*Published: VDE Kongress 2002 **NETWorlds**, Dreseden, October 2002*

The Heywow System for Location Based Services: Combining Navigation, Distributed Services and intelligent Mobile devices

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Summary

Location based services have earned significant attention and importance during the last few years. Their development is being fostered increasingly by the development of new, generic platforms. The Heywow system is one such platform and is being developed by DLR and other partners from research and industry. It makes use, amongst others, of the programmability of end-devices, implicit positioning through the use of short-range wireless (such as Bluetooth). The questions which arise concerning the use if heterogeneous networks, the provisioning of context adapted services, security and localisation and navigation define the research fields within the project. This paper serves as an overview of the contributions to the field.

1 Introduction

The motivation and development of new mobile platforms has during the last few years been driven by three rapidly developing technologies and changing environments:

1) The migration of mobile end-devices from simple terminals used for classical telephony and rudimentary WAP browsing and messaging towards programmable terminals which themselves offer the developer a local computing platform.
2) Parallel to the deployment of classical mobile radio systems of 2nd, 2.5, and 3rd generation, new wireless technologies aimed at short range, high rate communications have matured. The two most noteworthy examples are IEEE 802.11 Wireless LAN and the Bluetooth system. The integration of these systems with classical mobile radio offers new possibilities in terms of service provisioning and navigation.
3) The accuracy and availability of positioning technologies has improved greatly through the use of satellite navigation (GPS) and also mobile radio's inherent localisation capabilities.

The combination of these three tendencies requires the development of suitable software platforms since traditional architectures and applications do not always satisfy the changing requirements. For instance, in most cases they do not tolerate disruptions of the network connection. This paper is organised along the aforementioned three points: after an introduction to context sensitive services and their representation on programmable mobile devices, we outline security requirements of the computing platforms and suitable solutions. Then we focus on the use of heterogeneous networks, especially the integration of Local Service Points – LSPs, to provide information in very localised areas. Building upon this, we show how navigation can be improved with the Soft Location concept, SoLo, by integrating different location sources dynamically and optimally in the statistical sense. Finally, we extend the concept of a user's situation from just her/his location to a wider definition that encompasses a richer set of parameter in several dimensions. Hereby, *Situation Aware* services can be implemented.

2 Context Aware Services on Smart Mobile Devices in Heywow

As mentioned at the beginning, the introduction of programmable smart mobile consumer devices like the Motorola Accompli 008, Siemens SL45i or a number of Nokia devices has enabled a wide range of new services and service platforms. Such devices are more than a terminal in the traditional sense, they have the capabilities of a "computing platform". This is reached by a sub-set of the platform independent programming language Java and its libraries, which has been designed and standardised in the *Java2 Micro Edition (J2ME)* in accordance with the special features and limitations of smart mobile devices [1]. Different classes of devices are represented in J2ME by configurations and profiles. Mobile phones and PDAs as the most restricted devices are covered by the *Connected Limited Device Configuration (CLDC)* and the *Mobile Information Device Profile (MIDP)*. See **table 1** for typical characteristics of and requirements on CLDC/MIDP devices.

Requirements/Characteristics of CLDC / MIDP devices
160 kB to 512 kB memory for VM, CLDC- and MIDP-libraries and applications, and 256 kB persistent memory (eg. Flash) for system 8 kB persistent memory for applications ≥ 64 kB RAM for applications
16 or 32 bit processor
low power consumption, often battery driven
network connected, often wireless and unreliable connections with limited bandwidth
display with 1:1 pixel shape, and a minimum of 96 x 54 pixels 1 bit color depth
ITU-T-onehand-keyboard or touch-screen

Table 1 Characteristics of CLDC/MIDP devices

The Heywow platform uses this new ability to run programs and services on the end user's device, in various ways. In cases where no online connection to the platform is possible (e.g. because of missing network coverage) or allowed (e.g. inside an aeroplane), this feature of the smart devices allows services on the device to continue autonomously. Security may be enhanced by the possibility to use end-to-end encryption (which is currently not available on WAP). But the biggest advantages are to be reaped in the area of context awareness.

A system is *context aware* if it uses context information during offering or provisioning of information or services. *Context information* is defined as any information which can be used to characterise the state of an entity concerning a specific aspect. An entity is a person, a place or in general an object. An aspect is a classification, symbol- or value-range, whose subsets are a superset of all reachable states. Services accessing a position information as context information are grouped as *Location Based Services (LBS)*.

