Position technologies for internet connected mobile terminals, offering location based audio services.

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Abstract

The company Infotain wishes to offer location based audio guiding at museums. They wish that this audio is going to be available through the visitor's mobile phone. However, to be able to offer location based audio guiding a suitable positioning technology for mobile phones has to be found. Therefore the purpose of this thesis is to gather information about the technologies that can be used for location based information. After the technologies have been thoroughly examined we have to give Infotain a recommendation about what technology seems to best satisfy the demands. Important factors in evaluating the technologies are accuracy, response time, infrastructure power needs, and the ability to relocate site infrastructure. The seven technologies we found suitable are GPS, Mobile positioning, A-GPS, WLAN, Bluetooth, NFC and 2D barcodes. The two technologies NFC and 2D Barcodes were found the most promising as they satisfied the requirements to a high degree. Therefore these two were included in the testing phase. The testing was designed to simulate the situations a user of the guiding service could experience. Key factors recorded during the testing were time used and number of key strokes used. These results assisted in the choosing of a technology as they give a good picture of how the different technologies function. Based on its independence from electricity, its high accuracy, low response time and ease of site relocation, QR Codes was recommended as the most suitable technology.

Preface

This thesis concludes the two-year Master of Science program in Information and Communication Technology (ICT) at Agder University College (AUC), Faculty of Engineering and Science in Grimstad, Norway. The workload of this thesis equals 30 ECTS and the project has been carried out from January to June 2007.

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Abbreviation List

A-GPS	Assisted Global Positioning System
AoA	Angle of Arrival
AP	Access Point
CDMA 450	Code division multiple access 450 MHz
CPU	Central processing unit
DECT	Digital Enhanced Cordless Telecommunications
DHCP	Dynamic Host Configuration Protocol
EDGE	Enhanced Data Rates for GSM Evolution
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communication
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
LAN	Local Area Network
MP3	MPEG-1 Audio Layer 3
NFC	Near Field Communication
PDA	Personal Digital Assistant
QR Codes	Quick Response Codes
RFID	Radio-frequency identification
SIM Card	Subscriber Identity Module Card
SSID	Service set identifier
ToA	Time of Arrival
UMA	Unlicensed Mobile Access
UMTS	Universal Mobile Telecommunications System
URL	Uniform Resource Locator
USB	Universal Serial Bus
WAP	Wireless Application Protocol
WLAN	Wireless Local Area Network

1 Introduction

1.1 Background

Infotain's field of operation is development of technology and services for offering of information and entertainment for portable devices like mobile phones, MP3-players, portable multimedia players etc. Their main target area until now has been MP3 guiding. MP3 guiding is about playing a recording of a guide on an MP3-player which the visitor carries. This gives the visitor information about what they are looking at independent of what other visitors might be looking at. The MP3-player could be the visitors own, or it could be borrowed from the provider of the guiding.

Infotain's newest product is guiding by mobile phone. The user buys a package from the provider which contains a phone number, a user code and guidance. The user call the number provided and enter the user code. When the user is next to a sight or attraction they enter a number, which is indicated on the map, which will start the right soundtrack for that location. The recording of the guide will then play over the phone.

Using the mobile phone as a media player is becoming more popular as the mobile phones are becoming more adapted towards multimedia content. Because of this it would be natural to offer media services for these phones. It is the wish of Infotain to offer guiding in MP3 format for media phones. The media files will be sent or streamed to the mobile phones by GPRS or other suited data carrier. Furthermore it is Infotain's wish that the service should be very simple to use. This implies that it should be possible for the user to stand in front of a sight and get the correct media without having to manually connect the phone to an internet service and then choose the right media file. The different technologies require different behavior from the user. Because of this it might be necessary that the user e.g. points towards an electronic sender with their phone, takes a photo or has to go through some menus. The reason for requiring that the use is simple originates from the fact that the service is supposed to be offered users from all age groups and with varying experience in general use of technical devices. Because of this it is desirable but not a demand that most of the functions are automatic and doesn't require much from the user.

To achieve a high degree of automation there is a need for some type of positioning of the phone. Then it is necessary that a system starts download of media and playback with little need for user handling. Automatic download and playback can be easy to achieve with some technologies but for others that might be a challenge. Positioning the phone in its surroundings is also a challenge, and this problem is the main attention of this thesis. The problem that emerges when considering the different technologies is that they have quite different abilities and areas of application. The areas of application for MP3 guiding vary greatly. A sight can more or less be at any location e.g. it might be on a location without infrastructure like electricity. It is also possible that the sight is indoors where well known positioning technologies like GPS do not work.

There are some ways of determining the position of a mobile phone. The most relevant technologies are GPS and GSM positioning. In addition there are a many of technologies that primarily are used for data communication, but it is also possible to use them for determining the position of a mobile phone. The most relevant of these technologies are WLAN and Bluetooth. There are also some technologies that are made for identifying units in department stores and other shops. These technologies can be used to prove the presence of a mobile phone. The most relevant technology for this use is RFID.

1.2 Problem Description

Position technologies for internet connected mobile terminals, offering location based audio services.

Infotain AS offer products and services that allow cities and attractions to have audio guiding services for their visitors. The audio guiding is currently offered through rental of portable devices preloaded with audio guiding, downloading to the visitors MP3-player and as a phone service offered to the visitor's cell phone.

The audio guiding is a new service and several companies are now starting up and are producing content of good quality. The next step as we see it is to use location based services on the customer's private mobile terminal. As a mobile terminal, the mobile phone is the most likely device, but also MP3-players, navigation units and PDA's are possible terminals.

Infotain shall be in front and it is very important for us to understand and test the new technologies and to understand when it is suitable to offer audio guiding services on these terminals.

To have an efficient distribution of the content, the mobile terminal should be internet connected and have a good position capability. The mobile terminal should also be very easy to use, both in starting up the service and using it for an audio guided tour.

- What positioning technology is most suitable for offering location based audio services on internet connected mobile terminals?

Key issues for this thesis are:

1. Which technologies can be used for positioning a mobile terminal?

2. Evaluate the technologies and recommend the most suited for location based audio services.

3. Perform a field test or a simulation, if time allows, based on the proposed technical solution.

The thesis shall consider technologies made for positioning purposes and also technologies made for other purposes which can be used for positioning. Technologies that are present in mobile terminals today shall be the main focus. The technologies that are not found in mobile terminals but may be available through external devices shall also be considered if time allows it.

1.3 Delimitations

The terms "mobile terminal" and "mobile phone" includes all GSM and UMTS enabled handheld devices. This excludes portable and ultra portable computers, PDAs with plug in GSM/UMTS interface and all GSM/UMTS equipped devices to large to fit in a normal pocket or in a hand.

Also, devices designed for the Norwegian CDMA 450 network are not considered.

The term "Internet connected" is used on devices equipped with GPRS/EDGE, UMTS and/or WLAN. Other types of internet connections are not considered.

1.4 Use Cases and Site Characteristics

Likely places where location based audio services could be used can be divided into two main categories, indoor sites and outdoor sites.

1.4.1 Case: User at Indoor Site

A user visits a museum that has location based audio services available. At the information desk the user reads the information on the audio services. He gets the option to download the necessary mobile phone software through a data cable, via Bluetooth or from a WAP site over GPRS. The software is downloaded and installed with little effort from the user.

The user walks up to the first display and after less than 10 seconds he receives a notification on his mobile phone that tells him that audio information about this display is available. The user is prompted to press a button on the phone to download the audio file. When the file is downloaded the audio is played back on the phone.

The user walks towards the next display and as he gets within five meters of it a new notification on audio information pops up on he's phone. The offer on audio information from the previous display is no longer available as the distance to it is more than five meters.

1.4.2 Case: User at Outdoor Site

A user arrives at the historic part of the town he is visiting. He reads a sign that says that location based audio information is available at interesting locations throughout the town. To use the service the user must download the necessary mobile phone software. This software is available from the service's WAP site. It is required that the user's mobile phone is correctly set up for GPRS and WAP service. The software is downloaded and installed with little effort by the user.

As the user walks up to the first site where there is audio information available he receives within 10 seconds a notification on he's mobile phone offering him to download the audio information. He is prompted to press a button on the phone to proceed. When the file is finished downloading the audio is played back on the phone.

The user walks towards the next site where there is audio information available and as he gets within five meters of it a new notification on audio information pops up on his phone. The offer on audio information from the previous site is no longer available as the distance to it is more than five meters.

1.4.3 Indoor Site Characteristics

An indoor site is situated inside a museum building. Some of the displays have natural lighting shining at them through the windows and some of the displays have only artificial lighting. The artificial lighting varies in intensity from one display to the other ranging from very bright to very dimmed.

At each display there is electricity available either from a wall outlet by the display or through an extension cord. With limited financial recourses the museum cannot afford having electricians install new outlets.

The museum changes its displays regularly. The museum cannot afford to have specialists install and adjust infrastructure devices for the audio service every time a display is changed or when new displays are set up.

The museum building consists of both concrete walls and wooden walls. Some of the displays are made from large pieces of metal and glass; others are made from wood and other light materials. In some parts of the building good radio reception is difficult to achieve; in other parts the reception is excellent.

1.4.4 Outdoor Site Characteristics

An outdoor site covers a small town with several historic buildings. Location based audio information is available at each historic building. At some buildings there are outdoor electric lights that come on after sunset. At other buildings there are no electric outdoor lights.

Some of the buildings have electric installations on the outside while others do not. No buildings have electric outlets on their walls.

The museum making the location based audio available makes some changes to the tour from time to time. They cannot afford to have specialists install and adjust infrastructure devices for the audio service when changes are made.

The site covers a small town with some tall buildings and some narrow streets. The buildings are made from concrete and wood.

2 Evaluation of Technologies

2.1 Positioning Technologies

2.1.1 GPS

2.1.1.1 Description/Overview

The GPS system was made in the U.S. and was originally meant to be a guidance system for the U.S. Military and its allied. In the late nineties the system was made partly available to the public and now civilian GPS positioning is freely available to anyone who owns a GPS receiver. The GPS system consists of 24 satellites that orbit the earth. These satellites are controlled and maintained by the U.S. Air Force through base stations around the world. The base stations tracks the GPS satellites, uploads updated navigational data, updates the satellite clocks, and maintains health and status of the satellite constellation.

GPS positioning system uses the signals received from the satellites to calculate a 3 dimensional position, velocity, and time. The use of GPS signals is becoming more and more common in everyday situations. For instance there are many different devices the users mount in their car which contains map software that will show them their position on a map, and most software have the ability to guide the user to a chosen destination. The same systems exists in naval units, aviation, and hand held devices.

2.1.1.2 Accuracy

The GPS receiver calculates its position based on the information it gets from the satellites. To calculate the position the receiver requires the satellite time, the satellite position and the delay from satellite to receiver. By using this information the receiver is able to calculate the position with 3 meters accuracy. This is the best case scenario, but as with most things this is not the usual case. There are several error sources that can affect the position calculation for instance satellite clock errors can generate a 2 meter error in all directions. Normally a civilian GPS receiver will generate a position with accuracy between 3 and 15 meters.

Military GPS receivers also use an encrypted signal to determine its location. This signal makes it possible to measure the delay between satellite and receiver much faster and thereby increasing the accuracy. By using this signal in the best case scenario the error drops from 3 meter to about 30 centimeters. (1)

The United States is currently working on a modernization of the civilian GPS system which is scheduled to launch 2008. The new version will include three signals which will improve the existing service. By upgrading the GPS system the accuracy will increase dramatically as illustrated by the figure below.

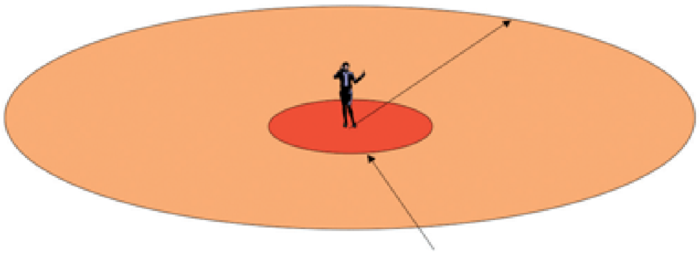

Figure 1 – Stand-Alone GPS Notional Horizontal Performance with New Signals. (1)

2.1.1.3 Positioning time

A GPS receiver is dependent on receiving signals from satellites to give a position. When a receiver is turned on for the first time receiving the needed signals and estimating a position can take several minutes. This is called the acquisition time. Popular handheld GPS devices such as Garmin GPS 60 and Garmin GPSMAP 60 have according to their user manuals acquisition times of up to 2 minutes. This is the worst case scenario where a new device has no previous knowledge of its position. When the device is turned on the next time, it uses stored positioning data to try to estimate its position faster. The above mentioned devices have acquisition times ranging from 15 to 45 seconds depending on if they have been turned off or if they have been idle.

2.1.1.4 Possible Solution

To use GPS as the positioning system in Location Based Audio Services a piece of software for the user's mobile phone would have to be developed. This software would display a user interface that would have some choices like turn on and off the GPS tracking and the possibility to play the downloaded files. The software behind the user interface would contain a database with the different GPS locations for the different sights. If the information about the different locations changes the software would try to automatically update the database. By using this database of locations the software can compare the terminal's location and the locations in the database to determine whether the visitor is within range of a sight or not. When the user gets within range of a sight the software prompts the user asking if he would like to download the audio associated with his location. When the download is accepted the software starts downloading the audio file from a centralized server to the terminal. When the download is complete the user will be asked if he want to play the file or not.

