Simulation of wireless, self-organizing and agent-based dynamic communication scenarios

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ABSTRACT

The inter-disciplinary research project SpeedUp focuses on an IT framework to support communication and collaboration for mobile rescue forces. Starting with the investigation of methods, organizational structures and strategies a separation of the professional and technical (IT) layers is achieved. In most cases rescue activities are highly dynamic, so the choice of a MANET supports best the application of mobile agents and different routing strategies. Using simulation, a number of representative, location-based scenarios are analyzed and evaluated.

Keywords

simulation, agent-based communication, ad-hoc network, MANET routing, self-organization, mobile data platform.

THE SPEEDUP PROJECT

The *SpeedUp*[1] research project activities are focused on an IT framework to support communication and collaboration between potentially mobile rescue forces (SpeedUp, 2012). Starting with investigations of organizational structures and strategies for courses of action within various rescue forces (firefighters, medical service and police) SpeedUp addresses the definition of an IT solution which is acceptable and utilizable by the different organizations in complex situations. The SpeedUp IT solution makes use of mobile devices for digital communication at the place of action. The communication between mobile devices is based on ad-hoc network strategies. As rescue activities are highly dynamic in nature, we complement the chosen existing technologies with mobile agents. In our understanding agents are smart software entities which fulfill tasks without assistance (Wooldridge, 2002).

[1] The work is part of the SpeedUp project which is funded within the German 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).

The technical SpeedUp *challenge* is hidden in the IT layer, where at communication time the need arises to discover a data path between two nodes within the dynamic and instable ad-hoc network. Moreover, rescue forces enter and leave the area so that the network they provide expands or collapses (Schau et al., 2010; Schau, Erfurth et al. 2011). Agents have to find an effective strategy to migrate (Braun, Rossak, 2005) from one node to another in a situation where a direct link is not available. The key issue in the context is an appreciation of the movement of mobile nodes and the respective change in link quality. Results in this scenario will enable modifications in migration strategies for highly dynamic location-based and mobile networks in general. An agent's behavior depends on: (1) the communication node's availability, position and motion, (2) point of services, (3) available communication nodes, (4) link quality, (5) communication modes and (6) amount of data to be transferred. To minimize the data volume agents can split the load by cloning and/or using mirror- and code-servers. Both methods increase agent efficiency, but in the context of dynamic mobile networks there are high risks. Pros and cons are analyzed in (Braun, Rossak, 2005).

Simulations are often used to overcome the drawbacks of real event analysis. Rescue trainings are expensive and time-consuming (Müller, 2002). Simulations help to understand complex systems, to discover hidden dependencies or weaknesses and to validate theories for increasing the power of the system (Chung, 2004).

APPLICATION SCENARIO DESCRIPTION

Typical examples for a *Mass Casualty Incident* (MCI) are bus, train or plane accidents. Insured people, rescue forces and equipment are spread over a large area. Structured and coordinated handling requires (1) data collection, (2) information forwarding and (3) hierarchical organisation (Schau, Erfurth et al., 2011). Paper-based processes are reliable but slow and incomplete. SpeedUp relies on electronic support for rescue forces using mobile communication devices (nodes). Known risks are inaccessibility, as well as lost or broken down nodes. The major strength is the autonomous and redundant replication of information within the entire ad-hoc network, if it is not partitioned.

Besides robustness the real physical topology of the rescue area requires attention. Figure 1 gives an example of the distribution of rescue forces in a regular event, classified as MCI level 0.5 and 1.0. A dot symbolizes their mobile devices, circles their direct communication range and arrows the tendency of movement. Due to task specialization clusters of different size and shape are formed. The ad-hoc network bottlenecks are areas without nodes or even sparsely covered places, as they split up the infrastructure into partitions (non-overlapping circles). However, moving devices can bridge this gap.

