Ubiquitous Peer-to-Peer Applications in Wireless Ad hoc Networks

Individual Project Report

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June 2004

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Abstract

To be completed.

Acknowledgements

To be completed.

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1 Introduction

1.1 Motivation

The key motivational aspects of this project.

- Might be an idea to start with a "scenario" – e.g. ubiquitous sharing of files (or references where those files can be found) based on musical interests. Or location-based services allowing a community to stay in touch, e.g. pointing out when friends are close by.
- What's changed in the last few years that makes this viable? Briefly describe the proliferation and increasingly pervasive nature of mobile computing.
- The worlds of computing and communication are coming together!
- Briefly, what is meant by ad hoc in this context? Why is this important?
- Briefly, explain the peer-to-peer paradigm, and why this is an ideal backbone in the area of wireless communication.

Text from initial project proposal (needs to be modified):

In the space of just a few years, peer-to-peer (P2P) networking has become a computing phenomenon. Millions of Internet users are communicating with each other through P2P file sharing software programs that allow a group of computer users to share text, audio and video files stored on each other's computers. However, as it becoming increasingly evident, P2P networks have capabilities and uses that stretch far beyond 'file trading'.

With the proliferation of mobile devices such as cellular telephones and PDAs, and the increasingly pervasive nature of wireless technology, it is clear that there is no longer a need for us to restrict peer-to-peer applications to fixed computers on wired networks, or indeed to constrict cellular users to traditional client/server applications such as WAP (Wireless Application Protocol). P2P and wireless technology are an ideal match, and deploying the two together will enable us to exploit a wide range of new opportunities that were previously not feasible. The inherent nature of mobile devices, in that they are suitably lightweight and portable to be carried around by people, makes them ideal instruments to form the peers of a global wireless data network, where information can be shared between individuals in a ubiquitous manner.

Unfortunately current 2G and 3G mobile networks are not suitable in isolation for delivering mobile P2P services, due to the relatively high cost of data transmission, latency and limited footprint. A mobile ad hoc network is a system comprised of mobile devices that act as both hosts and routers, communicating wirelessly in an arbitrary way without an existing network infrastructure. The devices on an ad hoc network are free to move about and the topology of this kind of network is therefore dynamic. A key feature is multi-hop support, which for example could allow a device that is outside traditional mobile coverage to still be able to access services by relaying requests to another device that is in range over a technology such as Bluetooth. Alternatively, it may be more economical to send data using a nearby WiFi hotspot rather than through a GSM mobile network – the potential practical uses of ad hoc technology are only limited by imagination. By introducing a peer-to-peer architecture over such a scheme could enable users to access fully decentralised applications and to discover new resources as and when they become available.

1.2 Project Objectives

- What are we trying to achieve here? Two phases – research and design/implementation.
- First try to find out what's state of the art. This involves looking at a wide range of related areas such as recent developments in the wireless telecoms sector, as well as routing protocols for multi-hop routing in ad hoc networks.
- Discover what the real challenges are, that need to be solved to further the adoption of peer-to-peer applications over wireless networks. How feasible is it to solve these now, and are there already things in the pipeline that will overcome these issues?
- We also take a look at platforms for development, e.g. Symbian, Java, Microsoft .NET, since one will be required for the implementation phase.
- The design/implementation phase will aim to tackle one or more of the identified challenges, and to produce a working demonstration of the achievements.

Text from initial project proposal (needs to be modified):

The aim of this project is to first of all investigate recent developments in the wireless mobile, peer-to-peer and ad hoc network arenas, in order to

fully understand the challenges that must be overcome for such a scheme to be commercially viable in the near future.

The second phase of the project will build upon the research phase above and will involve the design and implementation of a real peer-to-peer ad hoc wireless system to demonstrate the benefits of this next generation technology. The goal is to be able to demonstrate a set of applications such as multicast push-to-talk voice and location-based services on actual mobile devices running J2ME (Java 2 Mobile Edition). The devices will be capable of discovering each other, and adapting the types of service presented to the end user based on the methods of communication available, e.g. Bluetooth, GSM, WiFi. A universal framework will need to be defined in order to allow new applications to be added in the future. Issues of security and confidentiality in such a distributed environment are clearly important and will be taken into consideration during the design.

1.3 Document Roadmap

Chapter 1 (Introduction) looks at.

Chapter 2 (Background Research) looks at.

Chapter 3 (Project Specification) looks at.

Chapter 4 (High-Level Design) looks at.

Chapter 5 (Detailed Design) looks at.

Chapter 6 (Implementation) looks at.

Chapter 7 (Testing) looks at.

Chapter 8 (Evaluation) looks at.

Appendix A1 (User Guide) looks at.

Appendix A2 (Project Logbook) provides a chronologically ordered summary of work carried out during this project.

Appendix A3 (Bibliography) provides references to sources used during this project.

1.4 Glossary

To be completed.

