Knowledge Management in Mobile Ad-hoc Networks for Rescue Scenarios[1]

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Abstract. Information sharing is a mission critical key element in rescue and emergency scenarios. Mobile ad-hoc networks could provide the necessary infrastructure, but existing solutions to information and knowledge management do not adequately meet the challenges that we face. This position paper discusses the requirements imposed by the given scenario and outlines some solutions.

1 Introduction and Motivation

One of the goals of the AdHoc InfoWare project [1] is to develop middleware services to facilitate information sharing in a mobile ad-hoc network (MANET) for rescue scenarios. MANETs are composed out of heterogeneous devices ranging from cell phones and PDAs to Laptops that are equipped with wireless network interfaces. MANETS are very dynamic, because devices can join and leave the network range at any time. Such an infrastructure could be very helpful for rescue and emergency operations where each person is carrying a wireless device, because information sharing between these wireless devices enables coordination and cooperation of rescue personnel as well as gathering and distribution of information. Sharing of information in such a heterogeneous and dynamic environment calls for knowledge management. Although some distributed knowledge management solutions for MANETs do exist, e.g. [5], it has been acknowledged as an important research issue, e.g. [7], [10]. For our project, we have not found any solutions that fully satisfy our special requirements. Therefore, we currently develop a Knowledge Manager (KM) as one of five components in the Ad-hoc InfoWare middleware. In this position paper, we present the design of the KM, which we believe is a step in the right direction.

We conducted a requirements analysis based on interviews and accident reports of rescue organizations and monitoring of real-life emergency exercises. We have found a set of main requirements which have guided our choice of KM components: facilitate use and sharing of existing domain ontologies (or-

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ganizations); enable querying and retrieval of relevant information items; support metadata and ontology storage and management; keep track of information availability; support use of profiles and context for personalization and filtering of information; functionality supporting parsing of XML documents; scalable configuration to accommodate different device sizes. In addition, the KM should offer services both internally in the system, as well as externally to the application level. The above requirements directly reflect the problems we want to solve in our work.

The problems for middleware related to knowledge management for such a scenario include both inter- and intra-organizational information sharing. This means there is a need for translations between the vocabularies and metadata standards used in the organizations, as well as a standard language for information exchange. As most of the relevant ontology and metadata standards are represented in XML, and it is chosen as the international standard for message exchange in the health sector [6], tools for XML parsing are required. Getting the right information at the right time, in the right format, granularity, and context is essential in such a setting, and may even save lives. Overflow of information can be as bad as no information at all, so filtering and personalization is required. Given the hectic atmosphere in a rescue operation, as well as the dynamic nature of MANETs, information may become unavailable due to movement of actors carrying devices, i.e. the network nodes, as well as hindrances at the site. This calls for distributed solutions, and monitoring of available resources and information. In addition, there has to be a possibility to request information on demand.

The remainder of this position paper is organized as follows: In Section 2, we give an overview of related work with respect to knowledge management in MANETs. We present our envisioned design of the KM and the relevant research challenges in Section 3, and we summarize by stating the main research ideas and future research directions in Section 4.

2 Related Work

MoGatu [2] is a framework for profile based data management in a mobile ad-hoc environment using ontologies and profiles to perform filtering and prioritize data. They use a local metadata repository to cache metadata, which is similar to our approach of local data dictionaries. However, their solution does not offer a global view of knowledge available in the network. Shark [5] is a system for knowledge management and exchange among mobile users, using topic-based knowledge ports to handle knowledge management tasks. The architecture relies on stationary server nodes for knowledge and synchronization management. DBGlobe [4] is service oriented, and relies on fixed

network servers that keep track of node movement and store profile and context metadata. Due to the dynamic environment in our scenario we can not rely on a fixed network, so the above solutions will not suffice. AmbientDB [3] provides a global database abstraction over a MANET, but does not use ontology based solutions or methods from knowledge management. We need to deal with both inter- and intra-organizational information sharing in our scenario, so we need ontologies and knowledge management facilities.

3 Knowledge Manager Design

The Knowledge Manager (KM) is composed of five components, each with a dedicated area of responsibility, all working together to fulfil the KM requirements. In our scenario, we are dealing with three types of metadata: (1) information structure and content description metadata; (2) semantic metadata; and (3) entity profile and context metadata. This is reflected in the components in our design. The following components handle metadata: *Data Dictionary Management*; *Semantic Metadata and Ontology Framework*; and *Profile and Context Management*. In addition, we have two tool components: *Query Management* and *XML Parser*.

