“PANOULU CONQUEROR” - A PERVERSIVE LOCATION-BASED GAME FOR THE PANOULU NETWORK

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ABSTRACT

This thesis introduces a pervasive location-based game called panOULU Conqueror. It was designed to be a mobile multiplayer game, where players try to capture panOULU WLAN access points from other teams. The game works both indoors and outdoors, and the client devices do not need anything special besides WLAN capabilities and a web browser. After designing and implementing the game, a four-week-long tournament was held. Players’ actions were logged in order to study their mobility, network usage and playing patterns. The players were also invited to respond to a user survey, which was conducted to qualitatively measure the effects of pervasive gaming. The players were asked about how playing the game affects the players’ network usage patterns, how the players feel about pervasiveness and location-awareness, and what are the social aspects and impacts of the game. Further, a small group of the most active players were interviewed to gain some more insight into how the players feel about the game. The results indicate that the game was a successful mobile pervasive game that employs positioning as its source for contextual information. The game was deemed quite playable, and the users even gave some good ideas for future enhancements. It can be thus concluded that it is possible to create a pervasive location-based game that uses only the network’s services for positioning, in this case WLAN AP-ID positioning. It was also shown that a website can work as the client software for a pervasive game, which is something very few have done before.

Keywords: pervasiveness, location-awareness, game, wireless network

TIIVISTELMÄ


Avainsanat: pervasiivisuus, paikkatietoisuus, peli, langaton verkko
# TABLE OF CONTENTS

ABSTRACT

TIIVISTELMÄ

TABLE OF CONTENTS

FOREWORD

ABBREVIATIONS

1. INTRODUCTION ......................................................... 8

2. PERVASIVE AND UBIQUITOUS COMPUTING ....................... 10
   2.1. Pervasive computing ........................................... 10
   2.2. Ubiquitous computing ......................................... 10
   2.3. Mobility .......................................................... 11
   2.4. Context-awareness .............................................. 11
   2.5. Positioning ...................................................... 13
       2.5.1. GPS ......................................................... 13
       2.5.2. Cellular positioning .................................... 14
       2.5.3. WLAN positioning ....................................... 15

3. PERVASIVE AND LOCATION-BASED MOBILE GAMES .............. 17
   3.1. Computer games ............................................... 17
   3.2. Mobile games .................................................. 17
   3.3. Pervasive games ............................................... 18
       3.3.1. Technology ............................................... 21
       3.3.2. Game types ............................................... 21
       3.3.3. Challenges ............................................... 22
   3.4. Ubiquitous games .............................................. 23
   3.5. Game design .................................................... 24
   3.6. Examples of pervasive games ................................ 27
   3.7. Examples of location-based games ........................... 30

4. PANOUULU CONQUEROR GAME DESIGN ............................. 33
   4.1. panOUULU network ............................................ 33
   4.2. Game overview ................................................ 33
   4.3. Game mechanics ............................................... 34
   4.4. Game elements ................................................ 35
   4.5. Background story ............................................. 36
   4.6. Rules of the game ............................................ 37

5. SOFTWARE DESIGN AND IMPLEMENTATION ....................... 38
   5.1. Use cases ...................................................... 38
       5.1.1. Administrator ........................................... 38
FOREWORD

This master’s thesis was written for the MediaTeam Oulu research group at the University of Oulu. It is related to the panOULU project that was ended in 2007. The focus of the project was on building and maintaining a city-wide multi-provider public access WLAN network which provides a visitor network for the organizations involved, as well as research and development capabilities. This thesis has received inspiration from other projects that have used panOULU in innovative ways — one example is panOULU Luotsi, a location-based information mash-up.

I wish to thank my supervisor, professor Timo Ojala, and the reviewer, professor Jukka Riekki for their guidance and support during the writing process of this thesis. I am also deeply grateful to my colleagues Toni Hakanen, Ossi Salmi and Mikko Kenttälä, who have been an extraordinary bunch to work with, and to Otso Kassinen and Jani Pellikka, who have graciously donated their time to read and comment on this thesis. Also, I wish to thank Riku Suomela from Nokia for his contribution to the game concept.

My thanks go also to my dear family members and friends who have continuously pestered me with questions about my graduation. And thank you Elina, you have been a great support in writing this thesis and in my life in general.

Oulu, April 27, 2010

Juha Tiensyrjä
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>3G</td>
<td>3rd Generation mobile telecommunication</td>
</tr>
<tr>
<td>A-GPS</td>
<td>Assisted GPS</td>
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<tr>
<td>AP</td>
<td>Access Point</td>
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<td>AP-ID</td>
<td>Access Point Identification</td>
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<tr>
<td>API</td>
<td>Application Programming Interface</td>
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<tr>
<td>ARP</td>
<td>Address Resolution Protocol</td>
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<tr>
<td>CSV</td>
<td>Comma Separated Values</td>
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<tr>
<td>EER</td>
<td>Enhanced Entity-Relationship</td>
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<td>FRAP</td>
<td>Framework for Pervasive Gaming</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<td>GSM</td>
<td>Global System for Mobile</td>
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<tr>
<td>HCI</td>
<td>Human-Computer Interaction</td>
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<tr>
<td>HTML</td>
<td>Hypertext Markup Language</td>
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<tr>
<td>HTTP</td>
<td>Hypertext Transport Protocol</td>
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<tr>
<td>I/O</td>
<td>Input/output</td>
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<tr>
<td>IDE</td>
<td>Integrated Development Environment</td>
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<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<td>IP</td>
<td>Internet Protocol</td>
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<td>IRC</td>
<td>Internet Relay Chat</td>
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<td>JSON</td>
<td>JavaScript Object notation</td>
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<td>MAC</td>
<td>Medium Access Control</td>
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<td>MVC</td>
<td>Model-View-Controller</td>
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<tr>
<td>NFS</td>
<td>Network File System</td>
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<td>PC</td>
<td>Personal computer</td>
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<td>PDA</td>
<td>Personal Digital Assistant</td>
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<td>RFID</td>
<td>Radio Frequency Identification</td>
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<tr>
<td>SMS</td>
<td>Short Message Service</td>
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<tr>
<td>SNMP</td>
<td>Simple Network Management Protocol</td>
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<tr>
<td>TCP</td>
<td>Transmission Control Protocol</td>
</tr>
<tr>
<td>TDOA</td>
<td>Time Difference of Arrival</td>
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<tr>
<td>TOA</td>
<td>Time of Arrival</td>
</tr>
<tr>
<td>TOF</td>
<td>Time of Flight</td>
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<tr>
<td>UDP</td>
<td>User Datagram Protocol</td>
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<tr>
<td>UI</td>
<td>User Interface</td>
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<tr>
<td>WLAN</td>
<td>Wireless Local Area Network</td>
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<tr>
<td>WSDL</td>
<td>Web Services Definition Language</td>
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<tr>
<td>XML</td>
<td>Extensible Markup Language</td>
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<td>XML-RPC</td>
<td>Remote Procedure Call using XML</td>
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1. INTRODUCTION

Pervasive gaming worlds try to combine both the virtual and the real worlds together by utilizing contextual information gathered from different sources. An often-used source of contextual information is positioning. The most used positioning method in pervasive games is GPS (Global Positioning System), which usually limits the game to be played only outdoors. Interaction and mobility are other core aspects of pervasive gaming. Interaction can be of social type, or it can be related to the pervasive embedded computing environment with which the users interact. Mobility in pervasive games builds on always-on networking, which allows the players to play the game anywhere, anytime.

In recent years, the popularity of mobile gaming has steadily increased with the advent of a whole new level of devices capable of delivering impressive gaming experiences. However, usually mobile games are mostly simplified single-player versions of popular desktop games, and thus are only mobile-interfaced games. There have been some mobile-embedded games that use mobility as a game mechanic rather than a delivery channel, but they have mostly been scientific experiments with no emphasis on creating a game suitable for a larger audience. Recently, it has been concluded that the commercial potential of mobile games is increasing, especially due to Apple’s iPhone [1].

Location-based games designed for a broader audience have also been of scarce nature with only a single example of a popular commercial location-based game gaining hundreds of thousands players [2]. Due to increased availability of positioning methods in mobile devices, the number of location-based games is due to grow: already, some mobile gaming devices are able to locate themselves with the help of wireless local area network (WLAN) based positioning methods. GPS and cell-ID positioning methods are available for several mobile phones and it has recently been announced that a large mobile phone manufacturer will include GPS capabilities in most of its upcoming phone models. Thus, positioning oneself with a mobile handset — be it a phone or some other gaming device — in the coming years is made easier. This increase of location-aware devices will make it easier to develop location-based games as interfaces are standardised, as well as increase the markets of them. It is thus easy to argue that mobile location-based games have an enormous commercial potential in the foreseeable future [1].

Pervasive gaming is also a future trend. A gaming world that exists even though the player is not actively playing the game and which changes when the player changes place or does her normal day-to-day activities can be considered ubiquitous. Add a network connection that is available everywhere to obtain a pervasive mobile game in which players move and perform actions that can be seen by online players, even though the mobile players themselves may not be active in the game.

In addition to having an all-encompassing game world and being persistently connected, pervasive games also make use of contextual information. Most pervasive games employ location as their choice of contextual information, which makes them also location-based games.

Ubiquitous and pervasive computing has been studied for some time now, and large research projects are conducted to find out the real user needs of ubiquity and pervasiveness. A large part of a ubiquitous world is the consuming of entertainment, and a
significant part of that entertainment will be in the form of games. Pervasive games are also scarce in numbers; only a handful have been created so far, as can be seen from the pervasive games presented in section 3.6.

This thesis introduces a novel pervasive multiplayer location-based game called panOULU Conqueror, which uses the open and free-to-use panOULU network [3] to locate players inside the network to attack and capture access points. The positioning information that the server gathers from the WLAN access points in the network is used to track user’s movements throughout the network — knowing simply a user’s WLAN MAC (Medium Access Control) address, it is possible and easy to position the user and thus support rich location-aware applications for the network.

The game should be easy to join and easy to play, both meaningfully (i.e. dedicating one’s attention to playing the game only) and casually (i.e. playing on the side of doing something else). It should appeal to a wide variety of people: both male and female, from kids to elders. And the only thing a person needs to play the game is a WLAN capable device with a web browser installed on it — nothing more, no expensive special equipment or hard-to-install client software.

To study the effect that a pervasive location-based mobile game had on its players, the players’ actions were logged and a user survey was conducted. The survey focused on finding out how playing the game affected the players’ network usage patterns, how the players felt about pervasiveness and location-awareness, and what were the social aspects and impacts of the game. Further, a small group of the most active players were interviewed to gain some more insight into how the players feel about the game.

This master’s thesis is structured as follows: In Chapter 2 a general look at pervasiveness, ubiquitousness and positioning will be taken. The impact of mobility in gaming will also be discussed. In Chapter 3, a brief look at computer and mobile games will be taken, along with a short discussion of the social and economical impact of mobile gaming. Some pervasive games will be introduced with a discussion of their differences and similarities with some location-based games. Chapter 4 is dedicated to the design of the panOULU Conqueror game. The main game idea and rules for a location-based pervasive game called panOULU Conqueror will be explained; a game which works with both mobile and stationary clients, inside and outside of panOULU network. Chapter 5 includes descriptions of software design and implementation phases of the game development process. An empirical user evaluation study and its findings will be discussed in Chapter 6, along with statistics from the game tournament. Discussion of the game is in Chapter 7, along with suggestions for future work. Finally, a summary is presented in Chapter 8.
2. PERVASIVE AND UBIQUITOUS COMPUTING

2.1. Pervasive computing

Pervasiveness is defined to mean the state or quality of being present in all parts of a particular thing or place [4]. In the physical world, for example a sound that can be heard everywhere within a particular building can be considered pervasive, at least from the point of view of the building. The physical meaning of the term is thus quite clear, but the same cannot be said about the non-physical meaning; the term can have several different and contradicting meanings, all of them depending on the context.

An example of non-physical pervasiveness is pervasive wireless networking, like the current mobile telecommunication networks that work virtually everywhere. In the same way as wireless networking, an idea can be pervasive when it has caught on and is spread throughout people’s minds. Pervasive computing refers to the ability to access services anytime and anywhere [5].

Pervasive computing environment can be defined as being saturated with computing and communication capabilities integrated to the environment so gracefully that the capabilities “disappear” from the users; or that the users use the computing and communication technologies embedded in the environment without really being aware of them. It relates closely to both distributed systems and mobile computing. Pervasive computing incorporates four research areas: [6]

1. Effective use of smart spaces: making the software behave differently depending on the surroundings, or joining computing and building infrastructures;

2. Invisibility: making the pervasive computing technology disappear from the user’s consciousness, or in practice distracting the user as little as possible;

3. Localized scalability: the intensity and frequency of interaction between a user and his surroundings;

4. Masking uneven conditioning: reducing the variability of the computing environment and making it possible to mask the lack of “smartness” in the environment. [6]

2.2. Ubiquitous computing

Ubiquity is defined to mean the state or quality of being, or appearing to be, everywhere at once [7]. The definition is closely related to that of pervasiveness; the terms may be seen to be equivalent and, in many cases, interchangeable.

Ubiquitous computing devices are most often described as being aware of the location, as well as being embedded in the environment. Thus, ubiquitous computing enables the users to perform certain tasks without being aware of the computers that have vanished into the background. [5]

When discussing pervasive and ubiquitous computing, a key difference remains: ubiquitous computing is usually about devices that are embedded in the environment,
whereas pervasive computing most often means the services that may be used in an environment. These two terms are, however, very much intermingled within the research community and the distinction between the two is not clear. [5]

2.3. Mobility

Mobility in general can be defined as the condition of being mobile, or the movement of people and things [8]. In computer science, and more specifically in computer networks, there are several different types of mobility, for example, user, session and access point mobility [9].

Modelling user mobility is an essential building block in analyzing and studying mobile and wireless networks. Mobility models are needed among other things to plan and design wireless networks. As cell sizes decrease, the changing mobility patterns of users will affect the performance of the network. [10]

In order to effectively design and operate wireless networks, knowing user mobility patterns is important. Extracting mobility data may benefit applications such as location approximation and routing. By collecting and analyzing mobility trace data, it is possible to profile user movements and thus create a mobility profile for a user for further use. [11]

To model the users’ movement in a wireless network, real traces need to be used. The model needs to be general enough to describe the movements of every device: for example, mobile phones may be connected to the network at all times, but laptop computers are often disconnected from the network when the user is moving. This allows the model to be used to simulate new technologies before real-world deployment, since often it is not feasible to test new technologies in real wireless networks. Thus, a model that describes movements between access points is required. [12]

From a user’s point of view, mobility often means that the user can access her data and her personal environment from any place, for example to work in several places by any mobile terminal. User mobility models could be used to support mobile collaboration services. [13]

In computer gaming discourse, a mobile game is simply a game that can be played with a mobile device. It can further be divided into two categories: mobile-interfaced games and mobile-embedded games. The difference is that the previous provides merely a delivery channel for the game, whereas the latter includes features where mobility of the user is important to the game mechanics, i.e. it takes relative or absolute positions into account in the game rules. [14]

Some games include mobility as a core element. Players are required to physically explore the environment searching for game locations. Such mobility elements can also be found in non-computer games such as "hide and seek" and different kinds of treasure hunts. [15]

2.4. Context-awareness

Context-awareness refers to the abilities of services to react to changes in the environment. An example of context that can be used in pervasive games is proximity: how
near or far other players are. This type of context is usual for example in children’s
 games such as "tag" and "hide and seek". [16]

Formally, context-awareness can be defined as follows: "a system is context-aware
if it uses context to provide relevant information and/or services to the user, where
relevancy depends on the user’s task" [17].

Context is any information that can be used to characterize the situation of a per-
son, place or object that is considered relevant to the interaction between a user and
an application, including the user and the application themselves; or, in other words,
any information that varies can be used to help the applications. Context information
can roughly be categorized into eight categories: personal (e.g. pulse, mood), envi-
ronmental (e.g. light, humidity), task (e.g. explicit tasks, events), social (e.g. contact
list), spatio-temporal (e.g. location, time), device (i.e. capabilities), service (i.e. service
specific information) and access context (i.e. networking characteristics). [18]

There are some examples of games using contextual data to change the settings of
the game. A mobile phone’s camera or other integrated sensors such as temperature
sensor could be used to determine the current weather, and that could be reflected by
changing some aspects of the game — for example the weather of the game world. The
data gathered could be sent to a server along with positioning data. The same effect is
also possible to achieve by fetching the weather data from a central location to a device
based on its location, since mobile devices still have a limited amount of processing
power. [19]

When designing, prototyping and testing context-aware games, it can be shown that
location is by far the most often used context element, suggesting that location is in-
tuitive and the easiest to understand. Environmental and physiological context had
much less use in the game prototypes; other context sources than locationing should
anyhow be considered to make the games more versatile. Context-aware games should
react to a changing user environment so that the longer a game is ongoing, the more
the game world environment takes the context into account; for example, the weather
rarely changes during a five-minute long game, but it probably changes if the game
lasts for a week. [20]

From a technological point of view, there are projects to help utilize context-
awareness in pervasive applications. One example is Framework for Pervasive Gaming
(FRAP), which is an ongoing attempt at making context-awareness a feature in perva-
sive computing applications, especially games. The framework provides an abstract
interface for handling context. The interface allows the application to register an ob-
ject and associate context to it. The framework makes it possible to register for context
updates without the need to poll the object. [21]

An example of a game using context-aware technology already in the year 2003 is
"Real Tournament", which uses augmented reality technologies to combine real and
virtual worlds. The game uses GPS positioning, an electronic compass to get the ori-
entation of the gaming device, and also player’s status set by the players themselves.
The aggregated context allows for complex interaction between the physical and vir-
tual entities in the game, which in turn triggers a wide range of context-based game
events. [22]
2.5. Positioning

As seen with pervasive gaming, positioning is the most used source of contextual information in the field of pervasive computing today. There are several positioning sources available, ranging from the GPS, which works around the globe, to Bluetooth pico networks that only work within a distance of a few meters. The following sections describe the most used positioning methods in pervasive computing: GPS, cellular positioning and WLAN positioning.

2.5.1. GPS

The Global Positioning System was originally developed by the United States military for military use. Later on, it was released to the public; artificial limits on the system’s accuracy for non-military users were removed. There are 24 satellites orbiting the Earth, which continuously send a signal that can be picked up by GPS receivers. As long as at least three satellites are visible, the receiver is able to calculate its location on the planet — with four or more satellites also the altitude of the receiver can be calculated. Typical accuracy is around 2 to 10 meters, but with more visible satellites the resolution can be increased. GPS receiver technology has been integrated into mobile phones in an increasing rate; in 2001 there were only four handset models with integrated GPS hardware, but already in 2005 the number had increased to 150. [23]

GPS has some severe restrictions that hinder its use. In urban environments or indoors, positioning may be impossible because the receivers may not be in view of any satellites. Location acquisition time is also slow, in the range of 10 to 60 seconds. Hybrid solutions using GPS with cellular ID or using network assisted GPS (A-GPS) have been used to alleviate these problems somewhat. [23]

There is a method called triangulation to calculate the position of the (for example, a GPS) receiver. Triangulation can be divided into two sub-categories: lateration, which uses distance measurements and is used by the GPS; and angulation, which uses primarily angle or bearing measurements. GPS does not use angulation; a description of angulation can be found in section 2.5.3.

Figure 1 by Hightower shows an example of lateration: distances between object “X” and three non-collinear points need to be determined in order to find the position of “X”. If the position is needed in the third dimension, a fourth point needs to be determined. If the three points in the example have known coordinates, “X”’s coordinates can be found out absolutely; otherwise, the given coordinates can only be found out with regard to the three points. The method used with GPS is Time of Flight (TOF), where the GPS receiver compares timestamps from at least four different satellites to find out the difference in TOF, i.e. the distance to each of the satellites. This information is enough to determine the receiver’s position, as the satellites’ clocks are precisely synchronized. Three satellites would be enough to find the X-, Y- and Z-coordinates of the receiver (since the satellites are always above the receiver) if the receiver’s clock were synchronized with the satellites — however, the fourth satellite is needed to find the fourth unknown: the error between the receiver clock and the synchronized satellite clocks. [24]
Figure 1: 2D position determination using lateration.

