Real-time Mobile Communication

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Summery

In this application we propose research in a quit new field - wireless real-time communication. It is true that mobile communication based on radio signals is a vast research field. It is also true that this research is nearly always focused on average behaviour, throughput, and bandwidth utilisation. We foresee a wider use of wireless communication based on radio frequency (RF) signals in industry and transportation. This, however, calls for research efforts leading to new coding/decoding techniques and, protocols for time critical traffic. In this project we intend to address three research topics:

- *New coding and decoding techniques making wireless communication available for time and safety critical applications*
- *New network topologies for wireless real-time networks leading to enhanced performance and new applications.*
- *Investigating the suitability of existing standards especially "Bluetooth" for real-time wireless communication.*

Problem statement

Communication in industry is of an increasing importance for the competitiveness of Swedish companies. An increasing amount of equipment and people is being connected by means of various types of networks. The communication is often required to meet real-time demands.

Wireless communication has tremendous growth. New services and equipment is being developed at an increasing rate. In industrial communication we have not yet seen the same development although wireless technology has the potential to create new applications and big savings, e.g. cabling costs.

Research- and development in technologies like wireless communication[1], nomadic computing[2], and "Bluetooth"[3], point to an increased use of RF channels in data communication. It is clear that industry strives towards the potential market of building local area networks based on wireless RF communication. It is anticipated to be a vast growth in this market during the coming years. Standardisation work has made progress in the respect that specific RF bands are now available for data traffic. The most common such standard is IEEE 807.11. A new technology called Bluetooth has very rapidly gained recognition as a standard. Both of these standards use an unlicensed radio band at 2.4 GHz and CDMA as access method.

These standards do not support the concept of deadline and lack any strategy of trying to successfully deliver within such a deadline. This makes them less suited, or in some cases not suited at all, for industrial application. We need a delivery service based on a wireless communication channel that is both reliable and timely. When we say reliable we mean that the reliability must be controllable in such a way that the application requires a service to deliver with a given probability. Timeliness implies that a message must be delivered within a given time (deadline).

Applications like communication between autonomous vehicles in an assembly plant [4] need a wireless communication service that is both reliable and timely. It has not yet been a breakthrough for this communication medium for industrial time- and safety-critical applications. Studies, by our group, of a proposed protocol [5] show, however, that error rates can be achieved which are as low as with wirebound communication. The use of wireless techniques would lead to great cost reductions in industrial applications where today wires are required, and would in general imply the possibility of entirely new applications.

In order for this to happen, these new communication protocols and their implementation must rest on solid analysis and verification. We therefore propose a continuation of our work on coding and decoding of time critical communication channels, multi-hop network architectures for real-

time wireless industrial communication, and the suitability of existing and emerging standards for real-time wireless communication.

Main ideas

We purpose a research effort, based on earlier work by the group, investigating the following aspects of wireless real-time communication:

Coding and decoding of time critical traffic

The use of deadline and the probability of successful delivery as QoS parameters will lead to a new framework for time- and safety-critical communication over RF channels. Probabilistic analysis of the communication mechanism of a system relates to reliability modelling, so that statements about the system reliability including communication can be made.

Protocols based on retransmissions of information, where the coding of the message is depending on the closeness to the deadline, are to be investigated. Analysis of this kind of protocol has been done with promising results[5]. New decoding techniques such as soft decision decoding [6] is promising in order to enhance the performance. As part of the continued research we intend to investigate these techniques and quantify performance metrics in an industrial environment.

Network topologies for industrial wireless communication

The research issue is to investigate network topologies and high level protocols for wireless real-time communication. The background is that the dominating topology with basestation and mobile units is not always well suited for industrial needs. The base station is connected to a backbone network and is thus seen as access point to this net.

In industry we often find that much of the traffic is local with just a smaller portion of global communication. An example is two nodes two meters apart communicating with each other and today needing a broadband channel established over the basestation 50 meters away. The basestation topology will then not be very well suited because it will introduce unnecessary delay and interfering radiation causing system degradation.

