

Location-Based Mapping Services to Support Collaboration in Spatially Distributed Workgroups

Eike Michael Meyer¹, Daniel Wichmann¹, Henning Büsch¹, and Susanne Boll²

¹ OFFIS Institute for Information Technology, Oldenburg, Germany
{emm,wichmann,buesch}@offis.de

² University of Oldenburg, Oldenburg, Germany
susanne.boll@uni-oldenburg.de

Abstract. Mobile devices and systems reached almost every part of our daily life. Following the mobile computing trend, also business logics of distributed, cooperative applications started to move into the mobile client applications. With this shift, the cooperation aspect may also exploit the user's location and situation context and capabilities of the mobile device and integrate it into the actual cooperation and collaboration. In this paper, we present an approach for a Collaborative Map that exploits the spatial context of the member of a distributed group as a means to visualize and provide collaboration functionality. Then, a number of location-related cooperation methods become feasible such as getting an overview of the spatial distribution of the team members, identify an ad-hoc meeting place nearby, or chat with a group member who has a certain expertise in his or her profile. With CoMa, we move from standard collaboration tools that marginally consider spatial information towards context-aware mobile collaborative systems that can support a wide range of applications such as emergency response, maintenance work or event organization where human resources have to be coordinated in a spatial context and tasks need to be assigned dynamically depending on capabilities and situation context.

Keywords: mobile collaborative working environments, location-based services, map visualization, spatial distribution.

1 Introduction

Collaborative Working Environments (CWEs) are designed to support the work on collaborative tasks within groups of users. These workgroups may be either co-located or spatially distributed. However, people were used to remain at the same place for work in both cases. Through increasing dynamics in today's working world, the mobility of working people becomes more important every day. This not only includes people working from multiple locations but also potential movement during their activities, which implies a dynamically changing context. Advances in technology and an increasing number of available mobile

devices with sufficient computing power for collaborative working promote this development. Beyond that, more and more mobile devices provide appropriate hardware for spatial positioning. Recent approaches in research consider the increasing mobility of today's workpeople. They focus on collaborative solutions based on mobile network technologies, but they do not yet address the utilization of location-awareness in spatially distributed workgroups. This leads to the question of how to benefit from location-awareness in a CWE. Traditional collaborative tools like file sharing, discussion boards, chat or calendar hardly offer fitting means to make use of a user's location.

The idea presented in this paper is to bring the location aspect into CWEs by integrating maps with location-aware collaborative functionalities for the use on mobile devices. Using a map in a collaborative context enables to visualize the location of a user, the locations of others who participate in the related workgroup as well as points of interest (POIs). Furthermore such a map can link the users' position and POIs to traditional collaborative tools within the CWE to support a location- and context-related interaction. This approach allows to work collaboratively with other people on spatially located tasks. The approach of a location-aware mobile collaboration supported by an interactive map is applicable for a wide range of application scenarios with a spatial context. Potential professional application areas are, e.g., the coordination of workforce in emergency response, disaster management, construction and maintenance works or event organization scenarios where human resources have to be collaboratively coordinated in a spatial context and tasks need to be assigned dynamically within workgroups. The following scenario is presented exemplarily as it shows a potential application case for a CWE that incorporates spatial information:

The organization of public events is always a big challenge for the involved actors and groups. E.g., open-air music festivals of several days' duration take place in terrain that is not familiar to all participating workers. Additionally the masses of visitors make it difficult to keep the overview on everything that happens. During the actual event many different activities have to be performed by different professional groups. For example, members of the organizational staff arrange performing the festival program and take care for the general coordination. Technicians re-arrange the stage set up and fix technical problems. Security forces react in case of trouble and support emergency services. The involved professional groups are coordinated by team leaders in different granularities while the whole event is headed by the festival coordinator. In certain cases tasks are assigned to workers by the coordinator or by team leaders, in other cases self-coordination is applied within the groups. Furthermore, the members of the professional groups interact with each other to solve appearing problems. So the members of all involved professional groups form a number of redundant workgroups. An established way to coordinate the working at such events is by radio. This offers no visual representation of the people and the area as well as no meta-information for the tracking of tasks like, e.g., a task priority. Furthermore, the communication is complicated by noise. The high dynamics of emerging work

in the heavy-crowded event area require for spontaneous assignment of tasks to the performing and supporting workers.

