CAMPUS NEWS: an intelligent Bluetooth-based mobile information network.

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CAMPUS NEWS - an Intelligent Bluetooth-based Mobile Information Network

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ABSTRACT

In this paper we describe a network for distributing personalized Information in a metropolitan area. We discuss the system architecture of our Bluetooth-based information system as well as the reasoning process that fits users' needs with potential messages. We furthermore present our findings on parallelizing Bluetooth connection setup and performance.

Categories and Subject Descriptors

H.4.3 [**Information Systems Applications**]: Communications Applications; H.5.1 [**Information Systems Applications**]: Multimedia Information Systems

Keywords

Bluetooth, Location Based Services, Wireless Communications Technology, Mobile System Performance, Standards and Interoperability

1. INTRODUCTION

"In which rooms are my lessons?" - "Do they start this week or next week?" - "Where is the examination office or the office of the registrar?" These are typical questions students, both freshmen and senior students, are asking at the beginning of each new semester. Our concept of developing a campus information system supports the student life cycle in a personalised way at any time, at any locations. CampusNews helps the user on campus to find and access information, which is of interest and relevant to her; she only needs a Bluetooth enabled mobile device, which could be either a PDA or a mobile phone.

Other groups researching applications on mobile personal computers have come to the same conclusion as we have, that the main attention with pervasive applications has shifted from a "use anytime, anywhere" perspective to a location-based, personalized view [6]. A lot of work is happening in this area at the moment. Using a Bluetooth mesh for positioning to send data over non-local wireless links like GSM or GPRS is one avenue to take [1]. In our approach we opted for positioning and transmission over the same channel. The local wireless link can also be skipped completely, which leads to different usage models [5]. A bit closer to our usage scenario of a pervasive university than these mentioned projects is the project "mobile cafeteria menu"[1], although there are neither location-based nor personalized aspects involved.

2. CAMPUSNEWS – CONCEPT

The Campus News System is based on the result of the research project IASON[2], funded by the "Stiftung Rheinland-Pfalz für Innovation". Motivated by the development of powerful mobile devices and the semantic web, we defined a *Semantic Mobile Environment*. In such an environment, so-called service nodes are installed at chosen points of interest. These service nodes broadcast messages to nearby mobile users using bluetooth wireless technology. The kind of message depends on the location of the broadcasting access point. For example a bookshop could send its latest offers, or the University restaurant could present its menu or a faculty present the schedule of events to the students.

The huge amount of information which will be sent is filtered by the mobile device according to a profile set by the user. For that we annotated the messages semantically with a logical concept in Description Logic (DL) [3, 4]. We also gave the users the opportunity to build their individual interest profile, which was constructed as a DL concept, too. The user profiles and the semantically annotated messages are based upon the same ontology. The first usable prototype of the project (see [11]) was implemented in J2ME, such that the user profile and the inference engine for the personalization was stored in the mobile device. It is able to do more than just storing and displaying incoming messages. It includes a powerful reasoning engine which is able to solve TPTP problems. This reasoner, called Pocket KRHyper [10], is a re-implemetion of the KRHyper [13] system. It is the first theorem prover for first order predicate calculus running on a mobile phone. More information about the entire approach can be found in [8].

To get an idea of what happens inside the mobile application we created a simplified test scenario where we tested our IASONconcept. We set up the test-run to gather more data

[1] www.studentenwerk-dresden.de/mensen/handy.html
[2] www.uni-koblenz.de/~iason

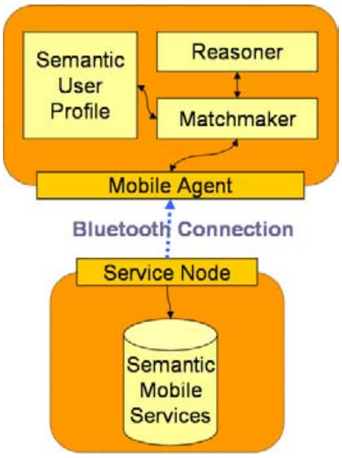

Figure 1: Iason System architecture

and get hands-on experience with these technologies. This test-run was conducted at the cafeteria of the University of Koblenz. The daily cafeteria menus were broadcast at all times. A client was available free of charge via Bluetooth data transfer for the cafeteria visitors, bundled with profiles fitting the menu and major food tastes. Along with the data and application transmission, users had the opportunity to fill out feedback forms and discuss the technology online in the University newsgroup.

