Background and Mission

MediaTeam Oulu (MediaTeam), founded in 1997, is a research group of about 35 people at the Computer Science and Engineering Laboratory of the Department of Electrical and Information Engineering at the University of Oulu. MediaTeam conducts leading edge research with the objective of making a visible and lasting impact on society. This involves technology-led research in selected areas, unique deployment of a pervasive computing infrastructure at downtown Oulu and development of “proof of concept” prototypes that are subjected to empirical evaluation in the hands of real users in authentic setting.

The visible results of our past and ongoing research include, for example, the panOULU WLAN network and the UBI-hotspots at downtown Oulu.

MediaTeam is highly multidisciplinary and international in its activities, collaborating with domestic and international research partners from different disciplines and contributing to the international academic community. For example, Professor Ojala serves as the chair of the steering committee of the international conference on Mobile and Ubiquitous Multimedia (MUM) and co-chaired the UBI Challenge Workshop at Ubicomp 2010 in Copenhagen, Denmark. MediaTeam was awarded its first FiDiPro (Finnish Distinguished Professor) post in March 2010, when Professor Vassilis Kostakos from the University of Madeira was appointed as a FiDiPro Fellow. Further, Professor Henning Schulzrinne from Columbia University, one of the leading internet researchers in the world, kicked off his sabbatical with a three-month research visit to our research group in summer 2010.

Scientific Progress

MediaTeam’s main research areas in 2010 were urban computing, multimedia and pervasive service computing, P2P networks and wireless sensor networks.

Urban Computing

Urban computing is an emerging interdisciplinary research field which considers public spaces as potential sites for the development of ubiquitous computing. Urban computing is driven by two important and related trends, urbanization and rapid deployment of computing infrastructure in urban spaces. However, while urban spaces offer the greatest opportunities and strongest demands for ubiquitous computing, there is no fundamental theory, knowledge base, principled methods nor tools for designing and building ubiquitous systems as integral elements of the urban landscape.

The UBI (UrBan Interactions) research program, comprising of multiple projects (UbiCity, UbiGo, RealUbi, UBI Anthropos, Urban Flows and Networks) funded by the Finnish Funding Agency for Technology and Innovation (Tekes), the ERDF, the Academy of Finland, the City of Oulu and industry, continued in 2010. The new three-year Urban Flows and Networks project starting in January 2010 is funded by Tekes as part of the Finnish Distinguished Professor (FiDiPro) program, inviting Professor Vassilis Kostakos from the University of Madeira to Oulu as a FiDiPro Fellow. In 2010 the multidisciplinary research consortium coordinated by MediaTeam comprised of groups from five different universities in Finland, Japan and Portugal, not just computer scientists and engineers, but also architects, cultural anthropologists, artists and designers. The Finnish members were the Aalto University School of Art and Design (Professor Lily Diaz), the Oulu University of Applied Sciences School of Engineering (project manager Veijo Korhonen), and from the University of Oulu the Intelligent Systems Group (Professor Jukka Riekki), the Department of Architecture (Dr. Aulikki Herneoja) and the Cultural Anthropology (Professor Taina Kinnunen). The international members were the Ubiquitous Networking Laboratory from the Tokyo Denki University (Professor Yoshito Tobe) and the Madeira Interactive Technologies Institute at the University of Madeira (Professor and FiDiPro Fellow Vassilis Kostakos).

The objective of the UBI program is to introduce a visible change in society by building a functional prototype of an open ubiquitous city in Oulu. From the user community’s point of view, such a city appears as a smart urban space providing rich interaction between the physical, virtual and social spaces. From the R&D community’s point of view, the city appears as an open horizontal testbed stimulating innovation, research and development of new services and applications. The testbed enables urban computing research in an authentic urban setting with real users and with sufficient scale and time span. Such studies are important because real world systems are culturally situated, and cannot be reliably evaluated with lab studies detached from the real world context. By deploying a system for a sufficiently long time “in the wild”, we can establish the technical and cultural readiness and the critical mass of real users, both of which are needed for determining whether the system can be deemed ‘(un)successful’.