A mobile collaborative application with dynamic location- and context-aware assignment of tasks would help to improve the coordination task. The involved people would receive a real-time spatial overview of teams and workers, their current tasks and the work progress as well as additional information like a worker's profession. Coordinators would be able to assign specific work tasks to teams or workers by their availability, location and profile information. This would improve the collaboration between teams and workers among each other and with the coordinators.

The next section presents related work in the field of mobile and dynamic collaboration as well as map-based location-aware systems where people can meet. In Section 3 we present our concept of a Collaborative Map. Section 4 introduces the mobile CWE platform POPEYE upon which the prototype for a Collaborative Map is built. The realization of the Collaborative Map is described in Section 5. Before we conclude this paper Section 6 illustrates ideas for potential future development of the Collaborative Map.

2 Related Work

Currently, both computer supported collaborative work and mobile applications based on location-aware services are active research areas. In the following, we present related projects and approaches.

The aim of the C@R (Collaboration at rural) project [9] is to provide collaboration tools for rural communities to support and catalyze the development of and in rural regions. As result a flexible worker-centric collaborative platform is envisaged. The definition of the platform will happen in cooperation with other CWE communities.

The POPEYE (Peer to Peer Collaborative Working Environments over Mobile Ad-Hoc Networks) project [14] aims to allow collaboration over mobile ad-hoc networks. Within its scope a middleware was developed that is extensible through plug-ins and allows to collaborate without any present network infrastructure.

The main objective of the WORKPAD (An Adaptive Peer-to-Peer Software Infrastructure for Supporting Collaborative Work of Human Operators in Emergency/Disaster Scenarios) project [16] is to develop an innovative software infrastructure for supporting the collaboration of human operators in emergency situations. A major focus of this project lies on the adaption to connection problems and task deviations of team members in these scenarios equipped with mobile handheld devices. In this context Bortenschläger presents in [4] a concept for geo-spatial collaboration on mobile devices based on geo-data provided by external GIS servers. The paper mainly concentrates on connectivity issues between the mobile client devices. Collaborative aspects of this approach and the user interaction are not further elaborated.

New collaboration models will be developed in the CoSpaces (Innovative Collaborative Work Environments for Design and Engineering) project [8] and a distributed software framework will be realized. By means of this framework users

in industrial environments will be able to easily create CWEs for collaboration of distributed workers and teams. The focus of the project lies on support for complex processes in order to produce complex products.

The inContext project [12] aims to enable dynamic collaboration of knowledge workers in a number of different projects at the same time. Therefore, a very flexible form of collaboration and the spontaneous emerging of new teams with dynamic interaction have to be supported. New techniques and algorithms are explored in this project to allow for such kind of collaboration.

The project GeoCollaborative Crisis Management [5,6,13] aims at supporting the management of large scale and distributed crises as it is a priority for government agencies. It uses geospatial map applications to display crisis events, affected resources and actions taken to handle these critical situations. While its approach is very domain specific, it does not consider overall collaboration areas.

Location based services represent an emerging class of computer systems nowadays, as the authors of GeoHealth [7] state. Their approach is to take advantage of this evolution by combining geographical location information, provided by mobile devices, with home healthcare services. Their prototype is providing distributed healthcare workers with a spatial view on their co-workers and patients and, if needed, further information about their patients' illnesses and injuries. While their prototype is web based, mobile devices are used in order to update the current position of each user.

The goal of BuddySpace [11] is to combine instant messaging and georeferenced map presentation in order to solve problems involving collaborative group work practices. Through having the online status of other users and these users themselves displayed on a geographic reference, the actual user of BuddySpace is always aware of the presence or absence of his buddies. Though the online status of the user's buddies is updated in real-time, their location isn't.

Mobile G-Portal [15] is a client application for Personal Digital Assistants (PDAs) to collect, to temporarily store and to transfer data from geography fieldwork. The main focus lies on collaborative collection of data and learning of the fieldwork. The system takes advantage of positioning and maps based on raster data to record and display the location of collected data.

Besides these research approaches, there are commercial navigation and mapping solutions such as Qiro¹ and TomTom². In addition to map-based navigation, these platforms allow their users to see their buddies on the map and allow for limited interaction with them. Mostly, this interaction is restricted to writing short messages. Thus, they do not enable real collaboration in working environments.

