1 Publishable executive summary

1.1 Summary description of project objectives

The aim of ATRACO project is to contribute to the realization of trusted ambient ecologies. Interactive appliances, collaborative devices, and context aware artefacts, as well as models, services, software components are parts of ambient ecologies. A context-aware artefact, appliance or device uses sensors to perceive its context of operation and applies an ontology to interpret this context. It also uses internal trust models and fuzzy decision making mechanisms to adapt its operation to changing context. Finally, it employs adaptive dialogue models to communicate its state and interact with people.

1.2 Consortium

ulm university universität uulm	Ulm University (UULM)	http://www.uni-ulm.de/
University of Essex	University of Essex (UESSEX)	http://www.essex.ac.uk/
Research Academic Computer Technology Institute CTI	Research Academic Computer Technology Institute (RACTI)	http://www.cti.gr/
CNRS LIMSI	Centre National de la Recherche Scientifique – Computer Sciences Laboratory for Mechanics and Engineering Sciences (CNRS)	http://www.limsi.fr/
inAccess NETWORKS	inAccess Networks (IAN)	http://www.inaccessnetworks.com/

1.3 Project Contact Details

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Project Logo

Fig. 1: Official project logo

Project Website http://www.atraco.org/

1.4 Work Performed

In this section, we describe the work performed since the beginning of the ATRACO project.

1.4.1 WP2 – Architecture and Integration

First Period
The main task of WP2 during the first year was to complete the system specification and design and to validate concepts. For that reason a state of the art survey has been done, ATRACO service specifications has been modelled and the architecture and system specification has been defined.

Second Period
The main task of WP2 during the second year was to coordinate the development of the first integrated ATRACO system based on the combined technologies of agents, SOA and ontologies and to test the intermediate prototype based on the 2nd Year scenario. This prototype matches to a certain extent the multilevel adaptation and trust requirements of the ATRACO objectives and addresses the challenges outlined in the context of ATRACO architecture. The prototype is able to realize a number of user goals as Activity Spheres and was implemented and tested both in the environments of the iSpace at the University of Essex (in the following: iSpace) and of the AmInOffice in Greece (in the following: AmInOffice). The current prototype features the following:

The Planning Agent is able to take an abstract plan and to find a concrete plan using Artificial Intelligence planning techniques. It semi- automatically provides the concrete plan as a workflow to the Sphere Manager. The Sphere Manager can read, parse and execute a workflow and bind dynamically devices to services by querying the Ontology Manager. An Activity Sphere can be established by the Sphere Manager that can start and coordinate all relevant components. Furthermore it can handle adaptation events that affect the configuration of the activity spheres with respect to a new person, a new resource (service/device), the changing location of the user, and the unavailability of a Resource. The Sphere Manager can control devices, provided that such devices are registered as UPnP and the corresponding device ontology has been defined.
The Ontology Manager can create the Sphere Ontology and answer queries posed by other components, by aligning resource ontologies (these include Upper Level Ontology, Device Ontologies, User Profile Ontologies, IA ontology, and Privacy Policy Ontology). The Fuzzy Task Agent can learn light preferences and can control lights and handle partial failures. The Interaction Agent can provide interfaces of various kinds depending on context such as user location. The Privacy Manager can support privacy protection to the user’s personal information as well as to the user’s personal space (when binding devices to services or when the “new person” adaptation event is produced).
The current prototype furthermore integrates UPnP device controllers and specific ontology instances. In addition we have updated the general ATRACO system design in terms of the constituent components to reflect the functionality integrated in the component platform.

Third Period
The main task of WP2 during the third period was to coordinate the development of the final integrated ATRACO system based on the combined technologies of agents, SOA and ontologies and to test the prototype in the iSpace testbed. In the context of WP2 we released ATRACO components as open source components and specified the interfaces for the final system prototype. The WP also supported technically the evaluation process during the extension period.
In a more technical view the following tasks have been accomplished:

1. replacement of the base UPnP communication driver with one specifically developed by the ATRACO consortium;
2. development of new device manager (use of Yupi library as a base communication library and support of interfaces and listeners for all the components);
3. upgrade from the service binding to a more complex device biding;
4. development of ATRACO BPEL extensions (full device binding, rule binding in conjunction with STEM, loop control, condition control);
5. design and implementation of new interfaces from SM to the rest of ATRACO components: IA: SM-IA communication has become event based, FTA: FTA now uses SM’s device manager and interacts with all the components though SM, TM: Seamless integration of the Trust manager in order to provide further trust information about the devices before binding, STEM: connecting with STEM, update the trigger, scene and associations in STEM, starting STEM rules, subscribing to STEM to listen STEM events, OM: Evolution of the interfaces in order to provide new required queries (such as whole device information), PA: Development of the appropriate interfaces in order to connect to OM in order to get the appropriate input for creating the rules and connect to SM to provide the BPEL output files);
6. development of mechanisms to support adaptation events including: device adaptation (new device added/ device failure), location adaptation (user is moving in space), user adaptation

(new user(s) entered/ left room), where these events not only are processed by the SM but also are passed to the other components, such as TM and IA in order to adapt accordingly;

7. design of a conflict resolution mechanism in SM working with a conflict resolution ontology that utilizes other ontologies that describe services and user profiles with preferences (examples of polices include aggregate functions (e.g., Average, Majority), FCFS, priority based on ownership);
8. implementation of generic log mechanism for logging times for further analysis for scalability analysis;
9. development of tools for visualizing device status and log events, a tool for visualizing activity spheres that includes workflow representation, task status, and current task bindings, in conjunction with OM, a user interface for user login and running spheres;
10. implementation of devices and services in AmIOffice for testing of the new ATRACO software and extensions to the User profile ontology;
11. integration of Alignment API to Ontology Manager, development of Alignment Ontology and integration with ATRACO upper level ontology and experimentation with Alignment Storing strategies;
12. development of a Proximity-aware device selection mechanism for ATRACO Ontology Manager;
13. ontology manager components execution speed optimization;
14. development of Trust Ontology Manager component for the needs of ATRACO UI and trust manager integration with API for synchronizing users with User Ontology Managers, adding and deleting Trust Groups, adding and removing members to/from Trust Groups, getting Trust Groups by owner, getting Trust group's members;
15. trust ontology modifications for supporting ATRACO UI (Added “groupname” data type property and owner object property for trust groups, in order to discriminate the groups created by each user);
16. development of integrated dynamic web user interface based on static html ATRACO UI: user web login and authentication based on cookies, extension of embedded web server for supporting data uploading, dynamic personal information editing page, Dynamic personal properties editing page, Dynamic trust groups editing page with storage in Trust Ontology.

1.4.2 WP3 – Ontology development

First Period

The main task of WP4 is to analyse the technical requirements and implement a set of basic components which complement the core research targeted components. An overall technical requirements analysis has been done and several basic components were derived. The implementation of those basic components supported the formation of the first year prototype which is the initial platform for the main prototype that will be developed in the next two years.

Second Period

During the second year, work in WP3 focused on engineering the complete set of ontologies required for the ATRACO research on alignment and for the system prototype as well as on the evaluation of alignment algorithms and the definition of the ontology management framework. More specifically, the set of engineered domain ontologies includes User Profile Ontology, Privacy Policy Ontology, Device Ontology, UPnP Device Ontology, Interaction Ontology and ATRACO

Upper Level Ontology[1]. Several instances of these ontologies were also created, to represent the devices in the iSpace and AmInOffice (the two project testbeds), other devices that can be found in a smart space, various users, etc. The Ontology Manager was developed to manage the system ontologies. In addition, an extensive survey of ontology mismatch issues and alignment algorithms was done, which resulted in the selection of a few existing alignment engines and APIs. These have been tested with the ontology instances (which were intentionally engineered to exhibit varying degrees of heterogeneity) and proven inadequate to support semantic alignment, which is a prerequisite for semantic adaptation of Activity Spheres. Nevertheless, the Alignment API is used in the first place, in order to support structural adaptation. The ontology management framework was designed, which includes (a) the ATRACO domain ontologies, (b) the Ontology Manager and (c) the Alignment API. Our proposal is to use a "trusted third party" to evaluate the semantic soundness of produced alignments; this can be an external knowledge repository, a human or an agent.

Third Period
WP3 has been concluded after the second period.

1.4.3 WP4 – Basic platform components

First Period
The main task of WP4 is to analyse the technical requirements and implement a set of basic components which complement the core research targeted components. An overall technical requirements analysis has been done and several basic components were derived. The implementation of those basic components supported the formation of the first year prototype which is the initial platform for the main prototype that will be developed in the next two years.

