The Connector Service - Predicting Availability in Mobile Contexts

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Abstract. In this thriving world of mobile communications, the difficulty of communication is no longer contacting someone (the receiver), but rather contacting them in a socially appropriate manner. Ideally, senders should have some understanding of a receiver's availability in order to make contact at the right time, in the right contexts, and with the optimal communication medium. This paper describes our ongoing research on the Connector, an adaptive and context-aware service designed to facilitate efficient and appropriate communication. We describe a set of empirical studies whose results converge upon the important subject of people's availability in mobile contexts.s

1 Introduction

1.1 Project CHIL and the Connector service

Computers are becoming more ubiquitous and seamlessly integrated into everyday life. At present, considerable human attention is devoted to operating and attending to computers, and people are often forced to spend precious time fighting with technologies rather than engaging in human interaction and communication. This unfortunate trend moves us further away from Mark Weiser's motivation for the post-PC era of ubiquitous computing, getting us away from staring at PC monitors with computers at the center of attention in order to re-engage in human interaction [1].

Having computers anticipate our needs and provide us with relevant information and services would help people to break the technological attention barrier and re-engage in meaningful human interactions. Such human-centered computational tools would be particularly beneficial in meeting situations or technologically-mediated communication.

Within the framework of the **CHIL project - Computers in the Human Interaction Loop -** we intend to develop context-aware, proactive computer services that assist people during daily interactions with others [2]. Rather than expecting people spend their time attending to technology, CHIL's goal is to develop computer services that are sensitive in attending to human activities, interactions, and intentions. In order to act in a proactive yet implicit way, services should be able to identify and possibly even understand human activities.

In this paper, we describe our ongoing research on a CHIL service called **the Connector** [3]. The Connector is designed to intelligently connect people at the right place, the right time, and with the best possible medium for socially appropriate communication.

1.2 Availability in mobile contexts

Modern communication technologies bring considerable advantages, as well as burdens, to both the sender and the receiver in a communication [4]. Despite the fundamentally social nature of communication, research and design of communication technologies disproportionately favors the initiators of communication, the sender, over the target of communication, the receiver. Therefore, the guesswork involved in making decisions about how and when to contact someone is placed in the hands of the sender. The sender calls when their situation is conducive to communication, but they do so with little knowledge of the receiver's situation. The problem is further exacerbated with the advent of mobile communication which decouples location from situation, thus decreasing the capacity for a sender to make informed decisions about the person they are calling. In the past, people were called at locations which reasonably described their current activity e.g. home, work, or school, but now that mobile phones are anywhere that people are, little contextual information can be inferred about the state of the receiver.

If there is no need to communicate in a synchronous way, this problem is much less apparent. Asynchronous communication, such as email, is reasonably convenient since the sender worries less about disturbing the receiving party. Instant messaging clients let the receiver set one's own online availability status, which has a number of benefits. However, the growing use and constant attending to instant messages often becomes a distraction to users [5] [6]. Moreover, text-based communication lacks the emotional richness and nuance found in oral communication where the same phrase said differently means differently. IM users are obviously aware of this pitfall as they very often use it to negotiate availability for a phone conversation [7].

The Connector aims at empowering both the receiver and the sender to establish communication, either synchronous or asynchronous, in a contextually appropriate way based on each party's availability. In order to inform the development of this technology, we have conducted a series of studies designed to understand how current mobile phone users negotiate and decide upon when to engage in communication. The results from these studies inform the development of a model of availability for communication and this model facilitates the design of the Connector communication service.

The remainder of this paper is organized as follows. Section 2 is an overview of related work. Section 3 outlines a series of large-scale field studies with one hundred mobile phone users conducted on a university campus to understand patterns of mobile phone use in everyday life. Section 4 describes the design and prototype implementation of the Connector Service as an adaptive and multimodal communication tool, with front-end clients running on smart phones, standard phones, WinXP and the World Wide Web. The following section presents results from a pilot study on availability collected with this system. We end with a summary and conclusions.

2 Previous work

It is assumed that 50 per cent of phone communications fail because they do not happen in the right moment in time [8]. Brown and Randell [9], in their essay on context sensitive telephony, discussed the possibility of an automated agent that blocks calls on the behalf of users. They concluded that a better solution would be to provide the callee's context information to the caller to let the caller make a more informed decision about whether or not to initiate the call.

