Midterm Progress Report:
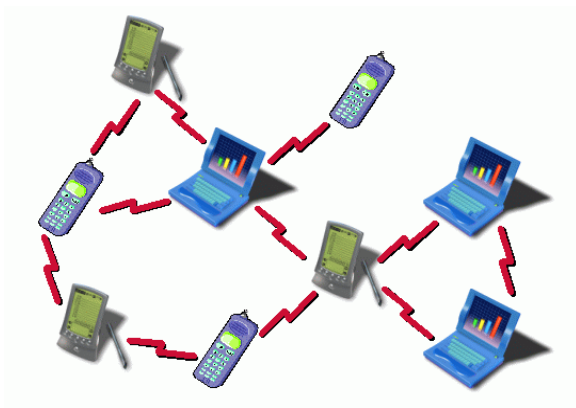
Mobile Ad-Hoc Networking - Transparent Virtual Directory

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1 Contents

2 Background

2.1 Main objectives of our project

The primary objective of our project has been to look at the possibilities and limitations of using mobile terminals for ad-hoc networking.

A secondary objective, which is of equal motivational value as the primary, has been to gain hands-on experience in using and creating mobile ad-hoc network applications.

To achieve these objectives within the time frame for the project, we decided early in the process to focus on finding an interesting example case / scenario on which a prototype application can be based. The process of designing and attempting to realize such a prototype application will illuminate challenges and possibilities at technical level, business level and social level, and enable us to gain insight into key concepts and technologies of mobile ad-hoc networking and mobile software development (without digging too deeply into low-level technical details such as various protocol details, etc).

2.2 Limitation of scope

Investigating all possibilities and limitations of using mobile terminals for ad-hoc networking may prove to be very challenging, hence we will concentrate on possibilities and limitations discovered during our work with the prototype application.

Further, since various technologies for ad-hoc networking and mobile application development exist, we have limited our scope further by first making a choice of what technologies we want to use and learn more about.

2.2.1 Choice of technology

It was natural for us to choose Bluetooth as the network technology for our project, since Bluetooth over the past 4-5 years has become the de facto standard for short-range, wireless, ad-hoc mobile networking and nearly every mobile phone being shipped these days has a built-in Bluetooth device.

Just as with Bluetooth, J2ME (Java Platform, Micro Edition) has more or less become the de facto standard for platform independent development of applications for mobile / embedded devices. It was therefore also natural to choose J2ME as the "target platform" for our example application's prototype.

Bluetooth and J2ME are presented in somewhat more detail in section 2.6.

2.3 External collaboration

Having agreed upon project objectives and what technologies to focus on, we tried for quite a while to establish external collaboration by contacting a set of companies/institutes that we and

the course instructor Jo Herstad thought might be interested in our project topic. The companies/institutes we contacted were:

- Telenor
- FFI (Norwegian Defense Research Establishment)
- UiO DMMS (University of Oslo, research group for Distributed Multimedia Systems)
- AHO (Oslo School of Architecture)

Unfortunately, the time spent on this did not yield anything, and instead of spending any more time searching for a mentor / "sparring partner", we decided to continue with our own ideas.

2.4 Abandoned ideas for example application

In the beginning, we were thinking along the lines of a Bluetooth-based application that somehow could be utilized in a disaster management- or rescue operation scenario. We had also thought about other application areas, but disaster management sounded impressive and appealing to us. Although, we soon realized that in order to satisfy the needs of such complex activities as disaster management and emergency rescue operations we would need to study more than just essential ad-hoc networking concepts and techniques for mobile software development. Hence, keeping the time frame in mind, we switched to another idea which perhaps would have been just as time consuming but sounded more interesting and executable at that time.

The new idea now was to try to develop a software-based positioning mechanism which would allow a mobile Bluetooth-node inside a piconet or scatternet to be positioned relative to three static reference nodes (using triangular positioning). This idea was kept alive for two weeks before deeper analysis of the planned application concluded that the probability for the planned prototype to be successful not in favour of executing the idea.

2.5 New idea for prototype application

The prototype application should employ the basic ad-hoc principles. With this in mind we came up with a new idea of a file sharing application. The main concept of this application is to share files ad-hoc between Bluetooth-enabled devices. File sharing is a well-known application domain. The ad-hoc version of file sharing, however, still has several unanswered questions and provides a good fundament for technical reasoning.

Several restrictions have been made to our prototype application due to the time constraint and the nature of this project. However, we feel that most of these restrictions apply to other aspects of application development rather than the principles and methodology of ad-hoc networking. For instance, file replication and load balancing are issues strongly related to development and research in the domain of distributed systems.

The next chapter elaborates our idea of the ad-hoc file sharing application, which we have named Transparent Virtual Directory.

