

μ PROS – Micro Protocol Based Development of Mobile Ad Hoc Networks

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1 Project Context

Communication systems are an integral part of large, distributed systems, they form the basis for operating systems and applications. The recent evolution of wireless communication and user mobility has led to a new main research focus, aimed at offering farther advanced and more flexible communication services while improving the effective use of communication resources. This requires, among other things, customized and flexible mechanisms for unicast and multicast routing as well as for quality of service provision. Customization of communication systems is closely related to an application area, and calls for new protocol engineering techniques that are based on reuse in order to manage the development effort. In the project, customization of protocols for mobile ad hoc networks in the Ambient Intelligence domain (AmI, [1]) will be addressed. Ambient Intelligence is a vision that inherits the dynamic topology and automatic configuration from mobile ad hoc networks, and exceeds ad hoc networks by new applications based on the integration of "intelligent" network devices into everyday's objects. By this large-scale information integration, the AmI vision aims at easing the peoples' life.

2 Project Framework

The project is carried out by the Computer Networks Group at the Technical University of Kaiserslautern in Germany, in cooperation with several partners, and is publicly funded. The project staff currently consists of 2 full time researchers, 2 PhD students, and 6 master students. Financial support is received from several sources and covers full time research positions as well as PhD grants, which are funded by the German Science Foundation, the government of the province Rheinland-Pfalz, and the University of Kaiserslautern. Infrastructural support is obtained via membership in the research network "Ambient Intelligence", a Center of Excellence funded by the provincial government. There is close cooperation with Concordia University in Montreal/Canada

and the Fraunhofer Institute for Experimental Software Engineering in Kaiserslautern/Germany. The project is planned for a duration of 5 years, and has started in October 2002. Being in a starting phase at the moment, the project is expected to double in size in 2004.

3 Project Objectives

The main objective of the project is the provision and application of engineering approaches and techniques for the development of adaptive, integrated mobile ad hoc networks. In the core of the project is the construction and the use of a library of specialized design components called "micro protocols" for (unicast and multicast) routing and quality of service provision in mobile ad hoc networks, as well as a micro protocol framework for their composition. A micro protocol [2] is a self-contained, ready-to-use building block covering a single protocol functionality. Micro protocols are then composed to form complex communication systems. The selection of micro protocols is based on an assessment of existing routing and quality of service mechanisms, augmented with measures for their adaptation and integration in the Ambient Intelligence domain. This domain is characterized by a high degree of mobility as well as diverse communication requirements. To formally define micro protocols, the design language SDL (Specification and Description Technique), which is widely used in industry, will be applied.

4 Challenges

There are a number of challenges that will be addressed in the course of the project, including:

- **Increase of productivity and quality in the communication systems development**

Reuse in the protocol engineering domain has not been very successful in the past. Yet, reuse is a key to increasing both quality and productivity. In a previous project, we have shown how to foster reuse in protocol design through specific design patterns called "SDL patterns". The challenge in this project will be to apply SDL patterns in order to define communication components called "micro protocols", and to provide a framework to compose them. Furthermore, it needs to be investigated how validation and implementation techniques can benefit from these reuse techniques.

- **Advanced services for heterogeneous applications**

Most research in ad hoc networks is aimed at IP networks, which provide general-purpose communication services for common applications. In a heterogeneous environment, applications require more specialized and diverse services, which can only be provided by special-purpose, customized communication systems. It is an open issue how to design and implement heterogeneous communication functionalities in an adaptive, integrated manner.

- **Adaptive routing and quality of service provision**

Routing as well as quality of service provision are major challenges in mobile ad hoc networks. This is due to the constantly changing topology and the sensitivity to noise. For instance, there is no single routing mechanism that yields best results in all situations. Therefore, techniques that take the current topology, channel quality, and traffic situation into account for short-term as well as for long-term adaptation are needed.

5 Project Tasks

The following is an excerpt of the list of tasks that have been defined for the project:

- **Provision of micro protocol design libraries for selected protocol functionalities**

In the context of mobile ad hoc networks, both multi-hop routing and quality of service provision are of specific interest. There exists a variety of mechanisms for these functionalities, which are to be assessed and compared using discrete simulation techniques. Based on the outcome, suitable mechanisms will be selected and encased into micro protocols. This will lead to design libraries of routing and quality of service micro protocols, which can then be composed into customized communication systems in the AmI domain.

- **Definition of a general micro protocol design framework**

In general, a component framework is understood as a rigid system skeleton to which components are attached in precisely defined places. In this sense, layered architectures are communication system skeletons. For the composition of micro protocols, this view needs to be generalized: a micro protocol framework is defined by a set of composition operators and mechanisms to build flexible, hierarchical communication systems from micro protocols. Thus, synchronization and causal relationships between micro protocols are established on a high level of abstraction.

- **Design of adaptation schemes for routing and quality of service provision**

Based on the micro protocol library, new adaptive protocols will be devised. We will focus on the design of the adaptation decision process (reliable in-system replacement of functionalities), each node's knowledge about the network, metrics, and cost functions. Based on these parameters, a run-time adaptation process that must be efficient (network and CPU load) and reliable (no loops or oscillation) will be designed. The adaptation approach will be analyzed by implementing adaptation schemes, and by studying them in the AmI domain. In particular, we will investigate how to substitute protocols properly, and how to design the decision process for substitutions. We focus on adaptive protocols for routing and quality of service provision.

- **AmI case studies**

In cooperation with other research groups of the AmI Center of Excellence, several applications and their customized communication systems will be developed. At the moment, the choice of applications is subject to further study. Possible candidates can, e.g., be found in the consumer domain ("Intelligent House"). Further tasks that are to be addressed in a later project stage are related to the effective implementation of micro protocols and their composition. First results on how to design micro protocols with SDL [2], to automatically implement micro protocol designs [3], and how to integrate quality of service mechanisms [4] are readily available.

References

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