GPRS	General Packet Radio Service
GSM	Global Standard for Mobile Communications
P2P	Peer-to-Peer
WAP	Wireless Application Protocol

2 Background Research

This chapter provides a summary of the research work carried out within fields related to this project. The aim of this exercise was to investigate and assess the impact of recent developments in the mobile computing, peer-to-peer networking, cellular telephony and ad hoc networking arenas. The chapter ends with a summary of the key technical challenges that have been identified.

2.1 Peer-to-Peer networks

- What do we mean by peer-to-peer? How is it different to the traditional client/server approach? No single point of failure with p2p, arguably better fault tolerance.
- Peer-to-peer has been successful over the Internet, e.g. Napster, Gnutella, mainly for file sharing networks.
- Point out that there are different types of p2p networks – some like Napster are not "pure" p2p since they use centralised directory servers.
- JXTA project – to provide a framework for developing p2p applications more easily. Ref [MAIB02]. Explain the JXTA architecture and protocols.
- Distributed.Net project, SETI@home – exploit the abundance of clock cycles.

2.1.1 P2P example: Free World Dialup

- Free Peer-to-Peer Voice over IP (VoIP) service started by Jeff Pulver. http://fwd.pulver.com.
- Designed to work over broadband connections. Utilises existing Internet bandwidth.
- SIP protocol – extremely lightweight. Discuss Kenneth Turner's work on VoiceXML and CRESS [TURN03].

2.2 Wireless WANs – cellular radio networks

- Brief discussion of history of mobile phone networks, from analogue systems to 2G GSM, to 2.5G with GPRS and EDGE technologies, to 3G with UMTS.
- Difference between FDMA, TDMA and CDMA technologies. Ref [http://www.rhowireless.com/wan/Default.htm].

- Current applications, via WAP, i-mode, cHTML – ability to read news, weather etc, plus ability on 3G to download video clips etc.
- Some messenger services can operate over GPRS, such as MSN Messenger and Yahoo! Messenger. But these are not Peer-to-Peer and require the cellular network.
- Uptake of SMS service over last few years shows that there is a strong demand for more than just voice services.
- Nextel PTT (Push to Talk) service in the US – extremely popular coast-to-coast walkie-talkie service for a flat monthly fee. Also TETRA networks (e.g. Dolphin Telecom).
- Cellular airtime is still relatively expensive – not suitable for frequent group communications. Also speed is limited, so not really suitable for file sharing.

2.2.1 2.5G example: FastChat

VoIP, PTT-type messenger service that launched recently in the UK. Works with a limited range of Symbian handsets only. http://www.fastchat.co.uk.

2.3 Wireless LAN technologies

Why Wireless LAN in addition to WAN? More suited to p2p applications, and can send data faster and cheaper than over current 2.5G and even 3G networks.

2.3.1 Bluetooth (IEEE 802.15)

- Piconets and scatternets, master/slave configuration. Ref [GROT01].
- Description of Bluetooth stack.
- Good for short range (i.e. < 10m communication). A wide range of telephone and PDA devices available that support Bluetooth.

2.3.2 WiFi (IEEE 802.11a/b/g)

- WiFi "hotspots" spreading fast, e.g. BT OpenZone, Starbucks Coffee.
- 802.11b is now quite cheap, and most new laptops have a transceiver built in. 11Mbps peak, though in reality a lot less than that.

- However, very suitable for p2p since it works over a much larger range than Bluetooth. But higher power requirements.

2.3.3 Proprietary low-range radio networks

- Example is the Cybiko device, designed for the youth market, which inherently supports p2p applications. Link to devices section to discuss the Cybiko unit in more detail. http://www.cybiko.com.

2.3.4 Infra-red

- Too short a range, not reliable – discuss briefly. Only advantage is that most devices seem to include an infrared port.

2.3.5 Personal Area Networks (PANs)

- Brief discussion of emerging IEEE 802.15 standard, and Zimmermann intra-body network. See [KORT02].

2.4 Ad hoc networking

- An ad hoc network has no fixed infrastructure. Therefore self-configuring. Born out of the idea of packet radio networks in the 1970s and 1980s.
- Refer specifically to MANET, useful material: http://w3.antd.nist.gov/wctg/manet/ and http://lists.consume.net/pipermail/consume-routing/2001-April/000193.html.
- Currently, main research areas are efficient distributed routing algorithms.
- Investigate the merits and shortcomings of the various routing protocols, such as AODV and DSR. Contrast table-driven with on-demand routing.
- Security is a major concern due to its features of open medium, dynamic changing topology, cooperative algorithms, lack of centralized monitoring and management point, and often lack of a clear line of defence. See http://www.wins.hrl.com/projects/adhoc/security.html.
- Look into IPsec etc.

2.5 Ubiquitous applications

- How can technology become more ubiquitous as part of our daily lives?

- An example is the Ubiquitous Coffee Table, as proposed by Bob Spence, Dept of EEE. Ref to his paper.
- This section really focuses on potential applications that can be delivered or certainly brought closer to reality by this project.

2.6 Hardware devices & software platforms

We only look at the main ones here, there are several others too. General discussion of form factor – e.g. mobile phone vs PDA.