To realize the open ubiquitous city, the UBI program engages an iterative cycle of deploying a new open pervasive computing infrastructure at downtown Oulu, technology-led research and application-led research. The technology-led research produces new technology and knowledge, which together with the new computing infrastructure...
creates fresh opportunities for application-led research. It produces novel proof of concept prototypes, which are empirically evaluated with real users in authentic urban settings. This provides valuable feedback and creates new requirements on the technology-led research and the computing infrastructure.

In 2010, the key activities in the infrastructure deployment included the installation of the panOULU WSN network, the expansion of the panOULU BT network, the installation of the UBI-projectors, and the maintenance of the UBI-displays and the core services of the panOULU WLAN.

The panOULU WSN is an IP-based wireless sensor network comprising of 13 edge routers (Sensinode Nano-Router Ethernet 2.0 Reference Platform) across the city (Figure 1a). The ERs are equipped with an IEEE 802.15.4 radio on the 868 MHz band and the 6LoWPAN protocol stack. 12 ERs are installed inside the panOULU WLAN mesh APs (Figure 1b-c), so that the mesh AP provides enclosure, power and IPv6 connectivity.

It should be noted that a mesh AP having sufficient free space for housing a small ER was not planned, but was just a lucky coincidence. One ER is placed inside an UBI-hotspot. An ER has about 500 m line-of-sight range with 1 mW transmission power. The first two use cases for the panOULU WSN are automated power metering (see the UBI-AMI pilot) and environmental monitoring using low-power sensors.

The panOULU BT is a network of Bluetooth APs (each equipped with three BT radios) scattered across the city center. In 2010, 18 APs were installed at traffic lights (Figure 1c) and they use the panOULU WLAN for Internet access. An additional 12 AP’s are placed inside the UBI-hotspots. All APs sniff bypassing BT radios and the real-time traces are used for modeling pedestrian and vehicular flows and networks. Further, the 12 APs inside the UBI-hotspots are used for distributing multimedia content to mobile devices over no-cost BT connectivity.

Two high performance UBI-projectors were installed at the City Theatre in October 2010 (Figure 2). Both units comprise of a Sanyo PDG-DET100L projector (7500 ANSI lumens) placed inside a weather proof Tempest Blizzard enclosure, a MacMini Server, an amplifier, loudspeakers and an IP camera for providing a video feed of the projections for monitoring in the web. Further, a mobile projector unit comprising of a Viewsonic Pro 8500 DLP projector (5000 ANSI lumens), a Macbook Pro laptop and an aggregator has been acquired.

The heterogeneous computing resources of our ubiquitous city constitute a large distributed system which is arranged and virtualized by the UBI-middleware. In 2010, our middleware related activities focused on distributed resource management, and creating open and standardized API’s for the computing resources. We developed a web-based framework for managing the screen real estate of interactive public displays using declarative XML based descriptions of virtual screens, and a finite state machine expressed with the State Chart Extensive Markup Language (SCXML) and implemented with the Apache Commons SCXML engine. The framework includes an algorithm for transforming the declarative virtual screens into a sequence of steps required for transitioning between layout states. The framework separates the layout description from application logic which allows rapid configuration of the interaction model upon application deployment. The upcoming UBI Open Urban Service Network API comprises of a set of open API’s which will allow the general public, the open source community and the SME’s to develop their own applications and services atop the UBI infrastructure.

The application-led research is driven by the domain-specific problems of urban computing, which the UBI pro-
gram addresses by developing two types of “proof of concept” prototypes, demos and pilots. A demo is a short-lived small-scale evaluation of new technology, service concept or user interface paradigm. It is often implemented using rapid application development, and empirically evaluated in the form of a small user test either in a laboratory or real-life setting. Successful functionalities from the demos are integrated into pilots, which are longitudinal larger-scale prototypes of the future ubiquitous city evaluated by real users in an authentic urban setting. The evaluation quantifies the benefits brought to the chosen application domain, and generates feedback and requirements on the technology-led research and the computing infrastructure to be taken into account in the next iterative design cycle.

