Mobile Use of IT

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1 Introduction

The emergence of worldwide computing networks is often said to make us all inhabitants of a "global village". It will not matter where you are in the world, you can still communicate with everybody else. You will be able to access relevant information regardless. This has not made us less mobile, however. On the contrary, we are more mobile than ever. It may sound like a paradox, but an impressive set of statistics supports our claim:

- 25% of computer systems sold are for mobile use.
- Europe has 55 million cellular telephone (GSM) subscribers.
- USA had 2,24 million users of wireless internet-access in 1997. There could be 10 million by the end of 2000.
- 300 000 people are, at any time, airborne above USA.
- 300 000 people travel by car and train into London every morning.

The global village is indeed a mobile one. Mobile Informatics is the field concerned with equipping the mobile society with innovative and useful services and applications. The purpose of this paper to explore the core concepts of Mobile Informatics, i.e., mobility and mobile IT use, and outline current problems and possibilities of IT use in mobile situations.

2 What is Mobility?

On one hand you can say that all of us are mobile. Who does not move? Most people go to work, they visit each other, they shop, they go to the beach, the soccer game, and so on. So, who is not mobile? Why use the word in the first place? At the same time, all of us sit still at some time every single day. Even the newsboy, the messenger, and the marathon runner sit still at some point in time, every single day, year in and year out. Does this mean that they are "stationary," that their job does not differ in important ways from say a secretary or a cook when it comes to mobility? The answer is obviously no. So how, then, do we measure mobility? By the number of steps taken per minute? By how long you walk during a day?

Mobility is one of those words that are virtually impossible to define in a meaningful way. You either come up with a definition that excludes obvious instances, or your definition is to too vague; it fails to shed light on important aspects. At the same time we all have a feeling of what it means; the newsboy and the travelling salesman are mobile, the secretary and the cook are not. Thus, we can conceive typical situations in which people are mobile and when they are not.

In this paper we will try to conceptualize, in a model, as well as illustrate, using

examples, what mobility ‘really’ is.

2.1 Types of mobility

We can distinguish between situations that are typical instances of a type of mobility. For instance, everybody who spends much time going in a car everyday seems to belong to the same category, everybody who takes the commuter train from a suburb to down town every day seems to belong to the same category, and so on. However, these kinds of categorizations can be done in many different ways. For example, the car commuter and the travelling sales man can be two examples of car drivers. But the car commuter can also be an example of a “commuter.” In this case she would be categorized along with people who go by train, bus, tram, etc., from a suburb to down town.

One way of conceiving types of mobility is to distinguish between travelling, visiting and wandering, shown in figure 1.

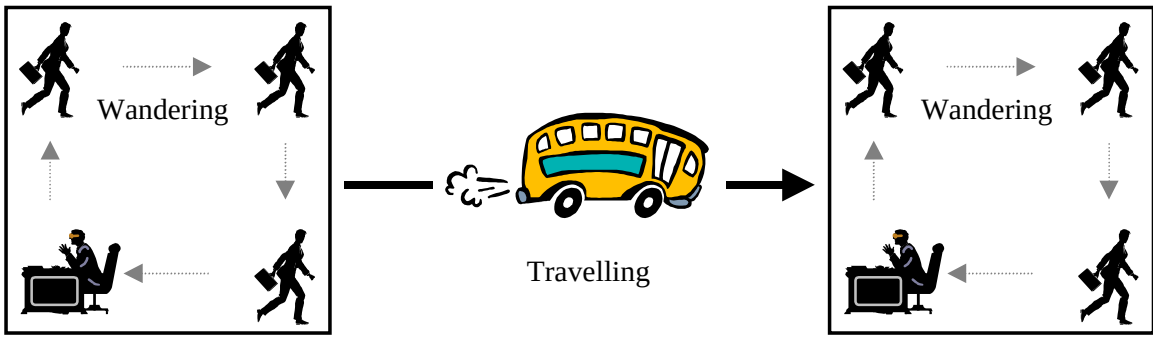

Figure 1: Three types of mobile modalities: travelling, visiting, and wandering.

Let us consider the three modalities in more detail. Distinctions between types of mobility need to be done carefully, and with the inevitable problem of categorization in mind – it represents one perspective out of many.

2.2 Travelling

Travelling is the process of going from one place to another in a vehicle. For example, the commuter is travelling when she goes by train from her home to the work place, the travelling salesman is travelling when he goes by car from on client organization to another, and the holiday maker is traveling when she goes by plane to Hawaii. The traveling type of mobility seeks to capture the mobility of people that go in vehicles.