Second Period
WP4 has been concluded after the first period.

Third Period
WP4 has been concluded after the first period.

1.4.4 WP5 – Adaptation and evolution components

First Period
For the first project year the main task of WP5 consisted of collecting research results on adaptation and evolution of adaptive and trusted ambient ecologies. Exploring the suitability of existing evolving mechanisms for the adaptation of the ambient ecology, reporting on the research results, provision of specifications and driving the development of the corresponding components for the next project years were also lying within the focus.

[1] All these ontologies are available at http://daisy.cti.gr/svn/ontologies/AtracoProject

Second Period

WP5 has been progressing according to the timeline of ATRACO where the research on adaptation and evolution has been working to the plan as clarified in the following paragraphs where D13 has been updated with the ongoing research in adaptation and evolution within ATRACO.

We have conducted an in-depth research into short/long term adaptation of artefact behaviour. As part of this research, we have described the concepts of Artefact Adaptation (AA). We have specified the requirements of AA within ATRACO and have delivered a fully working AA component as described in D14. We have evaluated the AA module via a series of real world (using real devices) experiments conducted in the kitchen area of the iSpace.

In parallel we have conducted an in-depth research into short/long term adaptation of user(s) behaviour model where we specified the requirements of User Behaviour model Adaptation (UBA) within ATRACO. The specified requirements have subsequently been taken forward to create a design for UBA within ATRACO. We have established the reasoning for the application of rule based systems and in particular, fuzzy logic rule based systems, stressing their ability for generalization (essential for learning) and uncertainty handling as well as their well accepted interpretability. Experiments designed to expose the individual stages of UBA in the context of a real world deployment of UBA in the iSpace have been conducted and presented in D15.

Regarding Interaction Adaptation we have decided to extend the WWHT model in order to provide adaptive interaction capabilities. Our first work thus consisted of adapting the model so that it does not only output information, but so that it is able to provide real two ways communication. We decided to switch to an ontology based modelling of the interaction context. A prototype of the interaction agent is able to do allocation and simple evolution.

The functionalities of Activity Sphere formation, adaptation and evolution were achieved with the combined implementation of Sphere Manager and Ontology Manager that can support at the moment structural adaptation (while semantic adaptation is planned for the third year) at the sphere level. An experimental prototype has been developed in the AmInOffice testbed to test activity sphere structural adaptation. We use supervisory control mechanisms, which use the semantic descriptions in the sphere ontology to dynamically control the behaviour of the sphere. This approach supports the specification of multiple asynchronous control flows, each of which can potentially cause a state transition of the activity sphere under consideration. To the best of our knowledge, this work is the first to introduce the concept of discrete-event supervisory control in ubiquitous computing systems.

Regarding Network Adaptation we have introduced UPnP in the network adaptation component as a suitable technology for device and service adaptation. We have proposed an UPnP device model and provided detailed descriptions of several device UPnP wrappers that have been included in the second year trial of the project. Device adaptation was also implemented along the reverse path through wrapping UPnP services as devices in the OSGi framework. Thus, various external UPnP services tracked by the OSGi UPnP base driver can be registered with the OSGi framework. Furthermore, we revised some details of the OSGi platform base and the development framework. UPnP wrappers were also developed for certain web services participating in the second year trial, such as clock and weather services, as dictated in the specification of the network adaptation component. An alternative distributed protocol design approach was also analyzed and included in the specification of the network adaptation component. Under this approach, R-OSGi was evaluated as an alternative for UPnP. Hence, the Network adaptation component has been finalised as reported in D18.

Third Period

WP5 has been progressing according to the timeline of ATRACO where by the end of the third year, the research on adaptation has achieved all the objectives targeted by WP5. We have conducted an in-depth research into short/long term adaptation of artefact behaviour. In year 2, we have developed the Stage 1 of AA which focused on the dynamic creation of adaptive device models based on mainly short-term, direct user-device interaction information. In the third year, we have developed Stage 2 of AA which focused on medium to long terms adaptation both in the presence and in the absence of the user. Furthermore, the Stage 2 approach incorporates the creation of a human-centred model from the information gathered from a series of individual physical artefacts / devices. We have shown how the individual models are combined based on agreement modelling and a sliding window approach in order to provide continuous and stable AA able to deal with both short and long term changes in device characteristics. We have evaluated the AA module via a series of real world (using real devices) experiments conducted in the iSpace as described in D14.