2.1.1.5 Pros and Cons

GPS delivers a satisfactory way of determining locations by the use of satellites. After the terminal has been connected to the satellites it is possible to get real-time position calculations. The fact that it is real-time makes it easy to build a high response application, which will request download as soon as the user steps within the range that has been predefined. This eliminates the need for unnecessary waiting before the download. This technology however is limited to outdoor use only because it only works when the terminal have line of sight to at least 3 satellites. The fact that it is only possible to use this technology in areas where you have a line of sight to several satellites reduces its usability for this task drastically. This is because many of the sights may be located within cities and often indoors. Another point worth mentioning is that there are only a few mobile phones that are shipped with a GPS chip. The lack of mobile phones with GPS hardware makes this, for the moment, an unlikely solution to the task, but it is possible to buy GPS receivers that one can attach to the mobile phone. These receivers could be rented by the visitors from local information booths.

2.1.2 Mobile Positioning

GSM positioning is a technology that by using parameters that is in use in the mobile network can give the position of a mobile terminal. The technology is based on two different techniques. First the network cell in which the mobile is located is given by the unique cell ID number. This number is unique on a global basis so that every cell in every GSM network in the world can be identified uniquely. If the cell is small and the base station antenna is directive this can give a positioning that may be accurate enough for some purposes. Secondly it is possible to say how far away from the base station of that cell the mobile is positioned. This is done by using the timing advance parameter.

When radio waves are propagated through the air, their speed is close to the speed of light. Although this speed is very high, it means that as with light, radio waves take some time traveling from point A to point B. The GSM systems maximum cell size is 35 km. A signal transmitted from a mobile at the edge of the cell to the base station 35 km away, will spend more time traveling than a signal transmitted from a mobile to the base station when the mobile is sitting right next to it.

The GSM system is a synchronized system. Every mobile has their own time slot assigned to it and it is important that the signal they transmit is received by the base station within this timeslot. A mobile close to the base station have no problem with that. When the mobile is synchronized with the base station, its transmission will be received almost immediately and make its time slot without any problem. When a mobile is far away from the base station the transmission must start earlier in order to arrive at the base station within the time slot. This short time differential is called timing advance.

The timing advance parameter says how long time the signal uses from the mobile to the base station and from this the distance the signal has traveled can be derived. This technique cannot give us the position of a mobile. It can only tell us the mobile's distance from the base station, if there is clear line of sight. If there are obstacles between the mobile and the base station that reflects the signal in such a way that the distance it travels is longer, the positioning will not be very accurate.

When a valid measurement of the distance between the mobile and the base station is captured, it is important to interpret it correctly. Because of the high speed at which radio signals travel, the distance measurement will have a significant degree of inaccuracy to it. Also the shape of the coverage area of the base station is important. If the base station transmits with equal power in all directions, and if there are no obstacles in the way, the coverage area will have the shape of a circular disk. This translates into an area in which the mobile is located which has the shape of a wide circle. However in most real situations the base stations have directive antennas that narrow the coverage area. As long as there are no obstacles in the way, the position of the mobile is narrowed into an area with the shape of a part of that circle.

Telenor offers access to GSM positioning data in their mobile network. The accuracy of a position in Telenor's GSM network is described as follows:

"The accuracy of GSM positioning varies in different areas depending among other things on the distance between antennas. A general assumption is that 90% of the mobile phones can be located within 500 meters inside of a city and that 90% of the mobile phones can be located within 10 km in rural areas. The GSM positioning always gives an outer limit of the area in which the mobile phone is." (2)

Also it is stated that “90% of the measurements in Oslo’s Ring 1 were inside of 330 meter and 50% inside of 120 meter.” (2) This means that absolute best possible accuracy of GSM positioning in Telenor’s network is, with 10 % error, 330 meters.

UMTS positioning is similar to GSM positioning. However, according to the specifications there has been made some effort to improve the accuracy of the UMTS positioning compared to GSM positioning. The most important difference is that mobiles in UMTS can be connected to more than one base station at one time. This makes it possible to give more accurate positioning.

In GSM a position is given as a distance from one specific base station. With UMTS the possibility of connecting to more than one base station makes it possible to give the position of a mobile phone as area of the overlapping parts of the positioning areas of two or more base stations. This may increase the accuracy of the UMTS positioning compared to GSM positioning, depending on the shape of the coverage areas, the shape of the landscape and the types of buildings in the coverage area.

Telenor uses both data from GSM base stations and from UMTS base stations to determine the position of a mobile terminal. They have although not implemented the type of multi base station positioning that is possible according to UMTS specifications. The UMTS based positioning data in Telenor's network is based only on cell ID. This will position a mobile within the coverage area of one cell, which for Telenor's UMTS network is approximately the same area as a GSM 1800 MHz cell. The reason that Telenor has not implemented such multi base station positioning is that this technology is not yet implemented in the equipment available from their suppliers. (3)

2.1.2.1 Using GSM/UMTS Positioning

Telenor is the owner of a mobile network where it is possible to give a rough estimate to the position of a mobile terminal. They do however not offer this possibility as a service to their mobile phone customers. Telenor only offers raw data for positioning to third party suppliers who in turn sells positioning services to companies, police and rescue services and to the public. Some restrictions connected to privacy issues dictate who has access to which data. As a basis all mobile users has the right to reserve themselves from being positioned. This right is enforced by restrictions in what data is being made available to companies who offer positioning services to the public. Some services however have access to positioning data of all mobile users, regardless of reservations. Such services are among others police and rescue services.

2.1.2.2 Proposed solution

Positioning data from Telenor's network can be delivered through Internet, VPN or frame relay. A system for location based audio services based on this type of positioning would have to have a centralized structure. A server would have to send requests for positioning data regularly to keep track of the mobile phones. This would require an initial registration of the phones whose owners would want to use the service. The tracking server would compare the positions received from the mobile network to a list of positions describing the locations of sites where audio were available. When the tracking server would get a match a message would be sent to the mobile present at the site. The message would contain a link to the audio file, giving the user the choice of downloading or not.

One problem with GSM/UMTS positioning is the low accuracy. In some areas the accuracy of 330 meters could be satisfactory but in most cases it would not. Another problem is the cost. Continuous tracking of a mobile phone would not come cheap as each position request costs from NOK 0.20 to 0.50 (2). A person in motion passing a point of interest would have to be instantly positioned. This would require very frequent positioning requests.

2.1.3 A-GPS

2.1.3.1 Overview

Assisted GPS (A-GPS) is a GPS technology that is used on receivers that has limited processing power, or when the receiver is located in a location with less than ideal signal, to shorten the position calculation time. A-GPS can be used where regular GPS systems do not deliver satisfactory results like urban areas, under heavy tree coverage or even indoors. This technology was developed mainly because of the E911 service in America where they require that the position of a cell phone is available to the emergency call dispatchers.

The difference between A-GPS and GPS is that a new “processing force” have been added, the Assistance Server. The assistance servers have high processing power, and access to reference networks. When calculating a position with A-GPS the receiver communicates with the assistance server via the mobile phone network and shares the workload with it. The assistance server can be operated by the mobile network owner, making A-GPS available to all their customers or it can be operated by a 3rd party company which buys GSM/UMTS positioning data from the mobile network owner.

A-GPS can be seen as an improvement both of the GPS system and of mobile positioning based on positioning data from the mobile networks. This is because A-GPS utilizes positioning data from both systems to give a more rapid and more accurate positioning.

The availability of A-GPS is higher in the USA than in Europe. This is because of requirements to mobile phone manufacturers that all phones sold in the USA shall be accurately locatable by the rescue services when a 911 emergency call is made. As GPS often does not work indoors and mobile positioning has very poor accuracy, A-GPS is necessary to make all mobile phones accurately locatable. In Europe the accuracy requirements of the location made available to the rescue services in an emergency situation is much lower. This makes it possible to solely rely on mobile positioning through the GSM/UMTS network for positioning the phones. The number of handsets available in Europe with GPS receivers built in is still low and the number of location based services offered to the public is also low. These types of services are mostly related to safety and security products for people and expensive property, such as personal portable emergency alarms and tracking devices for cars. Neither Telenor nor Netcom offer any A-GPS services or raw data today (2) (4) and according to Telenor the demand for these services is very low. Companies offering services and products as mentioned earlier rely on combinations of proven technology such as GPS, GSM/UMTS positioning and proprietary radio tracking. For rough positioning GSM/UMTS positioning is used. For pin point location radio tracking by a proprietary portable search device may be used. Also some use GPS only and some products support both GPS and GSM/UMTS positioning, making it possible to choose the positioning technology that works best in each situation. (5) (6) None of the leading companies offering these products and services in Norway uses A-GPS.

2.1.4 RFID

RFID tags can be divided into three main groups, active, semi active and passive. The active tags have a power source, usually a battery, which powers its radio transmitter, memory circuits and processor. Semi active tags rely on a battery to power their memory circuits and processor. The communication is powered by an electromagnetic field emitted by the reader. This technique is called backscattering. Passive tags do not have a battery, but rely on the energy generated from the reader's electromagnetic field to power their memory circuits and their communication.

2.1.4.1 Active Tags

By having a battery to provide the energy, active tags can have fairly advanced functions. The radio range is limited only by the frequency and the transmission power. The normal maximum ranges of active tags are between 3 to 100 meters. Without restrictions to the transmission power however the range could be several kilometers. Active tags have both read only memory and read/write memory. When choosing a tag, the amount of memory it should have relies on how much information that has to be stored. The type of memory depends on when information is going to be stored. Also if the tag is going to have advanced processing capabilities this dictates the size and type of memory. If the tag is only going to transmit a single ID number, very little read/write memory is necessary. The ID memory can be hard coded into the chip by the manufacturer, in which case it is stored in read only memory. If the ID is chosen and written to the chip by the customer, it can be stored in read many/write once memory or in read/write memory. If a customer wants the tag to be able to store data transmitted by a reader when in use, or if it is going to do advanced processing, it needs greater memory capacity.

Active tags does not need to be in the presence of a reader to transmit information, due to their built in power supply. They can be programmed to broadcast information regularly with a given interval so that readers will instantaneously be able to read them and readers far away will be able to read them. However, in order to save precious battery power active tags may be set to only broadcast when the signal from a reader is received.

2.1.4.2 Passive Tags

Passive tags draw their energy from the electromagnetic field emitted by the reader. By changing the load of the antenna the tag is able to radiate information which is transmitted back to the reader. The tag also powers its processor, memory and control circuits from the electromagnetic field radiated from the reader. This is done by induction. When the field hits the antenna on the tag, electricity is induced in the antenna. Not having a battery, these tags have very limited energy resources. This affects their reading range, their processing capabilities and their memory capacity. The maximum reading range of passive tags ranges from 0 to 30 meters. The tags have very little energy to spend on processing so these capabilities are limited. Also the memory is fairly small, but capable of storing the chip ID, the ID of the item it is identifying and possibly some additional information such as an inventory list. Due to the lack of battery the lifetime of these tags is much higher than on active and semi-passive tags. It is limited only by the durability of the tag itself.

2.1.4.3 Semi-passive Tags

These tags are equipped with a battery for powering their processor, memory and control circuits. The energy for powering the communication is harvested from the electromagnetic field of the reader. This makes the tag more energy conserving and the need for changing the battery or replacing the tag is less frequent. Semi-passive tags have the same limitations as passive tags when it comes to the communication. The range is limited and the tags can only communicate when in range of a reader. However the range can be improved by having a battery powering the internal parts. These tags are not able to communicate with other tags.

2.1.4.4 Tags Shapes

RFID tags come in different size and shapes. Active tags are generally larger than passive tags due to the need for a battery. Passive tags can be made very small. The size is dictated by the size of the antenna. Passive tags harvest their energy through their antenna and the amount of energy harvested is dependent on the size of the antenna and the strength of the electromagnetic field radiated from the reader. If the reader is very close to the tag, the antenna does not need to be very big. An example of a very small tag is the type that is used for injection in to pets. These tags are sealed in a glass casing. The small size is made possible because the reading distance between the tag and the reader is very short.

2.1.4.5 Frequencies

RFID systems operate at several different frequency bands. The different frequencies give the systems different capabilities with regards to range, power consumption, size, tolerance to weather conditions and data rates.

The main frequency bands are:

Low frequency, LF,	120-140 kHz
High frequency, HF,	13.56 MHz

Ultra high frequency, UHF, 860-960 MHz

Super High Frequency/Microwave 2.45 GHz and above

Low frequency band is mainly used by passive tags. The low frequency radio signals can penetrate dense materials such as aluminum and water and be detected by the reader even at the low signaling powers these tags can produce. The low frequency results in low data rates. The cost of these tags is higher than on other tags because of the longer copper antenna needed at low frequencies.

High frequency band requires a smaller antenna than LF band and therefore the prices on HF tags are lower. Signals in the high frequency band can penetrate water, wood, aluminum and other dense materials. The data rates are higher than for LF tags. Passive HF tags have a read range of up to one meter.

UHF tags operate at the lower end of the microwave spectrum, around the same frequency as some mobile phone systems. At these frequencies radio waves are very sensitive to obstacles in the radio path. This means that UHF tags does not work as well as LF tags and HF tags around water and metal. Range wise passive UHF tags are suitable for distances from one meter to ten meters. Active UHF tags can have read ranges of hundreds of meters. The data rates of UHF tags are very high. The cost of UHF tags is relatively low.

Super High Frequency systems, also known as microwave systems operate at 2.4 GHz and above. Important characteristics of tags operating at these frequencies are very high data rates and poor performance around obstacles made from water, metal or other dense materials. The read range of passive UHF tags varies from 30 centimeters to one meter.

2.1.5 NFC

Near Field Communication (NFC) is a technology based on RFID and the ISO-14443 standard, using the globally available 13.56 MHz frequency. NFC is basically RFID adapted for use with mobile terminals to allow them to interconnect with other NFC enabled objects in their soundings. The technology supports data rates of 106 Kbit/s, 212 Kbit/s and 424 Kbit/s (7). The main difference between NFC and RFID is that NFC is designed to only work at a distance of up to around five centimeters of range. This gives the communication an inherent protection against eavesdropping and allows for applications such as electronic key for opening doors and payment by using the phone as an electronic wallet. The short range also gives the user full control over the operation of the short range connections. This means that when a user puts the terminal close to an NFC device to initiate communication, one can always be certain that it is the intended device that responds to the signals and not another similar device close by.

