SICS Center for Networked Systems

Annual report 2008

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1. Impact and achievements

1.1 Introduction and fulfillment of overall goals

This document is the second yearly report covering 2008 for SICS Center for Networked Systems, an Institute Excellence Center hosted by SICS, Swedish Institute of Computer Science. The report is compiled according to the given instructions[1].

The research in the center has been very successful during the reporting period. While the first year (2007) was dominated by starting the center projects and getting to know each other, the second year is characterized by a set of focused projects with high productivity. We can report excellent progress towards the overall center goals. The collaboration between the center partners is close resulting in substantial industrial and academic impact.

At the end of 2007, the center received feedback from both the center's own advisory board and the external reviewers. The major issues were that the projects were covering a too broad area, lacking focus, that the center should strengthen its identity, and that more interaction between the projects should be facilitated, perhaps with a generic program open to all partners. In response to the feedback, a number of actions have been taken. The two technical focus areas defined towards the end of 2007 have been used as a means to redefine the projects starting 2008. The result is a more coordinated set of projects which all relate well to the focus areas, the overall center vision and goals, and to the industry partners application areas. To strengthen the center identity, a number of smaller actions have been taken. The center has its own graphical profile including a symbol that is used on printer material, presentations, posters and on-line material. The center participants have received door-signs and T-shirts with the center symbol. A common project has been formed for stimulating increased interaction between center partners and projects.

In the remaining part of this section we will report against the overall center goals as defined in the center research program[2]. The next section describes activities and publications. Section 3 reports detailed results per project. Organization and management is covered in Section 4, followed by the learning environment in Section 5. The report is concluded with financial reporting in Section 6.

1.2 Impact of the center on industry

The center is deliberately focusing its efforts on a small group of industrial partners. This strategy enables the establishment of the close collaboration needed for creating industrial impact. In addition, the center has a looser form of partnership called industry clusters with the purpose to reach a larger audience with less commitment.

The center serves as a strategic partner and a complement to the corporate research of the industrial center partners. In the center, opportunities offered by new technologies can be explored. Short-term technical problems identified by industry can be investi-

[1] **BILAGA B** TILL ALLMÄNNA VILLKOR FÖR KUNSKAPSCENTER VID FORSKNINGSINSTITUT, Rev. 2008-10-30

[2] SICS Center for Networked Systems, Research Programme and Work Plan, Annex 1 to the Partner contract, November 23, 2006.

gated. The center functions as a vehicle for competence development of industry researchers and developers through their participation in the center projects, workshops and seminars. The center serves as a marketplace and channel for contacts with researchers, locally and globally, and with other companies.

Center activities have already had substantial potential impact on major networked system products and services of all industrial partners, ranging from short term impact on existing products to long term strategic impact on future product generations.

Examples of such potential impact are listed below.

Goals by the year 2012:

Results and IPRs stemming from the center will have a substantial impact on major Networked System products and services of all industrial partners.

ABB's participation in center research regarding wireless communications and visualization for networked systems is making impact in three ways. *Standardization*: The research on wireless communications focuses on the *Wireless*HART standard, which is the first wireless communications standard within industrial automation, and an important platform for future wireless ABB products. The focus lies on aspects not fully covered by the current standard such as network management and end-to-end security. The ultimate goal of this activity is to contribute to the improvement of wireless standards for industrial automation. *Improvement of internal development*: A major challenge for the industry is to be able to implement current and future wireless standards in a cost effective and flexible manner. This includes the ability to support multiple wireless standards/protocols, as well as managing a rapidly changing technology base. This activity spans from short term topics such as simulation of WSN networks to aid the design process, to long term future wireless architectures such as software-defined radios (SDR). *Product features*: The research on visualization addresses the need for improved human understanding of complex networked systems. Focus lies on innovative means to visualize complex networks in order to support the design, deployment and maintenance phases of industrial networks. The goal of this activity is the inclusion of these concepts in future ABB products.

T2 Data address identity management for large scale deployment based on asymmetric keys. Combined with integrity control, the identity management covers both deployment and operation of targets in wired, wireless, and disconnected environments. There are patent applications in process that cover the unique identity assignment. The reference implementation of the T2 Data product portfolio includes a message bus where SICS researchers participating in CNS have contributed with distributed hash integration, portability, and language bindings. T2 Data intends to release the core of the message bus as open source outside CNS. T2 Data are also interested in business development including legal issues in an industrial research environment.

SICS through CNS researcher Adam Dunkels is a founding member of the IPSO (IP for Smart Objects) Alliance. The Internet of Things and IPSO were listed under TIME's Best Inventions of 2008. Other IPSO members include Ericsson, Cisco, Intel, and Sun Microsystems. By promoting and documenting the use of IP-based technology for Smart Objects, the Alliance paves the way for a growing market of interoperable products leading to industry growth.

The BART method jointly developed by SICS and Ericsson was for the first time successfully tested externally in an innovative commercial M2M application at Bombardier Transportation. BART is an end-to-end method, patented by Ericsson, for measuring available bandwidth on a network path. Ericsson is currently making use of BART in product development. The company Peerialism, spin-off from SICS, has signed an agreement with Ericsson for using BART. The BART method is being further developed within the center.

The research in the center has had a strong impact on the definition of several EU projects which SICS, Ericsson and KTH participate in. *4WARD – Architectures and Design for the Future Internet*, and *MOMENT, Monitoring and Measurement in the Next Generation Technologies* are two examples thereof.

The research in center Project 8 on automatic anomaly detection in alarm logs together with TeliaSonera's network operations center in Sundsvall is very promising. The work centers around automatic detection of faults and potential problems, and the reduction of consequential alarms, thus better pinpointing the actual problems. The work is expected to create substantial impact on the operating procedures, by earlier detecting problems and reducing the manual work load.

SICS-Saab collaboration has helped both partners to increase their technical knowledge and the practical requirements as integrator/system designer in the field of sensor networks for its usage in surveillance scenarios. In the last two years, through thesis workers and joint research activities, a flexible software framework (Contiki) has been modified to cope with the requirements of such scenario (increased battery lifetime, deployment support, channel quality estimation, robustness). As a result, papers and posters have been published, and Saab has incorporated the software solutions obtained into possible future products. Saab also sees it as great advantage that one of it business partners ABB is also involved in CNS. CNS competence and ambitions in security and communication also complement Saab's in Software Defined Radio research. This is shown in the plan for the CNS-activities of 2009.

At least 3 new companies will have been started based on the results of the center (in the area of the center).

Current measure: One company.

Peerialism was started based on results from research on peer-to-peer technology at SICS. Peerialism develops solutions to transport and store data on the Internet. Example solutions are video distribution for content owners and IP traffic optimization for broadband operators. The company currently has 14 people employed.

At least twenty-five industrial experts will have participated in center projects, and several hundred in other center activities, such as industry clusters and seminars.

Current measure: Twenty-five and well over one hundred, respectively.

At least fifteen researchers and thirty Master's students from SICS and academia participating in the center have moved to industry.

Current measure: Six researchers and three master students.

At least two new industry clusters have been created and are maintained.

