On Distributed Real-time Systems:
the mStar Environment, Net-based Learning
and Context-aware Applications

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The aerial photograph on the cover of the thesis depicts the summer residence of the author’s family in Saltsjön, which is located in the heart of the High Coast in Ångermanland, Sweden.

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Abstract

This doctoral thesis presents two frameworks for distributed real-time systems, the mStar environment for Computer Supported Collaborative Work (CSCW) and the Alipes architecture for context-aware applications, from the perspective of distributed teamwork and net-based learning.

The mStar environment was designed to be symmetric and fully distributed, which allows all users equal access and thus full interactivity, as well as scalable through the use of IP multicast and a server-less design. The environment makes use of reliable multicast, network resource management and packet loss recovery techniques to increase robustness. Heterogeneous networks and terminals are supported through tunneling and transcoding of media. Asynchronous use of the environment is made possible through support for recording and replay of sessions.

It is therefore well equipped to meet the requirements for net-based learning, as the inherent time- and location-independence allows students to follow distributed courses, when otherwise large geographical distances or time restrictions otherwise would limit where and when education could be offered. The student can be anything from a full-time student attending lectures physically at the university, to a part-time student following courses from his home during evenings and weekends. Students will thus have increased possibilities of taking part in education.

The Alipes architecture for context-aware applications allows multiple positioning techniques to be seamlessly interchanged and combined, enabling applications to utilize a single interface, yet benefit from several advantages that single positioning techniques cannot offer alone. Add peer-to-peer interchange of position information using ad-hoc networks, and the platform offers a wide variety of techniques to be interchanged or combined, with obvious advantages such as increased coverage and accuracy. Privacy issues are central to managing a user’s context information, for example his position, as that information could cause serious violations of personal integrity if misused. The Alipes architecture handles privacy through general criteria and contracts between users and location servers. Information exchange is typically carried out on a peer-to-peer basis using ad-hoc networks.

Integrated examples could be combining locating a nearby tutor with setting up a conference call to initiate a tutoring session, using context information to enhance the perceived feeling of presence within the mStar environment or to optimize network-usage depending on the user’s context. A final conclusion is that systems aiming at enhancing the social aspects of distributed applications by using context information might be important, if not vital, when creating new real-time services for mobile terminals.
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Preface

When I was little, I dreamed about becoming an engineer and a computer scientist. Not that I knew much about it, but those odd machines were fascinating and clearly represented the future to me. I vividly remember my father’s mechanical differential calculator at his office, early video games on my cousin’s TV (such as Pong), programming sprites on my father’s Luxor ABC computer at home, playing advanced games on our Commodore 64 and a friend’s Sinclair ZX-80, playing games on our Game&Watch Donkey Kong and Namco Pacman, using my Casio fx180p to program mathematical functions, and writing my project in Pascal on the “new color monitor PC’s” at the upper secondary school. Technology seemed to evolve at a rate that held great promise for the future. I decided to skip the fourth year of the course program at the upper secondary school and instead go directly to a university to study.

The greatest change in my life was therefore when at the age of 19 I moved up to Luleå in 1988 to study computer science at the university. It was a completely new world away from the safe haven of my previous life. I became acquainted with programming languages like ML, Modula-2, C, C++, Erlang and TCL-TK, while learning a great deal about computer systems in general. In 1990 I took a two-year break for my military service, which for me was good since I was tired of studying and needed new motivation. In the spring of 1994 I implemented one of the first WYSIWYG HTML editors together with Peter Parnes and a project group called IFTAP. In the autumn of 1994 I completed my Master’s thesis at Ericsson Erisoft in Luleå together with Mikael Nyström. It dealt with the specification of graphical user interfaces using early prototyping and hyperlinked requirement documentation using FrameMaker.

I graduated in early 1995 and started to work with software testing at Ericsson Erisoft. However, when asked by Peter Parnes and Dick Schefström in the spring of 1995 whether I was interested in starting to work at the newly founded Centre for Distance-spanning Technology (CDT), I accepted since it seemed adventurous. Since June 1995 my work, first as a graduate student and then as a research engineer, has been leading toward the completion of this thesis under the supervision and guidance of Dick and Peter.