NFC Interface and Protocol is standardized in ISO/IEC 18092:2004 and ECMA-340. The range of passive NFC systems is limited by the transmission power of the reader device as the power is used to induce a response signal from the tag. The standard states that the field radiated from the reader shall be between 1.5 A/m rms and 7.5 A/m rms. This gives a reading range from 0 cm to around 5 cm, depending on the level of radio noise and the type of surface on which the tag is mounted. The type of surface will influence the amount of electric energy induced in the tag by the radiated field. This will in turn influence the power radiated from the tag. The standard states that collision avoidance scheme with carrier detection shall be used to avoid two devices within range of eachother transmitting simultaneously. As the low power signals from passive tags are vulnerable to radio noise the standard states methods to ensure that data is received without errors. NFC uses Manchester bit encoding. At the end of each transmitted frame cyclic redundancy check is used to check for transmission errors.

NFC is seen by some as the key to making the mobile terminal the main device for humans to communicate with and control their surroundings. By using NFC it is possible to initiate a Bluetooth or WLAN session between two NFC enabled devices just by making one of the devices touch the other. Information on how to set up the session is then in an instance transferred between the devices using NFC and the session is set up automatically without further user intervention. NFC seems to be the leading road ahead for RFID on mobile terminals in Europe. This means that all mobile terminals in some time may be able to communicate with their surroundings using the same standard. At the moment NFC is supported by more than 100 different companies and among them the three mobile phone makers Nokia, Panasonic and Sony. Also, MasterCard and Visa support the technology. The technological architecture of NFC was released in June 2006, so it is still quite new. In this release three main modes of communication are presented. Besides the peer to peer mode, which will connect two electronic devices together and the Read/Write mode which will connect to a tag, the Card emulator mode is very interesting. This enables a device to act upon a reader as if it is a contactless smartcard. These types of cards are now becoming popular as an alternative to magnetic cards. This may explain the interest in NFC from MasterCard and VISA, as NFC may turn the mobile into an electronic wallet. (8) (9) (10)

2.1.5.1 Equipment

Nokia has produced two RFID readers for their mobile phones. The first is a clip on cover containing a reader for the 3220 model. The second is a cover with a built in RFID reader made to fit the Nokia model 5140. The first reader was launched in the summer of 2004. The second was released in 2006. The RFID covers are available as separate items and as a part of an RFID kit containing clip on cover reader and RFID tags operating at 13.56 MHz. Also included in the kit is software necessary to exploit the capabilities of the equipment. The kit is compliant with the ISO-14443A standard.

In January 2007 Nokia announced an NFC enabled phone, based on the 6131 clam shell model. The 6131 NFC will according to Nokia be available in the first quarter of 2007. Unlike the two previously mentioned models, it has NFC built into it and is therefore expected to have more matured NFC capabilities. In February of 2007 at 3GSM Samsung presented 200 specially made SGH-X700 phones with NFC capabilities. (11)

2.1.5.2 Possible Solution

One solution for using NFC for location based audio services would be this:
A sight is equipped with a sign saying that there is audio information about this sight available for users with NFC equipped mobile terminals. A user with such a terminal would make the terminal touch the NFC tag on the sign. The mobile terminal would connect to the NFC tag and a URL would be transferred from the tag to the terminal. This pointer would be interpreted by either the phones

NFC software or dedicated software for the audio service. The information in the pointer would give the specific path to the audio file telling about the site and on which server it would be found. Thereby the software on the terminal could start downloading the file after a confirmation is given by the user.

2.1.6 WLAN

2.1.6.1 General

WLAN is short for Wireless LAN and is commonly synonymous to the wireless Ethernet standards 802.11b and 802.11g. These are also known under the brand name Wi-Fi. 802.11b has a theoretical throughput of 11 Mbit/s and 802.11g has a theoretical throughput of 54 Mbit/s. Both operate in the unlicensed 2.4 GHz band and .11g is backwards compatible with .11b. The 2.4 GHz band is also used by other technologies such as DECT wireless telephones and baby monitors. This means that the level of radio noise can be very high. This can lead to short range and lower throughput.

2.1.6.2 Operation

A WLAN access point (AP) is normally set to broadcast its SSID, which is the name of the network. If the network has more than one AP, they all share the same SSID to make their network relation recognizable to the users. The SSID is chosen by the network administrator and it is possible, if a high level of security is needed, to choose not to broadcast the SSID. Then the users would have to know the SSID to connect to the network. Each AP uses one of 13 possible channels for communicating with devices. This allows for several APs to have overlapping coverage areas without interfering with each other. The maximum number of devices connected to an AP is not fixed but depends on the radio noise level and the quality of the AP. Under good conditions this number is very high.

2.1.6.3 Connection Setup Time

The connection setup time is the time it takes from a mobile device enters the coverage area of the AP till it has received an IP address from the DHCP server. It is critical that this time is as short as possible. If the connection setup time is to long the user may run out of patience and walk away. Typically the connection setup time for an 802.11b/g enabled device is a few seconds but this may vary with the quality of the connection and the implementation of the DHCP service.

2.1.6.4 Range

The radio range of a typical AP with a standard antenna is up to 100 meters with line of sight and low noise level. Anything blocking the line of sight will absorb some of the radio energy and partially reflect the signal in another direction, resulting in reduced range. Typical range is far less than 100 meters. If a small coverage area is desired it is possible to reduce the width and the length of the coverage area. This can be done both by reducing the radiated power and by using directional antennas to shape the coverage area.

2.1.6.5 WLAN in Mobile Phones

Mobile phones with built in WLAN adapters have been available for some time but there are not too many available on the market. Those that are available are primarily designed for the professional market segment, and packed with functionality. This results in relatively high prices. As prices on WLAN technology falls it is likely that it will be available in models targeted at the mass market. A problem with the WLAN circuits in phones has been high power consumption.

2.1.6.6 Positioning With WLAN

802.11b/g is not designed to have any type of positioning capabilities. It is however possible to use it for this purpose. The simplest type of positioning with 802.11b/g is to register the presence of a device within the coverage area of an AP with a well known position. This gives the position of the device to within the range of the AP. The range of the AP varies with varying noise level and therefore this type of positioning has great uncertainty built into it. If this type of positioning is used in a building, one cannot always know in which room the device is located due to the ability of the radio waves to penetrate the walls.

2.1.6.7 Positioning in WLAN Networks

Other more advanced techniques can be used to improve the accuracy of the positioning. To get a more accurate positioning several additional methods which require a network of APs as described in Indoor Location White Paper by Dr. Zeev Weissman can be used.

Triangulation uses signal levels from more than one AP and through a triangulation algorithm the position of the mobile device is found. Running the algorithm requires some processing in the network. Indoor triangulation is difficult because of multipath signals due to reflections.

Time of Arrival (ToA) measures the elapsed time from a signal is transmitted to a device and till a response is received. By using more than one AP, a more accurate positioning is possible trough triangulation. This method requires special hardware and antennas. This is a very accurate method as multipath effects can be filtered out.

The Angle of Arrival (AoA) measures the difference in power density of the received signal to a special antenna pair. A vector giving the direction of the highest signaling density is then calculated. Using vectors from more than one antenna pair, an accurate position can be calculated. This method requires multi-section, highly directional antennas. (12)

2.1.6.8 Base Stations

Base stations for 802.11b/g are widely available and they have very different capabilities. Some are just plain access points, others have a built in router and some also a firewall. They all come with proprietary software, however some enthusiasts have made some models run Linux. This opens up the possibility to run customized programs on the built in CPU instead of on a connected computing unit. This could be useful if simple services are to be offered to devices that connect.

An alternative to using a modified AP is to use a WLAN enabled mobile phone as an AP. These have the necessary 802.11b/g interface and also have a very capable processor and a battery. The built in processor is a convenient platform for running custom services that are available to devices that connect.

2.1.6.9 Base Station Power Consumption

The power consumption of a popular wireless router, Linksys WRT54G, is 5 watt. Continuous operation over 24 hours consumes 120 watt hours. 30 days of operation ads up to 3600 watt hours or 3.6kWh. A 12 volt 600 Ah lead acid battery drained to 50 % of its capacity would be sufficient to supply this amount of energy. A battery of this size weighs around 150 kg. (13)

Using a WLAN enabled phone as a base station is a more energy efficient approach. The WLAN enabled Nokia model 6136 is said by Nokia to have up to 5.5 hours of talk time (14) using UMA over WLAN. The phone has a 3.7 volt 820 mAh battery which holds 3.034 watt hours of energy. This results in a power consumption of 0.55 watt. Over 24 hours the amount of consumed energy is 13.2 watt hours. Over 30 days this adds up to 397 watt hours or 0.4 kWh of energy. A 12 volt 70 Ah lead accumulator drained to 50 % of its capacity would be able to supply this amount of energy. A battery of this size weighs around 20 kg. (13)

2.1.6.10 Possible Solutions

One possible setup would include an 802.11b/g router capable of running Linux and an internet connected media server. The server would have to run customized software that manages communication with the phones. The phones would need to run customized software that manages the network connection setup and the communication. The media files would be managed remotely by the service supplier over the internet.

As the user enters the coverage area of the router, the software on the user’s phone connects to the WLAN. Software running on the router starts communicating with the software on the phone and an offer to listen to audio information is sent from the router to the phone and presented to the user. As the user accepts the offer the software on the phone resolves the URL pointer stored in the offer sent from the router and starts downloading the correct audio file from the media server. When the file is finished downloading the customized software starts playback of the audio file.

Another possible setup would include an 802.11g router capable of running Linux and an external storage device connected to the router via Ethernet or USB. Media files on the storage device could be updated in three different ways. If the router was connected to the Internet via Ethernet or wirelessly through WLAN the files could be managed remotely. Otherwise the files would have to be updated either by manually connecting the storage device to a portable computer or by transferring them over WLAN from a computer that is within radio range of the router.

The user’s WLAN enabled phones would need to be equipped with customized software to provide the service. The router would need to run customized software that manages communication with the phones. As the user enters the coverage area of the router, the software on the user’s phone connects to the WLAN. Software running on the router starts communicating with the software on the phone and an offer to listen to audio information is sent from the router to the phone and presented to the user. When the user accepts the offer the audio file is transferred from the storage device connected to the router, to the phone. The customized software would start the audio playback.

An alternative to using an 802.11b/g router is to use an 802.11b/g enabled phone as an access point. In this scenario it would be possible to either store media files locally on a memory card or to store media on a media server. A mobile phone has a built in processor and is very capable of running customized software making it possible to offer special services in the coverage area. These solutions would be similar to the ones described above.

2.1.7 Bluetooth

2.1.7.1 Overview

Bluetooth is standardized with the IEEE standard 802.15.1.The frequency band for Bluetooth devices is located between 2,402 GHz and 2,480 GHz. This band has been assigned by the international agreement for the use of industrial, scientific and medical devices. There are a number of different devices that uses this radio band for communication, for instance garage-door openers and baby monitors. When so many devices operate within the same frequency band it is natural to believe that there will be major interference, but this is not the case with Bluetooth.

First of all the range of the Bluetooth device is somewhat limited. The range depends on the power class of the device. There are tree power classes, class 1, 2, and 3. Class 1 is the most powerful class. Its upper power limit is 100 mW which gives it a range of approximately 100 meters. Class 2 is the second most powerful class. This class has an upper power limit of 2.5 mW which gives it a range of approximately 10 meters. Class 3 is the least powerful class. Power class 3 has a maximum power limit of 1 mW which limits the range to approximately 1 meter.

The range limits the possibility for interference, but there may still be a high number of devices within range. For instance the device might be located in a home with Bluetooth enabled remote controls, baby monitor, computers and so on. This problem is solved by the use of spread-spectrum frequency hopping which reduces the chance of two devices transmitting on the same frequency at the same time by a large amount. When a device use the spread-spectrum frequency hopping technique it will randomly choose 79 individual frequencies within the Bluetooth band which it will transmit on. The Bluetooth device will change frequencies 1600 times every second. This ensures that if two or more devices transmit on the same frequency at the same time it will not result in much interference because the time spent on the same frequency will be only 1/1600 of a second.

The Bluetooth connection works similarly to an ad-hoc computer network. When two Bluetooth devices connect to each other one of the devices takes the role as “master” and the other “slave”. The master device can communicate with 7 active slaves simultaneously. This way of communicating is called a piconet. The piconet supports up to 255 inactive slave devices which can be made active by the master device at any time. When two or more devices connect to each other and form a piconet they will perform the frequency hops in unison so they can stay in touch and avoid other piconets that may be operating in the same area.

The Bluetooth specification says this about the duration of the searching and connection phase: “the inquiry substate may have to last for 10.24 seconds unless the inquirer collects enough responses and determines to abort the inquiry substate earlier” (15). In an environment without interference it might be possible to discover devices in less than 10 seconds, but this is rarely the case, most of the time it will take longer than 10.24 seconds to discover a device. Based on the situation, and the user, the perception of whether the connection time is too long or satisfactory will differ.

2.1.7.2 Access Point

A Bluetooth access point can either be an off the shelf access point with Ethernet connection or it can be a Bluetooth enabled computer or mobile phone.

Bluetooth access points are available off the shelf and offer network connectivity via Bluetooth. An example of such a device is the Belkin F8T030. These devices do not have advanced processing capabilities and they do not run customized programs. They do however have easily manageable Bluetooth configuration that allows customized setup. The network connection is provided by an Ethernet interface. In order to provide network connection where wired network is not available, the access point would have to be connected to a wireless network device or a computer with such capabilities.

An off the shelf Bluetooth access point do not have the ability to run any customized software. This means that if it is desirable to have some type of automated routines pushing information over Bluetooth on sight it would be necessary to install a computing device on sight by the access point. This could be a computer or a mobile phone with the necessary network connections.