2.6.1 Symbian

- Mainly Nokia (Series 60 - 7650, 3650, 6600, N-Gage) and Sony Ericsson (UIQ – P800, P900).
- C++ Development environment and SDK available, but relatively steep learning curve. Also, the Series 60 SDK isn't compatible with the UIQ one, so portability a problem.

2.6.2 Java 2 Micro Edition (J2ME) and PersonalJava

- Many new phones and PDAs have some form of Java support. But J2ME in particular is limited – gives very little control over hardware. Advantage is that it's cross-platform.
- JXTA for J2ME (JXME) project – still in early stages, since not proxyless. Communication is via HTTP requests only, not sockets.

2.6.3 Microsoft .NET Compact Framework

- Several versions - Pocket PC, Smartphone. Latest versions based on Windows CE .NET 4.2.
- Advantages are that applications developed for .NET Compact Framework can run on all devices that have the framework installed, therefore relatively portable.
- Relatively easy to deploy XML web services on mobile devices.
- .NET Compact Framework is a cut-down version of the .NET Framework, and development is now possible using VB.NET and C#.
- Developers can use Visual Studio .NET 2003 to develop applications – rich emulators and debugging tools provided to speed up the development process.

2.6.4 Cybiko

- This deserves a mention, because it's a good working example of a p2p communications device. Material available at http://www.cybiko.com.
- Find out how successful it was – what were the main problems? Probably that the range is so limited! Only works well within a 50m range I think.

2.7 Bringing it all together...

- All of the areas discussed above now to be brought together, since this is what the project is trying to achieve.
- What has already been achieved in this area?

2.7.1 Proem – University of Oregon

- See [KORT02] – much info here on the Proem platform.
- Worth summarising parts of their paper; interesting work on impromptu collaboration.
- Future research areas – not much work done at the application layer so far, according to the authors. Also, integration with ad hoc network functions and services such as device discovery, routing, multicasting.

2.7.2 Wireless Ad Hoc Messenger – The Virginia Polytechnic Institute and State University

- A project sponsored by Microsoft Research. Based on .NET compact framework. Also uses multi-hop routing, therefore extremely pertinent.
- See http://people.cs.vt.edu/~irchen/microsoft-grant/Website_HTML_Files/index.html.

2.7.3 MOBY – Motorola Labs and Purdue University

- [HOR02] describes MOBY. Jini-based. Interesting security model.

2.7.4 Miscellaneous research work

- Summarise the key points from recent related papers.
- [SUN01] describes some key research issues, such as multicast routing algorithms, QoS supporting model, security, reliability, availability and internetworking mechanisms.

- KPN Research [GROT01] work on Bluetooth MANETs – discussion of their findings.

2.7.5 What's missing?

- Whilst there is a lot of work related to general MANETs and targeting a specific technology, there doesn't seem to be much arguing for a hybrid approach.
- Devices these days may support Bluetooth, several WiFi standards and perhaps have 2G/3G cellular capability as well. How about if we could harness all these technologies and choose the best method of communication between devices in a network?
- This leads to some interesting possibilities – with a multihop ad hoc network, a device with Bluetooth but without WiFi could utilise a nearby node to relay traffic to another node that is further away and can only be reached by WiFi.
- Text messenger type applications have been deployed with some success in wireless ad hoc networks, but what about voice and video communication which require higher bandwidth?
- Peers don't have to be devices carried by people, they might be attached to a building too. E.g. when passing a shop, the peer device senses that we are near and sends us information that we might be interested in. Or when in a cinema, it could turn our phone to silent automatically if we've given it permission to do this.
- Location-based services – how can we calculate where users are in relation to one another? Can this be done reliably, and what sorts of algorithms would be efficient? Few devices have a GPS built in, so we might have to use something like triangulation.

2.7.6 Summary

Quick overview of the big challenges that we currently face.

- Security & trust issues
- Routing algorithms for multicast & multihop networking
- Internetworking between cellular and mobile ad hoc systems
- Killer applications for this emerging technology
- Accurate location detection

3 Project Specification

Here we will review the challenges discovered from the section above, to determine what the implementation phase of this project should deliver.

Thoughts so far:

- .NET Compact Framework seems like an excellent development platform. New Smartphone 2003 devices becoming available within 1-2 months, so a good opportunity to use cutting-edge technology. Also, we could develop something that could run on a Pocket PC (e.g. iPAQ) as well as a Smartphone.
- Might be more interesting to develop a p2p framework rather than just focus on a particular application.
- Look at ways to route data over a combination of Bluetooth, WiFi and GSM/GPRS where appropriate. Multi-hop routing essential – develop an efficient algorithm?
- Use of XML for passing messages between devices?
- Location-based services – how can we work out where the devices are in relation to each other?
- Not convinced I should focus on the issue of security/authentication, since this is an enormous area all on its own. Is this is sensible decision?
- How can we know which what devices are capable of doing? e.g. one may have a webcam built in. XML meta-data multicast across the ad hoc network?

4 High-Level Design

5 Detailed Design

6 Implementation

7 Testing

8 Evaluation

A1 Users' Guide

A2 Project Logbook

A3 Bibliography