Data Dictionary Management

The purpose of this component is to support availability information and metadata storage through the use of local data dictionaries and global distributed data dictionaries. The *Local Data Dictionary* (LDD) is stored locally on each node, and contains data structures and content descriptions of information items to be shared in the network. It is advantageous to have a fairly homogeneous structure of items stored in the LDD; this can be achieved by using classes of metadata defined in ontologies. The *Global Distributed Data Dictionary* (GDDD) keeps a global view of information available for sharing in the network. The requirements for the *Data Dictionary Management* component include managing storage of metadata; management of organization and update of LDD and GDDD; keeping track of data availability; and support request of information in the GDDD. Keeping track of data availability can be achieved in an active (eager) manner, which implies actively monitoring and updating data availability, or in a re-active (lazy) manner, where data availability is updated when it is discovered. The first alternative generates a lot of network traffic, which is undesirable for a MANET, so the second, reactive, alternative may be a better solution.

There are several possible solutions to storage and distribution of the GDDD; one is to let emergency team leaders only keep copies of GDDD in the form of abstracts or summaries of LDD content. Problems with this solution include centralization, and that it is connected to user role. Another possible solution can be to have three levels of GDDD reflecting what is known about

available information: (1) only information locally on node, i.e. in LDD; (2) information available at neighbour nodes, i.e. a medium level GDDD; (3) knowledge about what is available in the whole network, i.e. a high-level GDDD. This implies that nodes with sufficient resources have to request and store metadata from neighbours.

A third solution for the GDDD is to make it a "virtual GDDD". This is a solution similar to the Semantic Web [9], [10] and work by Schwotzer et al. [7], and consists of three layers: information layer, context layer, and knowledge layer. In this solution, the GDDD is "virtual" in that no global data dictionary is stored anywhere; it exists through links stored at the LDDs, together with the information item to be shared. Services from the *Semantic Metadata and Ontology Framework* are used to link LDD items (metadata) to the global view. In case of network merging and partitioning, similar procedures of creating or removing links could be used. The information items are – through metadata attribute values – linked to a semantic context consisting of concepts and relations between these. These concepts and relations are instances of entries in domain ontologies – the domain knowledge. If ontologies are to be stored only by users having a certain role we have similar problems of centralization and role dependency as the other solutions, but not effecting the global view of available information, as this is distributed through the linked information items in the LDDs. Also this solution may need coordination of update.

Semantic Metadata and Ontology Framework

The objective of this framework component is to support use and sharing of ontologies and semantic metadata. The requirements that have to be fulfilled to achieve this objective, are first of all to support information integration through ontology translation [8]: (1) mapping or integration, e.g. through using an upper ontology to bridge; (2) offer concept matching functionality to other components; (3) handle problems of partial available ontologies and semantic metadata; (4) enable traversal in hierarchy or semantic net; and (5) offer a simple reasoning engine. Furthermore, the framework should support a set of standards for semantic metadata and ontology modelling, e.g. OWL; provide a semantic context to relate information items to ontologies; storage management of internally used ontologies if required; reflect any run-time changes in semantic metadata; check link validity and consistence in semantic metadata and ontology structures. Automatic or semi-automatic gathering of metadata dynamically may also have to be supported. Changes have to be handled well by the framework, as the probability of many changes is high due to the heterogeneous and dynamic nature of our scenario, as well as the nature of MANETs. A possible use for ontologies internally could be classification of, e.g. devices; events; resources; and access level. Externally, i.e. towards the application level, the focus is on use and sharing of existing domain

ontologies from the participating organizations. Ontology creation is not supported; we assume this is solved *a priori* in the organizations[2].

Profile and Context Management

The main objective for this component is to support personalization and ranking of information through creation and use of profiles and contexts. Profiles [2], [4] give information of the "what" and "who" of an entity, and contain fairly static information. Examples for device profile content could be device type and resources, and for a user profile, identification, roles and preferences of the user. A context [2], [4] contains information concerning the "where", "when" and "why" of an entity, e.g. location, time, and situation. Context information is dynamic due to movement and situation changes.

Tool components: *Query Management* and *XML Parser*

The tool components are providing functionality that other components need to fulfil their requirements. Tool services are also offered towards the application level. The *Query Management* component should offer services related to ad-hoc querying and retrieval. Requirements include supporting other components in querying and retrieval; support of different approaches to querying; support creation of simple queries and dispatch of query; and to support filtering and ranking of results. The *XML Parser* will offer services related to parsing of XML documents, and may in addition support creation of (XML) structure templates.

4 Summary and Future Work

There are still many open issues that have to be addressed, and solutions to be worked out. For the *Data Dictionary Management*, we will continue our work towards an effective and efficient solution for the GDDD. For the *Semantic Metadata and Ontology Framework*, issues of metadata and ontology standards, ontology usage internally, methodology for translation and integration of knowledge; partially available knowledge and handling evolving knowledge at run-time. For *Profile and Context Management*, issues concerning profile and context structure and content have to be solved, as well as types of filtering to offer. A lot of work related to *Query Management* remains, including solutions to content based search and ranking, and choice of query languages to support (e.g. XQuery). For the *XML Parser*, we need a lightweight parser suitable for smaller devices, like a PDA.

[2] Relying on an a priori phase is a difference from typical scenarios for MANETs.

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