Most of the projects and approaches presented above focus on collaboration of stationary users and systems but they do not consider spatial information and mobility. Some first projects already combine collaboration and mobility. However, they are not location-aware in the sense of taking advantage of information about the current position of the user. They are not able to provide

¹ <http://www.myqiro.de/>

² <http://www.tomtom.com/>

location-based services or to react on the contextual changes resulting from workers' movement. One of these few projects that already address both collaboration and mobility is GeoHealth [7]. Its use is restricted to its application domain and it is for this reason not applicable for a broad variety of different scenarios. The devices used in the GeoHealth project are Laptops integrated in cars, while there is no support for mobile handheld devices such as PDAs that are ready to hand at any time.

3 Concept of the Collaborative Map

The goal of this work is to support collaborative workers and groups in dynamic distributed working environments in which the status of the workers, the tasks, and the locations are not static but changing over time. To efficiently collaborate, the current situation and the location have to be considered when working on common objectives, coordinating tasks, or communicating with each other. This can be supported by context-aware and location-based services on digital maps which allow interaction and collaboration while keeping the spatial overview.

We propose the concept of a **Collaborative Map**, in the remainder also called **CoMa**, which is not tailored to any specific domain to be applicable in a wide variety of application areas. The main goal of CoMa is to provide a spatial view on a collaborative workgroup and to offer location-based functions for collaboration within this workgroup. It is also designed to be capable for integration with other collaborative tools within an underlying mobile CWE system. CoMa enables collaboration support in highly mobile and dynamic environments in which persons do not have access to stationary computers or can not carry Tablet PCs or notebooks along. Therefore, CoMa focuses on mobile handheld devices such as PDAs or cell phones.

In the context of CoMa, a *workgroup* is a group of persons collaboratively working together on a shared task or a common topic. The members of such a group can be spatially distributed. The workgroup itself has a profile which describes its tasks or the topics the members work at. Each member of a workgroup has a certain role. One person is the creator of the workgroup and is able to invite others as well as to define its goals and profile information including the assignment of roles to members of the workgroup. Furthermore this person can define the set of tools which will be available for the group and grant additional rights for administration and coordination to other members. A workgroup consists of workers, also called *members*, that can be spatially distributed. Besides a location, each of the members has an own profile with information in different categories, e.g., research areas, topics of interest or skills. The profile data entries of these profiles can be set as private or as public. The public subset of the profile information can be accessed by other workgroup members. *Tasks* that the workers work at currently or in the future do have certain locations and corresponding conditions and parameters. They are specific objects that can have a state such as *unassigned* or *delayed*, a time interval in which they are valid, and further the task describing information. These information can be

entered manually or be generated automatically based on the current situation. Besides tasks, specific locations such as meeting points, dangerous places, or POIs are important objects within CoMa. They also do have a location and can be enriched with additional data such as a title or a short description.

The Collaborative Map allows for support of collaboration and coordination within a workgroup. This is achieved by a map-based visualization of a workgroup considering the location and dynamics of mobile working environments. CoMa visualizes all of its objects on a geo-referenced map. In the case of a displayed worker, both the location and status is represented. Members can be presented differently according to their activities such as *on the way to task's location*, *working at task* or *unassigned*. A task's visualization considers its current state. At a glance coordinators and other members of the workgroup can see whether a task has been assigned or not. Specific locations' representations give the viewer a general idea about what type that location is of. Thus, a meeting point is displayed in another way than a dangerous place is.

CoMa allows to interact with all entities visualized on the map. By exploring the map, users are able to learn these entities' locations and states, and monitor changes of those. Users can communicate with other members of the workgroup by means of a chat. This chat can either be one-to-one or one-to-many. Also, further information about each member can be retrieved as long as the member's profile is publicly available. Tasks can be created, modified or deleted. When a task is created or modified, the task can be described with a title and a description, its initial state can be chosen, and it can be assigned to a member of the workgroup. As a shortcut, tasks can be assigned to workers depending on the situation's context. Either the closest member can be assigned or the nearest member whose profile fits with the task's description. This assignment can either depend on the location or the task's description. The user can also mark specific locations on the map. They offer the same functionality as tasks except they cannot be assigned to members.