In 2010, the UBI program produced five research demos (UBI Ghostbusters, Ubinion, UBI-hotspot Video Guide, UFN Trails, UFN Heatmap) and two industrial demos by the SMEs supported by the UbiGo project. UBI Ghostbusters is a distributed pervasive game, where the objective is to hunt, with a mobile phone, ghosts appearing on UBI-hotspots (Figure 3a). Ubinion allows (young) UBI-hotspot users to playfully express their opinions, including automatic dissemination via Facebook and Twitter. UBI-hotspot Video Guide allows UBI-hotspot users to make video calls, which are managed and streamed using a RED5 Flash streaming server, and support real-time collaborative editing using Google Wave. UFN Trails establishes geospatial trails of particular devices from the wireless traces collected by the panOULU WLAN and panOULU BT networks. UFN Heatmap builds “heat maps” from the wireless traces to illustrate relative levels of activity around the city (Figure 3b).

In 2010, the UBI program conducted two pilots, UBI Pilot 2010 and UBI-AMI Pilot 2010 (reported in conjunction with wireless sensor networks). The UBI Pilot 2010 corresponded to the longitudinal evaluation of the UBI-hotspot version 2.0 (Figure 4), which was released at the 2nd Open Ubiquitous City Seminar on May 31, 2010. The new version of the hotspot included a revised interaction model including a subtle interaction phase, a new login mechanism based on Bluetooth ID and PIN, personalization of the hotspot in terms of visual appearance and Facebook integration, and a new “widget-based” service wizard and menu. The UBI-portal 2.0 contained a number of new services: a service directory, City of Oulu’s page, public transport, fast food in Oulu, UBI Mosquitoes game, 65 Degrees North news, and the first commercial third party services. We arranged in June-August 2010 weekly “UBI walks” that the general public could join to learn to use the UBI-hotspots. Research data was collected with various methods, including logging of quantitative usage, questionnaires, observations and interviews with hotspot users, and an online survey to Oulu businesses.

A common criticism targeted at many studies on interactive public displays is that their evaluation usually takes place in artificial lab environments and for short periods of time. Our hotspots represent the largest longitudinal study on the usage of interactive public displays by real users in authentic urban setting to date. It has revealed a number of factors that lab studies do not necessarily take into account: user sampling, location, curiosity, novelty, and weather. These substantial differences have led us to question the validity of lab studies in this domain. However, the external validity of our research comes with a substantial cost and a number of challenges. The greatest challenge in our deployment has been maintenance, as a substantial amount of our resources has been used to make sure that the system behaves as expected and to troubleshoot faults. Another challenge is the economic viability, ensuring that the hotspots become self-sufficient. To cover the operational expenses of the hotspots, we have generated revenue from commercial use, earning about EUR 105000 in 2010. However, the commercial usage has conflicted with
research objectives. A given capacity sold for example to digital signage has to be delivered, which constrains the screen layout and the interaction model. Thirdly, the discipline as a whole lacks standardized metrics for evaluating the success of such systems. In other words, despite the availability of huge volumes of quantitative and qualitative data on the usage of the hotspots, it is challenging to measure their actual impact on the community. Therefore, we applied for and were granted funding by the Academy of Finland on a new multidisciplinary four-year project titled “UBI Metrics - Multidisciplinary Framework for Evaluating Ubicomp Systems in Real-World Urban Settings”.

The dissemination of the results of the UBI program took place in different forms. We organized several international events and challenges discussed below. In 2010, we published two journal articles, one book chapter and 12 conference papers, one of which received the Best Presentation Award in ACM HotMobile 2010. The first UBI doctorate was born in May 2010 when Jürgen Scheible from the School of Art and Design of the Aalto University successfully defended his dissertation “Empowering Mobile Art Practice: A Recontextualization of Mobile and Ubiquitous Computing”. Four M.Sc. theses and two B.Sc. theses were completed in 2010. We gave presentations at 19 international events and three national events and appeared 36 times in popular media in 2010.

Multimedia and Pervasive Service Computing

The research on multimedia and pervasive service computing covers topics such as content processing, description, composition, and delivery techniques; service architectures; service provisioning and context-aware services. These research themes have emerged to be highly essential for enabling large-scale and interconnected multimedia systems and services, and have attracted industrial collaboration in several joint research projects. It is necessary for novel internet services to deliver topical and relevant content for end-users, while guaranteeing the quality of the service and experience. This includes also efficient search techniques for the contemporary multimedia services. Developing techniques for processing content descriptive data (metadata) elements enables scalable and interoperable service development and deployment.