(a)

(b)

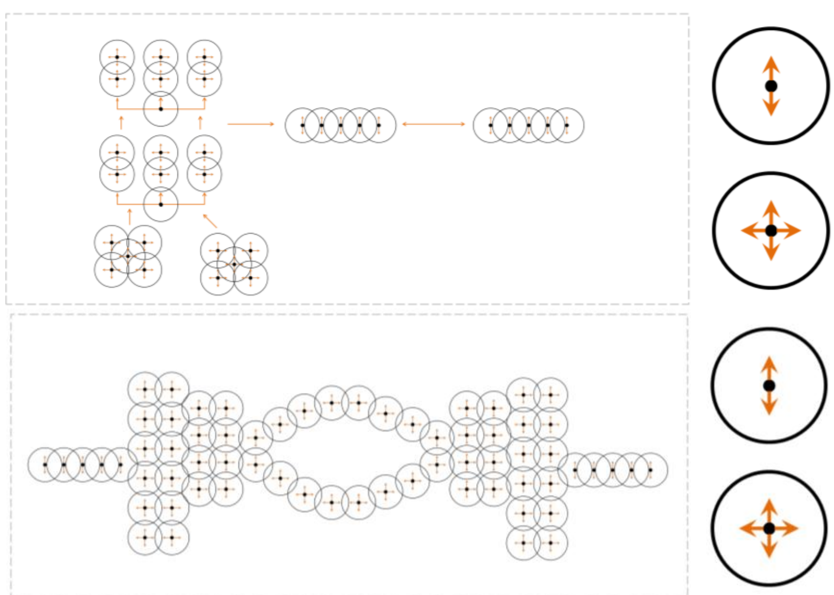

Figure 1. Distribution of rescue forces with freedom degrees in MCI 0.5 (a) and MCI 1.0 (b)

The exploitation of location-based information, e.g. geo-coordinates of nodes, allows a robust and efficient data communication regarding the node distribution. Normal routing algorithms do not take node distributions into consideration. Our approach proposes the pro-active distribution of active data packages by means of mobile agents.

A *mobile agent* consists of both, the data to be transferred (message) and executable code (program). It acts autonomously on the basis of current circumstances, the position of nodes and geographical specialities. It is able to increase the probability of successful information flooding in the entire network. In our work, we capture the autonomy based benefits of mobile agents (Braun, Rossak, 2005) by combining agents and Mobile Ad-hoc Networks (MANET) to achieve a more reliable and robust communication. As proposed by Schau (Schau, Erfurth et al. 2011), we use *Shared Map and Cloning (SMAC)* agents to transport rescue data in an approach similar to (Abdullah and Bakhsh, 2009) for navigation of mobile agents within the MANET. SMAC agents find the path on rescue specific node and location information.

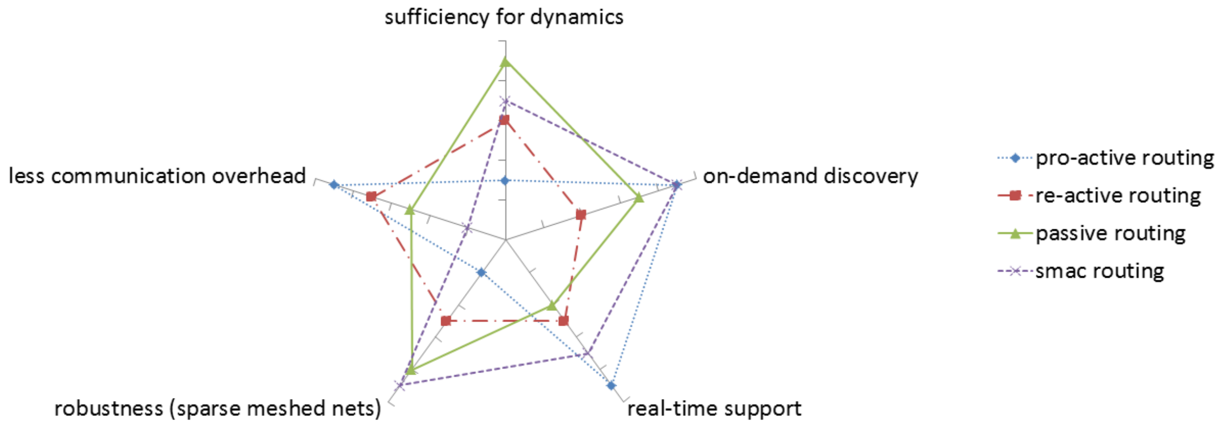

Figure 2. Characteristics of routing strategies (best value: outside)

