COMMIT

PROJECTPLAN

WORKPACKAGES

DELIVERABLES

BUDGET

SENSOR NETWORKS FOR PUBLIC SAFETY (SENSA) (P08)

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1. Background

The context in which SENSA operates is the increased complexity of society, with increased threats to safety in public places. This includes dangers coming from technical causes, like failing public transport infrastructure as well as malicious behavior of people, like vandalism or terrorism. Critical infrastructures such as power plants, large industrial areas, harbors, railway emplacements, but also people-rich structures like railway stations, are essential enablers of our economy and way of living. The threat to disrupt the normal functioning of these infrastructures is still growing and not likely to diminish in the coming years. The aim of this project is (1) to offer real-time automatic analyses of potential hazardous situations and detection of important events and (2) give support in these situations to first responders to guarantee the safety of the general public as well as of the responding authorities.

SENSA is a multi-disciplinary project that brings together partners from several scientific disciplines, commercial partners and public authorities. All are convinced of the seriousness of the increasing threat to safety in public space, and all know it is a problem without a simple solution that cannot be solved by just one party alone, or by parties separately. By collaboration SENSA not only contributes to a (technical) solution to this threat to safety, it will increase scientific and applied knowledge on heterogeneous sensor networks and strengthen the knowledge infrastructure, it will strengthen the economic position of the commercial partners, and it will support authorities in their effort to make public space more safe.

This project is a selective continuation of the successful BSIK projects Smart Surroundings and Freeband project AAF. ATHENA and COLOR INSIGHT are NTP projects in which Thales and TNO participate to combine infrared and night vision cameras (sensor fusion). Regarding ad-hoc communication this project continues where the Freeband AAF project left off, with extra dimensions in the direction of sensor networks. The framework developed in ICIS and adopted in SMart Surroundings is a candidate and potential starting point for SENSA's system architecture.

The IST-FP6 WASP project studies the full range from programming and configuring sensor networks to integrating them in a business environment. Part of the WASP results concerns a programming model that supports the coordination of large numbers of sensors. Though WASP has a much weaker notion of clustering, results of WASP may be applicable in SENSA. The ARTEMIS-SOFIA project studies interoperability and resource control of Consumer Electronics systems, including large numbers of embedded sensors and actuators (for, e.g., lighting control). The ITEA-CANTATA project studies video content analysis for low-resource devices like cameras. Artemiss JU project iLand researches deterministic behavior of wireless sensor networks and real-time streaming of data. Partners from WASP, CANTATA, SOFIA and iLand are also participating in SENSA. Other related projects are STW/Progress projects SmartCam and PreMaDoNA. SmartCam aimed at developing efficient architectures and corresponding design flow for intelligent cameras. SmartCam did not touch the network and data fusion aspects. STW

project NEST is a project on adaptive streaming application and architectures. EASY is on modeling streaming applications.

2. Problem description

Our research focuses on heterogeneous hierarchical sensor networks for safety and security in public places. In this context the project tackles problems in four areas: system architecture, intelligent streaming data sensors, networking protocols and distributed signal processing. Challenges common for all areas are heterogeneity, energy efficiency, scalability and dynamics. For the system architecture the major problem is the combination of processing streaming data (e.g. audio and video) and event-based processing (e.g. detection of fire or movement) in one system. These types of processing are totally different in nature (streaming data processing is complex, requires high bandwidth and has a low frequency of occurrence, while event-based processing is a low bandwidth, relatively simple operation with a very high frequency of occurrence) and not easily combined in one system, yet the architecture must accommodate both.

The major challenge for intelligent streaming data sensors is the ability to process streaming audio and video locally on the sensor in an energy efficient manner. The second problem is how to make already deployed sensors flexible so they can be remotely (re-)programmed for a specific task at hand. This may be because the actual situation demands a different type of analysis of the video stream, or simply because the software contains bugs.

One of the problems of a sensor network is its unpredictable behavior due to factors like mobility, varying number of nodes, changing radio communication circumstances or unknown communication paths from source to destination. However, the application of sensor networks in safety applications requires deterministic behavior as much as possible. SENSA faces the problem to devise methods, protocols and techniques to make the network reliable and real-time, while supporting streaming and event-based data. Another network related problem to be solved is how to deploy, program and reconfigure a large fleet of heterogeneous sensor systems. The last category of problems to be solved concern distributed signal processing (DSP). In most situations multiple sensor input is needed to catch a context. The first problem is how to reliably collect sensor data (see: network related problems) and to decide which data from which sensors is needed and must be combined to catch the situation (sensor data fusion). Once the situation is known, methods are needed to assess this situation for possible threats. A related problem is to find advanced algorithms for local and distributed activity and event modeling and understanding.

3. Objectives

Project's goal

It is our goal to increase safety and security in public spaces. Research shows that over 40% of people feel unsafe in the city. And, as demonstrated by the recent fire in a chemical plant and storage facility in Moerdijk, the authorities as well as the general public is often not well informed during emergencies. SENSA objectives are twofold. The first one is to increase (perceived) security in the city by means of a network of intelligent lamp posts (iLP) that keep watch over us with cameras and sound sensors. iLPs are able to autonomously analyze situations out of the ordinary and call for help if necessary. The second objective is to inform citizens and authorities about potential emergency situations, such as dangerous levels of CO2 or other substances that define air quality. Information is gathered by sensors in ordinary smart phones and by sensors attached to bikes, utility vehicles and public transport. The extend of spreading information is defined by the context: some information is only interesting locally, or becomes stale after a certain amount of time, while other information has global significance. Communication is opportunistic and uses the medium and sensors that is best suited or available. Information may be gathered centrally, while processed data is given back to the individual users, such as maps that show pollution or noise levels city wide, travel advice, etc..