2.1.7.3 Access Point Power Consumption

An access point would preferably draw its electricity from the electricity grid. In locations where this is not possible an alternative power source would be needed. Lead accumulators come in all shapes and sizes and meeting the power demands of the installation would only require finding the right accumulator size. The issue of weight would have to be considered when deciding on an accumulator as the installation sight would have to be built to hold the weight. Also the possibility of one person being able to replace a large accumulator depends on its weight.

A typical off the shelf Bluetooth access point may have a continuous power consumption of 5 watts (Belkin F8T030). Over 24 hours this adds up to 120 watt hours. With a recharging cycle of 30 days the accumulator would have to deliver 3.6 kWh of energy. As a lead accumulator should not be drained of more than 50 % of its energy, it should be able to store 7.2 kWh. This is equal to a 12 volt, 600 ah accumulator. Such a setup would weigh around 150 kg (13). When making these calculations the power consumption of a computing device installed together with the AP is not taken into consideration.

A Bluetooth enabled mobile phone could be used as a Bluetooth access point. Being a multi interface communication device and a processing platform all in one, a good estimate of continuous power consumption would rely on the usage of the phone's different components. The power consumption during a 3G phone call could be used as an estimate. For the 3G phone Sony Ericsson w610i the battery life during 3G calls is said to be 2 hours 30 minutes (16). The 900 mAh battery at 3.60 volts holds 3.24 watt hours. The continuous power consumption is then 1.29 watt. The consumption over 24 hours is 31.0 watt hours. Over 30 days this adds up to 933 watt hours or 0.93 kWh. A 12 volt 160 Ah lead accumulator drained to 50 % of its capacity would be sufficient to supply this amount of electricity. A battery of this size weighs around 40 kg.

2.1.7.4 Possible Solution

When using Bluetooth for location based audio services one would need to place a Bluetooth station at each site or display where audio should be available. The users would need to have special software installed on their phones and the Bluetooth interface on their mobile phones activated while they moved around in an area with Bluetooth stations. When the user walked close enough to the station the base station would try to connect to the user's phone. When the connection was complete the Bluetooth station would push a message or file to the phone containing a URL that the visitor could activate. After the URL was received the base station would disconnects from the user's mobile and the software on the user's terminal would start to download the correct file from the server. When the download was completed the user could start playback of the file.

The following example is similar to the system that was tested in the "Bluetooth and WAP Push Based Location-Aware Mobile Advertising System" (17) report. The way this is done is by registering each user in a database with information about their mobile phones Bluetooth ID and their phone number. At each site one would place a Bluetooth enabled terminal with connection to internet. When the user gets close to the base station it will register the ID of the user's phone and send it and the location of the terminal to the server which contains the information about the different users. The server will check the database and send a push message to the registered phone number containing the URL to the correct file for that location. When the user receives the push message he can activate the URL and download the file. When it is done downloading the user can start playback.

It is also possible to solve this by placing some kind of Bluetooth device at each site that contains the correct audio file for that location. For instance one could use a cell phone which has the file saved on its memory card. This solution would require the cell phone to run a program continuously that would monitor the devices that moved in and out of range. When a device gets within range of the cell phone the software would automatically send a transfer request to the new device. If the user that received this request accepts is the audio file for that location would be sent directly to the user through Bluetooth. When the download was completed the user could start the playback of the file.

2.1.8 2D Barcodes

2.1.8.1 General

The term barcode refer to the one dimensional type of codes found on all types of merchandise in any store. Recently however, new types of codes have emerged that look differently from the series of vertical lines we usually think of as a barcode. These new types are called two dimensional (2D) barcodes or matrix codes. The main reason for using a 2D barcode instead of a traditional one dimensional barcode is the ability to store larger amounts of information. Also 2D barcodes can be made physically smaller than conventional barcodes while containing more information. Many different types of 2D barcodes exist and some are standardized by international standardization organization ISO. The common feature of all these codes is that they are read optically. One dimensional barcodes are read by a laser scanner and two-dimensional codes can also be captured by a camera and then interpreted by specialized software. All these codes are directive in nature, meaning that a reader device must be pointed at the code in order to read it. Also there must be a clear line of sight between the reader and the code. The reading ranges of these technologies are only limited by the design and quality of the reader. For two dimensional codes the reader is a camera with some type of lens. The reading distance is therefore dependent of the optical capabilities of the camera, its resolution and also the lighting conditions for the barcode. The information capacities of barcodes vary greatly depending on the type. One dimensional barcodes can hold up to 30 numbers while two dimensional barcodes can hold much more information, several thousands of characters.

The ability to record a barcode with any camera is an interesting feature. This makes any mobile terminal with a camera a potential barcode reader. The only problem is that mobiles sold in Norway and Europe does not come with software for interpreting the codes. In Japan such software has been preinstalled on mobiles for some years. The most popular code type used in Japan is a type of 2D barcode or matrix code called QR Code which is short for Quick Response Code. It was designed and made available by a Japanese corporation called Denso-Wave in the late nineties and it was standardized under the ISO standard ISO/IEC18004, Jun 2000. QR codes are very popular in Japan and make it possible for mobile users to access online information through their mobile phone just by taking a picture of the QR Code printed on for example products and commercials. In Europe and the USA however, this technology has not had a break through, possibly because of the lack of demand from consumers and businesses. The problem of no pre installed reader software on the mobiles may be solved as some companies now offer free QR Code reading software for a number of mobiles. A Suisse company called Kaywa has made a reader program for both Symbian and for phones running Java. They support more than 20 different phones from Sony Ericsson, Samsung, Nokia and Motorola. QuickMark is a reader program from the Taiwanese company SimpleAct Inc that is available for both Windows mobiles and Symbian mobiles. Some of the more than 70 compatible mobiles listed seem to be Asian models, not available in Europe but both Sony Ericsson and Nokia is represented on the list with models available on the European market.

A QR Code consists of a number of black and white squares called modules. The size of a code is measured in number of modules. Distinguishable features in every code are the position recognition patterns present in three of the code's corners. All three must be captured by the reader for the code to be read flawlessly. The readability of the QR Code depends on the size of the modules and on the capabilities of the reader. Different readers are designed for different reading scenarios and have different capabilities. If a QR Code is printed with a 6oo dpi printer, each dot of ink will measure 0.041 mm. The minimum number of dots in one module should according to Denso Wave be 4x4. This is to ensure stable reading. One module will then measure 0.17 mm. A typical QR Code built up of 30x30 modules would then measure 5 mm by 5 mm. Such a high resolution QR Code must be read by a special purpose reader and is not readable by a typical mobile phone camera. To read a QR Code with a hand held mobile phone camera the Code needs to have a relatively large module size. The actual minimum size needed relies on the resolution and the low range focusing capabilities of the camera. The resolution needed depends on the number of modules in the QR Code. It will have to be larger than the number of modules so that all the modules would be recorded separately in the picture. A typical low resolution mobile phone camera has a resolution of 640x480 pixels which would in many cases be sufficient. The low range focusing capabilities of the mobile phone camera decides the lowest distance between the camera and the QR Code at which the modules are distinguishable. When the modules are distinguishable the QR Code can be recorded if it fits inside the camera frame. Else the distance between the code and the camera needs to be increased. Another factor influencing the readability of the QR Code with a hand held mobile phone camera is movement. If the camera is not held still in front of the QR Code the image will not have the optimal quality and the code may not be read. Codes with a small module size will be more influenced by this than codes with larger modules.

2.1.8.2 QR Code Generators

There are several free QR Code generators available in the internet. Kaywa and SimpleAct have some generator software available on their websites and there are other programs out there which can do the job. Some are free to use, others are not. Both web based generators and downloadable generator programs for your computer are available.

2.1.8.3 Reliability and Durability

The durability of 2D barcode technology depends greatly on the material on which the tag is printed. Tags that are printed on paper are vulnerable to moisture and general wear. Also fading of the ink due to solar radiation may occur. Tags printed on plastic are more resistant to moisture and general wear but may also fade if exposed to sunshine. 2D barcodes may also be etched into metal surfaces. This gives the tags a much higher durability and resistance to wear caused by the environment.

The reliability of 2D barcodes depends largely on the readability of the tag. Tags may be made unreadable from many different reasons but dirt, air pollution, and graffiti may be a few obvious sources. Paper tags may be difficult to clean and may need to be replaced when made unreadable. Plastic tags may be easier to clean. Tags etched into metal may be very easy to clean and need not be replaced.

The QR Code technology have a built in error correction feature. This is implemented by adding a "Reed-Solomon Code" to the data. Reed-Solomon Code is a mathematical error correction method which is used for disk drives, CDs, telecommunication and digital broadcast protocols. The Reed-Solomon Code requires twice the amount of data to perform its correcting function. For instance, if one were to create a tag which contains 100 words, and 50 of those needs to be corrected, one would need 100 words of Reed-Solomon Code to correct the error. QR Codes features four error correction levels which the user can freely choose among to adapt the tag to the environment it is supposed to be placed in. The four different levels are named, in ascending order, Level L, M, Q and H. Level L have an error correction capability of approximately 7%, level M got approximately 15%, level Q got approximately 25% and level H got approximately 30%. The higher level of error correction the larger the tag has to be as the Reed-Solomon Code requires the double amount of data to be able to correct the errors. Because of this it is important to consider the error correction level based on the real need for corrections as the tag would need to be quite big if one wanted to have much information on the tag with high error correction level. The most used level is Level M (15% capability). Because of this error correction feature in the QR Codes the impact of damage or vandalism of the tags is reduced. It is worth noting that if the damage has removed one of the position detection patterns the tag will be unreadable.

2.1.8.4 Number of Users

Visual codes can be put into the pointing category when it comes to method of use. This means that users have to point the camera of the mobile phone at the tag in order to record it. Depending on the size of the visual code this results in some limitation to how many people there is room for in front of the tag. If the tag is small there may only be room for two or three people. There is however no limit to the size of the tag and therefore also no limit to the number of people using it, given that the space to mount it is large enough. Another option that increases the number of people able to record the tag at once is to make more than one tag and mount them on each side of the attraction.

2.1.8.5 Advantage, Cost

The great advantage of visual codes is that they have a low production cost. Depending on the material on which they are printed or etched the cost will vary. The simplest way of making a tag is to print it on paper. This will give some incredibly cheap tags and they can be made in any size and number. To give them some added durability they can be laminated.

2.1.8.6 Possible Solution with Image Interpretation Server

The main problem with using visual tags for making the mobile interact with its surroundings is that although most terminals have cameras, none of those available in Norway have software for interpreting 2D barcodes. There is however a possibility of using visual tags for location based audio services without the required software on the terminal. It is based on the idea that the image processing software could run on a server. Such a setup would consist of a visual tag containing information on which audio file is to be downloaded, a mobile terminal with a camera, a server running the image recognition and interpretation software and a server storing the audio files. The tag would be printed on a poster or a sign giving information on the service and the phone number where the image should be sent. The user would then take a photo of the tag and send it as an MMS message to the given number. The image recognition server would receive the message and interpret the image. The information interpreted from the image would point to a specific audio file on the audio storage server. A message containing a link to the audio file would be sent to the user's terminal and by activating this link, the audio file would be downloaded.

2.1.8.7 Possible Solution with QR Code Reading Software on Camera Phone

With mobile phone software for reading QR Codes and launching internet sessions available through a third party, an easier solution for location based audio services based on QR codes is possible. The system setup would consist of barcodes at the sight of interest, the user's phone with or without QR Code reading software pre installed, a software downloading service and an audio server. QR Code reading software would have to be installed on the user's phone before using the service. This could be done by the capable users themselves or there could be some assistance given when signing up for the service. An online software installation could be the easiest way of installing the software although it would also possible to install from a computer via USB, Bluetooth or Infra Red. At the sight of interest a sign with information on how to use the service and barcodes printed on it would be mounted. The user would take a picture of the barcode and run the QR Code software. The internet link encoded in the barcode would be interpreted and the audio file pointed to by the link would be downloaded from the audio server over GPRS.

