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INTEGRATION OF MOBILE AD-HOC NETWORKS FOR WIRELESS SYSTEMS

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Abstract

The rapid development of wireless digital communication technology and the corresponding network software systems have created new horizons for communication beyond the Internet realizing the connected society. Among them, the field of mobile ad-hoc networking is experiencing unprecedented growth in its scale and application diversity. Without requiring the preexistence of communication infrastructures, a temporary network can be established on demand and disappears when there is no need. The presence of a fixed supporting structure limits the adaptability of wireless systems. In other words, the technology cannot work effectively in places where there is no fixed infrastructure. Future generation wireless systems will require easy and quick deployment of wireless networks. This quick network deployment is not possible with the existing structure of current wireless systems. Recent advancements such as Bluetooth introduced a new type of wireless systems known as mobile ad-hoc networks. Mobile ad-hoc networks or "short live" networks operate in the absence of fixed infrastructure. They offer quick and easy network deployment in situations where it is not possible otherwise.

Keywords: MANETs, IEEE802.11, WWRF, Routing Protocols, QoS.

1. Introduction

In the next generation of wireless communication systems, there will be a need for the rapid deployment of independent mobile users. Significant examples include establishing survivable, efficient, dynamic communication for emergency/rescue operations, disaster relief efforts, and military networks. Such network scenarios cannot rely on centralized and organized connectivity, and can be conceived as applications of **Mobile Ad-hoc Networks [1].** Ad-hoc is a Latin word, which means "for this or for this only." Mobile ad-hoc network is an autonomous system of mobile nodes connected by wireless links; each node operates as an end system and a router for all other nodes in the network. Since the nodes are mobile, the network topology may change rapidly and unpredictably over time. The network is decentralized, where all network activity including discovering the nodes themselves must execute the topology and delivering messages, i.e., routing functionality will be incorporated into mobile nodes. The set of applications for MANETs is diverse, ranging from small, static networks that are constrained by power sources, to large-scale, mobile, highly dynamic networks [5, 6]. The design of network protocols for these networks is a complex issue. Regardless of the application, MANETs need efficient distributed algorithms to determine network organization, link scheduling, and routing. The network should be able to adaptively alter the routing paths to alleviate any of these effects. Moreover, in a military environment, preservation of security, latency, reliability, intentional jamming, and recovery from failure are significant concerns. Military networks are designed to maintain a low probability of intercept and/or a low probability of detection. Hence, nodes prefer to radiate as little power as necessary and transmit as infrequently as possible, thus decreasing the probability of detection or interception [4]. The routers are free to move randomly and organize themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. Such a network may operate in a standalone fashion, or may be connected to the larger Internet."

2. Self-organization in Wireless Systems

A short look around shows the increasing diversity of smart and connectable devices users have to cope with. Embedded devices and sensors with basic wireless facilities potentially extend the available infrastructure. Applications span body, personal, home, vehicle, and wide area networks. This leads to the question how users can deal with this increased complexity without having to become technical experts. The solution could be self-organization. The basic idea of self-organization in the wireless area is to build on existing concepts, such as plug-and-play components, auto-configuration in the Internet and ad-hoc networking, but also to go beyond. The concept of self-organization is found in physics, chemistry, evolution, economics, and ecology, while its potential is not yet exploited in technological systems. The task at hand is to learn from other domains and develop a new category of solutions for technological problems in wireless world systems. Most of the actual research work in this embryonic field lies ahead of us.

Self-organization aims to bring orderliness to the evolving distributed systems with the least possible necessary human intervention. The following constraints apply to self-organization:

- The system should behave as the user expects, and the user should remain in control at some higher level and be able to correct erratic behaviors.
- The system should not compromise the privacy of the user and have adequate security mechanisms. It will be essential for the user to trust the automated behavior of systems.

Both user and technical requirements of self-organization need to be understood. The human being must be seen as part of the overall system. Self-organizing systems need built-in policies and learning properties. They need to be able to change and optimize the concrete behaviors based on more abstract input from users and administrators as well as use experience or feedback from the environment.

