ENVIRONMENT-MEDIATED MOBILE COMPUTING

Hans-W. Gellersen, Michael Beigl and Albrecht Schmidt
Telecooperation Office, University of Karlsruhe
Vincenz-Prießnitz-Str. 1, 76131 Karlsruhe, GERMANY
Ph. +49 (721) 6902-49, hwg@teco.edu

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ABSTRACT

Environment-Mediated Communication (EMC) is introduced as new concept for computer-mediated human-to-human communication in mobile settings. EMC is based on highly mobile computing devices such as handhelds, palmtops and wearables, and on emerging technologies facilitating interaction of mobile devices with their physical surroundings, for instance smart environments and context-awareness. In EMC, communication between humans is mediated by an instance of the physical environment, at least conceptually if not physically. This short paper presents an analysis of the EMC design space, and reflects on potential applications.

INTRODUCTION

Computer-mediated communication (CMC) is a commonplace tool in our work environments, utilizing the available networked computing infrastructure for conversation and messaging services. Advances in mobile computing have led to location-independent provision of CMC, with current research for instance aiming at facilitation of broadband and high-quality services over wireless networks. Like most mobile computing research, this is focused on abstracting from locality and mobility to provide services at the same level of quality as experienced in desktop environments. In contrast to these efforts, work discussed here aims to make the most of mobility and locality for innovative mobile computing applications. In this context, we propose *Environment-Mediated Communication* (EMC) as new concept for human-to-human communication in mobile computing.

From an application perspective, EMC is motivated by the real-world use of the physical environment to mediate information among people. For instance, it is a common form of communication to leave messages at specific places from where they can be retrieved by other people. Consider for example bulletin boards, notes left at office doors, or even graffiti at your local bus stop. Communication is mediated not only via specific locations in our environment; messages may also be attached to physical objects serving as mediator.

Technologically, EMC is motivated by advances in computer-environment-interaction (CEI). At PARC, the Ubiquitous Computing vision promoted the idea of using the environment as interface to computers, i.e. using the environment as mediator between human and computer [9]. The linking of virtual worlds with physical worlds has been further promoted by work on cooperative buildings [8]. Recently, a host of technologies have become available to actually realize CEI at low cost, for example infrared-based smart environments [7], badges to locate people and things [2,4], environment-control systems, and environment sensors small enough to be embedded in handheld devices [2,6].

Also, new metaphors for computer-based interaction with the physical environment are being explored, for example hyperlinks extending into the real world [1], and new user interface concepts such as *Pick-and-Drop* [5]. On similar lines we propose EMC as a new concept for human-to-human communication in mobile computing. In the following section we will analyse the EMC design space. Another section will then reflect on the application potential.

FROM *COMPUTER-MEDIATED* TO *ENVIRONMENT-MEDIATED* COMMUNICATION

We define EMC as follows: human-to-human communication is *environment-mediated*, if an instance in the physical environment serves as link between the communication partners. As a simple example consider electronic notes that can be prepared on a PDA and left at an office door, for a colleague to be received later on via their PDA. EMC is foremost a concept, and the conceptual view has to be clearly distinguished from the implementation.

Conceptual View

Figure 1 relates environment-mediated to computer-mediated communication. In CMC, communication between humans is mediated through a computer at the source, a computer at the sink, and a network in between. In EMC, an instance of the physical environment is introduced in this communication chain, either somewhere in the network, between network and either terminal, or in substitution the network. The physical instance can be mobile or fixed at a location; for the first though we exclude physical entities whose primary purpose is to carry information from one computer to another, such as disks and smart cards. For asynchronous communication, the physical instance can obviously be thought of as real-world relay station to store and forward messages; for synchronous communication, it can be thought of as a router. Following figure 1 we have four general cases in the EMC design space:

Fig. 1. From computer-mediated to environment-mediated communication

a *Direct EMC:* the physical instance replaces the network; source and sink have to move to the physical instance in order to leave or pick up messages. This relates to the real-world use of physical places such as office doors to relay messages from one person to another.

b *Location-bound-delivery:* communication is addressed to an instance in the physical environment from where messages or streams are delivered to a sink in that environment, i.e. at a specific location. This case relates to the use of places in abstraction of specific people, for example letters are often addressed to an office rather than a specific secretary. Also, regarding the office door example, people can leave notes from remote for others who might call in: "not feeling well, won't come in today".

c *Location-bound-send:* messages/streams are sent off from a specific location, where the mediating physical instance takes care of forwarding it to a sink. This case may seem more abstract but think for instance of an emergency message for which the destination is identified by the senders location. This case could also apply to the office door example, with notes delivered directly at one's door being forwarded as email for instance to a pager.

d *Virtual EMC:* source and sink use a mediating physical instance remotely, for example virtual visitors of a physical place such as a room in a museum or a lecture theatre. Applied to the office door example, neither sender nor recipient have to move to the door, but it may still have a specific meaning for communication, for example expressing urgency.