The traveling person can either drive the vehicle or be a passenger. In the latter case, it may be easier to do activities other than just going. For example, the commuter can use her laptop on the ride from a suburb to the work place down town. However, drivers can also be concerned with other activities. For example, the driver can talk to other using a mobile phone. Driving and doing other things at the same time tend to be dangerous however. Nevertheless, it happens that people who go by car during rush hours use a laptop when the traffic jam makes driving impossible.

2.3 Visiting

Visiting is spending time in on place for a temporal period of time before moving on to another place. For example, a consultant is visiting when spending time in a client organization, a researcher is visiting when giving a guest lecture in another university, and a stand in teacher is visiting when giving classes in a schools for a couple of days. The visiting type of mobility seeks to capture the mobility involved when people spend time in a place on a temporary basis before moving on to another place. The visiting person can either bring IT to the place she visits, e.g., a laptop, or she can use a PC that is already there.

2.4 Wandering

Wandering is extensive local mobility in a building or local area. A wandering person spends much time walking around. For example, IT support personnel in some organizations spend much time wandering around helping people, and a night-watch man who walks around a building checking that everything is alright is wandering. Due to the high degree of personal mobility in wandering, the IT people use in such mobility is often very easy to carry.

The following table combines typical situation with typical technology.

		Technology		
		Mobile	Portable	Desktop
Modality	Wandering	✓		
	Travelling	✓	✓	
	Visiting	✓	✓	✓

Table 1. Modalities and technologies.

Of course, one may conceive of examples in which these categories are ‘broken’. A workstation can be moved, even used in a mobile fashion if you put it on a trolley. It is not a convenient approach, though, and may lead to new and interesting cases of repetitive stress injury.

3 Why is the world such a mobile place?

The answer to the question is simple: Man is a hunter-gatherer. True, since the Iron Age we have continued to develop tortuous cities in which to dwell, and complex communication to reduce the need for travelling, but many factors contribute, literally, to keep us on our toes. Indeed, it seems that modern communication techniques increase, rather than decrease the mobility of our society. Fifty years ago most people never left their hometown. Today, all airline companies routinely accommodate toddlers.

But man’s nature is also to create, and our artificial world insists on mobility as well. We are surrounded (and surround) tools, organizations and society, within all three of which mobile issues may be identified.

Needless to say, the mobility trend is the product of a vast amount of factors, and it is difficult to pick the most important. In the context of work, one main reason is that most work in the modern company is cooperative. This was not so much true previously, where the work in most organizations where designed according to the principles of the bureaucracy. Today's project and team-based organizations are designed to promote cooperation that bureaucracy is designed to avoid. Cooperation leads to increased use of IT such as email and conferencing, which bridge distance, but it also leads to mobility; people travel to meet each other physically.

Another important factor is the emergence of service work as the main occupation in the western society. Since the beginning of the 1960s, manufacturing has decreased and service work has increased continuously. A service differs, of course, from manufacturing in many ways. One important way is where it takes place. Manufacturing takes place where the machinery is, which is one single place. A service often takes place where the customer is, which differs from time to time. Therefore, most service workers are mobile. The increased amount of service workers has made society more mobile.

Yet another important explanation is adoption of mobile phones. The mobile phone is designed to enable people to be mobile without being disconnected. New ways of working has therefore emerged in many organizations, where people assume to be accessible independent of place.

3.1 Society

We live in an open society. We know what is on offer elsewhere. Moreover, we can afford it. Thus, people go on holidays abroad• farther and more often than before. Students enlist at big universities far way from where they live. We can go to the other side of the world and back in a weekend for a conference, or overseas for a one-day meeting. Only fear of flying keep people from being mobile! Nostalgic people travel by rail or sea. On the ground, cars are high-power communication centers, with mobile telephony and radio as minimum capabilities.

3.2 Organizations

Consider business life. Organizations change to accommodate the open society, which they serve. They compete with other enterprises across the world. Of course, this means that this is where the customer is as well. This does not always mean that the customer gets a varied offer, with ample niches for all bidders. Often, the winner takes all. Customer loyalty is attenuated, and continual attention is to details is required to be successful. Details are where the customer is. So is requirements and service. Customization depends on knowledge about use. Therefore, mobility is necessary.