Heywow is context aware with respect to the definition above. For instance is context information used to improve the UI in a sense of pre-selection of services, which are relevant for the user at a certain place (e.g. nearby restaurants) or under certain conditions (e.g. postponed meeting). This is especially interesting on smart mobile devices where the user has typically only a reduced display and keypad. Thus e.g. pre-setting the starting point for a routing service with the current position disengages the user from entering this information manually, which improves the quality of the service itself on a subjective level.

In general, Heywow uses context information to adapt to changes in the environment. This is used in the back-end (e.g. by providing route information which depend on the current traffic situation) as well as in the local access network (e.g. by pre-fetching and caching data with local, or other aspect-specific relevance), or in the front-end on the end-user's device (e.g. by synchronising the local schedule with a schedule maintained in the office).

Context information is acquired by context sensors. Every context sensor is responsible for the acquisition and processing of an individual type of context information ("aspect") by observing a specific entity. The requirements on context sensors are very similar to those of software agents [3] (high degree of individuality, adaptability, autonomy etc.). Thus we have developed an agent system being able to run on the resource limited small mobile devices [2]. Using that agent system makes it very comfortable to design, implement and integrate new context sensors on the mobile device on the base of software agents.

3 Security Aspects

Security is always a compromise between two extremes. One extreme is no security at all which allows working without restrictions. The other extreme is total security which is so restrictive that reasonable work is impossible. It should be also considered that a security system must protect software from deliberate attacks as well as unintended damages.

In the Heywow system it is very simple to download and install a service (i.e. program code). This leads to the important problem of mobile code security. This downloaded code could destroy or illicit modify data on the users device. The code could also try to send secret data to dubious machines or try to block resources. To prevent this, the Heywow system employs the Sandbox principle. A Sandbox is a defined area of memory inside of the users computer. The service is kept enclosed in this memory area. Inside of the Sandbox the program code can do whatever it likes. But if the service wants to access something outside of it's Sandbox — like a data file or a connection to another computer — it must employ the help of a controller. This controller can then decide to either permit the access or deny it. Therefore it can prevent the service from performing unwanted actions. The quality of the controller depends critically on the information which it uses to make access decisions. In our approach, two modules provide the controller with information: Resource Consumption Protection and Information Spread Protection. (The information generated by these modules is not only used by the controller but by other instances of the security system, too.) [4][5]

The resources of a computer — like size of the persistent storage, communication bandwidth, CPU processing power — is limited, especially on mobile devices. Resource Consumption Protection tries to prevent resources from being consumed by unimportant services. Essentially, this is done by assigning each service a priority. The resources are then given to services with the highest priority.

A computer stores, sends and receives information. Information Spread Protection ensures that information does not reach the hands of unauthorised persons and that information is only accepted from sources which the user trusts. Essentially, this is achieved by assigning data, services, users and computers a security level. Simple rules govern whether information can flow from a security level to another one. It is even possible to deduce whether data must be encrypted and/or digitally signed.

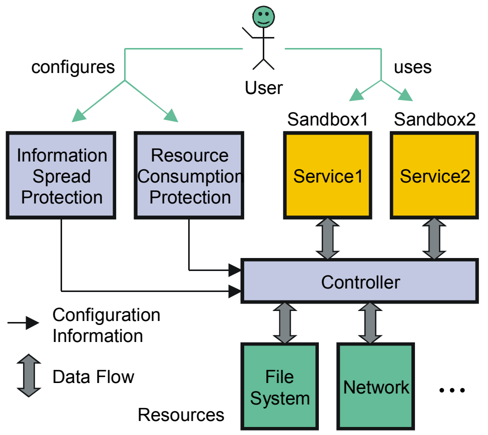


Figure 1 Simplified view of the security

Three of the most significant problems of modern computer security systems are:

1. Configuring and using such a system requires the user to have a deep understanding of the software to avoid mistakes which can easily cause the whole system to be insecure.
2. Configuration is a time consuming and cumbersome process due to the many parameters which must be set correctly (for example Java's Sandbox has more than fifty permission targets not including all the file- and socket permissions).
3. Security is seen as an aspect of each subsystem but not as a whole (for example a file system protects it's files from being accessed by an unauthorised user but not from being send by email to that user).