2.1.9 Technologies Comparison Chart

	Accuracy	Infrastructure needs	Infrastructure cost	Terminal software	Electricity independent	Positioning time	Change/adding of locations
Requirements	Better than 5 m	Existing or not needed is desired	Less than NOK 200 per site/display/AP	Existing or not needed is desired	Electricity/large battery dependence is not desired	Less than 10 s. Feedback from phone in less than 5 s.	Setup/removal of sites without skilled professionals.
GPS	Minimum 3m	Already existing	No cost	Yes, needs to be programmed	Yes, no need for new base stations.	Zero s. when on. Typically 15 s. to 45 s. from startup. Add software processing time.	No problem
A-GPS	Minimum 3m	Not existent	Not available	Yes, needs to be programmed	Yes, no need for new base stations	0.5-10 seconds	No problem
GSA/UMTS Positioning	Minimum 330m	Already existing	No cost Monthly fee plus a fee per update	Yes, needs to be programmed	Yes, no need for new base stations	Better than GPS	No problem
RFID/NFC	0 to 5 cm	Tag and a sign.	One dollar per tag + price of sign.	Is included with new NFC capable mobile phone	Yes, passive tags do not need electricity	7 seconds	Need a new location to place a tag
WLAN	0 to 100m	Must be built	> $100 per site/display	Yes, needs to be programmed	Partly, if base station is run on large batteries	More than 3 s.	Need electricity and need to build support for AP
Bluetooth	0 to 10m	Must be built	> $100 per site/display	Depends on the solution	Partly, if base station is run on large batteries	About 10,24s	Need electricity and need to build support for a Bluetooth device
2D Barcodes	Depends on the phone	Tag and a sign.	Printing cost. From NOK 1,- + price of sign	Yes, available for free on the internet	Yes, tags do not need electricity	Depends on the program, around 7 seconds	Need a location to place the barcode

Table 1 Technology Comparison Chart

2.2 Technology Discussion

2.2.1 GPS

GPS delivers a satisfactory way of determining locations by the use of satellites. After the terminal has been connected to the satellites it is possible to get real-time position calculations. The fact that it is real-time makes it easy to build a high response application, which will request download as soon as the user steps within the range that has been predefined. This eliminates the need for unnecessary waiting before the download. This technology however is limited to outdoor use only because it only works when the terminal have line of sight to at least 3 satellites. The fact that it is only possible to use this technology in areas where you have good visibility reduces its Potential for use with this task drastically as many of the sights will be located within cities and often indoors. Another point worth mentioning is that there are only a few mobile phones that are shipped with a GPS chip. The lack of phones with GPS hardware makes this, for the moment, a nearly impossible solution to the task. There is however some distributors who offer GPS receivers that one can attach to the phone. These receivers could be rented by the visitors from local information booths. Because of the inability to operate indoors the GPS as a standalone system is not a potential candidate for use with this project. A-GPS offers the same accuracy when determining the location of the receiver. The process of determining location is faster than regular GPS because the receiver uses a server with more processing power which calculates the position instead of the handheld device. A-GPS is supposed to be able to calculate positions even if the receiver is located in areas with narrow streets and tall buildings that block the line of sight to the satellites and even indoors. This means that it could be a possibility to use this solution for the location based information task. On the downside this is a service which one has to buy from a service provider and one has to expect to pay a monthly fee in addition to the price of each position check. This means that using this service as an automatically solution would be really expensive for the users as the updates most likely would happen every 10 seconds. By using this service manually each time the user is close to a sight one could cut down the usage cost drastically, but then one need to consider the connection time of GPS each time the user needs to calculate a position. Based on both the fact that tracking movement by A-GPS would be very expensive and on the electricity demand it is not a likely candidate and the group will not perform any testing on this technology.

2.2.2 Mobile Positioning

A solution based on mobile positioning would be quite similar to a solution based on GPS, the mobile phone would requests positions every 10 seconds or so and determine if this position is within range of the sight. The positive thing about this solution is that most users would have access to the technology as long as they have a mobile phone. One of the problems with this solution is the cost of continuously tracking of the phone, each position request would cost from NOK 0.20 to 0.50. Also if the system is supposed to track the users they would have to give a permit to the owner of the server to know where they are located. Also the accuracy of this service is not satisfactory as only cell ID and TA is in use in the Norwegian mobile networks. In a good coverage zone the network providers can produce an accuracy of 330 meters.

GSM/UMTS positioning could have been a good solution to the problem because all that is required is that the user has a mobile phone, but using this solution would be a costly process. First of all there is a high monthly cost and a connection fee, and there is a small fee for each position request. The tracking would need to be fairly frequent in order to match the position of a person in motion to a small site before the person was moved past the spot of interest. Because of the need for continuous tracking of a mobile this solution would not come cheap as each position request costs from NOK 0.20 to 0.50. The second and most significant problem to this solution is the lack of accuracy. At its best this solution is just able to provide an accuracy of 330 meters within a good coverage zone, this could be acceptable for some large outdoor sites but at such locations the network coverage tends to be much worse and one could end up with 2km accuracy. Based on the fact that the accuracy is far too inadequate for this use and the high cost the group decided to disregard this technology in the further study and testing phase.

2.2.3 Bluetooth

By using Bluetooth it is possible to achieve a high level of automation through the three different solutions. One of the solutions involves placing a Bluetooth base station at each site. This base station would push a message containing a URL to all devices which moved within range. The URL would point to the correct file for this sight. By using this solution it is possible to achieve a high level of automation because of the software that has to be installed. It will only require the user to accept the transfer and the rest should be automated.

The second solution will have some similarities to the first solution when considering automation. The difference between the solutions is that solution two requires the users to register their mobile phone in a database and in the way the system delivers the URL. The database contains the user's phone number and unique ID of the Bluetooth device. The base station would register the Bluetooth ID of the devices which gets within range and send it to the server. If the server has a database entry with that ID it would send a WAP push to the device containing the URL pointing to the correct file. Compared to the first solution the second solution would be slower because of the extra messages that have to travel between the base station and server.

The third solution would also have a high level of automation. This solution would require some software on a base station that detects and send files to the devices which get within range. The user would just have to accept the transfer and activate the file once it was downloaded. Compared to the other solutions this one would be much faster. The reason for the higher performance is that the user would get access to the correct file directly from the base station, and the transfer would go by Bluetooth which has a higher bandwidth than regular GPRS. Due to the transferring over Bluetooth the user does not have to pay for the transfer like they would have done if the file came by GPRS. The downside of this solution is that it would require a complicated updating system for updating the files located on the different base stations.

The Bluetooth technology provides a satisfying way of deciding the user's position because of its limited range. By lowering the power output one can limit the range enough to be sure that the user is within the desired range, and most likely avoid overlap of other sites terminals. Most phones on the market today has Bluetooth installed and a way to access internet information, so by using Bluetooth one can assume that all users will be able to use the service. To make the service as easy to use as possible there might be a need for a user interface to handle the receiving of files and playback. There lies much work behind a good user interface, and it has to be adapted to the different mobile phones. The biggest problem by using Bluetooth stations for location based audio is the power requirement. For instance the sight might be at a location where there is no infrastructure. This problem might be solved if one would use a mobile phone as a base station and connect it to a solar panel. The battery will be able to sustain the mobile phone for a long time when the weather is cloudy, and the solar panel will charge the battery when it is sunny. If there is a long duration of bad weather it is possible to have backup batteries which can be swapped manually, but the need for location based information on a site that is located in the “wilderness” might not be that attractive off season. It should be possible to use a 12V lead accumulator battery to power the Bluetooth base station located outside for longer periods, but this battery would require more powerful charging than a usual mobile phone battery.

One needs to consider the time aspect of the Bluetooth connection phase too. As mentioned the time it takes for a Bluetooth device to be “found” is between 10 and possibly 90 seconds, it is not easy to set an upper limit as interference may corrupt packages and require a resend. In the scenario this thesis deals with this delay could be seen as acceptable because of the situation the user is in. When you go sightseeing you usually plan to use most of the day watching sights. This means you most likely take your time while you are at the sights and therefore you most likely do not mind waiting for the Bluetooth device connection phase. Based on the different solutions need for power and the long connection phases the Bluetooth technology is not a likely candidate and will not undergo further testing.

2.2.4 NFC

The NFC solution would require an RFID tag in close proximity to each item which has location based information. This solution would have a high level of automation as the user only need to bring their mobile phone close to the tag to retrieve the URL. This solution is one of the better ones because of the low production cost of chips and the ease of use.

NFC would have the same functionality indoors and outdoors. The technology is based on passive tags that do not require much maintenance or change of battery. The durability of the tags is dependent on the design and tag packaging decided by the manufacturer. The placing of the tags would have to require some consideration. In order to be read a mobile terminal would have to nearly touch the tag. This means that tags have to be placed at a comfortable height and at a place where people can reach them. Not all sites, such as a scenic landscape would have a natural place for mounting the tags. In such a situation very readable and descriptive signs giving the needed instructions would be needed. This may be seen as a foreign object and may not be welcome at a scenic landscape sight. Having a read range of a few centimeters each tag would only be able to serve one tourist at a time. Considering a tourist group of ten to twenty people visiting a site makes one realize that a larger number of tags could be needed. The same may also be the case if audio on different languages should be available through separate NFC tags. This may not be practical in for example a museum where the physical space around each attraction may be small. Should however this feature be implemented through a menu of choices on the users terminal, it would not be a problem at all. Based on the low production cost and low maintenance needs the NFC solution will be a part of the testing process.

2.2.5 2D Barcodes

The great advantage of barcodes is that they have a low production cost. Depending on the material on which they are printed or etched the cost will vary. The simplest way of making a tag is to print it on paper. This will give some incredibly cheap tags and they can be made in any size and number. To give them some durability they can be laminated. To make this solution work all that is needed is to have the user install some free software on the mobile phone that is able to read barcodes. There are two different programs that one can install on the phone depending on which program supports the user's mobile phone. The fact that there are two different programs that reads barcodes makes it more likely that the phone is supported.

There are a few problems that come to mind when considering 2D Barcodes as a solution. The first problem is the need for maintenance. There is not much that has to be done to make a 2D Barcode unreadable or give the wrong information, for instance if someone make a pen mark at the tag it might return an address that does not lead anywhere or just make it unreadable. This problem should not be too much of a concern if the barcode is located indoors in for instance a museum, but if the barcode is located at an outdoor sight it would be easier for the person who wanted to sabotage the barcode to do it unnoticed. There is also an issue with the actual photographing of the barcode. The distance from the tag to the camera will most likely be a crucial point in the decoding process of the information. The further away from the tag you are, the smaller the picture will get and the quality would decrease. Light conditions could play a part too depending on the type of mobile the user has. Some mobile phone cameras are equipped with automatic flash which most likely would negate the effects of bad light conditions. The angle between the barcode and the camera might play a part in the decoding too; this depends on the programs ability to decode the information in the barcode. Because of the low cost and accessibility of 2D Barcodes the group has decided to test this technology as a final candidate. Concerns about photographing the barcodes will be answered when the actual testing is being performed.

2.2.6 WLAN

A possible solution to the project would be to set up a WLAN router and an internet connected media server which would allow the files to be remotely managed. The phones would need some software that manages the connection process automatically. When the phone gets within range of an AP there will be sent a URL pointing to the correct file on the media server which, if the user accepts, will be downloaded and played. This solution would provide the users with the correct audio relatively fast as the transfer rate on WLAN is quite high. The downside of this solution is that it would be required that there was a system that would handle the updating of files on every server that was placed at each area that needed location based information. If there was no internet connection available the files would have had to be updated manually at the base stations.

Another solution would be to use a mobile phone as a base station instead of a WLAN router. This solution would be quite similar to the solution above. The difference is that one could place the audio file on the phone's memory card.

WLAN has a few advantages worth mentioning when considering it for location based information. The first positive aspect of the WLAN technology is its ability to support many users at the same time. WLAN is able to support an almost unlimited number of users which is a really useful advantage for this usage. This means that it would not be a bottleneck at each exhibit because of low service rate which could appear at other technologies. Another advantage of WLAN is the possibility to limit the coverage area of the access point. It is possible to limit the range by using a directional antenna to shape the coverage area, or one could limit the radiated power which would lower the network coverage. Another positive aspect of the WLAN technology is the fast connection process. When a device discovers an AP it only takes a few seconds for it to connect to the AP if the signals are good. There are some negative aspects of the WLAN technology that affects its usefulness to this project. One of those problems is the need for power. Based on the research done the conclusion is that to achieve continuous WLAN operation one would need a battery of considerable size. For instance, if the goal was to power a WLAN router 24 hours a day for a month, a 150 kg battery would be required. This makes it very inconvenient as each AP would need one of these batteries and they would have to be changed every month. The power consumption is pretty high on a handheld device as well which limits its usability. Another problem is the intolerance of radio interference. The WLAN radio band is located in the same area as many different devices which are commonly used in today's society, and therefore it is a possibility that some areas would have high interference. Based on this the decision is to disregard the WLAN technology because of its great need for power.

2.2.7 Key Factors

2.2.7.1 Accuracy

When considering the different technologies there are some areas that have been considered vital to this project; one of these areas is the accuracy. The technology which has the lowest accuracy is GSM/UMTS. Today this technology is limited to the coverage area of base station which can be a very large area when you travel outside cities. But even within the city limits the coverage area is too big to be of any use for the purpose of this project. According to Telenor their coverage allows for an accuracy of 330m within the core of Oslo. Compared to the other technologies considered in this project GSM/UMTS has a long way to go when it comes to accuracy. Take Bluetooth for instance. Most Bluetooth adaptors have a range of 10m, but it is possible to narrow it down to 1m by using a lower "power class". This would provide much better accuracy than what the GSM/UMTS could. Another possibility is WLAN. It is possible to shape the coverage areas by using a directional WLAN antenna, and so it would be possible to narrow down the coverage area to a limited radius which would satisfy the requirements for this project. One problem that can arise is reflection of radio signals. This could result in a connection to a device that is not in the intended coverage area. It would also be possible to use GPS to locate the users. The GPS technology which is available to the public has an accuracy of between 3 and 15 meters. The reason for the big uncertainty in accuracy is that there are many different variables that can affect the accuracy of GPS, for instance bad weather or an error in the satellite clock. On a good day this technology would provide satisfactory positioning, but because GPS signals needs "line of sight" to at least 3 satellites this technology would not work as good in the core of a city or not at all indoors. This is a problem as there are a many of sights that would require location based information indoors, for instance a piece of art inside a museum. Because of this lack of usability GPS cannot be used as a standalone solution. A better solution would be to use A-GPS. This technology is said to be able to work under bad conditions and even indoors. If this is the case it would be possible to get satisfactory positions in most situations which would give this technology an edge in the "competition". But there are still some technologies which delivers better accuracy than the previously mentioned ones, one of them is QR Codes. This technology delivers high accuracy as it requires the user to stand in front of the barcode to be able to receive anything useful from it. The maximum range depends on the size of the barcode and the optic device in the mobile phone; it can range from a few cm to a couple of meters. The accuracy of this technology is only surpassed by the NFC technology. NFC is a type of RFID technology which requires the reader to almost touch the RFID chip to get a reading. The range of this technology is from 5cm and lower; in other words you almost need to touch the tag. This means that the accuracy of this technology is by far the best of all with only 5cm tolerance.