3 Prototype Application:
Transparent Virtual Directory

3.1 Introduction

The main goal of a service like 'Transparent Virtual Directory' is to provide a simple and intuitive way of sharing files with other people ad-hoc using Bluetooth capable devices. The concept behind this service is rather simple to understand. However, there are several important issues related to implementation and technology restrictions which must be addressed in order to achieve a seamless, flexible and stable system. We will try to identify these issues in the rest of this chapter. We will use three main scenarios in our explanation of Transparent Virtual Directory, TVD in short. The studying and reasoning about these scenarios will also result in a deeper understanding of the principles and ideas behind the concept 'ad-hoc networking'.

3.2 Distributed file access and file sharing

In short; TVD is all about sharing a common virtual directory. This directory may contain any form of file content from plain text files to binary files like pictures and mp3-files. The term 'virtual' does in this context refer to a directory which is shared among all of the concurrent users of the TVD-service. This virtual directory does first exist when there are at least two Bluetooth devices connected together using the TVD-service.

At present there are hundreds of devices supporting Bluetooth where mobile phones, PDAs and laptop computers are the most common application areas. The term 'transparent' used in the TVD-context refers to a notion of transparency when using the TVD-service across multiple platforms and device types.

There are two different modes supported by TVD; passive mode and active mode. The operations supported by the two different modes are based on a simple File Awareness Model. This model presents the users with an updated, uniform file list representing the content of the virtual directory, and maintains the hosts and routing information. We will return to this model shortly.

The two different user modes are related to the different states of a TVD server/client and the actions performed by the end users. The active mode is characterised by an ongoing file transfer and the associated file requests. The passive mode indicates the user being idle or browsing the common TVD file list. The transitions between the different modes are transparent for the end user. However, the differentiation between the different states is necessary due to load balancing and replication issues. The only supported functionality in active mode is file downloading. One or more files can be downloaded from various nodes simultaneously. Uploading of files is not supported. This prevents misuse like spamming, flooding and simple forms of DoS.

3.3 How it works

Transparent Virtual Directory is based on a peer-to-peer ad-hoc network architecture. This means every node in the network has the same capabilities and works both as a client and a

server. A node is therefore referred to as a 'server/client'. Please refer the section 'Distributed file access and file sharing'.

Each node in a TVD network may share one or more of its files with the rest of the network. The shared files will be visible for all the other nodes in the TVD network. However, the files are not copied to these nodes. A file is first copied to a node when this node requests the file. This way, all files presented in the TVD file list are distributed among the participating nodes in the network.

The basic operations of the TVD service can be categorised in three main scenarios:

- The network consists of two nodes where node A requests one or more files from node B.
- The network consists of three nodes where node A requests one or more files from node B and C. All nodes are within range of each other.
- The network consists of three nodes where node A requests one or more files from node B and C. The nodes A and B are within range of each other. The same applies to node B and C. In other words, node A does not have a direct connection with node C and vice versa.

Other scenarios can be explained using a combination of the three aforementioned scenarios.

3.3.1 The File Awareness Model

Each node in a TVD network has its own unique File Awareness Model, also referred to as FAM. A FAM consists of a table with information about every shared file in the TVD network and its associated node (owner). Each File Awareness Model represents a part of a complete TVD network. The union of all FAMs expresses the connection paths between every node in the network and works as a reactive routing protocol.

A given node does not store information about the addresses of nodes outside its own range. However, this node is still able to access all the shared files by the use of forwarding. The shared files are presented using a uniform file list. The exact same list is shared by all nodes in the TVD network and is extracted from a given node's File Awareness Model.

A given node in a TVD network may not share any files. However, this node is still useful for forwarding purposes. To be able to access this host, every reachable node has its own ghost entry in the File Awareness Model.

An example File Awareness Model is shown below:

File name	Host	Host address	Host alive
file A.txt	localhost	localhost	0:00:00
file B.txt	node B	btspp://102030405060A194C37429E4938:5	0:00:04
file C.txt	node C	btspp://1020304050604C277314562A3B0:5	0:00:10
file D.txt	node D	foreign	N/A
ghost	node B	btspp://102030405060A194C37429E4938:5	0:01:05
ghost	node C	btspp://1020304050604C277314562A3B0:5	0:03:10

3.3.2 Operation classes

The following figures use four operation classes which generalise four different types of operations. These operations are always executed in the following sequence; *requests*, *file existence tests*, *target destination tests* and *file transfers*. A *file existence test* is always preceded by a *request*, a *target destination test* is always preceded by a *file existence test* and so on. The following table shows an overview of the different operation classes. The number of hops indicates the number of forwards needed to get a requested file. In other words, how many nodes there are between a node requesting a file, and the target node on which this requested file is located. This number is equal to zero if the target node is within the range of the node requesting a file. The number of hops also indicates the distance between two nodes. A given *request* is closely related to a *file existence test*. The same applies for a *target destination test* and a *file transfer*. The figures are best read by following the order of the operation classes.