Here, the user configures the Resource Consumption Protection and Information Spread Protection modules which in turn configure and control the subsystems. This should lead to an easier understanding and make it easier to configure security parameters.

4 Network Aspects of Heywow

Mobile devices with greatly varying capabilities together with user mobility and stipulated scalability require careful planing of the network infrastructure. The network infrastructure of Heywow can be divided into two parts: Backbone- and access network (see **figure 2**).

The backbone relies on conventional infrastructure of the Internet, as it is already deployed at many Internet service providers (ISPs). Communications between nodes in the backbone uses TCP/IP, applications exchange XML coded messages or serialised Java objects using HTTP. User and service administration is part of a separated and firewalled part of the Heywow backbone, which is also used for providing data persistency and redundant storage. Persistency is required for users with multiple devices to allow services which for example can get configured from a PC at home or at work and will be used later on mobile devices which may not have continuous network access.

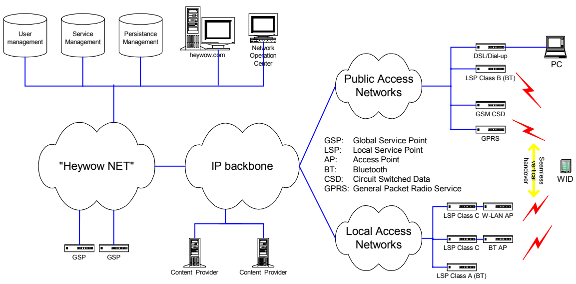
The access network includes both dialup lines in the fixed network and Internet access provided by the mobile network operators. This includes GSM circuit switched data (CSD or HSCSD) and packet based GPRS. Also, a local infrastructure using wireless LAN and Bluetooth is supported. Location based services have access to location information provided by the mobile operators or rely on inherent localisation of short range communications in small cells.

Service points connect backbone and access network. We distinguish between global and local service points (LSP). The latter are further divided into three classes: Local service points of class A have no backbone connectivity at all and therefore only transmit information which does not change often. Class B local service points have access to temporary connection with low bandwidth sufficient for occasional data updates. Finally, Class C local services points represent full gateways to the Heywow backbone.

Local access points communicate with the user's device (Wireless Information Device - WID) using wireless LAN (IEEE 802.11) or Bluetooth. The latter one is likely for wider spread among PDAs and smart phones due to lower cost per unit and lower power consumption compared to W-LAN. Since coverage of short range radio will be limited to hot spots, a backup connection via GSM, GPRS or later UMTS is indispensable. In case of missing cost effective local coverage, communication can take place via public networks using global service points (GSP). They perform essentially the same task as LSPs, in addition to harmonising the different localisation methods of the public networks.

Access points support both handover between other access point of the same type of network (horizontal handover) and between different types of networks (vertical handover). Whilst horizontal handover is well defined and deployed within GSM, a recognised specification for handover in Wireless and Bluetooth is still missing. However, handover between UMTS and wireless LAN is planned, but is unlikely to get deployed by the mobile operators due to the competition between theses technologies. Even in the current GSM network, a handover can be beneficial if it happens between the circuit switched modes and the packet switched mode GPRS: The current tariffs for packet based communication are often many times more expensive than comparable cost for dial-up connections. Especially when downloading large files, a changeover to circuit switched mode is desirable.

In order for a mobile WWW access to benefit from handover without human interaction, a setup of local proxies on the WID is necessary which communicate directly with LSPs and GSPs [6]. They also provide input to the access points with respect to neighbour lists and additional access options. In case of a network disruption, proxies take care of data buffering and data follow-up. Many devices will also support ad-hoc networks which allow direct or indirect one-to-one communication without using public infrastructure.