Let's shortly describe how it works. First we needed an ontology for describing our semantic environment, to build the user profiles and to annotate the messages. The ontology, profile and annotations are considered to be a finite set of axioms $C \sqsubseteq D$ and $C \equiv D$, where C, D are concepts of the Description Logic $\mathcal{ALC}$ extended by inverse roles and role hierarchies. Part of the whole ontology which has been developed in the IASON project, is shown in figure 2. The syntax of the ontology we used is Lisp-like, KRSS [12], which is a subset of the RACER-syntax [7]. This was necessary because a XML-based syntax like OWL [2] or DAML+OIL would require a XML-parser on our mobile device. Unfortunately, at the time of development there was no standard XML-parser available for the J2ME environment. Nevertheless the expressivity of our syntax is close to that of OWL-DL.

During the cafeteria test-run we provided an application with fixed profiles. This means that the users were able to choose from a predefined set of profiles but weren't able to edit them. The meaning of the displayed profiles (see fig. 3) are described below:

```
Profiles:
All Infos: (some offer meal)
veg. Abend: (some offer(and meal evening vegetarian))
Abendmensa: (some offer(and meal evening))
Mittagsmensa: (some offer(and meal noon))
veg.Mittagsm.: (some offer(and meal noon vegetarian))
```

For example this $\exists \mathit{offer}.(\mathit{meal} \sqcap \mathit{noon})$ is an equivalent notation for the Mittagsmensa in DL syntax.

```
(IN-TBOX iason)
(DEFINE-PRIMITIVE-ROLE OFFER :PARENTS SHAREINTEREST)
(DEFINE-PRIMITIVE-ROLE REQUEST :PARENTS SHAREINTEREST)
(IMPLIES time attributes)
(IMPLIES afternoon time)
(IMPLIES noon time)
(IMPLIES evening time)
(IMPLIES cuisine attributes)
(IMPLIES attributes abstract)
(IMPLIES meal food)
(IMPLIES food solid)
(IMPLIES solid physical)
(IMPLIES vegetarian cuisine)
```

Figure 2: A Simple Ontology

Figure 3: UniInfo Application (Fixed Profiles)

When in range of the service node, the users mobile device will receive a few offered services which are annotated. The following service was offered as a non vegetarian dish for lunch.

```
Services offered:
Annotation: (some offer(and meal noon))
Subject: Menu 1 Wednesday 7.Week
Text: Beef with Fries and Salad
```

Before displaying the service to the user, the mobile application has to decide whether the information fits the users interest or not. This deduction process called matchmaking [9] is done by the first order reasoner Pocket KRHyper. For the chosen profile (see fig. 3) the service is compatible and will be displayed. The subsumption test holds.

The decision whether a message matches a users profile is based on concept satisfiability and subsumption of the DL in use.

$$profile \sqcap annotation \not\equiv \bot \quad (1)$$

$$annotation \sqsubseteq profile \quad (2)$$

If the annotation satisfies test (1) the annotation is *compatible* with the profile. Because an unsatisfiable annotation will be subsumed by every profile, the first test prevents any unsatisfiable annotation to be considered as a match. This test avoids spam. Test (2) will give a better *match degree* for those annotations that are subsumed by at least one of the *positive* terms. We call these annotations a *match*. This second test is only performed after successfully testing satisfiability (1). In the cafeteria context the test (2) was not necessary.

During several tests in the University and in the City of Koblenz within the framework of an EU-project Spatial Metro[3] it turned out that most mobile phones did not yet fulfill our system requirements. They could not access the Bluetooth wireless functions via JSR-82[4] from Java. Apart from that we learned that the barrier to install software on mobile phones or PDAs is higher than with computers. The users aren't yet used to software for these devices and as such distrust them more. To overcome both the technical shortcomings of mobile devices and the need for application installation, we chose to move the decision process (the "reasoning engine") from the mobile phone onto a server, thus eleminating the application. The profile of the user now needs to be entered centrally on a web page.

3. SYSTEM ARCHITECTURE

As described in the chapter below we had to redevelop our entire concept from the IASON approach. The architecture of the Campus News Information System, consists of 3 components (as shown in fig. 4):

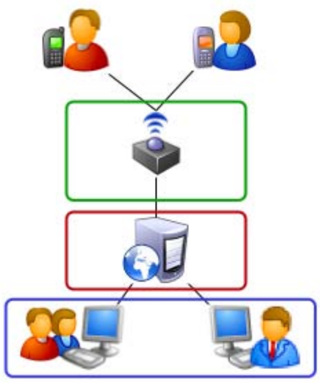

Figure 4: System architecture

a web application as the user frontend (blue) (see sec. 3.1), a server application (red) (see sec. 3.2) in the middle and a freely scalable number of service nodes (green) (see sec. 3.3) for deliviering the information to the mobile devices. In the following sections the components are described in detail.