Figure 1: Operation classes in a TVD network

3.3.3 Initialisation phase

An initialisation phase starts ad-hoc as soon as two or more Bluetooth devices running TVD are within reach of each other. The following is performed:

1. A detection of servers running TVD
2. A detection of the TVD service
3. Authorisation and authentication
4. Selection of the files to share
5. Building of a FAM for each node in the network
6. Presenting a conform file list on each node

The events 4 to 6 are performed dynamically and keep the FAMs updated with the newest available file and routing information.

Please refer the sections 'Load balancing', 'File replication' and 'Authorisation, authentication and encryption' for details.

3.3.4 File requests, file and node awareness and file transfers

This section explains the basic functionality of the TVD service using three scenarios. Several issues regarding load balancing and replication of files have been left out to make the explanation more clear. Please refer the sections regarding these topics for further details.

The network consists of two nodes where node A requests one or more files from node B.
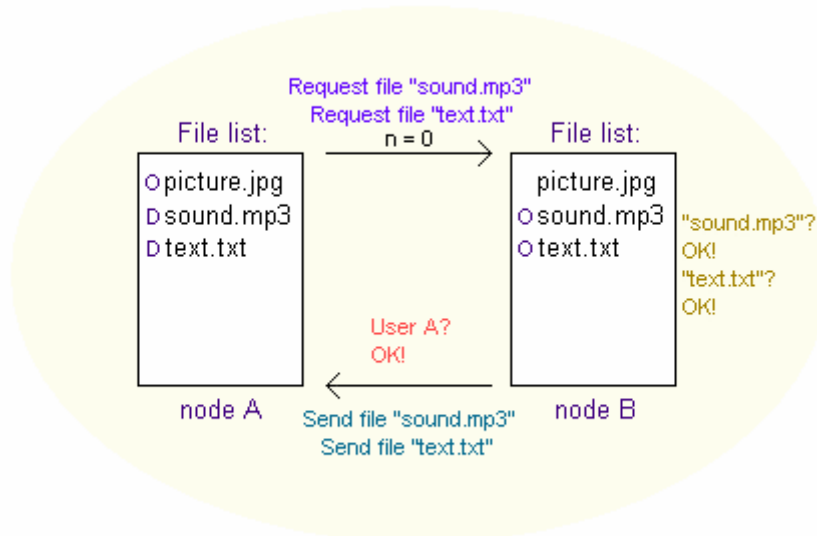
Figure 2: A TVD network consisting of two nodes

Figure 2 shows the basic application of the TVD service. There are two nodes/devices in the TVD network sharing three files. The figure shows the file lists as shown on the two Bluetooth enabled devices running TVD (some details are left out for the sake of clarity). The three shared files, as shown in the figure, are: *picture.jpg*, *sound.mp3 and text.txt*. *picture.jpg* is physically located at the device denoted by node A. (This is indicated with a capital 'o' - own or ownership, beside the file name in the file list.) The other two files are located on the device named node B. The figure shows the situation after the two nodes have come within reach of each other and the initialisation phase of the TVD service has been performed. The user of node A has marked the files sound.mp3 and text.txt for download. (This is indicated with a capital 'd' beside the file names.) The next sequence of actions is as follows:

1. The user presses the download button on his/her device.

2. Two lookups for the files *sound.mp3* and *text.txt* is done in the File Awareness Model of node A. A simplified example of this model is shown below. (For instance, the ghost entries and host addresses are not shown):

File name	Host
picture.jpg	localhost
sound.mp3	node B
text.txt	node B

File Awareness Model - node A

3. Two file requests are sent to node B. In the following only the processing of the first file request – *sound.mp3* is explained. The processing of the other file request is similar to that of the first request.

4. Node B checks its File Awareness Model for the file *sound.mp3*. This file is marked with localhost which implies the local storage of this file in node B. A simplified version of the File Awareness Model on node B is shown below.

File name	Host
picture.jpg	node A
sound.mp3	localhost
text.txt	localhost

File Awareness Model – node B

5. Node B then checks its File Awareness Model again to see if node A exists within the range of node B. Node A is found in the model/table and a transfer of file *sound.mp3* starts. The file is then stored in the Record Store of node A.