Examples of other specific items identified are:

- Self-configuration of attached devices and networks
- Self-organizing, adaptive, context-aware applications, services & middleware
- Self-organization in ad-hoc networks
- Self-organization of trusted groups with specific rights
- Self-organization capabilities of ad-hoc radio interfaces
- Self-adaptation to normal and disruptive or catastrophic changes
- Automatic adaptation of protocols and software
- Self-organizing key management

SIG3 is about to complete the first white paper on the state – of the art in self-organization. It has three specific Internet examples: IP auto-configuration, peer-to-peer networking, and shared open-content Web pages. Another item is self-organization in emerging ad hoc and sensor networks, with examples on paradigms to achieve cooperation and distributed topology control. Theoretical foundations and tools for self-organization in networks, such as game theory and random graph theory, are presented as a possible basis of work. The white paper also proposes a mobile, wireless networks and services architecture with a high level of self-organization.

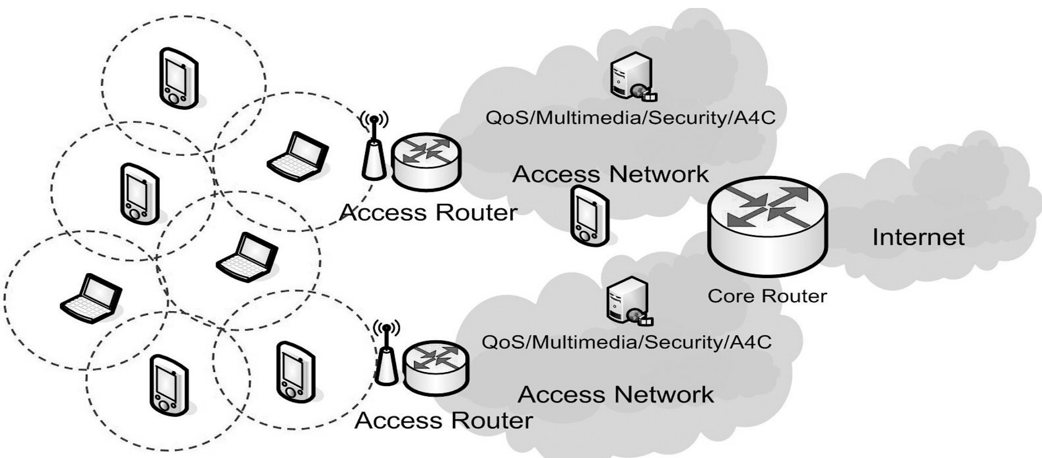
Ad-hoc communications has many different flavours: ranging from self configuration, load balancing and task distribution in sensor networks up to cooperative driving between communicating cars on the road. Cars being able to communicate with other cars and with their environment could not only help to avoid crash situations and to save lives on our streets but could also significantly improve the comfort and efficiency of driving with respect to time and energy. For about five years, FOKUS has been working together with industrial partners, car manufacturers, and universities on the different technical aspects of car-to-car and car-to-roadside communications. Main aspects of the research and development for vehicular networks are in the development of protocols and security mechanisms for trusted ad-hoc communications, usage of standardized transmission systems like 802.11 in ad-hoc mode and with geographic addressing and routing. In order to successfully introduce car-to-car communication, the development of suitable application scenarios in different areas like convenient driving, intelligent telematics, or active safety has to be carefully planned and merged into a deployment strategy. Significant parts of the research work have been supported by the German Federal Ministry of Education and Research (BMBF) within the

"FleetNet – Internet on the Road" project (2000–2003) and within the ongoing NoW project (Network on Wheels, 2004–2008).

One of these applications is the location based pin board application (LBPA), which has been developed by FOKUS. LBPA is used to distribute messages (pin board messages) in a predefined region using geographical addressing and a store-and-forward mechanism that relies on vehicle movement. These messages are generated by vehicles (mobile or stationary), stored in the vehicular network for a specified period of time and are accessible by other cars in specific areas of validity. The basic idea of LBPA is to provide an interactive means for the exchange of information between cars/drivers in a specific area of interest – like an electronic bulletin board.