Assisted GPS systems overcome some of the limitations of the GPS by using a cellular connection to transmit satellite navigation data from a base station to the handset. The benefits of this approach are reduced position acquisition time and possible indoor accuracy to within 50 meters. Also, network operators benefit: because, when users use A-GPS, they can be charged. However, there are also drawbacks: A-GPS can be less accurate than GPS because of multipath problems, and the lack of line of sight measurement can degrade performance. [23]

Currently, the European Space Agency is building a commercial alternative to GPS which could potentially offer higher degrees of accuracy than GPS, especially in areas of extreme latitudes. [23]

2.5.2. Cellular positioning

To locate the user of a cellular network, one only needs to look the location up from the unique ID each cellular site has. This allows for a rough estimate of the user’s position, usually in the range of 100 meters to around 10 kilometres, depending on the size of the cell. For higher degrees of accuracy, some other method like GPS should be used. Although cell-ID positioning is quite inaccurate, it is a fast positioning method with a location acquisition time of around three seconds. It also requires no modifications to the handset nor to the base stations. [23]

Some cellular systems like the Code Division Multiple Access One (trade name cdmaOne) have a common timing base. They can thus be used to estimate location by using Time of Arrival (TOA) systems, which measure the differences among multiple signals arriving at a device. At least three geographically distinct base stations are needed to estimate the position of the user either absolutely or differentially, in which case the system is referred to as Time Difference of Arrival (TDOA). The accuracy of TOA systems fall into the range of 50 to 250 meters — however, they are extremely susceptible to multipath accuracy problems. Non-synchronous systems such as the Global System for Mobile (GSM) are unable to use this positioning method. [23]
2.5.3. **WLAN positioning**

WLAN positioning systems have been an active area of research for some time now. They add value to wireless networks by providing user location without any extra hardware, and they also enable the use of location information in context-aware applications. [25]

WLAN positioning systems are, in general, *implied location solutions*; the device location is implied by the location of known infrastructure devices, such as WLAN access points. WLAN cells have a relatively small coverage area, usually up to 100 meters, so WLAN positioning can provide a general location area, an area where the WLAN signal can be received. There are proposals to use signal strength and interaction between different access points to obtain greater accuracy. Also, WLAN positioning can be used alongside Bluetooth pico networks to obtain a greater degree of accuracy. [23]

There are also other types of WLAN positioning systems than those based on access point ID positioning. Usually, they require specific software to function; first, some area of interest is scanned in an offline mode, i.e. the scanning device is not connected to any of the wireless networks, and the results of that scanning are saved to a database, resulting in a so-called radio map. In online mode, the device is connected to some wireless network and the software scans for WLAN signals and searches the database for the best match to estimate the user’s location. [25]

**Access point ID positioning**

Access point ID (AP-ID) positioning is a form of so-called proximity location sensing techniques. It is also known as wireless (cellular) access point monitoring. Other proximity based methods are physical contact detection (e.g. with pressure or touch sensors) and automatic ID system observation (e.g. credit card point-of-sale terminals or computer login histories). AP-ID positioning is based on server-side monitoring of when a device is in range of a wireless access point. It gives a rough estimate on where the user is located, or "near" the access point the user is using. [24]

**Signal strength positioning and triangulation**

Instead of rough positioning methods like AP-ID, some more fine-grained methods can be used. One of these methods uses the WLAN signal strength to calculate the position of the receiver. The receiver calculates the perceived signal strengths and thus estimates how far it is from each perceived access point. This works fairly well in controlled environments such as research laboratories, but it can be impractical elsewhere. There are several problems with the signal strength approach: multipath reception; frequency-selective fading; constantly changing environment, such as people and objects moving; competing technologies in the frequency range, such as Bluetooth, causing interference; geometry of the position of access points can degrade accuracy; and up-and-coming multiple-input multiple-output techniques, which will increase the multipath components. [23]

Triangulation can also be used with WLAN positioning. Lateration is very similar to how GPS works; see section 2.5 for more details. Angulation, as depicted in Figure
2 by Hightower, works the following way: the receiver performs two angle measurements and one length measurement (which is usually known beforehand), such as the distance between the two reference points, are needed. Given the geometric properties of the receiving array (in this case, the WLAN access points) and the difference in arrival times, it is possible for the receiver to calculate the angle from which the signal arrived from the array. [24]

![Figure 2: 2D position determination using angulation.](image)

Angulation requires an accurate and predictable relationship between the distance and the received signal strength, so it is not very good method for positioning using WLAN. However, better alternatives using received signal strength of all access points at a particular point exist. [26]

Histogram positioning, or fingerprinting, uses previously recorded location points for which it creates a fingerprint and stores it to the database. A fingerprint is usually a radio map at some distinct location. The client then senses the surroundings and creates a similar fingerprint; it is compared to the database in the server and the closest match for the device’s location is returned. The advantages include that the fingerprinting can be performed using offline scanning tools, so it does not interfere with the operation of the network. Also, the calculations can also be optimized, yielding good performance. The observed radio signals correlate to the distances and angles, but they are not directly related. As a downside, any change in the environment may necessitate a rescan of the area, because the changes affect the fingerprint. [24]

There are attempts at creating WLAN positioning methods that combine fingerprinting and triangulation methods to allow for more precise positioning. One example is the so-called kernel-based method: it is a mathematical method that incorporates the best of both triangulation and histogram positioning. It is designed to reduce the error in positioning, yielding better results than triangulation and histogram alone — however, it is quite a lot harder computationally than either of the other methods. [27]

There are several commercial WLAN locationing applications. One of the best known is Ekahau Wi-Fi Real Time Locationing System, which uses Ekahau’s own patented algorithm for position estimation. The algorithm essentially combines triangulation and fingerprinting. The system also uses a probabilistic approach to positioning, calculating possible locations at all times and selecting the best. [28]
## 3. PERVASIVE AND LOCATION-BASED MOBILE GAMES

### 3.1. Computer games

Computer games are extremely popular nowadays, and a successful application of computer technology. Modern computer games can be composed of even millions of lines of code. The development of computer games differs from developing other software; games have more artistic content, and their control systems are usually different than with other types of software applications. [29]

Playing computer games brings players the three main elements that contribute the fun in games: fantasy, challenge and curiosity. Games thus motivate the players intrinsically. Computer games need to have some sort of a goal that is somehow compelling, and the games need to have enough challenge to the same end. Fantasy is also important — without it, the appeal of the game can be lost. However, if the fantasy is chosen poorly or the target audience is wrong, it may make the game less interesting. [30]

Computer games attract people by creating the illusion of being immersed in a virtual world with computer graphics and sounds. The goals are also typically more interactive (i.e. the goals may change during the course of the game) than with traditional games, which gives players incentive to win the game. With optimally designed level of information complexity, games can provoke players’ curiosity. These advantages have made computer games more popular than traditional games. [31]

### 3.2. Mobile games

Mobile games are simply games that are run on a mobile device: an example is "Tetris" on a mobile phone [32]. Some mobile games include player mobility as a core game mechanic. These types of mobile games are commonly known as location-based games; most pervasive games are also location-based games.

Mobile games come in two varieties: those played alone and those requiring other players as well. For multiplayer games, the social impact comes from both the social aspect of multiplayer gaming and the changes to the society it brings, such as changing revenue streams and how people fill their interstitial time; for single-player games, only the latter part is true.

Mobile gaming can be very social for the players, especially as for multiplayer mobile games. Group dynamics constantly define game play in games that are played as teams; a great part of the overall experience is the social aspect and strategy in the game. People like playing in teams and collaborate against other teams. In a study concerning a multiplayer mobile game “CitiTag”, it was noticed that enjoyment and feeling social correlated significantly. In this particular game, the social aspect was particularly strong in the overall experience. [33]

With another mobile multiplayer game “Feeding Yoshi”, players reported that playing the game impacted some patterns of their lives. Some players played the game while at work, making it easier to do well in the game due using more time for playing. Also, some people played when they should have been working, which caused them trouble at work. Some players did well also when they set aside time for longer gaming sessions — instead of filling just interstitial time, they played intensively at a
specified time. If a user decided not to let the game disrupt the user’s daily life but instead made use of available short breaks and commuting time, the player played the game several times a day, resulting in both good and bad performances in the game depending on the player’s physical surroundings. Also, spending short breaks playing the game resulted in players being late for work or for getting home. The advent of multi-player mobile game thus seems to change the players’ everyday lives in several ways. [34]

Personal computer (PC) and console online gaming is becoming more popular, as faster broadband connections become available. The size of the market is already measured in billions of US dollars. Online networked games provide interpersonal interaction and sociality — they make the game about people. Also, human opponents provide more challenge in the games. Mobile online gaming, while popular, has still some catching up to do. The rapid increase in mobile phone pervasiveness and the increases in 3rd Generation mobile telecommunication (3G) connectivity have sparked a lot of interest in mobile online gaming. [35]

Because the mobile gaming market is growing so rapidly, interactive multi-player casual games on mobile phones seem to be natural candidates for filling interstitial time. By researching a multi-player brain teaser game, it is suggested that multi-player casual gaming on mobile phones is a promising area, although with some potential pitfalls, such as relatively ineffective team play. However, competition in the game acted as a good motivator for multi-player gaming. Because mobile phones are always with the user, casual mobile games will opportunistically fill interstitial time. [36]

Mobile phones are becoming an indispensable component of everyday life. Thus, the market for mobile gaming is likely to increase well into the future. A study shows that in the near future mobile gaming will overtake both console and PC gaming in terms of revenue. New entrants to the mobile gaming industry can exploit the new opportunities that are still emerging; key players in the gaming industry must do the same to remain key players. [37]

3.3. Pervasive games

Pervasive games — and to some extent also ubiquitous ones — also introduce the concept of an omnipresent gaming world. It lets players connect to the game anywhere and anytime [32]. Pervasive gaming can be defined as having the game world surround the players at all times. The game world sort of blends in, or is constructed on top of the everyday environment. The game brings new meanings to the real world and the real world has some sort of influence on the gaming world. [38]

When discussing pervasive gaming, the word pervasive can be defined in very different ways and from varying perspectives. The term may relate either to the technology behind the game, for example the pervasive computing environment discussed above, or to the game itself: the game world or the players’ actions. The perspective may thus be either technological or cultural. [5]

The technological perspective considers new technological advances to be important parts of pervasive gaming. New technology allows the users to interact continuously and promotes informal, unstructured activities without clear starting or ending points. Thus, pervasive gaming offers three promising dimensions of computer gaming: mo-
bile, place-independent game play; integration of real and virtual worlds; and social interaction between players. [39]

Cultural perspective regards pervasive playing to be mainly a social gaming process, rather than a formal system that regular games usually are. Players may join the game while it is running, or take over some other player’s assets when she has quit. These changes do not, however, take place within the formal game system. Rather, the boundaries of the contractual magic circle of the game world are expanded to accommodate these changes. Any action or sensory observation could be a part of the game. Thus, a pervasive game is a game that has one or more features that expand the contractual magic circle of play socially, spatially or temporally. [40]

Regarding pervasive computing, there are two essential qualities that are closely related to pervasive gaming: the explicitness of computational tasks, and the importance of physical space. The former means that players’ attention shifts from computer screens to the embedded computers in the pervasive gaming environment, i.e. the players interact with the pervasive computing equipment instead of performing data manipulation with a computer. The latter quality shows the importance of physical space and the objects therein: they can be seen as game objects; objects in the real world may also be objects also in the gaming world. Thus, a definition of pervasive gaming is proposed: pervasive gaming implies that there is either an augmented or embedded game world that resides on the threshold between physical and virtual space. The game may further include embedded software and information systems in order to facilitate a “natural” environment for game play. [14, 41]

Walther [14] has defined the four axes of pervasive gaming in order to further refine the general definition of pervasive gaming. The axes — each of which is a separate entity, not an opposite of the other similarly aligned axis — along with the depiction of pervasive gaming possibility space are illustrated in Figure 3.

1. Distribution: pervasive computing devices are often mobile or embedded in the environment, which requires for equally pervasive, always-on and unobtrusive access to resources in the network; pervasive computing requires the resources to be distributed to the users;

2. Mobility: computing, network and user mobility are key challenges in pervasive computing, as well as context-aware and cross-platform services; of particular interest in pervasive gaming are wireless local area networks, personal area networks such as Bluetooth and fast cellular data networks;

3. Persistence: the availability of the game world at all times;

4. Transmediality: the role of the user as media content archiver, annotator, appropriator, transformator and recirculator; unacknowledged support for user-oriented amusement by different media materials. [14]

The pervasive gaming possibility space illustrates the potential for creating games in the future. It is concerned with networking, or its constant accessibility; with freedom of device, so that games can be played with anything and the playing may trigger anything, anytime, anywhere; with non-closure, so that the game never really ends and the game world continues to be built; and with circular storytelling, where bits and pieces and story fragments may be the future of game storytelling. [14]
To engage the players in the pervasive game world, rich interaction between the player and the game, between the human and the computer (Human-Computer Interaction, HCI), and between players of the game (social interaction) in pervasive games is important.

If a game is not interactive, i.e. what happens in the game does not depend on the player’s actions, playing the game becomes strictly a technical operation in which the game is only played against the game logic. Playing games against other players becomes an interpersonal operation where logic is used to play against opponents. Interaction also transforms the situation from a passive to an active challenge. This difference has major emotional significance: passive challenges such as puzzles (e.g. a jigsaw puzzle) can be seen as being dead, while active challenges such as games are alive; they require the user to create her own solutions to the problems faced by using her own personality and that of her opponent. [42]

In pervasive gaming, social interaction can come in various forms. For example, an interactive storytelling game called Story Mashup features three-way interaction: a web player, a mobile player, and two other mobile players collaborate in real time by writing and illustrating stories. Mobile players compete against each other in trying to capture images of web players’ nouns as fast as possible, and by trying to guess which noun corresponds to the image. Together, they make the story go forward, but at the same time they compete with each other to get their own images and nouns presented in the story. Interaction in the game is linked also to the large display that shows the story as it is being written. This makes the public — the people near the large display — part of the game, or rather participants in the interaction of the players. [43, 44]

In addition to social interaction between the players of a game, human interaction with the pervasive computing equipment need to be considered as well. Since the devices used for gaming are usually embedded in the pervasive environment, the input/output (I/O) interaction may change with the device that is being used compared to for example gaming with a desktop computer. [45]
3.3.1. Technology

Pervasive games have three core technologies they are built upon [46]:

1. Displays that make digital content available to players — mobile phones, handheld computers, interactive projections, wearable computers, even tangible interfaces embedded in the ubiquitous computing environment;

2. Wireless communication channels that enable players to communicate with remote servers and other players — cellular technology (e.g. 3G), WLAN and Bluetooth;

3. Sensing technologies that capture context — GPS units, cameras, microphones, accelerometers, even physiological sensors. [46]

3.3.2. Game types

There are five different basic types of pervasive games: (1) smart toys, (2) affective gaming, (3) augmented tabletop games, (4) location-aware games, and (5) augmented reality games [31].

Smart toys integrate pervasive computing technologies, and due to their forms they might suggest the ways in which they should be played with. Toys are not bound by any rules or limitations, so in the strictest sense they are not actually games. They can, however, be used to explore the effects of integrated pervasive computing technologies on how the toys are played with and what kind of games the technologies can be used for.

Affective computing is described as computing that relates to or influences emotions. Affective gaming aims in integrating a player’s emotional state into the game so that the game world can adapt to create an enchanting gaming experience. Affective gaming is related to context-awareness, so that the game adapts to a player’s emotional changes in the same way a context-aware application adapts to changes in the user’s context. So, instead of who and where, affective gaming tries to capture the how a player is feeling to enhance the game.

Augmented tabletop games mainly add to the richness of the social situation in the virtual domain, or the magic circle. Augmented tabletop games are more or less traditional tabletop games which are combined with computer technology to capture the attractiveness of a computer game with the social interaction of a face-to-face setting of the tabletop games. Thus, instead of attractive computer games that lack social interaction and social tabletop games that lack multi-sensual stimulation, we would have games that have both communication between the players, as well as rich multimedia experiences.

In order to have pervasive games outside of tabletops and playrooms, the world itself needs to be considered a game board. Thus are born location-aware games that rely heavily on different positioning schemes such as GPS or WLAN cell-ID positioning, and make use of pervasive computing equipment in a building, a block or even in a city. There are some problems with location-aware pervasive games, mostly with the uncertainty of positioning and network coverage.
The last basic type of pervasive game uses augmented reality techniques to incorporate virtual reality objects into a real-world environment. Users use specific equipment to view the registered 3D objects in real space with three general approaches: head-mounted displays, hand-held devices or projectors. Head-mounted displays allow the user to see both the real world, as well as the augmented objects at all times. Light hand-held devices create a sort of a "window" to the augmented space: players see only a part of the augmented world at a time. Projectors may also be used to project images of the augmented objects on real-world surfaces — this approach is severely limited compared to the other two.

### 3.3.3. Challenges

Positioning methods and wireless networking technologies are often a source of error in pervasive games. They may or may not function everywhere, affecting the players’ experiences in different ways. In “Can You See Me Now”, the effect of uncertainty depends on the role of the player: street players (who move around in the streets of the city in which the game is being played, as depicted in Figure 4) suffer from network errors which makes catching online players much harder, and online players (who play the game from their homes) suffer from street players’ GPS uncertainty — street players can appear out of nowhere, capturing an unsuspecting online player. There are responses to the uncertainties caused by technology, the most popular being the development of better positioning and wireless networking technologies. It is also possible to deal with the uncertainty when it is present, with suggested two strategies:

1. Hide the uncertainty so that participants are less aware of it and feel minimally disrupted by its worst effects;

2. Reveal the uncertainty so that participants can work with it. [47]

Tasks that involve maintaining engagement with a compelling experience — like games, for example — should choose to hide the uncertainty. If there is a need to make important decisions based on uncertain information, the uncertainty should be revealed. [47]

There are also several other challenges and problems with mobile and pervasive gaming, in addition to possible problems with positioning and network connectivity. For example, network latency can be seen as a critical problem in real-time games. In mobile networks, the available bandwidth is usually lower than in fixed networks, and it is dependent on network technology, radio conditions and Quality-of-Service profiles. Related to latency is congestion — even though the network may be congested, the packets should arrive in-time (of which neither Transmission Control Protocol (TCP) nor User Datagram Protocol (UDP) can guarantee) and preferably in-order (only TCP orders the datagrams), so that the gaming experience is not ruined. [48]

Wireless signals and mobility may cause mobile networking to be unpredictably broken. Frequent movements of a device may result in broken links and stale routes. Mobile signals also suffer from fading and interference, which may cause gray zones
and frequent retransmissions. The user experience should be adjusted when the bandwidth drops or the retransmissions cause excess latency in real-time games. These problems cause losses of game state and game synchronization problems. [48]

In general, handheld devices have only a limited amount of electrical power in their disposal — networking and sensing the surroundings all cause battery drain, in excess of the power used by the game itself. If the game needs to be played for long periods of time, a non-exhaustible power supply is important. There is also a limited amount of internal memory and processing power in the mobile devices. If the mobile game is played in a massively multiplayer gaming environment, the need for memory and processing power is paramount. [48]

Since pervasive games are often played with mobile devices, such as mobile phones, the capabilities of such devices may not be enough to fully enjoy the game. Thus, there may be a need for more capable ways of playing the game, such as a website. “SupaFly” does just that — game interaction is done through mobile phones and GSM short message service (SMS) commands, and it is possible to follow the “hype” (a game concept) from the game’s website. The web platform allows for a media-rich, stationary platform for some game activities. [39]

In a ubiquitous world, it should be possible to play pervasive games with any device the user wants to use for gaming — even changing to another device in the middle of a game. It has been suggested that a situation-aware middleware that uses a sensor network to detect the player’s situation in the real world could take care of switching the game from a mobile phone to, for example, a large screen. The usability of functions like these need to be seamless, i.e. players should not feel disrupted by the service. [49]

3.4. Ubiquitous games

Ubiquitous games make use of the ubiquitous infrastructure embedded in the environment. Thus, ubiquitous gaming is closely related to the concept of ubiquitous computing. It can be understood to be a subset of pervasive gaming: ubiquitous games benefit from ubiquitous computing environments, but they do not take advantage of the game worlds residing on the threshold of tangible and immaterial space, like pervasive games do. [14]