A number of mobile awareness systems are doing work that aligns well with this approach. Context Phone [8] is a Smart phone application which enables users to share their context with their others who use the same application. Both ”Awarenex” [10] and ”Live Addressbook” [11] are systems on mobile devices that allow users see others' location and availability status with an interface similar to today's instant messaging buddy lists. Users can consider this information in order to make more informed decisions about contacting others. The ”Live Contacts” system [12] also provides preferences for communication channels. ”Enhanced Telephony” [13] is a desktop-based design of an enhanced PC-phone. In all of these systems, users must either manually update their availability state or context information is inferred automatically from sources such as login time, personal calendars, messenger status, idle time of computer input devices, and engagement in communication activities.

SenSay [14] is a mobile phone that follows a different approach. It adapts to changing user states by manipulating ringer volume, vibration, and phone alerts for incoming calls. SenSay uses a number of wearable sensors including accelerometers, light and microphones mounted on the user's body to provide context information.

The Connector is designed to combine many of the features mentioned above. Additionally, the Connector leverages machine-learning techniques to sense the receiver's availability from automatically gathered context cues. Connector clients run on Smart phones as well as WinXP platforms; it supports a standard phone dialogue interface. To inform the design of the Connector, we conducted a suite of large-scale field studies in order to understand mobile usage patterns in terms of receiver availability. These field studies consisted of both an exploratory survey field study a field experiment that involved controlled, randomly assigned experimental conditions.

3 Large-scale mobile phone field studies

We ran large-scale field studies with approximately one hundred mobile phone users in order to understand and enhance our understanding of mobile phone usage patterns. We designed the studies with a special emphasis on receivers in everyday life.

The **first study** focused on revealing the contextual characteristics that correspond to successful mobile connections. Multiple methods of inquiry were employed in order to provide a better understanding of receiver availability across a diversity of contexts within which mobile communication occurs. This model is carried forward into the **second study**, where it informs the design of a basic Connector service that facilitates contextually appropriate mobile phone conversations.

The overall intent of the field studies was to discover how to best facilitate successful, efficient, socially appropriate communication through mobile phone technology for the Connector service. Analysis of the extremely large amounts of collected data points is our current work in progress. We present our initial results in the following sections.

3.1 Availability study – Everyday mobile phone usage patterns

This study investigated the contextual circumstances under which successful, missed, and rejected calls occurred. The study deployed a system capable of randomly pinging users throughout the day to determine availability for conversation in situ. Additionally, participants indicated their availability for mobile conversations using an online calendar, hosted by an Exchange server. Availability probes were deployed throughout a period lasting one full week. The length of this period means allows data to be analyzed for differential use patterns during weekdays versus weekends, daytime versus evenings etc. Each ping consisted of a call, deployed by the server, to a human receiver. If the receiver answered, the server played a recorded voice prompt, asking the receiver to indicate his or her current availability for a conversation (by voice or DTMF). Upon being pinged, receivers responded with their availability by hitting a key on their mobile phone keypad, 1-9, regarding their availability at the moment. Our telephony server logged whether or not the appointments scheduled in the receiver's calendar, whether or not the receiver answered, and ambient acoustic noise during the call.

Finally, at the close of each day, participants completed an online questionnaire about their context when each phone call was received. They describe features of the situation that influenced their decision to communicate, or not, at the time. For example, *"I was visiting with a friend. We were talking and not too busy but he is a very close friend,"* or, *"My boss was in the room and asked what the call was about,"* or insights like *"I realized that when filling out the online calendar, I did not always block off times I could not answer the phone but instead times when I did not want to answer the phone."*

This study allows multiple evaluation strategies: correlation between plans and situated availability (similar to Suchman's plans and situated action [15]), models of usage patterns based on time of day or calendared activities, and content analysis of contextual features that predict availability for communication. The study will provide an empirical foundation for deriving a model of receiver availability. This model will be carried forward into the design of the Connector, in order to facilitate contextually appropriate mobile phone conversations.