Collaboration is supported by these interaction possibilities. Coordinators are supported in decision making through having access to the profiles of the workgroup's members. The profiles enable them to assess who can be assigned to tasks depending on, e.g., availability, proximity, current activity, or skills. Users can arrange meetings, talk about shared tasks, or ask for help by using the one-to-many chat. Contrariwise they are able to use the one-to-one chat in situations where bothering the others is inappropriate or a private matter has to be discussed such as discussing a specific task and resolving unclear issues. The context aware assignment of tasks to the nearest or the most appropriate member supports and simplifies the self-coordination of the workgroup. Members can create tasks and relay the assignment decision to the system. This also allows the coordinator to quickly response on changing situations. Besides tasks, users are able to place meeting points on the map. These meeting points can be either made visible to all other members or to a specific subset of the workgroup. They are thus able to collaboratively plan their further actions such as the next physical meeting.

4 The POPEYE Platform for Collaborative Applications

The work of CoMa is embedded in a larger context. The idea evolved within the POPEYE [14] project. In Section 5.4 this paper will show how CoMa is realized based on the POPEYE platform.

POPEYE is a Specific Targeted Research Project (STREP) in the New Working Environment of the European Commission's 6th Framework Programme which aims to enable dynamic, spontaneous, peer-to-peer collaborative group working environments, over heterogeneous mobile ad hoc networks (MANETs). The result of the project is a middleware called POPEYE [10] that offers collaborative services for frameworks that aim to enable spontaneous collaboration over P2P wireless ad hoc groups. POPEYE integrates a communication platform and context-aware, secure and personalized core services to enable the design and the usability of collaborative applications in mobile environments. The platform offers different kinds of basic services, such as group management, communication within groups of peers as well as between single peers and data sharing services while considering the flexibility and spontaneous character of mobile ad hoc networks. Furthermore, it provides extensibility by its plug-in infrastructure.

In POPEYE users meet in so called Workspaces. The term Workspace (WS) designates a group of users and the data and applications they share. The Workspace corresponds with the workgroup presented in the concept section. Users can search for and join existing WS or create new ones and invite other available users to join for collaboration. Sharing of data between all members of the WS is supported by the Shared Space which is associated to each WS. The applications the users employ for collaboration (e.g. file sharing, group calendar, whiteboard, etc.) can be plugged into the POPEYE environment at runtime. In POPEYE those applications are called plug-ins and their instances each associated to one specific Workspace and having a specific configuration are named (plug-in) Sessions. Based on the characteristics presented above, POPEYE offers suitable conditions to realize the CoMa concept.

5 CoMa Realization

To test the approach, the Collaborative Map has been realized as a POPEYE plug-in. It builds up on the infrastructure and system components provided by the POPEYE platform. In the following, the realization of CoMa is described. The concepts of the map-based visualization as well as the interaction possibilities of the user are presented. In Section 5.3 the implementation of collaboration aspects is illustrated. In the last step a detailed view on the technical aspects of the integration of CoMa with POPEYE is given.

5.1 Map-Based Visualization

The design approach of CoMa was to identify a graphic presentation of the map that is common to most users. Major decisions were taken based on our previous

experiences in location-based pedestrian applications [1,2,3]. It had to be decided what type of map would be displayed. One option is to use vector maps. There are several data formats for vector maps that allow storing different information such as plain geographic data or, in addition, topological relationship information. Besides, vector maps allow a fully scalable presentation. As semantically enriched maps are not necessary for the purpose of CoMa and most open and standardized vector data formats such as Geography Markup Language³ have a comparatively big overhead, it was decided to use raster maps at the cost of continuous zoom but with the benefit of performance increase. The position of users is crucial for a map application whatever it is used for. CoMa gathers the user's current position from a position receiver connected to the mobile device. It is automatically sent to the other Workspace members to enable them to see the position on their device. The position data is currently based on GPS (Global Positioning System) signals. When developing software for mobile devices such as PDAs the screen's resolution and size are both crucial for the user interface design. Because of the small display, the user has to have the possibility to toggle what is shown and what is hidden from the current presentation. Therefore, different visualization layers have to be implemented to present different types of information that can be added to or removed from the view. Besides a map layer, there is a user layer and a POI layer. Here users, tasks and specific locations are displayed by appropriate icons that change according to their state.

5.2 Interaction with CoMa

The Collaborative Map plug-in was realized as application for mobile handheld devices with touch screen interaction. Hence, the users are able to pan the map by dragging it. This is a very popular operating method at common mobile location-based systems, such as TomTom.