The Collaborative aggregated multimedia for digital home (CAM4Home) project was a pan-European industrial project in the ITEA 2 framework program in 2007-2010. The objective of the CAM4Home project was to create a metadata-enabled content delivery framework to allow end-users and commercial content providers to create and deliver rich multimedia experiences for networked communities. These multimedia experiences were based on a novel concept of collaborative aggregated multimedia that was run on the CAM4Home service platform and metadata framework. In the project, researchers in MediaTeam designed and developed a content annotation service that creates semantic CAM objects from multimedia files utilizing computational content analysis techniques. MediaTeam also developed a web-based end user service that allows users to upload multimedia files and produce semantic CAM objects to the interconnected platform services and applications for various multimedia delivery, distribution and consumption tasks (Figure 5). MediaTeam was also involved in the design and development of the CAM metamodel and metadata framework that enabled interoperability between platform services to support diverse scenarios for multimedia creation, delivery, distribution, modification and consumption. In the project, MediaTeam published 14 conference papers, one magazine article and three book chapters, had one research visit, and organized three international workshops. The CAM4Home project was coordinated internationally by Thomson Video Networks, and the Finnish partner consortium was led by VTT. The CAM4Home received the silver ITEA Achievement Award 2010 at the ITEA2/ARTEMIS Co-Summit 2010 event. The project was placed second in the comparison of the ITEA2/ARTEMIS projects.

Figure 5. Web application for content annotation that detects person sequences from the uploaded media.

The Adaptive Content Delivery Clusters (ACDC) project is a pan-European industrial project in the ITEA 2 framework program that started in 2010. The goal of the ACDC project is to research, develop and demonstrate an adaptive content delivery cluster, intelligent user-aware applications and new business models. The project aims at novel user-aware multimedia and entertainment TV applications (IPTV, web/internet TV and mobile TV), on demand video and entertainment, personal video recording and targeted advertising services on a variety of networks and termi-
nals (set-top-boxes, PC and mobile) with adaptation, personalization and anticipation features based on semantic knowledge. As a technological enabler for user-aware multimedia and entertainment applications, the project will research, develop and demonstrate a distributed computing infrastructure for large scale digital content and semantic knowledge processing, storage and delivery. Over the distributed computing infrastructure, the project will focus on software tools and a service platform to provide a development framework for user-aware applications. MediaTeam contributes by researching and developing semantic knowledge processing technologies to support business and application scenarios for user-aware applications. During the first year of the project, MediaTeam has produced two M.Sc. theses and four conference publications. The ACDC project is coordinated internationally by Thomson Video Networks while the Finnish consortium produced two M.Sc. theses and four conference publications. The Pervasive Service Computing (PSC) project funded by the Academy of Finland continued in 2010. The PSC project is a collaboration project between the Intelligent Systems Group and MediaTeam of the University of Oulu and the Embedded and Pervasive Computer Center of the Shanghai Jiao Tong University, who will work together with the Shanghai Jiao Tong University, who will visit us in Oulu in May 2011.

The Digital Watermarking of Speech and Holograms project, funded by the Academy of Finland, concluded in 2010. The project focused on digital rights management technologies, especially digital watermarking of speech signals and holographic data. Holograms are widely used for protecting products or trademarks against forgery. In most cases, the authenticity check has to be done visually, or with some specialized equipment such as laser readers. Digital watermarking is a method of embedding a secret sequence of bits in the host media such that it is hard to perceive or remove. This signature, encoding the ownership and/or distributor id, can be extracted from the host signal when a proper secret key and the necessary algorithms are available. The essential technical challenges in watermarking include invisibility, robustness and capacity. A wide range of algorithms have been proposed for watermarking, especially for watermarking of digital images. Generally, however, the resilience of this information in a physical printout, like binary images, holograms or color images has been less studied.

We have been successful in developing robust methods that make possible the extraction of an embedded message from a print-out of a digital image with a scanner and camera phone, and from binary images with a camera phone. In these, especially in the DA/AD transform, distortions caused by user interaction and air interface have been considered. When a watermark is read from a hologram, the reading process should be robust against lighting and reflections as the hologram surface is very reflective. The hologram also differs from printed images in that the colors depend on the viewing angle and vary across the hologram. Figure 6 illustrates the problem of watermarking holograms. In 2010, we have developed a method for reading a watermark from a hologram and the detailed results will be published in early 2011. In the future, we hope to deepen the understanding of especially mobile phone readable watermarks in printed images and holograms as well as integrate technologies with augmented reality applications.