A council for the Future Internet has started within Swedish ICT. The council members include Acreo, SICS Group and several industrial participants.

A security council has been formed within Swedish ICT, currently comprising the institutes in Swedish ICT and eight industrial partners, including the CNS partners Ericsson, TeliaSonera, and Saab Systems.

1.3 Impact of the center on SICS

The center strengthens the flow of ideas and collaboration with the academic research community by turning the center into a meeting point for researchers from the participating universities, industry companies, and SICS. The center is a vehicle for increasing the industrial involvement and interest in SICS and in the end attracting new members to FDF, the association of companies supporting SICS research. The center increases the visibility of SICS and promotes the institute as an external R&D resource of choice for partner companies. The capability and attractiveness of SICS as a contract research organization and as a partner in international R&D collaborations are enhanced by the center. The center furthermore stimulates personnel mobility between SICS, industry and academia.

Goals by the year 2012:

At least two new companies will join FDF, and an additional two will join the Center.

Current measure: Zero.

In the current world economy situation, we prioritize keeping the current industrial partners over trying to attract new ones. The center is an important vehicle for providing additional value to and strengthening the relation with the industrial sponsors of SICS.

The volume of commissioned industry research contracts assigned to SICS will be at least doubled.

The volume of commissioned research decreased by approx. 8 MSEK between 2006 and 2007 due to the conclusion of the research phase of the Swedish Armed Forces' Network Based Defense program. Since then, the volume of commissioned research has stabilized and we expect it to increase slightly during 2009 despite current economical crisis.

1.4 Impact of the center on university partners

The center increases the network of industrial contacts of the participating university researchers from the Royal Institute of Technology (KTH), Uppsala University (UU) and Mälardalen University (MdH). The number of PhD students working in projects together with industry is increased. The center broadens the academic network of participating researchers to include other research disciplines in networked systems. The center stimulates the development of highly attractive advanced courses at the respective universities.

Goals by the year 2012:

Each participating professor will have on average one Ph.D. student graduating per year based (partly) on center research.

We have found the formulation of the above goal unrealistic. We are therefore redefining the above goal as follows:

Ph.D. students enrolled at the university partners will on average complete three licenciate or Ph.D. theses per year based (partly) on center research.

Current measure: Seven.

At least three institute researchers will get professor positions in academia.

Current measure: One.

Ph.D. Thiemo Voigt, associate professor (docent), Uppsala University.

1.5 Conclusion and projection towards 2012

Overall we believe that the progress towards the 2012 goals is very good. The current measures for many goals are well in proportion to, or even exceeding, the expected level after two years. The goals related to the impact of the center on SICS are, however, in retrospect on the optimistic side. We will therefore consider revising these goals in discussion with the center funders.

2. Activities and publications

In this section we describe the major meetings, workshops and other activities that are hosted by the center, organized by center participants, or meetings where the center was formally represented. The activities serve to increase the communication and collaboration within the center, as well as communicating center results and achievements to industry, society and the public in general. The activities are reported in chronological order.

2.1 Activities 2008

CNS review meeting, March 18th, 2008

Participants: VINNOVA, SSF, KKS, evaluators, center board, industry and academy

On March 18, 2008 the evaluators, Gunnar Björklund, Kaj Mårtensson and Per Stenius, met with the Center manager, Bengt Ahlgren and representatives from Center Board, industry, university and researchers of the Center for Networked Systems (CNS) at SICS, for presentations and discussions on the organisation and performance of the Center.

The REALWSN'08 Workshop on Real-World Wireless Sensor Networks, April 1st, Glasgow, Scotland

Participants: 3 SICS, 1 Saab, 35 others.

SICS was the main organizer of this successful workshop that attracted researchers and practitioners working in the area of sensor networks.

CNS Workshop on Nano-bus and the Spread toolkit, April 2nd, 2008

Participants: 6 SICS, 1 Ericsson, 1 T2Data, 1 Uppsala Univ., 1 KTH.

CNS held an internal cross project workshop on the subject of T2Data's message bus and the Spread toolkit and how these two artifacts can be used as inspiration to the design of the information-centric network infrastructure in center Project 5. This was a half day workshop initiated by Project 5 that included discussions and presentations as well as hands-on exercises.

SNCNW, April 9-10, 2008

Bengt Ahlgren leads the steering committee of SNCNW, Swedish National Computer Networking Workshop. The 5th SNCNW was organized by Professor Adrian Popescu and his team at Blekinge Institute of Technology in Karlskrona, Sweden. Center participants presented one paper and one poster on work from the center projects. In total six persons affiliated with the center participated in the workshop.

SICS Open House, April 17th, 2008

Participants: over 300

SICS Open House is held annually in the spring. It is an event where the researchers at SICS present recent interesting results to industry partners, funding agencies, academic colleagues and all other friends to the institute. The center was represented at the open house with two presentations and three posters.

VINNOVA IEC Workshop, May 22nd, 2008

Participants: 1 ABB, 2 SICS, VINNOVA, CODIRECT, CIC, CNS, EcoBuild, FOCUS, IMAGIC and PRISMA.

In the first evaluation of the Institute Excellence Centers program it was found that the funders should conduct a workshop to exchange experiences and best practices among the centers. The workshop was organized so that each center was responsible for a theme, which they had managed well and could be an inspiration for other centers.

CNS Scenario Workshop, June 3rd, 2008

Participants: 14 SICS, 4 KTH, 1 MdH, 7 Ericsson, 1 ABB, 1 Saab.

CNS held an internal full day workshop with the purpose to present and discuss technical application scenarios, and to present current work in the projects. The expected results from the workshop were to complete the section on application systems/scenarios in the description of the overall CNS goals.

FOCUS Workshop "Sensor & Sensor Network Technology", Sept 3rd, 2008

Bengt Ahlgren presented the center at the FOCUS Workshop on Sensor & Sensor Network Technology. The workshop was arranged by the sister center FOCUS in the same program as SICS CNS. In total 11 centers of excellences were represented at the workshop.

CNS Workshop on hot topics, September 30th, 2008

Participants: 18 SICS, 1 TeliaSonera, 1 Ericsson, 1 Saab, 1 ABB, 1 KTH, 1 MDH, 1 T2Data

The first half of the day was devoted to presenting the current status of the CNS projects. In the afternoon invited speaker Pekka Nikander from Ericsson Research presented the background and motivation behind the approach in the PSIRP EU project. The title of his talk was *Information-centric Inter-networking: Architectural aspects*. The workshop continued with *hot topic* presentations from the CNS projects.

Swedish Sensor Networking Day, November 17th, 2008

Participants: 11 SICS, 4 ABB, 2 SAAB, 15 others.

As in 2007, CNS hosted the Swedish Sensor Networking day. This event took place at SICS. The day contained a lot of interesting presentations, lively discussions etc. The day also included a session on the outcomes of the ERA-SME project AppSN.

CNS Workshop with Scientific Advisory Board, 1-2 December, 2008

Participants: 28 SICS, 3 ABB, 2 Ericsson, 4 KTH, 2 Saab Systems, 2 T2Data, 3 ABB, 6 Scientific Advisory Board members.

