PDPT FRAMEWORK

Building Information System with Wireless Connected Mobile Devices

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Abstract: The proliferation of mobile computing devices and local-area wireless networks has fostered a growing interest in location-aware systems and services. Additionally, the ability to let a mobile device determine its location in an indoor environment at a fine-grained level supports the creation of a new range of mobile control system applications. Main area of interest is in model of radio-frequency (RF) based system enhancement for locating and tracking users of our control system inside buildings. The framework described here joins the concepts of location and user tracking in an extended existing control system. The experimental framework prototype uses a WiFi network infrastructure to let a mobile device determine its indoor position as well as to deliver IP connectivity. User location is used to data pre-buffering and pushing information from server to user's PDA. Experiments show that location determination can be realized with a room level granularity.

1 INTRODUCTION

The usage of various wireless technologies that enable convenient continuous IP-level (packet switched) connectivity for mobile devices has increased dramatically and will continue to do so for the coming years. This will lead to the rise of new application domains each with their own specific features and needs. Also, these new domains will undoubtedly apply and reuse existing (software) paradigms, components and applications. Today, this is easily recognized in the miniaturized applications on network-connected PDA's that provide more or less the same functionality as their desktop application equivalents. The web browser application is such an example of reuse. Next to this, it is very likely that these new mobile application domains adapt new paradigms that specifically target the mobile environment. We believe that an important paradigm is context-awareness. Context is relevant to the mobile user, because in a mobile environment the context is often very dynamic and the user interacts differently with the applications on his mobile device when the context is different. While a desktop machine usually is in a fixed context, a mobile device goes from work, to on the road, to work in-a-meeting, to home, etc. Context is not limited to the physical world around the user, but also incorporates the user's behaviour, and terminal and network characteristics.

Context-awareness concepts can be found as basic principles in long-term strategic research for mobile and wireless systems such as formulated in (WWRF). The majority of context-aware computing to date has been restricted to location-aware computing for mobile applications (location-based services). However, position or location information is a relatively simple form of contextual information. To name a few other indicators of context awareness that make up the parametric context space: identity, spatial information (location, speed), environmental information (temperature), resources that are nearby (accessible devices, hosts), availability of resources (battery, display, network, bandwidth), physiological measurements (blood pressure, hart rate), activity (walking, running), schedules and agenda settings. Context-awareness means that one is able to use context information.

We consider location as prime form of context information. Our focus here is on position determination in an indoor environment. Location information is used to determine an actual user position and his future position. We have performed a number of experiments with the control system, focusing on position determination, and are encouraged by the results. The remainder of this

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paper describes the conceptual and technical details of this.

2 BASIC CONCEPTS AND TECHNOLOGIES OF USER LOCALIZATION

The proliferation of mobile computing devices and local-area wireless networks has fostered a growing interest in location-aware systems and services. A key distinguishing feature of such systems is that the application information and/or interface presented to the user is, in general, a function of his physical location. The granularity of location information needed could vary from one application to another. For example, locating a nearby printer requires fairly coarse-grained location information whereas locating a book in a library would require fine-grained information.

While much research has been focused on development of services architectures for location-aware systems, less attention has been paid to the fundamental and challenging problem of locating and tracking mobile users, especially in in-building environments. We focus mainly on RF wireless networks in our research. Our goal is to complement the data networking capabilities of RF wireless LANs with accurate user location and tracking capabilities for user needed data pre-buffering. This property we use as information ground for extension of control system.

2.1 Location-Based Services

Location-based services (LBS) are touted as 'killer apps' for mobile systems. An important difference between fixed and mobile systems is that the latter operate in a particular context, and may behave differently or offer different information and interaction possibilities depending on this context. Location is often the principal aspect determining the context. Many different technologies are used to provide location information. Very common is the GPS system, which uses a network of satellites and provides position information accurate within 10–20 m. However, due to its satellite based nature, it is not suited for indoor positioning. In cellular telecommunication networks such as GSM, the cell ID gives coarse-grained position information with an accuracy of about 200 m to 10 km. For fine-grained indoor location information, various technologies are available, based on infrared, RF, or ultrasonic technologies often using some type of beacon or active badge. Given the ubiquity of mobile devices like PDAs, however, active badges will probably be superseded by location technologies incorporated in these devices.

In the context of our experimental setup, we need indoor position information accurate enough to determine the room in which the user is located. We must deploy a separate location technology, where we use the information available from a WiFi network infrastructure to determine the location with room-level accuracy. By this information possible user track is estimate.

2.2 WiFi - IEEE 802.11

The Institute of Electrical and Electronics Engineers (IEEE) develops and approves standards for a wide variety of computer technologies. IEEE designates networking standards with the number 802. Wireless networking standards are designated by the number 11. Hence, IEEE wireless standards fall under the 802.11 umbrella. Ethernet, by the way, is called 802.3 (Reynolds, 2003).