Also, users are able to center the map view on them and will thus not lose track of their own position. Also, they are able to zoom in and out of the map according to their personal preferences. These functionalities are accessible by using the buttons on the main interface (see Figure 1(a)). As described in Section 3, users can interact with CoMa by clicking on every position on the screen. This results in a context sensitive popup window that reacts on what was clicked on. As example, Figure 1(b) shows the window that pops up after a click on the map. Here the users can select to either start a chat or to set a new object on that position of the map.

If users choose to set a new object, they firstly can select what type of object they want to use, e.g., a task or a POI. After that, they can enter a title which is visible directly on the map. If users wish to provide further information, they are also allowed to enter a description. As Figure 2(a) shows, the map will be hidden and a new view is presented to the user if the *create POI*-option has been chosen. In this view the title (*Label*) and the description (*Description*) can be entered. Besides this, the users are able to select to make the object visible either

³ <http://www.opengeospatial.org/standards/gml>

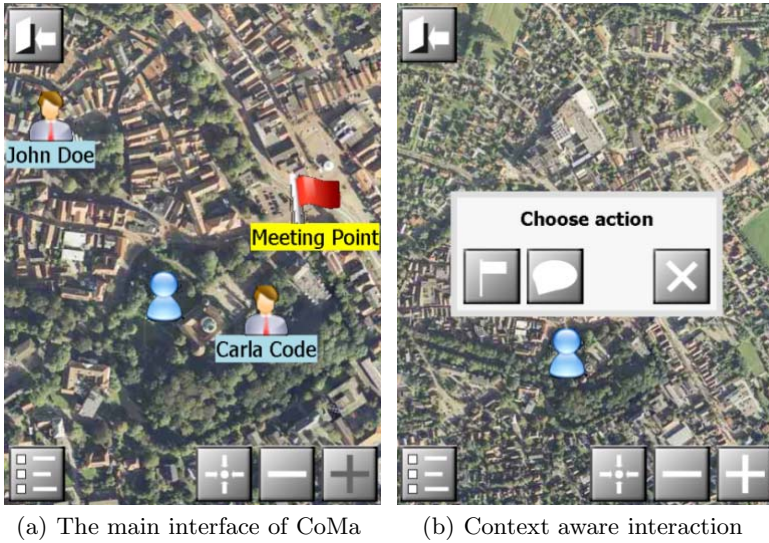


Fig. 1. CoMa's main presentation to the user

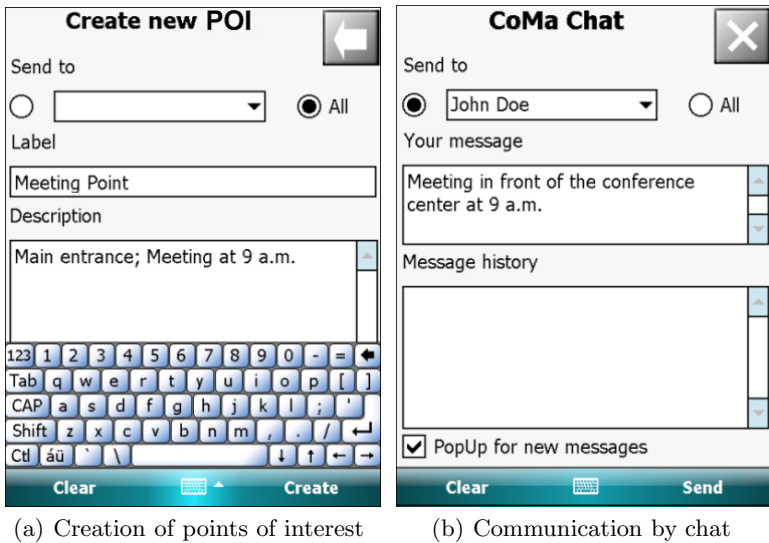


Fig. 2. Two types of interaction with CoMa

to all other users or just to one specific. If, contrariwise, the *create Task*-option has been chosen, the creator is able to manually or automatically assign the task to a member of the Workspace. Also, the task can stay unassigned. When the user chooses the chat option from the popup window, another view is brought up that is shown in Figure 2(b). Common unicast chat (one-to-one) as well as information broadcast by multicast chat (one-to-many) is supported within the

related Workspace. Thus, the users have to select whom to send the message to, right in the same manner as when choosing the visibility of a new object. Besides chatting and creating POIs, users are able to request further information about other members of the Workspace. In order to do this, they have to select the *receive Profile*-option from the popup window that shows up when clicking on another user's icon on the map. All profile information about this user, which is publicly available in that Workspace, will then be presented to the inquirer.