3.2 Connector Study – Mobile phone communication with connection assistance

The second study was designed to examine how the Connector, by facilitating a conversation between two individuals, affects ease of communication, social judgments and perceptions of each other, and assessments of the Connector system, across both coordination and collaboration tasks. Students engaged in both individual- and group-centered activities involving two features of the Connector. Feature 1 was the 1:1 Connector service, which facilitated 1:1 connections between two individuals by offering callee availability information to callers at the time of the call. Feature 2 was the 1:N Connector service, which facilitated connections from one caller to the a group of individuals, offering connections to those group members who are currently available at the time of the call.

Students used their own mobile phones to call the Connector telephone server (see Section 4). The system encouraged senders to complete a call only when receivers were available, thereby minimizing the risk of inappropriate interruptions or missed calls. Additionally, by placing a system between the sender and receiver, both sides were free to provide detailed information about their availability without allowing direct surveillance by other humans. Eight teams of students were asked to complete coordination and a collaboration tasks with eleven or twelve teammates. Teams were arranged to maximize likelihood of unfamiliarity with teammates by choosing students from different discussion sections. Experimental conditions were randomly assigned.

In a between-subjects 2 (feature 1 or no feature 1) x 2 (feature 2 or no feature 2) design, we had four conditions in this study with two teams per condition. We varied two dimensions, directly informed by the two Connector features, 1:1 Connector feature and 1:N Connector feature. The control condition consisted of team members completing the tasks through typical mobile communication. The other three experimental conditions consisted of either only the 1:1 Connector feature, only the 1:N Connector feature, or both the 1:1 and 1:N Connector features.

There were two experimental tasks in this study; one featured coordination and one featured collaboration. In the **first task**, participants had to contact at least half of their teammates for help solving a Mystery Person task. This task required collaboration and information exchange between participants because team members each had a different set of clues that collectively complete the process of elimination to identify their team's Mystery Person, but did not require a face-to-face meeting. In the **second task**, participants were asked to arrange a face-to-face meeting. At this face-to-face meeting, teammates took a group picture to prove that they met at the requested location (see Figure 1).

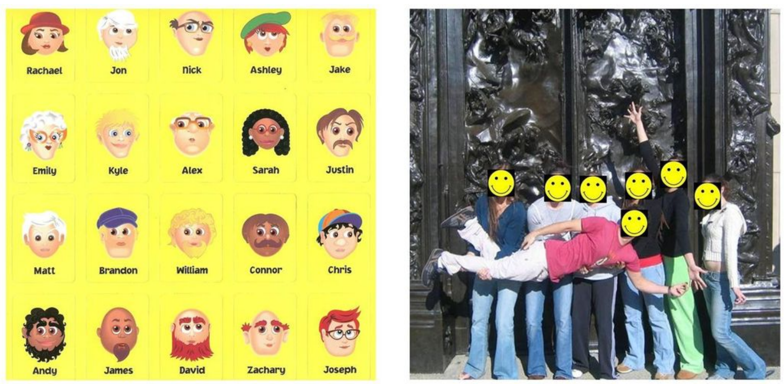

Fig. 1. Left: All possible faces in the Big Connector Study's Guess-Who-Task, each team had to collect clues from team members to find their Mystery Person. Right: Group picture taken during the coordination task.

3.3 Discussion

These large-scale studies were not only field studies, but also involve experimental manipulations that allow for controlled examination of what differences in Connector features will make a difference for future users of the system.

All studies were performed at Stanford University during the fall 2005 quarter, using roughly 100 college-aged students from mixed disciplines (social science, engineering, and humanities) from an introductory course in Communication. Evaluation of the collected data is work in progress. Initial results from the Availability Study indicate that participants with calendar appointments marked as busy or free did not significantly predict how available participants were for communication according to the in-the-moment availability as measured by pings from the server. This supports the claim that there is a problem with calendaring information, which could be framed as planned (scheduled in calendar) availability as being very different from situated (in-the-moment) availability. Therefore, we conclude that calendar information alone is not sufficient to estimate availability for communication.

This work suggests a need for a better predictive framework for receiver availability and a more detailed understanding of receiver location, environment, activities, social relationship to caller and communication urgency. The Connector service described in the following section is an attempt to create and test such a predictive framework.