6. Steps 4 and 5 are repeated for the file *text.txt*.

3.3.4.2   Scenario 2 – Three nodes within range of each other

The network consists of three nodes where node A requests one or more files from node B and C. All nodes are within range of each other.
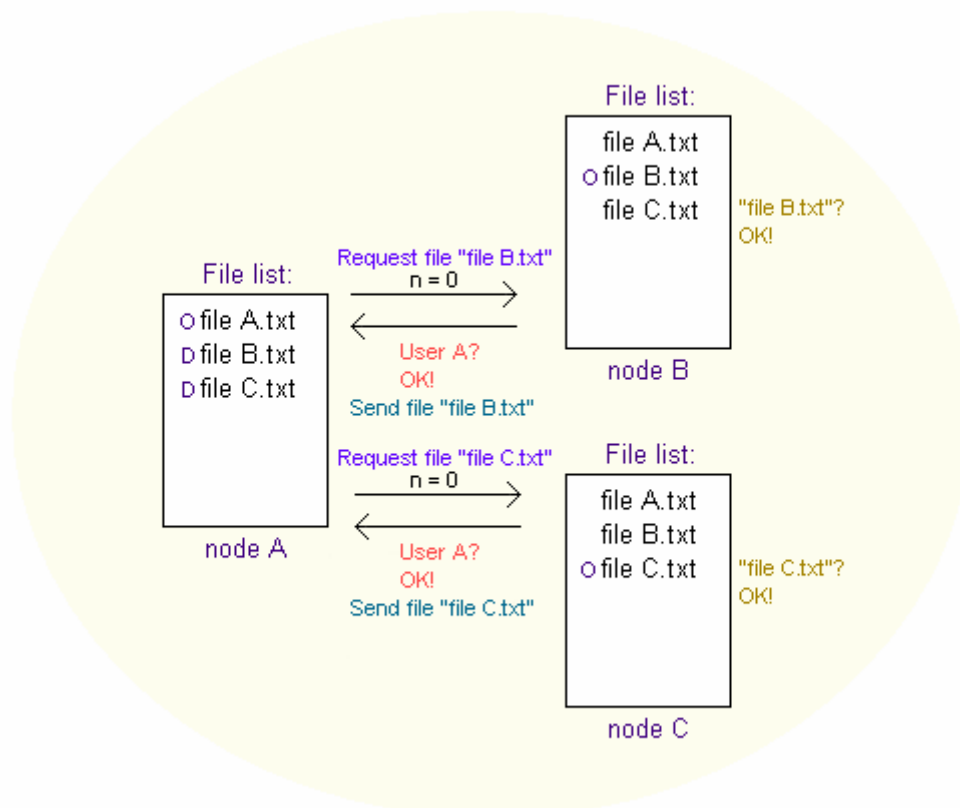
Figure 3: A TVD network consisting of three nodes/Bluetooth devices

Figure 3 shows a TVD network with three nodes. Every node is within reach of the other nodes. *file A.txt* is stored on the device represented by node A, *file B.txt* is stored in node B and *file C.txt*

in node C. The figure shows the situation after all nodes have been initialised and the user of node A has selected *file B.txt* and *file C.txt* for download. Simplified versions of the File Awareness Models are shown below:

File name	Host
file A.txt	localhost
file B.txt	node B
file C.txt	node C

File Awareness Model - node A

File name	Host
file A.txt	node A
file B.txt	localhost
file C.txt	node C

File Awareness Model - node B

File name	Host
file A.txt	node A
file B.txt	node B
file C.txt	localhost

File Awareness Model - node C

Sequence of actions:

1. Node A requests the files *file B.txt* and *file C.txt* from the nodes B and C, respectively (after lookups in the FAM).

2. Node B checks its FAM and verifies the ownership of file *file B.txt*. It then finds node A in its FAM and sends the *file B.txt* to node A. The same operations are performed by node C regarding the file *file C.txt*.

3. The files are stored in node A.

3.3.4.3   Scenario 3 – Three nodes whereof two are not within range of each other

The network consists of three nodes where node A requests one or more files from node B and C. The nodes A and B are within range of each other. The same applies to node B and C. In other words, node A does not have a direct connection with node C and vice versa.

Figure 4: Three nodes in a TVD network where node A and node C is out of reach of each other

Figure 4 shows a TVD network consisting of three nodes. Node A is not within reach of node C. The figure shows the situation after all nodes have been initialised and the user of node A has requested *file B.txt* and *file C.txt*. The simplified File Awareness Models are shown below:

File name	Host
file A.txt	localhost
file B.txt	node B
file C.txt	node C not reachable

File Awareness Model - node A

File name	Host
file A.txt	node A
file B.txt	localhost
file C.txt	node C

File Awareness Model - node B

File name	Host
file A.txt	node A not reachable
file B.txt	node B
file C.txt	localhost

File Awareness Model - node C

Sequence of actions:

1. The user of node A requests the file *file B.txt* and *file C.txt*. *file B.txt* exists on node B and is transferred directly to node A. However, the FAM of node A does not contain the host address to node C which implies that node C is out of range of node A. Node A sends a general request for *file C.txt* to all the reachable nodes in its FAM (here only node B). Node B does not own the file *file C.txt*, but checks its FAM to see if a registered, reachable node owns the file. It finds the address to node C and forwards node A's request for *file C.txt*. The information about the path back to node A is carried along and presented for node C.

2. Node C checks whether it has the address to node A, the node which requested the file. Since it does not have this address it sends the requested file to node B which forwards it to node A.