3.3 Tools

Size matters in technology development. Unless the trend is to make something bigger (buildings, bridges, computers) it is to make it smaller (cars, computers). We realize that in many instances, small is small for it's own sake, not because vendors want to support mobile IT use. Actually, as discussed below, often smaller simply means more power into a plastic cabinet of the old size. Software (and hardware) is a gas; it expands to fill the available space. But, given small components, innovators have started building small computers for mobile IT use.

4 Technology makes us mobile

Some mobile technologies have been amazingly successful. Consider, for instance, mobile telephones or the PalmPilot, both of which sell millions of units each year. In this section, we take a look at five types of mobile IT. These are (see figure below):
The mobile phone

- The PDA
- The hybrid
- The mobile information appliance
- The wearable computers

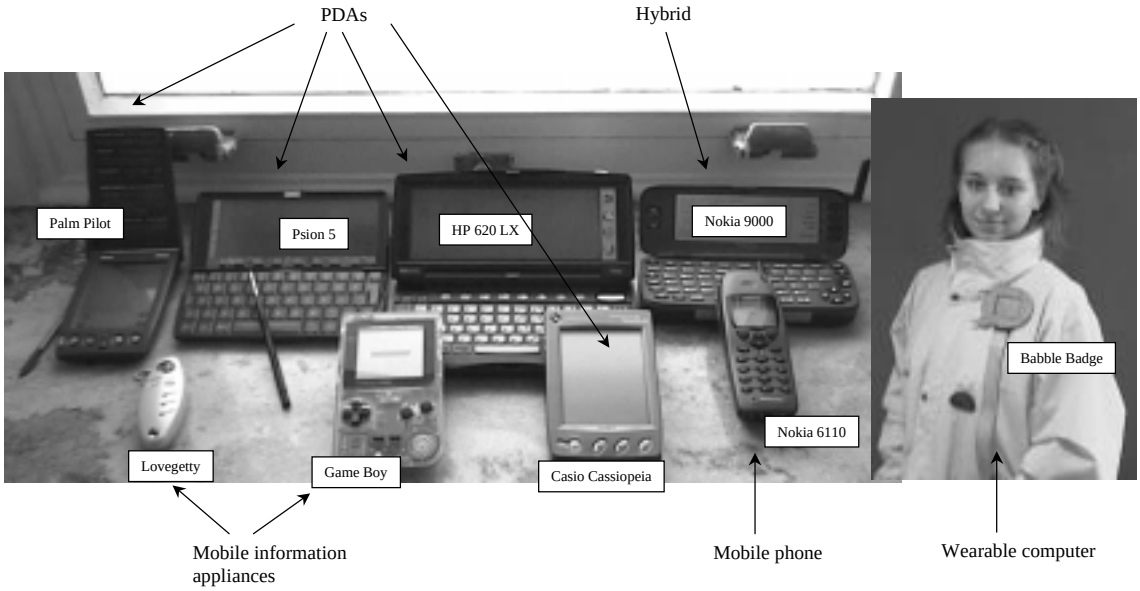

Figure 2. Mobile IT:
Let us now take a closer look at these four types of mobile IT.

4.1 The mobile phone

The most widely used mobile IT is the mobile phone; a communication oriented mobile device that makes it possible for us to interact independent of place. In other words, it enables us to be mobile, yet accessible. In many parts of the world, the adoption of mobile phones have been extensive the last couple of years. Just think about it. How many of your friends used a mobile phone in 1995? How many use one today? Or, perhaps the question is how many do not use one today? As the first country in the world, Finland in December 1998 had more mobile phones than stationary phones (56 per 100 citizens, 2.9 million users, average 1998: 60 000 new users each month). Most mobile phones use the GSM (Global System for Mobile communications) wireless communications standard. This is a wireless platform because it uses radio frequency. GSM phones can be used in most parts of Europe, and the coverage in the US is growing rapidly.

4.2 The PDA

The PDA (Personal Digital Assistant) is another main category of mobile IT. The PDA is often used for “individual organization tasks,” such as managing calendars and taking

notes in the field. It is often argued that Alan Kay coined the idea of a PDA. In the late 60s, while being a student in computer science, he developed a vision of “the Dynabook.” Kay described the Dynabook as a flat, wirelessly connected computer that was portable, interactive, and easy use.

The PDA connects to a network either via a cable to a computer, or wirelessly via a mobile phone. Currently, connecting a PDA to a network is quite cumbersome, and most people use the PDA for tasks that do not require constant network access. Users process personal information on the PDA, e.g., manage their address books and calendars. Shared information is most often updated asynchronously. Let us take an example: Sales representatives routinely visit clients. Before they leave, they can connect the PDA to the PC and transfer sales information about the client in question. This information can be updated during the visit. For example, a new order can be entered. While going back from the client to the office, they can connect their PDAs to the mobile phone and transfer the order to the company server. Increasingly, companies like Lotus and Microsoft offer client versions of business applications for PDAs.