The 802.11b is an updated and improved version of the original IEEE 802.11 standard. Most wireless networking products today are based on 802.11b. 802.11b networks operate at a maximum speed of 11 Mbps, slightly faster than 10-BASE-T Ethernet, providing a more than fivefold increase over the original 802.11 spec. The 802.11 standard provided for the use of DSSS and FHSS spread-spectrum methods. In 802.11b, DSSS is used.

We use only 802.11b infrastructure (PDA has only this standard) so other standards (802.11a or g) is not needed to describe. However, it can be possible to develop a PDPT framework with it.

2.3 Data Collection

A key step in the proposed research methodology is the data collection phase. We record information about the radio signal as a function of a user's location. The signal information is used to construct and validate models for signal propagation. Among other information, the WaveLAN NIC makes available the signal strength (SS) and the signal-to-noise ratio (SNR). SS is reported in units of dBm and SNR is expressed in dB. A signal strength of s Watts is equivalent to 10*log10(s/0.001) dBm. A signal strength of s Watts and a noise power of n Watts yields an SNR of 10*log10(s/n) dB. For example, signal strength of 1 Watt is equivalent to 30 dBm. Furthermore, if the noise power is 0.1 Watt, the SNR would be 10 dB. The WaveLAN driver extracts the SS and the SNR information from the WaveLAN firmware each time a broadcast packet is received. It then makes the information available to user-level applications via system calls. It uses the wlconfig utility, which provides a wrapper around the calls, to extract the signal information.

2.4 Localization Methodology

The general principle is that if a WiFi-enabled mobile device is close to such a stationary device – Access Point (AP), it can “ask” the location provider’s position by setting up a WiFi connection. If the mobile device knows the position of the stationary device, it also knows that its own position is within a 100-meter range of this location provider. Granularity of location can improve by triangulation of two or several visible WiFi APs as described on figure [Fig. 1].

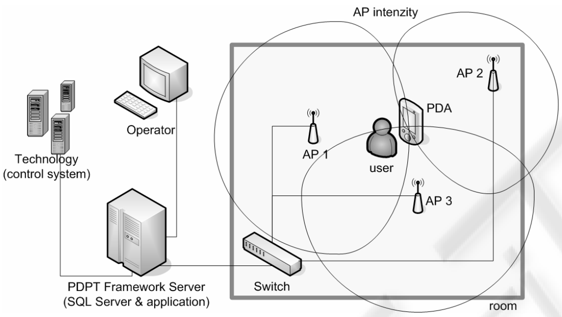

Figure 1: Localization principle - triangulation.

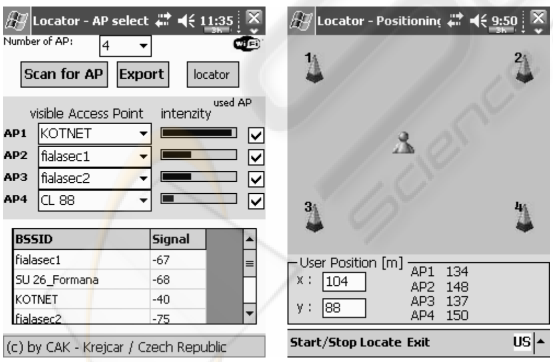

Figure 2: PDA Locator – AP intensity & Positioning.

The PDA client will support the application in automatically retrieving location information from nearby location providers, and in interacting with the server. Naturally, this principle can be applied to other wireless technologies.

The application (locator) based on .NET language is now created for testing. It is implemented in C# using the MS Visual Studio .NET 2003 with compact framework and a special OpenNETCF library enhancement (Tiffany, 2003) and (WWRF). Current application [Fig. 2] records just one set of signal strength measurements. By this set of value the actual user position is determined.

2.5 WiFi Middleware

The WiFi middleware implements the client’s side of location determination mechanism on the Windows Mobile 2005 PocketPC operating system and is part of the PDA client application. The libraries used to manage WiFi middleware are: AccessPoint, AccessPointCollection, Adapter, AdapterCollection, AdapterType, ConnectionStatus, Networking, NetworkType, and SignalStrength. Methods from the Net library are used for example to display Visible WiFi AP. See figure [Fig. 3].

```
dtVisibleAP = new DataTable("Visible
AP");
DataRow drDataRow;
adptrColection =
networking.GetAdapters();
foreach (Adapter adptr in
adptrColection)
{
  Application.DoEvents();
  if (adptr.Type==AdapterType.Ethernet)
  {
    foreach (AccessPoint ap in
            adptr.NearbyAccessPoints)
    { drDataRow = dtVisibleAP.NewRow();
      drDataRow["BSSID"] =
            (ap.Name.ToString());
      drDataRow["Signal [%]"] =
((ap.SignalStrength.Decibels).ToString(
));
      dtVisibleAP.Rows.Add(drDataRow);
    }
  }
}
```

Figure 3: Sample code – signal strength from AP.