The main purpose with the workshop was to receive feedback from the center scientific advisory board including suggestions for improving the scientific performance of the center research. During an intense afternoon, 12 talks and 18 poster/demos were presented to the advisors and the center members by researchers from different partners. The advisory board provided feedback on scientific quality and the presentation of the research.

Workshop SICS-ABB, December 18th, 2008

Participants: 5 ABB, 7 SICS.

The aim of this workshop was to discuss common interests, future collaborations within CNS and in other projects. There is a big interest in working together even closer than today (two SICS persons spend one day a week at ABB). The intention was to increase the number of common publication etc.

2.2 Publications

Conference or Workshop Item

1. Abrahamsson Henrik and Kreuger Per (2008). A case for resource management in IPTV distribution. In: *The 5th Swedish National Computer Networking Workshop (SNCNW 2008),* 9-10 April 2008, Karlskrona, Sweden.
2. Ahlgren Bengt, D'Ambrosio Matteo, Dannewitz Christian, Marchisio Marco, Marsh Ian, Ohlman Börje, Pentikousis Kostas, Rembarz René, Strandberg Ove and Vercellone Vinicio (2008). Design considerations for a network of information. In: *ReArch'08: Re-Architecting the Internet*, 9 Dec 2008, Madrid, Spain.
3. Bjurling Björn, Rasmusson Lars, and Johansson Ulf M. (2008). Qualitative policies for bandwidth priorities in ad-hoc networks. In: *First International Workshop on Automated Network Management*, April 13-18, 2008, Phoenix, AZ, USA.
4. Gunnar Anders (2009). Robust load-balancing under statistical uncertainty: models and polynomial-time algorithms. In: *The 5th Euro-NGI Conference on Next Generation Internet Networks* (NGI 2009), 1-3 July 2009, Averio, Portugal.
5. Jurca Dan and Stadler Rolf (2009). Computing Histograms of Local Variables for Real-Time Monitoring using Aggregation Trees. In: *11th IFIP/IEEE International Symposium on Integrated Network Management (IM 2009),* New York, NY, June 1-5, 2009.
6. Kathiravelu Thabotharan and Pears Arnold (2008). Benchmarking of Opportunistic Networking Experiments. In: *The 5th Swedish National Computer Networking Workshop (SNCNW 2008)*, April 2008, Karlskrona, Sweden.
7. Lungaro Pietro (2008). Pre-fetching in "Spotty" and Cellular Networks: a Characterization of the Energy, Memory and Coverage Trade-offs for Delay-tolerant Data Services. In: *Proceedings of the 8th Scandinavian Workshop on Wireless Ad-hoc & Sensor Networks*, May 2008, Johannesberg, Sweden.
8. Suarez Pablo, Renmarker Carl-Gustav, Voigt Thiemo, and Dunkels Adam (2008). Increasing ZigBee network lifetime with X-MAC. In: *The REALWSN 2008 Workshop on Real-World Wireless Sensor Networks,* 1 April 2008, Glasgow, Scotland.
9. Wuhib Fetahi, Dam Mads, and Stadler Rolf (2009). Gossiping for Threshold Detec-

tion. In: *11th IFIP/IEEE International Symposium on Integrated Network Management (IM2009),* New York, NY, June 1-5, 2009.

10. Österlind Fredrik, Dunkels Adam, Voigt Thiemo, Tsiftes Nicolas, Eriksson Joakim, and Finne Niclas (2009). Sensornet checkpointing: enabling repeatability in testbeds and realism in simulations. In: *EWSN 2009: 6th European Conference on Wireless Sensor Networks*, 11-13 Feb 2009, Cork, Ireland.

Journals

11. Shafaat Tallat M., Ghodsi Ali, and Haridi Seif (2008). Dealing with Network Partitions in Structured Overlay Networks, to appear in: the *Journal of Peer-to-Peer Networking and Applications.*

Technical reports

12. Holmgren Fredrik, and Janson Sverker (2008). Interactive Visual Analysis of Networked Systems: Workflows for Two Industrial Domains, *SICS Technical Report T2008:12*

Book Chapters

13. Kathiravelu Thabotharan and Pears Arnold (2008). *State of the art in Modeling Opportunistic Networks. Mobile Opportunistic Networks*: Architectures, Protocols and Applications, Mieso Denko, Auerbach Publications

Theses

14. Abrahamsson Henrik (2008). *Internet Traffic Management*. Licentiate thesis, Mälardalen University.

15. Champa Dey (2009). *Reducing IDS false positives using Incremental Stream lustering Algorithm*, Master thesis, Dept of Computer and Systems Sciences, Royal Institute of Technology, Stockholm.

16. Gillblad Daniel (2008) *On Practical machine Learning and Data Analysis*. Doctoral thesis, KTH, Stockholm.

Posters and Demos

17. Boano Carlo A., Voigt Thiemo, Dunkels Adam, Österlind Fredrik, and Hernández Pablo S. (2009). Exploiting the LQI Variance for Rapid Channel Quality (IPSN 2009). In: *The 8th ACM/IEEE International Conference on Information Processing in Sensor Networks*. April 13-16, 2009, San Francisco, USA.

18. Österlind Fredrik, Tsiftes Nicolas, He Zhitao, and Dunkels Adam (2009). Demo Abstract: Sensornet Checkpointing: Between Simulated and Deployed Networks (IPSN 2009). In: *The 8th ACM/IEEE International Conference on Information Processing in Sensor Networks*. April 13-16, 2009, San Francisco, USA.

2.3 Communications strategy

The communications strategy is based on well-defined target groups i.e. the network industry, media, other research institutes, governments and politicians. Dissemination of publications and posters are aimed at conferences and journals within the network research society nationally as well as internationally.

The communication plan has to large parts been followed. The scientific publication has doubled since last year. Activities in the center have moreover been visible in the popular press, presented in the SICS Annual Report, and are described on the SICS website.

To further strengthen the center identity a graphical profile was developed. The profile has been used for office signs, t-shirts, and distribution of USB memory sticks.

The center has contributed to SICS strategic vision that is currently communicated as *SICS vision 2025*. The vision is part of SICS contribution to ERCIM, a collaboration organization within the European IT-institutes. The vision is widely spread and communicated within EU.

3. Results

This chapter reports the results of the center research during 2008. As mentioned in the introduction, we have devoted substantial effort starting September 2007 to structure and focus the projects and activities. The definition of the two technical focus areas is the main instrument in this process. The following section describes the focus areas, and the sections after that reports the achievements for each of the center projects.

3.1 Technical focus areas

During the first year of the center, we realized that we needed something more than the overall vision of the reliable Internet in order to guide the research and create more focused projects. We therefore defined two ideas, or technical visions, on how to organize future networked systems. These ideas we call the center *technical focus areas*. The center projects for 2008 are defined with a strong relation to these areas.