5 Situation Awareness

The ultimate mobile device would act and help us in a similar manner as a trusted and experienced human assistant. Today's technology is still far from reaching this goal. As mentioned earlier, the resources of mobile devices are limited e.g. in terms of memory

Figure 2 Heywow Network Overview

nitude than what is considered standard in the fixed part of the Internet due to the physical limitations of the wireless communication channel. Together with display sizes that are ultimately limited by the physical dimensions of the device these bottlenecks constitute the most interesting challenges.
Instead of widening these bottlenecks, an alternative approach is to optimise the necessary communication via them. Making applications location-aware is a first step in this direction. Essentially most

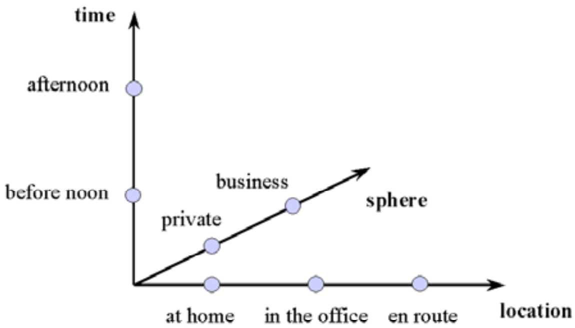


Figure 3 Simple Situation Space

cations of location awareness relieve the human from the burden to select something e.g. a shop, a train connection or the description of a historic sight from a long list by reducing this list to the items that are in proximity to the user. Thus, the amount of communication between the user and the device and between the system's backend and the device is reduced.
Indeed physical location is an often applicable discriminator for relevancy, yet it is only one of many possible and mostly still unexploited. We therefore suggest to generalise the principle of location awareness towards a principle of *situation awareness*.
Especially simple to access and to apply is the aspect of time. Suppose a person is in urgent need of some medication and is searching at night for a pharmacy. Of course the pharmacy has to be near but it also has to be on emergency duty *this night*. Combining the information of location and time the system can become truly valuable by suggesting *one* near *and* open pharmacy. This example can be nicely continued by supposing the system knows

and reacts to the situation that the person suffers from diabetes and that his concentration of blood sugar requires an insulin injection by actively alarming him of this fact and proposing a near and currently open pharmacy having the drug in stock.
In order to create technical systems that act so prudently we have to enable the gathering and useful interpretation of information about the situation. For this purpose we start with a brief definition of some useful terms and concepts.
A *situation* is defined to be a point respectively a set of points of a *situation space*. A situation space is spanned by its *aspects*. These aspects are sets whose elements are called *components*. This is easily understood with the help of an example. In **Figure 3** we see a simple situation space. We see that "at home", "in the office" and "en route" are components of the aspect "location". The other two aspects of this situation space are "sphere" and "time". A possible situation within this space would be "before noon" – "en route" – for "business" purposes.

The proposed structure can be well represented within databases or common data types of computer languages. This facilitates using the concept as a building block of situation aware services.
In order to use the knowledge about the current situation to predict future situations and useful proactive actions it is necessary to find a suitable metric for describing the "nearness" of one situation to another. If the situation is fully determined by the geographical location something like the Euclidian distance may be useful. Yet, as humans tend to move forward, usually a location lying in the continuation of a person's path is more likely to be obtained in the future than one lying in the opposite direction. For this and the reason that geometric distances are sensible only for a small subset of possible aspects we refrain from using any geometric distance within a situation space.
Instead, we consider transition probabilities to be well suited for our purposes. By observing the transition between situations we can gather statistical data that allows us to estimate the transition probabilities. Using this concept we can apply well-known techniques from the analysis of Markovian random processes.
In-depth understanding of these processes' structures and properties allows us to finally apply situation awareness for optimising the communication between the mobile device and the backend by taking advantage of temporal load fluctuations on the communication channel. We adapt to these fluctuations by speculatively pre-fetching of data, thus substantially reducing the perceived latency of the network for the user [7].
We experiment with and apply situation awareness as one of our tools to achieve the objective of creating systems that are capable to act sensibly based on effective communication with the human.

6 Soft Location for Navigation

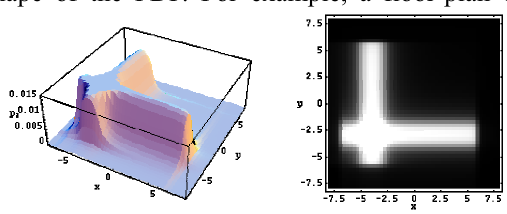


Figure 4 An example of a floor-plan as a PDF

Upcoming mobile devices capable of using multiple network access methods and being able to execute custom applications can lead to new possibilities in personal navigation.
It is a challenge to provide accurate location information from within a heterogeneous sensor infrastructure.
In Heywow we studied selected aspects of location calculation based on probability density functions (PDFs). This study led to the concept of Soft Location (SoLo) [8] which becomes especially interesting in conjunction with Java equipped smart phones or other hand held PCs. Research revealed the necessity of a framework managing different location sensors and dynamic adaptation to changing positions.

