

1 Research Group on Computer Networks and Distributed Systems

1.1 Personnel

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| Guests: | Saurabh Bhargava | Indian Institute of Technology, (IIT), Roorkee, India May 2008 – July 2008 |

* with financial support from a third party

1.2 Overview

The research group for Computer Networks and Distributed Systems (Rechnernetze und Verteilte Systeme, RVS) is active in several areas of computer communications and distributed systems.

Multimedia Communications The Internet is increasingly being used for multimedia data transfer (audio, video, data). We are investigating

how services with high demands on the quality and reliability of communication systems and networks can be supported. Overlay networks and peer-to-peer systems are becoming more important for new Internet services, in particular to support communication within user groups. We are focusing on the design, development, and evaluation of methods to construct overlay networks supporting the quality-of-service requirements of distributed applications and using network resources efficiently.

Wireless and Mobile Communication Decentralized system architectures and self-organization are fundamental concepts of future wireless and mobile communication systems. These concepts are particularly important in application scenarios such as sensor networks, mobile ad hoc networks and wireless mesh networks. There is an urgent need for research on routing and transport protocols as well as on security and management mechanisms. In sensor networks, limited energy, computing and memory resources as well as limited reliability require special forms of distributed data processing and management.

Security in Distributed Systems The Internet simplifies access to distributed resources and services such as web services, e-learning contents, computer grids or sensor nodes. Traditional techniques for authentication and authorization are not very user-friendly and barely scalable. We investigate, design, implement, and evaluate novel schemes for efficient and secure authentication and authorization.

Distance Learning In all our lectures, we are using distance learning elements that are based on standard components but also on developments resulting from recent research projects. We are developing new methods and tools to support learners and teachers in e-learning environments. In particular, we aim to support practical experiments.

1.3 Research Projects

National Competence Center in Research for Mobile Information and Communication Systems (NCCR-MICS)

The NCCR-MICS (<http://www.mics.ch>) project was launched in 2001. Its goal is to study fundamental and applied research questions raised by new generation mobile communication and information services, based on self-organization. Such systems have become very topical with the advent of mobile ad-hoc, peer-to-peer, and sensor networks. NCCR-MICS is composed of more than twenty research projects distributed over four clusters. The research project of the RVS group on “Distributed event detection and localization architecture for wireless sensor networks” (IP4) aims at designing and implementing a distributed event detection, event localization, and event classification framework. It includes efficient and reliable signaling protocols as well as mechanisms to dynamically reconfigure its specific sensor network applications.

Based on previous work, the distributed event detection and localization architecture (DELTA) has been refined. The DELTA implementation already provided algorithms to efficiently detect environmental events and dynamically establish tracking groups to monitor them. Furthermore, DELTA has already been able, based on data collected at designated group leaders, to accurately localize events and estimate their emitted signal power(s). Localization procedures have been investigated in more detail and classification procedures have been added. The proposed classifier is tuned by unsupervised learning mechanisms and supports the filtering of false alarms, i.e., the filtering of event reports which do not satisfy a given quality criteria. The classifier modeling includes soft computing mechanisms, i.e., fuzzy logic concepts. Learning the classifier parameters from training data eases the application and distribution of the classifier as no expert knowledge is required. Preventing false alarms saves costs in terms of energy, time, and money. Once the training has been done, the computed parameters are downloaded onto the sensor nodes, where all subsequent classification can be performed based on locally collected data provided by DELTA.

So far, the classifier has been successfully applied in an application classifying varying light sources. To support DELTA with a routing topology and to provide an energy saving mechanism, a virtual backbone has been developed and implemented. The virtual backbone mechanism allows the temporary disconnection of redundant nodes, which are not part of the backbone, from the network. It is periodically (re)established to distribute

the backbone load and it provides link repair mechanisms. This backbone is also used to distribute the classifier parameters learned in the classifier tuning phase.

Research staff: Markus Wälchli, Reto Zurbuchen, Samuel Bissig, Torsten Braun

Financial support: Swiss National Science Foundation Project No. 5005-067322 and University of Bern

Mobile IP Telephony (MIPTel)

Wireless mesh networks (WMN) are evolving to an important access technology for wireless broadband services. They provide a cost efficient way to interconnect isolated networks as well as to enhance wireless network coverage. WMNs usually consist of static mesh routers and mobile or static mesh clients. Both support multi-hop communication and may act as routers. The mesh nodes might support multiple heterogeneous radio interfaces. WMNs offer a more robust and redundant communication infrastructure than many wireless networks deployed today. They provide communication facilities even in special situations where certain systems such as GSM are overloaded.

Our project aims at exploiting WMNs as an infrastructure for Mobile IP telephony. IP telephony requires short delays and moderate packet loss. In WMNs the quality of the routes may vary unpredictably because of the unreliable and erroneous wireless medium. Routes may break, if the network topology changes due to node or link failures. Links and nodes may become congested, which leads to larger delays or packet loss. This makes the deployment of a real time application such as IP telephony a challenging task.

We see two important approaches to improve the speech quality and to reduce outages in a Mobile IP telephony application in WMNs: path diversity and multi-stream coding. The characteristics of multiple paths are usually uncorrelated, i.e. the delay, jitter, and loss rate of the paths differ a lot from each other. Therefore, the transmission over multiple paths can be used to compensate for the dynamic and unpredictable nature of WMNs. In order to exploit this path diversity for improving the quality of the audio transmission, a robust multi-path routing protocol and a mechanism for selecting appropriate coding and path allocation for the given network conditions are needed.