3. Node A stores the file *file C.txt* in its Record Store.

3.4 Technical challenges

This section describes the main technical challenges which are expected during implementation of TVD.

3.4.1 File replication and file ownership

Many strategies for data replication in mobile computing have been proposed in research articles, such as **Feil! Fant ikke referansekilden.**. Most of these strategies assume an environment where mobile hosts access databases at sites in a fixed network, and create replicas of data on the mobile hosts. This because wireless communication is more expensive than wired communication. The strategies address issues of keeping consistency between original data and its replicas and propagating update operations to the replicas with low communication costs. Many of these strategies are considered to be similar to our approach; creating replicas on mobile hosts. However, these assume only one-hop wireless communication. The approach in the article 'Effective Replica Allocation in Ad Hoc Networks for Improving Data Accessibility' **Feil! Fant ikke referansekilden.** addresses these issues for multi-hop communication in ad-hoc networks. It proposes three replica allocation methods which differ in emphasis put on access frequency and network topology:

SAF (Static Access Frequency) method: Only the access frequency to each data item is taken into account

- DAFN (Dynamic Access Frequency and Neighbourhood) method: The access frequency to each data item and the neighbourhood among mobile hosts are taken into account
- DCG (Dynamic Connectivity based Grouping) method: The access frequency to each data item and the whole network topology are taken into account

At this point we have decided to apply restrictions to our TVD-application to avoid the difficulties file replication may cause:

- Only one node in the TVD-network may share a file with a given name
- The aforementioned node owns this file

- Files downloaded by nodes in the TVD-network are not automatically shared by these nodes

3.4.2 Routing

There are many different routing protocols and routing strategies available today. Many routing protocols have also been designed to be used in ad-hoc networks. These ad-hoc compatible protocols are classified in three groups; proactive, reactive and hybrid routing protocols.

Proactive routing protocols work by keeping all nodes in the network updated with routing information to all the other nodes in the network. Reactive routing protocols, also known as on-demand routing protocols, maintain routing information for active routes only. Routes are determined on-demand when a given node needs to send data to another node in the network. Hybrid routing protocols use a combination of the principles of both proactive and reactive protocols.

At this point we think that a reactive point-to-point (hop-by-hop) protocol will be the most appropriate choice for TVD. With the use of this protocol each data packet only carries the destination address and the next node in the route. All intermediate nodes between the node issuing the request and the target node use the information in their respective routing tables and forward the data packets. This routing strategy is well adapted to ad-hoc networking and dynamic changes of the network. However, the nature of this routing strategy requires that each node stores information about the active surrounding nodes. This means that "hello messages" need to be sent to keep the stored routing information up-to-date.

JSR82 specifies the use of Bluetooth in J2ME-applications. This standard categorises the different nodes in the Bluetooth network as either a master or slave, where one master and seven slaves constitute a pico-network. Several pico-networks make a scatternet. TVD is thought to be a peer-to-peer service where each node in the TVD-network is equal with regard to the master/slave-philosophy. JBAN is a java.net project utilising JSR82. This library makes it possible to establish unlimited Bluetooth connections without the need for the end user of JBAN to explicitly think about the master/slave-issue. This library also contains functionality to deal with routing and load balancing.

We will be using the JBAN library in our prototype application. This library will work as the network interface to the rest of the application. This simplifies the implementation of the prototype application significantly. The JBAN project is released under the Lesser General Public Licence (LGPL).

3.4.3 Load balancing

An important issue in the context of file sharing is load balancing. A network may consist of several nodes sharing the exact same files. It is desirable that requests for these files are distributed among all the nodes sharing these files. Firstly, this reduces the load each node is exposed to. Secondly, it is more likely to avoid popular routes through the network which may cause traffic jams.

The article *'Dynamic Load-Aware Routing in Ad hoc Networks'* **Feil! Fant ikke referansekilden.** presents a routing protocol named Dynamic Load-Aware Routing (DLAR), which supports load balancing. This protocol uses the load of intermediate nodes of a given route as the main route

selection metric. The active routes in a given network implementing this routing protocol are monitored and alternative routes are constructed when a load threshold is exceeded. DLAR uses the number of data packets buffered on a given node as the main criteria for selecting routes. Load balancing is fulfilled by using the least-loaded routes.

Associativity-Based Routing (ABR) is the only major ad-hoc routing protocol available today that uses the load of nodes as a metric to decide which route to use. This protocol uses the number of routes a node is a part of as the indicator for routing load. However, this routing load is only used as a secondary metric.

We will not reason more about load balancing for TVD at this point. We will be using the JBAN library to deal with this issue. Construction and implementation of explicit load balancing would be somewhat out of scope of this prototype application.