Today's positioning and navigation systems rely on different methods to determine their actual position. Satellite systems like GPS for example provide absolute positioning information in a defined coordinate system. This location data is only accurate if there is an uninterrupted line of sight from a least four satellites to the receiver. As soon as a person with a mobile navigation device enters a building for example, data from other sensors than the GPS system has to be analysed for seamless location services.

Therefore we need to analyse as many sensors as possible and combine them in a reasonable way. This includes for example local beacons based on short range communication systems like IrDA or Bluetooth. They profit from inherent location information due to proximity to the stationary sender whose location is usually known with high precision.
We want to describe all these different sensors in a standardised way with probability density functions in order to achieve a better location estimation.

For this Soft Location concept we use PDFs as soft primitives as described in [8]. These PDFs are composed of simple mathematical functions like the Gaussian function, which can be described with only very few parameters. The functions also model the accuracy of the associated location method by the shape of the PDF. For example, a floor-plan of a building can be represented by rectangular shapes with smoothed borders (**figure 4**). The combination of different PDFs is a simple multiplication over the location space which should leads to a better location estimation.

The current implementation of the SoLo system consists of a Java engine on a mobile device that can be provided over the air with all kinds of PDFs that meet a common interface definition. Using this object oriented implementation, the engine on the mobile device can request the whole PDF class without knowing anything of its internal implementation.
The result of the multiplication of PDFs is also represented as a PDF so that it can be saved for later processing or it is being passed to other instances of the program for further actions e.g. determination of the most probable location for a mobile user.
A possible procedure is as follows: When the mobile device is able to detect and connect to a Bluetooth access point, this device will send back its characteristic propagation parameters as a PDF class file to the mobile device. The parameters had to be measured before for each beacon individually and saved on the device (**figure 5**). The mobile device has to set the parameters of the PDF class before it can be used in the SoLo engine. For example this could be the measured "TransmitPowerLevel" of the Bluetooth RF-module.

We are studying an extension to the system, that allows us to take into account the movement of the mobile user with his receiver. This is important when it is not always possible to measure for example the GSM time advance parameter or gather Bluetooth data. The consideration is to introduce an uncertainty function of the time, which models the movement or other changes of the situation of a person based on their last known position.
The method is based on the addition of two independent random variables in the time domain:

$$\vec{p}_i^{\,filtered}(t) = \vec{p}_i(t_0^i) + \vec{\Delta}_i(t - t_0^i)$$

$\vec{p}_i^{\,filtered}(t)$ - filtered location vector at time t for source i

$\vec{p}_i(t_0^i)$ - location vector at time t_0^i for source i

$\vec{\Delta}_i(t - t_0^i)$ - movement vector relative to time t_0^i (i.e. movement since t_0^i)

The filter $(\vec{\Delta})$ is influenced by different events, situations or statistics. It represents any change of the location situation between two points in time. With this extension, the system does not need to perform simultaneous measurements of all available location sensors for example. Adding the two random variables leads to a convolution of the PDFs. Unfortunately, such a convolution takes more multiplications compared to a simple multiplication of two dimensional matrices (only n multiplication operations). This could lead to very long calculation times depending on the size of the matrix, especially on mobile devices with very limited resources.

For an implementation we will therefore have to consider carefully between desired accuracy and information gain on the one hand and calculation time on the other hand.

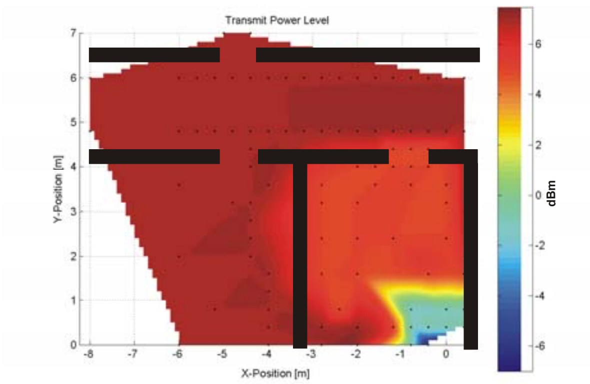


Figure 5 Measurement of Signal Strength in a building

7 Literature

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