Figure 6. Watermarking of a hologram.
Further, the project developed novel methods of classifying emotional speech samples on the basis of prosodic features. Classification of the emotional content of short Finnish emotional [a:] vowel speech samples was performed with a new method using prosodic features derived from vocal source and traditional intonation contour parameters. A multiple kNN classifier based decision level fusion classification architecture was proposed for multimodal speech prosody and vocal source expert fusion. The sum fusion rule and the sequential forward floating search (SFFS) algorithm were used to produce leveraged expert classifiers. Automatic discrimination tests in five emotional classes demonstrated that significantly higher than random level emotional content classification performance is achievable using both prosodic and vocal source features. The fusion classification approach is further shown to be capable of emotional content discrimination in the vowel domain approaching the performance level of the human reference.

In 2010, as a result of ten years of research on content-based video retrieval, MediaTeam released Kuukkeli-TV (http://kuukkelitv.virtues.fi), a novel content-based search engine for indexing and retrieving television programs (Figure 7). Kuukkeli-TV allows users to search TV programs broadcasted in the Finnish DVB networks based on Finnish closed captions. The service matches query terms against metadata that has been extracted from the DVB stream, and returns a list of matching programs. The goal is to obtain knowledge of the impact and usage of novel content-based technology for accessing rich multimedia data. The users of the openly available service are encouraged to give feedback about the service in a short questionnaire and give votes on the quality of the hits. The service is unique in that it allows users to view matching content within the television program through multimedia quotes and allows them to search for a particular program’s web stream from the internet. The service is the first of its kind in Finland, and one of the first publicly available services in the world that utilizes multimedia content data effectively in locating and browsing timely video broadcasts.

P2P Networks

We have been witnessing a turning point in networking, so that peer-to-peer (P2P) based systems have challenged the traditional client/server (C/S) based systems. In the past ten years, P2P networks have rapidly evolved from the early unstructured systems towards structured systems, where the nodes are organized in a controlled manner, according to certain rules and topologies, such as distributed hash tables (DHT). P2P networks have also expanded from the traditional content sharing to a broader range of application areas, such as interpersonal communication (e.g. Skype) and social content distribution (e.g. Spotify), to mention but a few. At the same time, the mobile internet continues its growth due to the emergence of more capable mobile devices and wireless access technologies. P2P networking is thus becoming an interesting option for mobile devices, as well. However, mobile devices and networks constitute a challenging environment for P2P systems.

The key project in this research area was the Decentralized Inter-Service Communications (DECICOM) project that was funded by Tekes and industry was concluded in 2010. DECICOM was a so-called parallel project of two universities (University of Oulu and Aalto University School of Science and Technology) and three companies (Ericsson, Exfo NetHawk and Nokia). In addition, the consortium included two SME companies (Futurice and Iccom) as supporting members participating in the meetings of business and technology expert groups. The primary focus in our work was on the utilization of P2P technologies for communication purposes, referred to as decentralized interservice and interpersonal communications. The characteristics of interservice and interpersonal communications differ from the traditional resource sharing applications, leading to different kinds of traffic patterns and usage of resources. To enable experimental evaluations, we developed a prototype architecture consisting of both real-life and simulated protocol prototypes, as well as experimental applications on top of them. The prototype architecture is based on the forthcoming Peer-to-Peer SIP (P2PSIP) standard of the Internet Engineering Task Force (IETF).
Using the prototype architecture, we gathered a comprehensive set of results concerning the performance, robustness and efficiency of P2P systems in different communication scenarios, in both mobile and fixed environments. We evaluated the user experience, and linked the technical results with business analysis to establish guidelines for developing better solutions for P2P-based interservice and interpersonal communications. To summarize, we pointed out that further optimization for the current and emerging P2P communication technologies are needed on the protocol and algorithm levels, especially when they are utilized in mobile systems. We showed that runtime optimization of the P2P overlay is needed to ensure a high level of robustness, performance and efficiency of the system. Additional load balancing mechanisms are also necessary components in structured P2P systems due to the inability of the existing P2P algorithms to equally balance the load generated by the network management and the pay-load traffic. In systems including mobile nodes, fair load balancing requires advanced load monitoring capabilities that take into account the energy status of the participating nodes. Further, if a P2P network includes group management functionalities, organizing the overlay hierarchically according to the group topologies is the preferred solution for improving the performance, efficiency and security of the communication. Finally, structured P2P networks require advanced query mechanisms for providing a keyword search and other types of complex queries. By following these guidelines, the performance, robustness and efficiency of P2P-based interpersonal communication systems can be significantly improved.

