Towards a P2P-Based GeoCollaboration System for Disaster Management

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Abstract. GeoCollaborative applications used for disaster management are usually client/server architectures. As disaster management inherently happens in highly dynamic environments, these applications suffer from deficiencies with respect to maintaining connections to the server representing their sole source of information. We propose to exploit peer-to-peer networks to interconnect field workers. Consequently, one active connection between one peer and the control room at a time is sufficient to perpetuate the disaster management system. The data can be further exchanged in the local network established by the peers, resulting in a consistent data set and an increased availability of the GeoCollaborative application.

1 Problem Statement

Disaster management is highly complex. In the response phase (c.f. Leitinger 2004) right after the emergency occurrence, the officer-in-charge situated in the disaster control room has to make fast and reliable decisions to rescue or help the affected population. To cope with this situation successfully, the officer-in-charge needs a realistic view of the disaster situation. To obtain this information, field workers with mobile GIS tools are sent to the disaster site. To date, these field workers communicate this information either by speech over radio transceivers or by mobile devices (e.g. mobile phones, laptops, or PDAs) with GIS applications installed. We refer to this kind of collaboration based on geographic data as "GeoCollaboration" (Cai 2005). Today's GeoCollaboration applications, however, are based on the client/server (C/S) paradigm and consequently suffer from major drawbacks such as the need for direct, highly available, and reliable communication channels. This is especially true when it comes to address the specific characteristics of disaster situations which, by nature, represent highly dynamic mobile environments with frequent (network) topology changes and potential disconnections. Furthermore, an added-value can be generated if appropriate means would be provided to directly interconnect field workers without the need of connecting through a central server. In this paper we propose to integrate peer-to-peer (P2P) based concepts into

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GeoCollaboration applications. Our work is based on considerations such as in Tomaszewski et al. (2006), which, however, mostly address web-based applications and do not explicitly consider mobile field operators. The adaptability of P2P networks (Androutsellis et al. 2004) shall be exploited to meet the characteristics of disaster situations.

2 Related Work

We define P2P networks as distributed systems with interconnected, heterogeneous and equal entities – i.e. peers – which are able to dynamically adapt to the topology of the physical network according to the available nodes, for the purpose of beneficially sharing resources respectively distributing geographic content independent from any central authority or control. Due to a great autonomy of the involved peers resulting in the self-regulating behaviour, such networks are very well prepared to address the frequent changes of topology, information and positions. Peers cannot only communicate with one server but can exchange information among themselves. Also, the scalability feature is related to this, which offers support for dynamically joining and leaving nodes and spontaneous networking. Because of these characteristics inherent to the P2P paradigm (Androutsellis et al. 2004, Oram 2001) the advantages of applying this paradigm to GeoCollaboration for disaster management as an alternative to the most prevalent C/S approaches of current GIS become apparent.

Mobile P2P systems are a rather novel approach (Kellerer et al. 2005) for combining P2P concepts with mobile computing technologies such as WirelessLAN, Bluetooth, and telecommunication networks like GSM, GPRS, or UMTS (Oberender et al. 2004). Support for mobility is becoming a more and more important research issue in the design of P2P systems. As a consequence, the flexibility and independence of the users may be increased also in a physical way, such that they are able to interact with the mobile P2P-based GIS whenever they want and wherever they are.

In (MacEachren et al. 2003) GeoCollaboration is defined as “visually enabled collaboration with geo-spatial information through geo-spatial technologies”. More generally, GeoCollaboration can be seen as any collaborative (i.e. two or more users) activity supported through the use of geoinformation technologies. There has been a lack of technological advances in achieving feasible GIS-based solutions that would efficiently support GeoCollaboration (Cai 2005) and allow for dynamic geoinformation services.

Tools to collaboratively work on geographic information are only very rarely available. An example is Toucan Navigate[1] which allows distributed members of a team to conjointly modify maps using the Groove P2P technology. However, the tool only supports desktop-based clients. Cai (2005) describes a further C/S-based architecture to support collaborative work, using standard OGC web-services[2]. None of these, however, support mobile field workers carrying mobile devices.