A subset of ubiquitous games called lifestyle ubiquitous games has been proposed. These types of games have certain characteristics that allow the players to perform certain uncomfortable activities, such as cleaning, in their lives: lifestyle ubiquitous games need to be enjoyable and players need to participate in the game willingly; the games need to support some daily activity; players should not feel burdened nor do they need to be concentrated to play the game; and finally, the game should enrich the player’s daily activities, thus improving the quality of the player’s life. The games are played in the background of normal daily activities such as cleaning and cooking: the embedded ubiquitous computing environment senses the player and her activities and advances the game. [50]
3.5. Game design

When designing computer games, three factors need to be taken into account: challenge, conflict and interactivity. There are always some rules that are imposed upon the player of a game. Rules may come from a source outside of the game’s domain — gravity always affects a ball game somehow — but the important rules are those that define the nature of the challenge and that make it an interesting challenge. Conflict, on the other hand, reveals character and ability. If there is a challenge but no conflict, the game becomes predictable. Conflict, the possibility of an antagonist to have initiative, enlivens and animates challenge — the protagonist must be put under stress by the conflict, forcing choices that reveal character. Interactivity can be seen to be nothing more than a useful component in the design of entertainment software; as a capability of the computer, much like graphics, music and sound. However, interactivity is the one thing computers can do better than anything. They internalize the rules, carry out calculations, permit complicated behaviours and present the results better than any other medium. [51]

Another important trait of any game is the illusion of winnability. To provide a continuing challenge to the player, the game must also provide a continuing motivation to play: it must appear to be winnable. In order not to lose its appeal, the game must, however, never be truly winnable. A prime example of a game that appears winnable to most players is “Pac-Man”; yet it is never quite winnable. [42]

Game design determines what choices the player will be able to make in the game world and what consequences these choices will have on the rest of the game. It also determines what win or loss criteria the game may include, how the game is controlled, what information the game communicates to the players, and establishes the difficulty of the game. In short, game design determines every detail on how the game play will function. There are three lessons to be learned when designing computer games: [45]

1. Furnishing the visual elements widens the audience;
2. What the players bring to the game is as important as the game itself;
3. The social aspect of play is all-important and leads to further socialising, which in turn, leads to more play. [45]

It is, however, not enough to use only previous game design experiences and theories when designing more comprehensive applications, such as pervasive multiplayer games. The problem needs to be approached with a wider scope, in one part with rich interaction design. Successfully applying rich interaction design requires knowledge from the fields of interaction theories and interaction design. [45]

In a multiplayer setting, the presence of real players for opponents brings a tremendous change in players’ perceived importance of playing the game: instead of just winning or losing the game in private, winning or losing a multiplayer game becomes a public affair and thus significantly more meaningful. Regardless of whether they win or lose, the potential for glory and shame can make a multiplayer game a much more emotional experience than engaging in a single-player experience. [52]

When designing pervasive games, there is a difference that depends on whether the game is designed to be played in Paris or in Los Angeles. Thus, the anthropological
approach to pervasive game design becomes part of game design methodology. It is a challenge as pervasive contents and scenarios change depending on the type of urban setting. [53]

There exist some early design precepts for computer games that should be followed in game design process. The first precept is to make the machine perform tasks that are suited for it. For a game designer, the convenience of the computer is not of interest. The performance extracted from the computer should be its maximum — we can only do this by making it perform functions which it performs well. Also, simply recreating games that are previously designed and originally developed for some other medium as computer games is fundamentally flawed. Games played with computers should be designed for computers. [42]

One of advantages with computer games is the computer’s ability to calculate. However, it’s I/O (or, nowadays often referred to as Human-Computer Interaction) — moving the information between the computer and the human player — is a weakness. Thus, the primary goal for a computer game designer is that the game must be designed in such a way that the information given to the player flows naturally and directly from the screen layout and sound output. Without a good I/O structure, the player cannot appreciate the architectural beauties of the game, because the display structure is confusing. Also, the game designer should remember to use input devices — keyboards and such — well, so that they do not create unnecessary challenge for the players. [42]

It is very important to keep the overall structure of the game close to heart when developing the details of the game structure. Resorting to quick patches that are slapped on the main game make the overall design less clean. [42]

Computers are sometimes thought of primarily being information storage devices. This is not the case, however: computers are information processing devices. Information storage is a necessary precondition for information processing, but not the main issue in computing. An ideal program strikes the optimum balance between storage and processing; most games are long on storage and short on processing. [42]

It should also be noted that games must be designed, but computers must be programmed. Both skills, design and programming, are difficult to acquire, and very rarely, can they be found in one single person. Development teams consisting of a non-technical game designer and a non-artistic programmer are often formed to overcome this limitation. It would work if either programming or game design were straightforward processes that require little trade-offs. Both activities are, however, desperately difficult ones demanding many painful choices. [42]

In addition to the design precepts, game rules must be created. There are six invariant parameters of game rules [54]:

1. Rules (games are rule-based);
2. Variable, quantifiable outcomes;
3. Values assigned to possible outcomes (different potential outcomes are assigned different values, some positive, some negative);
4. Player effort (games are challenging);
5. Players attached to outcome (players will be winners and “happy” if there is a positive outcome; players will be losers and “unhappy” if there is a negative outcome);

6. Negotiable consequences (the same set of rules can be played with or without real-life consequences, e.g. playing poker with or without real money bets). [54]

To adapt these parameters to also consider pervasive games, some compromises must be made. For example, when the game rules and their logical structure are moved from the digital computer into the tangible world, the computational rule logic must be distinguished from the real-time interaction patterns, i.e. how the game’s internal states (governed by the game rules) and the player’s interaction with the real and the game worlds are managed together. Also, there is a certain uncertainty with pervasive games that relates to tangibility of the game world, which must become a part of the rule structure, i.e. it must be inscribed in the computational representation. [14]

A pervasive game design document should consider the design precepts and invariant parameters of game rules. The design document can be adapted from a computer game design document outline by Rouse [52], which includes: (1) an introduction or an overview (2) a section for game mechanics (3) a description of artificial intelligence used (4) game elements descriptions (5) a story overview (6) game progression, and (7) system menus. Naturally, not all game design documents have all the listed sections, since for example not all games have an artificial intelligence.

After game design and implementation, the games are tested against a predefined set of criteria. In order to test the software for playability and classify possible problems, a mobile game evaluation model could be used. The model includes three modules: game play, mobility and game usability. They are common ground in any mobile game. The three modules are correlated, however: game usability and mobility have correlation in mobile games; to evaluate game play, there should not be any major playability problems in game usability or mobility; and even though mobility is a separate module, there are also mobile issues in game usability heuristics that need to be taken into account. [55]

In addition to testing the game, some actual user data needs to be gathered. In different research projects regarding pervasive gaming, the researchers have observed the users in different ways. For example, the creators of an outdoor augmented reality game called “Sky Invaders” evaluated user satisfaction and learnability by letting the players ask questions from the developer, which then answered them. The players also provided feedback in written form by filling out a questionnaire. [56]

In a pervasive game called “Feeding Yoshi”, the research group took a rather different stance in collecting user data. They made the users participate in an ethnographic study by collecting data through interviewing the players, videoing the game play and making the users write a personal game diary. Also system logs were used in observing the players’ responses to the game and its underlying technology. [34]

The makers of “SupaFly” decided that an ethnographic approach which studies the players in actual gaming situations to record the players’ interaction with the environment and other players would need vast resources and possibly even invade the players’ privacy and integrity. Thus, they decided to use three different methods of user evaluation, namely system logs, a qualitative questionnaire, and focus group interviews. [39, 57]
3.6. Examples of pervasive games

“Human Pacman” is an interactive entertainment system that combines the physical world with a fantasy virtual playground. It makes use of mobile computing, wireless networks, ubiquitous computing and motion-tracking technologies to deliver an augmented-reality computer fantasy with role-playing elements. The game emphasizes collaboration and competition between players in an outdoor physical area. This time the Pacmen and the Ghosts are real human players in the real world, who experience mixed computer graphics fantasy-reality by using wearable computers. The game incorporates virtual cookies and actual, tangible physical objects to allow for seamless transitions between real and virtual worlds. [58]

“Can You See Me Now?” is a mobile mixed reality game of catch where online players are chased through a virtual model of a city by runners, or street players, who are professional performers. The runners have to traverse in the physical world to capture the online players. The game employs handheld computers with WLAN connectivity and GPS receivers to relay the runners’ position to the online players, as depicted on Figure 4. The runners’ walkie-talkie communication is also streamed to the online players to provide real time descriptions of the runners’ actions. [59]

Figure 4: A runner and his equipment from “Can You See Me Now?”.

An adaptation of a traditional outdoor sport, “Capture the Flag” is a mixed-reality version of the team game. It uses smart phones as the main interface to the game. Players use the phones to physically role-play virtual characters who try to catch enemy flags, like in the outdoor game. There is thus a link between the real and virtual worlds, making the game a characteristic pervasive game. The game also employs wireless networks to maintain seamless contact with other players in both the real and virtual worlds. This implementation of “Capture the Flag” is focused on true mobility with minimal hardware. Figure 5 shows two players playing the game; one is playing the game using the desktop view, while the other plays on the street with the phone view. [60]

Another game played outdoors with augmented reality equipment is called “Sky Invaders 3D”. The game idea is shooting down alien invaders, who can come from three different directions. This forces the user to use the augmented reality helmet to look around to find objects to shoot and move from one place to another to use her gun — the user is thus fully immersed in the game. The objects shoot back, and to avoid
being hit, the player must physically move around. The game employs GPS units to find the position of the player. [56]

“Mobimissions” is a social game in which players use camera phones and cell-ID positioning to participate in creating, sharing and replying to real-world missions. Missions are defined by sequences of digital photographs and text annotations, and any player can make a mission for other players at any location. The game is not multiplayer per se — the players do not directly compete with each other, and the online status of a player at any given time makes little to no difference to other players — but it has certain elements that provide to a social experience. For example, although the game could be played only alone, some players preferred co-located play, where two or more people tried to complete a mission in a same place. [61]

“Story Mashup” introduces a new form of interactive storytelling. It allows distant people to collaborate in real-time in writing and illustrating stories. The game links the physical and virtual worlds and engages the players in a collaborative and competitive effort of storytelling. Web players write sentences, from which keywords are selected and sent to mobile users. The mobile users need to take a photo with her camera phone that depicts the word in a certain amount of time, after which the photo is uploaded. The photo is sent to two other mobile users along with a collection of words — the players need to guess which word the photo is about. If either of them guesses cor-
rectly, the photo is approved into the resulting visual story, which is displayed both in
the web and on a large public display. Players are awarded points for taking photos and
choosing the right keyword, so the game is highly competitive and fast-paced from the
street players’ viewpoint. From the web player’s viewpoint, the game can be seen as
a collaborative leisure, whereas the street players may see it as an urban game. “Story
Mashup” is a pioneer in using large public displays with a pervasive game. The large
public displays used in the game can be seen in Figure 6. [44, 43]

![Figure 6: Large public displays used in “Story Mashup”](image)

Most pervasive games employ location as their choice of contextual information.
There are however other, quite easily exploitable sources of contextual information,
such as environmental data. In addition to location data, “Mythical: The Mobile Awak-
ening” uses environmental data from public sources to enhance the game play. In the
game, real weather conditions on the player’s home town change how the game is
played. The game has also other pervasive features, including using mobile devices as
playing devices, and player interaction. [19]

Another way at looking at pervasive gaming could be to forget all about positioning;
this is exactly what the creators of “Team Exploration” have done. Instead of con-
centrating on maps and trajectories and focusing uniquely on geographical skills, the
players of the game can enjoy the diversity of urban experiences. The game makes
use of self-configuring ad-hoc WLAN networks and mobile internet tablets to make
players find objects in a few images from the surroundings, as can be seen from Figure
7. Teamwork is required to find the sources of all the given images in due time, pro-
 moting the use of mobile ad-hoc networks. Because there are no central servers, the
game allows new forms of exchange and spontaneous organization. [53]

“Burgomaster and Pedro” is a location-based pervasive multiplayer game that uti-
lizes GPS and smart phones. The main idea is to explore villages to find real or virtual
objects that need to be transferred to other villages. The objects have visual markers
that need to be recognized; the game software running on mobile phones can do this
when a player takes a picture of said object. [62]

There are some frameworks for creating pervasive games. One of them is called
FRAP, which is used to create a context-aware multiuser game “King of Location” —
a simple capture-the-flag type of game. The pervasive elements of the game are: rules,
goal, scoring and the wireless communication between players. A mobile phone with
GPS capabilities, wireless network connectivity and a web browser are required to play
the game. [21]
3.7. Examples of location-based games

There are a number of games that, while not pervasive, make heavy use of location-awareness. The main difference between location-based and pervasive games using location context is that in the former category of games, the game world and the real world do not affect each other; rather, location-based games simply use position information as a game mechanic. For comparison with pervasive games, some examples of location-based games are listed here.

One of the first mobile games to employ WLAN networks was “NodeRunner”. The game consisted of a PDA equipped with an 802.11 WLAN network interface card and a camera. Teams raced against time, trying to find as many wireless access points as they could, and uploading photos of them to a central server. While the game employed WLAN networks and access points, it did not make use of them beyond verifying their existence. [63]

An early example of an Internet enabled street game where players stage and document small plays on the streets of New York is called “FIASCO”. The purpose of the game is to claim turf on a virtual map of the city. Players generate stunts online, organize with the rest of the team, stage actions on the streets and then return to the website to claim territory by uploading multimedia elements from the stunts to the game website. The game employs location as a game mechanic — however, the game is not location-based per se. [64]

Another early location-based game that employs WLAN and GPS devices with a PDA is called “Treasure”. The game is played by collecting virtual coins from outside a wireless network, and then running back into the range of the network to upload the coins, thus gaining points. The game builds on a concept called “seamful design”, but instead of smoothing the seams — such as network coverage and the lack of it — the game uses the seams as a game mechanic. It is suggested that the concept of seams can be a productive resource in game design, but potentially also in the design of ubiquitous systems in general. [65]

“Feeding Yoshi” is also a game that provides an example of seamful design. The game exposes the underlying technologies — the coverage and security characteristics of WLAN — as a core element of game play. In addition to being location-based,
the game is also a long-term, wide-area game that embeds in the players’ daily lives. Figure 8a depicts the game’s mobile user interface: Yoshis (secured wireless networks) can be fed fruit grown in plantations (open access points). It is also possible to play the game using the map screen, as seen in Figure 8b. [34]

![Feeding Yoshi mobile user interface](image)

(a) A Yoshi.

(b) Map screen.

Figure 8: Mobile user interface examples from “Feeding Yoshi”.

The traditional version of “Snake” has been around in mobile phones for years. There is also a location-based version, which requires the player to use a PDA with a GPS receiver, and to move around. Instead of using a joystick for moving the snake on the screen, the player must manoeuvre herself to manoeuvre the serpent. In addition to being fun, location-based games can also do double-shift as exercise. [66]

“Conquer the Tag” is a location-aware game that employs Bluetooth tags that the players need to capture. The tags can be protected by some virtual element the player needs to disarm before she can capture the tag. WLAN ad-hoc networking is employed in the game — the game area does not need to be always where a network coverage can be found. [67]

Radio frequency identification (RFID) tags can also be employed in a location-based game, as “PACLAN” shows. A Paclan uses her mobile phone to capture pills which are in the form of coloured discs containing RFID tags. The pills are placed around the maze. Four other players act as ghosts who attempt to hunt down the Paclan by using their mobile phones to either get the most recent location of the Paclan from the pill discs, and then finding Paclan and scanning the RFID tag on her. [68]

A game of tag is a well-known children’s game. A version of it called “CitiTag” can be played with a personal digital assistant (PDA) that has a GPS receiver and wireless network capabilities, such as in Figure 9, in which a player just got tagged. A player of the game belongs to either of the two teams, and the goal is to find a player of the opposite team to tag with the software running on the PDA. The players may hide
from the opposing team by running for cover, i.e. to a place where there is no WLAN connectivity. [33]

Another similar game is yet another “Capture the Flag”, which is special in that it uses a so-called Wizard-of-Oz method for positioning; the positioning part of the game is simulated. The goal of the game is to conquer and retain virtual flags, which only exist on the digital map of the game and have no physical entity. [69]

Finally, “SCOOT” is a mixed reality event that integrates web, mobile devices and public displays as tools of play. Players of the game must seek out mystery objects, interactive carnival boxes that are hidden in a public place. Players are sent clues via SMS challenging them to find and solve clues and progress in the game. The main idea behind “SCOOT” is to research how mobile phones are integral to making a “now everything is a game” experience. [70]
4. PANONULU CONQUEROR GAME DESIGN

The design and implementation of a novel game panONULU Conqueror is facilitated and motivated by the availability of a city-wide municipal WLAN (IEEE 802.11) network dubbed panONULU (public access network OULU) [3] in the City of Oulu. The network provides different services, for example, a positioning service, which makes it extremely suitable for the use of a pervasive location-based game.

4.1. panONULU network

panONULU is an open (no user authentication) and free-to-use (no payment) WLAN network which provides wireless broadband Internet access in its coverage area to the general public, mostly in Oulu with some access points in Kajaani and in Kokkola. The network started as a joint operation by several actors who wished to combine their visitor networks. The original participants were City of Oulu, University of Oulu, Oulu University of Applied Sciences, and Oulun Puhelin Plc. (later DNA Plc.), who signed a co-operation agreement in 2003. Later, VTT Technical Research Centre of Finland, Elisa Plc., Netplaza Ltd., and Pulmonary Association Heli joined the consortium. In 2009, the network was expanded to become a regional network when eight municipalities adjacent to Oulu installed access points in their premises, creating the so-called panONULUSeutut network.

The network combines several local area networks from different actors into a single network. The benefits of this approach include seamless session mobility [9]. Currently (February 2010), the network holds more than 1,200 access points from several different vendors. There were over 18,000 different client devices using the network in January 2010, with almost 360,000 use sessions and over 15.5 million online minutes.

Due to the characteristics and the wide deployment of the panONULU network within the city, the network can easily be used for relatively accurate positioning, described in section 5.4. Other resources in the network include an advanced IP network analysis system and a centralized monitoring system. [3] Thus, the network can act as a testbed for several different research and development activities, including the panONULU Conqueror.

4.2. Game overview

panONULU Conqueror is a novel game that allows teams to capture real panONULU WLAN access points with their mobile devices. It is thus a multiplayer mobile game. Furthermore, the game is pervasive: whatever the players do in real world changes the all-encompassing game world — be it by giving additional points to the owner of the access point currently in use, or by capturing an access point from another team. The game is also location-based, meaning that the players are located at all times, and their location matters in attack and in defence.

The pervasive part of the game can be played in with mobile devices that are equipped with a WLAN radio within the panONULU network in active and passive
modes. An active mode means that the player is logged in the game, while passive playing happens when the player is simply using her mobile terminal in the panOULU network while not being logged in the game. A WLAN positioning engine in the network is used to track the players’ location. In active mode, players perform attacks on neutral and hostile access points, and in both active and passive modes, try to defend their own access points up until the midnight, when the scores are finally calculated and the winners for the day announced. The game includes several randomly occurring events, some of which have great impact on the game play.

It is also possible to play the game without using panOULU at all, i.e. in offline mode. This way, however, the game play is limited to moving one’s avatar on the game map, to try to defend the team’s assets. What is more, attacking is not allowed when playing offline.

Access points all have different values. The values change daily, depending on the number of users the access point has that day. If a team wishes to keep access points under their control, they must visit them often — failure to visit the access points means less points for the team.

The game is also a social event: players discuss with each other using the inbuilt communication system, and team members meet with each other in real-life to make a grand entrance to a place filled with access points — the more people a team brings, the more easily the access points fall under their command.

4.3. Game mechanics

Playing the game begins with creating an account on the website. If the player was invited to join some team by some other player, she can do that. She can always start her own team. After account creation, the player can log in the game using her username and password.

If the player is playing the game using the panOULU network, she will be located by the positioning engine. The player can move around in the physical world, and her avatar on the map follows her movements. When she discovers a hostile or a neutral access point, she can try to attack it by using the only game-related command: “Attack”. If successful, she gains some experience, possibly boosting her strength and increasing the number of daily attacks; otherwise, she will just lose one of her daily attacks. In case she stumbles across a friendly access point that is owned by her team, she automatically starts to defend that access point, making it harder for other teams to capture it. To easily find nearby access points to attack, the game interface provides a list of nearby access points and their statuses, as well as a list of nearby players, so the player can avoid the places where there are enemy forces.