3.1.1 Networking of information focus area

The first focus area, *networking of information*, is an approach for designing the network of the future based on an *information-centric paradigm*. The approach is believed to result in a network that is better adapted to information distribution and retrieval, which are the prevailing uses of current network technologies. Current technologies are in contrast based on a *device-centric paradigm*, focusing on the interconnection of devices, such as computers, mobile devices, servers and routers. In the latter, the communicated information, e.g., web pages, music, videos or computer software, is largely anonymous when transferred over the network, making efficient information distribution hard, alternatively solved in overlays on the network infrastructure.

In a network based on the information-centric paradigm, the information objects are first-class citizens with unique identity independent of the device it is stored on. This approach enables efficient and application-independent information caching by the network infrastructure, and thus, allows large-scale information distribution without violating basic assumptions or resorting to special tweaks or add-ons.

Information-centric networking is said by Internet pioneer Van Jacobson to be the third generation of communication networks. The first generation, the telephone networks, connected phones with physical wires, allowing humans to make conversations with each other. Second generation networks connected devices with each other, enabling services on those devices to communicate. The third generation will be about disseminating information, making that information available to applications and users efficiently on a large scale.

In the center, Projects 5 and 6, directly or indirectly explores the information-centric paradigm.

3.1.2 Self-management of networks and systems focus area

The second focus area, *self-management of networks and systems*, is a vision for future networked systems requiring no manual management. Traditional methods of network management involve considerable human supervision and carry rapidly escalating costs. The increased size, complexity, dynamism and heterogeneity of the networked systems make it infeasible to manage future networks as we have done before. Not only will the cost be prohibitive, it will simply not be possible to maintain an adequate overview and react quickly enough in order to keep availability, utilization and quality of service at an acceptable level. In CNS we are creating some of the methods and building blocks to address this. In particular, in Project 7 we are studying resource management issues and in Project 8 we are studying monitoring and disruption management issues.

3.2 Project 5: Application scenarios and communication paradigms for networking of information

Project leader: Björn Grönvall

3.2.1 Purpose and goals

The long term research goal for the project is the vision of Networking of Information, where the information is in focus rather than the nodes, as described in detail in the CNS focus area with the same name. Part of that goal is to design a new platform for information distribution with a communication service better suited to the application needs compared to today.

The goal for 2008 was to come to a conclusion on the design of a NetInf communication paradigm, which is suitable for the application scenarios of the participating industrial partners.

The results below were expected during 2008. The aim was that the project will continue 2009, taking the next step towards the longer-term research goal and vision of networking of information.

- Descriptions of application scenarios with derived communication requirements.
- Conclude on one or a small set of communication paradigms that support the chosen applications.
- Define evaluation criteria for assessing the extent to which the NetInf paradigm supports the chosen applications.
- Reports and papers with results from the experimental evaluation.
- Publication on reliable DHTs.
- Improved scalability of scheduled communication.

3.2.2 Achievements and results

This project was planned for a two year period (2008, 2009). During the first year we have analyzed a number of scenarios that has been suggested by both industrial and academic partners. This analysis taken together with our investigations of candidate communication paradigms has resulted in a preliminary NetInf design based on the concept of *in-network-storage* and a *publish/subscribe* style of communication [2]. This far, we have qualitatively evaluated the design against the scenarios to see if the design supports the communication requirements of the scenarios. Quantitative evaluation is an activity that is planned for 2009.

A key component of the NetInf design is a mechanism for key-value lookups. The reliability and robustness of this mechanism, in particular with respect to network failures, has been investigated [11].

How to manage resources (e.g energy, memory, coverage, bandwidth) in a NetInf network has been investigated [1, 7]. In particular we have studied how we can best utilize *in-network-storage* by scheduling the distribution of TV media. Great progress has been made to improve the scalability of the scheduling algorithms, which are NP-complete.

Finally, we have also worked on the problem of supporting DTN-style communication by means of *opportunistic communication* [6, 13].

3.2.3 Participants and project meetings

SICS, Ericsson, T2 Data, Saab, TeliaSonera, Uppsala University, KTH

In addition to the general CNS activities the project had 8 formal meetings where minutes where taken. The formal meetings where typically divided into an administrative section for planning etc. and the remaining time used for technical presentations and discussions. The meetings typically lasted for two hours. In addition to this, informal meetings where held when needed.

3.3 Project 6: Predictable performance and scalable security for resource-constrained networked embedded systems

Project leader: Thiemo Voigt

3.3.1 Purpose and goals

Long term research goal: The focus of past research on wireless sensor networks (WSNs) has been on fundamental design issues, protocol design, energy conservation and localization. Very little attention has been paid to situations where performance assurances are desirable, especially in regard to timelines and dependability but also power consumption. However, many WSN applications such as plant automation, surveillance, vehicle control or health monitoring will demand a degree of certainty in their ability to respond to external stimuli. Furthermore, these applications also require security. The long-term research goals are secure and robust wireless sensor networks that meet application-specific performance targets.

3.3.2 Achievements and results

The project plan is defined for 2008 and 2009. Some of results are expected to be achieved by master theses that are co-supervised by ABB/SICS resp. Saab/SICS. Three master students are currently active within this project. The thesis with Saab by Carlo Boano is almost finished. It is supervised by SICS and the former CNS MSc student Pablo Suarez, now at Saab. A joint poster has been accepted next week at IPSN one of the top conferences in sensor networking and we expect one or more full papers that build on the results of this thesis. A master thesis on implementation and evaluation of wirelessHART, a new standard aiming towards robust and predictable industrial sensor networking, is running well and we expect that the results will be of importance not only for ABB. Regarding security, the project has identified two lines of investigations. One is on security issues on wirelessHART. Also this thesis is run under co-supervision from ABB and SICS. We expect to submit one or two joint publications. The other work item has been a Contiki Crypto Library that will be released as open source code.

Together with Saab, we have worked on robustness issues in wireless sensor networks. The focus of this work has been on the impact of communication failures caused by channel noise, interference etc. By improving routing metrics, this work increased the robustness of data collection in Contiki. This work continues in 2009 and we expect a full paper and valuable insights for a broader set of applications.

As an extension of a 2007 project, SICS has developed novel mechanisms for moving node state between simulation and testbed. This groundbreaking work has been accepted for EWSN, the most important sensor networking conference in Europe and a demo has been accepted for IPSN 2009. The work enables a set of interesting applications such as automated protocol tuning, repeated testbed experiments and testbed fault injection.

3.3.3 Fulfillment of goals

Many of the goals of the project plan for 2008/2009 have been fulfilled or are going to be fulfilled during the next year: the implementation of TSMP/WirelessHART is on the way, and a Crypto Library for Contiki has been implemented. Experiments have shown that existing MAC protocols such as X-MAC and LPP are not able to provide predictable performance. The work with Saab has focused more on robustness than on predictability. Important results have been achieved: a common SICS-Saab poster has been accepted and more joint publications are planned. Regarding security, it has been decided to focus on security in WirelessHART rather than secure code updates. The master thesis on WirelessHART has been successful and based on the thesis' results, joint SICS-ABB publications are planned.

3.3.4 Participants and project meetings

SICS, Saab, ABB.