3 CONCEPT DESCRIPTION

In our work, we propose to interconnect the mobile operators by P2P-based networks. In the design of the architecture for the GeoCollaborative application we basically differentiate between two main components (see also Figure 1):

1. The **back-end (BE)** component subsumes several different and integrated geo-data sources possibly connected in a grid fashion.
2. The mobile operators working in the field and which are equipped with mobile devices (such as PDAs, tabletPCs, laptops, smartphones) constitute the **front-end (FE)** component.

The BE and FE are interconnected by a reliable, secure, and fault-resilient wireless communication channel. Basically, the BE provides different data to the FE entities on request. As soon as this data arrives at one front-end node it can be replicated to the other nodes in a P2P-based fashion.

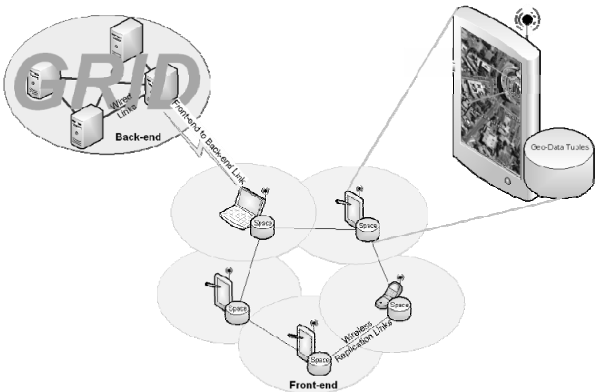

Figure 1: Geographic Information System Set-up

[1] See http://www.infopatterns.com
[2] See http://www.opengeospatial.org

In this work, we concentrate on the FE part and assume *(i)* BE geo-data servers, and *(ii)* a working FE-BE link available to exchange geo-information with the front-end. The mobile entities are interconnected in a P2P fashion using ad-hoc network technology. We exploit the fact that data can be kept in the local network established by the P2P nodes without the dependence on a connection to a central server. Hence, the availability of the system is increased. Furthermore, the FE-BE link – usually a rather low bandwidth link compared to LAN technologies – is relieved. Data which is available in the local P2P network can immediately be requested and distributed.

On the mobile devices, geographic data is displayed in an appropriate manner (i.e., on digital maps such as raster/vector graphics or orthophotos). Additionally, representing the added-value, specific features can be defined which are updated on a regular basis. These features can range from very basic elements such as points, lines, or polygons up to more complex entities such as persons or particular objects-of-interest and according meta-information.

In order to realize the P2P-based FE system, we adopt a decentralized space-based computing (SBC) approach (Picco et al. 2005), which is very similar to Linda-like systems (Gelernter 1985). This P2P system serves as an overlay above the ad-hoc network and provides the mechanisms to distribute and replicate the information available within the nodes present in the FE. The characteristics of mobile and ubiquitous environments as outlined in Section 1 are addressed by the high degree of spatial, temporal, and referential decoupling, which is inherently provided by the SBC approach (Bortenschlager et al. 2006). Every involved node carries a local space that is replicated with the other available participants of the FE according to variable strategies. To date, a full replication strategy is intended which can be accomplished in an event-based (i.e., information push) and in an on-demand manner (i.e., information pull).

According to our experience, the size of disaster management teams is only in very rare cases more than 10 members. Consequently, we assume that full replication should scale well. The geographic information displayed on the screen of the mobile devices is updated on a regular and configurable basis by reading the tuples contained in the local space.

4 Summary and Further Work

We presented an approach to extend current GeoCollaborative applications which are mostly C/S based and do not ideally tackle the requirements of mobile field operators. In order to address the characteristics of such environments, we introduced a distinction into a FE and a BE component. In this paper we focus on the FE where we introduced a P2P-based overlay middleware. This middleware provides information replication functionalities among the involved peers within the FE which is accomplished by adopting the decentralized space-based computing approach. The added-value is the provision of a consistent geo-data set to mobile field operators who can exploit and amend such data.

The next steps are to finish the implementation of the prototype and to thoroughly evaluate the proposed concepts. This evaluation will be twofold: verification (i.e., investigation of scalability and performance aspects through lab set-ups and simulations) and validation (by conducting user field trials within the scope of the EU research project WORKPAD[3]). Further extensions are going to be the implementation of other replication strategies (such as context-dependent instead of full replication) and richer notifications mechanisms about changes in the local spaces.

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