The player can communicate with her team members by using the game’s chatting function. By coordinating their efforts, the team members can use their strength together to capture access points more easily. And the more often the players visit different access points during a day, the more they benefit the next day in the form of extra attacks.

When players play the game, it possible for them to stumble upon some random event. The events may increase or decrease the player’s attack power, give extra attacks, or make the player unbeatable for some time. Access points may also gain
random events: some may become the victim of a plague, giving zero points for that
day, while others give double points, some change hands to some other team, and some
cannot be captured at all. The effects of the random events last until the end of the day,
after which the effects are discarded.

The game can also be played in offline mode when the player is not using panOULU.
This way, a player can move her avatar around the map in friendly access points, to try
and defend them from other teams, albeit with lowered defensive abilities. Communication
is also possible, but not attacking. It is also possible to passively play the game:
by moving around in panOULU, but not actually playing the game, the avatar moves
together with the player.

It is possible for the player to check the scores on the website at all times. The scores
are updated daily at midnight. Each access point gives as many points as there were
different users during the day. The users affect the game also in another way: the more
people are using an access point at some moment, the harder it is to capture it.

The graphical web-based user interface comes in two different varieties: a desktop
view and a mobile view. The desktop view includes a panel from which the player
can check her stats, and below it an automatically updating list of current game events.
In the interface, there is also tabbed panel with different tabs for playing the game,
communicating, looking at information about different game elements, looking at a list
of nearby objects, and reading the instructions. The gaming tab is the most crowded, as
it includes the game map, information concerning the current access point, and some
other status information, including the current events for the team.

The mobile view is a bit simpler. The game tab of the desktop view has been split
down into three tabs: the game tab that includes the player’s statistics panel and infor-
mation about the current access point, the map tab that includes only a simplified game
map, and the current events tab, which includes current events for both the whole game
and for the team. The rest of the tabs are the same as with the desktop version.

4.4. Game elements

The game comprises of three elements: access points, players, and random events.

Access points come in three kinds: friendly, neutral and hostile. Friendly access
points are those that the player’s team owns; they are marked with green icons in the
access point information panel and in the map. Neutral access points are those that
no-one controls. They are always black in the user interface. Hostile access points are
owned by any other team than the player’s team. They are marked with red icons. If
there are multiple access points in one position on the game map, they are marked with
a single turquoise icon.

For any player of the game, there are two other types of players: friendly players,
or those that belong in the same team as the player in question; and hostile players,
that belong in any other team. Friendly players in the same position as the player help
either in attacking the access point (if the access point is hostile or neutral), or help to
defend the access point (if it is friendly). Hostile players in the same position make it
more difficult to win the attack to an access point (if the access point is hostile), or can
try to attack the access point (if it is friendly).
There are exactly eight different random events, four that can happen to a player and four that can happen to an access point. The random events for players are:

1. Divinity: the player wins the next attack action today with the probability of 1, regardless of the amount of defensive strength the opposing team has;
2. Sickness: the player’s strength is halved for the rest of the day;
3. Health: the player’s strength is doubled for the rest of the day;
4. Bonus attacks: the player gains three bonus attacks to be used today.

Players’ random events can happen at any time a player is playing the game.

Random events for an access point (AP) are:

1. Golden AP: an AP gives twice the normal points for the day;
2. Plague: an AP and all other AP’s within 50 meter radius give no points for the day the plague hit;
3. Revolt: an AP switches sides to some other team;
4. Immutability: an AP cannot be captured from the team currently holding it today.

Access points’ random events happen once a day for Golden AP, Plague and Revolt in the entire game world. Immutability happens once per hour.

4.5. Background story

The background story for the game has not been created; it can be argued that one is not needed in a game as simple as this. However, a short introductory text which tells the main idea of the game for the players has been written, for use in the game website and possible promotional material:

panOULU Conqueror is a multiplayer game with a simple objective: connect to panOULU network with your device, attack and capture as many access points you can from the opposing teams and earn points for your team. The more users there are in an access point at a given day, the more points your team will get when it controls the access points at the end of that day — but wary: if neither you or your teammates visit the access point you control, your hold on the access point will start to slip, and you will get less and less points each passing day. So remember to keep your access points by visiting them daily to earn maximum points each day!

By succeeding in capturing access points, you will get more powerful and eventually get more attacks per day. You may also defend a friendly access point simply by being connected to it, so it is harder for your opponents to capture it. It is also possible to help your teammates capture a hostile access point by being connected to it while your teammate attacks.
Your strength helps your teammate’s, thus making it easier to capture those valuable access points which harbour hundreds of points daily!

What to do when you are not connected to panOULU network? Do not worry; you can play this game outside of panOULU too! Just log in to the website to check the latest standings, watch other players move in the playfield in real-time and help your team by moving your character to defend the access point of your choice.

4.6. Rules of the game

The rules for panOULU Conqueror have been written out by using the game design outline and the invariant parameters in section 3.5 as the basis for them. During development, the rules changed quite a lot because of game balance related reasons and because of early user feedback. The final rules used in a month-long tournament can be found from Appendix 1. panOULU Conqueror rules include sections for explaining game related terms to the players, actions one must take in order to play the game, including the concept of a team, actions a player can do when playing, descriptions on when an attack is won, and how scores are calculated.
5. SOFTWARE DESIGN AND IMPLEMENTATION

Software design of panOULU Conqueror roughly follows the waterfall model, originally described already in the year 1970 [71]. Figure 10 provides an overview of the waterfall model, starting with the requirements gathering and specification phase, continuing onto software design and then implementation, followed by verification to make sure the software functions as it is supposed to function and follows the design. Finally, the software enters the maintenance phase.

![Waterfall Model Diagram]

Figure 10: The waterfall model.

The following sections in this chapter describe the requirements gathering, software requirement specifications, and the implementation processes of the game. Verification and maintenance phases will not be covered.

5.1. Use cases

It is necessary to gather requirements by identifying use cases to aid in the design of the game. This section includes briefly some general use cases for panOULU Conqueror — only those that consider a component of the system as a whole are included, including more specific use cases would not be applicable. This section is divided into two subsections, namely administrator and player use cases.

5.1.1. Administrator

A1. Information handling

Amy, an administrator of the game, wants to know how many players there are in total, how many have played the game on a given day, and all sorts of other information, like how many unsuccessful attacks there were in the last hour. Amy needs to have a single information source which will tell the needed information with ease. This information
source is the server itself, which prints out web pages and CSV (comma separated values) files with the wanted information, if the user is an administrator.

Amanda is an experienced administrator, so she wants to use the command line to find out information. It is extremely easy for Amanda to simply use common Unix tools on the log file generated by the server to find out exactly what she wants. The log files are kept forever: all the game information is stored for later retrieval.

A2. Game administration

Amy, an administrator, has heard that there is something wrong with the game. She needs to fix it quickly, so she simply logs in the game website, chooses the administration link and uses the logging facility to find out what is happening. She notices that during the last hour at least 20 AP’s have become neutral, so she uses the administration interface to return them to their owning teams and to find the cause for it.

Amy receives a complaint from a player, Adam, who says someone is sending him very weird messages and that he feels threatened. Amy, with permission from Adam, finds out who is sending these messages and decides to give that player a warning. If he ever did it again, Amy would lock his player account from the server.

As a skilled administrator, Amy wishes to hack some new functionality for the game. She uses the available Application Programming Interface (API) to create the wanted functionality.

A3. Playing the game as an administrator

Amy would like to also play panOULU Conqueror. She knows that she is almost unbeatable in the game, so for game balance reasons she is not allowed playing in the role of an administrator. Amy decides to create another player account for playing, and Amanda then strips some of Amy’s privileges so that she cannot use her administrative privileges to help her own character advance any faster.

5.1.2. Player

P1. Creating a new player

Claire, a casual panOULU user, hears there is a new game called panOULU Conqueror and wants to give it a try. She browses to the game website and clicks on a link to create a new player. Her friend Charles has already created a team, so she selects to join Charles’ team. Upon successful player creation, a confirmation message is sent to the e-mail address Claire gave. She then clicks on the link in the message, which activates her account so she can start to play.

P2. Creating a team

Charles, a veteran of networked multiplayer gaming, decides to create his own team for panOULU Conqueror. He logs in to the game website, navigates to “Team” settings and clicks on a link to create a new team. The help text explains that it is not possible
to create several teams by any one player, but it is possible to change the team’s name afterwards. Charles then writes a name and chooses a colour for his new team. The colour is used as a visual aid in the game, in maps and in scoreboards, etc. Charles, being the captain of his team, is also able to move his team members’ avatar around on the map when they are not using the panOULU network.

P3. Changing teams

Claire is unhappy on how Charles is managing his team’s efforts in winning new AP’s. Her friend Chuck has also a team in panOULU Conqueror, so Claire decides to switch to his team. She first logs in the game website, navigates to “Team” settings and clicks on a link to switch team. Claire then chooses to join Chuck’s team. After a confirmation, she is a member of Chuck’s team. Claire loses one half of her experience points in the process.

P4. Playing the game

Claire has created a player account and wants to play the game. First, she logs in to the game website. A tabbed page showing the latest happenings is presented to her. On every page, there is a simple status section which shows Claire’s current level, experience, remaining attacks for the day and the AP she is associated at. Also other information, including that of random events, is displayed in that section, as well as a small map on nearby AP’s and players. There is also a tab for instructions, which Claire likes to read from time to time.

Claire notices that she is connected to an AP which is in control of the other team. By clicking on the AP icon in the status section, she is presented with a list of choices, ranging from displaying detailed information on the AP to attacking the AP. Claire decides to click on the attack button after checking her odds of actually winning that AP.

A short battle animation is presented to Claire who jumps in joy — she just captured an AP! Thrilled, Claire moves around to try to associate to some other AP which her team does not own. The map shown on the page helps in accomplishing this. Claire also sees that Chuck is nearby, so she messages him to join her in trying to capture the next AP. Chuck sees the message and comes to the cafe in which Claire is. With combined strength, they try to attack the AP in the cafe, but at first they fail. Claire had used up all her attacks, but Chuck still has some left, so he attacks the same AP and wins the fight.

At the same time, members of the rivalling team associate at the AP in the cafe. Claire quickly checks their information by clicking on a link with the team’s name. They try to recapture the AP, but are unsuccessful as Claire and Chuck are defending it. Since both players have used all their attacks for the day, they decide to quit playing — this way, their players stay with the last associated AP to defend it. After the day, the very popular AP in the cafe is still owned by Chuck’s team, so they receive lots of points for it.
P5. Showing scores
Claire is in a hurry but she wants to know how her team did yesterday. She navigates to the game website to see the monthly scoreboard on the first page. Intrigued, she follows the daily link to see all of yesterday’s scores. An all-time scoreboard shows that in all-time statistics her team is quite near the top.

P6. Viewing the game map
Chuck wants to know how many players there are in the game at this time — this is strategic information, as when there are only few players, there is little defence in rival AP’s. He filters out AP information from the map, which now clearly shows how many players there are and where they are located. Chuck notices that there are several opposing team players in a restaurant, so he does not want to go there. Instead, he spots a few of his own team in a movie theatre where there are several AP’s without an owner. He decides to head there and persuade his teammates to attack and capture the AP’s.

Charles wants to know the current standings easily, so he uses the map. First, he filters out the markers designated to players from the map so that he can see AP’s more easily. Then, he realizes that some of the AP’s have grown in size since this morning! It takes him only little time to figure out that the larger the marker of a single AP is, the more points it will give.

Charles notices also that by using the map it is easy to find out information about AP’s in general: who owns them, which players (if any) are currently associated with them, how many points they are worth today, and so on. With this information, it is easier for Charles to plan his and his team’s attacks.

P7. Communicating with other players
Chuck is in a meeting, but he still tries to follow the game map. It seems that Charles’ team is advancing on Chuck’s best AP with force. He immediately messages all his team to physically move in that location to defend the AP against all attacks. Some of the team members nearby come to the assigned spot and defend the AP successfully.

Claire wants to congratulate Chuck on his birthday, so she navigates to the messaging tab of the game and sends Chuck a message.

P8. Following the game
Charlotte is an outsider who is not playing the game. She still wants to know what is happening there because her husband Charles plays it, so she visits the game website often. She is able to see the scoreboards and follow the almost real-time map, but she is not able to communicate with the players or do anything which requires her to be logged in.

P9. Playing the game with a mobile device
Mary likes to play panOULU Conqueror with her mobile phone while sitting in cafes and restaurants, while walking around the city, and while waiting for the lectures to
start at the university. The phone is a small-powered device with a small screen and a restricted browser, but she wants to have full gaming experience with it. Mary knows that complex mapping software does not work on her phone, so she is willing to have a static map of the gaming area instead of a live one. However, Mary wants to have full access to attacking and defending access points, messaging and other basic functions of the game.

Mary’s phone has such a small display with a small resolution that it is hard to fit much information in it. Mary is, however, happy with how panOULU Conqueror arranges all the information: there are four tabs that contain different things. The first one includes general information on the player’s progress and her currently associated AP. The second one is a messaging tab, where it is easy to message other players and Mary’s own team. On the third tab, there is a simple map for mobile use, and on the fourth there are settings. A fifth button, which does not lead to a tab, is also present; it servers as a logout button to stop playing.

Meredith owns a netbook computer, i.e. a tiny laptop computer. She thinks this computer is ideal for playing panOULU Conqueror — it has a full-featured web browser and a large enough screen to be able to hold most of the game data. Meredith plays the game usually in buses and in places where it is easy to open the netbook, but finds it quite hard to play while on the move.

Michelle owns an old PDA, which has WLAN functionality but has a browser that misses some important features like JavaScript support, so that playing panOULU Conqueror is virtually impossible — the game requires users to have JavaScript enabled on their browsers. Instead, she uses her laptop to play the game while she has some spare time, but as the laptop is quite large, truly mobile gaming is not easy to accomplish.

P10. Viewing the game map with a mobile device

Mary has a mobile phone with WLAN capabilities which she uses to play panOULU Conqueror. As it has only little processing power, it is not feasible for her to use the entire mapping application of the game. Instead, she chooses to use a more restricted version of the map with no live mapping capabilities. She is informed in real-time on associating to another AP and on the number of other players nearby. This information is not shown on the map.

P11. Casual mobile play

Mary likes to play panOULU Conqueror whenever she has a few minutes spare time. Starting to play the game is simple, as it is possible to start playing the game with a single login, one just must remember to tick the box which says “Remember me”. From there onwards going to the game website logs Mary in automatically, and she can start to play instantaneously.

Whenever Mary receives a message from Michelle or something happens nearby, the phone in her purse makes a sound. She does not always need to have the phone in her hand to know something has happened in the game; instead, she can just idle away and react to game events as they happen.
5.2. Software requirement specifications

In this section, we will briefly discuss the software requirement specifications of panOULU Conqueror. A full requirement specification document is not included, as it is not the main topic of this thesis. Rules of the game, which can be found in Appendix 10, as well as use cases mentioned above, have been used in finding out the requirements of the software. This is also reflected in the tables listing the requirements.

This brief software requirement specification section concerns panOULU Conqueror, a location-based pervasive online multiplayer game for the panOULU network. The purpose of this requirement specification is to define the functionality and interfaces of the game in question, each of these in its own subsection.

The general functional requirements of the software are listed and described in Table 1. It should be noted that the requirements presented here are of very general nature. Tables 2, 3 and 4 are dedicated, respectively, to the functional requirements of the server and client components of the software and to the user interface requirements.

Table 1: General functional requirements of the game

<table>
<thead>
<tr>
<th>ID</th>
<th>Requirement</th>
<th>Use case or rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Active playing must be possible with a device, such as a mobile phone or a laptop computer, used in the panOULU network and which supports JavaScript</td>
<td>2. Preliminary actions, P9. Playing the game with a mobile device</td>
</tr>
<tr>
<td>2</td>
<td>Passive playing must be possible within but not outside of panOULU network</td>
<td>2. Preliminary actions</td>
</tr>
<tr>
<td>3</td>
<td>Offline playing must be possible from outside of panOULU network</td>
<td>P8. Following the game</td>
</tr>
<tr>
<td>4</td>
<td>All game-related information must be accessible to players from both within and outside of panOULU network</td>
<td>P5. Showing scores, P8. Following the game</td>
</tr>
<tr>
<td>5</td>
<td>Scores and all other general information must be accessible also from outside of panOULU network</td>
<td>P5. Showing scores, P8. Following the game</td>
</tr>
</tbody>
</table>

5.3. Software design

Design of the software follows the Model-View-Controller (MVC) development pattern. MVC is a software approach that separates application logic from presentation. In web programming practice, it permits web pages to contain minimal scripting since the presentation is separate from the program logic. [72]

1. Models represent data structures; typically model classes are used to retrieve, insert and update information in the database;

2. Views are the information that is presented to the user; typically it is a web page, but it can be a page fragment like a header, a syndication feed, or any other type of “page”;
### Table 2: Functional requirements for the server

<table>
<thead>
<tr>
<th>ID</th>
<th>Requirement</th>
<th>Use case or rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Each action performed by an administrator or a player must be logged to a database or a text file for later access</td>
<td>A2. Game administration</td>
</tr>
<tr>
<td>7</td>
<td>The server must keep track of all active and passive players until they have deemed to have gone offline</td>
<td>2. Preliminary actions</td>
</tr>
<tr>
<td>8</td>
<td>The server must allow administrators to execute game-related functions that affect players and/or access points</td>
<td>A2. Game administration</td>
</tr>
<tr>
<td>9</td>
<td>The server must offer an Application Programming Interface through Hypertext Transfer Protocol (HTTP) which allows the client software to execute queries and actions</td>
<td>A2. Game administration</td>
</tr>
</tbody>
</table>

3. Controllers serve as intermediaries between models and views; they usually contain the application logic, process the HTTP requests and generate the web pages. [72]

### 5.3.1. Models

There are a number of models in panOULU Conqueror. Their main function is to act as intermediaries between the information store (the database) and the controllers that require information from the database. There are altogether six different models; each one is responsible for a specific task in the game. The models are PHP classes, each of which includes a constructor and several methods.

- **Content** model includes methods for fetching and updating the textual content in the database. It makes it possible for a controller to select the last 25 messages that have something to do with a particular team, for example.

- **Locationing** model allows getting users’ current locations from the database and setting them whenever a controller requests them to be changed. It is possible for a controller to search for the location of an individual player, a team, or all players using the methods in this model.

- **Logging** model inserts log messages into the database. It makes it easy for a controller to add log messages and helps in finding log messages of different severities and happenings by different users.

- **Messaging** model inserts and fetches the user’s instant messaging communications.

- **Scoring** model allows for fetching scores. The controllers may need the scores by different criteria, such as by a time frame, or by user.