In parallel we have conducted an in-depth research into short/long term adaptation of user(s) behaviour model. UBA has been implemented in two stages where the Stage 1 approach developed in year 2 has been shown to provide adequate user behaviour adaptation capabilities. However, the Stage 1 approach while interpretable by the user, remain difficult for the user to associate with. The Stage 2 of UBA was developed in year 3 to allow creating a highly dynamic and user-centred approach to UBA which provides rapid learning of user behaviour as well as adaptation to changes in that behaviour. Furthermore, Stage 2 allowed the realisation of UBA components that can handle multiple occupants in intelligent spaces, Experiments designed to expose the individual stages of UBA in the context of a real world deployment of UBA in the iSpace have been conducted with success and reported in D15.

During the third period, we created a formal model of Sphere adaptation based on Category Theory, we finalized the ATRACO alignment strategy (and developed a tool to support it) and we applied Swarm Intelligence to deal with cases where the Sphere has to adapt to operate without the presence of the Sphere Manager.

Regarding Network Adaptation, during the third period we focused mainly on supporting the final prototype, developing an alarm service and UPnP wrappers for new devices participating in the activity spheres developed for the final prototype. A major achievement during the third period is the enhancement of the NA layer with an OSGi based UPnP service for task execution, which is called STEM (Simple Task Execution Manager). Based on a simple or nested condition evaluation, STEM generates a UPnP event about the result of the evaluation and even executes a set of actions on one or more UPnP devices when the evaluation is true. In order to be able to evaluate conditions, STEM subscribes to the services of the devices that are included in the conditions of the various triggers. STEM, by itself, is not a UPnP control point, so it is not aware of the available devices. It becomes aware of the existing devices using the OSGi API of the OSGi UPnP base driver. When a STEM user adds a scene or a trigger, these are validated with respect to the existing UPnP devices.

Further effort relevant with the Network Adaptation developments involved a significant technical contribution to the development of the Youpi UPnP library and the respective OSGi wrapper according to the OSGi 4.2 Compendium specification, which was developed by the technical project team to support the prototype runtime environment, replacing the original Felix framework which suffered significant runtime problems.

During the second period we have extended the WWHT model in order to provide bidirectional (input and output) adaptive interaction capabilities to the Interaction Agent. After this, during the third period we have implemented the extended model and integrated it into the ATRACO system. Thanks to this extended model and to the development of an interaction ontology on which it is based, the Interaction Agent is now able to adapt the interaction to the user context.

1.4.5 WP6 – User interaction and privacy policy management components

First Period
Research on multimodal user interaction design and specification has been done in the first year. For that purpose a reusable Wizard of Oz platform has been developed and an evaluation with real users has been done.

Second Period
During the second year, six tasks were conducted: three of them were ending while three others were starting. The three tasks that were completed during this second year are T6.2 “Multimodal User Interaction Design, Specification and Tools”, T6.4 “Intelligent Planning” and T6.6”Privacy components”. Task 6.2 and 6.6 led to the design and development of the Interaction Agent and its software tools as well as the privacy components that were both integrated within the second year ATRACO prototype. Concerning Task 6.4 it was decided during this second year, in coordination with the other ATRACO partners, to use the concept of workflows to represent the control of the Ambient Intelligence environment. This required the development of an appropriate language for this purpose. The specification of this language, called ATRACO-BPEL, is still under development. For that reason, the integration of the Planning Agent (PA) into the ATRACO was done using a semi-automatic generation of workflows.
The three other tasks that started during this second year are T6.3 "Development of Simulation Tools", T6.5 "Adaptive Spoken Dialogue Modelling" and T6.7 "Trust Models and Trust Management". The first steps of T6.3 concerned the analysis of the simulation tool that we have already developed in the framework of the WWHT model in order to identify the new functionalities we must introduce in the new simulation tool and the old functionalities we should modify to stay pertinent in regard to the ATRACO approach. Concerning T6.5, the work done in this task lead us to the design and implementation of an ontology-based Adaptive Spoken Dialogue Manager (SDM). Furthermore three kinds of spoken dialogue adaptation have been identified: Device Adaptation, Event Adaptation, and Task Adaptation. A significant result is the design of the Spoken Dialog Ontology[2]. Finally, the work conducted within T6.7 aims at establishing a reliable and adaptable trust model. Different levels of trust have been identified. At each level specific approaches need to be applied. For instance, the ground trust level may use a certificate based approach with a public key infrastructure. To develop a higher trust level more sophisticated approaches based on observation of social interactions and user decisions need to be applied.