2.6 Predictive Data Push Technology

This part of project is based on model of location-aware enhancement, which we used in created control system. These information about are useful in framework to increase real dataflow from wireless access point (server side) to PDA (client side). Primary dataflow is enlarged by data pre-buffering. These techniques form the basis for predictive data push technology (PDPT). PDPT copies data from information server to clients PDA to be on hand when user comes at desired location.

The benefit of PDPT consists in reduction of time needed to display desired information requested by a user command on PDA. Time delay may vary from a few seconds to number of minutes. It depends on two aspects. First one is the quality of wireless Wi-Fi connection used by client PDA. A theoretic speed of Wi-Fi connection is max 825 kB/s. However, the test of transfer rate from server to client's PDA, which we have carried out within our Wi-Fi infrastructure provided the result speed only 160 KB/s. The second aspect is the size of copied data. The application (locator) based on .NET language is now created for testing. Current application (see figure [Fig. 2]) records just one set of signal strength measurements. By this set of value the actual user position is determined.

2.7 Framework Design

PDPT framework design is based on most commonly used server-client architecture. To process data the server has online connection to the control system. Data from technology are continually saved to SQL Server database (Tiffany, 2003) and (Reynolds, 2003). The part of this database (desired by user location or his demand) is replicated online to client's PDA where it is visualized on the screen. User PDA has location sensor component which continuously sends to the framework kernel the information about nearby AP's intensity. The kernel processes this information and makes a decision if and how a part of SQL Server database will be replicated to client's SQL Server CE database.

The kernel decisions constitute the most important part of whole framework because the kernel must continually compute the position of the user and track and make a prediction of his future movement. After doing this prediction the appropriate data (part of SQL Server database) are pre-buffered to client's database for future possible requirements. The PDPT framework server is created as Microsoft web services to handle as bridge between SQL Server and PDPT PDA Clients.

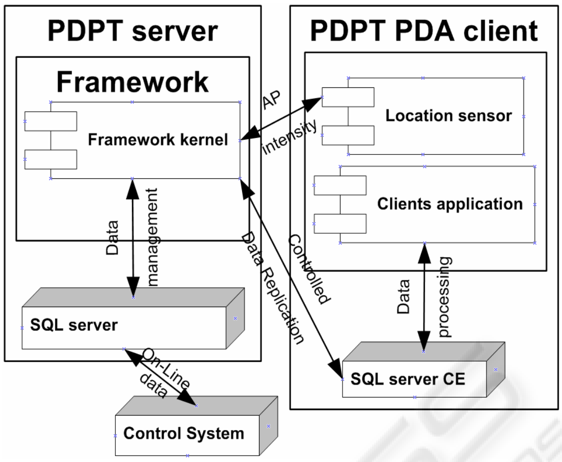

Figure 4: System architecture – UML design.

3 EXPERIMENTS

We have executed a number of indoor experiments with the PDPT framework, using the PDPT PDA application. WiFi access points are placed at different locations in building, where the access point cells partly overlap. We have used triangulation principle of AP intensity to get better granularity. It has been found that the location determination mechanism selects the access point that is closest to the mobile user as the best location provider. Also, after the loss of IP connectivity, switching from one access point to another (a new best location provider) takes place within a second in the majority of cases, resulting in only temporary loss of IP connectivity. This technique partially uses a special Radius server (RADIUS) to realize "roaming" known in cell networks. User who loss the existing signal of AP must ask the new AP to get IP. This is known as "renew" in Ethernet networks. At the end of this process, user has his same old IP and connection to new AP. Other best technique to realize roaming is using of WDS (Wireless Decision System).

Currently, the usability of the PDPT PDA application is somewhat limited due to the fact that the device has to be continuously powered. If not, the WiFi interface and the application cannot execute the location determination algorithm, and the PDPT server does not receive location updates from the PDA client.

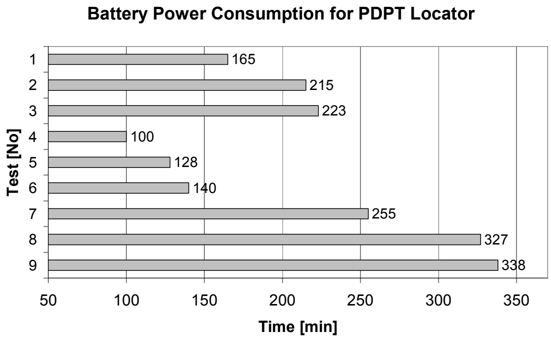

Figure 5: Battery power consumption graph.