Derived from this scenario, the resulting constraints for messages exchange are: (1) highly dynamic ad-hoc networks need to be supported, (2) robustness in sparse meshed parts of the networks is required, (3) no message loss or duplication (from the application's point of view), while delayed message delivery is acceptable, (4) depending on the roles of involved people different kinds of messages will be generated, (5) at least a few devices (role depended) need to have a nearly complete and up-to-date information base build up by incoming messages and (6) no central routing/control instance is assumed.

On base of these constraints the characteristics of a *pro-active routing protocol* do not fit the requirements. Also *re-active routing protocols*, working on-demand, cannot help, as the destination of messages is not known in advance. As MANETs need to be self-organizing and self-restoring on a peer-to-peer basis we propose a *passive routing strategy* (carry and drop message by autarkical agents) that helps to reduce the central control overhead, while increasing pro-active data messaging at the same time (Murty and Das, 2011). The SMAC approach ensures high robustness. Figure 2 compares the four approaches.

PROFESSIONAL AND TECHNICAL LAYER

Two layers can be derived from the scenario: (1) professional and (2) technical. The professional layer covers contents which are related to the acting of rescue forces, their tasks, strategies, procedures and hierarchies to solve the situation (we refer to figure 1 of (Schau et al., 2010) by combining the two layers "SpeedUp Szenario" and "SpeedUp Praxis"). The *simulation* takes only the spatial distribution for its model to predict possible links between nodes. Therefore, it focuses on the technical (IT) layer, describing the communication infrastructure in combination with mobile SMAC agents (layer "SpeedUp Technologie" in figure 1 of (Schau et al., 2010)). For more details about all layers we refer to (Schau et al., 2010) and (Schau et al., 2011).

SIMULATION PROCEDURE

Pre-condition for the simulation is the generalized MCI scenario from Figure 1. It contains both, positions and movement vectors of rescue forces' communication devices (nodes) (I-1ab, figure 3) over a time of 1000s. Each node sends regularly messages to be distributed to its neighbours to reach all nodes. The sending interval between two messages is 1s, which allows us to distribute 1000 information per node. These characteristics are captured by the *Network Simulator ns2* (I-2b) in stage I. Within stage I the positional relationship of nodes is discovered.