Third Period
During the third period, three tasks were conducted: T6.3 "Development of Simulation Tools", T6.5 "Adaptive Spoken Dialogue Modelling" and T6.7 "Trust Models and Trust Management". T6.3 concerned the development of software simulation tools which allows checking the interaction choices made by the designer before in-situ evaluation. Thus, we have developed a graphical

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[2] http://it.e-technik.uni-ulm.de/~heinroth/sdo/OwlSpeakOnto.owl

simulator, called "Simulate" that helps designing behaviours for the Interaction Agent. More details about "Simulate" are given in deliverable D20.
T6.5 addressed the implementation and integration of the SDM into the ATRACO system. A state-of-the-art Spoken Dialogue System has been used to allow spoken interaction within the iSpace test-bed. The SDM, integrated as a sub-component of the IA, updates the actual dialogue definitions during runtime and therefore enables the users to interact with the environment depending on the context. Besides deliverable D22 a further significant result is the SDM component, which is available as open source on SourceForge[3].
Finally, T6.7 investigated technical and social trust models. Technical trust is involved to establish trust between system components and services. The basic trust level is determined by digital certificates and signatures. Further trust level refinement can be achieved by combining this credential-based mechanism with reputation-based trust assessment mechanisms. Social trust is involved in multi-user scenarios. It is based on trust groups to enforce access control to user interfaces of an activity sphere. Both concepts of social trust and technical trust do further support the privacy manager in protecting information privacy and territorial privacy (see D23). The concepts were realized in a trust manager component. More details about the trust manager are given in deliverable D24.

1.4.6 WP7 – Evaluation and Testing

First Period
Definition of several visionary scenarios and their mapping to the five dimensions of adaptation has been done. A basic scenario that guides the development of the first year prototype combined with detailed task descriptions form the second part of WP7 during the first year.

Second Period
The second year objectives for Task 7.2, have been partially completed. The D27 deliverable details the outcomes of a concept validation study in accordance with Annex I – Description of Work (2007: 24), based on the on the second year ATRACO prototype and a scenario illustrating a future vision of ATRACO. The document will be updated with results for the evaluation of the prototype by the mid 2010, representing the completion of task 7.2. The study took stock of current development efforts and highlighted areas in which the social relevance of the work can be enhanced in terms of the direction of future development and in the way the work is discussed and presented.
Outcomes suggest that participants were generally positive about the notion of living with ATRACO and were particularly enthusiastic about the adaptation of the music player interface so that it always appeared on the device closest to them as they moved around the space. However, they were concerned about maintaining control over their environment, the changeable nature of human moods in relation to an electronic presence, the erosion of every day life skills and domestic cultural norms and rituals, and the risk of data loss and unauthorized access to the system. Participants suggested a key motivation for acquiring ATRACO would be energy saving and carbon reduction. The report recommends that in relation to the final year prototype, the ATRACO partners:

[3] http://sourceforge.net/projects/owlspeak/

- Consider how to balance perceptions of user control with symbiotic delivery of services.
- Consider how to provide support for the changeable nature of human moods
- Consider how to balance the minimization of human effort with the development of life skills and positive support for existing socio-cultural rituals.
- Consider how to minimize the risk of data loss and unauthorized access.
- Consider focusing development on energy saving and cost reduction

Third Period

The final year objectives for task 7.2 have been completed in accordance with Annex 1 (2010). The D27 deliverable details the outcomes of a qualitative social evaluation study conducted with ten participants involving iterative exposure to the prototype and the ability to play freely with the system functionality (in contrast to the scripted scenario based sessions in year 2) in line with reviewers expectations. It also summarizes the interim year two study.