2.2.7.2 Energy Needs

Another aspect that should be considered for this project is the off grid capability of the different technologies. What is meant by "off grid capability" is if the technology is able to function without constant power connection. GPS is one of the technologies that do not require any connection to the power grid. The GPS technology is not in need of a base station to function, it only needs to operate on the mobile device. Because of this there is no need for a constant connection to the power grid; everything depends on the power of the portable device. Because A-GPS is based on the GPS technology it has the same capability when it comes to power needs. A-GPS depends solely on the power of the portable device as well. There are more technologies that is off grid capable; RFID for instance. RFID/NFC that relies on a passive tag has no need for power. The only power needed is the power that the reader in the portable device requires to activate the tag. Mobile positioning is also one of the technologies that do not need to be connected to the power grid to work. This technology is also dependant of the power capabilities of the portable device as it only uses the mobile phone network to determine its position. Another technology that does not depend on the power grid is QR Codes. This technology uses the power of the mobile phone to run the software which decodes the QR Code tag. When it comes to technologies that needs constant power connections there are only two technologies that has been considered for this project; Bluetooth and WLAN. Depending on the solution the power consumption of Bluetooth will wary but will always require the base station to be powered through the whole period of time the service is offered. It is possible to solve the power need in two ways; you can connect the base station to the power grid or use some large batteries. Power should not be a problem for station that are placed indoors but if one is to place the base station outdoors you would have to either get a remote connection to the power grid or use batteries. If one went for the battery approach there would be a lot of work maintaining the power; one would have to change fairly large batteries at least once a week. The same problems appear when one considers the WLAN technology. This technology requires pretty large amounts of power as well.

2.2.7.3 Speed

The time it takes from a user's mobile phone enters the coverage area of the audio service covering a site to the audio is available on the phone is critical to this service. If it takes to long the user may assume that the service does not work or he may just get bored and move on. The technologies considered have different capabilities when it comes to the speed of their positioning. Some of the technologies have response times that are well known and others have response times that vary greatly. Unpredictable response time is a problem. To be certain that one technology will perform satisfactory every time one needs to have a fairly accurate estimate of the response time or at least of the maximum response time.

WLAN is a technology with uncertainty connected to its response time. It is possible to predict that the lowest response time form this technology at around 3 seconds. This is the lowest time it usually takes from a WLAN capable device enters the coverage area till an IP address is obtained. This time may though be much longer depending on the quality of the radio signals and the design of the access point. Additionally the software running on the mobile phone needs time to negotiate with the access point and to receive an audio service offer. The time needed to perform these tasks depends also on the design of the software and the processing capabilities of the phone. Typically a Java phone would be slower at running the software than a Symbian based phone and therefore use more time. The uncertainty related to the radio conditions, the infrastructure hardware and to the capabilities of the mobile phones means that in some cases this technology may respond very rapidly but in other it may perform poorly or not respond at all. This means that one can neither expect a constant or a low response time with this technology.

GPS is another technology with uncertainty connected to its response time. As with WLAN this technology may sometimes have response times under 10 seconds. The normal response time however is between 15 to 45 seconds for popular handheld GPS devices. Using GPS with location based audio services would require software processing on the mobile phone which would be added to the response time of the GPS system. This means that as with WLAN, GPS has an expected response time that is higher than the required 10 seconds.

Mobile positioning is based on positioning information that is continuously updated and stored in the mobile network. The time needed to retrieve this information and send it to a mobile phone depends on the response speed of the mobile network, the positioning server running either at a third party provider or at the location based audio service provider and on the GPRS connection speed. None of these numbers are available from the providers operating in the Norwegian market but literature on the topic claims that mobile positioning has much lower response time than GPS. This would mean that one could expect a response time well below 15 seconds, somewhere between 0 and 10 seconds. Mobile positioning would then have an acceptable response time for use with location based audio services. As these numbers may not be representative for mobile positioning in Norway they must be regarded as a rough estimate.

A-GPS uses both GPS and mobile positioning to deliver GPS accuracy or better with lower response time than GPS. The response time of A-GPS is between 0.5 and 10 seconds according to several none scientific papers and web articles. The fact that these numbers may be seen as less reliable is not very important for the purpose of this thesis as long as they all are under ten seconds. The number of sources makes the material more reliable. As all these measurements are made in the USA they may not be directly transferable to a Norwegian scenario. As no A-GPS service is available in Norway there are also no Norwegian respond time measurements available.

Bluetooth has a variable response time. With good radio conditions the system will have finished the search sequence in 10.24 seconds and found all devices within this time period. However one cannot be certain of good radio conditions and the response time may therefore be longer than 10.24 seconds. This gives Bluetooth the same problem of uncertain response time as WLAN and GPS.

NFC has a very predictable response time. The response time of this technology depends mostly on the software running on the mobile phone and the processing speed of the phone. As this technology is only implemented in three phones, all from Nokia, on the European market and the software is included with the phones there are no unknown factors with regards to software and processing speed. The response time of the RFID tag is much lower than the total response time of the software and is therefore a smaller contributor. On the NFC phone tested in this thesis the total response time was about 7 seconds. This includes the automatic launch of the NFC software when a tag is within range and the communication with the tag. The NFC phone tested is not among the most modern phones and it is therefore reasonable to assume that models that are released during the writing of this thesis will perform better on processing tasks. In all, this places NFC above the previously mentioned technologies when it comes to response time and response time predictability.

The term 2D barcodes include many different types of codes. As this thesis focuses on only one type, QR codes, the possibility of other types having different properties is present. The response time data used here comes from measuring two different QR code reader programs on two different mobile phones. As there are more programs available, these may give different response times. The fastest response time measured was 7 seconds making QR codes as fast as NFC. This is obviously depending on the type of program and the processing speed of the phone. The general response time of QR codes may therefore be faster or slower than 7 seconds. However when the program is known and the types of phones compatible with this program is known the maximum response time can be determined. This gives QR codes a predictable response time which is a characteristic it shares with NFC.

2.2.7.4 Deployment and Change of Site Requirements

The technologies are very different with regards to the need for infrastructure in the field and the properties of the infrastructure. Three of the technologies have no need for deployment of special infrastructure as they rely on already existing infrastructure. These technologies are GPS, Mobile positioning and A-GPS. GPS rely solely on satellites and needs no field infrastructure. Mobile positioning uses the existing mobile network. A-GPS use both GPS and the existing mobile network. In addition it uses a positioning server located either in the mobile network, at a third party service provider or at the audio service provider. This device is not considered when the issues of deployment and change of site are discussed. As these technologies are not dependent of special infrastructure they do not require any field work when a system is deployed or when sites are changed.

WLAN and Bluetooth infrastructure have similar properties as they both need electricity. Calculations have been made on battery requirements for powering the devices over a time period of 30 days. The size of the needed batteries makes this an inconvenient solution. When the depleted batteries would need replacement depending on the site sometimes two men or one man with lifting equipment would be needed to do the job. Therefore connecting the devices to the electricity grid seems like the only solution. This would in many cases involve hiring an electrical to make the necessary installations. This would not make deployment an easy or fast operation. Removing and adding sites would also require the same actions to be taken and could not be done swiftly. Both

WLAN and Bluetooth rely on a radio footprint to define a coverage area which also defines the accuracy of the positioning. To set up each site so that the coverage area is accurate to within the requirements a specialist would be needed to adjust antennas and transmission power and to make measurements. This would also make deployment and removing and adding sites a cumbersome task.

NFC and QR codes are two very different technologies that have some clearly similar physical properties. The infrastructure needed for these technologies consists of small tags that do not need any electricity. NFC tags are generally designed as stickers that can be placed anywhere. QR codes can be made as stickers but can also be printed directly on the desired object. Printing the codes on stickers may be an advantage as this makes replacing broken tags easy. Durability may however be a good argument for permanently printing the code on a sign. Both technologies need each site to be equipped with a sign where the tags can be placed. This cannot be seen as a disadvantage as other technologies also need an information sign at each site. Reading QR codes requires that the tag is illuminated by a light source, either natural sunlight, electric lights or the photo light fitted to some mobile phones. Installing permanent electric lighting makes deployment and removal and adding of sites to cumbersome so an alternative may be a small solar powered battery light fitted with a motion detector to save electricity. Some sites are not visited after sunset so this may in some cases not be a concerned. With this said the properties of both NFC and QR Codes make deployment and removal and adding of sites less problematic and cheaper than using WLAN or Bluetooth. GPS, Mobile positioning and A-GPS are however not affected with any of these issues.

3 Testing

3.1 Testing Introduction

After having examined seven technologies by studying them theoretically, the two candidates NFC and QR codes are considered to be acceptable. To have a better foundation for comparing the two against each other the two technologies needs to be put through some practical testing. This testing aims at evaluating the technologies in a typical user situation and compares their properties to the requirements set earlier. Also this will reveal how the technologies function in real life. The results of the tests will be considered together with the results of the theoretical studies to find the best suited technology.

The testing of NFC and QR codes will focus on measuring the time spent by a user reading a tag in a real life situation. This total time spent consists of three parts, startup time, read time and a variable part that depends on the user behavior. Together the startup time and the read time make up what is called the response time. The response time is defined as the time from the phone enters the coverage area till the offer to download an audio file is received on the phone. The response time of each technology platform is static and need only be measured once. As the comparative tests will be oriented towards a real user situation the total time spent will be measured from the user starts walking towards the tag till the URL is received on the phone. The recorded times will then include delays caused by factors related to user interaction with the phones and the users behavior when trying to read a tag and factors related to unpredictable technical faults in the systems.

3.2 Technology Test Setup

The test setup consists of the following components:

Nokia 5140i with NFC shell
Nokia 3250
Sony Ericsson 810i
Quickmark software
Kaywa Reader software
SIM-card from Telenor with Djuice Cash prepaid subscription
NFC compatible RFID tag, sticker type
QR code printed on paper
Laptop computer running Windows XP
Apache web server software
MP3 file 16 bit mono, 11 kHz sampling rate, 23 seconds long, 69.4 kB of data

To have full control over the experiments the choice of using a web server running locally on a laptop computer instead of a commercial web host or HIA's web server was made. The Apache web server is one of the world's most popular web servers. It is free and with a size of just over 4 MB the install file is easily downloaded.

The Software was downloaded from a mirror fileserver in Norway which was accessed through the Apache website. The installation process was straight forward and took just two minutes. The firewall running on the computer was set to accept incoming connections at port 80 which is reserved for web content. An MP3 sample file was specially prepared for this experiment. To avoid the need for downloading large amounts of data through an ordinary GPRS connection the music sample quality was reduced and the length was cropped to 23 seconds. The resulting file with a size of 69.4 kB was placed in the web server folder available to internet connected devices.

For the testing a URL with a certain length was needed. The complexity of the QR codes increases as the length increases, making the reading more difficult. The following URL was chosen as it has some directory structure and is not too long:

62.113.135.42/ibsenmuseet/spor35.mp3

Three systems were tested, one RFID reader and two QR code readers. These ran on three different mobile phones. The testing was done under two typical scenarios with a general tourist approach to reading the tags. This means that the distance from the phone to the tag and the movement of the phone in front of the tag varied with each trial. The two scenarios are:

Testing under good lighting conditions, meaning bright daylight.
Testing under poor lighting conditions, meaning dimed indoor lighting.

Each test was conducted 10 times and the total number of tests was 60. The tags were placed on a wall with a wooden surface, 1.5 meters from the ground. The testing involved a measurement of the time it took for a "tourist" to retrieve the URL from the tag. The clock was started when the tourist passes a line a few meters from the tag, and ran until the URL was displayed on the phone. The test ended as the URL was displayed, before any file was downloaded from the internet to the phone. The time it takes to download a file varies as the phones have different internet connection capabilities. To avoid personal traits to affecting the results, two "tourists" conducted the tests.

The programs were not running when the “tourist” started walking from the line. The barcode is 5 cm square.

3.2.1 QuickMark

Equipment used:

Nokia 3250
SIM Card
Data transfer cable

After assembling the phone and starting it, the required software had to be installed. The software needed is located at the QuickMark homepage in the download section (18). After browsing to that location one has to find the mobile phone one wants to install the software on. When the download is complete one needs to copy the install file to the mobile phone. The transfer from computer to mobile phone can be done by any means available to the phone and computer; in this case a data transfer cable was used. The installation file must be placed in the correct folder which depends on the make and model of the mobile phone, sadly there is no installation guide on the homepage so some searching was needed. After some browsing of the mobile phone a folder was found that contained other .sis files, the same format as the downloaded install file. The name of the folder was \private\10202dce. After the file had been placed in the correct folder an automatically installation process started.

When the installation process was finished it was time to test the program. First a barcode needs to be generated so the program has something to decode. To generate a barcode one could use any type of QR Code generator but to be on the safe side the QuickMark generator was used. This can be found at the QuickMark code generator page (19). After generating a barcode one can test the program. One browses to the program section on the mobile phone and starts the QuickMark program. When the program has started one need to “aim” the camera towards the tag that has been generated. When the tag is located within the area on the screen, the program will start scanning for codes. If the tag is readable the program will display the information stored in the tag. If the tag contains a URL the program will offer to access it through the internet connection of the phone. The test barcode that was generated contained a URL to an MP3 file on the server described earlier. When the barcode was decrypted by the program a URL to this file was received and the program offered to connect to the internet. After allowing the program to connect to the internet the file was downloaded to the mobile phone and playback was started. Now everything was ready for the rest of the testing process.

3.2.2 Kaywa reader

Equipment used:

Sony Ericsson W810i
SIM Card

After assembling the phone and starting it the required software had to be installed. After the phone was turned on the homepage for the Kaywa reader was visited at the Kaywa Reader download page (20). At the pages there were some instructions on how to acquire the software needed. Quote from the site: “Point your mobile phone's browser to http://reader.kaywa.com. We'll check if you have a phone which is supported by the Kaywa Reader.” (20) The phone’s browser was directed to the given address to download the software. When the site was loaded into the browser one could choose to download an English version of the software or choose a different language; in this case the English version was chosen. The program was downloaded into the applications folder on the mobile phone and no further installation was required.