The Apple Newton was one of the first PDAs available on the market. The Newton was a so-called pen computer. The user operates the computer with a pen directly on the screen, which is touch sensitive. For example, to enter the text “Jolly good fellow,” you simple write this text done with the pen on the screen. Dialogues are handled the same way. For example, if you quit an application and the computer asks “Do you want to save the file?” then you simply presses “yes” if you want to, “no” if you do not want to, etc. Hand writing for input sounds like a great idea. Unfortunately, this did not work very well at the Newton, which might be one reason why it never became a big success. Another reason may be its size and weight.

Currently, there are three dominating brands of PDA: the Pilot, the Psion, and the Palm computer:

The Pilot, or PalmPilot, is a small, handheld PDA. The user inputs characters by a pen using a technique called “Graffiti.” Graffiti was developed to make it easy for the PDA to recognize user input (compare the problems with the Newton). The Pilot runs an operating system called “Palm OS.”

The Psion (series 3 and 5) differs from the Pilot in that it has a keyboard. However, the screen is touch sensitive as well, and the computer is also equipped with a pen. The Psion uses the EOPC operating system, which also serves the foundation for the well-known Symbian initiative launched in fall of 1998.

Another broad category of devices runs the MS Windows CE operating system. Windows CE is a lightweight version of the Windows operating system. Microsoft has never told for what “CE” stands. One common guess is Consumer Electronics. Or it could be Compact Edition. The Sharp Mobilion Handheld PC is one example of a Windows CE based PDA.

4.3 The Hybrid

A third category of mobile IT can be called “the hybrid.” A hybrid is partly a mobile phone, partly a PDA. The Nokia 9000, “the Communicator,” is perhaps the most well known example. It is usually considered a product of limited success and reviewers seem to find to find it works well as a phone, but less so as a PDA . This category of mobile IT is classic, inasmuch as it is an example of devices that aim to integrate appliances from different domains.

4.4 The mobile information appliance

A fourth category of Mobile IT is what Donald Norman perhaps would have called "mobile information appliances," i.e., a simple, usable mobile device explicitly designed for a particular task. The "lovegetty" is one example. The lovegetty helps you find company. There is one kind for boys, another for girls. The device got three buttons, which specify in what ways you want to interact with others: have cup of coffee, go to the kareoke bar, or meet a partner. You simply turn the lovegetty on, press the desired button, and then do what ever you want. If you meet someone that has the same preferences as you, then the device notifies you. The lovegetty has become very popular in Japan. The sales figures are impressive. Other kinds of similar devices are emerging all the time.

4.5 The wearable computer

Wearable computing is a very future-oriented research area, with a growing number of projects. Briefly, it focuses on the ubiquitous use of dedicated, small computing devices that are fully or partly synthesised with the clothes we wear. Displays may be embedded in purpose-built glasses and gloves can be used as input devices. Perhaps can our bodies generate enough energy to transmit digital data across shorter distances? We are primarily interested in future applications and effects of this technology.

4.6 What is the meaning of these old-fashioned devices in this paper?

Looking beyond the physical manifestation of mobile technology we fined that there are several conceptual characteristics of which we will emphasize two:

- Mobile applications pretend to build on physical metaphors, such as "assistants", "diaries" or "maps", but instead, they rely on the desktop applications with, perhaps, in their turn, were inspired by these metaphors. MS Outlook is not imitating a pocket diary; it imitates MS Outlook running on a stationary computer. As we shall see this makes a big difference. There's a corollary to this issue, which says that people want power not convenience. The trade press has some responsibility here, it is usually muscle that wins tests of new computing (on basis of which people buy their machines), with elegance as runner up. Unfortunately, perhaps, the winner takes all.
- Mobile communications, e.g., GSM, is telecommunications rather than data communications. Telecom people prefer line switching (historically and financially, it makes sense), whilst the Internet builds on packet switching. Conceptually, the difference is between sharing and caring (sharing resources or caring for the customers). With packets, user must take what they get. On the other hand it is cheap, robust and easily flexible. Line switching makes it easier to guarantee quality-of-service and we know whom to bill. It is not very flexible, however. If you phone someone already phoning someone, the call is incomplete. If you try again, and get through, the line is all yours. The Internet has no busy signal, but as we know, it slows down under heavy traffic. So, if packet switching is like cars and line switching is like trains• which will be more successful? The answer, of course, is it depends.