We have designed ATOM (Adaptive Transport over Multipaths), which is an architecture to enable real-time communications in Wireless Mesh Networks. ATOM reduces the problems of real-time transmissions over WMNs by using path diversity and multi-stream coding. At session establishment, ATOM decides on the used parameter set (encodings, paths etc.) considering current network conditions and collected historic data. After session establishment, the effect of this decision is continuously monitored and if necessary adapted.

We ported an existing framework for multi-channel communication to latest Linux kernels and integrated it into our Linux image for the wireless mesh nodes. In order to use small MIPS-based mesh nodes in our testbed, we customized and further reduced the size of our Linux image. Furthermore, we have set up a cross-compile toolchain that can build images for x86 and MIPS-based nodes. The toolchain runs on most Linux distributions and does not require a special Linux system anymore.

To make experiments with Linux based nodes in larger topologies, we have designed VirtualMesh, which provides a virtualization of a wireless mesh network. Several mesh nodes are running on top of one computer using host virtualization (XEN). They communicate over an emulated wireless medium provided by a network simulator. Our architecture can provide networks consisting of real and virtualized mesh nodes using an adapted wireless interface driver.

In addition, we have designed a temporary WMN based system to support video communication in large construction sites, which faces the problem of missing communication facilities at the time of electric installation. By providing video communication over an “easy-to-install” temporary WMN, the requirement of costly on-site visits by an electrical engineer is reduced.

Research staff: Thomas Staub, Stefan Ott, Daniel Balsiger, Reto Ganzenbein, Christine Müller, Saurabh Bhargava, Mona Farsad, Torsten Braun

Financial support: Swiss National Foundation Project No. 200020-113677/1

Efficient and Robust Overlay Networks (ERON)

The ERON projects aims at developing an efficient and robust overlay network. An overlay network is a virtual communication network built on top of an existing communication network such as the Internet. Overlay networks

are used for different tasks such as routing of multicast messages. Since the full-mesh overlay network, in which every pair of participants is communicating directly with each other, is not scalable, overlay networks usually have other structures. One of the most important criteria for deciding, which overlay network participants get “connected” is the communication delay, since it is the limiting factor on the maximum effective bandwidth for the TCP connections. Similar to a full-mesh overlay network, measuring the communication delay between all overlay participants does not scale. To exploit the communication delay information, numerous communication delay prediction systems such as IDMaps, GNP, ICS, Vivaldi, S-Vivaldi etc. were developed. Most promising communication delay prediction systems are coordinates-based. In coordinates-based systems, communication partners are represented as points in an n -dimensional Euclidean space such that the distance function in that space predicts the communication delay.

Moreover, we are developing a protocol for building an overlay networks based on round-trip time (RTT) as a distance metric. The goal of this protocol is to provide a fisheye view of the overlay network for each end system that is a part of this network. Having a fisheye view of the overlay network means that each end system has a quite good knowledge about hosts located near itself, but at the same time it should have knowledge of distant hosts to be able to achieve efficient routing. The distinguishing feature of our approach compared to others is that we do not rely on a priori embedding into a virtual space. We only use measured RTTs as a distance to calculate the fisheye views of the end systems in a distributed manner.

Combined with the PIM-DM like routing protocol we developed earlier, this overlay network should provide a very efficient Application Layer Multicast (ALM) infrastructure. Our preliminary simulation results show that such an ALM is far more efficient in terms of RTT optimization of the multicast tree compared with Scribe/Pastry. We started to investigate a distributed method for assigning positions in a virtual space to hosts. The approach for determining coordinates we are pursuing, bases on assigning positions as a part of a crystallization process. The assumes that the end-systems are already interconnected in a fisheye-view based overlay network. The crystallization itself starts at one point in the overlay network and spreads like a shock wave trough the overlay network leaving a crystal structure behind.

Research staff: Dragan Milic, Roger Strähl, Torsten Braun

Financial support: Swiss National Foundation Project No. 200021-109270/1

End-to-end Quality of service support over heterogeneous networks (EuQoS)

The *EuQoS* project (<http://www.euqos.eu>) aimed to resolve outstanding design issues presently associated with the delivery of end to end Quality of Service across heterogeneous networks. With the help of EuQoS the network infrastructure should be upgraded so that new applications can be supported by the Internet and new service packages can be offered by operators, ISPs and other service providers. Our research group was involved in the work packages 1, 3, 5 and 6.

WP1 (Business Model and System Design) defined an architecture for different aspects of the EuQoS system. We finalized the support for QoS regarding IP Multicast. Our research focused on providing an efficient and transparent support for ALM on end systems but still offering the IP Multicast API. Mechanisms for setting up a QoS-aware P2P overlay network have been investigated and resulted in an architectural adaptation of Scribe / Pastry. The Multicast Middleware framework was extended with the ability to perform QoS reservations for IP Multicast groups by the end-user through a web-service enabled interface. The Multicast Middleware maps the reservations for the multicast groups to the respective unicast connections of the ALM and performs the corresponding QoS reservations in the EuQoS system.

WP3 (Implementation of the EuQoS System) delivers the proposed applications and services according to the architectures defined in *WP1*. We developed a transparent multicast facility known as "Multicast Middleware," which is based on a virtual network interface (TAP) and has been implemented mostly using Java (version 5.0) to support different operating systems (Win32, Linux and Mac OS X). The Multicast Middleware is independent from the underlying QoS mechanisms. It uses the EuQoS QoS signaling to reserve the required QoS in underlying network. The overlay network is constructed using a Scribe/Pastry implementation called Freepastry. This implementation has been extended to support QoS-aware construction of multicast trees by Scribe through modifying the basic node distribution mechanisms of Pastry. Another focus has been the performance. Therefore, the Multicast Middleware has been optimized to support high bandwidth data dissemination with 100 Mbps and more on end-systems with recent hardware. The Multicast Middleware has been successfully

demonstrated at the final review of the EuQoS project.