[3] www.spatialmetro.org

[4] http://jcp.org/en/jsr/detail?id=82

3.1 Organizing user interests hierarchically

We implemented two different kinds of frontends, one for each group of users. We need an administration interface for the users which want to offer the information to the public. This frontend is called the Management console (see fig. 5). Here messages can be added to all or specific nodes. There is also a flexible statistics tool, as finding the ideal location for service nodes needs statistical data as a foundation.

Figure 5: CampusNews management console

We also need a user interface for the recipients of the information, in our case the students. This is called the Userweb; it is depicted in figure 6. After logging in with the campuswide student login credentials the type of mobile phone and a target Bluetooth friendly name have to be selected. In the next step interests can be selected from a tree menu. The focus of the base nodes is very unspecific and broad, i. e. "Campus information", "Student services". The leaves specify these basic concepts more clearly. The parents subsume their child-nodes. This implies that selecting a general node also selects the more specific sub-nodes.

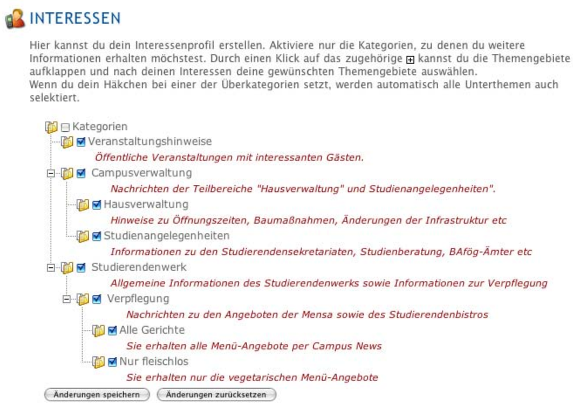

Figure 6: CampusNews Userweb

Both frontends access the backend, consisting of a relational database and a server application. The database acts as central storage for message data, profile data and service node information. Both web frontends store changes made by the users here.

3.2 Intelligent message filtering

The server application also accesses the database, but uses this data to drive the service nodes. As soon as mobile devices are recognized by the service node, the server looks up the profiles of the corresponding users.

Based on the approach from the IASON project using a subsumption check on the annotations of the messages and the users' profile, the server decides on which information conforms to the users' interests. This decision whether an information is of relevance for the expected user is very important. Nothing is more annoying for a user of a system as receiving unwanted information. In the next step a history query is made to ensure that no mobile device receives the same information twice. All relevant messages are then transferred to the service node by either wireless or wirebound networking.

3.3 Streamlining data transport

The service nodes scan for mobile devices with activated Bluetooth visibility. After handing this information to the server and receiving the messages, they attempt to transfer this data. After two successive rejections by the mobile device no further attempts will be made according to a backoff algorithm, to adapt to users that are not interested in the service. This also frees bandwidth and transmission slots for users that want to receive information.

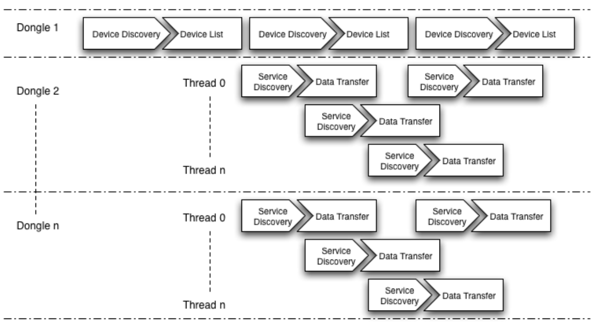

Figure 7: Flowchart of action timeline for Service Node

We discovered early on in the development that we would need to take special care to streamline data delivery. Users don't want to wait while their mobile device receives data. Having to wait for a connection request is even worse. Because most mobile phones and PDAs on the market today contain Bluetooth hardware that still adheres to the older Bluetooth 1.1 standard, there is no specific support for IEEE 802.11 and Bluetooth coexistance. Hence, wireless LAN interferes with Bluetooth to a high degree in this situation. This means that optimizing data transfer is of even higher importance. As removing IEEE 802.11 from the site of deployment or upgrading the firmware of mobile devices is not possible, we attempted to parallelize the data transfer pipeline.