We therefore intend to investigate the multi-hop network structure for real-time wireless communication. The advantage of this network topology is that each node only have to reach its closest neighbours and outputs only very little interfering radio energy. The network also poses fault tolerant properties as traffic dynamically can be rerouted in the network. A first study of this kind of networks for real-time communication has been done by the group [7].The continuation of the work is to introduce new decoding techniques for CDMA that have the potential of making this network architecture an attractive candidate for real-time networks. By decoding several CDMA codes simultaneously a collision free multi-hop network could be achieved. This could mean a breakthrough for a new kind of network with very promising real-time properties.

Implementation and standardisation issues

Research in the area of communication must consider existing standards and the ability to implement the research results. The proposed research is of fundamental nature and is implementation oriented. There are fundamental questions concerning coding, decoding and modulation of time critical channels that needs to be addressed. In conjunction to this there is a need to investigate the real-time properties of existing protocols and if the new proposed techniques can be mapped on existing or emerging standards. This is especially interesting concerning the new emerging standard ”Bluetooth”. We intend to evaluate the real-time properties of this new standard for low cost short range radio communication in co-operation with industry .

Expected results and impact

We expect to reach a solid understanding of the basic properties of this real-time communication mechanisms and thus be able to make quantitative analysis of performances and security. This implies that a comprehensive model of protocol and the channel is developed. We expect to verify this model with relevant measurement in industrial locations.

In addition to this we intent to built hardware platforms for evaluating protocol properties. One such platform is based on wireless LAN modems. Another is an evaluation platform for Bluetooth for industrial use.

We hope that the research results can be the basis of new product in the field of wireless industrial communication within a 3 year period from now.

The project is expected to result in a licentiate degree and one PhD for two graduate students .

Project plan

Year 2000

Work packages:Investigation of deadline dependent coding (E. U.)
Basic properties of real-time multi-hop networks (U. B.)

Deliverables: Conference paper on deadline dependent coding

Mile stone: Licentiate theses for Elisabeth Uhleman (late in the year)

Year 2001

Work packages: Soft decision decoding in real-time wireless communication (E.U.)
Evaluation of real-time properties of the Bluetooth concept (U.B.)

Deliverable: Conference paper on real-time multihop network
Conference paper on evaluation of Bluetooth
Journal paper on Soft decision decoding in real-time wireless communication
Journal paper on routing in wireless real-time communication systems

Year 2002

Work packages: Verification of soft decision decoding in on industrial environment (E.U.)
Study of new access methods for wireless real-time systems (E.U.)
Multihop network based on Bluetooth(U.B.)

Deliverable: Demonstration of real-time multihop network
Conference paper on real-time networks based on Bluetooth
Journal paper on new access methods wireless real-time systems

Mile stone: Licentiate theses for Urban Billstrup

Year 2003 (early in the year)

Mile stone: PhD theses for Elisabeth Uhleman

Related research

Research on coding theory for mobile communication by Prof. Tor Aulin. Prof Aulin has been granted a Senior Individual Grant from **SSF** and he is also participating the PCC research initiative by **SSF**. Prof. Aulin is the main theses advisor for one of the PhD student in the group (E. Uhleman)

Research by Kang Shin on Quality of Service approach in scheduling theory.
Professor Shin and his group at University of Michigan are initiating a research program on an approach to scheduling where the application is involved in a negotiation of the service provided by the scheduling sub-system. These ideas are closely related to the ideas of QoS within the communication field.

Other research on real-time systems at CCA
The research at the Centre for Computer Systems Architecture at Halmstad University has two complementary themes: Embedded Supercomputing and Intelligent Mechatronics. The proposed project is highly relevant to both of these. Among the ten projects being run at the centre, the following have direct connections to the proposed project:

- Parallel architectures for high performance computing in embedded signal processing systems
- High speed communication in distributed real-time systems. Magnus Jonsson - Bertil Svensson
- Distributed real-time systems for active noise control.