Planning of all dimensions

The general planning over the dimensions results, impact and valorisation, dissemination, international embedding and synergy is as follows:

- A system architecture that supports these goals. During year 1 and 2 three iterations of the architecture will be made. All other tasks can start when the firsts iteration is available at M6. The final architecture is ready at the end of year 2 after feedback from other tasks. These tasks: streaming processing platforms, network protocols, and distributed data processing are executed in parallel and structured similarly: survey (finished M12), design and initial implementation (M24), final implementation (M36) and evaluation (M42).
- SENSA will employ 5 PhDs that will do most of the writing. We expect each PhD to write 1.5 journal paper (there will be collective papers), and 6 conference or workshop papers. This will result in approximately 38 papers, spread over the duration of the project. Following academic tradition, some of these publications will be after the project has finished. At the end of year 4 the PhDs will have written their theses.

Software developed will be open source where possible and available for download. At least two Android or iPhone applications are available through their respective app stores no later than M36. Two demonstrators will be designed and implemented, one for LANE and one for CLOUD (or opportunistic) scenarios: Urban Sensing and Flock of Phones. A third demonstrator will show the integration of the first two. LANE deploys cameras and sound sensors in intelligent and "green" lamp posts. We envision that results can be patented. Technology will be transferred to industrial partners and licensed to outsiders. Potential customers are authorities, like municipalities. CLOUD depends on public participation and results will be open source and available in app stores.Initial versions of the demonstrators are available in M36, final version will be shown at M48.

For the first two years a close cooperation with EIT ICT Labs "Digital Cities of the Future" is foreseen in the support of testbeds and staff mobility. Further plans to continue this cooperation in KICS and action lines in the following years are in preparation. Two workshops are planned, at M24 and M48. The workshops intend to collect input for the project and to start discussions with other parties (from COMMIT or external). There will be synergy with at least 2 other COMMIT projects: P12 and P19. P12 is involved in the integrated demonstrator, and with P19 the project will share scenarios.

Results

We plan to have a great number of scientific papers in different categories. The best results will be publicized as journal papers and conference contributions. The project will deliver algorithms for data fusion, signal processing and network protocols for data dissemination in linear array and cloud networks. A programming framework will be designed and implemented and a number of Android phone applications are planned. These apps will be publicly available via appropriate app stores. Working (likely FPGA based) implementations of the streaming platform are available at the end of the project. Two demonstrators are planned that use intelligent lamp posts and sensing mobile phone prototypes. Halfway the project and at the end open workshops are planned to present results and to encourage synergy with other projects. Insights gained in the project are used in several courses and projects, e.g., Ubiquitous Computing, Smart Environments, Codesign Project, Multidisciplinary Design Project (MDDP) and graduation projects. Software is whenever possible open source and made available, e.g., via Sourgeforce. The participating industrial partners will use the developed systems, methods, and tools withing their organization.

Deliverable Impact and Valorization

This project will lead to new (high level) network protocols for LANE and CLOUD type networks that may be utilized by other applications as well. E.g., information dissemination in phone networks can be used to spread emergency information between mobile phones when the normal GSM service is overloaded or unavailable.

Partners in ICT Labs Digital Cities of the Future showed interest is results and applications of our work. For 2011 and 2012 ICT Labs will provide catalysts for testbeds and mobility. In the years after that, we plan to propose to add patent catalysts.

The city of Enschede is interested in and willing to participate in applications for mobile phone sensing to measure "city stress" (air quality, noise, traffic logistics etc.). They will facilitate iLP deployment and mobile sensors on utility vehicles. The University of Wageningen and RIVM have shown interest in this (cheap) new way of sensing air quality.

Work on the intelligent lamp post (iLP) is expected to be ground for patents and licensing to third parties. In addition to its safety functions, the iLP is energy aware and reduces light

pollution. Work on mobile phone flocking is open source to encourage awareness and participation by citizens. Apps will be available.

Deliverable Dissemination

The defined use cases will be made available as press releases and to popular media. We also are planning to reach authorities (municipalities, RIVM) and the general public with our two demonstrators and applications in app stores.

The results will be used in existing and new courses at the universities. ESI plans courses for professionals as part of their consolidation tasks. ICT Labs Digital Cities of the Future provides catalysts for the project (testbeds, scientists' mobility and patents). The activities for 2011 are approved and new plans are being made for 2012 and after.

We plan to deliver a SENSA book based on the results and experience obtained during the project. SENSA papers will be presented at conferences and workshop, and already invitations for keynotes are received to present SENSA's vision. We will interact with relevant IIPs, such as IIP Sensor Networks and IIP Mobility.

International Imbedding

Our project's ideas are new, timely and innovative. Recent conferences are addressing similar aspects, but as far as we know, all of them use a different - less ambitious - approach. Although the project has not officially started yet, its objectives *have already attracted attention outside the COMMIT community. Sensing phones are researched at a number of places worldwide (MIT, Dartmouth College), but the idea of flocking phones and ensembles, is new and innovative. Also, the streaming data platform as used in the intelligent lamp post attracts interest from different parties. We have initiated cooperation with the University of Melbourne to come to intelligent cameras. During EIT ICT Labs workshops in Helsinki and Paris it became clear that parts of our project are going to be used as basis for a number of activities for 2011 and 2012. In particular, our project will be involved in the KIC Digital Cities of the Future, Safety in the City action lines.