Pablo Suarez and Zhitao He had regular meetings at least once a month. Carlo Boano, Pablo Suarez and Thiemo Voigt had weekly to biweekly meetings. The SICS-ABB thesis workers Shahid and David met the ABB contacts several times and had phone conferences. In Shahid's case, his SICS co-supervisor Adriaan Slabbert attended these as well. ABB also put them in contact with a specialist at ABB, Switzerland. Niclas Finne, co-supervisor of David's thesis, met the ABB co-supervisor Tomas Lennvall regularly since he spends one day per week at ABB.

3.4 Project 7: Resource Management

Project leader: Martin Nilsson

3.4.1 Purpose and goals

The over-all purpose of the "Resource Management" project is to develop measurement and control techniques for self-management of networks; optimize network performance; and develop novel services involving network management. One goal is to develop and evaluate novel methods for measuring and controlling transmissions in overlay and virtual networks that share a common underlying network infrastructure. This involves a simulator platform aimed at next generation network concepts, such as overlay networks, isolated virtual networks, and virtual routers on a shared infrastructure.

Another goal is to implement bandwidth allocation and policy control on this platform. Reactive methods in which the network responds to simple measurements will be researched and implemented. The focus is to develop methods that can act in a decentralized manner to enable scalability. Market-based methods will be used to limit the harm that can be caused by malicious or non-cooperating network elements/users. The policy control mechanism aims towards an autonomic management of the network resources. It provides a rule-based language in which soft policies can be implemented. It enables human policy makers and network managers to provide configuration goals in higher level conceptual terms such as user groups, business state, etc., rather than on the level of the individual routers. The research will address issues in the topics of security policies in terms of access control and identity management; network policies in terms of resource usage and allocation privileges; service provider policies for debit and charging; and quality-of-service and context-dependent priority policies.

A final goal is to review and re-evaluate previous research in the area of traffic monitoring and management, using recent data from operational IP networks.

3.4.2 Achievements and results

The work can be divided into three subtasks: infrastructures for measurement and control; ad-hoc radio networks with policy-based control and automatic bandwidth allocation; and robust routing, subject to stochastic uncertainties.

As for the measurement-and-control infrastructure task, we implemented a "real" platform, rather than a simulator platform, for administrating the collection of network measurement data, using a REST-style server-oriented architecture. This work is related to, and was coordinated with that done within the MOMENT EU-project, involving partners from SICS, Ericsson and MdH. SICS and Ericsson also together carried out a successful pilot test of the BART method for measuring available bandwidth at Bombardier Transportation. This is the first sharp test of BART that has been performed at a commercial customer site.

As for the ad-hoc radio networks task, the goals regarding bandwidth control were found ambitious, and the allocated resources did not reach all the way towards fulfilling all the goals set up for 2008. During the fall, we have developed an optimal, stable, centralized algorithm for Libra, which will be used to benchmark the results obtained by the dynamic, decentralized resource-balancing algorithm. We have also achieved results towards a scalable decentralized policy control for bandwidth usage in ad-hoc radio networks. This has been achieved partly through the definition of a language for specifying qualitative high-level priority policies for prioritizing among the users of the ad-hoc network, and partly through the implementation of a market-based enforcement mechanism for the priority policy language [3].

As for the robust routing task, in order to balance network load, the operator needs an estimate of the traffic situation in the network. Such estimates are usually based on a statistical traffic model in combination with measurements and/or some estimation procedure to obtain values of the model parameters. Due to the stochastic nature of the traffic, estimates of the traffic matrix from a finite number of data will always contain inaccuracies, and the optimized routing will be subject to variations from the nominal case it was optimized for. Hence, it is important that the routing setting is insensitive, or robust, to deviations from the nominal case. As shown by multiple authors, the classical routing optimization based on linear programming is sensitive to uncertainty in the problem. With robust routing it is possible to optimize the routing setting not only for a nominal traffic situation, but also for a set of traffic situations. As long as the traffic situation stays within the bounds assumed using the optimization, the performance is guaranteed to be better or equal to the optimization objective. During 2008, we have studied how traffic behavior can be captured by a statistical model that captures the most likely traffic scenarios in a network. This model has been incorporated in an optimization problem to find a routing setting that is optimized for all traffic scenarios included in the model. We have evaluated our algorithms in an operational IP network to highlight features and benefits of our approach. The results are presented in a paper currently in submission (Anders Gunnar and Mikael Johansson: "Robust load-balancing under statistical uncertainty: models and polynomial-time algorithms").

3.4.3 Participants and project meetings

SICS, MdH, Saab, Ericsson, T2 Data.

Participants in the "infrastructures for measurement and control" subtask hold lunch meetings on a weekly basis. Apart from this, half-day thematic meetings are also held once every 1-2 months. Five meetings were held during the year for the purpose of discussing progress and new results in connection to the subtask "Bandwidth control in ad-hoc radio networks."

3.5 Project 8: Monitoring and Disruption Management

Project leader: Björn Levin

3.5.1 Purpose and goals

Project 8 aims at building mechanisms and tools for monitoring and responding to anomalies such as faults, overload, miss-configuration, and intrusion. The scope includes data gathering and estimation, statistical anomaly detection, policy based security, and the methods and tools for finding the root-causes of anomalies of various kinds and for suggesting counter-measures. During 2008 the scope also included new visualization tools that give a good overview of the network and its state. (From 2009, this has been moved to project 6.)

The long term research goals are to enable self-healing and resilience in networked systems. The motivation is simple: given the increase in size in the networks, there is too much to keep an eye on for humans to cope, and the increasing complexity and interdependency makes anomalies potentially more destructive, as well as harder to anticipate, detect and diagnose. For the solutions to scale, it is also important to make them as decentralized and distributed as possible.

In the project, we develop specific novel tools and ideas, ensure that they fit together and start building the framework in the long-term vision.

3.5.2 Achievements and results

Work in the project has been focused on five activities: Anomaly detection in logs, Automated response to attacks, Flow anomalies, Reconfiguration triggering, and Visual analysis. Each of these, and their results and fulfillment of goals, are described below.

Anomaly detection in alarm logs & automated response to attacks

The goal of these two activities has been to develop practically applicable and efficient tools for alarm filtering, clustering, and disruption management for telecom equipment. This includes both handling of equipment failures and managing attempts of attacks or intrusions. (As of 2009, these two activities have been merged into one.)

The following results have been achieved:

Further development of the anomaly detection algorithms

In order to enhance the anomaly detection mechanism used for both causal modelling and intrusion detection, we have focused on the underlying statistical models. So far they have been based on a fixed time interval (Poisson distribution). This is not always appropriate, for example in situations where fast changes must be detected. Therefore we have also derived anomaly detection equations for the case of a fixed number of events (Gamma distribution), and for the combination of the two. This combination is as far as we can tell new, and gives a very flexible anomaly detector. The new equations have been implemented in the code base, validated, and can now be used when continuing the work in the parts below.