After the download is complete one can start using the program but first one need to generate a barcode so the program has something to decode. To generate a barcode one could use any type of QR Code generator but to be on the safe side the Kaywa generator was used. This can be found at the Kaywa Code Generator homepage (21) . After generating a barcode the program can be tested. One browses to the program section on the mobile phone and starts the Kaywa Reader program. Once the program has started one need to “aim” the camera towards the barcode that was generated on the website. When the barcode is located within the frame one must press the button labeled snapshot and the software will take a picture of the barcode. After the picture has been taken the program starts scanning the barcode for information. If the decoding was successful the program will prompt the user with the information from the barcode, for instance if it is a URL the program will try to redirect the internet browser on the mobile phone to the given address. The test barcode that was generated for the testing contained a URL to an MP3 file on the server described above. When the barcode was decrypted by the program a URL to this file was received and the program offered to connect to the internet. After allowing the program to connect to the internet the file was downloaded to the mobile phone and playback was started. Now everything was ready for the rest of the testing process.

3.2.3 NFC

The Nokia 5140i NFC package contains:

Nokia 5140i mobile phone
Nokia Field Force NFC (RFID) shell
Two compatible RFID tags, sticker type
Li-Ion battery (BL-5B)
Battery charger (ACP-12E Europe)
Stereo headset (HS-23)
User manual for Nokia 5140i and for the NFC shell

One noticeable difference from the NFC shell to the ordinary 5140i bottom shell is the size. The NFC shell is wider, thicker and longer than the original shell. At the back the NFC shell has a large bulge which makes room for the NFC electronics.

When turning on the phone the applications Cover Browser and Service Discovery was automatically downloaded from the NFC shell and installed in the phone’s memory. This installation took a few minutes. When finished the GPRS and WAP configuration was set up by ordering an automatic setup file from the Telenor website.

The two RFID sticker tags delivered with the 5140i NFC package have no text or digits printed on them other than “1kB”, assumed to indicate 1024 bytes of storage capacity. The user manual for the NFC package says that the two tags are of the brand MIFARE. It also says that the tags should be placed on non conducting surfaces such as glass, plastic or wood and not on conducting surfaces such as metal. For this testing the tags were placed on a wooden surface.

As the back side of the phone, where the NFC reader is located, was brought close to the tag the Service Discovery program on the phone was launched. The tags have no information stored initially and the program therefore prompted the user with “No shortcut on tag” and “Please create a shortcut for writing”. Then the user was able to select between the shortcut types Call, URL and SMS. As URL was selected a text input box for the name of the shortcut and then one for the URL itself was displayed. After inputting the text the shortcut was stored on the phone and it was ready to write the shortcut to the tag. The display said “Please touch tag” and as the phone was brought close to the tag the shortcut was written to the tag and the display said “Writing successful”. The tag was now ready to be read.

Reading the tag was very easy. As the phone was brought close to the tag the Service Discovery program started up automatically. The information read from the tag was recognized by the program as a URL and the user was prompted to press a button to open the URL. If it pointed to a file readable to the built in internet browser, such as html, the content was displayed. If the URL pointed to an MP3 file the file was downloaded and the user was prompted to press a button to play the audio file.

Before conducting the main test with all three technologies a small test of the NFC phone was performed. The maximum reading range was measured and the system's response to different types of behavior when trying to read the tag was tested.

3.2.4 Phones and Software

For the testing of QR Codes two different programs and telephones were selected. The two different programs that were chosen were QuickMark and Kaywa Reader. The reason for choosing two programs was that they supported different types of mobile phones, and if this was going to be a relevant technology it should be able to support many types of mobile phones. The QuickMark program only supported Symbian and Windows Mobile while Kaywa Reader supported Java technology and some Symbian based phones. The two mobile phones that were acquired were Sony Ericsson W810i and Nokia 3250. The Nokia phone was selected as it was a Symbian based mobile phone which was supported by the QuickMark reader. As one of the group members had a Java supported mobile phone which was supported by the Kaywa Reader that mobile phone was selected; a Sony Ericsson W810i.

Based on previous experiences it can be assumed that the phone which is running the Symbian program will outperform the phone which runs the Java application. So in other words there will most likely be a bottleneck in performance when running the Java application on the W810i. As mentioned this bottleneck would not appear because the mobile phone has lower processing power, but because of the way Java applications are created and the way they are executed.

3.3 Test Results

During the testing the number of key stokes needed before the URL was downloaded were counted. The counting started when the software on the mobile phone was executed and stopped when the URL from the tag was received. While examining these results it is easy to see when there was some type of error as the number of strokes increased. The increase in key strokes resulted in a great increase in time spent. The QuickMark software does not require any key strokes after the program has been executed because of the way it is designed. The QuickMark software continuously scans for barcodes and will automatically read the code. In the case of user errors while using QuickMark you will only see an increase in the recorded time.

The time spent on retrieving the URL is a result of more than one factor. The time used can be split into three parts: Startup, Reading, and a variable time depending on the user of the software. Startup and reading will be constant for each of the different technologies and will not be affected by user errors. However the startup time and the reading time will most likely be different on mobile phones that are of another make or model as the different mobile phones have different hardware. Startup time is measured from the user starts the program until the program is ready to read the tag, for instance the QR Codes. Reading time is measured from when the tag is available for the software until the URL is received. The variable time will be individual as users can behave differently when using the technologies.

3.3.1 QuickMark on Nokia 3250

	Bright light	Dimmed light	Trial with read error
Average Time	6.5s	6.9s	14.3s
Response Time	4.0s	4.0s	4.0s
Variable Time	2.5s	2.9s	10.3s

Table 2 QuickMark Test Results

After testing the different technologies according to the specifications described earlier some interesting results were found. The results for the test in good light conditions with the QuickMark reader was similar to when the test was performed with bad light conditions. The results for the QuickMark reader in good light conditions were 6.55 seconds, and in bad light conditions it was 6.99 seconds. According to the requirements that were specified these results are within the required time of 10 seconds. These results indicate that for the QuickMark software the light conditions do not affect the results as long as there is sufficient light for the objective to get the contrast it needs. The only considerable variation in time came from a user error. When the error occurred the time went from the average of 6.55 seconds to 14.31 seconds. This indicates that errors have great impact on the time needed to retrieve the URL while using the QuickMark reader.

Startup Time	2.9s
Reading Time	1.1s
Total Response Time	4.0s

Table 3 QuickMark Response Time

The results for the tests are, as earlier mentioned, split in three. QuickMark reader on the Nokia 3250 had a starting time of 2.9 seconds. The reading time for the QuickMark program on the Nokia 3250 was 1.1 seconds. The reading time for QuickMark is measured from when the QR Code is located on the screen until the URL is received on the mobile phone. To get the most accurate read on only the reading time this approach to timing was chosen to eliminate the variable user time. This means that 4 seconds of the recorded time is a constant time that does not change between each test and that is the very least time possible to spend while using the QuickMark software on a Nokia 3250. This leaves the variable time that the users spend trying to get a read. In the testing that has been done the average time were 6.55 seconds for good light conditions and 6.99 for bad light conditions. If you subtract the 4 static seconds you are left with 2.55 seconds and 2.99 seconds which is the variable user part.

3.3.2 Kaywa Reader on Sony Ericsson w810i

	Bright light	Dimmed light
Average Time	18.7s	14.7s
Response Time	12.6	12.6s
Variable Time	6.1s	2.1s

Table 4 Kaywa Reader Test Results

The results for the test in good light conditions with the Kaywa reader was a little different to when the test was performed with bad light conditions. The results for the Kaywa reader in good light conditions were 18.7 seconds, and in bad light conditions it was 14.7 seconds. The time needed for this software exceeds the requirements, which was 10 seconds, by 8.7s and 4.7s. While examining the results from the testing one can see that the reason for the higher average in good light is because of two tests that had user errors. In those two occasions the time that were spent getting the needed information was almost doubled compared to those tests without user error. This is the reason for the jump in average time and if those results are disregarded one can see that there is not much difference in the results from bad to good light conditions. This means that user errors will have a great impact on the time spent reading a tag with this software as well. And just like the results for the QuickMark reader one can see that good or bad light conditions does not affect the results noteworthy as long as there is enough light to create good enough contrast for the camera.

Startup Time	5.0s
Reading Time	7.6s
Total Response Time	12.6s

Table 5 Kaywa Reader Response Time

Kaywa Reader on Sony Ericsson w810i has a startup time of 5 seconds. The reading time for the Kaywa Reader on this platform was 7.6 seconds. The Kaywa Reader software on the Sony Ericsson requires the user to press a button to take a snapshot of the QR Code. This makes it easy to obtain an accurate measurement on the reading process. The reading time is measured from when the snapshot button is pressed and until the URL is received. Based on these measurements the total response time that the Kaywa Reader on the Sony Ericsson needs is 12.6 seconds. This time is the very least the program needs to retrieve the URL. From the difference between the static time needed and the time recorded while testing one can calculate how much of this time the user spent on trying to perform a successful reading. For bad light conditions the recorded time was 14.7 seconds and for good conditions 18.7 seconds. If one subtracts the static time from those results one will be left with 2.1 seconds and 6.1 seconds.

3.3.3 Platform Influence on the Results

As one can see from the results the best performer is the QuickMark reader on the Nokia 3250. The reason the QuickMark software performs better than the Kaywa Reader software is that the Nokia 3250 runs on Symbian. Symbian is known to perform better than the Java based software that the Sony Ericsson w810i uses. Late in the writing process a Kaywa Reader edition for the Nokia 3250 was made available. The difference between Java and Symbian became clear when the Kaywa Reader for Symbian systems were installed on the Nokia 3250. The startup time dropped from 5 seconds to 4 seconds, and the reading was so fast that it was not possible to measure the reading time.

3.3.4 NFC on Nokia 5140i

The initial tests of the NFC technology were conducted to establish what type of behavior was required to successfully read the content of a tag. It was found that the read time depended greatly on if the phone was in motion across the surface of the tag or if it was still. When the phone was swiped across the tag it was not possible to get a reading. The phone had to be nearly still or in very slow motion to get a reading. When the phone was moved towards the tag, touching its surface and moved back away all in a quick motion, the tag was recognized but the information was not read. The tag was recognized as being empty and the user was prompted to write a shortcut to the tag although the tag was already written to.

In a separate test setup the read distance of NFC was measured. The test data showed maximum read distances ranging from 4.0 cm to 4.9 cm. The average maximum read distance was 4.5 cm. The maximum read difference was 0.9 cm and the standard deviation was 0.26.

	Bad Light Conditions	Good Light Conditions
Average Time	14.0s	11.0s
Response Time	7.0s	7.0s
Variable Time	7.0s	4.0s

Table 6 NFC Test Results

When it comes to the main test the results for the NFC tests shows a small difference between good and bad light conditions. The results for NFC in good light conditions were 11.0 seconds, and in bad light conditions it was 14.0 seconds. NFC on Nokia 5140i need a bit more time than the requirements that were set to 10 seconds. The extra time was 4 seconds and 1 second. Based on the technology there should be no effects from light conditions at all as the NFC technology do not need to "see" the tag, it just need to send and receive radio signals. While looking at the test results one can see that there were many errors during the bad light condition testing. Those errors affects the average time to a large degree as 4 of 10 tests generated read errors. One can see by looking only at the error free tests that the average time for both bad and good light conditions is about 10 seconds, and so the general interpretation is that errors has a great impact on the NFC technology performance. The testers does not know why there were so many errors while testing in bad light conditions, but there was speculations about the interference from other radio sources being one of the reasons.

Startup Time	6.0s
Reading Time	1.0s
Response Time	7.0s

Table 7 NFC Response Time

The NFC software on the Nokia 5140i has a startup time of 6 seconds and has a read time of 1 second. The NFC software on the Nokia 5140i does not require the user to press any buttons to start or retrieve the URL from the tag, instead all one need to do is touch the tag with the mobile phone. Although the program does not need to be started it is possible to do so the same way as you start all other programs on that mobile phone. To get an accurate reading of the time required for the software to read the tag the program was started and left in “ready mode”. The time was started from when the mobile phone touched the NFC Tag and was stopped when the URL was displayed. If one adds the startup time to the reading time that was recorded one gets the lowest possible time required for the program to acquire the URL from the tag; this response time is 7 seconds. Based on the results from the testing one can calculate the time the user needed to retrieve the URL. The recorded times were 11.0 seconds for good light conditions and 14.0 for bad light conditions which one subtracts the static time from to receive the variable time. This gives us a variable time of 4.0 seconds and 7.0 seconds.

3.3.5 Technology Comparison

Technology	Good light conditions	Bad light conditions
QuickMark, Nokia 3250	6,5s	6,9s
Kaywa, Sony Ericsson w810i	18,7s	14,7s
NFC, Nokia 5140i	11,0s	14,0s

Table 8 Test Results

QuickMark on Nokia 3250 needed 6.5 seconds in good light conditions and 6.9 seconds in bad conditions. Kaywa Reader on Sony Ericsson w810i needed 18.7 seconds in good light conditions and 14.7 in bad conditions. NFC on Nokia 5140i needed 11.0 seconds in good light conditions and 14.0 in bad light conditions. During the testing phase the errors were recorded as well. While testing QuickMark on Nokia 3250 there was 1 user error in good light conditions and 0 errors in bad light conditions. While testing the Kaywa Reader on the Sony Ericsson w810i there was 2 user errors in good light conditions and 0 errors in bad conditions. While testing NFC on Nokia 5140i there was 1 error in good light conditions and 4 errors in bad conditions. These errors that were recorded were both user errors and system errors. The time difference in the different light conditions and the extra key strokes needed is a result of these errors.