WP5 (EuQoS Pan European trials) built a testbed environment in which the developed prototypes and applications can be tested and evaluated. Different heterogeneous networks (WLAN, UMTS, LAN, xDSL, etc.) are interconnected in a full mesh among the partners. Our testbed represents a high speed gigabit-LAN-based network interconnected by GRE tunnels to twelve other testbeds belonging to other EuQoS consortium partners. Different prototypes of the EuQoS system and some of its applications have been successfully tested in this environment. The testbed located in Bern was also used for evaluating and testing the Multicast Middleware. Furthermore, a seminar held in Poland has been broadcasted to several other partners through the testbed using Video Lan Client (VLC) in combination with the Multicast Middleware.

WP6 (Dissemination, Standards and Training) focused on delivering the project results to the public. In addition to leading and managing the whole work package, our main contributions addressed the training activities. Within this context, a course focusing on QoS related topics has been developed for students and industrial learners. The goal of the course is to raise the familiarity with QoS technologies for next generation networks and applications. The course is based on distance learning technologies and consists of seven QoS related modules. We have developed the didactical concept of the e-learning course and coordinated its implementation. In particular, we have developed the course modules “Applications’ QoS demands”, “Implementing protocols on network simulators” including a tool for the visualization and animation of simulator trace files (VAT4Net), “Multicast in EuQoS system”, and an overview animation for the “EuQoS overview” module.

Besides the e-learning activities, the EuQoS partners have written the learning book “End-to-End Quality of Service Over Heterogeneous Networks” published by Springer. It covers QoS mechanisms in heterogeneous networks, the EuQoS system as a case study for a comprehensive end-to-end QoS architecture, and development methodologies. It fosters awareness of QoS mechanisms and presents the EuQoS approach as a comprehensive architecture offering end-to-end QoS over heterogeneous networks. The book provides the basis for different network lectures at universities and shows the latest QoS developments and standards for industrial researchers and engineers. Members of our research group coordinated the publication and editing process of the book.

Research staff: Marc Brogle, Dragan Milic, Matthias Scheidegger, Thomas Staub, Patrick Lauer, Gerald Wagenknecht, Markus Wulff, Jana

Krähenbühl, Daniel Frey, Milan Nikolic, Luca Bettosini, Sonia Schär,
Torsten Braun

Financial support: EU project IST-2003-004503

Virtual Internet and Telecommunications Laboratory of Switzerland (VITELS)

VITELS, a first series Swiss Virtual Campus (SVC) project has been funded within the SVC consolidation program. The goal of VITELS has been to develop an e-learning course in English language that provides theory and practical hands-on exercises in the area of telecommunications and computer networks with real network hardware for computer science students. VITELS consists of eight modules, six designed and maintained by University of Bern, one by University of Neuchâtel, and one by University of Fribourg. The course is fully operational and has been productively used in different regular courses on the Bachelor level at the Universities of Bern (in the “Computer Networks” lecture), Fribourg, and Neuchâtel. Updates in the theory parts of the modules have been integrated. Recently, the main focus was on the hands-on experiments. Three of these experiments, namely “IP Security”, “Sockets & RPC”, and “Security and Privacy in the Internet”, have been improved or reimplemented to ensure a better usability and reliability. For maintenance of the VITELS modules the comments and suggestions from students have been taken into account. Security certificates for the lab exercise and portal servers has been changed to ensure better compatibility with common Web browsers.

Research staff: Markus Anwander, Torsten Braun, Patrick Lauer, Thomas Staub, Markus Wulff

Financial support: Staatssekretariat für Bildung und Forschung (SBF), Virtual Campus Switzerland Project No. 991043

Operating Systems Laboratory (OSLab)

The Operating System Laboratory, OSLab, is an online course to teach students about the principles of computer operating systems using a progressive approach and problem-oriented learning. OSLab focuses on the

hands-on training experience of the students and will complement existing lectures. The course is modularly structured, each module covers a topic and is self-contained. A teacher can select modules according to his needs and easily add new modules to the course.

Three new modules have been created, namely, “Memory Management”, “Distributed File Systems”, and “Inter-Process Communication & Synchronization”. This includes the theory section as well as the hands-on exercises. In the hands-on part the students have to solve programming and/or configuration tasks in order to deepen the theoretical knowledge.

Additionally, the OSLab tools framework has been improved. The framework basically consists of two Java applets and aims to present a common user interface for the hands-on exercises. The learners applet can be adapted to the special needs of the respective exercise and provides a graphical user interface in the Web browser for the remote hands-on exercises. If the learner solved the exercise he/she gets an encrypted passcode to be sent to the course tutor. The second applet is for the course tutor and allows to decrypt the solution sent by the learners and helps to organise the received solutions. Furthermore, the tutor can review the exercise solutions (e.g. programme source code) and is provided with a basic plagiarism finder.

The e-learning infrastructure used for OSLab and VITELS has been revised. By using virtualisation techniques, less hardware is needed and at the same time the maintainability and reliability of the e-learning laboratory could be improved. Furthermore, a monitoring software has been installed to receive detailed information about server and network usage. Finally, a new backup system now provides a faster recovery of the e-learning services after a system failure or data loss.

Another central component of the e-learning infrastructure is the reservation system which manages the access to the laboratory resources. It has been reimplemented and provides some new features and a higher reliability.

