Geolocated Communication Support in Rescue Management

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ABSTRACT

Efficient communication on base of consistent and up to date information is the key factor to cope with hard rescue missions. With the new generation of mobile devices local peer-to-peer communication in conjunction with geolocated information is promising to improve information's quality. Thereby, the routing of information in ad-hoc networks is very dynamic. This contribution, based on work of the SpeedUp project, analyses protocols and presents an approach which combines mobile software agents, routing in ad-hoc networks, and geolocated information to build up a reliable communication infrastructure. The 2MANS simulator allows efficient graphical model building. Geolocated information will be utilized as a map representation to improve the overall situation for unified rescue forces management.

Keywords

Mass casualty incident (MCI), localization, communication, mobile agents, SpeedUp.

INTRODUCTION

Typically, caused by unforeseen events, rescue missions are characterized by fast decision making based on available information and resources as well as clear responsibility assignment according to skills, experience, and rank. Despite of intensive trainings and predefined rescue plans, every mission has its own occurrence. Experienced rescue forces use defined communication channels to assemble situation sum ups for efficient handling and management. Especially in mass casualty incidents (MCI), cooperation between different rescue forces and involved organizations is essential to allocate resources most powerful.

The paper follows the question how to exchange currently used paper/radio based communication with digital data transmission to achieve better data quality, faster information transfer, and geolocated information on rescue forces

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and injured person. This work is part of the *SpeedUp project*[1] which investigates courses of actions and cultures in rescue organizations to seek for useful IT support for rescue management at the spot.

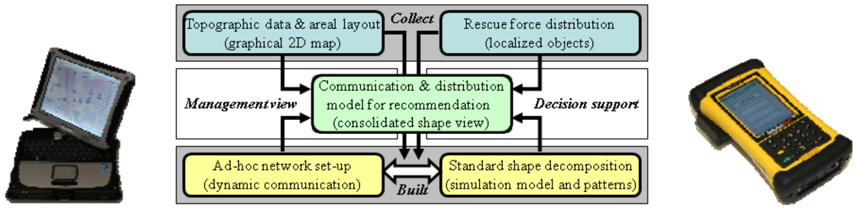

Figure 1. Process steps to form a map-based, location-enriched management view for rescue decision support and mobile devices for representation

GEOLOCATED RESCUE MANAGEMENT

The main function of Command and Control Systems (C2S) in rescue situation is to gather and scatter information to enhance the collective situational knowledge and understanding, also known as *shared mental model*. There is a lack of standardized information exchange formats as forces rely on different mobile devices and communication tools. A map-based common information base is recommended to align all involved persons and objects within a consolidated shape view. As the status is changing every minute, localization of person and objects can help to reach overall consistency and build up communication and distribution models (see figure 1).

Relevant locations can be both, single points (single persons or rescue means) or areas (defined areal layout). Spatial information are attached to any point of interest. Once recorded these datasets they have to be shared and synchronized via wireless data exchange to all interested forces as all other dynamic data. Co-localization is a key to bridge information derived from different sources. Cheep physical ID tags, which consist of a visual barcode and an RFID can be attached to nearly any object of interest (Schau, Kirchner, Erfurth and Eichler, 2010). They will be given their initial location by means of NFC using the mobile devices of rescue workers at the moment of set up.

To make maps richer, static information is supplemented by dynamic data e.g., location and state information of operational units, emergency vehicles and inquired or concerned people (figure 2). Different forces have different needs of informational detail level and views to make appropriate decisions. The officer-in-charge is mostly interested in an overall view, while other members of rescue forces need more local details. So localization and data communication is very important to gather information for an accurate mental model of the situation. Ruggedized devices with touch screen like Panasonic Thougbook CF-19 or Timbatec Nomad and Yuma (figure 1) are used for visualization and data acquisition. Common basic maps are preloaded and more detailed or specialized maps will be provided if required as soon as the target area is known.

On-site Situation and Requirements

Based on the received information after an emergency call and potentially further relevant settings like access ways or other rescue teams, initial information is overhanded by the emergency control center (ECC) using radio or mobile telecommunication systems. As rescue units move, they are tracked and notify their position by GPS tracking.