	Errors		Average Key strokes	
	Indoors/dimmed	Outdoors/bright	Indoors/dimmed	Outdoors/bright
QuickMark	0	0	1	1
Kaywa	0	2	3	3.4
NFC	4	1	0.4	0.1

Table 9 Numbers of Errors and Average Key Strokes

3.4 Testing and Results Discussion

3.4.1 Java/Symbian

There are some differences between the ways the different software for QR Code decoding works which affect the total time needed to read the codes. One of these differences is the fact that one of the programs runs on Java and the other runs on Symbian. This is the most obvious source of difference in the performance as Symbian is known to perform better than Java. Not only does the performance of Java versus Symbian directly impact the performance, but because of the different support of the languages the software has to be designed in different ways. The difference in design is obvious as the QuickMark software for Symbian continuously scans the screen for QR Codes and the Kaywa Reader for Java requires the user to take a snapshot of the code he wants to decode. The difference became even clearer when the Kaywa Reader by the end of this work became available for the Symbian phone that was used for testing the QuickMark software. The Symbian edition of the Kaywa Reader software has a completely different way of scanning compared to the Java edition. Now the Kaywa Reader scans continuously for QR Codes just like the QuickMark software. When using the Java edition of Kaywa Reader the decoding process takes 7.6 seconds from you press snapshot until you get the decoded information, instead of less than 1 second on the Symbian edition.

3.4.2 Errors

When examining the different recorded times for the tests one can see that there are some spikes in the recorded time. These spikes occur when there is an error of some type. These spikes have one thing in common; they almost double the time needed to read the tag. This example is taken from the raw test data which is presented in the appendix: The Kaywa Reader on Sony Ericsson in good light conditions has an average time usage of about 16 seconds but when an error occurs it takes about 30 seconds to read the QR code. This is not a onetime occurrence; it happens for both of the other technologies as well. QuickMark jumps from about 6 seconds to 14 seconds and NFC from 10 seconds to 19 seconds. This means that errors are a big problem for all of the technologies that were tested, and it greatly affects the test results.

3.4.3 Errors from shadowing

The test results show that for QR codes no read errors occurred during indoor testing with dimmed lighting. During outdoor testing in bright sunlight 3 errors occurred out of 20 trials, 2 with Kaywa reader and 1 with QuickMark. It was noticed that the person holding the phone and performing the test cast a shadow on to the QR code when at least one of the errors occurred. If during bright and direct sunlight a shadow covers a part of the code when the image is recorded by the camera the contrast between the bright part and the shadowed part is very high. This may have hindered the camera from measuring the light correctly resulting in one part of the image being very bright or one part being very dark. In both cases this may have lead to the read error as the QR code reading software was not able to read the entire code. Such a situation may also occur in dimmed ambient lighting conditions if the code is illuminated by a bright and direct light from which the user casts a shadow onto the code.

3.4.4 Camera

The ability to read a QR code is dependent on light in order for the image to be captured by the camera. The testing showed no problems with reading codes in poor light conditions but this does not mean that light conditions are irrelevant. The light conditions during testing were low compared to normal indoor lighting but not at the level where one would for example be unable to read a newspaper. The light sensitivity of different mobile phone cameras vary and the cameras on test phones would have to be considered to be in the upper part of the quality scale. Should one try to read a QR code in a situation where the light intensity is at a borderline level of what is necessary it seems reasonable to assume that different cameras would show clear differences in performance.

The read range of QR Codes is limited upwards by the physical size of the code and downwards by the near focus limit of the camera. Mobile phone cameras have very varying quality. While the best can focus at ranges as low as four centimeters many phones have less capable cameras with longer near focus range. The near focus limit may affect the possibility of user errors. If the camera has a long near focus range, holding the phone too close to the code will result in a read error. When this occurs and no code is detected by the software the reading process takes considerably longer than if the code is read successfully at the first attempt. As the user after a few tries learns how to use the phone for this purpose it is reasonable to assume that the chance of such errors will decrease. The high number of user errors during testing may be a result of lack of experience with the test phones and the software by the testers. If this is the case then the tests indicate the chance of user errors for a fist time user of the software and service.

3.4.5 Radio Conditions

When testing the NFC phone, read errors occurred at 5 out of 20 trials. This number is surprisingly high and higher than for both of the QR code reader programs. As NFC rely on radio signals at very low power levels radio noise may be a probable cause for these errors. The results of the testing showed four errors during indoor testing and one error during outdoor testing. This supports the theory of radio noise being the culprit as the building where the indoor tests were conducted are covered with radio signals and probably have high noise levels generated by numerous electrical devices. The outdoor site is located some meters from the same building and may therefore have lower noise levels.

3.4.6 NFC maximum range

During the preparations the read range of the NFC phone was tested. The maximum range of NFC was measured to be between 4.0 cm and 4.9 cm and the average was 4.5 cm. These tests were conducted indoors under unknown radio noise conditions. According to the specifications the maximum read distance of NFC is around 5 cm. Why there is a difference between the results and the predicted range is impossible to say for certain. Possible influencing factors may be radio conditions or that the construction of the phone limits the radiated power. However when using NFC the maximum range is not a critical factor as the most convenient way of using it is by making the phone touch the tag, resulting in a range close to 0.

4 Discussion

4.1 Technology Combinations

Of the technologies previously discussed only two are considered to be usable both indoors and outdoors. The only other technology that is considered to be usable, but only outdoors, is A-GPS. A-GPS is being used in the USA and although it is not available in Norway yet it may be in the near future. Should this be a reality a combined solution with QR codes and A-GPS or NFC and A-GPS could provide some of the lacking properties from a solution using only one of the technologies. A-GPS would remove the need for any outdoor NFC tags or QR codes and with specialized software on the user's phone oddly shaped areas could be defined as audio service coverage areas. When entering such an area the user would get an instant notification on the phone. By removing the need for outdoor NFC tags of QR Codes one would remove the need for time consuming maintenance.

The two technologies QR codes and NFC share many desirable properties. NFC can however be seen as more user friendly as one does not need to download and install software and as the reading of the NFC tag may, depending on the QR code reading software, be slightly easier than reading a QR code. NFC could therefore be the best choice of technology but as it is not yet available on the market it seems that QR codes is the most realistic choice. In the near future NFC phones will hopefully be more widespread and therefore a combination of NFC and QR Codes could be made to give each user the most optimal experience. A QR code could be printed on each NFC tag making the target for reading the same for both NFC users and QR code users. The space needed on a sign to make both technologies available would thereby be the same as if only one of the technologies were used.

4.2 Size of QR Codes

QR codes can be printed in almost any size. The limitation is set by the reader's camera. When reading a code it is easier to read a large code than a small code and it is easier to read a code with little encoded information than a code with much encoded information. When printing or placing a code on a sign or poster it is desired to keep the physical size small, typically under 4 cm x 4 cm. This is because the appearance of a QR code may not be seen as visually attractive and it may disturb the graphical design of the poster or sign. A QR code measuring 4 cm x 4 cm encoded with a short text string such as the URL used during the testing in this thesis is easily readable with a mobile phone camera. Should one however wish to encode the QR code with more information one would need to investigate the limitations given by the least capable camera phones that could be used.

4.3 Durability

When it comes to durability the NFC tag should not be very vulnerable to physical damage from nature effects. It is however not known how a NFC tag would perform in cold weather. The chip might be affected by the cold and stop working or just perform slightly slower. However the most likely source of damage is the possible vandalism that might occur on remote locations. For instance if one were to break the antenna cord that is located within the tag the ability to send and receive data would probably disappear.

QR Codes are more vulnerable to performance limiting damage like dirt when located outside. The risk of environment damage will most likely be reduced by using a more durable material to print the barcode on. There is also the risk of people vandalizing the code by tagging or physical damage. The damage from vandalism and environment is less serious on QR Codes as there is a good error correction method built into the tag, but as long as one of the orientation squares is ruined the code will not work.

4.4 Usage

Both QR Codes and NFC requires the users to approach the location of the tags to receive the URL and both have limited range. NFC requires the user to place their phone within 5 centimeters of the tag to receive the information that is available, but to place the phone close to the tag is all that is required to get the wanted information. When using a QR Code program to receive the URL the user has more freedom to choose their location as the QR Codes can be read from an angle and one does not need to stand as close to it as with the NFC tag. The QR Code programs usually require a bit more work to operate, but at most the user has to take a snapshot of the QR Code. The technologies require similar user behavior, as both require that you point the phone in the direction of the tag.

4.5 Phone Hardware

The processing speed of the mobile phones is important when processing demanding tasks such as image recognition. Insufficient processing recourses give a long read time which leads to lowered usability. Comparing the capabilities of different phones would therefore point out which ones are the most suited for the task. Mobile phone manufacturers use very different hardware in their phones and therefore it is not possible to directly compare the processing resources of two phones by looking at for example the clock rate of their processors. What makes it even more difficult to compare hardware is that manufacturers often do not release detailed information about their hardware. The tests performed here indicate that although the hardware has some influence on time it takes to perform a reading, it is not the only contributor. As the development of phone hardware races forward the processing capabilities of the phones of the near future will by far outperform the phones of today. Considering that the phones tested here performed relatively well there should not be any concern over the processing capabilities of the phones that are to be used in the near future by audio guided museum visitors.

5 Conclusion

5.1 Conclusion

Of the seven technologies examined in this thesis five have undesirable properties that make them unsuited. GPS have a long response time that varies greatly. The unreliable response time makes the technology unsuitable. Mobile positioning has very poor accuracy, far below what is required for this task. This makes the technology unsuitable. A-GPS has unreliable accuracy during indoor use which makes it unsuitable. Bluetooth and WLAN require electricity at each site or display, and may require professional tuning of antennas and transmission power. This makes these technologies unsuitable.

The two technologies that are suited are QR codes and NFC. They both have high accuracy, short response time, no need for electricity and are easy to deploy and makes adding and removing sites and displays easy.

The software and hardware platform on which the mobile phone software is running has a great influence on the performance and thereby also on the usability of the QR code software. A phone with a powerful processor running Symbian is desired compared to one running Java, as Java steals some of the processing capacity.

2D Barcodes, such as QR Codes, stands out as an excellent choice of technology because it to a high degree satisfies the requirements that were set initially. The software that is available for decoding the code tags is possible to download freely via the mobile phone or computer, and it is easy to use. Additionally QR Codes are very cheap to produce as the only cost is printing the tag and acquiring a surface to print it on. The low price of this technology makes deployment and maintenance of the service affordable. During the testing it was clear that the QR Code program QuickMark performed best of the three candidates. It had the best times, the lowest amount of errors, and the least key strokes.

5.2 Advice on the Choice of Technology

According to the current status of 2D Barcodes and NFC it is recommendable to choose a QR Code based solution. In this solution the URL pointing to the audio information is encoded in each tag and placed on the correct locations. When or if NFC becomes commonly available in the future it would be possible to make some changes to the solution. One could for instance change the system completely and use NFC only. Another possibility could be to make a combined solution with both NFC and 2D Barcodes on the same tag to give the users the opportunity to choose the technology they prefer.

5.3 Further work

NFC is so simple to use that read errors cannot be mostly blamed on the user. NFC is still in an early phase and not commonly available. This makes it difficult to get a clear view of why these errors occur and the lack of a user group with experience does not help this. The reason for NFC read errors cannot be established in this thesis. Further work on this field must be done by others.

There is also a concern about how big impact damage has on the tags. The main problem here is damage to the antenna or the chip. There is also a possibility that cold weather could affect the performance of a NFC tag the same way as other electronic devices get affected. Further work is needed to get a clear view of these topics.

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7 Appendix

7.1 Test results

Good Light Conditions						
Test #	Quickmark reader Nokia 3250		Kaywa Reader w810i		Nokia NFC	
	Keystrokes	Seconds	Keystrokes	Seconds	Keystrokes	Seconds
1	1	5,73	3	14,76	0	10,72
2	1	6,10	3	16,32	0	10,34
3	1	5,66	3	15,50	0	10,39
4	1	5,64	3	15,41	0	9,85
5	1	5,68	3	15,37	0	10,06
6	1	14,31	3	17,49	0	9,84
7	1	5,33	5	32,15	0	9,83
8	1	4,39	5	28,53	1	19,12
9	1	6,34	3	16,45	0	10,41
10	1	6,27	3	15,89	0	10,13
Average	1,00	6,55	3,40	18,79	0,10	11,07

Bad Light Conditions						
Test #	Quickmark reader Nokia 3250		Kaywa reader w810i		Nokia NFC	
	Keystrokes	Seconds	Keystrokes	Seconds	Keystrokes	Seconds
1	1	7,13	3	13,72	0	10,45
2	1	6,53	3	13,27	0	10,49
3	1	7,99	3	13,90	1	21,02
4	1	5,96	3	13,99	1	18,73
5	1	7,60	3	14,49	1	18,37
6	1	5,51	3	15,63	0	10,60
7	1	7,24	3	14,38	1	19,00
8	1	7,65	3	15,06	0	10,96
9	1	7,80	3	17,17	0	10,46
10	1	6,55	3	15,99	0	10,11
Average	1	6,996	3	14,76	0,4	14,019

7.2 NFC Reading Distance Test

Test	Read Distance NFC
1	4,4
2	4,7
3	4,2
4	4,6
5	4,5
6	4,9
7	4,4
8	4,4
9	4,2
10	4
Average	4,49

7.3 Startup and Reading Test

	Kaywa Ericsson		Kaywa Nokia		QuickMark Nokia		NFC Nokia	
Test	Startup	Reading	Startup	Reading	Startup	Reading	Startup	Reading
1	5,0	11,6	3,9	0,1	3,1	1,4	5,9	1,0
2	5,1	7,8	4,2	0,2	2,9	1,1	6,1	0,9
3	5,1	7,5	4,1	0,3	2,9	1,0	6,0	1,1
4	4,9	7,5	4,1	0,1	2,9	0,6	6,1	1,0
5	5,0	7,7	4,1	0,1	2,9	1,4	5,9	1,0
Average	5,0	8,4	4,1	0,2	2,9	1,1	6,0	1,0