Evaluation of anomaly detection for clustering of mobile network alarms

One targeted application area of the anomaly detection is filtering and clustering of mobile network alarms. This application is based on examples and data from the monitoring center of TeliaSonera in Sundsvall. Earlier in the project (2007) we proposed the use of anomaly detection to detect causal connections between alarms (showing up as deviation from independence). Such connections can then be used to cluster alarms with the same root cause. During 2008 this method was validated on simulated data. We generated synthetic alarm data from a known causal graph, mimicking the same probabilities as found in real data from the mobile network. The algorithm was able to recover all the causal links, except two that were assigned so low probabilities that they were not sufficiently represented in the generated data. This verifies that the method is able to uncover the hidden causal structure between alarms.

Evaluation av anomaly detection for filtering IDS alarms

Another important use of statistical anomaly detection is for intrusion detection. There are many powerful commercial intrusion detection systems today, often based on signatures, i.e. rules that match different attacks. One problem with those systems is that they tend to produce a large number of false alarms.

During 2008, we have studied the performance of using statistical anomaly detection to filter alarms from a signature based intrusion detection system (SNORT). The results were very good: The true number of attacks in the data set used for evaluation was 74, but the total number of alarms from Snort during the same period was 33500. The anomaly detection managed to detect 70 of the 74 attacks, while reducing the number of alarms to 216, of which 137 was related to the real attacks. This gives a recall rate of 95% and an alarm reduction rate of 99.4%.

A master’s thesis was produced: Champa Dey, “Reducing IDS false positives using Incremental Stream Clustering Algorithm”, Master thesis, Dept of Computer and Systems Sciences, Royal Institute of Technology, Stockholm, 2009.

Statistical risk modeling for network attacks

We have developed a framework for statistical risk modeling of network attacks, which lets an operator perform real-time risk analysis based on a model of how data flows in the network, an attack graph, a Bayesian statistical model of attacker skills, and an exploitation model of the required skills to successfully exploit vulnerabilities.

We compute the security risk using a Bayesian approach to probability estimation, assuming that a record of historical attack data from a honey-pot is given. The risk computation consists of two parts, a probability estimation and an impact estimation. The impact estimation of an attack is computed using a data flow model in combination with an attack graph. The estimate of the probability of a successful attack (a loss event) is computed by first classifying each vulnerability into a required skill-level category that denotes how hard it is to successfully exploit the vulnerability. Then, based on historical attack data from a honey-pot, we can create a statistical model of the attacker skill using a Bayesian approach. Finally, the security risk is computed by marginalizing over the attacker skill.

Flow anomalies

The goal of this activity has been to model and analyze a generic aggregation protocol in a dynamic network environment. Since estimation of aggregated quantities is the basis for more complex operations, it is important to quantify performance as a function of message passing strategies and churn (nodes joining and leaving the network).

The work done in the past year has focused on putting forward a dynamic model where nodes need to estimate the aggregate of local values, while at the same time nodes may leave the system and new nodes can join. The challenge is to construct a model detailed enough to capture relevant properties of the system and simple enough to keep it tractable. Inspired by particle models in physics and chemistry, a so-called master equation based model has been constructed and partly solved with numerically verified results.

The initial model investigated in this work aims at constructing a dynamic spanning tree over the complete set of nodes. This is relevant in relation to any message passing protocol in that each node broadcasts information about its current state and the flow of this information is spread throughout the network as a spanning tree rooted at that node. The flow follows the shortest path from sender to receiver.

The following results were achieved:

- A generic aggregation model has been constructed. The average number of nodes at any level in the logical spanning tree, as a function of join and leave rates, has been solved theoretically using the master equation approach.
- An extension to the model to involve the error estimation at any given node has shown more challenging but has been formulated in closed form using master equations. Using this equation we can answer questions like "how much maintenance do we need to do in order for the aggregated estimate at the root to be at most 10% off from the true value."

These results are now tested against numerical simulations. A draft version of a paper on the topic exists and will be ready for submission shortly.

Reconfiguration triggering

Part of adaptation and self-healing is the detection of when to initiate a reconfiguration of one or several network elements. Alternatively, this can be done in a more or less continuous, self-organizing way. In both cases, this is partly an estimation and detection task, partly an optimization task, partly a protocol design task, and partly a control stability issue. In this activity, we have focused on the estimation and detection part, and on the protocol design part.

The work has been based on a practical use-case brought by Ericsson, concerning paging in mobile networks. This use-case has been the basis for studying how self-organization can be used instead of a previously centralized and manual process for configuration. The use-case also enables, at least partly, penetration of the issue of whether to discretely trigger reconfiguration, or more continuously perform operations in a decentralized and self-organizing way. The idea is to use the work on the use-case to later generalize to other similar situations.

This activity complements work done in the Vinnova funded DiSC project. The activity also contains work on how properties are estimated in a decentralized manner, and how the accuracy and stability of these aggregates behave under churn.

The following results were achieved:

- The use-case of mobile paging was selected after a thorough process to ensure that it is both a industrially relevant problem, that it has academic depth, has economic potential, and that we have a reasonable approach and chance of completing the work within the allocated time. A comprehensive use-case description has been produced, stating the current practice, the relevant issues and parameters, etc. (This document is under Non-Disclosure Agreement and is hence not available and therefore not referenced in the list of publications.)
- The core of a continuously operating, self-organizing protocol for the paging has been developed. This is a very different protocol from the configure-and-use type of methods used for mobile paging today, and is a good vehicle also for studying the relative merits of the two approaches.
- Two publications, to which the work in CNS has contributed, and related to self-organizing data aggregation, have been produced by the group at KTH during 2008: D. Jurca, R. Stadler, "Computing Histograms of Local Variables for Real-Time Monitoring using Aggregation Trees", 11th IFIP/IEEE International Symposium on Integrated Network Management (IM 2009), New York, NY, June 1-5, 2009; and F. Wuhib, M. Dam, R. Stadler, "Gossiping for Threshold Detection", 11th IFIP/IEEE International Symposium on Integrated Network Management (IM 2009), New York, NY, June 1-5, 2009.

Visual Analysis

When detected anomalies lack policy-based or other automated responses, manual troubleshooting is necessary. Information visualization methods aid our human cognition, and can help us analyze and understand anomalies in large and complex abstract data sets.

The purpose of this activity has been to explore the potential of visual analysis to aid human understanding of complex networked systems, and how to achieve engineering efficiency through the use of a standardized framework and architecture. The short term goal has been to create visual analysis workflows (use-cases) that utilize both visual and statistical methods in the detection and analysis of anomalies in networked systems and perform experiments on elements of workflows ("micro-demonstrators").

Two problems from two different levels of networked systems were studied and resulted in micro-demonstrator workflows. The visual workflows illustrate the potential of visualization. The techniques used gives an indication towards what support that is to be expected from an ideal visualization tool for networked systems, both in terms of visualization views and interactions - in terms of simplicity and flexibility in use, configuration and initial setup.

A study of possible inclusion of statistical methods into the visual workflows was begun. This work lead to a basic understanding of the characteristics of the problems were statistical analysis has been used but never got to the point were an inclusion into any existing workflow was considered.