5.3 Implementation of Collaboration

Collaborative work is supported by the afore-mentioned interaction possibilities. The user has got a spatial overview of the workgroup, its tasks and other specific locations based on a reference map. This allows for the assessment of the spatial aspects of the current working environment and the location-based assignment of tasks. Also, the arrangement of meetings is simplified. On one hand, it is eased by being able to discuss all of the meeting's circumstances via chat. This discussion can be done privately between two coordinating persons or publicly between all Workspace members. On the other hand, meeting points can be placed on the map and be provided with a title. At a glance all Workspace members can see where the meeting will take place and what its topic will be. Tasks can be created and assigned to members of the Workspace. Through this, the workgroup is supported in its self-coordination. Members of the workgroup are able to create new tasks if needed or let the system choose whom to assign these tasks based on the current context. Also coordinators of the workgroup are supported in their work. They no longer have to concentrate on finding workers with appropriate skills but can focus on identifying the actual tasks. Users can retrieve profile information about other members of the Workspace. This supports coordinators in decision makings and planing further actions. Members benefit from becoming aware of the profession and skills of other workgroup members and thus know whether they can request help from that person or not. Furthermore, objects displayed by the Collaborative Map can refer to other tools within the surrounding CWE for performing specialized collaborative tasks.

5.4 Integration of CoMa with POPEYE

The architecture of the POPEYE platform presented in Figure 3 is designed as a layered architecture with vertical macro-components for security and context. The layers group the components for network abstraction, middleware, application level and user interfaces. The plug-in concept that has been integrated in the POPEYE architecture allows easy extensibility of the platform's functionalities. So, being implemented as a POPEYE plug-in, CoMa is able to make use of the infrastructure provided by the POPEYE platform. To add a new functionality to POPEYE a new plug-in has to extend the basic *Plug-in* class and must provide an appropriate *Plug-in-specific UI* component. In Figure 3 the box named *CoMa* shows where a Collaborative Map plug-in takes place within the POPEYE architecture.