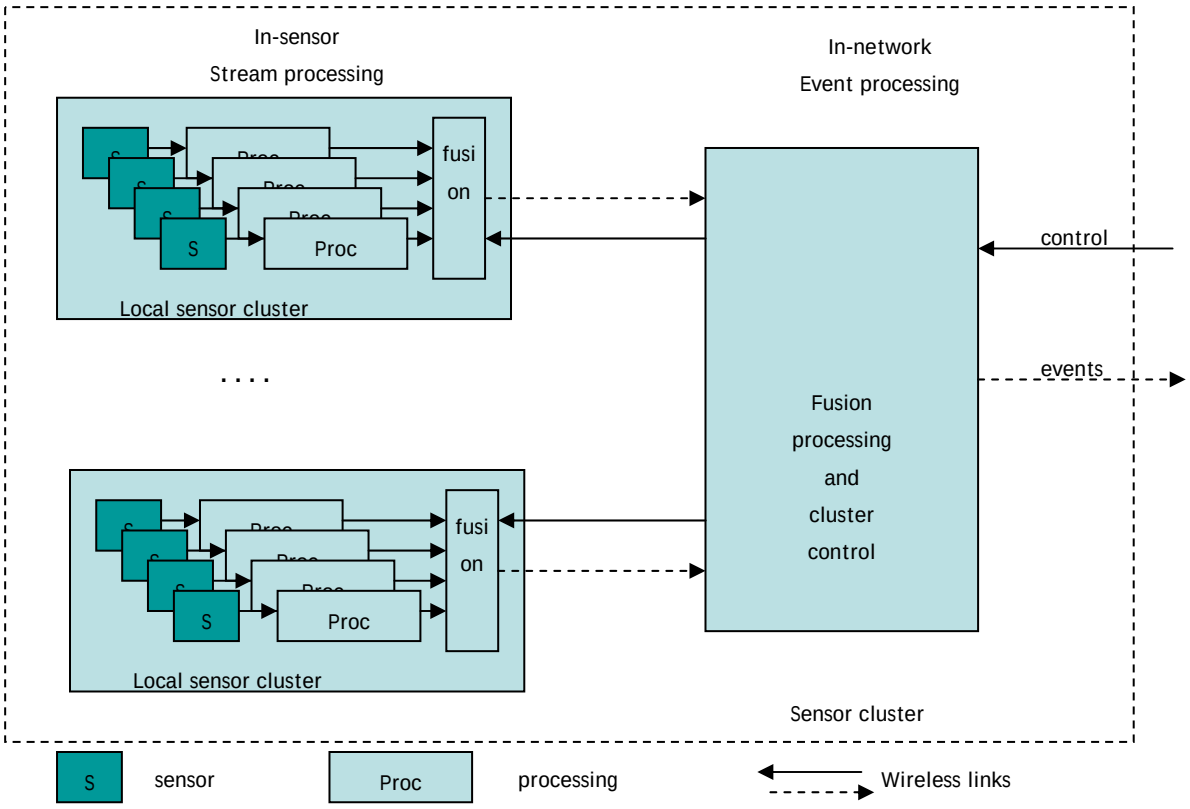
Based on the ideas of our project, we were invited to give a keynote at the Ubicomp 2010 Opportunity Workshop in Copenhagen on urban sensing. We are invited for the coming ESF workshop The Internet of Things for Sustainability organized by the *University of Brussels. We are organizing the Internet Of Things conference in 2012, in which we plan to have a separate track on our project's objectives.

Deliverable Synergy

This project plans to have two open workshops to discuss the results of the project and synergy with other projects. We will also participate in workshops organized by other projects. The

initiation of cooperation and enable synergy is one of the explicit objectives of the workshops. When the project starts, we will actively initiate bilateral meetings with other projects.

We plan to have a website available to COMMIT partners and will have newsletters at regular intervals. Specifically, ESI plans to integrate the P8 and P12 demonstrator, and there is cooperation in scenarios with P19. Although a strong intention is there, it is for individual projects difficult to get a detailed overview of all COMMIT projects and come to synergy. We encourage the organization of a COMMIT wide cluster workshop on public safety.



4. Economic and social relevance

Today, substantial monitoring equipment has been installed in many places but requires significant operator attention. Moreover, these systems are not integrated; they typically have fixed functionality and are not capable of responding to safety issues arising from spontaneous (unplanned) hazardous situations. Because there is no cooperation between different types of safety systems, the systems cannot be adapted after installation and cannot anticipate on emerging hazardous situations. This limits the effectiveness of these systems substantially.

A special category of equipment needs special mentioning here because of its immense potential in safety related systems: the mobile smart phone. Smart phones not only exhibit characteristics needed in safety systems, like a full range of sensors (audio, video, GPS, acceleration), powerful processors and sufficient memory, they are flexible in functionality and

have a huge installed base. Smart phones used in opportunistic and participatory sensing are par excellence suitable to create crowd awareness and participation.

SENSA proposes an integrated system approach where potential hazardous situations are automatically analyzed, assessed and, if needed, acted upon. The system is augmented by information collected through smart phone participatory sensing. It supports first responders to guarantee the safety of the general public as well as of the responders. Timely and effective responses to potential hazardous and unsafe situations not only increase the (perceived) feeling of safety, correct assessment of these situations can in many cases prevent a potential dangerous situation from becoming a real disaster with associated high or even extreme costs. The active participation through participatory sensing by citizens with their mobile phones will increase the chances for acceptance of the system and, in our view, add to the feeling of safety.
Correct assessment of situations resulting in authorities taking action when and only when necessary avoids wasting public funds and responders can be deployed in a far more effective and efficient way.