3.4.4 Security

As with almost all communication technologies, also TVD has its problem, or rather to say more difficult, areas. These areas are:

- File security
- File integrity
- Routing of data
- Unit security (phone, PDA… it selves)

Basically we have 3 places thing can go wrong:

- The Protocol Layer
- The Application Layer
- The user

When it comes to the main transmission of data, the bits and bytes between units, we in this project relies on the built in security features of Bluetooth. This protocol is under constantly development, but offers all the basic security we need. It's communication and authentication is encrypted with an 128bit key, and it uses the SAFER+ algorithm. Consider the calculation power available in mobile devices; this is satisfying for most communication.

The application layer is the main base of the security we will add to the program. This section is not completely planned yet, but we have taken a couple of decisions. To start with, we will only let users be able to download data. There will be no way of pushing information onto a unit. Allowing pushing of data would make the security much weaker, and also it would be more challenging for the user to configure the software the best way. The other issue we have decided on is that we need some sort of group access. So you are given the choice between sharing to all users nearby, and only to those the information are meant to.

The last problem maker is maybe the hardest to protect the users from, themselves. Their ignorance and non thinking can lead to all possible situations, at this part there are currently much to come.

3.5 Why we want to realize TVD?

3.5.1 Purpose and usefulness

Ad Hoc networking is basically a result of the demands modern human beings has to daily life technology. We want communication and information when and where we find ourselves, and we don't want to have to rely on an external part, which just offers a little service. Ad Hoc networking it selves has a variety of usage areas. Examples:

- Dating services
- Chatting
- Customer oriented sales / On demand
- Work situations out in the field:
  - Emergency areas
  - Military operations
  - Hunters out in the wood
- File sharing
- Media streaming services
- Mobile game play

It's just the imagination that limits the service possibilities and usage areas of Ad Hoc networking. It's a very strong basis everywhere we want to communicate between mobile units.

Our application, TVD, will offer the users the possibility to easy share different type of files between multiple media devices, wherever and whenever they want to. It will be easy, intuitive and effective. Then who could be interested in using such a service? Well, here there are a lot of possibilities. You and your friends wanting to share pictures or music, colleges at work updating each other in front of a meeting, grandmothers meeting to share cookie recipes, or the lecturer that wish to share his presentations and maybe some background information to the audience. In all there's a lot of possible situations where we wish to share information as files.

One of the big advantages of the TVD is that you can communicate between different sort of equipment. The only demand is that it can communicate with the Bluetooth protocol. You can transferee between PC, PDA, cell phone, MP3 players and so on.

A important sales argument for TVD, is that it also will remove the need of one of all these electronic equipment we are carrying around today, the memory stick. Today we have one portable unit which integrates more and more functions, the cell phone. Vi can talk, listen to radio, take pictures, listen to music, play games and so on. Today almost every cell phone is made with the possibility to contain a memory card, so why just don't use this space for file transport. This is of course also possible today, but it's not in common use reason to difficult GUI's and applications that desires much of the users. Our plan is to make this simple.

3.5.2 Usage scenarios

TVD has a usage area for as good as everyone wanting to share or transport data between multiple mobile units. Here are some more or less good examples:

3.5.2.1 Scenario 1

Ole is an important and busy businessman, which shuttles a significant distance to and from work everyday. He has much to do and is depending on being able to take some of the work home for the night, but since the travelling time to and from work takes up much time, he also wants to be able to some work at the train or bus. His work also contains sensitive information, so transfer over the Internet is not the best. Ole has earlier used both laptop and memory sticks to transfer data, but with the stick he can't work while he travels and the computer is big and much more than he needs for some reading and writing. The solution for Ole is TVD. At the office he easy transfer files to his PDA / cell phone lying in his jacket. No need for cables or installations. While travelling he has lots of space even is the train is full of people. And he can both read and write to his documents. At home Ole just runs TVD at his desktop computer and easy transferees the work to this, while the phone still leys in his jacket.

3.5.2.2 Scenario 2

Ole from scenario 1 also often has to go to different meetings in his workplace. In front of and during these meetings there is a lot of document trading going on. Today you have to make a print out in X number of copies or share an link to the documents. This is both expensive, time taking and either these links are forgotten or the paper thrown away by someone don't want anything more to carry around. But then came TVD. Quick and easy Ole shares the documents current to the meeting, and those wanting them can grab what they want. Since this also can be documents containing sensitive information, Ole makes use of TVD's build in group access features, which only gives users with the right access rights, the possibility to download the files.

3.5.2.3 Scenario 3

Elisabeth has been on a class trip in for the whole weekend, and now they're all on the bus back home. Naturally there's been taken a lot of pictures during the weekend, and everybody wants to see what the eager photographer Elisabeth has gotten. In her cell phone she has a big memory card containing tons of pictures. Had this been the good old days, everyone would have had to copy each image one in a time from phone to phone, but now we have TVD. Easy Elisabeth shares all the pictures with access for everyone(well she has nothing to hide) and the copying starts. The speed is good, since TVD at every time gets data from the nearest and fastest unit in the network. This ways Elisabeth's phone don't have to serve all the users downloading. The result is quick and easy sharing, and satisfied friends.