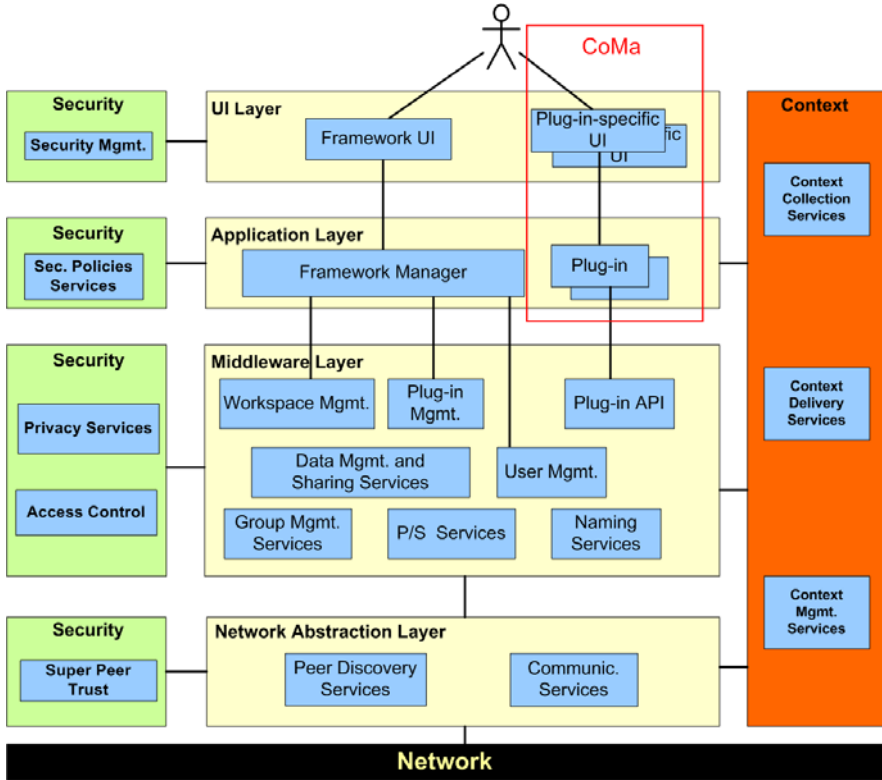


Fig. 3. The location of CoMa within the POPEYE architecture

The *Plug-in API* represents a well defined interface that encapsulates the set of those lower level functions which are to be accessed by (third party) application plug-ins like CoMa. Application plug-ins are not allowed to use all administrative functions of POPEYE components like, e.g., the *Workspace Management*, which controls the lifecycle of Workspaces and Sessions. The *User Management* component provides profile information about participating users of all Workspaces. CoMa consumes these information from the local instance of the User Management component, which acquires the information from other peers over the MANET. Which data is provided by each user is managed in association with the POPEYE Security modules.

As application plug-ins run within Sessions each CoMa instance is associated to one specific Workspace. Consequently, the access rights defined for this Workspace are also applied to CoMa. The communication between two instances of a CoMa plug-in Session on different peers occurs by means of the *Communication Services* component. The main part of this component is the Communication Channels that are associated with Workspaces. Named Communication Channels represent a dedicated way for sending messages for a specific purpose, i.e., they enable Workspace-specific and Session-specific communication between

different peers. CoMa employs Communication Channels to broadcast messages to all peers in the Workspace as well as to send messages to single peers. In that way CoMa distributes the profile and position information of users, POI information and chat messages to all members of the Workspace or just to specified ones. Building up on the Communication Services the *Publish/Subscribe Services* component offers a fully-decentralized topic-based subscription mechanism, where durable and non durable topic subscriptions are supported. It is suited for instance for plug-ins' synchronization, i.e., in future work CoMa will be able to forward to other application plug-ins and to interact with them within POPEYE by means of Publish/Subscribe Services.

6 Future Work

For the future development of CoMa a number of extensions of the current prototype is planned. One idea to emphasize the collaborative character of CoMa is to create a whiteboard overlay for the map so that users can use a "paint"-feature to show routes, areas or locations on the map to others in an intuitive way. Another collaborative approach is to allow users an interactive geo-referencing of plain pictures that are shared within a Workspace, e.g., a building plan where users can mark their own location and in that way annotate a valid position. From a certain number of annotated positions CoMa would be able to calculate the necessary data to generate a geo-referenced map from the picture. In a similar approach also users without valid location information may be allowed to appear on the map by placing themselves manually, even if no GPS signal or indoor positioning is available. A further option is to allow POIs to be associated with additional data like, e.g., external sensor or inventory information. Finally, the usability and the interaction have to be evaluated in detail.

7 Conclusion

In this paper, we have shown how the Collaborative Map (CoMa) allows for enhanced interaction and mobile collaboration of spatially distributed workgroups by means of location-based services. CoMa is targeted towards mobile handheld devices which are at hand in most situations, even in very mobile and dynamic environments. The provided tools for collaboration and coordination of common tasks are quickly accessible via an easy-to-learn map-based interface with an interaction designed and adapted to the challenges of mobile devices and environments. The realization is based on top of POPEYE which is a platform for the development of mobile collaborative applications. CoMa extends the POPEYE functionality with location-based services and sets the existing plug-ins for typical CWE tasks in a spatial context for the workgroup. In return, CoMa takes advantage of the functionality already provided by POPEYE. The integration of the CoMa map-based view can thus be used to support mobile collaboration scenarios.

Acknowledgments

This work is supported by the POPEYE project: Peer to Peer Collaborative Working Environments over Mobile Ad-Hoc Networks. POPEYE is part-funded by the EU under the 6th Framework Program, IST priority Contract No. IST-2006-034241. <http://www.ist-popeye.org>. We would like to acknowledge each member of the POPEYE consortium.