Mobile IT-support is characterised by unpredictability, unreliable connections and the need for lightweight, user-friendly devices. Many aspects within different, traditional research areas such as user interfaces and security are exacerbated or changed entirely in mobile work. It takes place in unfamiliar or mutable environments: New, urgent tasks are likely to arise, and local resources may be insufficient for dealing efficiently with the

tasks. Thus, we need radically new applications for mobile workers as well as adapting traditional office-support to the requirements of mobile work. Therefore, let us next examine the desktop once more, before going properly mobile.

5 Is today's information technology mobile-aware?

The purpose of communication and computation will determine which technology is best. Sounds easy? Well, since the proof of the pudding will be in the relationship between the conceptual qualities of the technology and the use situations, rather than the technical specs that you get from the trade press, it my be slightly more involved. One way of approaching the question is to consider the use of mobile computing in a mobile setting. Consider the following example:

Consider using the Psion 5 palmtop while travelling in a crowded bus. The bus is crowded so you have to stand up. The application you want to use is a web browser. You connect the palmtop to your mobile phone. Since you stand up, you use one of your hands to keep the balance. Thus, there is only one hand left for the mobile equipment. Because you stand up, you probably have difficulties to place the mobile equipment somewhere. Thus, you need one hand just to hold the equipment. So, how do you operate it? How do you use the keyboard? You need one hand not to loose your balance and one to hold the equipment. Using the keyboard is not easy.

What happens when you need to operate the mobile phone? Then you probably have to place the palmtop in your pocket. Since the mobile phone probably, with some effort, can be operated with the same hand that holds it, the operating problem is probably less. Let us say that you have the technology up and running and you in some way manage to use the web browser. Suddenly, the bus passes by an area that does not have good contact with the mobile phone network. The connection goes down. You then have to start all over again: dial the number to the modem pool, login, enter password, etc.

Figure 3. Poor mobile users…

As the example above shows, using the H/PC to surf the Web in a mobile

situation is indeed very different from using the PC in the office. Your PC is likely to offer a permanent, reliable and fast network connection. It has a big color screen, a mouse, and a large keyboard placed on a flat surface. Browsing is fast and reliable, and you can use booth your hands to type.

Do the H/PC and mobile phone not offer the same basic functionality as a PC in the office? Is it not only a matter of performance?

We do not think that this is the case. That is why we focus on effect rather than functionality. By effect we mean what the user actually accomplishes. Effect is related to functionality, i.e., what the technology used offers. But, as the example above shows, turning functionality to effect takes place in a context. And as the bus example implies, the context plays a very important role. The H/PC offers similar functionality to stationary equipment in the office, albeit with lesser performance. The effects of the use situation are, as shown, very different.

Accordingly, developing IT for mobile use based on ideas grounded in the stationary setting, is likely to be unfortunate. In order to help designers to grasp the mobile setting, we suggest a model of the use of IT in mobile settings. The purpose of the model is to provide designers with a framework of concepts to understand and talk about how people use IT in mobile settings.

We hope the model could help designers to invent new concepts and imagine new metaphors for the mobile setting. The model should, therefore, characterize in what ways the use of IT in mobile settings differ from the use of IT in stationary setting.

6 Mobile IT use

Now that we have introduced “mobility” and “mobile IT”, we in this section outline a model of mobility and IT use. The focus of the model is the situation in which a mobile person uses IT. One objective of the model is to reflect the ways in which using IT in mobile settings differs from using IT in stationary settings. The three main components of the model are environment, modality and applications. Environment is the physical and social surroundings. Modality is the fundamental patterns of motion. Application is the combination of technology, program and data you use.

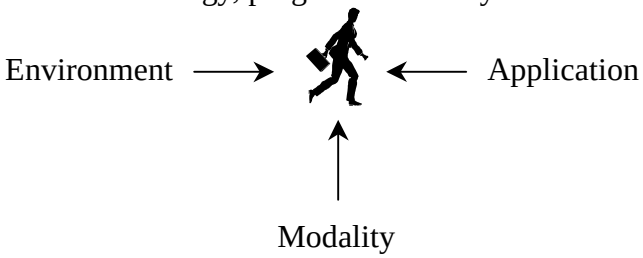

Figure 5: Model overview.

Let us now describe the components in more detail.

Mobile IT use is the overall situation of that the model seeks to describe, i.e., a mobile person’s use of IT. One example is a commuter using a laptop on the train to the city. Another example is a management consultant using a laptop in making a presentation in a client organization.