3.5.3 Existing similar applications

BEDD is a technology company which develops social networking software including wireless community applications and services. It provides a mobile ad-hoc platform for socializing and sharing. It is built on platform-independent technology and currently supported on Symbian Series 60. It uses Bluetooth, but can be integrated into any wireless platform, such as WiFi or WiMax, according to BEDD. It is supported on a wide range of phones, and requires 1MB of memory, as well as Bluetooth support. BEDD is free to use.

Compared to the approach taken by our project, BEDD provides more mature an advanced functionality. They seem to have solved the technical challenges to allow for ad-hoc file sharing (in their BEDDpic tool). The major disadvantage with BEDD is the relatively big footprint.

3.5.4 Transparent Virtual Directory in place and space

Harrison and Dourish describes place and space as important collaborative concepts. A space represents a physical location, such as a meeting room. They define the concept place, which represent an awareness of the meaning of a place, i.e. that a place is defined by how it is used. They identify different kinds of places, such as space-less places (places with no physical location, but a virtual one) and hybrid places (a mixture of physical and virtual spaces). The Transparent Virtual Directory application will define a place where its users meet to share content. Since the users share a physical proximity when meeting at the TVD place, it can be viewed a place with multiple dynamic spaces (i.e. not space-less).

3.5.5 Mobile ad-hoc networks and context awareness

Schilit et al describes context awareness issues and application areas and characterise how different kinds of technologies influence awareness and behaviour with respect to social context and communication. They do not address the field of mobile ad-hoc networks, which brings a different aspect to context awareness. Social awareness can be established implicitly triggered by the technology awareness of established ad-hoc networks. Kortuem et al addresses these aspects in what they call impromptu collaboration, and exemplify this with an ad-hoc MP3 file sharing scenarios. With respect to the Virtual Transparent Directory application, proximity awareness can be triggered by established ad-hoc connections and the visibility of specific files, or types of files. A particular file (e.g. a picture, music file, interesting text), may influence the ad-hoc participants to engage in more specific interaction, either using the mobile ad-hoc network or by engaging communication in a physical space (with the physical person).

3.6 Technologies used

3.6.1 Bluetooth

3.6.1.1   What is Bluetooth?

Bluetooth is a wireless standard for connecting devices, using short-range, low-power, inexpensive radios. The specification is managed by the Bluetooth Special Interest Group (SIG) founded by Ericsson in1998, together with IBM, Intel, Nokia and Toshiba, later joined by more that 2000 member companies. The latest version is 2.0 was released in 2004, and supports up to 3 Mbps speed. The radio operates in the licence-free 2.4 GHz ISM (industrial, scientific, medical) band, using 79 channels, each 1 MHz wide.

The original idea was just to get rid of the cables of the previous wired communication protocols, but the standard soon expanded in scope and, at version 1.1, at 1500 pages, had more than 13 profiles (applications / use cases in UP terminology), like file transfer and data synchronization, built on top of more than 9 protocols.

3.6.1.2   Why Bluetooth?

In this project, we want to experiment with ad hoc networks built on the Bluetooth radio technology. However, communication protocols built on radio of infrared waves is nothing new, and we have some alternative RF (radio frequency) technologies to consider. Below, we will briefly compare Bluetooth with the two main alternatives, infrared networks (IrDA) and 802.11* (Wi-Fi, WLAN), and point out the reasons why they were dismissed.

IrDA is similar to Bluetooth in cost and range characteristics, but requires line-of-sight (cannot penetrate solid objects), supports only point-to-point communication (the master of a Bluetooth Piconet can transmit to up to seven slaves simultaneously, half of the time) and has somewhat shorter range, usually only up to one meter.

802.11 is too expensive, both in money costs (three times as much) and energy consumption (uses five times more power), according to www.bluetooth.com. Neither has it gained widespread use on small, handheld devices yet. But this is rapidly changing in the next 6-12 months, when the first cell phones with built-in Wi-Fi arrive at the market.

There are also a lot of other RF technologies, like Ultra-WideBand, Certified Wireless USB, WiMAX, etc., that deserves further study, but most of these probably lacks widespread deployment on smaller handheld devices, or only works in specific geographical regions.

3.6.1.3   Drawbacks with Bluetooth

Bluetooth introduces some problems as well. It seems more difficult to use than 802.11, where one can build on a base of std. IP protocols. Bluetooth also has rather serious interference problem with WLAN, since they use the same radio frequencies. This was at least a known problem in version 1.1, where some user companies reacted with banning Bluetooth use in Wi-Fi zones (the forthcoming versions of Bluetooth might solve this, due to changing radio frequencies).