Research staff: Torsten Braun, Gerald Wagenknecht, Markus Wulff, Daniel Frey

Financial support: Staatssekretariat für Bildung und Forschung (SBF), Programm Virtueller Campus Schweiz, Project No. P-4-019, and University of Bern

E-learning in Distributed Data Network Laboratory (Edinet)

Edinet (<http://www.svc-edinet.eu>) is a multilateral cooperation project in the 'Lifelong Learning Programme' of the European Commission. Its objectives are to a) analyse common pedagogical principles for blended learning (blended learning include several forms of learning tools) based on common understanding as a ground for curriculum development and implementation; b) promote virtual mobility by implementation of semi-virtual campus (a virtual campus where actually studies will be done with real equipment via network connections); c) enhance open education resources by sharing, integrating, and mutually improving local resources (including knowledge) and best practices by establishing a semi-virtual campus; and d) to promote the usage of expensive laboratory environment through an innovative blended eLearning system in the field of data network technology.

Our research group is mainly involved in two work packages. For the Edinet infrastructure we are developing the Authentication and Authorization Infrastructure (AAI). The goal is to export the available knowledge to establish a AAI federation with the European partners. Furthermore, a TCP congestion control learning module is being developed and several contributions to other work packages like for the pedagogical framework of the Edinet virtual campus have been provided.

Research staff: Torsten Braun, Patrick Lauer, Markus Wulff, Markus Anwander, Thomas Staub

Financial support: Staatssekretariat für Bildung und Forschung SBF, LLP/Erasmus, Edinet, SBF-No. LLP/07/06-E

Energy-efficient Management of Heterogeneous Wireless Sensor Networks

This project investigates efficient and reliable communication mechanisms for the operation of a wireless sensor network (WSN) management framework. Reliable and robust transport protocols are needed to distribute operating system / application level code and node parameters efficiently as well as to solicit specific node information.

ESB, tmote SKY, BTnodes and micaZ nodes have been chosen to build a heterogeneous sensor network. For the backbone a Wireless Router

Application Platform Board (WRAP) has been selected. The mesh network allows to interconnect WSNs with sensor nodes of different types.

In order to realize such interconnection between the WSN and an external network without any proxies or middle-boxes, we propose to use TCP/IP as the standard protocol for all network entities, e.g., for configuration and uploading application code to the sensor nodes. We developed TSS (TCP Support for Sensor Nodes) a protocol which enables using TCP in wireless sensor networks. TCP/IP allows to connect a WSN to other networks such as the Internet. Thus, a user can monitor, control and manage WSNs remotely. The TSS protocol is located between IP and TCP. It contains a number of mechanisms, such as caching packets, local retransmission, aggressive acknowledgment regeneration and recovery. Packets are cached on intermediate nodes on the path from the sender to the receiver. In case of a lost packet a end-to-end retransmission is avoided. This reduces the number of transmitted packets and thus energy consumption. In case of lost acknowledgment packets the intermediate node can regenerate the acknowledgment to avoid unnecessary retransmissions.

We developed a MAC protocol called BEEM (Burst-enabled Energy-Efficient MAC) implementing the MAC layer of nonbeacon-enabled personal area networks (PANs) defined in the IEEE 802.15.4 standard for peer-to-peer topologies. It provides multihop communication and is the first implementation in this way. The MAC protocol holds a buffer of configurable size to store the incoming frames from the lower layer (radio transceiver) and the upper layers (TCP-TSS- μ IP). To ensure a reliable hop-to-hop transmission we use explicit acknowledgments and implicit acknowledgments

To optimize the performance of the protocols interchanging cross layer information is necessary. Thus, we designed a cross layer interface. Every protocol can subscribe for information from another protocol. Thus protocols on different layers can better collaborate. For example, the physical layer can provide additional information about the transmissions. The radio transceiver provides information about the channel and the signal to the MAC protocol, which decides whether a frame can be transmitted to a neighbor node. The MAC protocol and the TSS protocol exchange information about retransmission state of a frame, about the traffic between the nodes and the TSS buffer size. This information is important for the reliability and congestion control mechanisms.

The protocols have been implemented in the OMNeT++ simulator and evaluated with several scenarios. We compared a pure TCP implementation and a TCP implementation with TSS. The simulations showed that the performance can be increased by the factor of 10. Further, we

compared both acknowledgment mechanisms. Explicit acknowledgments cause faster transmission times as using implicit acknowledgments. We showed that up to 90% of consumed energy can be saved using these mechanisms.

Research staff: Markus Anwander, Gerald Wagenknecht, James Math-eka, Simon Morgenthaler

Financial support: Hasler Foundation under grant number ManCom 2060 and the Swiss National Science Foundation under grant number 200020-113677/1

Wireless Sensor Network Testbeds (WISEBED)

The *WISEBED* project (<http://www.wisebed.eu>) started in June 2008. It aims to provide a multi-level infrastructure of interconnected testbeds of large-scale wireless sensor networks for research purposes, pursuing an interdisciplinary approach that integrates the aspects of hardware, software, algorithms, and data. This will demonstrate how heterogeneous small-scale devices and testbeds can be brought together to form well-organized, large-scale structures. The *WISEBED* project will implement recent theoretical results on algorithms, mechanisms and protocols and transform them into software. The project intends to make these distributed laboratories available to the European scientific community, so that other research groups will take advantage of the federated infrastructure. Our research group is involved as task leaders in several work packages.