4 Design and implementation of the Connector Service

The Connector is an adaptive and context-aware service designed for efficient and socially appropriate communication. It maintains an awareness of its users' activities, preoccupations, and social relationships to mediate a proper moment and medium of connection between particular people. In this system, personal agents act as virtual administrative assistants, who know how to selectively facilitate some calls while blocking others.

In order to be ubiquitously accessible for users, Connector clients can run on a set of Smart phones, as a Windows XP application, and as a web service. A dialogue interface is supported for all standard phones. Machine-learning techniques are used in order to learn individual user availability, from automatically detected context cues, as well as direct user input.

4.1 System overview

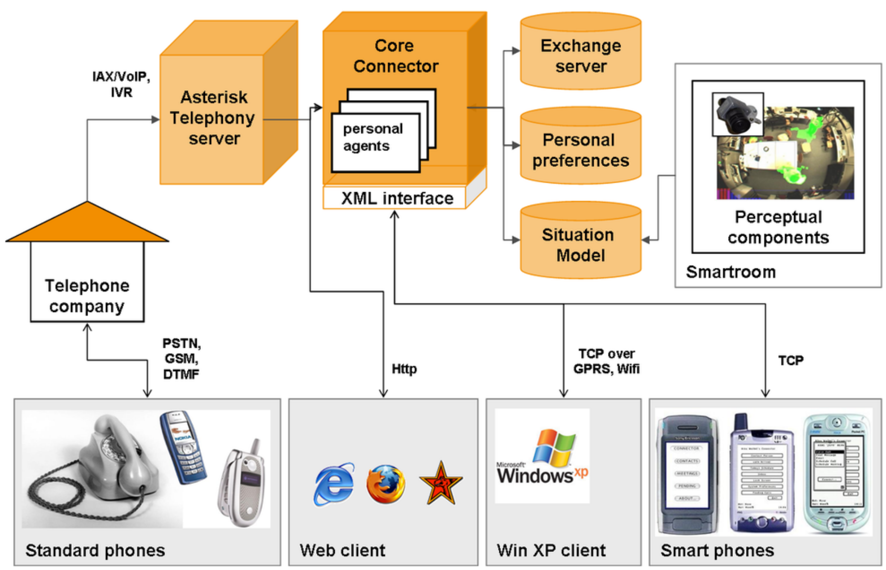

Fig. 2. Overall Connector architecture.

The system architecture in Figure 2 shows how various clients are integrated and communicate to the core Connector module. So far, all the logic is placed on the server side of the system. The core Connector module is responsible for collecting context information and learning the users' availability model. Data such as user preferences and settings are stored in a database. Calendar information is hosted by an Exchange server. The client-server communication is XML-based over TCP. Brief description of the clients follows.

4.2 Connector clients

Connector **smart phones** run a custom-built graphical Connector user interface, indicating current receiver availability. The system controls incoming calls, outgoing calls, messages, and phone alerts. Currently supported platforms include Sony Ericsson P900 Symbian phone and Windows CE devices. The smart phones contact the user's server placed personal agent to determine how to respond to incoming calls or messages. The communication takes place via Wifi or GPRS.

MyConnector is the Connector client running on **Windows XP** (screenshot shown in Figure 3). It provides an interface to set preferences and manage contacts. Along with phone communication, MyConnector lets the user send emails, send instant messages, and allows conference calls (via the Skype API). In the contact list, various symbols are displayed showing the availability of the contact person for communication media such as Skype IM, Skype call, email, office phone, home phone and cell phone. MyConnector does as well gather PC activity in the background as context cue to learn user availability.

Fig. 3. Screenshot of the MyConnector Windows XP client and web interface showing a user's public profile.

Not everyone owns a smart phone and will be willing to install the MyConnector WinXP application. Therefore, a set of Connector functionality is available from every **standard phone** via a voice dialogue system. By calling a person's (toll-free) Connector number, the call is routed through our telephone server. As the caller, once you identify yourself and the person you want to contact, the Connector service will inform you about the receiver's current availability; and then proceed to route or block the call, accordingly. This is the setup that was used and tested in the field studies described in section 3.

User profiles and current availability are also viewable from **web browsers**. Each user has a public profile accessible by anyone and different custom profile, which typically has more detailed information for selected individuals. Figure 3 demonstrates a public profile. We integrated the Google Maps service to display the current location of a user. Also, an overall availability level and details of the callee's current location is displayed. Icons indicate availability for different communication media; active icons may be clicked to use that communication medium to contact the person. The level of information granularity displayed is user-defined in the owner's privacy settings.