Some of the main technical issues still to be worked out with respect to high velocity vehicular ad-hoc networks are:

- The development of position-based routing and forwarding protocols
- Adaptation of communication protocols to real-world car networking environments
- Security aspects and trusted ad-hoc communications
- Development of suitable antenna designs for car-to-car communication



Ad-hoc Network Architecture

3. INTEGRATION OF MOBILE AD-HOC NETWORKS

A major challenge for future networks is how to ubiquitously provide access to an unlimited set of IP based services at reduced costs for the users and providers. One response to this need is the emergence of numerous hotspots all around the globe. This evolution is profitable for providers, who can increase their revenues, and beneficial for users, who can connect to the Internet with high bandwidth. Due to the small coverage area of a WLAN hotspot, ad-hoc networks can be an interesting supplement. They can increase the covered area without infrastructure investments by an operator. The flexibility introduced by the multi-hop characteristics of mobile ad-hoc networks makes them especially suitable to provide increased radio coverage at low cost.

The delivery of services to users in an ad-hoc network, with features like QoS, security, authentication, authorization and charging, requires several functionalities in the ad-hoc network and integration strategies:

- Discovery of a gateway to an operator network to obtain a unique IP address and efficient routing mechanisms to support the mobility of users inside the ad-hoc network with minimal overhead. Moreover, since mobility is a key aspect of next generation networks, the ad-hoc architecture should support handovers of mobile ad-hoc user terminals (nodes) between different ad-hoc networks. This handover procedure will be significantly different from handovers in mobile operator networks, because the control information exchanged in ad-hoc networks needs to be minimized.
- QoS support in terms of differentiation, admission control, and recovery from congestion situations. Due to the mobility of ad-hoc users, whose terminals form the connectivity backbone of ad-hoc networks, and due to the absence of a central node with knowledge of the network resources, QoS support is a major challenge in ad-hoc networks. Therefore, QoS needs to be realized in a distributed way, with mechanisms for fast reacting to the mobility of the nodes.
- Security mechanisms must guarantee that only authorized users can access the ad-hoc resources and the services in the operator's managed network. Eavesdropping as well as modification of the transmitted data must be prevented.
- Charging and rewarding of mobile ad-hoc nodes. An essential issue in ad-hoc networks is the requirement for mobile nodes to cooperate in traffic forwarding. A basic economic idea aims to provide some rewards to nodes that correctly forward data packets. Due to the dynamic nature of ad-hoc networks and the requirement of the knowledge of the overall path in the rewarding process, charging and rewarding is a challenging task.

Self-organization is an embryonic area in the domain of wireless world systems. There is significant potential both from initial concepts of self-organization in the field as well as from other established areas of science and nature in general. The WWRF has taken up the issue and established a Special Interest Group to deal with the area.

CONCLUSION

The integration of ad-hoc networks into operator environments is currently a hot topic. Its success will strongly depend on the existence of a significant interest of both users and operators. Users must be attracted by the variety of services or cost advantages that ad-hoc networks can bring them, and they should be prepared to provide their mobile terminal for setting up the network. Operators must find their part in the value chain, as the revenues can be very high. Self organization is an embryonic area in the domain of wireless world systems. There is significant potential both from initial concepts of self-organization in the field as well as from other established areas of science and nature in general. The WWRF has taken up the issue and established a Special Interest Group to deal with the area. The challenges are enormous, and a lot of research lies ahead of us. The popular IEEE 802.11 "WI-FI" protocol is capable of providing ad-hoc network facilities at low level, when no access point is available. However in this case, the nodes are limited to send and receive information but do not route anything across the network. Mobile ad-hoc networks can operate in a standalone fashion or could possibly be connected to a larger network such as the Internet. Mobile ad-hoc networks can turn the dream of getting connected "anywhere and at any time" into reality.

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