Within WP1 (*Hardware Installation*), we plan to deploy a wireless sensor network testbed in the Engehalde area. The construction of a testbed or a WSN deployment has many crucial steps. To ease the installation of hardware for such a testbed or the deployment of large WSN, we will work on an automatic neighborhood and transmission-power configuration solution. In long-term experiments huge series of data will have to be collected, which a sensor node may not be able to transmit. We therefore plan to co-deploy a mesh network backbone to the WSN research testbed in order to gather data and simplify remote configuration and management.

Within WP2 (*Testbed operation, access, and management*) we will develop a workflow management system that will enable the execution of plans for verification, testing and performance evaluation of algorithms and applications. Workflow management systems provide a clean interface for the definition of the execution logic, by means of sequences of operations.

A webservice-based solution would be most useful, since it allows for very flexible dynamic reconfiguration, for convenient access for software development, deployment and experiment. We intend to integrate the workflow system with the rest of the software infrastructure. The operation of the testbed will remain secure and confidential to the user of the testbed.

Real-world environmental data is of major importance for significant simulation results. The idea of WP4 (*Producing traces for hardware*) is to feed recorded data back into the simulator. We will define a common data representation language in order to create a trace model that can be employed at all sites. This includes various parameters of network topology, but also communication parameters and received signal strength indicators. Most testbeds break down regularly because some nodes fail to operate. Integrating the data back into simulators will be an invaluable source for fault analysis when trying to find out why certain algorithms failed.

Research staff: Philipp Hurni, Torsten Braun

Financial support: EU project ICT-2008-224460

Power Saving in Wireless Ad Hoc Networks

Today's energy saving wireless MAC protocols periodically switch the radio transceiver hardware between the costly operation modes receive and transmit and an energy-saving sleep mode. The majority of the existing power saving MAC approaches tries to synchronize the state changes of the nodes in the network and introduces mechanisms to let the nodes synchronously wake up at designated points of time, which however requires costly synchronization. With low traffic, the energetic overhead may exceed the energy spent for the actual data traffic.

We investigated on modifications and optimizations on recently proposed fully unsynchronized power saving MAC protocols for wireless sensor networks based on asynchronous wake-up patterns, and intended for sensor networks with low traffic requirements. We carried out investigations on the following aspects:

A performance optimization scheme considering the broadcast operation mode achieves a higher energy-efficiency both at the sender and the receiver. Experimental results approve the energy-efficiency of the scheme called *best-instants broadcast* when a limited amount of neighbors has to be reached.

An alternative allocation and arrangement scheme of sensor node's wake intervals averts performance degrading systematic overhearing and fairness effects of existing power saving MAC protocols with a fixed static wake-up pattern. A cross-layer solution to exploit the properties of the unsynchronized MAC and the alternative arrangement scheme of the wake-up intervals has been designed, which achieves to find paths with the least-possible delay.

We developed a mechanism to improve the traffic-adaptivity of wireless sensor MAC protocols in cases with multiple nodes aiming to forward data over certain receivers, which are likely to occur in wireless sensor network topologies. It succeeds in increasing the throughput in comparison with existing approaches in both simulation and sensor testbed implementation.

We tested the proposed mechanisms and improvements in a network simulator environment and on a prototype implementation on a sensor hardware testbed. Some of the developed mechanisms delivered motivating results in simulation and real-world experiments.

Research staff: Philipp Hurni, Torsten Braun

E-learning module “Sensor Networks”

The e-learning module “Sensor Networks” addresses key characteristics of wireless sensor networks. The module is designed to deepen the understanding of students concerning contributions and challenges of wireless sensor network technologies. The course is guided, self-explaining and in a closed form.

The course essentially consists of a theoretical part introducing the course subject in detail, and of a practical part, in which the learned theoretical concepts are applied. The theoretical part contains references to continuative literature and self-tests to improve the learning process of the students. In the subsequent hands-on sessions some of the acquired concepts are investigated from the practical point of view. Thus, the students get an impression of implementation details and challenges. The theoretical concepts have been implemented in the Contiki OS, a well-known operating system for tiny embedded systems. The solution can be tested and evaluated in the COOJA simulator, which is provided by the Contiki OS. The course provides web-based applications for both development and evaluation.

The scientific focus of the course is on medium access control and localization in wireless sensor networks. Both are basic challenges of wireless sensor networks research and development. The e-learning course provides a medium to address these two aspects in more detail than it would be possible in a lecture only.

Research staff: Markus Wälchli, Torsten Braun

Financial support: University of Bern, VC-Kleinprojekt

Testbed for Mobile and Internet Communications

Our research group maintains its own testbed network for various purposes. The testbed is used to build networks of experimental routers and end systems in order to be able to evaluate the behavior of new networking procedures and architectures in a realistic environment. The testbed also forms a productive network of Linux PCs and provides the storage capacity and CPU power for many of the RVS group's projects. The ERON project for example uses the available CPU power to compute embeddings of network distances into Euclidean space. Furthermore, a significant part of EuQoS project's testbed is still located within the RVS testbed. It is a Gigabit LAN environment of 10 machines for pan-european trials, and it is connected via IP tunnels to 11 partners' sites. The available CPU power is used by three network traffic measuring points. An educational laboratory network for students' training is also connected and being extended by the OSLab project. The RVS group also takes part in PlanetLab (<http://planet-lab.org>), an open platform for developing, deploying, and accessing planetary-scale services. For this purpose we are hosting four PlanetLab nodes in our testbed network. The RVS group owns a number of sensor nodes: Embedded Sensor Board (ESB), tmote SKY nodes, BTnodes, MSB nodes and micaZ nodes. A testbed consisting of multiple mesh nodes has been deployed throughout the building and work environment of the research group. In this testbed, reliable secure communication and software distribution/updates are being performed and evaluated.