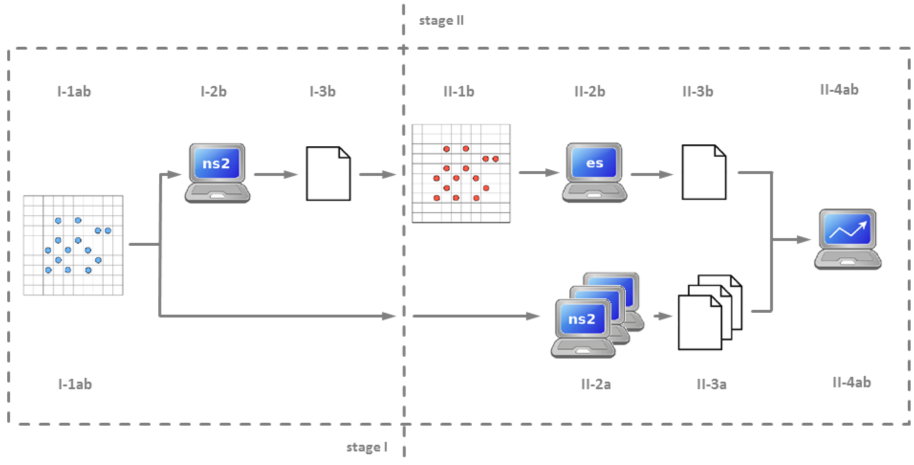

Figure 3. Two-stage-two-paths simulation procedure

For our purpose we consider two ways in stage II. The *Network Simulator ns2* (II-2a, figure 3) is used to simulate classical routing protocols (DSDV, AODV and DSR (Schau, Erfurth et al., 2011)) and node movements (line II-2a up to II-3a) based on the position and movement vector data (I-1ab). The *Ellipsis multi-agent system es* (Multiagentsystem Ellipsis, 2012) (II-2b, figure 3) examines agent based routing (line I-2b up to II-3b) by *mobile shared map and cloning agents* (Schau, Erfurth et al., 2011) based on pre-processed node connectivity (II-1b). The pre-processed data provides the direct connectivity between two nodes generated from the ns2 run in stage I (I-2b up to I-3b). The overall result of the two-way run is then consolidated and analysed (II-4ab) by utilizing the trace files (II-3a, II-3b).

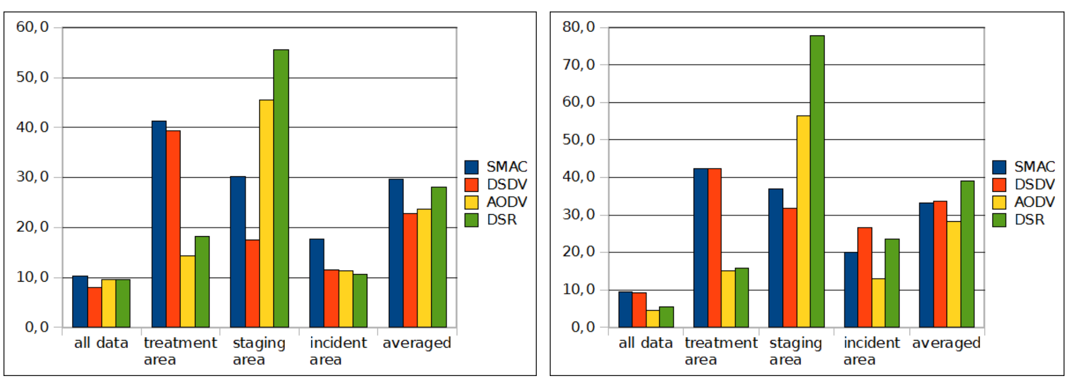

Figure 4. Robustness and Sufficiency for dynamics at levels MCI 0.5 (left) and MCI 1.0 (right)

SIMULATION RESULTS

To compare different classic routing protocols with the SMAC approach, simulations of different dynamic levels were set up. The results for MCI 0.5 and MCI 1.0 are compared in figures 4. The ordinate shows the completeness of information distribution within the entire MANET as well as dedicated operation areas (y-ordinate in %).

The agent approach works inefficient within sparse areas, e.g. a staging area, for both simulations due to its large migration overhead. In the context of a highly-dynamic scenario missing alternative paths are a heavy drawback for agents, if compared to other routing protocols. Data packets of routing protocols are using the limited time frames for existing links more efficient due a smaller packet overhead. Therefore, more packets are able to pass.

At the incident area MCI 1.0 shows similar behaviour of agents and routing as in the staging area, while agents for MCI 0.5 are more successful at dense node distribution. In well-structured areas, like the treatment area, the advantage of agents is clearly visible. High node density and many different stable link options support even a very large amount of data. Taking all data into consideration, a slight advantage of the agent approach can be recognized (all data, figure 4).

CONCLUSION AND FURTHER WORK

There is still potential to minimize the payload of agents (code plus data) for sparsely populated and highly-dynamic areas. In our future work we will deal with different migration strategies that also take into account the agent size. That is a challenge, as we need quite a number of training scenarios and, therefore, cannot optimize such a strategy by observing real life rescue operations. We will have to use high-performance-computing cluster to simulate all the facts. Even a simulation will, however, consume a critical amount of time at the MCI level (e.g. 18k hours for MCI level 1 for a run of 1000s rescue operations). Still, the presented results, seen as work-in-progress, already emphasize the potential of agent based routing as a valid alternative for routing within a set of mobile data platforms in a rescue scenario. In addition, the agent approach profits by the possibility to take application level information, e.g. role of message sender or receiver, into account for routing activities. By this means agents are able to guide messages in an intelligent manner – a promising way to spread information in MCI scenarios successfully.

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