Orthogonal to these four cases, communication semantics form another dimension in the conceptual design space. In EMC, sender and recipient are linked by a mediating instance and thus do not necessarily have to know each other, facilitating anonymous communication. In general, with a mediator in place, a range of different communication semantics can be defined in addition to "email semantics", for example:

- *deliver-once:* a message can only be picked up once, which makes sense if it is required that exactly one person gets the message. For example applied to our office door scenario, only the first person to arrive in the office would receive the note.
- *deliver-n-times:* a message can be picked up by at most n recipients, which may make sense for controlled dissemination within a community while there is some practical concern about the number of contacts invoked. This relates somewhat to notes on bulletin boards with the contact information on little snippets to be torn off.
- *deliver-until:* a message may only be stored and forwarded within a specified time frame. In the office door example, this would be useful for messages such as "please see me if you are back before 2pm".

Implementation View

EMC can be implemented in several ways, transparent for the user (for both sender and receiver). Three general options for implementation are shown in figure 2. First, of course, the actual message could physically be left at the mediating physical instance for retrieval by a sink (one or more sinks actually, depending on communication semantics, cf. above). In this case the mediating instance would have to have reasonable storage capacity. A second option is to relay only references via the physical instance, and to use a global store for the actual messages. In this case, the physical instance can be implemented in a simpler fashion with very little memory. In contrast to the first option this would require the mobile termi-

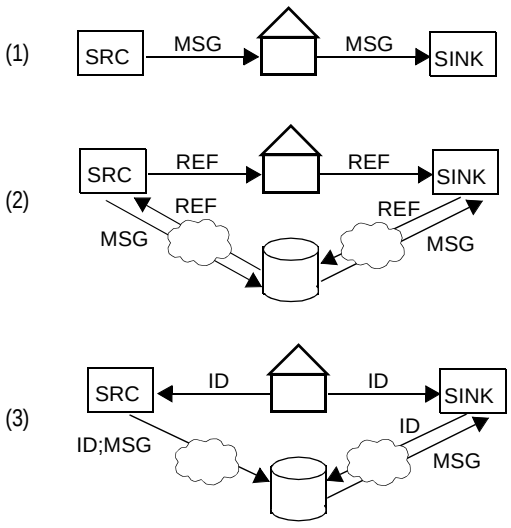

Fig. 2. EMC Implementation

nals to have a network connection to a global store rather than just a local connection to the immediate environment (with the current generation of PDAs for instance global connectivity is of course feasible but not an ideal assumption). The third option depicted in figure 2 is even less demanding on the mediating environment. In this case, an ID of the mediating instance is used to tag messages which are actually forwarded through a global store in the network. Mobile terminals could obtain the ID directly from the environment, for example simply by scanning a bar code, or indirectly, for instance via global position.

Another set of design decisions for EMC implementation relates to the capabilities placed in the environment-based part of an EMC system. For example, it is a fundamental whether the environment is capable of initiating direct delivery to "passers-by", i.e. to push messages. Another fundamental question is whether the environment has some ability to identify passers-by.

APPLICATION OF EMC

While, to our knowledge, our work is original in developing a design space for environment-mediated communication, we certainly do not claim to invent this style of communication. The PARCTAB experiment for example demonstrated location-bound delivery of notes. This was facilitated by relating dedicated parts of a file system to rooms, and by delivery of entries in this file structure to mobile devices (Tabs) at the specified location based on RF technology [9]. Another example for EMC can be found in the Locust Swarm, an infrared-based technology for locating and messaging. In this system, references rather than complete messages are stored and forwarded, reducing communication between mobile devices and environment to single bytes for low-cost implementation. An interesting aspect is that messages can hitch a ride with passers-by, to be spread in the environment [7]. Another nice example for EMC are stick-e-notes: messages tagged with an absolute position obtained from GPS. Stick-e-notes have been used in fieldwork to access messages of local relevance such as wildlife observation in a specific area ("human-giraffe interaction" [2]).

Of the above examples only the third one is application-driven, highlighting some interesting aspects of EMC: anonymous communication facilitated by a specific location, and use of location as filter to obtain only messages of local relevance. Other practical use cases for EMC, yet to be studied, are for example:

- addressing not a specific person, but one in a group/community, for instance the first person to arrive in a workplace: *"Good morning! Please make coffee..."*
- communicating messages of entirely local relevance: *"This copier doesn't work properly; it will be repaired after lunch"*
- anonymous communication in local communities: leaving messages at the off-chance of being useful for somebody
- attaching messages to mobile things, for example annotations to library books
- spatial organisation of message exchange in work environments, associating messages with physical entities, for example the hallway calendar, and announcement board.

CONCLUSION

We have proposed and analysed *Environment-Mediated Communication* (EMC) as a new concept for computer-supported human-to-human communication in the context of mobility. EMC is motivated by the apparent significance specific locations have for communication in groups and communities, and by advances in mobile device technologies and in CEI. While examples of EMC already exist, the presented work is a first contribution toward a design space as foundation for systematic study. Besides analysis of general design considerations we have also briefly reflected on the application potential of EMC. We believe that EMC facilitates new and beneficial ways of human-to-human communication in mobile settings, but applicability and usability remain to be investigated with empirical methods. An EMC application about to be studied in our office environment are electronic notes on office doors, as used as example in this short paper. Our implementation uses PalmPilots as mobile devices, infrared for CEI, and several alternatives as environment-based technology, covering the three options presented in figure 2.

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