناريوهات مصطنعة و شبه واقعية للحصول علي نتائج صحيحة.

ان ما نقترحه من اطار لانتقال المعلومات بين الاجهزة المزودة بتقنية البلوتوث يخلق فرص عديدة وسيناريوهات مختلفة لتحقيق الاتصالات بين النقاط المختلفة. ولبيان اهمية هذا النوع من الأنظمة فاننا سوف نطبق النظام المقترح علي حالة خاصة الا وهي الحج الي مكة في المملكة العربية السعودية. ففي كل عام يذهب حوالي ثلاثة ملايين حاج الي مكة. ويؤدي هذا الازدحام الشديد الي كثير من الحوادث بسبب التدافع الشديد والمصادمات. هذا الازدحام الشديد الذي يؤدي الي كثير من الكوارث يلقي الضوء علي الاهمية القصوي لوجود مثل هذا الحل للتحكم في هذه الحشود ومعالجة التجمهر. فلقد تم بالفعل استخدام التقنيات الحديثة في كثير من مجالات الحياة لحل كثير من مشاكلنل اليومية، الا انه علي الرغم من ذلك فأن امكانية استخدامها لحل مشاكل التجمهروالاحتشاد لم تختبر بعد ولا زال هناك العديد من التحديات التي تحتاج الي حلول من قطاع الصناعة.

General Terms

Network Protocol, Hajj crowd management, Management, Design, Experimentation.

Keywords

Wireless networks, Mobile Sensing, Message Routing Protocols, Delay Tolerant Networks, Bluetooth Broadcast.

1. INTRODUCTION

Internet, phones and mobile devices, such as mobile phones, enable an alternative mode of communication to global connectivity via infrastructure networks (cellular, WLAN). However, centralized users, achieving infrastructures are not always available. 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 (Johnson et al., 2006) 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 propose and analyze a fully distributed system based on short-link wireless communications which allow an ephemeral message to be spread in a viral manner 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.

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 current 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. This work will be reported fully once the evaluation phase has fully completed.

2. Background

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 (pcworld, 2011). 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 (Bluetooth SIG, 2011) describes the concept of a ScatterNet. A ScatterNet is defined as two or more PicoNets joined together through the mechanism of a common node (bridging node). There is also a growing body of research being conducted with the goal of developing algorithms to efficiently form ScatterNets (Donegan et al., 2007). The MMPI library was created to allow for parallel computing across Bluetooth enabled mobile devices (Doolan et al., 2002). Bluetooth mobile advertising system is developed by (Aalto et al., 2004) which used Bluetooth for delivering permission-based location- aware advertisements to mobile phones. More recent work, (Davidrajuh et al., 2007) 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 utilise 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 centralised base-station or fixed infrastructure.

The communication is at 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.

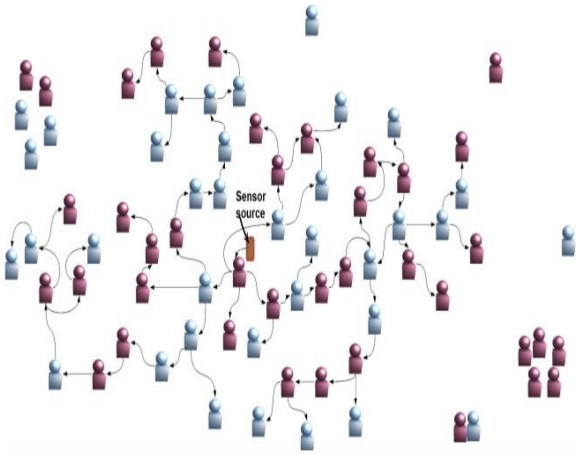

Figure 1 System topology based mainly on mobile devices with short-range radio capability

3. DESIGN CONCEPTS

In our deployments, ViralNet nodes use short-range wireless protocol. We use Bluetooth primarily because the ease of development and configuration. As a commodity protocol, it is available on most modern mobile phones at very low cost. Ultimately, we look for Bluetooth 4.0 to combine low-power rendezvous and 802.11-speed communication. WiFi-based messaging is not ideal for viral messaging since it is associated with high power demands, difficulty in set up and maintenance, small market penetration of suitable handsets and difficulty in convincing users to leave handset WiFi turned on. However with most people using their phones to access the Internet, the ViralNet message could be broadcasted through a mobile phone with a WiFi friendly name. Then the unit will broadcast out the message to the WiFi network. When a user sees the network and connects to it, the message will be played. WiFi works with phones, laptops and tablet PC's meaning a greater reach to users.