References

1. Ahlers, D., Boll, S., Wichmann, D.: Virtual Signposts for Location-based Storytelling. In: *GI-Days 2008*, Münster, Germany (2008)
2. Ahlers, D., Pielot, M., Wichmann, D., Boll, S.: GNSS Quality in Pedestrian Applications - A Developer Perspective. In: Kaiser, T., Jobmann, K., Kyamakya, K. (eds.) *5th Workshop on Positioning, Navigation and Communication WPNC 2008*, Hannoversche Beiträge zur Nachrichtentechnik, pp. 45–54. Shaker (2008)
3. Baldzer, J., Boll, S., Klante, P., Krosche, J., Meyer, J., Rump, N., Scherp, A., Appelrath, H.-J.: Location-Aware Mobile Multimedia Applications on the Niccimon Platform. In: *IMA 2004*, Brunswick, Germany (2004)
4. Bortenschläger, M., Leitinger, S., Rieser, H., Steinmann, R.: Towards a P2P-Based GeoCollaboration System for Disaster Management. In: *GI-Days 2007*, Münster, Germany (2007)
5. Cai, G., Bolelli, L., MacEachren, A.M., Sharma, R., Fuhrmann, S., McNeese, M.: Geocollaborative crisis management: Using maps to mediate eocmobile team collaboration. In: *Proceedings of the 2004 annual national conference on Digital government research*, Seattle, WA, USA, pp. 1–2. Digital Government Society of North America (2004)
6. Cai, G., MacEachren, A.M., Sharma, R., Brewer, I., Fuhrmann, S., McNeese, M.: Enabling geocollaborative crisis management through advanced geoinformation technologies. In: *Proceedings of the 2005 national conference on Digital government research*, Atlanta, Georgia, USA, pp. 227–228. Digital Government Society of North America (2005)
7. Christensen, C.M., Kjeldskov, J., Rasmussen, K.K.: GeoHealth: a location-based service for nomadic home healthcare workers. In: *OZCHI 2007: Proceedings of the 2007 conference of the computer-human interaction special interest group (CHISIG) of Australia on Computer-human interaction: design: activities, artifacts and environments*, pp. 273–281. ACM, New York (2007)
8. CoSpaces.: *Innovative Collaborative Work Environments for Design and Engineering*. Integrated Project, IST programme of the European Commission's 6th Framework, <http://www.cospaces.org>
9. C@R.: *Collaboration at Rural*. Integrated Project, IST programme of the European Commission's 6th Framework, <http://www.c-rural.eu>
10. Duong, H.D.H., Melchiorre, C., Meyer, E.M., Nieto, I., Paris, G., Pelliccione, P., Tastet-Cherel, F.: A Software Architecture for Reliable Collaborative Working Environments. In: *3rd International Conference on Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom 2007)*, November 15 (2007)
11. Eisenstadt, M., Komzak, J., Dzbor, M.: Instant messaging + maps = powerful collaboration tools for distance learning. In: *Proceedings of TelEduc 2003*, Havana, Cuba, May 19-21 (2003)

12. Truong, H.-L., Dustdar, S., Baggio, D., Dorn, C., Giuliani, G., Gombotz, R., Hong, Y., Kendal, P., Melchiorre, C., Moretzky, S., Peray, S., Polleres, A., Reiff-Marganiec, S., Schall, D., Stringa, S.: InContext: a Pervasive and Collaborative Working Environment for Emerging Team Forms. IEEE Saint (2008)
13. MacEachren, A.M., Cai, G., McNeese, M., Sharma, R., Fuhrmann, S.: Geocollaborative crisis management: Designing technologies to meet real-world needs. In: Proceedings of the 2006 international conference on Digital government research, San Diego, California, USA, pp. 71–72. ACM, New York (2006)
14. POPEYE.: Peer to Peer Collaborative Working Environments over Mobile Ad-Hoc Networks. Specific Targeted Research Project (STREP) in the New Working Environment, European Commission's 6th Framework, <http://www.ist-popeye.eu>
15. Theng, Y.-L., Tan, K.-L., Lim, E.-P., Zhang, J., Goh, D.H.-L., Chatterjea, K., Chang, C.H., Sun, A., Yu, H., Dang, N.H., Li, Y., Vo, M.C.: Mobile G-Portal supporting collaborative sharing and learning in geography fieldwork: an empirical study. In: JCDL 2007: Proceedings of the 7th ACM/IEEE-CS joint conference on Digital libraries, pp. 462–471. ACM, New York (2007)
16. WORKPAD: An Adaptive Peer-to-Peer Software Infrastructure for Supporting Collaborative Work of Human Operators in Emergency/Disaster Scenarios. Specific Targeted Research Project (STREP), European Commission's 6th Framework, <http://www.workpad-project.eu>