

# Peer-to-Peer-Based Collaboration for Virtual Communities

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## INTRODUCTION

Internet applications nowadays are part of our everyday life. Gathering information from any networked site in the world, exchanging documents, transferring information via e-mail, telephone and video conferencing, e-learning or Web shopping are well known examples for Internet collaboration. The common characteristic of all these activities is the elimination of the spatial distance between involved partners. Furthermore, the information can be accessed with different devices, from hardwired PCs via WLAN-capable notebooks and PDAs (Watters, 2003) to mobile phones.

The introduction of wireless communication in recent years opened new opportunities for collaboration based on so called *location-based services* (Schiller, 2004; Jagoe, 2003). These benefit from the fact that the most wireless devices need a dedicated access point to connect to the network. This access point registers all users in the neighborhood, and thus adds new information relevant for communication: the current spatial position of the device and its user. All registered users/devices create a local neighborhood for ad-hoc communication. This scenario is very common in our everyday life: People contact other people at different locations and start a conversation. Furthermore, they often share documents to learn (e.g., lecture slides), for entertainment (e.g., holiday photos) or—most common—to collaborate and to develop products in a team. All this is possible in the Internet, too, and countless applications were developed in recent years. However, each user has to know the persons to be contacted a-priori and have the access information available—for example, e-mail address or ICQ number—before the first contact. In opposite, users in the local neighborhood can approach other members *without knowing each other a-priori*. The partners must declare their willingness for communication; for example, by installing a client program and setting the security parameters accordingly.

In summary, the restriction to a local neighborhood or the consideration of the current location is opposite to the main design idea of the internet to bridge the gap

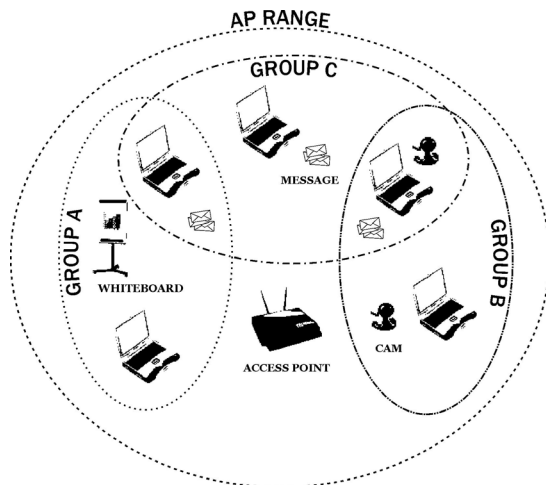
between spatially divided users and resources. However, this approach aims to satisfy human needs to learn more about their current local environment, the infrastructure and the people in the near neighborhood. Therefore, peer-to-peer-based collaboration platforms allow a location-based selection of relevant information and ad-hoc communication with users in the range of the current access point.

## BACKGROUND

A typical wireless network infrastructure is based on an access point, which receives the connection requirements of incoming mobile devices and supplies these with the necessary access information. A sample is given by a wireless LAN access point in lecture/conference rooms, coffee shops, airport lounges and so forth. The access point defines—due to the spatial extent of its signal—a stationary local neighborhood for the integrated devices. This locality can be used to satisfy communicational needs between neighbors and to enhance a collaborative work by providing conferencing tools or sharing facilities limited to this certain group.

A sample classroom scenario starts when the teacher enters the room and the teacher's notebook joins the community of all currently active members (students) in the classroom. Subsequently, the teacher opens the directory containing the documents for the lesson for all members registered by the access point in the room. The students can now load the documents and display them on the local screen of their own notebooks. Moreover, the shared whiteboard replaces the traditional blackboard with the advantage that the board content can be archived locally. Newer and more individual teaching mechanisms, like real group-wise working, are supported by providing chatting/audio/video capabilities. This can also be achieved under large costs with standard instant messengers from Microsoft, AOL or ICQ. The scenario described here is realized *without the necessity to agree on a server*, to upload the documents and to distribute passwords before the lecture starts, which

Figure 1. Network zone of an access point



currently is the common way of resource sharing in the Internet. In the area of peer-to-peer platforms for mobile ad-hoc applications, first prototypes are available (Kortuem, 2003; Ishikawa, 2003); however, they still do not integrate location-aware services.

## MAIN THRUST

This article describes an adaptive, universal and extensible platform for peer-to-peer-based collaboration in mobile wireless environments. It uses the neighborhood information of access points to provide location-aware services without the necessity of marking/tracking objects and devices to determine the user location. Any mobile host or device equipped with a network adapter is viewed as peer, because it can potentially join the ad-hoc community. The access points, on the other hand, are the essential part of the wireless LAN network infrastructure. An access point sets a border for the location-aware community, which is defined by the spatial extent of its radio signal (in the following, named *network zone*).

The basic workflow starts as soon as a new peer enters the network zone. It sends and receives a sequence of discovery packets that detect the most suitable access point in that zone and register subsequently. The address of a new member is stored in a list of the access point, which also holds the addresses of all other already registered and currently active (connected) members in the assigned network zone. Moreover, the member can join multiple groups, as shown in Figure 1. Groups can be characterized by functionality (e.g., ongoing video conference) or particular security settings (e.g., private chat session), where the user has to ask for an invitation before entering the forum. After the auto-

matic registration, the communication middleware downloads the complete list with the information from the access point. Every peer member polls this availability/connection list from the access point in certain, short time intervals (e.g., every five seconds) combined with techniques to detect temporal signal interruptions or transmission errors occurring in this unreliable type of wireless network. Thus, each member has always an overview about which peers are active in the network zone and which location-aware services are available. Further details are described in (Kao & Rerrer, 2004).

The next question is related to the needed services for this type of platforms for computer-supported collaborative work. The broad acceptance of network-based services such as e-mail or wireless devices like multimedia cell phones led to a significant change in the way we work and interact today. They allow collaboration using voice, text and document sharing over any distance; thus, the basic communication forms messaging and file sharing have to be integrated. However, human interaction includes more than verbal communication. Often, visual contact is required to catch the partner's mood or enrich the information with mimics and gestures. Humans judge and categorize information unconsciously by recognizing minimal changes in voice or face. This expedites the information interchange and acceptance (Chen, 2001). For this reason, audio and video components for creating, transmitting, receiving and playing video streams are necessary, too. The main difference to existing components is that no initial configuration/preparation is required.

The described services are combined in a communication platform, whose design is shown in Figure 2. In following we focus on the high-level collaboration services, audio/video conferencing and shared whiteboard. Together with the low-level services messaging and file sharing, all necessary tools and the impression in order to simulate a "natural" way of collaborating is created.

A session starts by activating the audio/video module developed with the Java Media Framework (JMF, 2004). It creates ports for transmitting and receiving messages via Real Time Transport Protocol (RTP, 2003) and notifies all other members in the network zone that a new session is available. If a member joins the session, its audio/video module creates ports for transmitting and receiving (only listening is also possible). If more than two members participate, the RTP uses multicast communication to address the recipients of the streams. The performance depends on the current traffic and latency in the network. The bandwidth issues are covered by the underlying protocols using compression and optimization for real time video. On the basis of the multicast capabilities and the advantage of a wireless communication, no significant traffic increase is gener-

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