Research staff: All members of the RVS research group

1.4 Master and Diploma Theses

- Philipp Hurni: Unsynchronized Energy-Efficient Medium Access Control and Routing in Wireless Sensor Networks, November, 2007
- Jana Krähenbühl: Theory and Hands-on Exercises with Network Simulators for E-Learning on Distributed Systems, September, 2007

1.5 Bachelor Theses and Computer Science Projects

- Luca Bettosini: Performance Comparison of Native Multicast versus Overlay Multicast, April, 2008
- Milan Nikolic: WinJTAP Interface for Multicast Middleware on the Win32 Platform, March, 2008
- Daniel Balsiger, Michael Lustenberger: Secure Remote Management and Software Distribution for Wireless Mesh Networks, September, 2007
- Dave Wick: Delay Tolerant Networks in a Nutshell, August, 2007

1.6 Further Activities

Memberships

- Chair of ERCIM working group on eMobility (Torsten Braun)
- Secretary General of ERCIM working group on eMobility (Markus Wulff)
- Erweitertes Leitungsgremium Fachgruppe "Kommunikation und Verteilte Systeme", Gesellschaft für Informatik (Torsten Braun)
- Management Board of EU IST project EuQoS (Torsten Braun)
- Integration Coordination Board and Steering Committee of EU IST project Wisebed (Torsten Braun)
- Swiss Representative, Management Committee Member, and Working Group Chair of COST 290 Action "Traffic and QoS Management in Wireless Multimedia Networks" (Torsten Braun)

- SWITCH Stiftungsrat (Torsten Braun)
- SWITCH Stiftungsratsausschuss (Torsten Braun)
- Kuratorium Fritz-Kutter-Fonds (Torsten Braun)
- Expert for Diploma Exams at Fachhochschule Bern (Torsten Braun)

Editorial Boards

Torsten Braun

- Editorial Board of Elsevier's Computer Communications Journal
- Editorial Board of Elsevier's Computer Networks Journal
- Editorial Board of Informatik Spektrum / Springer-Verlag
- Editorial Board of Journal of Internet Engineering (Editor in Chief)

Conference Chairs

- Co-Chair of the Fourth ACM SIGACT-SIGOPS International Workshop on Foundations of Mobile Computing (DIAL M-POMC 2007), August 16, 2007, Portland, Oregon, USA (Torsten Braun)
- General Chair of 2nd ERCIM Workshop on eMobility, May 30, 2008, Tampere, Finland (Torsten Braun)
- TPC Co-Chair of 2nd ERCIM Workshop on eMobility, May 30, 2008, Tampere, Finland (Markus Wulff)

Conference Program Committees

Torsten Braun

- 33rd EUROMICRO Conference 2007, Lübeck, Germany, August 28–31, 2007
- 7th International Conference on Next Generation Teletraffic and Wired/Wireless Advanced Networking (NEW2AN), St.Petersburg, Russia, September 10–14, 2007

- 1st IEEE International Workshop on Enabling Technologies and Standards for Wireless Mesh Networking, Pisa, Italy, October 8, 2007
- 32nd Annual IEEE Conference on Local Computer Networks (LCN), Dublin, Ireland, October 15, 2007
- IEEE Workshop on “Monitoring, Attack Detection and Mitigation”, Toulouse, France, November 5–6, 2007
- IEEE Globecom, Washington, USA, November 26–30, 2007
- 3rd International Conference on Wireless Communication and Sensor Networks (WCSN), Allahabad, India, December 13–15, 2007
- 2nd IEEE Broadband Wireless Access (BWA) Workshop, Las Vegas, USA, January 12, 2008
- 5th IEEE/IFIP WONS Annual Conference on Wireless On demand Network Systems and Services, Garmisch-Partenkirchen, Germany, January 23–25, 2008
- 5th European conference on Wireless Sensor Networks, Bologna, Italy, January 30–31, 2008
- IEEE Wireless Communications and Networking Conference (WCNC), Las Vegas, USA, March 31 – April 3, 2008
- Workshop on Real-World Wireless Sensor Networks (RealWSN), Glasgow, UK, April 1, 2008
- 11th IEEE/IFIP Network Operations and Management Symposium (NOMS), Salvador da Bahia, Brazil, April 7–11, 2008
- 2nd IEEE International Workshop on Bandwidth on Demand (BoD 2008), Salvador da Bahia, Brazil, April 11, 2008
- IEEE INFOCOM High-Speed Networks Workshop (HSN), Phoenix, USA, April 13, 2008
- IFIP Networking, Singapore, May 5–9, 2008
- 3rd IEEE Broadband Wireless Access (BWA) Workshop, May 19, 2008, Beijing, China
- IEEE International Conference on Communications, Beijing, China, May 19–23, 2008

- 6th International Conference on Wired/Wireless Internet Communications (WWIC), Tampere, Finland, May 28–30, 2008
- 15th IEEE Workshop on Local and Metropolitan Area Networks, Princeton, USA, June 10–13, 2007
- Fachgespräch Future Internet der GI/ITG-Fachgruppe “Kommunikation und Verteilte Systeme”, Heidelberg, Germany, June 17, 2008
- 3rd IEEE Workshop on advanced EXPerimental activities ON WIRELESS networks & systems (EXPONWIRELESS08), Newport Beach, USA, June 23, 2008
- IFIP Conference on Wireless Sensor and Actor Networks, Ottawa, Canada, July 14–15, 2008