Arrived on-site, the first rescue team tries to get a situation report in order to start rescue operations. Gathering all relevant data is done by radio or local peer-to-peer (p2p) communication. According those reports, forces initiate rescue activities immediately. Situation reports have a great importance and are continuously issued by on-site management. Started with the first rescue team these reports are overhanded to the next levels of on-site management organization and the emergency control center. Thus, for all rescue forces on the way the ECC is the only information channel for basic situation data. On the spot rescue teams receive updated data, situation reports and local orders via radio, p2p or mobile telecommunication network. In most instances p2p networks are the only information channel for rescue forces and are more stable than telecommunication infrastructure networks. Mostly, all telecommunication devices work only in one radio cell which overloads the entire capacity. A p2p system in our

[1] The work is part of the larger SpeedUp project which is funded within the Federal Government's program "Research for Civil Security" (call "Rescue and protection of people") by the Federal Ministry of Education and Research (duration: 1 May 2009 - 30 April 2012).

understanding is a kind of self-organized traditional or passive network that consists of smart nodes sitting at the edges of the network. These nodes, e.g. smart phones, are capable of performing computations and maybe utilizable as simple p2p routers that interconnect the nodes. In the highly dynamic area of rescue operations p2p networks are extremely limited. Although p2p router nodes may modify a packet's header, they pass the rescue data opaquely without examination or modification. Furthermore, the header computation and associated router actions are specified independently of the rescue operation process or application that generates the packet.

Hence, the concept of active networking emerged from DARPA research discussions (Tennenhouse, Smith, Sicoskie, Wetherall and Minden, 1997) addresses several problems: The difficulty of integrating new approaches and standards into the shared network infrastructure, poor performance due to redundant operations at several protocols, and difficulty accommodating new services in the existing architectures. The idea of messages carrying programs and data is a natural step beyond traditional circuit and packet switching, and can be used to rapidly adapt the network to changing requirements. Coupled with a well understood execution environment within rescue network nodes, this program-based approach provides a foundation for expressing networking systems as the composition of many smart components with specific properties: Rescue information and services can be distributed and configured to meet the needs of rescue operations and statements or command orders. Examples of active (node, packet and hybrid) networking architectures are approaches proposed e.g. at Columbia University, Carnegie Mellon University, University of Kansas and Arizona. There have been introduced three main different approaches – discrete (ANTS, CANES and DAN), integrated (IP Option, ANEP and Smart Packet) and hybrid (SwitchWare and NetScript) approaches (Hu and Chen, 2000).

NETWORK MODELING AND MOBILE AGENTS

Many active network architectures currently use the *code mobility paradigm* (Braun, Rossak, 2005; Fuggetta, Picco and Vigna, 1998) that is very close to mobile software agent technology. The idea of active network is much more general in terms of protocol encapsulation and service customization. A fundamental difference is that active networks use the concept of network layer processing, whereas mobile agent systems run as application programs. The *mobile agent paradigm* proposes to treat the network as multiple agent-friendly nodes and mobile agents as programmatic entities migrating from one node to another to perform user-specific tasks. From this point of view, a mobile agent may be regarded as a specific type of an active packet. A mobile-agent-compatible node of traditional networks could be regarded as a specific type of an active node (Psounis, 1999). Summarily, the benefits (Braun et al., 2005) to use mobile agents includes reducing network traffic, protocol encapsulation, asynchronous and autonomous execution, dynamical adaptation, integrating heterogeneous systems, and achieve robustness and fault-tolerance.

Figure 2. Map of a sample rescue spot. Left: point view; right: decomposition shape view.

Regarding on-site local p2p communication the technical base are *mobile ad-hoc networks* (MANETs) composed of mobile nodes over wireless links. Network topology in MANETs is subject to continuous and abrupt change. In the area of rescue forces we have to deal with highly dynamic topology changes, limited bandwidth availability and long run energy constraints. Three main different protocol groups, proactive, on-demand and hybrid approaches, have been introduced for ad-hoc network routing (Schau et al., 2010). The dynamical adaption of mobile agent technology offers an additional promising solution for routing problems. Choudhury (Choudhury, Paul an Bandyopadhyay, 2004) have designed Multi-Agent Routing Protocol (MARP), where the agents are responsible for updating the node routing information. The mobile agents are broadcasted to all neighbor nodes and are only accepted by the next destination node (neighbor nodes know sender node as neighbor). Amin (Amin, 2003) introduces an Agent-based Distance Vector Routing (ADVR) using an active population of agents. Multiple agents communicate with each other using synthetic pheromones. The population of agents can be changed dynamically at run time and help to propagate the new topological information within the neighborhood. Plesse (Plesse, Adjih, Minet, Laouiti, Plakoo, Badel, Muhlethaler, Jacquet and Lecomte, 2005) introduce a population of agents that continuously traverses the network maintaining a brief history of its journey. At every node visited, the agent updates the routing table of the node. The agents coordinate among themselves by sharing the history information with each other on the same node, thereby attaining information about parts of the network, without actually visiting it. In our work, we capture the autonomous benefits of mobile agents (Braun et al., 2005) by combining agents and MANET to achieve more reliable and robust communication. Using *Shared Map and Cloning (SMAC)* agents to transport rescue data we use a similar approach like (Abdullah and Bakhsh, 2009) for navigation of mobile agents within the MANET. SMAC agents find the path on rescue specific node and location information. Therefore, all agents and nodes maintain a map by aggregating all nodes, location information, neighborhoods and connection information on its journey. At each hop agent and node synchronize and verify their maps which establish and update a network view including relevant historic data for an agent to decide forward or backward migration (backtracking). The movement of SMAC agents follows a cloning strategy regarding the reliability in the highly dynamic network. Each possible and new node for forward migration will be visited by an agent clone. The agent as an intelligent package is able to take additional information into account to improve routing in MANETs. Hence, rescue unit location information and rescue specific node information are significant using *Mobile Agent MANET (2MANET)* routing to pass through a highly dynamic mobile ad-hoc network.