Mobile IT use always takes place in an environment. By physical environment we mean the observable, physical surrounding of the use situation. For a train commuter, the physical surrounding is the chairs, tables, etc., of the railroad car. The physical environment imposes important constraints of the use situation. For example, if the

railroad car is full and the commuter has to stand up, then the conditions for using IT has changed quite radically, e.g., there is not table on which a lap top can be placed, you need at least one hand to keep the balance, etc.

As opposed to the stable physical environment of the office, where you always have a desktop to place the computer, a nice chair, etc., the physical surrounding of mobile IT use is often not configured for IT use. Furthermore, it often changes from time to time (e.g., the train commuter).

To cope with the physical environment, the mobile person needs to configure the use situation according to the present situation, i.e., chose a practical combination of task, technology, etc. For example, if the railroad car is full she has to do work that require the lap top but the mobile phone, if the train passes places where the mobile phone does not connect to the network she may want to work off line, etc.

In the case of the reporters of Radio Sweden, the physical environment stipulates what kind of antenna to use. Sometimes the antenna on the rack, which holds the radio equipment, is sufficient to broadcast, but often a larger antenna on the van in which they travel needs to be sat up, and sometimes the van even has to be moved to a more appropriate place. The physical environment is sometimes used for support, e.g., as a "table" for writing reports.

Figure 6: The physical environment. To the left, the reporter has moved the car and run up the antenna of the van in order to get contact with the base unit. To the right, he uses the physical environment as a writing pad.

The social surrounding is another important aspect of the environment. By social surrounding we mean factors such as formal structures, e.g., rules, and informal structures, e.g., power.

Mobile workers needing to get in touch with collaborating partners holding a certain role may exemplify the social environment. For example, at a shipyard, verification work is sometimes based on the social network of surveyors and engineers. Alternatively, formal roles need to be engaged in order to achieve a legal result. Also, consider the example of maritime consultants in Oslo who are affiliated with the sister company in England when issuing certificates for which institutions in Norway may not yet be accredited.

Modality is the fundamental pattern of motion of an activity. The basic kinds of

modalitites are mobile and stationary. Specifying the general criteria for an activity to be mobile or stationary is difficult. One reason is that virtually all activities involve mobility of some kind. Traditional office work, for instance, is often described as stationary. Nevertheless, it often involves local mobility such as short trips to the coffee-machine or copiers, visits to offices, etc. We consider this modality, called walking an omnipresent mobility, even for stationary work.

Our ambition is not to suggest exact definitions of the mobile and stationary modalities, but to offer examples from real-world studies of what it typically means to be mobile. In order to do that, we introduce three archetypes, called wandering, travelling and visiting.

Wandering is an activity characterized by extensive local mobility. IT-support people, for instance, spend a considerable part of the working day wandering around in buildings. To help users, they often need to go to their offices, and on the way they often meet other users that want help. The policy of such groups is often “to be visible.” This requires extensive local mobility, or wandering.

Travelling is an activity that takes place while traveling in a vehicle. The reporters at Radio Sweden often used the mobile phone to coordinate meetings, check information, etc., while traveling between the base unit and the place from which to report. Their van was equipped with a hands free mobile phone.

Visiting is an activity that happens in one place for a coherent but temporal period of time. Programmers in central IT departments sometimes go to branches in other places in the city to implement software. If the implementation is complex then the person might spend some days in the branch. This kind of mobility is called visiting.

The technological part of mobile IT use is called application. The three components of the application are technology, data and program. Consider a situation where a mobile worker makes entries in the scheduler on her palmtop. Here, the palmtop is the technology, the scheduler the program, and the entries the data.

Technology is the carrying platform, or medium of the application. Technologies involved in mobile IT use may be pigeonholed as stationary, moveable or portable. Example of a stationary computer is a PC, a moveable is a laptop, and a portable a palmtop. Note that all these kinds of technologies can be involved in mobile IT use. For example, when staff from the central IT department make visits to clients, they very often use stationary computing on site to do various tasks.

Data is the second part of the application. Examples of data are the Lotus Notes databases used by a central IT department, the “to do items” stored in the Apple Newton used by a IT support group, the telegrams received at Radio Sweden, and so on. A program processes data. Examples of programs are the scheduler on the Apple Newton used in an IT support group, and the Lotus Notes based document system used at the central IT department.

The figure below describes the complete model.