Safety in public spaces is par excellence a concern for government and public authorities and cannot be left to private parties alone. SENSA will answer scientific and societal relevant questions that transcend the capabilities of individual partners and that can only be answered with an integrated multi-disciplinary approach with public authorities participating.

SENSA leads to new (high level) network protocols for LANE and CLOUD type networks that may be utilized by other applications as well. E.g., information dissemination in phone networks can be used to spread emergency information between mobile phones when the normal GSM service is overloaded or unavailable. SENSA has drawn attention both at the national and international level. Partners in the newly started EIT initiative ICT Labs Digital Cities of the Future showed interest in applications of our work. Part of SENSA (opportunistic mobile phone sensing) is going to be used as basis for a number of activities for 2011 and 2012. Although sensing phones are researched at several places worldwide, the idea of flocking phones is new and innovative. We have initiated cooperation with the University of Melbourne in the area of streaming platforms and intelligent cameras. The city of Enschede is interested in and willing to participate in applications for mobile phone sensing to measure "city stress" (air quality, noise, traffic logistics etc.). The University of Wageningen and RIVM have shown interest in this (cleap) new way of sensing air quality.

Work on the intelligent lamp post (iLP, see scenarios in the appendix) is expected to be ground for patents and licensing to third parties. In addition to its safety functions, the iLP is energy aware and reduces light pollution, and may lead to new "green" markets.

Results of mobile phone flocking are intended to be open source and available to the public to encourage awareness and participation by citizens. Apps to support this will be available (see project plan).

5. Consortium

SENSA is a multidisciplinary project and requires partners with very diverse backgrounds (ranging from research institutes and high-tech companies to problem domain stakeholders) to cooperate and bring in their expertise and technology. The research has a highly exploratory nature that may put the Netherlands at the frontline of this domain. The SENSA project has brought together leading industrial companies in the safety and security domain.
In the consortium we have two problem domain owners (Philips Research (intelligent lighting), VTS Politie NL (national police organization)), four high-tech companies (VDG Security (smart cameras), Centric TSolve (system integrator), Thales Nederland (systems for public safety), Ambient Systems (wireless sensor networks) and three knowledge institutes (UT (chairs PS and CAES), TU/e (chairs SAN and ES), ESI).

Philips is a well-known supplier of lighting solutions for consumer, professional and public applications. Energy saving and public safety are important drivers for the introduction of dynamic lighting systems that adapt itself to current conditions. In the SENSA project, Philips will specify an advanced adaptive lighting control system that provides assistance in safety and security situations on the basis of sensor input. Such a system can be applied for example in road safety, personal security, public disorderly behavior, or safety in public transport. Dynamic sensor networks for lighting control are relevant when sensors are mounted on people or vehicles.

VTSPN employs 3000 highly qualified people and has a long track record in data and telecommunication solution for and from the police. The R&I department (around 12 people) developed and introduced prize winning innovations and graduation projects (Bakkenist prize for the best scientific thesis [on context-based services for “motoragenten”]). VTSPN was instrumental for the now worldwide TETRA standard. In the FRUX Freeband project VTSPN combines science and practice in the newly opened innovation-center-m-doit.

Thales Nederland employs about 2000 people. Its main products and services include surveillance equipment, combat management systems, weapon control equipment, program management and combat system integration, training and integrated logistic support. Over the years, the company has gained extensive expertise in implementing procurement programs together with local industries in customer countries and to cater for comprehensive Transfer of Technology programs. Thales Nederland Land & Joint Systems researches ground surveillance sensors, communication systems and hand-held electro-optic devices. In this field Thales Nederland masters the art of integrating its systems with virtually any system.

The University of Twente and the research institute CTIT (Centre for Telematics and Information Technology) participate in the SENSA project with the chairs CAES (Computer Architectures for Embedded Systems) and PS (Pervasive Systems). Energy-efficiency and dependability are the main drivers for the research of CAES. PS's main research topics are opportunistic and participatory sensing, wireless sensor networks, distributed data processing and their applications. Research of the groups is and has been sponsored internationally by EU and Artemis, and nationally by CTIT, BSIK, NWO and STW. Examples EU-FP5 Eyes 2002–2005, EU-FP6 project 4S Smart Chips for Smart Surroundings 2004–2007, EU-FP6 e-Sense, EU-FP6 COBIS, EU-FP6 TEAHA, EU-FP7 project CRISP 2008-2010, EU-FP7 project ADVANCE 2010-2012, EU-FP7 project So(o)S 2010-2012, Artemis projects TOETS 2009-2011 and iLand 2009-2011, BSIK projects AWGN 2003–2007, AAF 2005–2008, STARS 2009-2013, NWO projects Gecko 2002–2007, EASY 2008-2012, @HA 2002-2005, STW projects Chameleon 2000-2005, Feather light 2004–2009, CMOS beam forming 2008-2011, A4 2005-2009, NEST 2009-2013

The Embedded Systems Institute (ESI) aims to advance academic excellence and industrial innovation in embedded systems engineering, acting as a bridge between the high-tech industry and the 3TUs. In this project, ESI will concentrate on knowledge management and consolidation activities, as well as bring in its expertise on multi-disciplinary systems engineering. ESI's goal within the project is to consolidate the scientific results of the project (e.g., scientific knowledge, algorithms, tools), and to form a bridging partner between the projects P7, P8, P9 and P12, and possibly also with other projects within COMMIT.