Map-based Shape Approach and Simulation

Based on node's map data agents and rescue forces have access to location information of all known rescue units to find each other. Figure 2 presents a 2D map example of a sample rescue spot. On the map tracking information discover distribution of rescue forces and give an overview e.g. for the officer-in-charge. To organize the coordination of rescue forces the ground around the hot spot of the emergency is classified in different areas (core, handling of insured, access way for forces et cetera). Several classified areas are caused by the emergency and others are selected by the officer-in-charge. Adding time frames to location data as an additional layer for classified areas, the tracking enriched information leaves a mark of rescue unit density and areal layout. On the other hand defined areal layout and area information implicitly form a decomposition under communication considerations. To handle this decomposition, those areas are modeled. Although polygons are very flexible, the description is complex. Therefore, decomposition into a set of multiple standard shapes consisting of ellipse, triangle and rectangle is recommended. These sets of standard shapes are less complex to analyze under both intercommunication and transcommunication effects. The analysis is done by pattern classes with significant properties (e.g. node density, network structure et cetera). These pattern classes are enriched for simulation by real environment information such as location data. Thus, simulation results of area decomposition and rescue unit density disclose intercommunication weak spots which need short distance support in communication structure. Considering shape borderlines location information and time frames indicate coherence components as transcommunication weak gaps.

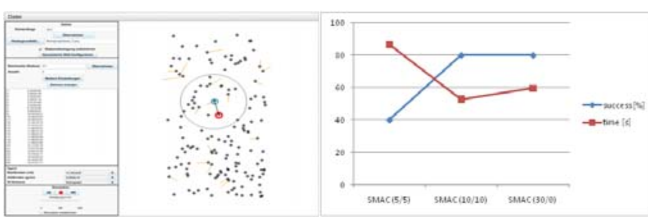

Figure 3. Simulation. Left: 2MANS tool; right: SMAC agent results (agents/map updates)

With 2MANS (Mobile Agent Mobile Ad-hoc Network Simulator), a simulation program was developed. The GUI (figure 3) allows both, efficient modeling as well as performing calculation of different agent approaches and dynamic mobile ad-hoc environments by means of pre-calculated structured or mapping onto known pattern. Figure 3 shows a simulation of the agents movements using SMAC. On the right side the diagram presents the success of SMAC agents to hit the mark at the ratio of time (best by SMAC (10/10)). The model behind the simulator framework provides a base for different kinds of geo-layers, like physical access rights, forces and rescue equipment distribution and communication infrastructure. Although various network simulators already exist, such as NS-2, GloMoSim or QualNet, we developed an own and smart simulator under the purpose to model the conditions of dynamic, mobile ad-hoc, p2p networks such that algorithms for distributed computing in the application layer can compared easily. In contrast NS-2 and GloMoSim are the most popular simulators used in the research field of mobile ad hoc networks but they have not met our modeling requirements. QualNet is a commercial version of GloMoSim and beyond the alternatives.

By simulation the reliability of the p2p communication can be checked. Furthermore in rescue missions suggestions for additional infrastructure elements to support the local p2p communication can be derived. Localization information is on the technical level useful for routing mobile agents and on application level most welcome for rescue forces to localize team members, people concerned, or for map-based situation reports. Our geolocated communication infrastructure approach is promising to support the ad-hoc communication within the SpeedUp Technology level of the SpeedUp project. The project's goal is to support rescue forces in complex situations like mass casualty incident. Within this project our approach will be evaluated in real training scenarios in future.

CONCLUSION

For efficient coordination of rescue forces in action reliable communication and information is important. In future mobile devices could be integrated in a p2p communication infrastructure to collect and distribute information. Thereby such devices can support the localization of rescue members, injured persons, or can annotate information with geo-information. Situation reports built up by collected information and relevant additional information like maps are a crucial instrument for decision making. Our approach utilizes the benefits of mobile agent technology and tries to solve routing challenges using 2MANET routing to pass information through a highly dynamic mobile ad-hoc network. Based on a geographical separation of the spot using patterns a simulation tool is developed. The tool is used to test different routing algorithms and suggests based on current situation suitable routing algorithms for a reliable communication. Following this approach the quality of information and the up-to-dateness of the data are improved essentially. However the application of IT for rescue forces needs to take a wide range of requirements and surrounding conditions into account which is also in the focus of the SpeedUp project (Schau, Späthe, Eichler, 2010).

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