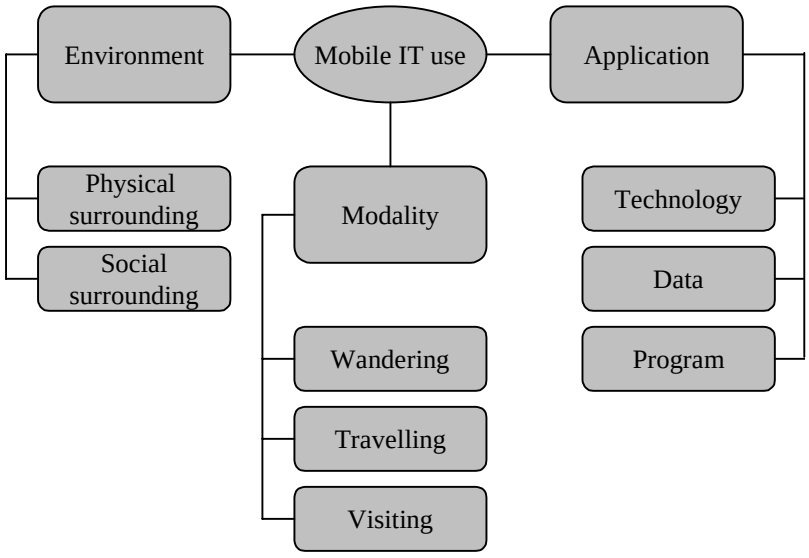

Figure 7: Basic reference model of Mobile Informatics.

It is important to note that this is a design model, not a theory of human action. In the model, we introduce the notions of modality and environment as candidates to understand the specifics of using IT in mobile settings.

7 Simply say “yes” to innovation

The starting point for our investigations was the lack of innovation and new applications for mobile people. Why this concern for innovation? Should we not as researchers focus on concepts, and permanent aspects of technology? After all, tomorrow is another day. Well, in some sense this may be noble and true, but, on the other hand, who will have faith in the expertise of people who don’t even use the technology of which the gospel themselves? Also, it can be argued that there is more to this than immature technology and ephemeral problems which will solve themselves shortly. Let us look more closely at this argument.

Mobile computing consistently fails to live up to expectations. Early adopters complain about the size and resolution of displays, awkward input devices and limited bandwidth (Winograd 1996). There is every reason to assume that the complaints will be exacerbated for mobile CSCW (Computer Supported Co-operative Work) and communication, since most collaborative computing is computationally intensive, often synchronous and visual. In addition, computer-mediated communications require minimal latency in order to be socially acceptable.

Many enthusiasts respond to this challenge by suggesting that new mobile technologies will be sufficiently powerful to meet the needs of CSCW. We assert, however, that expectations and requirements of the user community will proportionally increase by new advances in computing technology. The ante will, in a sense, be upped once more.

At the same time, mobile IT design is clearly stationary ‘biased’: de facto industrial standards have adopted the desktop metaphor and offer ‘pocket’ versions of familiar office applications. For example, there is Pocket Word (without styles) and Internet browsers (without support for Java and plug-ins), which, in addition, hardly display content but one line at a time.

People expect, and, thus “need” the performance offered by stationary computing.

Organizational design and new tasks are shaped according to state-of-the-art technology, and this technology can be found on the desktop, not in the pockets of enthusiasts.

This problem represents a fascinating challenge given that today's mobile devices are immensely more powerful than the desktop computers of yesteryear, but at the same time they are a far cry from what users want today. We believe this challenge is fundamentally about ideas rather than technology; today's mobile computing paradigm is simply not suited for handheld CSCW!

Based on the premises offered above, the following argument can be given: Mobile IT is inferior to stationary computing in terms of performance and bandwidth. For example, bandwidth is limited, keyboards are awkward and there is no desk on top of which to put the devices when typing.

It seems, therefore, that this is a conceptual, rather than a technical cul-de-sac, since "users' needs", in these terms, will always exceed what mobile computing can offer. But as the following argument demonstrates, this can be conceived as a result of a naïve design paradigm.

Is advanced document management or internet-based multimedia publication purposeful operations for mobile workers? Are there mobile use contexts where a typewriter-metaphor based terminal with a connected keyboard and screen will be useful at all? Consider the example of electrical maintenance workers equipped with a desktop metaphor-based device. When operating the device as afforded by its design, i.e. sat down in from of the user in one arms length distance, the objects of work, which are switches and power cables in a roadside cabinet, cannot be reached. If the device, on the other hand, is put down on the only other flat surface, which is the top of the cabinet, then the display cannot be seen when squatting to reach the switches and cables .