The present versions, 1.1 and 2.0, has a smaller data rate than both IrDA and 802.11, at 1 or 3 Mbps, but this also gets addressed in the two next generations of the std., which aims at 10 and 100 Mbps speeds. Compared to IrDA, Bluetooth is less secure from eavesdropping, since radio waves may penetrate building walls. And finally, Bluetooth lacks a single, open specification, managed by a neutral body (like the 802.* specs of IEEE). At present there exists one family of specifications at the SIG, and one overlapping set at IEEE (802.15.*), but these might converge in the future.

3.6.2   J2ME

3.6.2.1   What is J2ME?

J2ME, the Java Platform Micro Edition, is the mobile and embedded devices' Java platform. J2ME is basically made up by a set of technologies, specifications and APIs targeted at application development on consumer and embedded devices, and employs a smaller virtual machine tailored for resource constrained devices. Most of the components in J2ME are small-footprint subsets of Java SE (Standard Edition) components.

J2ME was found to be suitable for our needs for the following three reasons:

- Provides a Java Bluetooth API that hides much of the complexity of Bluetooth-protocols and the Bluetooth stack and hence allows us to focus on the application being developed

- The Java Bluetooth API in J2ME is an open, non-proprietary standard for Bluetooth application development and hence relieves us from fear of vendor lock-in in our choice of technology (as long as the devices support Bluetooth and J2ME, they can run on our application).

- J2ME is well documented and in wide-spread use, and can almost be viewed as a de facto standard for mobile application development.
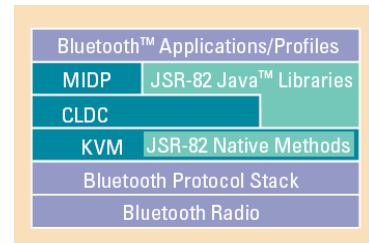
3.6.3 JBAN – A possible pain reliever

Although the J2ME and the Java Bluetooth API hides much of the complexity with Bluetooth, there are still some headaches left for the application developer. Firstly the process of forming a scatternet out of piconets is usually not dynamic and practical, and the scatternets formed are not robust. Secondly, the application developer has to give significant consideration to routing and network management details during application development.

JBAN is a newly "born" open source Java library for Bluetooth networking which aims to remove a lot of these headaches from the developer and allow him/her to focus on the actual application being developed. JBAN provides a new way to form an ad-hoc network at the Java application level so that routing and network management is performed at high level. The result is more robust networks (where there is no distinction between master and slave nodes in constrast to standard piconets). JBAN also allows unlimited devices to form a network dynamically.

The JBAN library may help us reduce some of the challenges such as routing and network management to non-existing issues (in the ideal situation). Although, we will have to proceed with extreme caution if we use JBAN as there is very little (almost none) documentation and nobody seems to have reported any experiences of using.

4 Project status

4.1 Current state

4.1.1 Where do we currently stand?

From the beginning and until now we have focused on background reading, understanding the technology and development tools, and evaluated interesting ideas for a prototype application. We have faced a steep learning curve and now stand with greater insight and understanding of concepts within the area of ad-hoc networking and technologies like Bluetooth and J2ME. Furthermore, we now have a well elaborated, feasible idea for a prototype application; Transparent Virtual Directory.

4.1.2 Evaluation of the work so far

We believe that the process we have gone through so far in this project has been fruitful for us, and the fact that we are not working in collaboration with any kind of external partner has allowed us to think freely and independently about ad-hoc networking and Bluetooth and hence learn more than we ourselves had expected. The idea of Transparent Virtual Directory may not have been born if we had locked ourselves into a more or less pre-planned project.

4.2 The path forward

4.2.1 Focus, method and goal

We are now ready to embark on realization of the planned prototype application; TVD. So far our work has been mostly theoretically oriented, and we are eager to roll up our sleeves and get our hands dirty with some practical application development work.

Since we are a large group we have decided to divide ourselves into smaller subgroups during implementation. This will ease the iterative development process and enable a better learning environment during the practical work. The result will hopefully be a greater theoretical and practical insight into the field of mobile ad-hoc networking and especially into Bluetooth and Java Micro Edition Platform (J2ME).

If we are successful in implementation and testing of the prototype, further development of Transparent Virtual Directory may be interesting (for us and others; perhaps as an open source project). The main goal will of course still be to broaden our insight into ad-hoc networking.

4.2.2 Key milestones (tentative)

Keeping in mind the short time-frame and an upcoming Easter vacation, we have agreed on the following tentative progression plan for further work with this project:

- Mon 17.04.2006 Prototype scenario 1
- Wed 19.04.2006 Review feedback on midterm progress report
- Mon 24.04.2006 Prototype scenario 2
- Mon 01.05.2006 Prototype scenario 3
- Mon 08.05.2006 All work on final report finished
- Wed 10.05.2006 Submit final report

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