The fact that transporting data to multiple destinations at the same time is problematic in Bluetooth Piconets came as a surprise. In contrast to modern wireless LAN hardware, the firmware in the Bluetooth dongle is responsible for most baseband and low-level protocol transactions. Standard Bluetooth operations (like connecting to another device) that run flawlessly when serialized can break when another connection is already active on the connecting Bluetooth device. Most of these constraints disappear with more modern Bluetooth hardware, where a newer firmware corrects these bugs. Newer driver version also react better to parallelization. A logical conclusion would be to attach multiple Bluetooth interfaces to the service node and spread the operations out. This decision in itself restricts available operating system platforms. In our case we had to move from the mainline embedded Linux kernel 2.4 to kernel 2.6, which isn't widely used in embedded applications yet. The older platform did not correctly support multiple Bluetooth controllers.

As with most Bluetooth applications, each transaction cycle for the service nodes can be divided into four stages – device discovery, name inquiry, service discovery (for detection of the RFCOMM channel number) and data transmission via the standard OBEX protocol. It doesn't make sense to run multiple device discoveries at the same time as most embedded operating systems used on mobile devices cannot respond to device discovery queries while already connected to another Bluetooth device. All other pipeline stages can be run in parallel, one on each dongle. As expected, multiple data transmissions can be opened even from the same Bluetooth device, the maximum depending on the device firmware. Unfortunately service discovery and name inquiry cannot be run in multiple instances on one Bluetooth device, as this easily corrupts results. The resulting timeline can be seen in figure 7. There is no need to run the name inquiry on each cycle, results can be cached for a while. The same is not necessarily true for results of the service discovery. Although fixed in theory, the RFCOMM channel number of the OBEX file transfer service on the mobile device side can change without a discernible reason.

The Bluetooth baseband self-organizes network nodes into Piconets consisting of one Master and up to seven Slaves. We tried different configurations of these settings in a benchmark. All our benchmarks were done with three smartphones (Nokia 6630, Nokia 6680, Sony-Erricsson P910) placed in a circle around a service node with a fixed amount of Bluetooth interfaces. These interfaces utilized a CSR BlueCore chip with firmware revision 0x7ad. Changing Master/Slave settings on any Bluetooth device or combination of Bluetooth devices did not affect the outcome. Table 1 lists average time from node startup to service discovery ("SDP"), initial connection request ("ConReq") and transfer of a total of four files ("Total") for each of the three devices in the columns. Row one shows the time for these phases when only one Bluetooth interface is used for all activity, row two for two Bluetooth interfaces, and the third shows our default configuration using three Bluetooth dongles. All tests where run one hundred times under the exactly same conditions and the resulting time differences averaged.

There are some interesting facts to be learned from these numbers. For one, Device Discovery can and should be physically seperated from other Bluetooth activity if high performance and/or high turnover is essential. We noticed

Table 1: Benchmark with three mobiles and one to three Bluetooth devices. The numerals indicate the order of events, i.e. SDP 2 means the second mobile completed service discovery after 16.88 secibds

No. BT Interfaces	SDP 1	SDP 2	SDP 3	ConReq 1	ConReq 2	ConReq 3	Total 1	Total 2	Total 3
1	9.5	16.88	25.63	20.88	23.63	30.63	33.38	44.63	45
2	7.64	10.09	13.36	12.91	15.18	17.55	28.36	30.09	32.82
3	7.20	7.20	9.40	14.10	14.20	15.60	24.90	25.00	26.90

that even using up-to-date drivers and Bluetooth firmware, Device Discovery and Service Discovery could interfere with each other, resulting in blocking system calls or "device busy" errors. Apart from that, the available bandwidth on the PicoNet scaled as we had expected when two or more clients transferred data at the same time, as can be seen in the degradation of transfer time. Two interfaces behave quite different. In this scenario one interface would do device discoveries in a loop, while the other interface does a Service Discovery on each of the devices found by the first interface, and a subsequent transfer of all applicable files.

As explained before, the only blocking network function here is the parallelization of Service Discoveries. The resulting process is depicted as a flowchart in figure 7. Comparing the numbers for rows two and three of the table underline the implications of this chart. The need for serializing each Service Discovery action results in the delay between SDP 1, SDP 2 and SDP 3. With two interfaces, there is a noticeable delay between all three Service Discoveries. The node with three interfaces can run two Service Discoveries in parallel, and the third SD is run on an interface that is not as congested as in the former scenario.