It has been a rocky ride that has, however, offered a great deal of fun and been very rewarding. I have had the privilege to work with many very skilled persons in various projects and areas of research, as well as to travel to many locations in the world. I was first involved in the MATES project, where I worked on the mStar environment in general and audio tools in particular. I then worked briefly in the Roxy project with prototyping an integrated audio and video media client. I was also involved in the use of the mStar environment in teaching, giving several distributed courses with varying results, and taking part in the MediaSite project regarding net-based learning.
In 1998 a group of colleagues at CDT created Marratech AB, a spin-off company that commercialized the mStar environment. I worked for a year in parallel with my studies to assist in creating the first set of products. There were also other spin-offs like IT-Norrbotten, Effnet and Operax, which emerged as results of the projects at CDT and LTU during this time.

In June 1999 I presented my Licentiate Thesis on the mStar environment and net-based learning, and later that year I moved for personal reasons down to Stockholm to work at CDT from a distance. During this period I worked in the SITI-VITI, MediaSite and CampusNeo projects. I moved back in early 2001 to finalize my thesis by working in and leading the Alipes project on context-aware applications.

My supervisors and I believe that research should be carried out so that it may benefit society, but also that society could act to verify our research. The best way to achieve this is probably to implement and test research prototypes and systems. Therefore, a large component in my research concerns how to design frameworks for distributed real-time systems for the internet which are based on experience gained from early prototypes and close feedback loops from users.

The research carried out at CDT has therefore been conducted in close cooperation with industry, feeding back experiences from real usage into the research projects. This has been a success factor, even if the research performed has at times bordered on development. Our belief at CDT is that our collaboration with industry gives momentum and in some ways also direction to our research, in that we are allowed to try out our ideas and prototypes in real environments. Much of the work presented here is the result of needs and requirements expressed by users using our prototypes for electronic meetings and net-based courses.

It is said that being a graduate student is the schooling necessary for becoming a researcher, and the time at CDT and Luleå University of Technology has taught me many invaluable lessons. I do not claim to be an established researcher yet, far from it, but I am starting to realize what is required. It will be interesting to see what the future will bring.

Melbourne, May 2002
Kåre Synnes
Publications

This doctoral thesis consists of an introductory chapter plus ten papers. The introductory chapter provides a coherent discussion of the issues in the ten papers, and points out some future work in the area.

Paper A  Peter Parnes, Kåre Synnes, Dick Schefström, 
“The CDT mStar Environment: Scalable Distributed Teamwork in Action”. 
In the proceedings of Group 1997, Phoenix, Arizona, USA, November 1997.

Paper B  Peter Parnes, Kåre Synnes, Dick Schefström, 
“Lightweight Application Level Multicast Tunneling using mTunnel”. 

Paper C  Peter Parnes, Kåre Synnes, Dick Schefström, 
“A Framework for Management and Control of Distributed Applications using Agents and IP-multicast”. 
In the proceedings of IEEE Infocom 1999, New York, USA, March 1999.

Paper D  Peter Parnes, Kåre Synnes, Dick Schefström, 
“mStar: Enabling Collaborative Applications on the Internet”. 
In the Journal of Internet Computing, September/October 2000.

Paper E  Kåre Synnes, Peter Parnes, Dick Schefström, 
“Robust Audio Transport using mAudio”. 

Paper F  Kåre Synnes, Serge Lachapelle, Peter Parnes, Dick Schefström, 
“Distributed Education using the mStar Environment”. 
Paper G  Kåre Synnes, Peter Parnes, Johnny Widén, Dick Schefström,
“{Student 2000:} Net-based Learning for the Next Millennium”.
Research Report 1999:05, ISSN 1402-1528, ISRN LTU-FR--99/05--SE,
Luleå University of Technology, April 1999.
In the proceedings of WebNet 1999, Honolulu, Hawai’i, USA, October 1999.
Also presented in a shorter version at SCI/ISAS 1999, Orlando, Florida,
USA, August 1999.

Paper H  Kåre Synnes, Tor Söderström, Peter Parnes,
“Learning in Desktop Video-Conferencing Environments”.

Paper I  James Nord, Kåre Synnes, Peter Parnes,
“An Architecture for Location-aware Applications”.
In the proceedings of HICSS-35 (Nominated to Best Paper), Big Island,
Hawai’i, USA, January 2002.