4.3 Privacy settings

Whenever personal data such as this is broadcasted, privacy immediately becomes an extremely important issue to the user. This becomes obvious, as most people do not want their detailed location being shown in a Google map on the web. The Connector provides the opportunity to specify *who* should be able to see *what* information *when*. E.g. *I want all my colleagues to see the building I am in, but only during working hours, but my family can always see where I am. The default should be only specifying what world continent I am on (as opposed to what country, city, street,building, or room).*

We implemented hierarchical privacy rules in a rule based system. Each rule specifies when it will fire depending on the time of day (free time or work time) and the location of the user. Such privacy rules can be created for users or groups in the address book; the default setting is used for unknown persons.

According to previous research [16][17], it is necessary to provide appropriate default settings when it comes to privacy related data. We ran a survey with 43 people to find appropriate default privacy settings for the Connector service. In this survey people were asked which details about their location and current activity they would like to broadcast to their wife/husband, family, friends, acquaintances, coworkers and their boss, during work time and free time. The time of day seemed to be only relevant for work-related persons (co-workers, boss). As expected, less known persons (such as acquaintances) were less trusted than people in more proximate social circles (such as family and friends).

4.4 Learning user availability

The Connector uses machine-learning techniques to model contextual knowledge about the user and to infer the user's availability for communication. Input comes from **automatically detected context cues** collected in the MyConnector WinXP application such as:

- **personal calendars**: entries in a personal calendar
- **PC activity**: keyboard and mouse events, active application, window switching frequency
- **location in office**: based on the analysis of video-streams from cameras installed in our research labs

Our system uses Bayesian networks. Investigating different classifiers, such as decision trees and other Bayes-based classifiers, and attribute combinations is work in progress.

Further analysis of the MyConnector pilot study described in section 5 will definitely impact the design of future MyConnector systems as we learn more about the usefulness of various context cues to be used as attribute combinations for the classifier.

5 MyConnector Pilot Study - Predicting user availability

In order to inform the development of the MyConnector technology, we have conducted an experiment to understand which or which combination of a large set of context cues (either automatically collected by the MyConnector system or manually entered by the participants) have a strong predictive power for gauging one's availability.

5.1 Study design

We ran a pilot study with 9 participants at research labs in Karlsruhe and Stanford for one week in order to investigate the predictive power of context information currently used by MyConnector, as well as a number of possible future measures, that were self-reported by our subjects in this study. We used an experience sampling technique, and pinged subjects about their current availability and current activity during their normal daily activities. A popup window appeared on their screen about every 20 minutes. By simultaneously collecting sensor data as described in Chapter 4.4 we can examine offline which of the following factors would have produced the best estimates of one's availability.

Additionaly, participants were asked to manually enter availability feed-back every 20 minutes, **self-reported context cues** were the following:

- **current location**: e.g. office, home, transit on campus
- **accessibility of communication media** e.g. Email, IM, office phone
- **social acceptability**: How socially acceptable would it be to take a phone call in the current situation
- **activity category**: one of: *basic needs* (e.g. eating, sleeping), *household needs* (like cooking), *intellectual needs* (at job, at meeting, ...), *transportation needs*, *communication needs*, *interpersonal needs* (socializing with friends, ...), *personal needs* (reading, watching TV, ...)
- **mental and physical engagement**: while doing the current activity
- **importance and urgency**: of the current activity
- **point in lifespan**: of the current activity (beginning, middle or end)
- **collocation**: with how many people

Providing no data was interpreted as not available at all. **Ground truth** was a **self-reported availability level** between 1 and 4, meaning:

- **1**: not available at all (e.g. sleeping, swimming)
- **2**: basically not available, but exceptions possible (e.g. meeting, driving a car)
- **3**: busy but can be disturbed (e.g. internet browsing, preparing slides)
- **4**: free, communication encouraged (e.g. doing public transportation, waiting for an appointment)

For the offline data analysis, we used an iterative learning approach to get comparable results to an online classifier. Data entries were sorted by timestamps, and for each data entry t the classifier has been trained on data entries 1 to t-1. For the final result, the classification results for each item were counted.