- **User** model works as a general-purpose model for the game; almost all database actions that happen in the game are user-inflicted, so the User model handles these situations. For example, fetching of the current random events are handled by this model.
Table 3: Functional requirements for the client

<table>
<thead>
<tr>
<th>ID</th>
<th>Requirement</th>
<th>Use case or rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Signing in and out of the game must be possible with the client software</td>
<td>2. Preliminary actions</td>
</tr>
<tr>
<td>11</td>
<td>Viewing all information concerning the connected access point must be possible</td>
<td>P4. Playing the game</td>
</tr>
<tr>
<td>12</td>
<td>Viewing some information about any access point must be possible</td>
<td>P4. Playing the game</td>
</tr>
<tr>
<td>13</td>
<td>Viewing basic information about any player must be possible</td>
<td>P4. Playing the game</td>
</tr>
<tr>
<td>14</td>
<td>Attacking an access point must be possible</td>
<td>5. Attacking</td>
</tr>
<tr>
<td>15</td>
<td>Viewing the game map must be possible</td>
<td>4. Moving</td>
</tr>
<tr>
<td>16</td>
<td>Viewing general game information must be possible</td>
<td>P4. Playing the game</td>
</tr>
<tr>
<td>17</td>
<td>Viewing the user’s own information must be possible</td>
<td>P9. Playing the game with a mobile device</td>
</tr>
<tr>
<td>18</td>
<td>Changing team related settings must be possible for team leaders</td>
<td>P2. Creating a team</td>
</tr>
<tr>
<td>19</td>
<td>Chatting with other people must be possible</td>
<td>P7. Communicating with other players</td>
</tr>
<tr>
<td>20</td>
<td>Attacking an access point must be possible</td>
<td>P4. Playing the game</td>
</tr>
<tr>
<td>21</td>
<td>Defending an access point must happen automatically</td>
<td>6. Defending</td>
</tr>
<tr>
<td>22</td>
<td>Offline playing must be possible</td>
<td>P8. Following the game</td>
</tr>
<tr>
<td>23</td>
<td>Passive playing must be possible</td>
<td>2. Preliminary actions</td>
</tr>
<tr>
<td>24</td>
<td>Finding access points and players nearby must be possible</td>
<td>P6. Viewing the game map</td>
</tr>
<tr>
<td>25</td>
<td>Changing the user’s own preferences must be possible</td>
<td>P4. Playing the game</td>
</tr>
<tr>
<td>26</td>
<td>Viewing scores must be possible</td>
<td>10. Scoring, P5. Showing scores</td>
</tr>
<tr>
<td>27</td>
<td>The user must be able to refresh her location manually</td>
<td>4. Moving</td>
</tr>
</tbody>
</table>

### 5.3.2. Database

From the above six models, it is possible to find the necessary tables and their contents for the game database. The database tables are listed in Table 5. Figure 11 shows the Enhanced Entity-Relationship (EER) model of the actual game database explained in the table. The EER model describes the physical data model of the panOULU Conqueror database, i.e. it shows the actual structure of the database design, instead of the simple relations of entities in an Entity-Relationship model.
Table 4: User interface requirements

<table>
<thead>
<tr>
<th>ID</th>
<th>Requirement</th>
<th>Use case or rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>The game must have a player user interface which is customized to specific</td>
<td>P9. Playing the game with a mobile device</td>
</tr>
<tr>
<td></td>
<td>mobile devices identified by their HTTP user agent strings</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>The game must have a player user interface with more capabilities intended</td>
<td>P4. Playing the game</td>
</tr>
<tr>
<td></td>
<td>for use in more powerful devices than mentioned in the previous requirement.</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>The game must have an administrator user interface which has more functionality</td>
<td>A1. Information handling</td>
</tr>
<tr>
<td></td>
<td>than the player user interfaces and it must look different</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>All different user interfaces must be tabbed</td>
<td>P4. Playing the game, P9. Playing the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>game with a mobile device</td>
</tr>
<tr>
<td>32</td>
<td>The user’s own information must be easily accessible</td>
<td>P4. Playing the game</td>
</tr>
<tr>
<td>33</td>
<td>Attacking must be available in the first tab</td>
<td>P4. Playing the game</td>
</tr>
<tr>
<td>34</td>
<td>Team leaders must be able to move their offline team members in the map view</td>
<td>P2. Creating a team</td>
</tr>
<tr>
<td>35</td>
<td>The UI must periodically position the user</td>
<td>4. Moving</td>
</tr>
<tr>
<td>36</td>
<td>There must be an event log of recent events</td>
<td>P4. Playing the game</td>
</tr>
<tr>
<td>37</td>
<td>The UI must distinguish between active and inactive tabs</td>
<td>P9. Playing the game with a mobile device</td>
</tr>
<tr>
<td>38</td>
<td>Playing instructions must follow a clear structure</td>
<td>P4. Playing the game</td>
</tr>
</tbody>
</table>

### 5.3.3. Controllers

There are several controllers needed by the game. The controllers include the logic of the game, i.e. they handle the HTTP requests, perform game-related actions and return some information from the models for views to handle. The following controllers can be identified:

- **Admin** controller includes methods and logic to administer game players and happenings.
- **Conqueror** controller works as the default controller, i.e. the controller that is called if no other controller matches. It includes the front page and some other pages, but very little logic.
- **Game** controller includes methods for playing the game, such as attacking and calculating the probabilities of attack successes.
- **Location** controller handles positioning requests and it can find the location of the requesting player as well as all other players.
- **Map** controller includes methods for selecting and returning a correct map and its elements.
- **Message** controller allows users to send and receive instant messages from other users.
Table 5: Database tables with table contents and using models

<table>
<thead>
<tr>
<th>Table</th>
<th>Content</th>
<th>Used by (models)</th>
</tr>
</thead>
<tbody>
<tr>
<td>aps</td>
<td>name, location, scores</td>
<td>Locationing, Scoring, User</td>
</tr>
<tr>
<td>teams</td>
<td>name, leader</td>
<td>Scoring, User</td>
</tr>
<tr>
<td>messages</td>
<td>sender, team, time, message</td>
<td>User</td>
</tr>
<tr>
<td>scores</td>
<td>ap, team, score, date</td>
<td>Scoring, User</td>
</tr>
<tr>
<td>users</td>
<td>username, password, name, e-mail, team, Internet Protocol (IP) address, Medium Access Control (MAC) address, experience, creation time, extra attacks</td>
<td>Content, Locationing, Messaging, Logging, Scoring, User</td>
</tr>
<tr>
<td>attacks</td>
<td>user, ap, time, result, experience</td>
<td>Scoring, User</td>
</tr>
<tr>
<td>invites</td>
<td>user, team, time, new player's name and e-mail</td>
<td>User</td>
</tr>
<tr>
<td>log</td>
<td>user, severity, time, messages</td>
<td>Logging, User</td>
</tr>
<tr>
<td>ap_random_events</td>
<td>ap, event type, date</td>
<td>User</td>
</tr>
<tr>
<td>user_random_events</td>
<td>user, event type, date, used</td>
<td>User</td>
</tr>
<tr>
<td>events</td>
<td>time, event text</td>
<td>Logging Model, User</td>
</tr>
</tbody>
</table>

Scores controller includes logic for fetching game scores from the corresponding model and sending them out to the views for processing.

Team controller includes methods for team information manipulation, available for team leaders.

User controller handles all kinds of user information, for example allows the user information to be fetched, handles logins and logouts and returns the number of attacks a user has left.

5.3.4. Views

To give the players a good gaming experience, the user interface (UI) needs to be convenient, reliable, usable, and it needs to work well with the game. This way, the players can concentrate on playing and enjoying the game instead of struggling with the user interface. [55]

There needs to exist two different user interfaces because map applications take quite a lot of processing power and memory, thus, the need for a full-fledged desktop UI and a less power-hungry mobile interface. There are also things like screen space to consider when building different user interfaces: mobile devices tend to have small low-resolution screens, so the mobile UI should be optimized for them. Desktop computers in general have high-resolution displays, thus, it is possible to show more information on one page.

To address the needs of the user interfaces, the game requires a number of different views, composed either of Hypertext Markup Language (HTML) or Extensible
Markup Language (XML). The views may include some PHP code to handle the information coming from the models through controllers. HTML views are mostly small parts of a complete web page, because most of the views are usable in both desktop and mobile user interfaces. Some views cannot be used in either of the user interfaces, so there needs to be some special views for handling UI-specific situations. The XML views are handled by the underlying JavaScript code, thus, they can be the same for both user interfaces.
Desktop user interface

The desktop user interface consists of several tabs, each of which shows different information about the game. Figure 12 shows a typical screen shot of the desktop UI. There are a few items visible at all times on the left side: the links to the web site’s subpages, user’s details and the latest events of the game. Also, below the game are the news. There are altogether five tabs: (1) the game tab that holds the map, information about the current access point, and also some information about the team; (2) the team chat tab, which allows the users to communicate; (3) the tab showing a list of nearby access points and players, so that the players can decide where to head next; (4) the information tab, which shows information about access points, users or teams — the user needs to click on a link to access this tab; (5) and the instructions tab, which includes help and instructions for the game play.

![Desktop UI](image)

Figure 12: Desktop user interface, a screen capture from Mozilla Firefox.

Mobile user interfaces

Like the desktop UI, the mobile user interface consists of several different tabs. Figure 13 shows two screenshots of the mobile UI. Figure 13a is a screen capture from an Apple iPhone and Figure 13b is a simple mobile user interface, as seen in Nokia N95 phones. To accommodate for the smaller screens in mobile devices, the sizes of the desktop UI tabs were reduced, and the navigation links were changed to a horizontal
pattern. As there is precious little screen space available, the map and the current events were moved to their own small tabs. Also, the user information panel is shown only on the game tab; it is always shown in the desktop UI. Missing from the screen shot are the information tab, which appears once a link in any other tab is clicked, and some smaller UI enhancements made late in the development cycle.

Figure 13: Mobile user interface examples.

The mobile user interface aims to be as clean as possible, with very little extra information showing at any time. Another version of the mobile UI was also made for devices that experienced troubles with the still quite processing intensive mobile UI. The other UI was dubbed “simple mobile UI”, and two tabs were left out: the map tab, since showing and updating the map and its elements take up a lot of processing power; and the events tab, since fetching game events periodically caused the user interface to freeze with some low-powered devices.

5.4. Positioning in the panOULU network

panOULU Conqueror uses the panOULU implementation of WLAN access point ID positioning engine. The engine was implemented in 2007. It can be used to find out where any player is at any given time. The current implementation works simply by connecting to a semi-public web service with a client device. The web service makes a query to a panOULU logging server called panDaemon with XML-RPC (Remote Procedure Calls using Extensible Markup Language), which returns the client’s current position by informing the web service of the access point in which the client hast associated last. This information is used by the web service to determine the client’s coordinates, which it then returns to the client. If the client has been offline for a
certain amount of time, the panOULU server will have terminated its session, and is thus unable to find the client’s current access point. The client may also ask its position from outside panOULU network, in which case the web service will detect this and return a location unknown message. The sequence diagram in Figure 14 clarifies the positioning procedure with a simple case, where the client device can be found.

![Diagram: panOULU Positioning Service Page 1](image)

**Figure 14:** Sequence diagram of panOULU positioning engine.

It is possible to hear several access points at one place; there are more than thousand access points in the panOULU network, of which many reside in the university campus area. It is not uncommon to be able to capture signals from six or seven overlapping access points while standing in one place. This makes positioning in panOULU difficult and inaccurate, since the range of a single access point can still be in the range of 50 to 100 meters. Trilateration could alleviate the problem by making the positioning more accurate, but with a caveat of needing to run client-side software on the mobile terminals.

Before panOULU Conqueror, there was already one other service that took advantage of the positioning engine. This service is called “panOULU Luotsi”, which is a multi-device location-based information mash-up provided for the users of the network. The site aggregates XML based content in various forms and maps the data with a location. The service uses the panOULU positioning engine to estimate the location of the user, and shows her relevant information about services, sites and events of interest near her. [73, 74]

A previous implementation of the positioning engine originally implemented in 2006 consisted of polling each individual access point with a Simple Network Management Protocol version 2 (SNMPv2) query for the currently associated clients to find out in which access point the client’s device was associated with. This approach worked with a small number of access points, but as the number of access points in the network grew larger, the delays in positioning caused by offline access points were deemed too long. Also the SNMP polling did not work with all access points that are used in the network, specifically with the Linksys brand access points, which caused the
positioning not to work in several locations within the university campus and in the
city centre.

The positioning engine is able to pinpoint the player to a specific access point — the
user’s actual location is always near the access point, often within 50 meters from it.
This is accurate enough for the game, since the game is about capturing access points,
ot capturing access points at some specific location.

5.5. Description of software implementation

The game implementation was started in the autumn of 2008, and it continued until the
next autumn. The implementation started with creating class templates for the models
and the controllers, and creating the first tables in the database. After the initial setup,
some basic methods related to user information handling were created in order to test
the database setup. After a few basic methods were available, the web site outlook
template was created. The template was tested with creating a few user accounts and
logging in and out with them.

In general, the implementation process had three steps. First, a controller would be
developed. It would use the methods in some of the models to retrieve or save infor-
mation to the database. If these methods did not yet exist, they would be programmed
next. When the necessary methods in the models were done, an HTML view for the
controller would be created as the third step.

When most of the models, controllers and HTML views designed were done, it was
time to do some JavaScript programming to bring the user interfaces to life. There were
four different JavaScript files, and the ones used were determined by the browser’s
capabilities. All browsers were given a file with some common JavaScript methods. If
a browser was a known mobile browser in the development framework’s list of mobile
browsers, it would get the mobile UI JavaScript file; if it was a known mobile browser,
but had some problems with the mobile UI, a simple mobile UI file would be given;
the rest received the desktop file. This way, it was possible to automatically select the
correct user interface for each browser.

Before the month-long tournament, a number of features were decided to be left out
of the software, due to time constraints. The largest part of the software that was left
out was the administration part, since the administrative functions could already be
handled by querying the database directly. Person to person chat and public chat were
also not included. Mobile map was also a troublesome part of the implementation, so
its functionality was mostly disabled; it only shows the player’s current location as an
avatar on the map, but no other map elements.

During and after the implementation phase, the software was also tested so that it
actually fulfils the goals set in the game design section. The testing was done with
the help of several mobile devices: a laptop computer running Ubuntu Linux operating
system and several different web browsers, a Nokia N95 mobile phone, a Nokia E90
mobile phone, a Nokia N810 Internet Tablet and an Apple iPod Touch music player.
The laptop computer naturally used the desktop user interface. The Nokia mobile
phones used the simple mobile UI, and the tablet and the music player were capable
enough to use the normal mobile user interface. Regression testing was performed
whenever a large change occurred in the code base: the game would be tested with the
five devices mentioned to see it still works and no regressions had been introduced — if it did not work, the game would be fixed and tested again until it worked.

During the implementation phase, three colleagues of the author and two outsiders tested the game and its different functions. They reported when there were problems with the game, and these reports were studied to find the cause of the problem, and to fix it.

To get some more testing before the month-long tournament, the game was released to the public a week before the tournament. During this time, some sixty people created accounts and tried to play. Many players reported problems, which could be fixed before the beginning of the tournament. During the tournament, some problems and concerns were voiced by the players. These reports were handled, and the problems fixed.

The game makes heavy use of panOULU positioning service described in section 5.4 to locate players while playing the game. In addition, the panDaemon, an information and logging service used in panOULU is used to find different data concerning access points and players by querying it with XML-RPC requests. The panDaemon parses syslog messages sent by panOULU access points in order to find out in which access point any client MAC address active in the network can be found. The daemon keeps a state of each MAC address it sees and periodically sends Address Resolution Protocol (ARP) packets to each client MAC address to find out if the clients are still online.

A development framework called CodeIgniter was chosen as a basis for the software to ease the task of programming. CodeIgniter is a small yet powerful toolkit aimed to make development with the PHP programming language fast and easy by including ready-built classes for several commonly used tasks in web programming, such as database access and from handling. Figure 15 from the CodeIgniter web site shows us the application flow chart for an application developed with the framework. The flow chart shows that CodeIgniter is based on the Model-View-Controller development pattern, which makes it easy to separate the logic from the presentation. [72]

![Application flow chart.](image)

As a data storage backend, the game utilizes a popular open source database called MySQL. The database is commonly used in web applications, because it has good performance, high reliability and it is easy to use. [75]

For performance reasons, the game server array consists of four web servers and one database server, all which are running Linux operating system. The web servers use the Apache HTTP Server as their choice of web server software [76]. One of the
web servers acts as a load balancer: it redirects HTTP requests to the game’s website (http://conqueror.panoulu.net/) to the three backend servers.

The application is developed with the PHP programming language using the Quanta Plus integrated development environment (IDE) [77]. In addition to plain HTML, the user interfaces for the game use jQuery JavaScript library. It is a cross-browser framework which supports many necessary user interface extensions to make the game playable in both regular browsers used in desktop environments, as well as mobile browsers, which are usually somehow limited in functionality. [78]

5.6. System architecture

panOULU Conqueror system architecture is a mapping of software components onto the hardware components of the panOULU network. A depiction of Conqueror system architecture can be found in Figure 16.

Figure 16: panOULU Conqueror system architecture.
The software components of the game have been distributed to several different physical and virtual servers. Directories related to Conqueror reside in the physical File server inside the panOULU core server room. They can be mounted on the different virtual web servers by using Network File System (NFS). The Database server is also a virtual machine. Access points send their syslog messages to the physical Log server, while the Gateway handles connections to and from the Internet.

There are four virtual web servers that actually run the game. One of them, Web server functions both as a game server and as a load balancer. Due to some performance problems during the testing phase of the game, three Backend web servers were added to the mix to provide more processing power for the game. The four web servers and the database server are all virtualized, i.e. they are run inside a number of physical Virtualization hosts that run VMware virtualization software [79]. This way, the game is not dependent on one single point of failure — if a virtualization host is broken, the virtual machines inside can easily be redeployed on another host, and in the case of an acute need of processing power, it is simple to deploy another backend web server to help alleviate the load.
6. EMPIRICAL USER EVALUATION IN REAL-WORLD SETTING

6.1. Tournament set-up

In order to evaluate and study the players of panOULU Conqueror and its impact on the use of the panOULU network, a four-week tournament was decided to be held. People were invited to play the game by distributing a press release to local news agencies which told of the tournament. The press release was also distributed through panOULU website, the social media sites Twitter and Facebook, by sending invitation e-mails to the University of Oulu mailing lists, and by spreading the word in Internet Relay Chat.

Before the tournament, people were allowed to test the game for a period of one week in the beginning of September. During this time, a lot of feedback and some bug reports were received from the testers, which helped in finishing the game for the tournament. Already 92 accounts were created during the testing phase and 46 during the tournament. Only 96 accounts out of the 138 accounts created were active at least once during the tournament’s period – 63 accounts active in the tournament were created before, and the rest 33 during the tournament. Thus, 13 players out of the 46 that created an account during the tournament did not actually take part in the tournament.

It was decided that groups of six people would be sufficient in the tournament because almost anyone can quite easily find five friends to start a team with. Also, when team dynamics were considered, six seemed to be a good compromise — any more and only the groups that could recruit as many players as possible could win the tournament, any less and the team aspect of the game would be gone.

The tournament started on the 7th of September 2009 at 00:00 and ended on the 4th of October 2009 at 24:00, lasting a total of four weeks. During the tournament, some quantitative data in the form of game logs and HTTP server logs were gathered. Also feedback was gathered during and after the tournament. After the tournament had ended, a qualitative questionnaire form was created and the players were given a chance to fill it. Also, a focus group interview with two of the most active teams was held in order to gain their insights about the game.

6.1.1. Data collection

Data from the tournament was gathered from various sources. During the tournament, all players’ gaming actions were logged into a database, which provides approximately 784,000 log lines. The web servers itself logged all HTTP requests; there were approximately 28 million HTTP requests during the tournament, or on average a million per day. These sources provide the quantitative data sources used in the analysis of the game’s effects on its players and the use of panOULU.

Also some qualitative data was gathered, mainly using the methods used with “Sky Invaders” [56] and “SupaFly” [39] would be sufficient. It would be unfeasible to study the actions of all or even a part of the users recruited — there were altogether 96 players during the tournament — so an ethnographic study like the one used with “Feeding
Yoshi” [34] was out of the question. Thus, a questionnaire form was created, which the players were asked to fill in after the tournament. To gather more interest in filling the form in, it was decided that a piece of networking equipment would be raffled amongst the users that filled in the questionnaire form. Also, a focus group interview was organized to interview the members of the most active teams in the game.

The questionnaire was composed of 32 questions. The topics of the questionnaire were:

1. Demographics;
2. panOULU usage before the tournament;
3. panOULU usage during the tournament;
4. Changes in general and mobile panOULU usage;
5. Location awareness and pervasiveness in panOULU Conqueror;
6. Game, gamers and the social aspects of the game.

By looking at the participant list, it was obvious that all 96 registered players that actually played the game during the tournament were in fact Finnish. Because of this, the questionnaire form was written only in Finnish. An English translation of the complete questionnaire form may be found in Appendix 2. Tournament participants were given two weeks to answer the questionnaire right after the tournament had ended. During the two weeks time, altogether 57 people answered the questionnaire.

The following sections provide information on the different user evaluation methods applied. We will start by going through the data by looking at the player demographics, as collected from the questionnaire and the log data. Then, we will take a look at some game play statistics generated from different log data sources. Qualitative data analysis will be done next by analysing the questionnaire results, discussing the results of the focus group interview, and finally briefly going through the verbal feedback collected during and after the tournament.

### 6.1.2. Player demographics

The age distribution of the players as reported by the respondents of the questionnaire was from 16 to 44 years of age. The mean age was 23.98 years, whereas the median age was 25 years. The most common age, i.e. the mode, was 20 years. Out of the 57 people answering the questionnaire, 54 were male and only 3 female.