Bluetooth capabilities of most mobile phones and similarly-powered devices are typically limited to a transmission range of approximately 10 metres. 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 the mobile device. The message can then be accepted or rejected by the user. Mobile Nodes only store messages temporarily, before it re-transmitted again to a new neighbouring node which is within the Bluetooth range of the second device. Other mobile node d_1 subscribed to the service will be able to obtain a copy when it gets "in range R_1", this turns the new device d_2 into data mule which in return disseminates the message to other devices in range.

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 they choose to accept it, it will then be viewed and downloaded to their phone. If they decline the invitation, the advert will NOT be sent so 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. TECHNICAL FRAMEWORK

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 allow 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 to transfer data. Also we are interested in the TCP/IP protocol stack which is enabled over PPP over RFCOMM, 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, (see figure 2).

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 "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).

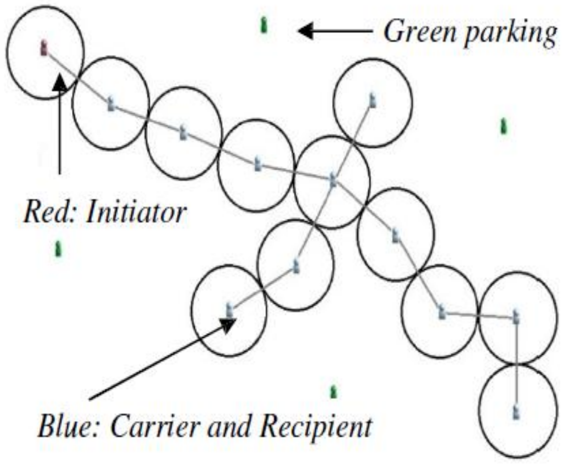

Figure 2 ViralNet message path

User Interface

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 figure 3).

Figure 3 A screenshot of ViralNet mobile interface.

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.

To fully test the domino effect of the system in passing messages, one needs a significant number of mobile devices (far in excess of eight) to cover a 100 square meter zone. Such resources were unavailable at the time of implementation, but we have a plan to get more devices for extensive evaluation process which will be reported in a future publication.

The development phase was carried out mainly tested on four Android phones. These are HTC Desire HD, HTC Desire, Nexus S and LG Optimus, and LG Optimus 3D. We found that the system performs well on Samsung Nexus and LG Optimus, nevertheless, we faced some difficulties with the HTC phones. The HTC Desire HD was performing well when a request is made to connect to the device to deliver a message. However the same device failed to initiate a Bluetooth connection with other phones.

5. 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.

nodes, which represent We consider the forwarding of the message *m* between *k* mobile 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 and opportunistic networks. 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 (Zhang, 2006) 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. This will minimise the number of connection to one per each Bluetooth 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 n1 which meets n2 and n3, if $P^{n1-2}t > P^{n1-3}t$, then n1 transmits m to n3 by the delivery deadline Dm.

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:

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

By using one or more of Bluetooth metrics such as RSSI it will be possible to decide which node to send the message to RSSI (Signal Strength Indicator). RSSI measurement is helpful since, it does not involve sending extra data wirelessly and so it does not consume power at the mobile device (Bandara, 2004).

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 ViralNets functional, since any algorithm that requires keeping global information is not suitable since the Bluetooth 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 Bluetooth device 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 Bluetooth device 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 is kept to minimum.

6. CONCLUSIONS AND OUTLOOK

This paper discusses the design tradeoffs and early experiences in developing a viral framework for message passing in crowded places.

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 are planning to conduct a user test on number of participants in Graz, Austria and Cambridge, UK to test usability and user experiences.

The expert interviews and the discussion will lead to several new requirements for the acceptance of viral short-range broadcast services. They will be considered in the further development of the framework as soon as they are validated.

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 behaviours will standarise an applications will be easier to deploy.

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