The System Architecture and Networking group at Computer Science in Eindhoven works for many years in the domain of real-time embedded system. Past experience includes tight cooperation with Philips Research and other companies in the area of networked multimedia. In the BSIK Freeband project Ishare the group cooperated with research groups in the Netherlands on service composition for sharing. An ongoing cooperation with the department of Electrical Engineering (prof. De With, prof. Corporaal, prof. Basten) exists within several national and international projects. Relevant contributions for SENSA are the VITRUVIUS project (IOP Gencom) which studies access control to data and software running on a body sensor network; the IST-FP6 WASP project, which yields tools for programming and controlling large sensor networks; the ARTEMIS-SOFIA project which studies large numbers of embedded sensors and actuators (for, e.g., lighting control). The ITEA-CANTATA project studies video content analysis for low-resource devices like cameras and represents cooperation between VDG and TU/e-SAN. As these projects are running the SENSA project can benefit from the presence of the available researchers as well as from the tangible result of their work. Within SENSA, TU/e SAN will cooperate directly with TU/e-ES on the topic of sensor programming, with VDG on the topic of video sensor fusion and efficient sensor data routing. TU/e-SAN will bring tooling to the project as described above to realize part of the demonstrators.

The mission of the Electronic Systems (ES) group of TU/e-EE is to provide a scientific basis for design trajectories of digital electronic circuits and systems 'from (generalized) algorithm to realization'. Apart from the above mentioned cooperation with SAN and other academic partners, like UT Computer Architecture and Control Systems groups, LIACS in Leiden, and Computer Engineering at TUDelft, ES colaborates with most major DUTCH industries in the Embedded Systems are, including Philips, NXP, OCE and ASML and many smaller ones. Projects in ES which relate to SENSA are NEST, about the design of highly parallel streaming systems, requiring real-time guarantees, EVA about Embedded Vision Architectures, ALWwEN about sensor networks applied to personal healthcare, and the above mentioned project WASP. A lot of tooling on the predictable design an mapping of applications to multi-processor systems has been developed and is available for being used within SENSA.

Ambient Systems was founded in 2004 with the vision to create a robust, scalable, and very low-power embedded wireless networking platform for industrial applications. Ambient continuously works on research and product development, in which knowledge and years of experience in embedded systems, electronics, and communication networks are of major importance. Ambient Systems develops hardware and software to build reliable, low-power embedded wireless systems. Ambient's technology provides solutions for industrial automation, asset monitoring and security. Ambient has been involved in European IST projects on wireless sensor networks (Cobis, e-SENSE, and Sensei), and has been involved in the Dutch Smart Surroundings project on ubiquitous computing.

With more than 12 years experience as manufacturer and distributor of camera systems throughout Europe, VDG Security has established a leading position in the video-surveillance market. Started with our own developed digital video recorders, the DV-REC range. Later extended with specific applications for license plate recognition and facial recognition detection algorithms. The next generation is an completely new developed platform: DIVA, Digital Intelligent Video Architecture. It is based on open (IP) video management software with analytic support and IP devices with embedded analytics. The latest addition in analytics is the ObjectR Retail people counting software package. With a team of 14 highly qualified R&D people VDG is able to implement individual customer needs, a successful example is the POS interface developed for gasoline stations.

Centric TSolve B.V., as part of the Centric group (9.700 employees), is a professional services company based in the Netherlands and Germany focusing on embedded solutions ((http://www.centric.nl and http://www.tsolve.com). Centric offers end-to-end solutions for different areas, amongst others government, financial services, housing corporations, construction, trade and industry. Centric TSolve provides generic services like (remote) secondment, consultancy, product and system development projects and near-shoring. Our services encompass the complete product lifecycle and includes project, requirements, test, integration and configuration management, (system) architecture, (embedded) software

development, hardware design (digital, analogue, mixed board level design, ASIC, FPGA), functional and reliability testing, integration, type approval, logistics and production support services. We take overall responsibility and subcontract to partners if required. Centric TSolve develops products for many applications and delivers these to different Centric departments and to external partners and customers. We work on board computer solutions for the logistic market, on sensor systems for the healthcare market and on many products with wireless technology. Apart from the electronics and software development, Centric TSolve serves as the integration partner who also manages the pilot stages of the projects. In the HTAS-Eureka Cooperative Adaptive Cruise Control programme (Connect & Drive) and Senior (Pieken in de delta oost-nederland) project we work together with the technical universities, TNO, WMC, Fourtress, het Roessingh, Ambient, Inertia, Indes and TTC. In the Senior project we act as the system integration partner. At Centric TSolve we have an experienced team with embedded HW and SW competencies for end-to-end system development. We have experienced all-round engineers available for system integrations management, lead-integration engineers, integration engineers and integration and system testing roles. We are experienced in multi-national and multi-site cooperation with many development parties and are often in the (integration) lead in such cooperations.

6. Workplan

SENSA adopts the proven strategy to keep the structure in work packages of the project as simple as possible to maintain a high degree of control over the project. The Pervasive Systems group at the University of Twente leads the project.

The composition of the work packages is as follows:

- WP1: Architecture and coordination, led by ESI and UT
- WP2: Stream processing platforms, led by UT/CAES
- WP3: Networking, led by Ambient Systems
- WP4: Distributed data processing, led by UT/PS
- WP5: Coordination, integration and consolidation, led by Centric TSolve

WP1 and WP5 are "horizontal" integrating packages of the project with almost all partners participating. The main body and kernel of research are the work packages WP2, 3 and 4.