3.1 Battery Power Consumption Tests

We have executed a number of tests of battery power consumption with three PDA devices running PDPT Locator. The tests were executed from 100 % battery level to 20 % battery level with balanced load. The first was HTC Blue Angel PH20B which is known also as MDA III from T-Mobile (Intel XScale PXA263 CPU, MS WM2005 OS). The second one was iPAQ h4150 from Hewlett & Packard Company (H&P) (Intel XScale PXA255 CPU, MS WM2003 OS). The third one was iPAQ hx4700 from H&P (Intel XScale PXA270 CPU, MS WM2003 SE OS). These devices have Li-Ion battery with different capacity (1490 mAh, 1000 mAh and 1800 mAh). MDA III device has integrated GSM module in addition.

Test	Type	CPU [MHz]	Scan	WiFi	Backlight
1	MDA III	400	2 s	ext.	50%
2		400	10 s	norm.	off
3		100	2 s	norm.	off
4	h4150	400	2 s	ext.	50%
5		400	10 s	norm.	off
6		100	2 s	norm.	off
7	hx4700	624	2 s	ext.	50%
8		624	10 s	norm.	off
9		104	2 s	norm.	off

Figure 6: Battery tests description.

The test chart [Fig. 5] shows number of results. The first, most evident and expected result is caused by different battery packs. The power consumption is worse for h4150 model and the best for hx4700 model. The second aspect is evident as well. The score is better when the backlight is turned off. However, the very large score is at hx4700 test case comparing to two other PDA. The last interested result is however in 100 MHz CPU speed setting. The speed decreasing was controlled by special utility managing the core of operating system. When the maximum speed of CPU was decreased, the working time of PDA increased about several percent. This result is last useful thing for enlarge battery power consumption.

The practical type of PDA usage with PDPT application is somewhere between minimum and maximum score of these tests for such model of PDA. For example the mean usage of the worse PDA iPAQ h4150 is about two hours of working time so it is not very comfortable, but it is usable for many types of operations. Other two devices have battery consumption time higher so practical use is without remarkable limitation.

3.2 Data Transfer Increase Tests Using PDPT Framework

The result of utilization of PDPT framework is mainly at data transfer speed reducing. The second test is focused on real usage of developed PDPT Framework and his main issue at increased data transfer. At table [Fig. 7] are summary of eighteen tests with three type of PDA and three type of data transfer mode. Each of these eighteen tests is fivefold reiterated for better accuracy. At table are only average values from each iteration.

Test	Type	Mode	Data [kB]	Time [s]	Speed [kB/s]
1	MDA III	SQl CE	257	0.4	643
2		SQl CE	891	0.4	2228
3		SQL	257	5	51
4		SQL	891	13	69
5		PDPT	257	1.1	234
6		PDPT	891	3.2	278
7	h4150	SQl CE	257	0.5	514
8		SQl CE	891	0.5	1782
9		SQL	257	5	51
10		SQL	891	14	64
11		PDPT	257	1.2	214
12		PDPT	891	3.7	241
13	hx4700	SQl CE	257	0.3	857
14		SQl CE	891	0.4	2228
15		SQL	257	5	51
16		SQL	891	13	69
17		PDPT	257	0.9	286
18		PDPT	891	2.5	356

Figure 7: Data transfer tests description.

The data mode column has three data transfer mode. The SQL CE mode represents the data saved at mobile device memory (SQL Server CE) and the data transfer time is very high. The second mode SQL means data which are stored at server (SQL Server 2005). Primary the data are loaded over Ethernet / Internet to SQL Server CE of mobile device and secondary the data are shown to user. The data transfers time consumption of this method is generally very high and the waiting time for user is very large. The third data mode PDPT is combination of previous two methods. The PDPT mode has very good results in form of data transfer acceleration. Realization of this test consists at user movement from location A to B at different way direction. Location B was a destination with requested data which are not contained at SQL CE buffer in mobile device before test.

4 CONCLUSION

The main objective of this paper is in the enhancement of control system for locating and tracking of users inside a building. It is possible to locate and track the users with high degree of accuracy.

In this paper, we have presented the control system framework that uses and handles location information and control system functionality. The indoor location of a mobile user is obtained through an infrastructure of WiFi access points. This mechanism measures the quality of the link of nearby location provider access points to determine actual user position. User location is used in the core of server application of PDPT framework to data pre-buffering and pushing information from server to user PDA. Data pre-buffering is most important technique to reduce time from user request to system response.

The experiments show that the location determination mechanism provides a good indication of the actual location of the user in most cases. The median resolution of the system is approximately five meters. Some inaccuracy does not influence the way of how the localization is derived from the WiFi infrastructure. For the PDPT framework application this was not found to be a big limitation as it can be found at chapter Experiments. The experiments also show that the current state of the basic technology used for the framework (mobile device hardware, PDA operating system, wireless network technology) is now at the level of a high usability of the PDPT application.

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