Players’ educational background varied quite a lot, as can be seen from Figure 17. Most of the players, or 45 out of 57, were students in or had graduated from either a university or a polytechnic school. Less than one third of the players were students in secondary schools, i.e. high schools or vocational schools. None of the players were in primary schooling, and only one person chose not to disclose his educational background.

The amount of young people playing the game can be explained mostly with the fact that the game was advertised mostly by announcing the tournament in the e-mail lists...
of the Oulu University. Thus, most of the players were expected to be relatively young, and with a background in university studies. A press release was also sent out before the tournament, but unfortunately, it gained only little publicity in the local media. The small number of female players compared to the number of male players was, however, a bit of a surprise.

In addition to players, it is also possible to study the formation of teams. There were altogether 31 different teams in the tournament. Team sizes varied from one to six people, six being the maximum size. The number of teams for each possible team size is shown in Figure 18. It should be noted that the most common team size was one person; there were several teams of sizes five and six members, and it seems that a larger team had clear advantage over a smaller one.

### 6.2. Game play statistics

During the tournament, different quantitative data was gathered in two ways: by logging the requests to the web server to its log files, and by saving game related information to the database.

From the web server logs, it is possible to extract certain interesting pieces of information. One example is the number of unique MAC addresses by players actually
playing the game, which during the tournament was 160. This suggests that each player had on average over 1.6 different WLAN capable devices that he or she played the game with. This correlates well with the questionnaire data from the tournament participants — the average amount of devices per player reported by the respondents was 1.89.

It was interesting to note also that there were almost as many unique HTTP browser user agent strings as there were unique client MAC addresses. The number of user agent strings was 155, but even though the number closely resembles the number of unique client MAC addresses, it does not imply there were 155 different kinds of devices used during the tournament. Instead, several of the user agent strings were related to each other by small differences in browser version numbers, changes in preferred language, etc. From the user agent strings, it can, however, be found out that the players used at least 14 different types of Nokia manufactured mobile phones and a selection of Nokia internet tablets. There were also different iPhone or iPod Touch versions, as well as other mobile phone makes. Mozilla-based browsers were by far the most common browsers used during the tournament, followed by Nokia phones and then by the desktop and mobile versions of Apple Safari.

On average, each unique client MAC address encountered during the tournament had 13.64 panOULU use sessions in August, before the tournament. During September, the number had risen to 76.17. The median number of use sessions in August was 1, in September already 36. Use times were also increased quite a lot: before the tournament, the mean use time for the player’s devices was 11 hours with the median just above two minutes, while in September the mean use time was over 28 hours — almost an hour per day — and the median nearly 10.5 hours. Thus, it can be deduced that playing the game increased the use of the panOULU network quite a lot.

In August, the player’s devices had accumulated a total of 188 mobile sessions in the panOULU network out of the total 11,340 mobile sessions recorded, or only 1.7 %. In September, the number was 3,048 out of 18,046 mobile sessions in the whole network, or 16.9 %, which is a tenfold increase in the percentage to the numbers in August. To conclude, in addition to using the network more, players of the game were also much more mobile during the tournament period than before it.

There were 96 active players when activity is defined as attacking at least one access point during the four weeks of tournament time. The players had a total of 9,727 play sessions, on average over a hundred sessions per active player, or almost four sessions per day. This is quite a large number, considering that not all of the 96 players were active daily.

The total number of attacks made by the players was 16,137. The number of attacks by individual players ranged from one to 975. On average, the players attacked 168.09 times during the tournament, or almost exactly six times per day. However, when calculating the standard deviation from the data, it can be seen that the few outliers on the top influence the total number quite heavily: the standard deviation was over 169.

Perhaps, a better indicator on player activity would be the median, which was in this case 107.5 attacks during the four-week tournament. The daily average comes down to less than four attacks per day, which is a somewhat smaller number when considering player’s activity. In relation to the number of playing sessions, it seems that players captured perhaps a single access point during a playing session.
The most active players had quite naturally also the most wins. The number of attacks won ranged from 0 to 879 wins, and the number of attacks lost from 0 to 96 losses. When considering that some players used only one attack during the whole tournament, the largest win-percentage was 100%. The best “real” win-percentage was 93.33% with 255 attacks and 238 wins, whereas the average winning percentage was somewhat lower: 82.5%. It is still quite a large number, and it clearly shows that the emphasis of the game was clearly in capturing access points, not in defending them.

The number of active players per day can be found in Figure 19. It can be seen that the game caught on quite rapidly with the largest peak in daily players happening already during the first tournament week. After the first week, however, the popularity of the game suffered. During the last week, the highest number of active players per day was just above 30 daily players, or less than half from the peak in the first week. The teams presumably lost their motivation to play due to losing the “illusion of winnability”, i.e. they felt they could no longer surpass the leading team before the end of the tournament. The figure also tells us that, although the first weekend was still quite active, the playing ceased during the weekends.

When finding the average number of attacks per active player — also in Figure 19 — for the tournament’s duration, it can be seen that, even though the number of active players diminished to the end of the tournament, a player’s activity remained nearly constant throughout the tournament. In other words, the players that played the game throughout the tournament were nearly as active in the end as they were in the beginning.

![Figure 19: Number of active players and average number of attacks per player during the tournament, per game day.](image)

The hourly distribution of attacks during the four-week tournament is depicted in Figure 20. It can be clearly seen that there was some activity during the daytime, but come midnight when the daily points were starting to become an issue, the players activated. In fact, almost one third of all attacks performed during the tournament were done between the times of 23:00 and midnight. Thus, the game rules clearly work — however, they skew the game play and make the focus on capturing access points as close to midnight as possible.

Figure 21 depicts mobile sessions on September 15, 2009 from 23:30 to 00:00 in the university main campus area. Orange markers depict access points; larger markers
Figure 20: Number of attacks per hour during the tournament.

mean more sessions have passed through it (or them, in case there are multiple access points at certain coordinates). Blue lines indicate between which access points the sessions have travelled. It can be seen that during the half-hour period players have moved inside the university campus trying to capture access points, but also on the outside; there are some access points in the mobile sessions that are not accessible at night from the inside of the campus, but they can, however, be captured by trying to connect to them outside.

Figure 21: Mobile sessions in the university main Campus area at night.

On average, the amount of players’ experience points were 173.9. It translates to quite a strong player character, who can win undefended access points very easily; however, also in this case, the most active and thus the most successful players skew the average a bit to the higher side. The average number of experience gained from an
attack was 1.035, which is very near to the expected 1.0 average — see Appendix 1 for more information concerning the distribution of experience points per attack.

The average number of attacks per team was 520.55; here, as in individual statistics, the median number of 304 attacks per team could be a better indicator on team activity than the average, since the number of attacks per team ranged from one to 2,907. Again, the most active teams raise the average quite significantly. The number of attacks per player in a team ranges from one to 484 — it is easy to see that some teams were extremely active even as a whole and some tried the game once and then quit.

The top two teams in the tournament were by far the most active teams of all. The winning team (dubbed #1) and the runner-up (#2) together performed nearly 30 % out of all attacks during the tournament, while the top four teams performed almost half. Thus, only a few teams were responsible for most gaming actions in the game.

Relative proportions of hourly attacks for teams #1 and #2 can be seen in Figure 22. The figure gives some insight into their playing strategies. It seems that team #2 used some of its attacks already during the day, with a small peak a few hours before midnight. The team then stopped playing for a few hours before resuming nearer to midnight. Team #1, on the other hand, played almost solely during evening time, from 17.00 to midnight. As team #1 was more successful in the tournament, it can be concluded that its strategy for performing attacks was better than that of team #2.

A significant difference between the two teams’ strategies was also the choice of playing field. Table 6 shows the numbers of attacks by provider for both teams. Team #1 controlled the university with a vast amount of attacks used there, while team #2 was mostly in control of the access points in the city centre. Since the university is densely packed with access points, team #1 was able to use more attacks there than team #2 in the city — roaming from access point to another in outdoors environment can be difficult since the cell size is quite large compared to cell sizes indoors. Thus, even though in general individual access points at the city centre gave as much or even more points than their counterparts at the university, team #1 performed well by capturing large amounts of access points close to midnight.

Figure 23 shows the accumulated points for the eight best teams during the tournament. It shows a few interesting notions on how the tournament went. First, it can be seen that team #1 was the leader in scores during the whole tournament. Team #4 was following the winners closely for approximately two weeks, but after that their...
activity ground to halt; teams #2 and #3 surpassed team #4 during the last ten days of the tournament. The competition was stiff also between teams #5 to #8. At first, teams #7 and #8 had the upper hand, but #5 and #6 surpassed them after about two weeks. Teams #7 and #8 continued playing up until the end, but teams #5 and #6 stopped almost completely during the last week of the tournament. It can be accounted for also by the fact that team #4 had broken away from the pursuers, and teams #5 and #6 lost their illusion of winnability; they felt they could not do better, but neither were other teams threatening their places.

![Figure 23: Accumulated points for eight best teams.](image)

### 6.3. Changes in panOULU usage

One particular area of interest in studying the players was how their panOULU usage has changed while playing the game. The players were thus asked a few relevant questions regarding their use of panOULU network in August 2009 and in September 2009: before and during the tournament, respectively. Later on, the players were asked
to identify reasons for any changes in the network usage — both reasons related to playing the game and other reasons.

To study how the usage of panOULU changes when playing a pervasive game such as panOULU Conqueror, the players were asked their frequency of network use in August and in September 2009. The results for these questions are in Figure 24. It is easy to see from the figure that the players used panOULU network more frequently in September, during the game tournament, than in August before the tournament. This change is most likely due to the game: it was easier for a team to do well if the members used panOULU often. The rules were constructed so that extra attacks could be gained by visiting several access points; this gives incentive to use panOULU daily or at least almost daily. None of the players answering to the questionnaire used panOULU less frequently than once a week — an increase from the figures of August.

Figure 24: How often players used panOULU in August and September (questionnaire data).

Figure 25 shows the actual usage frequency numbers of all devices that have been used to play the game, as gathered from the log data. There were 80 devices that were used as gaming devices in September that were not seen in the panOULU network at all in August. Also, it should be noted the log data shows that a large number of players used the network more rarely than what was reflected in the answers to the questionnaire. This may be because the respondents were active players, and those players that were not particularly active in the game did not answer the questionnaire.

Mobile use — which was for simplicity’s sake defined in the questionnaire to be moving while using the network — is another topic worth researching: user mobility is becoming more and more common with new powerful mobile devices that have pervasive network access. panOULU network is a geographically large Layer 2 network which supports mobility by design; devices roam from access point to another seamlessly on the panOULU coverage area. Figure 26 tells us how mobile use has changed while playing a location-aware game that requires for the player to move. It is easy to see that the players were far more mobile during the game tournament phase than before it — over one third of the players were mobile at least four times out of five use sessions in September. The number reported by the respondents had almost tripled from August.

The numbers for mobile usage given by the respondents can be compared to actual log data from August and September. Figure 27 shows the numbers of mobile sessions
as gathered from log data, with the definition of mobile session being: a session is mobile, if it has passed through at least three different access points, two of which must be at least 50 meters apart. It can clearly be seen from the log data that most usage in August was quite stationary, whereas in September the use was more mobile among the players of the game.

The numbers reported by the questionnaire respondents seem to be exaggerated — most definitely one third of the players were not mobile at least 80 % of their use sessions. The differences may, however, be explained by the two different definitions of mobility: the definition given to the players was quite simple; whereas the definition used to get mobile sessions from the log data is more complicated.

When asked to identify reasons for any changes in mobile use, the most common answer was, unsurprisingly, playing the game. Some people told they had received a new mobile device that they use panOULU with, while others had started to leave WLAN turned on on their devices — presumably to associate to a number of access points in order to gain more attacks for the next day.

The mean number of different devices used in panOULU network by a single person during August was 1.56, i.e. most people used just one device and only six people more than two. In September, the average number of different devices used in the network was 1.89, a 21 percent increase. The mode changed from one device in August to
two devices in September, but in September, already 12 people used more than two
different devices in the network. From Figure 28 it is easy to see that WLAN capable
mobile phones, laptop computers and so-called netbook computers, were mainly used
among the players both in August and in September. Notable and somewhat surprising
is that the game was mostly played with phones and full-fledged laptop computers,
whereas netbooks were not so common. Before the tournament, it was thought that
netbooks that are considerably smaller and easier to use while moving than average
laptops would be at the same commonality level as phones and laptops — the game
user interface was even designed with small-screen netbooks in mind. The “Other”
category included portable gaming consoles such as Playstation Portable and Nintendo
DS, as well as a Linksys WRT54GL WLAN access point.

When asked simply whether the use of panOULU Conqueror increased or decreased
one’s panOULU usage in September in general, 84 % replied that playing the game
increased or somewhat increased their panOULU usage. No players answered that
playing the game decreased their panOULU usage. Figure 29a shows the increase
because of the game and any other possible factors, respectively. Figure 29b instead
compares the increase in panOULU usage due to playing the game to changes in the
usage due to other possible factors. It is easy to see that for most people the game did
not have any meaningful change in other uses of panOULU, but it also suggests that for some players playing did in fact increase use times of the network also in general.

![Changes in panOULU usage due to reasons other than playing](image1)

(a) Changes in panOULU usage due to playing the game and other reasons.

![Changes in other panOULU usage when panOULU usage had increased due to playing the game](image2)

(b) Changes in other panOULU usage when panOULU usage had increased due to playing the game.

Figure 29: Increases and decreases in panOULU usage.

The players were also asked to identify reasons for the changes in their panOULU use, other than playing the game. The most common reason was that during September it was possible to use panOULU in a school or work environment, when in August it was not possible. Some people reported that they had received a new WLAN capable device that warrants some use. One player reported that because of the game he now knows where panOULU works, and thus can use it in new places.

6.4. Positioning and pervasiveness

In the questionnaire, the players were asked whether spatial elements represented in the game user interface, such as the game map, location of access points, current location of other players and a listing of nearby access points, were relevant to the gaming experience. Almost everyone, or 55 participants, answered that the elements mentioned above were an integral part of playing the game. Two people disagreed. It can be argued that the game itself would be playable even without a map and information where other people are — the simplest user interface used automatically with less powerful
mobile phones does actually that — but for full gaming experience, spatial elements in the user interface seem to be important.

A source of controversy during the testing phase and the tournament was the positioning engine, or its malfunctions. Thus, it became necessary to ask whether this type of WLAN access point ID positioning method was suitable, i.e. did it work and to what accuracy. Figure 30 shows the results of questions concerning the functionality and accuracy of the positioning engine. It seems that the players were quite satisfied with how the positioning worked, as almost all participants answered that the positioning worked always or at least often. A few said that positioning worked rarely, and one said it had never worked.

The accuracy of positioning was not deemed to be very accurate, as can be expected when WLAN positioning is considered; in panOULU’s case, it is possible to hear several access points in one location, making the positioning both difficult and inaccurate. For most of the players, the accuracy was accurate often or rarely, and only about a fourth of the players thought the positioning was accurate always. During the tournament, there were some problems with the logging parser responsible for finding the players by sifting through the panOULU network logging data, which caused problems, especially with the accuracy: for some time, the players received positioning information from several minutes, or in one case, several hours ago. The logging parser was fixed before the end of the tournament and the messages received concerning positioning problems stopped.

The pervasiveness of the game is also one very interesting topic. Out of the 57 players answering the questionnaire altogether 41 of the participants (72 %), considered the game to be pervasive, when pervasiveness was defined to be that of real world affecting the game world, or in lesser scale, the game world affecting the real world. During the tournament, a few players gave some remarks on the latter part of the defined pervasiveness, however: people reported seeing other players walking by using their mobile and not minding anything but the game. At least on one instance, a policeman had come to ask a player what she was doing when she hung out near the police station trying to capture some access point.

Pervasiveness as a measure of the game world’s existence in the complete spatial world even in the city area was, however, not of particular interest; a known fact is that
panOULU network works only in certain areas, and it is only possible to play in offline mode when not using panOULU network.

6.5. Best and worst aspects of the game

The best and worst parts of the game according to the questionnaire participants are depicted in Figure 31. It can be easily seen that location awareness, social aspects and pervasiveness were by far the best parts of the game. Due to the nature of the game — it being a location-based pervasive game that is played in teams — all these results were quite expected. What was a little unexpected was the addictive nature of the game: several people considered addictivity to be the best part of the game. Thus, it can be argued that the game idea, even though being quite simple in nature, is quite good and well received by the players.

On the negative side, rules, functionality and user interface were the parts of the game users disliked the most. Especially the rule that points were given out only once per day, at midnight, was disliked by many. In addition to specifying rules as a disliked item in the list, some answers in the “Other” category also considered the scoring rule to be unfair; the rule got also a lot of feedback before and during the tournament. The second largest dislike was functionality, or the lack of it. It can be considered that the user interface is also a part of functionality in this sense: the UI had its share of bugs and it missed some important features like a map for the mobile UI. Thus, functionality and user interface being the second most disliked components of the game were not a great surprise.

![Figure 31: Best and worst parts of the game.](image)

The players were also asked whether playing the game was meaningful or casual, i.e. did the players play the game just for playing the game, or was the playing simply a by-product of doing something else. One half of the players played the game in a meaningful or mostly meaningful way, while one fifth played mostly casually. The rest, 30% of the players responded that they played half-and-half, i.e. both casual and meaningful playing alike. The amount of meaningful playing is quite interesting, as it suggests the game is addictive, and especially that the players were committed to playing the tournament to the fullest. Most mobile games so far are simple ways to spend some time while idling, but not as a special activity that requires long-term
concentration — panOULU Conqueror seems to be in the class of multiplayer online games that need constant attention.

Respondents were also asked how often and in which ways did they communicate to other players about the events and happenings in the game. Most of the players, or 84% of them, communicated with their own team at least weekly, with over half of the players messaging their own team at least every other day. On the other hand, players communicated about the game with other people than their team members much less; only 44% of the players communicated with other people at least every week. It seems that at least the most active teams had to communicate with each other in order to agree upon a strategy; or when and where they should meet and try to capture access points. Favourite methods of communication between the players were, in this order: face to face meetings, Internet Relay Chat (IRC), game internal chat, phone conversations, and SMS’s.

It should also be noted that, when asked whether playing the game increased one’s sense of communality, a total of 49% of the people thought that the game increased their sense of communality, 44% thought otherwise, and 7% gave no answer. The increased sense of communality, or in other words the feeling of being part of a team, could be seen as coming from the teams that were the most active: their communications with each other were much more frequent than those who did not feel that their sense of communality had increased, as can be seen from Figure 32.

![Figure 32: Sense of communality and communication frequency.](image)

The players were also asked to give verbal feedback in the questionnaire. Players’ comments, criticisms and ideas for improvements gathered from the questionnaire as well as from other sources are discussed in section 6.7.

### 6.6. Focus group interview

To gain more understanding into what the players thought of the game, a focus group interview session was decided to be organized. After the tournament, the members of top three teams, altogether 18 people, were invited to a session to share their feelings and discuss the game. Of the 18 invited people ten did come — a suitable number for the focus group session, which typically has from six up to twelve participants.
The purpose of the focus group interview was to find out what made the members of the three teams become inspired by the game; what kind of other games do they enjoy to play and what kind of hobbies they may have; how the pervasiveness of the game was manifested and what it meant for the players; and how would the players make the game more rewarding.

Focus group participants were all from the two best teams: all six people from the winning team, and four from the team in the second place. The top two teams were by far the most active teams during the tournament. Members of the team placed third were also invited to join the session since they started very actively, but dropped out before the end of the tournament. It was a small disappointment that none of the third team members came: they could have given some insight also into why they lost interest and decided to stop playing the game.

All ten interviewees were male and in their twenties, and all of them studied at the University of Oulu. Most of them were originally from the Oulu region, with two people from Lapland and two from central Finland. The interviewees enjoyed various kinds of games: various (usually multiplayer) computer games, console gaming, board games and sports. No one gaming genre was common between all the participants, but two people said they don not play games at all except for panOULU Conqueror.

When asked the main motivators to play the game, several people answered that it was good exercise to walk around the university campus or the city centre. Almost everyone also said that the idea was fresh and interesting, and that the game was very social: players got to meet friends and beat other teams in which their other friends were playing. The game was compared to geocaching, where people use GPS receivers to search for objects that other geocachers have hidden, and leave their mark in the accompanying booklet.