SENSA plans to have a number of scientific papers in different categories. The best results will be publicized as journal papers and contributions in well-known and prestigious conferences and workshop. The project will deliver algorithms for data fusion and signal processing and network protocols for data dissemination in linear array and cloud networks. A programming framework will be designed and implemented and a number of Android phone applications are planned. These apps will be publicly available via appropriate app stores. Working FPGA implementations of the streaming platform are available at the end of the project. Two demonstrators are planned that use intelligent lamp post and sensing mobile phone prototypes. Halfway the

project and at the end open workshops are planned to present results and to encourage synergy with other projects. Insights gained in the project are used in several courses and projects, e.g., Ubiquitous Computing, Smart Environments, Codesign Project, Multidisciplinary Design Project (MDDP) and graduation projects. Software is whenever possible open source and made available, e.g., via Sourgeforce.

WP1 has three main activities. The first one is project coordination with yearly progress reports. The second activity is the definition of two use cases. These will be the basis for the demonstrators in WP5. Descriptions of the use cases are to be published as press releases. The last activity is the definition of the architecture, which takes place in three steps. Each step is finished with a paper describing the work. Architecture is a common effort from all partners, while work on the use cases is mainly done by the business partners and ESI.

WPs 2,3 and 4 are on stream processing platforms, networking and distributed data processing respectively. They all follow the same structure: survey, definition, design and implementation, and evaluation. Each phase results in a paper.
Other results are:

- WP2: FPGA implementation of a streaming platform, and streaming data algorithms;
- WP3: final implementations of LANE and CLOUD networking protocols, and mobile phone app in the Android Marketplace;
- WP4: final implementations of data fusion, signal processing and programming framework; mobile phone app in the Android Marketplace;
- WP5: two open workshops, one halfway and one at the end of the project; two demonstrators, as described in a separate document (Appendix B). The scenarios are shared with adjoining projects in Commit, specifically P7 and P9.

Appendix A describes two scenarios of SENSA, two demonstrators that implement the scenarios and the innovations shown in the demonstrators.

	Year 1	Year 2	Year 3	Year 4
WP1 Architecture and coordination				
WP2 SoC stream processing platform				
WP3 Networking				
WP4 Distributed data processing				
WP5 Integration and consolidation				

WORKPACKAGES

Project number P8	
WP title & acronym	WP1: Architecture and coordination
WP leader	ESI (Architecture), Paul Havinga, UT/PS, coordination

Objective:

To develop architecture for a wireless network for monitoring and control that supports both streaming and event-based data. The architecture must: support two diverse types of network topologies that are typical for the application domain: LANE and CLOUD types of networks, including smart phone opportunistic networks, support heterogeneous sensors, actuators, and networks, provide a framework for distributed data and signal processing, event detection, and control-loops enabling a programming abstraction allowing dynamic and real-time reconfiguration and adaptation

Work package

The work package starts with a concise assessment and specification of the application requirements. The overall problem requires a thorough analysis of the combined sensor networks, the data to be fused, the level of sensor data enhancements/optimizations and the way communications between responders is affected by the environment. Two real-life use cases, defined in this work package, form the leading threads for the whole project. One case, provided by VTS Politie NL, employs intelligent cameras, vehicular mounted sensors, mobile phones and environmental sensing; and one case, from Philips Research, uses sensors networks for intelligent lighting systems for public infrastructures (e.g. roads, public transport). The former is basis for CLOUD networks, the latter for LANE networks. The architecture integrates both types of network and is used throughout the rest of the project. The (intermediate) results of WP1 are input for WP3, 4 and 5, while the same WPs are used for refinements in the architecture.

Task T1.1 Assessment and specification of the VTS case (VTS)

Task T1.2 Assessment and specification of the Philips Research case (PR)

Task T1.3 Specification of the system architecture (TH)

Task T1.4 Coordination (UT/PS)

Project number P8	
WP title & acronym	WP2: SoC stream processing platforms
WP leader	Gerard Smit, UT/CAES

Objective

To develop a wireless processing platform that is energy efficient, yet capable to process streaming audio and video data.

In the SENSA project an important part of the processing is done in or close to sensors. Audio and video are typical examples of streaming data that will be used in SENSA. This means that efficient stream processing platforms are needed that can be built into such sensors. Because of the flexibility, the programming platforms need to be programmable (or reconfigurable), and should enable easy and efficient execution of stream processing algorithms. Energy-efficiency is one of the major design constraints of such high bandwidth and processing intensive sensor nodes. It is expected that, in the coming years, semiconductor technology will advance in such a way that devices with hundreds of cores can be designed and will become available. Multiple cores of different type (e.g. low-power RISC, SIMD, accelerators, etc.) can be placed onto one (heterogeneous) platform interconnected by a Network on Chip (NoC). Such architectures are interesting because images from cameras and sound from microphones can be processed in parallel on a SIMD processor. Techniques will be needed to scale performance and power-consumption of individual cores through voltage- and frequency scaling or to isolate cores by switching them off completely. This last technique can also be used to switch-off faulty cores, increasing reliability of MP-SoCs. WP2 will not be able to deliver a real chip as prototype. Prototypes are functional FPGA implementations without the desired energy consumption profile that can be used in WP5. The results of WP2 are used in WP5.