Ph.D. Jury Memberships

Torsten Braun

- Mark Doll: Management qualitätsbasierter Gruppenkommunikation im Internet, Universität Karlsruhe, December 14, 2007
- Dominik Jungo: VeriNeC - Secure Network Configuration Through Verification, Université de Fribourg, July 29, 2008

Reviewing Activities

Torsten Braun

- Swiss National Science Foundation (SNSF)
- nano-tera.ch
- Research Council of Norway (RCN)
- Agence Nationale de la Recherche (French National Research Agency, ANR)
- COST office of Swiss State Secretariat for Education and Research
- IEEE Network Magazine
- IEEE Transactions on Parallel and Distributed Systems

- Journal of Medical Systems, Springer-Verlag
- Security and Communication Networks, Wiley

Invited Talks and Tutorials

- Torsten Braun: Telematiknetze, Kaderkurs Telematik, Bundesamt für Bevölkerungsschutz, November 27, 2007, May 6, 2008, May 27, 2008, Schwarzenburg, Switzerland
- Thomas Staub: Réseaux de communications, cours de cadres pour chefs de la télématique, Office fédéral de la protection de la population, May 6, 2008, May 27, 2008, Schwarzenburg, Switzerland
- Torsten Braun: Sensor Networks, 15th TF-Mobility Meeting, September 28, 2007, Zürich
- Torsten Braun: Sensor Networks, 16th SWITCH Mobile Working Group Meeting, December 7, 2007, Zürich
- Torsten Braun: Power Saving in Wireless Multi-hop Networks, 10th COST 290 Meeting, October 1, 2007, Vienna, Austria
- Torsten Braun: Energy-efficient Management of Heterogeneous Wireless Sensor Networks, Haslerstiftung ManCom Workshop, April 25, 2008, Bern

Organized Events

- Organizing a Computer Science Summer School seminar together with the TNS group of University Fribourg and the IIUN of University Neuchâtel, at Quarten, Switzerland, June 23–26, 2008

Awards

- Winner of the competition “Wer hat die beste e-Schule” (who has the best e-school) conducted by IBM. The course “Computernetze” (Computernetworks) won the first price in the academic category.

1.7 Publications

Publications submitted in the academic year 2007/2008 and appearing in 2008/2009 or later are not listed.

Books and Book Chapters

- Arunabha Sen, Torsten Braun: Dial-M-POMC 2007, The Fourth ACM SIGACT-SIGOPS International Workshop on Foundations of Mobile Computing, Portland, Oregon, USA, August 16, 2007, ACM, ISBN 978-1-59593-874-9, CD-ROM
- Torsten Braun, Geert Heijenk, Dimitri Konstantas, Markus Wulff: Second ERCIM Workshop on eMobility, Tampere, Finland, May 30, 2008, ISBN 978-952-15-1972-7
- Torsten Braun: Entstehung und Funktionsweise des Internets, Virtuelle Welten? Die Realität des Internets, Vol. Kul. Vorl., Nr. Band 106, April, 2008, pp. 15-28, Peter Lang Publishing Group, ISBN ISBN 978-3-03911-310, Book chapter

Reviewed Journal and Conference Papers

- Torsten Braun, Jana Krähenbühl, Thomas Staub: VAT4Net - a Visualization and Animation Tool for Network Simulations, 6th Symposium on Design, Analysis, and Simulation of Distributed Systems 2008, Edinburgh, UK, June 16 - 18, 2008, pp. 244-251, Summer Computer Simulation Conference (SCSC'08), ISBN 1-56555-320-9, CD-ROM
- Markus Anwander, Gerald Wagenknecht, Torsten Braun: Management of Wireless Sensor Networks using TCP/IP, International Workshop on Sensor Network Engineering (IWSNE) at the 4th IEEE/ACM International Conference on Distributed Computing in Sensor Systems, Santorini Island, Greece, June 11, 2008, pp. II.1-II.8, ISBN 978-90-9023209-6
- Markus Wälchli, Samuel Bissig, Michael Meer, Torsten Braun: Distributed Event Tracking and Classification in Wireless Sensor Networks, Journal of Internet Engineering, Vol. 2, Nr. 1, June, 2008, pp. 117-126, Klidarithmos Press, ISSN 1791-177X

- Thomas Staub, Torsten Braun: ATOM: Adaptive Transport over Multipaths in Wireless Mesh Networks, 2nd ERCIM Workshop on eMobility, Tampere, Finland, May 30, 2008, ISBN 978-952-15-1972-7
- Gerald Wagenknecht, Markus Anwander, Torsten Braun, Thomas Staub, James Matheka, Simon Morgenthaler: MARWIS: A Management Architecture for Heterogeneous Wireless Sensor Networks, 6th International Conference on Wired/Wireless Internet Communications (WWIC'08), Tampere, Finland, Springer LCNS, Nr. 5031, May 28 - 30, 2008, pp. 177-188, ISBN 978-3-540-68805-1
- Markus Wulff, Patrick Lauer, Torsten Braun: Content management and architectural issues of a remote learning laboratory, 2nd International Workshop on e-learning and Virtual and Remote Laboratories 2008, Hasso-Plattner-Institute Potsdam, Germany, February 14 - 15, 2008, ISBN 978-3-940793-17-1
- Philipp Hurni, Torsten Braun: Increasing Throughput for WiseMAC, IEEE/IFIP WONS 2008, Garmisch-Partenkirchen, Germany, January 23 - 25, 2008, ISBN 978-1-4244-1958-6
- Torsten Braun, Marc Brogle, Patrick Lauer: Peer-to-Peer-Netze: Informationen effizient im Internet verbreiten, Bulletin SEV/VSE, Vol. 07, Nr. 21, December, 2007, pp. 9-12, Electrosuisse, ISSN 1660-6738
- Markus Wulff, Torsten Braun: OSLab: An Interactive Operating System Laboratory, Nr. 71, October, 2007, pp. 46-47, ERCIM EEIG, ISSN 0926-4981
- Matthias Scheidegger, Torsten Braun: Meridian-based Grouping in Overlay Networks, it - Information Technology, Vol. 49, Nr. 5, September 17, 2007, pp. 289-297, Oldenbourg Wissenschaftsverlag GmbH, ISSN 1611-2776
- Dragan Milic, Torsten Braun: Optimizing Dimensionality and Accelerating Landmark Positioning for Coordinates Based RTT Predictions, IEEE BroadNets 2007: Fourth Annual Conference on Broadband Communications, Networks, and Systems, Raleigh, North Carolina, USA, September 10 - 14, 2007, ISBN 978-1-4244-1432-1
- Marc Brogle, Dragan Milic, Torsten Braun: Supporting IP Multicast Streaming Using Overlay Networks, QShine: International Conference on Heterogeneous Networking for Quality, Reliability, Security