Paper J  Kåre Synnes, James Nord, Peter Parnes,
“Location Privacy in the Alipes Platform”.
Research Report 2002:08, ISSN 1402-1528, ISRN LTU-SR--02/08--SE,
Luleå University of Technology, April 2002, submitted for review.

Related publications not included in this thesis:

Peter Parnes, Kåre Synnes, Dick Schefström,
“Real-time Control and Management of Distributed Applications
using IP-Multicast”.
In the proceedings of the Sixth IFIP/IEEE International Symposium on
Integrated Network Management (IM 1999), Boston, USA, May 1999.

Ulrika Wiss, David Carr, Kåre Synnes, Dick Schefström,
“CRES: a Competitive Reactive Eco-system Agent Architecture”.
Technical Report 1998:02, ISSN 1402-1536, ISRN LTU-TR--98/02--SE,
Luleå University of Technology, January 1998.

Peter Parnes, Mattias Mattsson, Kåre Synnes, Dick Schefström,
“The WebDesk framework”.
In the proceedings of INET 1997, Kuala Lumpur, Malaysia, June 1997.

Peter Parnes, Mattias Mattsson, Kåre Synnes, Dick Schefström,
“The mWeb Presentation Framework”.
In the proceedings of the Sixth International World Wide Web Conference,
Santa Clara, USA, April 1997.

Kåre Synnes,
“Net-based Learning and the mStar Environment”.
Licentiate Thesis 1999:20, ISSN 1402-1757, ISRN LTU-LIC--99/20--SE,
Luleå University of Technology, April 1999.
Acknowledgements

It has been a long journey: seven years from June 1995 to June 2002. This journey has been an experience that I will never forget, because I have learnt so much both on a personal and a professional level. I have had the privilege to work together with a number of persons without whom this doctoral thesis would not have been possible.

I cannot send enough thankful thoughts to my supervisor Dick Schefström for being a true visionary with the stamina to bring his ideas to reality, my resourceful colleague Peter Parnes for countless hours of advise and directions, Johnny Widen for being a centerpiece of stability, James Nord, Serge Lachapelle and Tor Söderström for working with me in projects and on papers, Ulrika Wiss, Fredrik Johansson, Bengt Lennartsson, David Carr, Anders Söderlund, Ulf Bodin and Paul McMillen for reading and commenting on my work, Mattias Mattson, Roland Parvioinen, Per-Erik Björk and the CD* people for believing in me. I would also like to thank Leif Kusoffsky for his vast efforts as an inspirational teacher and colleague, Sven Molin for organizing a sanctuary down-under for completing the thesis, Kristina Strandberg and Therese Ivarsdotter for all their caring support, and my friends at Marratech for bringing our vision to commercial reality. Special thanks to Mikael Börjeson for encouragement in times of distress. He mouthed “…but the packets that arrive sound good!” in a comforting voice when the sound from my machine was utterly distorted.

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I would truly be a lesser man without my family and friends. Ruth, your loyal love and kind heart will always make my day brighter. Olav, with your caring thoughtfulness and endless trust you will always be my role model. You are the all perfect parents. Leiv, my brother of blood and soul, with that special belief in me, I would be lost without you. I thank my cousin Stefan for being the third musketeer and a brother in heart. Thanks are also due to my relatives, Ulrika, Viktor, Karin, Per-Olof, Oskar, Elisabeth, Kristina, Katja, Paul, Bjorn, and all of you for your loving support. I would especially like to thank Mattias Wahlqvist, a true brother in arms, for always being there. Nor could I forget my close friends through blood, sweat and tears from the former A-group of Sollefteå Swimming Club for that special kinship, or all of you whom I have not mentioned.

Finally, I would like to thank my girlfriend Kristina, for her unrestricted love and selfless caring when enduring a distance-spanning relationship 1000 kilometers away.

Melbourne, May 2002
Kåre Synnes
“The best way to predict the future is to invent it.”

- Alan Kay, 1971

The Full Alan Kay Quote:

“Do not worry about what anybody else is going to do... The best way to predict the future is to invent it. Really smart people with reasonable funding can do just about anything that does not violate too many of Newton’s Laws!”

- Alan Kay in 1971, inventor of Smalltalk which was the inspiration and technical basis for the MacIntosh and subsequent windowing based systems (NextStep, Microsoft Windows, X-Windows, Motif, etc...).
To My Family and Friends