In 2010, our research produced Zhongong Ou’s doctoral dissertation “Structured peer-to-peer networks: Hierarchical architecture and performance evaluation”, 4 journal articles and 2 conference articles. In addition, the DECI-COM project contributed to three doctoral dissertations at the Aalto University, as well as several M.Sc. and B.Sc. theses both at the University of Oulu and at Aalto University. International collaboration included two research visits to Columbia University in the USA. An important activity was standardization in the IETF, where the DECI-COM project partners published several RFCs and internet drafts related to the project. Research continues in the ICT SHOK Future Internet program that MediaTeam will join in 2011 for the third phase of the program.

**Wireless Sensor Networks**

The UBI-AMI Pilot 2010 conducted by the **UBI (UrBan Interactions) research program** focused on the real-time metering of energy consumption at homes using multi-hop IP-based wireless sensor networks. The architecture of the UBI-AMI system comprises of three functional building blocks (Figure 8a). Sensors in multiple 6LoWPAN sensor networks measure the loads and turn on/off devices connected to the sensors. Each network has a router collecting packets from multiple sensors over a multi-hop mesh topology, i.e. a sensor is able to forward packets of other sensors. The central UBI-AMI server receives packets from the routers, stores the data in a database and creates different representations of the data. The user can browse the measurement data with a web browser and subscribe to RSS feeds summarizing the data. Further, the user can control the sensors and subscribe to email/SMS alerts based on load measurements.

A socket sensor (Figure 8b) measures the loads of individual devices or groups of devices equipped with pluggable power cords. A mains sensor (Figure 8c) measures the load at the root of the load tree of a building, including all non-pluggable devices such as electric heating, water heaters and lighting. The sensors are furnished with a Radiocrafts RC2301 radio module which is equipped with an IEEE 802.15.4 radio on the 2.4 GHz band. The radio module is flashed with a Sensinode NanoStack 2.0 protocol stack, which implements the IETF 6LoWPAN specification for transmitting IPv6 packets over IEEE 802.15.4 devices. Effectively, the protocol stack provides the sensors with half-duplex multi-hop IPv6 connectivity. The sensors transmit measurement data every 10 seconds and receive possible turn on/off commands in a response message. We built the WSN router on an affordable Linksys WRT54GS WLAN router by adding a Radiocrafts RC2301 radio module to a free serial port connected to an external antenna connector. The Linksys router was flashed with customized Kamikaze OpenWRT Linux firmware capable of routing packets between the 6LoWPAN network and the internet. The UBI-AMI server was realized on top of the open source GSN (Global Sensor Network) middleware in Java. The UBI-AMI user interface (UI) was implemented as a website on top of the open source GlassFish application server as Java Server Pages, providing various views such as power and energy consumption. The user can also configure alarms received either via email or SMS to a mobile phone, and turn on/off individual socket sensors and the attached appliances.

![Diagram](image)

**Figure 8.** (a) UBI-AMI architecture; (b) Socket sensor; (c) Mains sensor.
The UBI-AMI system was assessed by longitudinal user evaluation in seven households in the Oulu region in 2010. While the households used the UBI-AMI system for 11 months, we only used the quantitative data collected in August-December 2010. By omitting the first six months we wished to eliminate any bias contributed by the curiosity and novelty value of a new system introduced in a household. Qualitative data was collected through questionnaires and interviews with the test users. The results confirm that visibility of both the aggregate load and appliance level loads in a home is very useful functionality that has an impact on how people use electric appliances. The UBI-AMI system shows that IP-based wireless sensor networks and the web provide a very potent technology platform for implementing such functionality in a cost-effective, reliable and standardized manner, in contrast to the many proprietary solutions on the market.