Research at the Department of Computer Engineering at Chalmers University of Technology.
CCA and the Department of Computer Engineering at Chalmers have tight contacts through joint research projects and Ph.D. education. The following researchers and areas are related to the area of this application:
Jan Torin - Research on dependability of distributed real-time systems
Jan Jonsson - Symmetric multiprocessors in high-performance real-time applications
Jonas Vasell - Currently joining CR&T. This company is active in related areas to our group and is thus a future candidate for co-operation.

Relation to profile

The ARTES view of a real-time system as a collection of building blocks fits well into the framework proposed here with nodes interconnected via the proposed communication mechanism. This mechanism does not put any requirements on the node design. It is, however, a long term demand that nodes communicating via the service need to conform to a standard, thus this research effort must take standardisation work into account and possibly influence existing standards. This is an important issue that has impact on the industrial use.

Industrial relevance

The possibility to transmit safety- ant time-critical signals over a wireless channel means that large wiring costs can be saved. Also new applications that are not possible today will emerge. Wireless communication has until now been focused on speech transmission. Data transmission is a fast-growing area, and it is now realised that the development is towards a situation where the borderline between packet switched data transfer and speech transfer is not so clear.

Innovation team AB is a company active in design and implementation of wireless communication system. The real-time aspect is been put more in focus recently by the introduction of multimedia over wireless channels. The results from the research work will hopefully result in new services and products offered by the company. The company is partner in the project.

Industrial fielbus systems is an area well suited for introduction of wireless networks. HMS Fieldbus Systems AB is a company working in this area. The company has presented a technology for bridging over different standards of fieldbuses - ANYBUS. This has been accepted by many automation companies. Wireless connections would give fieldbus systems new flexibility and open up for new applications. The company is partner in the project.

The group is leading a masters theses project in collaboration with NDC AB on wireless real-time communication between autonomous vehicles in assembly plants. The research results are likely to have a big impact on the design of theses systems.

Another application is mobile measuring systems with time critical trigging signals. Such a system is the measuring of different parameters in a paper machine. Cables are a safety risk as they can be drawn into the machine causing danger to the user and possible damage to the equipment.

Relation to SSF programmes

In "Related research" above several SSF activities related to the research were mentioned. Among these, we have specifically co-operation with Prof. Tor Aulin.

Context

The research group

The following persons are included in the research team:

Bertil Svensson Professor	Scientific leader
Per-Arne Wiberg Lic.Tech. CE.	Project manager
Elisabeth Uhleman	PhD student
Urban Billstrup	PhD student
Tor Aulin, Professor	Adviser

Complementary activities and funding

This project until now has been funded by the Ministry of Education as part of a larger program and funds from Chalmers University of Technology.

Masters theses project funded by KK-foundation.

Research co-operation

Research at Department of Computer Engineering: Prof. Tor Aulin (as mentioned above)
Chalmers University of Technology, Department of Computer Engineering (as mentioned above).

Industrial co-operation

Innovation Team AB - see supporting letter

HMS Fieldbus Systems AB- see supporting letter

Nestler &Dahlgren AB- NDC is a company developing transportation system for the manufacturing industry. These system have a big number vehicles communicating with each other. This traffic has hard real-time constraints. The research group co-operate with NDC in a masters theses project. This co-operation can be widened include more fundamental research issues.

Innovation Team AB and HMS Fieldbus Systems AB is participating the project as member of a reference group and providing case studies. All three companies are potential ARTES nodes.

Budget

Salary: PhD student (E. Uhlemann)	100%	3 years	939 000
Salary: PhD student (U. Billstrup)	100%	2 years	626 000
Salary: Senior researcher (PA Wiberg) (half financed by the university)	25%	2 years	218 000
Department cost, incl. equipment	(10% of the above)		178 300
Localities	(8.7% of the above)		170 633
University administration	(13.64% of the above)		290 800
TOTAL (for three years)			**2 422 728**

References

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2. http://ficus-www.cs.ucla.edu/travler/
3. http://www.bluetooth.com/v2/default.asp
4. http://www.lazerway.com/
5. http://www.hh.se/staff/bettan/
6. J.G. Proakis, *Digital Communications*, 3rd ed., McGraw-Hill, 1995.
7. http://www.hh.se/staff/remote/

Appendix

Short CV of applicant

Supporting letter from industry

Will be sent to ARTES by ordinary mail

Bertil Svensson, Ph.D., Professor

Date of birth: February 15, 1948, Eldsberga, Sweden.