We assert that this is not an extreme example. Working with mobile consultants, journalists, surveyors and inspectors (typically mobile workers according to any definition) such work situations continually occur.

8 Further readings

We share the views of Abowd et al. (1997) when they maintain that although effective use for mobile technology will give rise to an interaction paradigm shift, it is difficult to predict what that shift will be. The model presented in this paper aspires to aid this process. Relatively few researchers are involved in establishing a set of maximally beneficial mobile applications [2]. Our model contributes to this enterprise, as we show below by applying the model to existing research in mobile computing. This section, therefore, uses the model to categorize relevant designs, an exercise, which also offers pointers to relevant work in this area.

Mobility is essential also in work that is not designated as mobile work. It supports interaction and offers awareness, and is essential in the use of shared resources (Bellotti and Bly 1996, Robinson 1993). Bellotti and Bly (1996) report on a field study of distributed work at a design consulting firm, in which they found much more mobility than anticipated, in particular what we previously called walking. Their paper points to shortcomings in parts of CSCW research that exclusively concern itself with desktop support (i.e., stationary modality). They found an interesting relationship between modalities and applications in this example of mobile IT use: While local mobility is integral to local collaboration, it often severely penalizes long distance communication.

Abowd et al. [2] describe a set of prototypes of a mobile, context-aware tour-

guide for their lab. It is particularly concerned with maintaining and exploiting data from the environment, namely location and orientation. The model could frame this application idea in the following manner:

Mobile IT use: The application supports visitors to the lab, presenting them with necessary information to navigate the building, understand the projects and enjoy the visit.

Environment: IT research labs usually do not adhere to a significant layout, i.e., it is impossible to say what people do only by glancing. Although visitors are frequently from abroad, such labs are usually not sign-posted in many (if any) languages.

Modality: Typically, tourists walk. They are usually content to carry a book or handheld device, but not with larger, expensive items which restrict the freedom of mobility. Tourists do no stay for long, however, they are likely to, in this case especially, stop and talk with "the natives."

Technology is, as in the many of our field studies, manual documents, laptop computers and the available (or not) infrastructure such as telephony or transportation.

Data for tourist guides may include coordinates of position and orientation, "invisible structures" such as organizational charts or project information, notes, and real-time voice.

Programs support the intention of visiting. Abowd et al. [2] suggest many interesting solutions for the mobile tour guide: personalized tours, language translation, note-taking, synchronous communication and group interaction. Some concrete services suggested were Cartographer, Librarian, Navigator, and Messenger.

Many more applications are well covered by the model, even if mobile IT use is not on their agenda. Hagimont and Ismail (1997) describe a protection scheme for mobile agents, in which access to objects is controlled by means of mutually suspicious agents. It is concerned with the use of mobile code to support stationary work. It is still possible to apply the model to the use of the protection scheme, for instance in the shared calendar example of the authors.

The overarching phenomenon, in this example, is mobile calendar use. The application may be described as effortless organization of meetings. An agent manages calendars, and creates proposal objects, i.e., data. Technology is manifested as networks, which may or may not be connected. Agents exchange tokens, as access right signifiers. These tokens may be part of the organizational environment, inasmuch as they can limit initiators' capability of manipulating the calendar of their boss, or it may be physical, if no server exists to negotiate capability requests. In a truly mobile use situation, the meaning of environment is even richer, insofar as it may constrain the possibilities of operating the technology in the first place.

Pratel and Crowcroft (1997) present an almost identical approach. They describe a ticket based service access for the mobile user. In this case, mobile IT use is targeted with tickets instead of capabilities. It falls nicely within the model, and brings especially to the fore relationship between available applications (for which tickets are "purchased"), mediating technology and the use context of environment and modalities, which direct the users' intentions and continually introduces constraints such as, for instance, which service provider is available.

For further work, we will continue to combine empirical studies with the conceptual framework of the model to produce innovative, mobile-aware applications. By technical experimentation and empirical evaluation, such applications can inform re-design and improvement of the model, and, thus, contribute to improving the research agenda.

9 Conclusion

This paper has described a design-oriented reference model of mobile IT use. It holds up well to new empirical cases, and we have shown that it can be used to capture central aspects of existing mobile computing research. We believe that this model will provide useful pointers toward a future research agenda. It is already being used in several collaborative projects between the Norwegian Computing Center (www.nr.no) and the Viktoria Institute (www.viktoria.org) to define and develop improved support for mobile work.

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