During the test-runs described in section 2, we noted that having to wait for a connection request for a few seconds after activation of Bluetooth or entering the transmit zone portraied a feeling of unreliability of the system to the user. Every second that can be stripped from this time slot is an active gain for the users' comfort. The time spent waiting for transfers to complete is much less constrained in this way, as action is happening on the users' screen. With our multi-threaded, multi-device approach we can scale with the number of users while only minimally increasing delay.

Our approach supplied maximum throughput, which could not be achieved with one Bluetooth interface, event though the transfer speed was nowhere near line speed.

4. USAGE

Currently the Campus News System is used by the Administration of the University of Koblenz as distributors of new information. This information comprises the daily cafeteria menu, special offers by the bistro (cafe), interesting news on the Campus, additional lectures or special events. At the moment there are five service nodes distributed around the campus, one is in the bistro and four are inside and outside of the main building. We are planning to increase the service node count step by step (see fig. 8) until we achieve a campus-wide network with each building sporting at least one service node. Thus all information could be transported location-based and context-sensitive, i.e. information regarding physics can be broadcast in the physics lab. The buildings inform everybody about themselves.

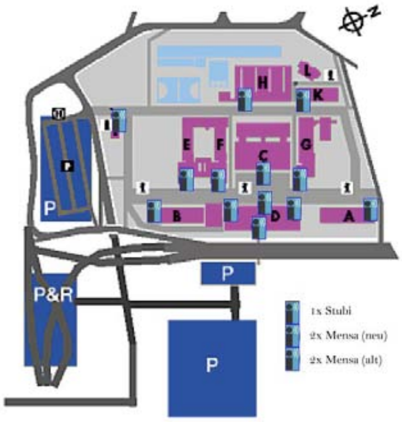

Figure 8: Campus University Koblenz

The steps to use the system are very simple for both administrators and end-users. An administrator would simply open the Campusnews Management Console web site in his web browser. There he will find a text form to enter text messages and the possiblity to upload files for multimedia notifications. All news can be added in multiple languages (see fig. 9).

On the end users' side the steps are even more intuitive. As soon as the mobile phone is in range of a service node for the first time, a welcome message with a link to the projects web site[5] is sent, along with a short explanation of what can be gained from joining. This message will only be sent once per mobile phone. If the user enters the link in a web browser on his computer or his mobile phone, he can create a Campusnews account by entering their university email address and selecting their mobile phone brand and model. The next step is selecting interests and disinterests (see fig. 6 right), which are organized in a hierarchy to cater to specific and broad interests/disinterests. This step is recommend to ensure that the users receive the information personalized, this means they will only get the amount of messages they are interested in. The connection between university email address and Campusnews account enables us to only store and maintain a minimum of personal data while still retaining enough to be open for extensions, as will be shown in the next chapter. This connection is completely optional, though.

5. RESULTS AND OUTLOOK

Now, two weeks after introducing the Campus News System at the University of Koblenz, we are pleased to say that

[5] `http://www.uni-koblenz.de/campusnews/`

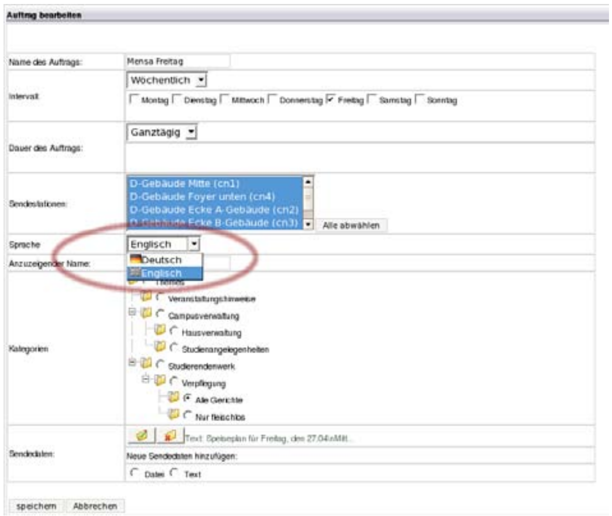

Figure 9: Form for adding new Information

the usage and acceptance by the students is very high. We detected over 2000 different mobile devices with Bluetooth activated. 115 Students are registered users of the new system. We transmitted over 1500 different messages in this short time frame (see fig. 10).

The next step is building a pervasive community by extending the system for reception of messages. Every registered user will be able to inject messages into the system directly from her mobile phone. This will require extended filtering mechanism for exclusion of unacceptable (i.e. insulting or hateful) messages. The connection between email account and Campusnews account would also make personal messaging possible.

Figure 10: Usage of the Campus News System

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