The Academy Fellow project Cross-layer Optimization of Wireless Sensor Networks led by Dr. Junzhao Sun has investigated high-level cross-layer optimization techniques for wireless sensor networks in a top-down fashion in order to bridge the gap between the technologies for modeling, processing and networking. Modeling techniques for applications, data, systems, and the environment have been studied. Processing techniques for query optimization and multi-sensor fusion have been investigated. The research has also focused on the networking mechanisms for self-organization and routing of sensor data. In 2010, the research has focused on SQL query language extensions for data collection and information retrieval in WSNs. To query the sensor database, four extensions to traditional SQL query language have been proposed, including timing, aggregations, QoS, and semantics. In each extension, the unique features of a database for wireless sensor networks have been taken into consideration. The proposals are general, and thus enable a database view with query based interaction applicable to most sensor network applications and tasks. Re-programmability refers to the capacity of being able to deploy applications dynamically to WSNs that have been deployed in the field, without the need for manual intervention. This capacity brings great flexibility and adaptability to WSNs, and thus has attracted increasing research interest. In 2010, the research produced a survey on existing OS-based approaches and code dissemination protocols for re-programming WSNs, and identified related research issues and trends. In the emerging pervasive social computing paradigm, an interesting topic is how to blog with automatically association of user behavior. In 2010, we developed Mlogger, an automatic blogging system that can detect, recognize and track user behavior for automatic association with new blog entries. In the system, Sun SPOTs were used for sensing raw behavioral data. The Mlogger processes the raw data and infers high-level user behavioral information such as “what the user is doing, and where, when, and with whom”. Associated with the inferred information, a new entry about user behaviors can be created and published automatically.

**Events in 2010**

MediaTeam organized and contributed to a number of events in 2010.

We organized the 2nd Open Ubiquitous City Seminar held in Oulu, Finland on May 31. The high profile seminar featured many distinguished international experts addressing various aspects of ubiquitous and urban computing. The seminar was capped with a panel, which gave the 140 strong audience an ample opportunity to interact with the speakers. (http://www.ubioulu.fi/en/2nd-Open-Ubiquitous-City-Seminar)

We organized the 1st International UBI Summer School 2010 held in Oulu, Finland, on May 31 - June 4. It comprised of six parallel workshops instructed by leading international experts on ubiquitous and urban computing: “Real World Context-Aware Systems” (Professor Anind Dey, Carnegie Mellon University, USA), “Urban Informatics and Sustainable Cities” (Professor Marcus Foth and Dr. Jaz Choi, Queensland University of Technology, Australia; Patrick Hofmann, Google, Australia), “Urban Social Networks Analysis” (Professor Vassilis Kostakos, University of Madeira, Portugal), “Creating and Sharing Artistic Experiences with Ubiquitous Technology” (Dr. Jürgen Scheible, Aalto University, Finland), “IP-based Wireless Sensor Networks” (Chief Nerd Zach Shelby, INFOTECH OULU Annual Report 2010 47

Figure 9. (a) Instructors of the 1st international UBI Summer School 2010 posing with their souvenir 'kuksas'. (b) Recipients of the best poster awards with Professor Timo Ojala.
Sensinode, Finland) and “Interactive Textures – rethinking materiality” (Professor Mikael Wiberg, Umeå University, Sweden). The summer school had enrollments by 72 students from 20 countries via an open international call. All students attended a number of joint events, including a poster session where students presented their background and ongoing research, an opening plenary where each workshop was introduced and the closing plenary where each workshop presented their results. Each workshop had its own curriculum and activities, which included theoretical presentations by the instructor and practical projects conducted in groups of 3-5 students. The summer school also included Adam Greenfield’s walkshop in downtown Oulu. In addition to researcher training, the summer school also promoted the upcoming UBI Challenge. (http://www.ubioulu.fi/en/UBI-summer-school-2010)