Pervasiveness was a big topic during the interview. The participants were asked the ways in which the game was linked to the everyday world and how the normal world was entwined to the game. Some people changed their daily routes just to find some new access points and to capture them; for example, when going from a lecture hall to another at the university, one could take a detour through another hallway even though the detour is much longer than the straight route. But there could be several access points to capture on the way. Another way the everyday world was linked to the game was that people kept checking who had captured which access point, and what strategy should they use to get the access points captured themselves. Also, people left their cellular phones connected to the panOULU network during the day just to gain more attacks for the next day.

Real world was seen in the game very clearly in the form of points gained from the access points: players knew where most people were using panOULU and learned to capture those access points near midnight daily. However, it was mostly in vain to come and capture access points in the university during weekends, as the hallways were empty most of the time, and thus the number of users on the access points stayed small. The game gave a good perception on where people roamed and when. At some point of the game, the changes in access point strength by the clients associated to it became irrelevant, since it was easy to gain so much experience that the small changes in access point defensive strength made very little difference anymore.

The participants got excited when the topic was changed to making the game better. In general, the interviewees hoped for more tactical elements to the game to make
the game more challenging. Thus most ideas were concerned on creating more challenge to the game, for example by incorporating nearby access points into one larger collection, which could function as one entity. That entity could then be captured by a team working together. The attack would happen with some delay, so that the defending team would have time to come by and try to defend the entity. One common request was to have some sorts of quests, where players could gain extra points or new features for themselves or for the team. For example, a quest could be to capture ten access points in a given time. Quests could also be team quests, where a larger amount of people performing the quest would help the team as a whole.

Large displays that were installed in the city centre some time before the tournament were also discussed. The focus group participants thought they could be used to show some information about the teams and the state of game play, or as a part of the game by ordering “bombardments” to some area. The displays could also be used to get some quests: this could work also to lure new players to try the game, by giving them simple quests to perform. To give players incentive to move outside the university, some people hoped that a tournament could be held also in the summer, when it is easier for players to travel to the city centre.

6.7. Feedback

During and after the tournament, players gave feedback from the game. Most of the feedback during the four weeks related to malfunctions in the game, most often in positioning. The positioning engine was fixed and tuned a few times in the first two weeks, and during the last two weeks it seemed to be fixed — or at least people no more complained it was broken. There were also some other smaller problems with the game which were mostly fixed during the tournament.

A source of controversy both during and after the tournament was the scoring system. Players were dissatisfied with the rule that points were given out to the team owning the access point at midnight. Several people suggested that the scores should be handed out in a different way — perhaps by dividing the daily point total so that each team that owned the access point gets a slice, or simply giving out points more than once per day. This is a fact that needs to be addressed in the future: almost everyone writing verbal feedback to the questionnaire form complained about the scoring.

Another prominent topic in the feedback was the lack of motivation. The tournament was considered to be too long and the few extremely active teams made it impossible for others to win the tournament. Those were a few reasons why people stopped playing the game at some point. Some people also wanted more objectives, simply attacking and defending access points did not seem to motivate them enough. Some of the ideas mentioned in the focus group interview came up also in the questionnaire feedback, such as quests and bombardments.

The university was seen as too superior a place to play the game. There are a few hundred access points in the university campus, and usually, they have a lot of users, so this concern seems to be justified. Players suggested that there should be also ways to get people out of the university to play the game, such as honey pots with large amounts of points around the city.
Defending access points was seen as a thing that simply did not work. Some people saw that there was no reward in defending access points, as you might as easily capture it back. This and the fact that at some point, for any active player, it was almost a certainty to win some attack, should again be taken into account when considering the future of the game.

As a somewhat positive criticism, the idea for the game was considered good, innovative and fun by many of the players. Most of them also said that the implementation was average, and there were far too many bugs and problems to fully enjoy the game. However, some people liked even the atmosphere of the upcoming midnight scoring moment, as it was possible to see a lot of players running around in the university and in the city centre trying to capture as many access points as possible.

To sum up, the game was deemed to have its share of even severe problems, but generally, people liked the idea and would like to play it again in the future — if it is better than it was during the tournament.

6.8. User evaluation results

The user survey conducted for the tournament participants gave a few surprises. First of them was the gender distribution of the questionnaire respondents: only three of the 57 people were female. This issue raises some questions like whether the game is somehow too technical for the female players, or if the concept of the game relates only to men? Without further investigations into the subject these questions are almost impossible to answer. The object was to create a game playable by both genders alike — apparently this has failed to some degree.

Age distribution of the questionnaire respondents was not, however, a great surprise. The average age was 24 years and the median age 25 years, so the game seems to interest mostly young people. One reason might be that younger people are more savvy technology users and they are more likely own capable mobile devices with WLAN capabilities than older people. Also, the press release of the game was distributed in the university students’ mailing lists, and university students tend to be young. Due to the press release not being printed in almost any of the local newspapers, it is no surprise the average age of the players was so low.

There were also some changes in the network usage of the participants. It seems like in some cases playing the game also produced an increase in other uses of panOULU network, possibly because the players were more aware of the locations where panOULU can be used. It was not universal, though: most people did not change their use patterns of panOULU, and only three people reported that their other panOULU use had decreased due to playing the game. Mobile use on the other hand increased because of playing the game, which was to be expected. The most important realization is, however, that playing the game made many people more aware of the existence of the network.

The game was mostly deemed pervasive, but over a quarter of the respondents did not think so. This warrants the question addressed also in Chapter 7: should the game include more pervasive elements in order to immerse the players more deeply into the game world? Some players thought that because of badly functioning positioning the game was not as addictive as it could have been — the magic circle was thus broken.
There is a need to find a more robust way of positioning the users with using only the network’s services, or to at least make the current method more robust. But there still remains the problem with some access points — especially the mesh network at the city centre — that makes positioning difficult in those areas.

Considering the social aspects of the game, it can be noted that the game had some effect even on some participants’ social lives. A few players were addicted by the game to the point where they would neglect sleep in order to capture as many access points as possible close to midnight. Not all felt this way, naturally, but several others described it to be addictive as well. The way the players played the game was mostly meaningful, i.e. the game was played as the only activity, instead of on the side of doing something entirely else. The amount of casual playing should be increased somehow, perhaps by making the game give more instant rewards in the form of points, instead of making the players wait until the midnight, so that the players should not need to think only about winning the tournament.

Players were also keen on communicating about the game. Communication methods inside the game should be considered with more detail in the future, as the internal chat function lagged and was quite buggy.
7. DISCUSSION

panOULU Conqueror, or Conqueror for short, is a pervasive game that shares some characteristics with other pervasive games described in section 3.6. For instance, the game uses a WLAN network for data transfer, like several other games do also. Some even use ad-hoc WLAN networks between gaming devices, but for the rest, cellular data is used as their method of connecting to the game servers. Thus, Conqueror falls in the line of other pervasive games as for the use of networks as part of the game.

When thinking of the four axes of pervasive gaming and the pervasive gaming possibility space by Walther [14] (see Figure 3 on page 20), panOULU Conqueror can easily be classified as a pervasive game. The game uses mobile devices with wireless networking to enable easy always-on and unobtrusive access to the resources in the network. Mobility is a key point in the game: it is played with mobile devices, it employs WLAN networks, and it allows user mobility. The game world is also available at all times. Transmediality can be thought of as allowing users to produce their own content — the game does not fully support transmediality, but the user community that was formed around the game did endorse it by, for example, creating some fan art. Thus, Conqueror sits in the middle of the pervasive gaming possibility space, allowing it to be one of the few completely pervasive games according to this definition.

Several pervasive games use positioning information as their primary source of contextual information — so does Conqueror. What is different, however, is that the other games use primarily GPS positioning, while Conqueror employs WLAN AP-ID positioning. This makes the developed game a novel example of a pervasive location-based game.

Most pervasive games need some client software running on a mobile platform for the player to be able to play the game. panOULU Conqueror uses simple web pages to enable game play, as do only “King of Location” [21] and “Team Exploration” [53] from the ten prime examples of pervasive games presented in section 3.6. It is rare to use web pages instead of a piece of dedicated client software because gaining the contextual information and feeding it to the game servers always requires some sort of client software; in the case of Conqueror, the network instead of the client device takes care of gathering the necessary information for playing the game.

There are some forms of uncertainty present in Conqueror. The foremost source of uncertainty is the positioning method used. Even though WLAN AP-ID positioning works both outdoors and indoors while, e.g. GPS has difficulties indoors, it is far from perfect: an access point may not send an association message to the log server, or the message may never arrive; the positioning is always mostly proximity positioning instead of accurate positioning; and there is always some delay when representing positioning changes to a player. Thus, from the choices presented by Benford [47], the game chooses to show uncertainty by letting the players know what is happening, by for example spinning a wheel on the user interface when the user’s location cannot be found. It is thus expected that the players are aware of this uncertainty, and choose to work around it. The players understood the uncertainty factors quite well and found solutions to its effects: even though the players thought that positioning was not always functional or accurate, it did not lessen the value of the game.

The game utilizes the nearly pervasive open and free-to-use panOULU WLAN network for network connections, as well as for positioning. This and the permanent game network...
world make the game pervasive by definition. However, the meaning of pervasiveness for Conqueror is diminished because the game uses the pervasive elements only minimally, as is somewhat reflected by the answers to the questionnaire: almost a third of the questionnaire participants thought the game was not pervasive. To emphasize the pervasiveness in the game, it should possibly make use of some more pervasive elements, such as using cameras and sensor networks. In addition, the role of the users as media content producers, transformers and recirculators went mostly unused; the players were not able to directly affect the game’s content, even though they may have wanted to.

panOULU Conqueror uses the players’ locations as contextual information, but also some other data such as the number of current users of an access point, and also the total number of different users in an access point for a given day. Using location is the most common way to use context when designing pervasive games. Some games also employ cameras and possibly even sensor networks to accumulate contextual information, to deepen the immersive effect of the pervasive game world. This is something that panOULU Conqueror should possibly look into in the future; how to create a pervasive game world that changes every time the user does something — anything — so that every action counts. To make better use of available contextual information is a challenge. Some examples of possible future ideas for increased use of context-awareness in Conqueror may be found in section 7.2.

Interaction, both between a player and the gaming server, and between players, is important. When playing Conqueror, the players interact with the game in only some small ways: by attacking access points and by positioning themselves. Most of the gaming interaction is left in the background, so that it does not confuse the players. However, the players interact with each other to make the game a better game. The players communicate with each other; they even play team against team in the middle of the night. Results of the questionnaire show that the more the players interact and socialise with each other, the more successful they seem to be at the game. Thus, interaction is a key component to successful pervasive gaming.

One may wonder whether the game would work better if the positioning was done with a more accurate positioning method, such as the GPS, instead of relying on simple proximity-based positioning. The game would unarguably be different: it would require dedicated client software for positioning and perhaps also for finding access points nearby. It would also be hard to play the game indoors, as GPS coverage is somewhat limited inside a building. In short, it would change the pervasive aspect of the game from mixed indoors-outdoors scenario to a purely outdoor game. On the other hand, it would be possible to expand the game — now the playing area is limited to the coverage area of the panOULU network, but with GPS, it could be possible to hunt and attack access points anywhere.

panOULU Conqueror is also a good example of a game which employs mobility as a core game mechanic. Some players even hopped on a bike and rode around the city to capture as many access points as possible. Players, after capturing the obvious access points nearby, reported they wanted to find some more to attack, and thus needed to travel around looking for new access points to play with. It could be possible to take advantage of tracing the users’ mobility patterns, for example to speed up the positioning, and perhaps to create some more contextual information related to an individual person for the game’s use.
The game also changed the player’s panOULU usage, as can be seen from both the quantitative log data and the qualitative questionnaire data. When looking at the usage frequency of the network — both log and questionnaire data — it can be seen that the players used the network more often during the tournament than before it. Mobile usage of the network increased also, but with a clear bias in the questionnaire data: respondents thought they were more mobile than they actually were. It can also be seen that, in most cases, playing the game resulted in increased use of the network. Thus, it can be generalized that playing a pervasive game in a city-wide wireless network increases the players’ use frequency of the network, as well as both mobile and overall usage.

7.1. Game development

When designing games, it is important to have good guidelines and instructions. In the case of pervasive games, this is unfortunately not the case. It has been noted that the “traditional” game design methods do not apply for pervasive games — most, if not all literature in game design considers mostly basic computer games. There are exceptions, of course, but even they take only mobile-interfaced games into account. Thus, pervasive game designers have to make do with what other creators of pervasive games have exposed, which is not very much. This has made the game design process for panOULU Conqueror slow and tedious, with a lot of complications to sidestep.

Game rules design is that of thought and consideration. In the case of Conqueror, the rules were mostly good — or at least they did not hinder the playing experience much. There were, however, a few rules that would have needed some more evaluation iterations before being exposed to a large crowd of players. One example is the scoring rule, where scores are calculated once per day, and the team owning an access point at the scoring time receives all points for it. Had it been discussed thoroughly before the tournament, it could have been changed on time. Now, it was decided that the rules should not be changed during the tournament.

Some challenges also arose during the implementation phase of the game. One main problem was to make the game work with as many devices as possible, in order to maximise the number of potential players. At first, only two different user interface layouts — the desktop UI and the mobile UI — were to be made, but after encountering severe problems with the jQuery JavaScript library and some common Nokia brand mobile phones, it was decided that a third user interface dubbed “simple mobile UI” needed to be made. This interface removed the mobile map, required a minimal subset of jQuery functionality, and did not use any animations provided by the jQuery library. This came with the unwanted side effect of duplicating functionality in the user interface side, which caused a lot of extra work. The mobile map was also left unfinished: it caused some performance regression with the mobile devices, i.e. it made the user interface feel lagging, and it was also hard to get all the required map functionality to work before the start of the tournament. Thus, it was decided that it should remain unfinished.

During the tournament, there were some technical problems that did not have anything to do with the game itself, but which nevertheless affected the gaming experience of the players. First of all, the logging daemon responsible for keeping track of clients
broke down a few times during the tournament. It caused the positioning engine to fail for some time, so the players could not get updated positions. There were also some access points missing from panOULU database, which caused problems to those who tried to attack them. This includes the whole panOULUseutu network, which is a regional expansion of the panOULU network that was being installed during the tournament. The third problem was related to the mesh topology WLAN network at the city centre which, while working as usual, did not always allow the user to be positioned. The exact reason for that behaviour is still unknown.

Positioning the players had also its share of challenges. Usually, the positioning process was slow — it could take up to 30 seconds after roaming for the current location to be updated on the player’s device. The locationing is near-instantaneous on server-side, but due to a limited amount of processing power on the logging server, the positioning service cannot poll the server every second. The method chosen for querying for an updated position was chosen to be client pull, which is easy to implement with timers and call-backs. Server push could have been better, so that the server would let the client know whenever there is a change in the player’s position — implementing it would, however, have been impractical and tricky.

Mobile devices in general have only a limited amount of battery power. The more a player plays the game, i.e. uses the device’s WLAN capabilities and keeps the screen lit up, the more it consumes the battery. The sheer amount of broadcast traffic in the whole panOULU network was sure to keep the WLAN adapter up and running, effectively disabling any power saving methods the adapters may have. Thus, playing the game for an extended period of time was hard.

7.2. Future work

There are several things that would need some more work in order to make the game more enjoyable for the players. The first and foremost is the evolution of the game’s rules. The scoring system was not considered to be very good, so that needs quite a lot of improvement. For example, it could be possible to calculate points each time an access point is captured, so that the losing team gains points at that point — if some access point is not captured away from the owning team, the team would still get points at midnight.

Increased use of context-awareness in the game would also be a welcome addition. At the least, other users of the network should effect the playing more than they do now. By capturing an access point, the team could get bonus points by the number of users in that access point at the moment. Capturing the access point would also be harder the more users (perhaps they could be called “inhabitants”) there are, to make the game more balanced. The effects that time, weather and perhaps other sources of contextual information could have on the game should also be investigated.

Some players considered the number of extra attacks a player could gain by visiting several access points to be too large. When some players have only a few attacks per day and others may have well over a hundred, something needs to be done. One suggestion was that the number of extra attacks could follow a logarithmic scale, so that instead of receiving a hundred attacks by visiting two hundred access points, the player could receive maybe ten.
The appearance of the game was also somewhat the engineering kind, i.e. quite complex and in clear need of a designer’s touch. In the future it could be possible to enhance the appearance of the game, for example by getting a graphic artist to do her thesis on the subject, or something similar. What are also needed are multimedia elements: the game should have some animations and even sound effects. Also the use of UBI Displays located at the city centre for gaming purposes should be investigated.

panOULU Conqueror should also include more meaningful content to make the game less boring and repetitive. For example, some location-based missions that could be picked up from the UBI Displays would make the game more fun. There needs to be also room for some sort of advancements for the players’ characters. They could be more like characters in role-playing games so that they would have different abilities. When gaining experience through winning attacks, the experience could be used to enhance some ability over another: one player could have very strong attack skills, but very low defensive power; some other could gain extra attacks every day, and so forth. This would add meaningfulness to the game, and it would probably attract more players.

Other ideas to add to the game include combining several access points in one place to one super access point, which would be harder to capture, but would yield large amounts of points for the owner. Also mines, traps and extra weaponry to defend or attack access points more effectively were suggested. An interesting idea is to allow teams to ally themselves with other teams in order to defeat a stronger team — during the tournament, it was almost impossible to beat the leading team by one single team on any given day, but it would have been possible if teams would have allied themselves against the one team controlling most of the university access points.

The game should also employ better methods for communication, since communication between the players is a key factor in good performance. Thus, at least person-to-person chat should be added to the game, and to enable more communality, it could be possible to chat in a group with all players from all teams. IRC integration was considered at some point; it would enable even outside people to participate in the game communications, but it would make the communication system more complex, and it would also add another server machine to the requirements of the game. Push-to-talk was also discussed, however, it may be impossible to realize with JavaScript only.

To enable players to make their own versions of the gaming software, a documented API of the game’s public methods should be created. The API should make use of JavaScript Object Notation (JSON) to make it easier to handle complex data structures in the client software. To make it easier to create game clients with other languages than JavaScript, also Web Service Definition Language (WSDL) could be used to expose the remote-callable methods in XML form. These advancements could allow for example automatic playing software which, when the player is moving around, would attack each access point it can.

Commercialization the game has also been discussed. It should however be researched in more detail to find the commercial potential of the game: a technical feasibility study should be conducted in order to see what and how much resources a commercial version would require, and a quantitative market analysis to see if markets for such a game exists. To generate revenue, some networked games allow players to buy, for example, more power and better weapons with real money — the same ideas could be applied to Conqueror as well, but it could also make the game imbalanced.
Pervasive gaming can be understood from either technological or cultural perspectives. The technological perspective offers three dimensions of pervasive gaming: mobile, place-independent game play; integration of real and virtual worlds; and social interaction between players. The cultural perspective regards pervasive playing to be mainly a social gaming process.

Interaction and context-awareness are important aspects in current pervasive games. Interaction is often related to the pervasive embedded computing environment with which the users interact, as well as to social gaming and storytelling. Most pervasive games also use contextual information to enhance the game play; pervasive gaming worlds try to combine both the virtual and the real worlds together. This game world often needs input from the real world to make the game world immersive to the players.

An often-used source of contextual information is positioning. The most used positioning method in pervasive games is GPS, which usually limits the game to be played only outdoors. Other positioning methods include WLAN AP-ID positioning, which is employed with panOULU Conqueror. Pervasive games in general need to have also some sort of network connectivity; usually either WLAN or 3G networking is used.

The game introduced in this thesis should be easy to join and easy to play both casually and meaningfully. It should appeal to a wide variety of people: both male and female, from youngsters to elders. The only thing that is needed to play the game is a WLAN capable device with some web browser installed on it.

Remembering the foundations of game design and the goals for this particular game, Conqueror was designed to be a multiplayer mobile game played in teams with the goal of capturing as many access points as possible, and keeping them until midnight, when they would be scored. An overview of the game was written, its elements and mechanics described, and the rules constructed. Also the use of positioning in the game was explained.

After the game design, the game software design was done. The software was implemented using the model-view-controller paradigm to separate the content from the logic. Conqueror models and controllers were written with the PHP programming language, while views were mostly HTML and JavaScript.

To be able to study the effect that a pervasive location-based mobile game has on its players, a month-long tournament was held. After that, the participants were asked to fill in a user questionnaire which was focused on finding out how playing the game affects the players’ usage patterns, how the players feel about pervasiveness and location-awareness, and what are the social aspects and impacts of the game. Further, a small group of the most active players were interviewed to gain some more insight into how the players feel about the game. The user survey results were analysed along with some statistical data.