and Robustness, Vancouver, British Columbia, Canada, August 14 - 17, 2007, ICST, ISBN 978-1-59593-756-8, CD-ROM

Technical Reports

- Lothar Braun, Torsten Braun, Georg Carle, Falko Dressler, Anja Feldmann, Dirk Haage, Tobias Limmer, Tanja Zseby: 5. 08102 Working Group – Measurement Requirements, Perspectives Workshop: Network Attack Detection and Defense, Dagstuhl, Germany, Nr. 08102, March 2 - 6, 2008, Schloss Dagstuhl - Leibniz-Zentrum für Informatik, Germany, ISSN 1862-4405
- Wojciech Burakowski, Jordi Mongay Batalla, Marc Brogle, et al: Report on scalability evaluation of EuQoS system, EuQoS Report, January 25, 2008
- José Enríquez, María Ángeles Callejo, Marc Brogle, Dragan Milic, et al: Annex to D1.2.2: EuQoS Architecture update for, Annex to EuQoS Deliverable D51.2.2, CEC Deliverable Number 004503/TID/DS/D1.2.2/A2 - ANNEX, December 28, 2007 José Enríquez, María Ángeles Callejo, Marc Brogle, Dragan Milic, et al:
- EuQoS Architecture update for Phase 2, EuQoS Deliverable D51.2.2, CEC Deliverable Number 004503/TID/DS/D1.2.2/A2, December 28, 2007
- Donal Morris, Marc Brogle, Dragan Milic, et al: Annex to D1.2.3: Exploitation Cookbook, Final, EuQoS Deliverable D1.2.3, CEC Deliverable Number 004503/TID/DS/D1.2.3/A1 - ANNEX, December 28, 2007
- Halina Tarasiuk and Wojciech Burakowski, Marc Brogle, Dragan Milic, et al: Methodology for testing EuQoS system, EuQoS Deliverable D2.2.5, CEC Deliverable Number 004503/WUT/DS/D2.2.5/A2, December 28, 2007
- María Ángeles Callejo, José Enríquez, Marc Brogle, Dragan Milic, et al: Annex 1 to D3.2.5: Implementation Final Report Detailed design, EuQoS Deliverable D3.2.5, CEC Deliverable Number 004503/ED/DS/D3.2.5/A1 Annex 1, December 28, 2007
- María Ángeles Callejo, José Enríquez, Marc Brogle, Dragan Milic, et al: Annex 2 to D3.2.5: Implementation Final Report EuQoS

users manual, EuQoS Deliverable D3.2.5, CEC Deliverable Number 004503/ED/DS/D3.2.5/A1 Annex 2, December 28, 2007

- Olivier Dugeon, Marc Brogle, Dragan Milic, et al: Prototype P#4 tests report , EuQoS Deliverable D5.2.3, CEC Deliverable Number 004503/FTRD/DS/D5.2.3/A1, December 28, 2007
- Olivier Dugeon, Marc Brogle, et al: EuQoS System Demonstrations Report for Phase II, EuQoS Deliverable D5.2.4, CEC Deliverable Number 004503/FTRD/DS/D5.2.4/A1, December 28, 2007
- Thomas Staub, Marc Brogle, et al: Report on teaching experiences of the e-learning course, the improvements to be done and the improvements achieved, EuQoS Deliverable D6.2.4, CEC Deliverable Number 004503/UBern/DS/D6.2.4/A1, December 28, 2007
- Michel Diaz, Donal Morris, Thomas Staub, et al: Third Standardization Report, EuQoS Deliverable D6.2.5, CEC Deliverable Number 004503/CNRS/DS/D6.2.5/A1, December 28, 2007
- Martin Potts, Mark Günter, Thomas Staub, et al: Third report on dissemination activities (demonstrations, publications, participations...), EuQoS Deliverable D6.2.6, CEC Deliverable Number 004503/Martel/DS/6.2.6/A1, December 28, 2007
- Torsten Braun, Ulrich Ultes-Nitsche, Marc Brogle, Dragan Milic, Patrick Lauer, Thomas Staub, Gerald Wagenknecht, Markus Anwander, Markus Waelchli, Markus Wulff, Carolin Latze, Michael Hayoz, Christoph Ehret, Thierry Nicola: RVS Retreat 2007 at Quarten, December, 2007, IAM-07-004