Present position: Professor of Computer Systems Engineering, Halmstad University and Chalmers University of Technology, Halmstad and Göteborg, Sweden.

Qualifications:

- Ph.D. with the thesis "LUCAS Associative Processor Array - Design and Applications" at Lund University, Lund, Sweden, 1983.
- M.Sc. in Electrical Engineering at Lund University, Lund, Sweden, 1970.

Experience:

- December, 1998 to present: Professor of Computer Systems Engineering, Halmstad University and Chalmers University of Technology, Halmstad and Göteborg, Sweden.
- December, 1991 to April, 1999: Professor of Computer Systems Engineering, Chalmers University of Technology, Göteborg, Sweden.
- May, 1983 to December, 1991: Associate Professor in Computer Engineering, Halmstad University, Sweden.
- 1974 to 1983: Periodically Lecturer, periodically Research Assistant, Dept. of Computer Engineering, University of Lund, Sweden.
- 1977 to 1983: Co-founder and co-owner of Synthese, a company for development and production of development tools for microprocessors, Lund, Sweden.
- 1970-1971, 1972-1974: Teaching assistant, Dept. of Computer Engineering, University of Lund, Sweden.

Appointments:

- July, 1993 to April, 1999: Vice-Dean of the School of Electrical and Computer Engineering at Chalmers University of Technology and, as such, responsible for the undergraduate study programme (for the Master's degree) in Computer Science and Engineering
- November, 1987 to present: Head of the Centre for Computer Systems Architecture (CCA), Halmstad University, Sweden. (First called the Centre for Computer Science).
- May, 1986 to June, 1988: Initiator and co-leader of the Centre for Image Processing and Computer Graphics
- October, 1983 to December, 1991: Vice President of Halmstad University, Sweden.
- July, 1989 to October, 1991: Acting Professor of Computer Systems Engineering, Luleå University of Technology, Sweden.

Publications: More than 60 papers published in international journals and conference proceedings. Co-author of two books.

Research supervision: 13 Licentiate theses, 5 Ph.D. theses

Research orientation: Massively parallel computer architectures, real-time parallel computer systems, artificial neural networks, autonomous robot navigation.

CV for Per-Arne Wiberg, Lic.Tech.C.E.

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Per-Arne Wiberg was born February 18, 1953, in Karshamn, Sweden. He received his M.S. degree in mechanical engineering in 1992 from the University of Lund, Sweden, and his Lic.Tech. degree in computer engineering in 1996, from Chalmers University of Technology.

After studies in Lund he joined Karlstads Mekansiska Werkstad **1979** as research engineer. His task was to invent and evaluate new formation methods for formation of newsprint paper. He also verified a novel method for removing condensed water from drying cylinders.

1981 he joined Teknikdata as technical consultant and was dedicated to the development of the supervision systems for two Swedish nuclear plants, Forsmark 3 and Oskarshamn 3.

1982 he invented a new drying technique for the paper industry. The same year he was awarded the grant ”Idéstipendium” from Trygghetsrådet for this invention. In **1983** he was granted a patent in all the major industrial countries for this invention.

1983 he joined ASEA Atom as project manager for the development of subsystems of the supervision systems of Forsmark 3 and Oskarhamn 3 nuclear plants. He was responsible for the development of a periodic testing function of the reactor security system. During this period he also had the responsibility for the integration of a complete supervision system to Barsebäck.

1985 he was assigned project manager for the development of a new supervision system for alarm reduction in nuclear plants. In this position he led a group of 15 developers. Such a system was delivered to Leibstadt Nuclear plant in Switzerland. As chief designer he was involved in the marketing and contract negotiations for this installation.