Analysing the data and the subsequent results shows that the game was a successful mobile pervasive game that employs positioning as its source for contextual information. Designing and implementing the game took time and the result is not perfect; there were several challenges, including technical problems with several mobile handsets. In the end, the game was quite playable, and the users even gave some good ideas for future enhancements.
It is thus possible to create a usable and addictive pervasive location-based game by using a large open and free-to-use WLAN network infrastructure for positioning and for data transfer. A complete pervasive game world is, however, hard to achieve, since the panOULU network cannot be used absolutely everywhere around the city. It can be left open for discussion whether it would be better to simply create some game client software for some selected mobile terminal which would use 3G networking for data transfer, but would still allow access point capturing with ease — however, this would be quite a different game.

Unlike most other pervasive context-aware games that employ location as the main contextual information, panOULU Conqueror shows that GPS is not required for fun pervasive gaming; instead, other positioning methods can be used. The fact that Conqueror uses WLAN AP-ID positioning only widens the amount of possible mobile handsets the players can use to play the game, thus, widening the potential player base.

It can also be shown that a web browser can function as a game software client with relative ease even for a pervasive location-based game. However, there have been some compatibility problems with the browsers’ JavaScript implementations, especially in mobile phones, but as the technology matures, these kinds of problems should disappear. There is no real need for a dedicated piece of software to function as a gaming client. Creation and distribution of such a client to more than one device is hard: there is a need to create a version to every major smart phone operating system, and also a version that can be played with mobile computers. Thus, regarding compatibility, the web browser is the best solution.

Pervasive games are new to most people. It seems that people get excited about games that are versatile and well-made — some even get addicted to them. panOULU Conqueror is an innovative and novel multiplayer game. It is also different from all other pervasive games. It must be reminded, though, that the quality of the game is of utmost importance when trying to get people to play it. Bad games just frustrate people and make them stop playing. Although some people stopped playing the game after an initial round of testing, panOULU Conqueror can still be considered successful: people felt different emotions while playing the game, and most of the players that started the tournament played quite actively.
9. REFERENCES


## 10. APPENDICES

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>panOULU Conqueror rules</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>User questionnaire form</td>
<td>95</td>
</tr>
<tr>
<td>3</td>
<td>Licensed images presented in this thesis</td>
<td>105</td>
</tr>
</tbody>
</table>
APPENDIX 1: PANOUULU CONQUEROR RULES

1. Terms

The terms which are used in the rules are listed and explained in Table 1.

<table>
<thead>
<tr>
<th>Term</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active playing</td>
<td>being logged in the game while using panOULU network</td>
</tr>
<tr>
<td>AP</td>
<td>access point</td>
</tr>
<tr>
<td>Ascending</td>
<td>gaining an extra level by collecting enough experience points</td>
</tr>
<tr>
<td>Attack</td>
<td>an active action to capture a neutral or a hostile AP to one’s team</td>
</tr>
<tr>
<td>Attack point</td>
<td>the number of attacks a player may have per day, depends on the level</td>
</tr>
<tr>
<td>Defend</td>
<td>a passive action to prevent the capture of a friendly AP by an opposing team</td>
</tr>
<tr>
<td>Friendly AP</td>
<td>an AP which is owned by the player’s team</td>
</tr>
<tr>
<td>Hostile AP</td>
<td>an AP which is owned by an opposing team</td>
</tr>
<tr>
<td>Level</td>
<td>a number indicating player’s strength and attack points</td>
</tr>
<tr>
<td>Neutral AP</td>
<td>an AP which is not owned by anyone</td>
</tr>
<tr>
<td>Offline playing</td>
<td>playing the game outside panOULU network</td>
</tr>
<tr>
<td>Passive playing</td>
<td>using panOULU network but not being logged in the game</td>
</tr>
<tr>
<td>Strength</td>
<td>a number indicating player’s attack and defence strength</td>
</tr>
<tr>
<td>XP</td>
<td>experience point, gained by capturing AP’s</td>
</tr>
</tbody>
</table>

2. Preliminary actions

Every player must register to the game before she starts to play. The required pieces of information are full name, nick name, e-mail address, team, and password. After a successfully completed registration the player may play the game. To play the game actively the player must log in to the game website while using panOULU. After the player logs out of the website, she becomes a passive player for as long as she remains in panOULU network.

3. Teams

There are initially two teams in the game. Any player can create a team. A player must join a team during registration phase. If the player later wishes to switch to some other team, she may do so, but her character will lose one half (rounded up) of all previously gained experience, and thus some levels. When a player creates a new team, she will be automatically transferred to that team. No loss of experience happens in this case.
4. Moving

A player may move in the game by physically moving around so that her gaming device associates with some other AP than the current one. The game detects the movement within one minute after the association and reports the current location to the player. She may also manually refresh her location; there is no need to wait for automatic detection. If the physical location of the AP is not known, the player may not attack or defend it. A player may see the location of herself as well as the location of other players in a map to help her decide which AP she should move to.

There is always some randomness in roaming from one access point to another if there are several access points to roam to. In panOULU network a client radio is usually able to hear several access points, all of which the client may connect to next. This means that by physically moving, the player is not guaranteed to move exactly to the access point of her choice.

5. Attacking

An active player may attack an access point if and only if the following preconditions are met:

- the AP is either a hostile or a neutral access point
- the player has at least one attack point left for the day

When a player attacks any AP, an attack point is subtracted from her. If a player gains control of a neutral AP, she gains one (1) XP. If a player wins an attack against a hostile AP and gains control of it, she gains a minimum of one (1) XP and a maximum of five (5) XP. This is determined on how large the winning odds are, as can be seen from Table 2:

Table 2: Winning odds and experience

<table>
<thead>
<tr>
<th>Winning odds</th>
<th>XP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-19.9 %</td>
<td>5</td>
</tr>
<tr>
<td>20.0-39.9 %</td>
<td>4</td>
</tr>
<tr>
<td>40.0-59.9 %</td>
<td>3</td>
</tr>
<tr>
<td>60.0-79.9 %</td>
<td>2</td>
</tr>
<tr>
<td>80.0-100.0 %</td>
<td>1</td>
</tr>
</tbody>
</table>

If the attack is unsuccessful, the player gains no XP.

Other friendly players currently using the AP affect the attacking the following way: each friendly player using the AP under attack gives the attacker a 20% boost to her strength. Maximum boost for any given attack is 100%, which can be gained by having five or more friendly players using the access point at the time of the attack.
6. Defending

An AP is defended in the following way:

- an active or a passive friendly player is connected to the AP: defensive strength equals 1 + her strength divided by 2
- several active or passive friendly players are connected to the AP: defensive strength equals 1 + their strengths added and then divided by 2
- offline players’ avatar is assigned to defend the AP: a quarter of that player’s strength is added to the defensive strength of the access point
- no friendly players are assigned or connected to the AP: defensive strength equals 1
- additionally, every client connected to the AP who is not a friendly player nor the attacks adds 0.1 to the defensive strength

7. Determining the winner of a fight

The winner of a fight is determined the following way (A is the attacker’s strength, D is the defenders’ strength, R is a random number between 0 and 1):

$$R > \frac{A}{A + D}$$

Winner is the attacker if R is greater than the right side of the equation. Otherwise the defender wins.

8. Levels

A player ascends a level automatically when she has gained enough XP to warrant ascension. If the player ascends a level, she will be able to use the possible increases in strength immediately, if she has attacks left for the day. The levels are listed in Table 3.

Level 11 can not be achieved by normal players. It is reserved for administration use only.

A player may also receive extra attacks if she has used panOULU on the previous day. The amount of extra attacks equals the number of visited access points on the previous day divided by two, rounded up. These extra attacks are not conserved.

9. Random events

The game includes random events. There are several distinct random events. Some of them can happen to a player, and some can happen to an AP controlled by a team. The random events can be found from Table 4.
Table 3: Levels

<table>
<thead>
<tr>
<th>Level</th>
<th>XP required</th>
<th>Strength</th>
<th>Attacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>75</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>105</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>140</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>9</td>
<td>180</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td>225</td>
<td>23</td>
<td>15</td>
</tr>
<tr>
<td>11</td>
<td>1000000</td>
<td>201</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 4: Random events in the game

<table>
<thead>
<tr>
<th>Random event</th>
<th>Explanation</th>
<th>Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golden AP</td>
<td>An AP gives twice the normal points for the day</td>
<td>AP</td>
</tr>
<tr>
<td>Plague</td>
<td>An AP and all other AP’s within 50 meter radius give no points for the day the plague hit</td>
<td>multiple AP’s</td>
</tr>
<tr>
<td>Revolt</td>
<td>An AP switches sides to some other team</td>
<td>AP</td>
</tr>
<tr>
<td>Immutability</td>
<td>An AP cannot be captured from the team currently holding it today</td>
<td>AP</td>
</tr>
<tr>
<td>Divinity</td>
<td>The player wins the next attack or defensive action today with the probability of 1, regardless of the amount of defensive or attack strength the opposing team has</td>
<td>Player</td>
</tr>
<tr>
<td>Sickness</td>
<td>The player’s strength is halved for the rest of the day</td>
<td>Player</td>
</tr>
<tr>
<td>Health</td>
<td>The player’s strength is doubled for the rest of the day</td>
<td>Player</td>
</tr>
<tr>
<td>Bonus attacks</td>
<td>The player gains three extra attacks to be used today</td>
<td>Player</td>
</tr>
</tbody>
</table>

Random events concerning AP’s are raffled daily at midnight. An exception is the Immutability event, which is raffled hourly and lasts until the end of the day. Each random AP event is assigned to one particular AP. The events are revealed to the players in-game, so that they know where the affected AP’s are.

Random events concerning players may happen at any time the player executes an action in-game. However, only one random event can happen to any given player during one day — no player may receive more than one random event per day. If a random event is not used during the day, it will be discarded.
10. Scoring

When an AP is controlled by a team at the end of a day, it will give points to that team. The number of points is one plus the number of different users in that access point during that day. If the AP is affected by one of the random events, it will give a different number of points, depending on the random event. If an AP has been neutral for over five (5) days, it will give out extra points (one per day after five days) the next time it is captured.

If a captured AP has not had any friendly visitations during a day, the number of points for that day is reduced by 20% of the original, rounded up. This effect is accumulated, so if an AP has not had any friendly players for five days, it will give no points to the team, and again becomes a neutral AP.

The scoreboard is updated daily right after the points are computed. There is an information page, which shows an hourly updated number of users in every AP on that day, to help players decide which AP’s are valuable and which are not.

Scores are zeroed out at the change of month. The winning team of previous month is advertised on the game site. All-time scores are also kept, to see which teams have been successful in the long run.
APPENDIX 2: USER QUESTIONNAIRE FORM

panOULU Conqueror - User questionnaire

Answer the user questionnaire by filling the form below with your answers. A Linksys WRT54GL WLAN access point will be raffled between those who have filled the questionnaire before 2009-10-18. Remember to save your answers by clicking on the “Save answers” button on the bottom. The results of the questionnaire will be covered anonymously for the Diploma thesis of Juha Tiensyrjä.

Basic information

1. Age (years)
2. Sex
   - Female
   - Male
   - I don’t know / I don’t want to answer
3. Educational background (choose the school you are currently enrolled in, or that you have graduated from most recently)
   - Elementary school
   - High school
   - Vocational school
   - BSc. (undergraduate)
   - MSc. (graduate)
   - PhD.
   - I don’t know / I don’t want to answer

Usage of panOULU network before the game

The purpose of this section is to find out how often and how much the players have used the panOULU network before starting to play the game. Thus we assume that you have used panOULU network in August 2009. If you have not used panOULU in August 2009 because you have for example been in another city at a summer job, you may answer questions 4 to 8 by filling in values and estimates from some other previous timeframe of about one month, when you have resided mostly in Oulu.

4. How often did you use panOULU network in August 2009? (Choose the nearest option.)
5. Estimate the total time you have used panOULU network in August 2009.
- 0-1 hours (about 0-2 minutes per day)
- 1-5 hours (about 2-10 minutes per day)
- 6-10 hours (about 11-20 minutes per day)
- 11-20 hours (about 21-40 minutes per day)
- 21-30 hours (about 41-60 minutes per day)
- 31-60 hours (about 1-2 hours per day)
- 61-100 hours (about 2-3.5 hours per day)
- 101-150 hours (about 3.5-5 hours per day)
- 151-200 hours (about 5-7.5 hours per day)
- over 200 hours (over 7.5 hours per day)
- I don’t know / I don’t want to answer

6. How large percentage of your panOULU usage was mobile during August 2009?
(Mobile is defined as moving from one place to another while using the network.)
- 0-10 %
- 11-20 %
- 21-30 %
- 31-40 %
- 41-50 %
- 51-60 %
- 61-70 %
- 71-80 %
- 81-90 %
- 91-100 %
- I don’t know / I don’t want to answer

7. How many different devices you used panOULU network with during August 2009?
8. What kind of devices you used panOULU network with during August 2009? (Choose all that apply.)

- Desktop computer
- Laptop computer
- Netbook
- Cellular phone
- Music player
- PDA / Internet tablet
- Other device, what:

9. How often did you use panOULU network in September 2009? (Choose the nearest option.)

- Every day
- Almost every day (4-6 times a week)
- Two-three times a week
- Once a week
- Two-three times a month
- Less often
Appendix 2: User questionnaire form

10. Estimate the total time you have used panOULU network in September 2009.
   - 0-1 hours (about 0-2 minutes per day)
   - 1-5 hours (about 2-10 minutes per day)
   - 6-10 hours (about 11-20 minutes per day)
   - 11-20 hours (about 21-40 minutes per day)
   - 21-30 hours (about 41-60 minutes per day)
   - 31-60 hours (about 1-2 hours per day)
   - 61-100 hours (about 2-3.5 hours per day)
   - 101-150 hours (about 3.5-5 hours per day)
   - 151-200 hours (about 5-7.5 hours per day)
   - over 200 hours (over 7.5 hours per day)
   - I don’t know / I don’t want to answer

11. How large percentage of your panOULU usage was mobile during September 2009? (Mobile is defined as moving from one place to another while using the network.)
   - 0-10 %
   - 11-20 %
   - 21-30 %
   - 31-40 %
   - 41-50 %
   - 51-60 %
   - 61-70 %
   - 71-80 %
   - 81-90 %
   - 91-100 %
   - I don’t know / I don’t want to answer

12. How many different devices you used panOULU network with during September 2009?
   - 0
   - 1
   - 2
   - 3
Appendix 2: User questionnaire form

13. What kind of devices you used panOULU network with during September 2009? (Select all that apply.)
   - Desktop computer
   - Laptop computer
   - Netbook
   - Cellular phone
   - Music player
   - PDA / Internet tablet
   - Other device, what:

   Changes in panOULU usage

One of the most important research factors is to find out whether playing the game affects other use of the panOULU network, and if so, in what ways.

14. Has playing panOULU Conqueror increased or decreased your use of panOULU network in September 2009, when compared to August 2009?
   - Playing has increased my panOULU network usage a lot
   - Playing has increased my panOULU network usage
   - No change
   - Playing has decreased my panOULU network usage
   - Playing has decreased my panOULU network usage a lot
   - I don’t know / I don’t want to answer

15. Has other use of panOULU network (than playing the game) increased or decreased in September 2009, when compared to August 2009? If your other use has increased, please answer question 16 next. If decreased, please answer question 17. If there has been no change or you do not wish to answer this question please jump forward to question 18.
   - Decreased a lot
16. Which factors have had effect in the increase of your panOULU network use, other than playing the game? (Select all that apply.) Go forward to question 18 next.

- Possibility to use panOULU network in school or in work
- Getting a new device with WLAN capability
- Expansion of panOULU network near home, or moving to an area with existing panOULU coverage
- Increased use of Internet services
- General increase in free time
- Other reason, what:

17. Which factors have had effect in the decrease of your panOULU network use, other than playing the game? (Select all that apply.) Go forward to question 18 next.

- Return to school or to work where panOULU use is not possible
- Stopping the use of a WLAN capable device
- Decreasing coverage of panOULU network, or moving away from an area with panOULU coverage
- Decreased use of Internet services
- General decrease in free time
- Other reason, what:

18. Has your mobile use of panOULU network (i.e. you have moved from one place to another while using the network) increased or decreased in September 2009, when compared to August 2009? If your mobile use has increased, please answer question 19 next. If decreased, please answer question 20. If there has been no change or you do not wish to answer this questions, please jump to question 21.

- Decreased a lot
- Decreased
- No change
- Increased
- Increased a lot
- I don’t know / I don’t want to answer
19. What factors have influenced your increased mobile panOULU use in September 2009? (Select all that apply.) Please move forward to question 21 next.

- Playing the game
- Getting a new WLAN capable device that is easy to use when mobile
- Increased mobile messaging
- Keeping WLAN on on a device, so that reconnecting is not needed (for example, to save time)
- General increase in network usage
- Other reason, what:

20. What factors have influenced your decreased mobile panOULU use in September 2009? (Select all that apply.) Please move forward to question 21 next.

- Playing the game
- Stopping the use of a WLAN capable device that is easy to use when mobile
- Decreased mobile messaging
- Turning WLAN off on a device, even though the connection is soon needed again (for example, to save device battery)
- General decrease in network usage
- Other reason, what:

**Location awareness and pervasiveness in the game**

panOULU Conqueror is meant to be a location aware game that is tied to certain places. Positioning happens using WLAN access points installed to the panOULU network. Pervasiveness in this context means the coalescence of virtual (i.e. game) and real worlds: the players are constantly surrounded by the game world in the form of panOULU network. Also, the events of panOULU (that need not be related to events caused by the players) affect the game.

21. Are location based elements such as the map, access point location information, nearby access points and players, etc., relevant to playing the game?

- Yes
- No
- I don’t know / I don’t want to answer

22. Did the game positioning work?

- Yes, positioning worked always or almost always.
- Yes, positioning worked most of the time
- No, positioning worked only rarely
• No, positioning never worked
• I don’t know / I don’t want to answer

23. Did the game positioning work accurately?
• Yes, the game positioned me always near my actual location
• Yes, the game positioned me usually near my actual location
• No, the game positioning was often amiss
• No, the game positioning never positioned me near my actual location
• I don’t know / I don’t want to answer

24. Did you feel the game to be pervasive, i.e. did you experience that the virtual and real worlds affected each other?
• Yes
• No
• I don’t know / I don’t want to answer

25. When playing the game, was your playing usually meaningful (for example, you went to the city centre just to capture some access points), or was it a by-product of other actions (for example, you went to the supermarket and captured some access point on the way)?
• Always meaningful
• Mostly meaningful, rarely by-product of other actions
• Half of the time meaningful, half of the time by-product of other actions
• Mostly by-product of other actions, rarely meaningful
• Always by-product of other actions
• I don’t know / I don’t want to answer

Game and players

26. The best parts of the game are... (Select all that apply.)
• User interface
• Rules
• Social aspects / Communality
• Functionality
• Addictiveness
• Emotions caused by the game
• Location awareness (playing requires moving around)
Appendix 2: User questionnaire form

- Pervasiveness (real world’s effect on the game)
- Other, what:

27. The worst parts of the game are... (Select all that apply.)
- User interface
- Rules
- Social aspects / Communality
- Functionality
- Addictiveness
- Emotions caused by the game
- Location awareness (playing requires moving around)
- Pervasiveness (real world’s effect on the game)
- Other, what:

28. How often did you communicate with your team members regarding game-related matters?
- Every day
- Almost every day (4-6 times a week)
- Two-three times a week
- Once a week
- Two-three times a month
- Less often
- Not at all
- I don’t know / I don’t want to answer

29. How often did you communicate with people not in your team regarding game-related matters?
- Every day
- Almost every day (4-6 times a week)
- Two-three times a week
- Once a week
- Two-three times a month
- Less often
- Not at all
- I don’t know / I don’t want to answer

30. Do you feel the game increases your communality?
- Yes
31. In what ways did you communicate with other players (both players in your team and other players) regarding game-related matters? (Select all that apply.)

- Face-to-face
- Telephony (including IP telephony)
- SMS
- Game internal chat
- Internet Relay Chat (IRC)
- E-mail
- Instant messaging
- Other, what:

32. Give free-form feedback on the game:
APPENDIX 3: LICENSED IMAGES PRESENTED IN THIS THESIS

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