- Task 2.1 Advanced power saving technologies to reduce the power consumption of processors for streaming applications (UT/CAES)
- Task 2.2. Development of low-power architectures for streaming data, with an implementation and evaluation on FPGAs (TU/ES)
- Task 2.3 Development of streaming data algorithms that can run on the developed platforms (VDG)

Project number P8	
WP title & acronym	WP3: Networking
WP leader	Lodewijk van Hoesel, Ambient Systems

Objective:

To develop methods, protocols and techniques to support streaming and event-based data in a heterogeneous sensor network.

This work package aims at developing efficient, robust and reliable communication protocols, which routes information between dynamic clusters being formed in the network by taking into account quality of service required by the application and resources available in the network. Routing protocols can be dynamically installed and adapted using the programming system of WP4.

Two cases are studied in particular:

large linear structures of sensor nodes (LANE) as occurring, for example, in street lighting and pipeline monitoring (in accordance with the Philips Research use case; see WP1)

clouds of smart sensor phones (CLOUD) with highly dynamic behavior and where nodes are heterogeneous and non-stable in terms of availability (in accordance with the VTS Politie NL use case; see WP1)

These network topologies are typical in the various application domains, and have different requirements and system characteristics. LANE and CLOUD networks will be able to interact and use each other's infrastructure in several ways. E.g., mobile phones are used as data mules to offload (stored) information from sensors in street lighting (as found in delay tolerant networks), or sensors in street lighting are used to augment mobile phone ensembles (see WP4). WP3 uses WP1 as input and its results are used in WP4 and 5.

Task T3.1 Networking protocols for LANE wireless sensor networks (AS)

Task T3.2 Opportunistic network protocols for participatory and opportunistic sensor nodes (UT/PS)

Task T3.3 Integration of LANE wireless sensor networks and CLOUD smart sensor phone networks (UT/SAN)

Project number P8	
WP title & acronym	WP4: Distributed data processing
WP leader	Paul Havinga, UT/PS

Objectives

To develop methods and techniques to reliably collect sensor data from diverse sources and to capture the context of a situation, to develop methods to analyze context and assess a situation, to develop and assess programming abstractions and a framework for correct design of distributed processing algorithms.

This work package develops techniques that detect events as well as abnormal occurrences and recognize out of the order activities in public spaces. It investigates new programming abstractions such as rule-based programming techniques to program a scalable network with hundreds of sensors e.g., as found in LANE type networks. For CLOUD networks this WP investigates data fusion by ensembles of smart sensor phones. An ensemble is an opportunistic cluster of smart sensor phones, with a collective set of sensors large enough to detect context and situations. Phones in an ensemble may have different kinds of sensor, but by sharing and fusion of sensor data, phones complement each other. Ensembles are highly dynamic and will search for and include phones until the set of collective sensors is sufficient to assess a situation. Mobile phone ensembles (CLOUD) are augmented by sensors in the infrastructure around, e.g. street lighting (LANE). WP4 uses the results from WP1 and 3 and its results are input for WP1 and 5.

Task T4.1 Distributed data fusion-based event detection in ensembles of smart sensor phones (UT/PS)

Task T4.2 Distributed signal processing and control for situation assessment (TU/ES)

Task T4.3 Programming framework (TU/SAN)

Project number P8	
WP title & acronym	WP5: Integration and consolidation
WP leader	Rudi Broekhuis, Centric TSolve

Objective

Integration, evaluation and consolidation of the results of the architecture, stream processing platforms, networking protocols, and distributed processing techniques.

In WP5 the results of WP2, WP3, and WP4 will be integrated and evaluated based on the cases defined in WP1. For each case a small-scale prototype will be developed and evaluated. The work will be embedded in the architectural framework as developed in WP1, which will allow the various parts and protocols to be integrated in the overall demonstrators. Work in WP5 will start with the first initial results from WP1, 2, 3 and 4 in M18. Integration is an iterative process that uses the results from the other WPs when they become available.

Successful knowledge consolidation incorporates a variety of activities: (1) the elaboration, quality improvement and generalization of research results, (2) the application of the results in a different context, i.e., in different projects within or outside of COMMIT, in completely different user domains or for new industries, and (3) the embedding of results in educational programs. WP5 uses the results from all other WPs.

Task 5.1 Integration and evaluation of the VTS case (defined in WP1, CLOUD) (VTS)

Task 5.2 Integration and evaluation of the Philips case (defined in WP1, LANE) (PR)

Task 5.3 Consolidation (ESI)

DELIVERABLES

Number of important journal paper
7

Number of important conference contributions
30

Products

1. Use cases

   Two use cases are defined in the first 6 months of the project. They are the basis for two demonstrators: Linear Array Urban Sensing, and Flock of Phones (see attached file for the description of two scenarios).

   - WP 1 YP 2011

2. Initial architecture

   Together with the use cases, WP1 delivers an initial architecture for SENSA at M6. This initial architecture is important because it is the starting point for WP 2, 3 and 4. The architecture has three main components: platforms, network and processing. The architecture includes:

   - two types of platform: an embedded platform for intelligent lamp posts, and mobile phones;
   - two types of network: linear array networks (LANE, as in a row of lamp posts), and opportunistic networks of mobile phones;
   - multiple types of processing: streaming data processing in lamp posts, distributed data processing in clusters of lamp posts, distributed data processing and resource sharing in ensembles of mobile phones.