1986 he joined Norsk Data as a member of a designer team developing a communication system (DISA) for the Swedish defence. The DISA system was specified to take care of all vital communication in peace, and war time within the Swedish defence.

1987 he was appointed technical manager and chief designer of the DISA system. In this role he had the responsibility for design and quality assurance of the total system. In this project several organisations were involved: Operating system design (Oslo), Communication subsystem (Trondhejm), user interface and communication software (Frontec, Stockholm). Due to financial difficulties for Norsk Data the project was withdrawn in 1989.

1989 he joined Halmstad University, Sweden, as lecturer in. Computer Engineering. His teaching and research interests were software engineering and real-time systems.

1990 he started a research project on development tools for hard real-time systems. The focus was on changeability and graphical programming.

1994 he received his Lic.Tech. degree in computer engineering on a theses on Change-Oriented Time-Deterministic Real-Time Systems.

1996 he was granted funding on an application to the EU Esprit program in collaboration with five other European research institutions and industries. Since then he has been project manager of the Halmstad node in this project(Motor Cycle Rider Simulator - MORIS). Discussions concerning national exploitation of this project has taken place with the management of Prosolvia AB.

1996 he was granted funding on an application to the KK-stiftelsen on an project proposal on active noise control using neural networks. Since then he has been project manager of this project (Orfeus). The first part of the Orfeus project has been successfully finalised. In this part the group shows that new methods for placing loudspeakers and microphones in an aeroplane cabin results in better noise attenuation than achieved before.

In 1997 he invented a new type of loudspeaker for active noise control. Industrial partners (Saab AB and ABB) in the Orfeus project has shown great interest in this invention. A renewed application to the KK-foundation was granted and the Orfeus project will be devoted to the application of this new loudspeaker in aviation applications and in ventilation systems.

1996 he invented a communication protocol for wireless real-time traffic and initiated a research effort. Initially a master theses work was performed on the new communication protocol. This work was successful and was awarded a grant by Sparbanken Kronan. An application for patent has been made for the protocol.

During **1997** and **-98** further development of this protocol has taken place. Basic research in coding and modulation, on the basis of this new protocol, in collaboration with prof. Tor Aulin at Chalmers University of technology. Industry has shown interest in the idea and there are ongoing discussions concerning exploitation.

1997 he was appointed chairman of the Swedish National Association for Real-Time (SNART).

At Halmstad University he is responsible for two lecture courses:

- *Distributed real-time systems* in the masters program
- *Real-time programming* in the undergraduate program

List of publications

Optimising the Placement of Microphones and Loudspeakers in an aeroplane Mounted Active Noise Control System using Stochastic Search Methods, Wolfgang Svensson and Per-Arne Wiberg Proc. Of *Noisecon'98*, Detroit, USA, March , 1998

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Brains for Autonomous Robots: Hardware and Surgery Tools, Lars Bengtsson, Bertil Svensson, Per-Arne Wiberg, *Presented at PerAc'94: From Perception to Action*, Lausanne, Switzerland, September 7-9, 1994

Change-Oriented Time-Deterministic Real-Time Systems, Per-Arne Wiberg, *Part of licentiate thesis*

Autonomous Systems Demand New Computer System Architectures and New Development Strategies, Bertil Svensson, Per-Arne Wiberg, *Presented at IECON'93* ,Maui ,Hawaii ,USA ,Nov. 1993

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Towards Modular, Massively Parallel Neural Computers, Bertil Svensson, Tomas Nordström, Kenneth Nilsson, Per-Arne Wiberg, *Presented at SNCC -92, Swedish National Conference on Connectionism*, Skövde, Sweden, September 9-10, 1992

A Modular, Massively Parallel Computer Architecture for Trainable Real-Time Controle Systems, Kenneth Nilsson, Bertil Svensson, Per-Arne Wiberg, *Presented at AARTC'92: 2nd IFAC Workshop on Algorithms and Architectures for Real-Time Controle*, Seoul, Korea, August 31 - September 2, 1992. *Publiced in Control Engineering Practice, Vol 1, No 4, pp.655-661*