The following results were achieved:

- In cooperation with Ericsson, a set of micro demonstrators and visual workflows have been created for parts of the design and verification phases of a "Virtual Flower" service introduction.
- In cooperation with ABB, a treemap-based micro-demonstrator has been created for a status supervision use-case.
- A first prototype for "Unified Supervision" based on the developed micro demonstrator was developed by ABB and SICS. This work was initiated by ABB (Norway) who also performed the integration into the 800xA system. Configuration and adaptation of the visualization and the underlying visualization framework was performed by SICS. The ABB prototype was well received and is now undergoing further development by ABB towards inclusion in the 800xA system as a product.
- A technical report describing the results from this project and the Knowledge Foundations funded Demonstrator Light Project "Interactive Visual Analysis of Networked Systems" was produced: Holmgren F. and Janson S., “Interactive Visual Analysis of Networked Systems: Workflows for Two Industrial Domains”, SICS Technical Report T2008:12.

3.5.3 Fulfillment of goals

The goals for 2008 for the activity on “Anomaly detection in alarm logs” were:

- Validation of the results of anomaly detection in TeliaSonera's alarm logs.
- A method for constructing causal trees from alarm log statistics, which can be used for alarm clustering and root cause identification.

All of the goals were reached and the activity has progressed according to plan for 2008.

The goals for 2008 for the activity on "Automated Response to Attacks" were:

- A targeted literature study of data driven methods for intrusion detection.
- An evaluation of our method for anomaly detection applied to intrusions.
- A framework for modelling the vulnerability of a network.

All of the goals were reached and the activity has progressed according to plan for 2008.

The goals for 2008 for the activity on "Flow anomalies" were:

- Assess the suitability of Belief propagation and PCA methods for detecting network flow anomalies by evaluation on representative simulated data.

The goal was not reached, but good progress was made. The initial aim to theoretically analyze belief propagation and its suitability for complex operations such as PCA turned out to be quite complex. It became apparent that in order to analyze the performance of more complex protocols one needs to understand properties of more fundamental generic properties of message passing protocols such as the estimation of global aggregates and also estimation of the variation in these values. A survey of the existing literature showed that performance analysis of generic aggregating protocols is rare and partly lacking. It has there for been necessary to start out with a less ambitious aim in order to proceed.

The goals for 2008 for the activity on "Reconfiguration triggering" were:

- Use-case identification, definition, and selection.
- Detailed use case specification.
- Development of a self-organizing approach.

All of the goals were reached. The process of selecting the use-case took more time than expected and put us slightly behind schedule. However, the thorough way in which it was done also facilitated later steps, so that we were able to catch up enough time to be on schedule again at the end of the year.

The goals for 2008 for the activity "Visual analysis" were:

- Create visual analysis workflows (use-cases) that utilize both visual and statistical methods in the detection and analysis of anomalies in networked systems.
- Perform experiments on elements of workflows ("micro-demonstrators").

Both goals were reached and the activity has progressed according to plan for 2008.

3.5.4 Participants and project meetings

SICS, TeliaSonera, ABB, Ericsson, KTH.

The visualization activity has also had a two day-visit from a participant from ABB Norway, and two additional meetings with groups from Ericsson to demonstrate and get feedback from the developed micro-demonstrators.

3.6 Project 9: Common activities

Project leader: Bengt Ahlgren

3.6.1 Purpose and goals

The purpose with this project is to provide a generic program, open to all partners, facilitating interaction and learning within the center. The project is responsible for all center-wide activities, including workshops and seminars. One specific goal of the project is to link the research in the center to the industry partners' applications through the definition of application scenarios.

3.6.2 Achievements and results

Technical application scenarios have been defined by the industry partners in discussion with the rest of the center participants. The scenarios were first presented and discussed at the center workshop in June, and then further revised and discussed at the center workshop with the advisors in December. The application scenarios were then an important input to the project plans for 2009.

The center workshops in June, September and December are results from this project. See above in Section 2.1 for details. The organization, implementation and documentation of these events are part of this project.

The seminars reported below in Section 5 are also organized as part of this project. Seminars by visitors, some specifically invited, are crucial for the scientific discussion and the adoption of new ideas in the center research. With the invited talks, the center provides another level of quality for the participating industry researcher.

3.6.3 Fulfillment of goals

The goal to define technical application scenarios for the industry partners has been achieved. The overall purpose to facilitate interaction and learning within the center is a qualitative goal that has been achieved.

3.6.4 Participants and project meetings

Participants: in addition to the participants of the other projects, the management team and the board, Stefan Hagdahl, Saab Systems and Johan Sjödin, T2Data/Projectmill have participated in the activities of this project.

Project meetings are listed above as part of the results.

3.7 Other results

A patent application has been submitted for a method for localization of wireless sensor nodes invented by Martin Nilsson.

4. Center organization and management

4.1 Management team and project management

The management team consists of the center director, project leaders and people that contribute with specific skills to the center. A new member in the team is the center co-ordinator who was employed in the fall 2008. At the end of year 2008, the following people were engaged in the management team.

Bengt Ahlgren	Center director
Janusz Launberg	Business manager
Maria Holm	Coordinator
Björn Levin	Project leader
Thiemo Voigt	Project leader
Björn Grönvall	Project leader
Martin Nilsson	Project leader
Björn Bjurling	Senior researcher
Sverker Janson	Senior researcher

During 2008, seven minuted management team meetings were held and numerous informal meetings. Management meeting topics include, budget, project plans, progress and the overall administration of the center.

4.2 Center board

Members of the board were the following at the end of year 2008.

Olle Viktorsson	Ericsson	Chairman
Göran Olofsson	Telia Sonera	Member
Jan-Erik Frey	ABB	Member
Staffan Truvé	SICS	Member
Gunnar Karlsson	KTH	Member
Björn Lisper	Mälardalens högskola	Deputy member

Ronny Engelin	T2 Data	Deputy member
Sigvard Brodén	Saab Systems	Deputy member
Per Gunningberg	Uppsala University	Deputy member
Bo Granbom	Saab Communications	Deputy member

During 2008, five board meetings have been held. A rotation of location of board meetings has successfully been introduced. The rotation provides an opportunity to visit and to a greater mutual knowledge and understanding between the partners of the center.

4.3 Scientific advisory board

The center has engaged the following eminent members to the center advisory board.

Anna Brunström, Prof.	Karlstads Universitet
Erland Jonsson, Prof.	Chalmers
Geoffrey Voelker, Prof.	University of California, San Diego, USA
Jürgen Quittek, Ph.D.	NEC Network Laboratories, Heidelberg, Germany
Peter Druschel, Ph.D.	Max Planck Institute for Software Systems, Saarbrücken, Germany
Serge Fdida, Prof.	Pierre & Marie Curie University, Paris, France

In December a very successful work shop was held in Steningevik, Märsta, with more than 50 participants from SICS, the academia and center industry partners.

The advisory board reported their findings directly at the workshop. Their report contains suggestions for enhanced strength within the center along with notifications of improvements from previous report.