   (N.B. the attached GANTT gives a detailed description of all work packages, tasks and deliverables, not just "initial architecture")

   - WP 1 YP 2011

3. Final architecture

   The initial architecture (for a description see previous point) is further refined in two iterations and the final version is available at M24. The architecture needs to be defined halfway the project, because it is essential for the final phases of all other work packages WP 2, 3, 4 and 5. - WP 1 YP 2013

4. Surveys

   For M12 several surveys are planned in WP 2, 3 and 4. They describe the state of the art for power saving strategies for streaming platforms (WP 2), networking in linear array networks and opportunistic networks (WP 3), and data fusion, signal processing and programming frameworks (WP 4). (N.B. Surveys not only in WP 2, but WP 3 and 4 as well)

- WP 2 YP 2012

5. Phone applications

   Two mobile phone applications are planned in M36. The application implemented in WP 3 shows how information is disseminated in a network of mobile phones in an opportunistic manner. Possible ways to communicate are via Bluetooth, WiFi or the GSM network. The second application is the result of WP 4 and shows how phones form ensembles (clusters of mobile phones) and share resources necessary *to complete a task. The applications will be made available through the Android app store. See also scenario 2, Flock of Phones, for more details of the applications. (N.B. WP 3 and WP 4)

   - WP 3 YP 2014

6. Initial design of Demonstrators

   In M24 the design of the two demonstrators is ready. The demonstrators are based on two scenarios (see first point). The design gives details on the implementation and setup of the demonstrators.

   - WP 5 YP 2013

7. Demonstrators

   The demonstrators are based on two scenarios. The demonstrators are ready in 2015 and are full implementations of the scenarios, and its integration.

   - YP 2015

Software

1. System sw for the streaming data platform

   The streaming data platform will be implemented as a multi-core system on a chip. This platform must be flexible and reconfigurable. It should enable easy and efficient execution of stream processing algorithms. Energy-efficiency is one of the major design constraints of such high bandwidth and processing intensive sensor nodes. Embedded system software en special techniques are needed to scale performance and power-consumption of individual cores through voltage and frequency scaling or to isolate cores by switching them off completely. This last technique can also be used to switch-off faulty cores, increasing reliability of MP-SoCs. There will be several stages in de design and development of this system software, but the final version is planned for M36.

   - WP 2 YP 2014

2. Application sw for the streaming data platform

   On top of the system software, the actual audio and video data processing takes place in the streaming data platform. This software implements the algorithms for image and sound recognition. An initial version is planned in M24, the final version is available in M36.

   - WP 2 YP 2014

3. Network protocol sw

   For both the intelligent lamp posts as well as the opportunistic network, protocols need to be designed and implemented for network communication. The iLP uses a special type of topology, the linear array, where each node has a limited number of neighbours. There is one main medium for communication between nodes. Communication in the opportunistic network, can use many means, ranging, from Bluetooth, WiFi to GSM (GPRS, UMTS), and from direct communication to delay tolerant networking (DTN). Network software for both types must be designed and implemented. The initial version is ready in M24, the final version in M36.

   - WP 3 YP 2014

4. Data fusion and signal processing software

   Phones must look around to find resources in iLPs or other mobile phones that are needed to form ensembles, so they may complete their task. This layer of system software lays between the network and application layer. Versions of this software are planned in M24 (initial) and M36 (final).

   - WP 4 YP 2014

5. 2d Software Application sw for mobile phones

   See previous section (Products: mobile phone apps). (WP 3 and WP 4)

   - WP 3 YP 2014

6. Programming framework

   Description Applications for linear array and opportunistic networks are distributed and inherently complex. SENSA will design and implement a framework for building applications from distributed resources with (soft) predictable performance, which is planned for M24 (initial) and M36 (final).

   - WP 4 YP 2014

User studies

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Other results

1. Theses

   Five PhD students are working in SENSA. The general subjects they will work on are: Energy efficient architectures, Streaming data architectures, Opportunistic networking and data fusion, Methods, tools and programming frameworks and Linear array sensor networks. There will be strong cooperation in the area of architecture, and all PhD use the scenarios as leading theme in their work.

   - WP 1 YP 2015

2. Workshops

   Two open P8-P12 COMMIT workshops will be organized, halfway and at the end of the project. The theme of the workshops will be sensor networking for public safety. The focus will be on architectural aspects for sensor networks for public safety, and means to add intelligence to such networks. The first workshop, at the end of year 2, will present initial results from the two involved projects (P8, P12) and outline the status and plans for an integrated demonstrator. We foresee two tracks, one targeting a scientific audience and one targeting (other) societal stakeholders. The workshop intends to collect input for the integrated demonstrator and to start discussions with other parties (from COMMIT or external) potentially interested in participation in the demonstration. Participation of external parties will strengthen the dissemination of results. Close to the end of the COMMIT program, by the end of year 4, a second workshop will present mature results from the involved projects and the integrated demonstrator. Again, we foresee two tracks targeting scientific and societal stakeholders.

   - WP 5 YP 2013

3. Input to courses

   Spread over all WPs and during the course of the project: Insights gained in the project are used in several courses and projects, e.g., Ubiquitous Computing, Smart Environments, Co-design Project, Multidisciplinary Design Project (MDDP) and graduation projects. We also plan to have invited lectures in these course by key participants of the project.

   - WP 1 YP 2015

4. Patents and licenses

   The character of the results for the sensing mobile phones is free and open source with the goal to attract as many participants in the general public as well as authorities as possible. However, we expect that work on the intelligent lamp post has a strong potential for patents and licensing. We plan to initiate *EIT ICT Labs action lines for 2013 and further to provide catalysts for patents.

   - WP 1 YP 2015

5. The SENSA book

   To conclude the project, the SENSA book is planned in M48. The book will contain materials for consolidation, such as papers, experiences, applications and software. The book is the combined effort of all project partners.

   - WP 5 YP 2015