We organized the inaugural UBI Oulu Forum in Oulu on August 30. The forum invites researchers, practitioners and the general public to get together for engaging discussions on the broad and multidisciplinary fields of ubiquitous and pervasive computing. The stage is set by stimulating and maybe even provocative position statements by senior scholars, who anchor the ensuing discussion by serving as a panel for Q&A with the participants. Designated scribes record the discussion and present an immediate summary at the end. The theme of the first forum was real world relevance and the speakers were Professor Henning Schulzrinne from the Columbia University, Professor Vassilis Kostakos from the University of Madeira and Professor Timo Ojala from the University of Oulu. There were about 30 people in the audience, mostly junior academics. (http://www.ubioulu.fi/en/UBI-Oulu-Forum)

We organized the UBI Challenge Workshop 2010 (UCW 2010) at Ubicomp 2010, in Copenhagen, Denmark, on September 26. The workshop promoted the upcoming UBI Challenge and solicited original contributions within the broad scope of real world urban computing. The full-day workshop had two sessions. The morning session comprised of presentations of the four accepted papers, an overview of the recent activities in the open ubiquitous Oulu and an introduction of the UBI Challenge. The presentations provided the stimulus for the afternoon session, which focused on prototyping of new urban computing applications and services using different prototyping methods and starting assumptions. The workshop had 11 participants. (http://www.ubioulu.fi/en/UBI-Challenge-Workshop-2010)

We have organized two challenges to make our open urban computing testbed available to the greater R&D community and to stimulate the innovation of new services. The national UBI Challenge 2010 (UBI-haaste 2010) was opened in February 2010, challenging both individuals and organizations to innovate and implement new services to UBI-hotspots. A EUR 4000 grant was awarded to each proposal selected for implementation by a local expert jury. Further, the service deemed most successful among those deployed on the UBI-hotspots would receive an additional grant of EUR 2000 and a high end smart phone.

Participation was stimulated by a raffle of a high end smart phone between all entries. By the submission deadline in May 2010, we received nine valid proposals, from which the jury selected three for implementation: Battleship (game proposed by two local exchange students), Diversus Oulu (interactive multimedia art piece proposed by a local freelancer artist couple) and UBI Mixer (interactive music mixing application proposed by an SME). Eventually, Battleship and Diversus Oulu were successfully deployed on the UBI-hotspots. (http://www.ubioulu.fi/UBI-haaste)

The 1st International Open Ubiquitous City Challenge 2010-2011 (“UBI Challenge” for short) was prepared together with a number of leading international experts on ubiquitous and urban computing. It challenges the global R&D community to design, implement, deploy and evaluate novel applications and services in a real-world setting in the City of Oulu, Finland. The motivation of the international challenge is to stimulate global research collaboration on urban informatics in a very concrete manner, to provide the international R&D community with an opportunity to transfer ideas from labs into real-world urban environment, to make our testbed available to the international R&D community, and to support developing communities for evaluating urban computing infrastructure and applications in a real-world setting. Participation was encouraged by advertising that up to five proposals would be invited as finalists for deployment in Oulu, receiving a grant of up to EUR 10000 and a full paper in the MUM 2011 proceedings (subject to regular peer review by selected members of the challenge jury). The program of the MUM 2011 conference, to be held in Beijing, China, in December 2011, will have a special session dedicated to the challenge, including presentations by the finalists and the presentation of the awards to the winner(s). 11 written proposals were submitted by November 2010 deadline, three from Finland, six from Europe and two from outside Europe. The international jury invited four proposals to the final. All four proposals were submitted by European university teams, who will arrive in Oulu at the beginning of June 2011 to finalize the implementation and deployment of the service by the beginning of July. Empirical evidence will be collected in July-August for reporting in September. Further, the jury’s Oulu-based members will meet and assess the finalists in-situ. Each finalist has been assigned a dedicated liaison researcher to serve as the primary technical contact point. As the first task, the liaison researchers provided the finalists with detailed technical, content related and cultural assessments of the proposals in the light of our own knowledge and experiences of the open ubiquitous Oulu. (http://www.ubioulu.fi/en/UBI-challenge)

We contributed to the organization of the Oulu Open Hack on November 11-12. The 24-hour event solicited hacks in three categories: open, QML and UBI. Two “lightweight” UBI-hotspots were taken to the hack site at the premises of the Center for Internet Excellence. Two hacks were submitted to the UBI category, an adaptation of the Heia service and an adaptation of the FourSquare service. (http://ouluopenhack.posterous.com)
Personnel

<table>
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External Funding

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Doctoral Theses


Selected Publications