Findings compared to last year's recommendations:

- The center now has a more coherent vision
- The two center focus areas are ambitious, important and timely
- The number of projects has been reduced
- Industry collaboration is strong
- Academic collaboration is well defined

Recommendations from the advisory board:

- Continue to aim for excellence
- Facilitate more interaction between activities
- Continue to emphasize activities that have short term industry impact, connection to the CNS vision and long term research perspective
- Clarify each activities´ role in fulfilling the CNS vision
- Prioritize the center objectives explicitly
- Monitor performance, and progress
- Further improve the presentations of project

4.4 Collaboration

The form of working in the center where all partners actively participate in the projects has resulted in a very close collaboration involving all center partners. We are especially seeing a deepening of the collaboration with partners that SICS already had long term relationships with. The activities in the center also lead to the creation of new projects funded from other sources with participation from the center partners.

The common infrastructure in the center is a very important part of and prerequisite for the collaboration within and between the center projects. In addition to email lists of different kinds, the center has a Wiki serving as a shared workspace for the organization of the work and discussions, and a BSCW server for storing shared documents.

Personnel mobility is starting to take place. We continue to have master thesis students sharing their time between SICS and Saab. Mats Björkman from MdH and Börje Ohlman from Ericsson have offices at SICS where they work approximately one day per week.

5. Learning environment

5.1 Learning and interaction

The feedback received from both our Scientific Advisory Board as well as the reviewers confirmed our own observation that the research in the center had become too fragmented during the first year. The work initiated in September 2007 to focus the projects towards common goals has resulted in the definition of the earlier described two technical focus areas. These have served as a framework for the redefinition of the projects at the beginning of 2008. The lesson learnt from this is that the management team and the board continuously need to work on defining clear common goals that can guide the work in the center projects.

Workshops open to all center participants are an important means for the learning in the center. The workshops have stimulated to discussions that have lead to new insights for the participants from all center partners. These workshops have been described above under "Activities". We note that the center workshops have both had a high participation and have been highly appreciated by the center researchers. The organization and structure of these workshops have been formalized as part of a separate center project (Project 9).

Seminars organized as part of the project work where state-of-the-art relevant for the project and own previous work are presented and discussed are an important mean for increasing the common learning.

Visitors, invited talks and interaction with related initiatives and projects are other components of the environment that contribute to the common learning. We list some of the more important initiatives below.

5.2 Learning activities

Peter Sjödin, Associate Professor at KTH, visited SICS and the center on May 8, 2008. He gave a talk on “Network Virtualization”.

Dr. Andy Bavier visited SICS and the center on August 19, 2008. He gave the talk "VINI and its Future Directions." Dr. Bavier is an architect and core developer of the VINI project. He has also been involved with PlanetLab, a planetary-scale testbed for distributed applications, since its inception in 2002.

At the center workshop on September 30, 2008, Dr. Pekka Nikander, Ericsson Research, Finland, gave the invited talk "Information-centric Inter-networking: Architectural aspects".

Dr. Anders Lindgren visited SICS and the center on November 6th 2008, giving the talk "Wildlife Monitoring and Human Communication in Sparse Wireless Networks". Anders Lindgren defended his PhD thesis in Luleå a couple of years ago and has since then spent time as a post-doc at UCL and Cambridge in England.

Professor Holger Karl, University of Paderborn in Germany, visited SICS and the center for two weeks November 17-28, 2008. During his visit he gave the talk "Exploiting diversity by cooperation – from analysis to system architecture".

Staffan Truvé, managing director of SICS, particpated in the seminar series "Kunskapens Krona" at the Stockholm Royal Castle sent on SVT Tuesday November 18, 2008. The title of the four seminars was "Vår natur i förändring".

On November 20th 2008, Henrik Abrahamsson defended his licentiate thesis titled "Internet Traffic Management" at Mälardalen University in Västerås. Opponent: Dr. Markus Hidell, KTH. Examinator: Prof. Hans Hansson, MDH. Tutor: Prof. Mats Björkman, MDH.

5.3 Relation to other projects

4WARD

SICS, Ericsson and KTH are also partners in 4WARD – Architecture and Design for the Future Internet, a project with about 35 partners coordinated by Ericsson in the EU 7th framework program. The project takes a clean-slate approach to research towards the Future Internet. There are synergies between 4WARD and the center in two areas: Networking of information and Self-management of networks and systems.

WISENET

Uppsala VINN Excellence Center for Wireless Sensor Networks (WISENET) at Uppsala University is lead by Per Gunningberg, involving close collaboration with Hectronic, SenseAir, Silex Microsystems, FOI, Banverket, TNT-Elektronik and Triona. The interaction between WISENET and SICS CNS is extensive. At the person level, SICS participates in the WISENET management team. Per Gunningberg is one of the deputy board members of SICS CNS, and Staffan Truvé, SICS, is the chairman of the WISENET board and member of the SICS CNS board.

MOMENT

SICS and Ericsson are partners in the EU project MOMENT, Monitoring and Measurement in the Next Generation Technologies. MOMENT is a project aimed at integrating different platforms for network monitoring and measurement to develop a common and open pan-European infrastructure. The work on BART within center Project 7 benefits from the complementary work on the open infrastructure within MOMENT.

CONET

CONET, the Cooperating Objects Network of Excellence, is a EU-funded project under ICT, Framework 7 with duration of 4 years. CONET participants are 11 top research institutions and five companies from 10 European countries. We will use CONET to disseminate SICS results and work closer with other European top institutions. Ericsson will join CONET's industrial advisory board that is currently under construction.

GINSENG

GINSENG is a EU FP7 STREP project that targets performance-controlled sensor networks. Content-wise GINSENG has some overlap with CNS Project 6. The projects will strengthen each other. We expect that this will lead to improved project benefit for the CNS industrial partners.

RESENSE

ReSense is a SICS/KTH project within VINNOVA's "Banbrytande informations- och kommunikationsteknik 2007". The project proposal was supported by ABB, Saab and Ericsson. Both ABB and Saab interest in one of the ReSense topics, software-defined radio, is very high so that it was decided to strengthen this work through CNS.

Promos

"Promos: Sensor Network Programming Made Easy" is an SSF-funded project. The project proposal has been supported by ABB and one of the companies in our sensor networking network.

MilSense

MilSense is a joint project proposal from Saab, SICS and FOI towards FMV that will strengthen the collaboration between Saab and SICS in the area of networked embedded systems.

6. Financial report

6.1 Contribution from KKS, SSF and VINNOVA

Year	Cash amount (SEK)
1	4 690 000
2	8 110 000
3	
Total	**12 800 000**

6.2 Contribution from industry partners

Year 1	**In-kind Outcome/h**	**In-kind Outcome/SEK**	**Cash SEK**	**Total outcome SEK**
Total	4 329	3 808 000	3 050 000	6 858 000
Year 2	**In-kind Outcome h**	**In-kind SEK**	**Cash SEK**	**Total outcome SEK**
Total	3 749	3 078 720	3 050 000	6 128 720
Total year 1+2	***8 078***	***6 886 720***	***6 100 000***	***12 986 720***

Kista 2009-02-25

Bengt Ahlgren
Center Director

Olle Viktorsson
Chairman