5.2 Initial results and observations

Table 1. Results of using various context cues in the Bayes classifier to predict availability.

attribute	**classifier result** [%]	**attribute**	**classifier result** [%]
Time (hour, weekday)	54.3	Collocation with others	48.0
Location	51.6	Interaction with others	49.2
Time - Location	58.0	Activity category	42.8
Active program	48.4	Activity importance	47.3
Keyboard activity	28.5	Activity urgency	46.1
Mouse activity	29.3	Activity mental engagement	45.0
Window switching	28.7	Activity physical engagement	38.7
Online connection	46.9	Activity point in lifespan	37.7
Skype	32.3		
Active Program and Online Connection	49.1		

Table 1 shows the results of using various context cues in the Bayes classifier to predict availability. We see that learning a person's availability seems to be a very hard task. Partially, this may be due to the fact that a person's 'stated' or 'planned' availability as e.g. scheduled in a calendar, does not always correspond to their 'demonstrated' or 'in-the-moment' availability. On the other hand, if an event is planned, interruptions are probably much more awkward then in a spontaneous meeting.

The time of day was especially powerful in combination with self-reported location information, but only for people with a structured day and regular office hours. As well, the predictive power of personal calendar information was only significant for some of our participants. It was found that the existence of an appointment is not always a good indicator for a lower availability.

Results from PC activity information were lower then expected, even though the active program showed to be the best indicator. This was probably due to the fact that a number of participants used multiple computers throughout the day. People were more interruptible if engaged in Skype communication and in general, if they had connection to the internet.

Looking at a person's activity information, the urgency and importance as well as the mental engagement in the current activity seemed to be more valuable then the activities category and a person's physical engagement in the activity. This may be good news, since urgency and importance could be extracted from email communication or calendars entries, whereas engagement in the activity may be harder to sense. Our participants were more interruptible towards the end of an activity then at its beginning.

In order to estimate the statistical significace of some of the factors, we applied a standard multiple regression analysis to predict the dependent variables of level of availability set manually by the participants. Regression analysis shows that only two variables, the social acceptability of a phone call ($p \leq .01$) and the urgency of the current activity ($p \leq .01$), contribute significantly to predictions of the person's availability level. The R^2 for regression is significant ($R2 = .32$, $adjR2 = .31$, $F(1, 166) = 24.29$, $p \leq .01$). In other words, the less socially acceptable receiving a phone call in the current environment would be, the less available a users is. Also, participants were more available when doing current activities that were judged as not urgent. Along with these findings, physical engagement appears to be another possible predictor for availability (p=.078) as it approaches, but does not reach statistical significance. All other self-reported factors, such as the activity category, the point in lifespan of the activity, the importance of the current activity, and collocation with others are not statistically significant predictors of availability under this case ($p \geq .1$). We still believe that these factors may be interesting and aim to study a larger sample size to get a more thorough understanding of these factors and their predictive power for gauging one's availability.

This statistical analysis shows, that the results presented here should be considered with care. To strengthen some of our observations, a larger experiment would be necessary.

6 Summary and Conclusions

The focus throughout the paper is on how receivers in mobile contexts negotiate and decide upon when to engage in a communication, to generate a model of receiver availability and to design more efficient and socially appropriate communication services, such as the Connector service.

Large-scale user studies with about 100 mobile phone users suggest that planned availability as scheduled in a calendar is very different from situated, in-the-moment availability and that we need a better predictive framework for receiver availability. As such, the Connector service was introduced as an adaptive context-aware service designed for efficient and socially appropriate communication. Pilot studies with the Connector prototype attempted to show the impact of various contextual cues on the user's availability. Results indicate that location and time, as well as the urgency of the current activity and social acceptability of a call in the current environment are significant indicators for a person's availability.

Further larger-scale studies are planned in order to get a more thorough understanding of these findings. All findings will be carried forward into the design of the future Connector service.

Ongoing work in Karlsruhe focuses on the development of perception technologies, such as audio-visual speaker tracking [18] and person identification, head pose estimation [19] and speech recognition [20]. Technologies will have to be improved and tuned to detect the most significant context cues automatically, in order to make the Connector a real proactive CHIL service.

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