The third year study was more comprehensive than the previous year in depth and scope, in response a more coherent and stable prototype. It involved a total of eleven participants interacting freely with the prototype in individual sessions based around three different Activity Spheres (AS); Entertainment, Sleep and Work/Study at home. Six of the participants returned to take part in all three of the AS sessions enabling them to become increasingly familiar with the system. Sessions were conducted in the UESSEX iSpace and each involved a period familiarisation with the functionality of the AS being evaluated, followed by a period, recorded on video, where the participant was left alone to explore/play with the system. Each session finished with a semi-structured interview, part of which involved the interviewer and the participant reviewing the video footage together and discussing the participant’s perceptions of the prototype and how it related to their everyday lives. This allowed the researcher to inquire about the participant’s emerging experience as well as their view from the end point. A closing interview was also conducted at the end of the three sessions.

In total 25 interviews were conducted generating over 620 minutes of audio data. The data was transcribed and then analysed (using Atlas ti) identifying themes, recursivities, contradictions and narratives that together provide a comprehensive reflection of the overall participant response to the prototype and the ATRACO concepts. Due to the exploratory nature of the inquiry, the findings are detailed and wide ranging, reflecting the participants’ responses to both the physical prototype and the overall ATRACO concept. The importance of context in qualitative work makes it difficult to reduce outcomes to a small number of sound bytes; however, key outcomes are tentatively summarised in D3 and D5 as follows starting with the responses relating to the individual components of the prototype and then the general themes that emerged from the data:

Overall, the evaluation efforts of WP7 have highlighted the strength of the AS concept and the importance of user control particularly in defining, setting up and managing AS groupings. They have shown that ATRACO is relevant to able-bodied householders (as well as having potential value in the area of assisted living) and that energy conservation would be a motivation to acquire the technology. The work also showed that non-instrumental user needs (e.g. domestic cultural values, moods and emotions) and existing, familiar devices and services play a significant role in the acceptability of AmI in the home, and should continue to inform any future development initiative.

As an exploratory study, the results provide the foundation for further qualitative and quantitative research on AmI in the home. The innovative approach to data gathering also contributes to the

discourse on evaluation method, particularly in relation to AmI in the home and the use of Living Labs in research.
WP7 also includes task T7.3: Simulations, and task T7.4: Scalability analysis. This task was led by RACTI and involved the research of the scalability of the ambient ecology concept. Tests were conducted on the prototype components in the iSpace and at RACTI with respect to the simulations and scalability of artefacts, the communication platform and the Ontology Manager. These tasks are now complete and the outcomes are documented in D28.

1.4.7 WP8 – Dissemination, Collaboration and Exploitation

First Period
This WP incorporates the development and execution of the project dissemination plan and the production of the project's promotion material. During the first year, the objective was to successfully position the ATRACO project in the European & International RTD arena.

Second Period
During the second year, the project team intensified efforts to increase the project impact to the scientific community. Numerous project publications were produced in 2009, demonstrating a significant increase of 450% over 2008. It is worth mentioning that by PM24 the project has published 45 scientific papers. The dissemination, collaboration and exploitation plan was revised with new action items. Besides the long list of project publications, further dissemination activities included press releases, participation in international events and committees, organization of international events, as well as participation in Panorama cluster initiatives. Collaboration within the project was significantly improved with the introduction of new tools (e.g. orderly meetings, focus groups, strict review procedures etc.) contributing to a sound project technical progress leading to a working second year prototype hosted in the iSpace in Essex demonstrating a "feeling comfortable with guests" scenario for concept validation and prototype evaluation. Furthermore, a project video was produced with the evaluation sessions that took place in the iSpace that will be enhanced with slides and animations in order to produce a project video.

Third Period
During the third period, the project team continued the intense efforts to increase the project impact to the scientific community. Approximately 40 publications were produced during the third period, maintaining the pace of the second period. It is worth mentioning that the project has published more than 80 high-quality scientific papers. Moreover, ATRACO invested a lot of effort and time in order to contribute a state-of-the-art scientific book to the scientific community, titled "Next Generation Intelligent Environments: Ambient Adaptive Systems". The book consists of eight chapters each covering a detailed look on a specific scientific area within the field of intelligent environments and pervasive systems. Besides the long list of project publications, further dissemination activities included press releases, participation in international events and committees, organization of international events, and participation in Panorama cluster initiatives. The harmonic collaboration of the project team, such as the large-scale collaborative task of system integration, focus groups and research collaboration, contributed to a successful technical progress leading to a working final prototype hosted in the iSpace in Essex and a valuable and sophisticated evaluation.

A final plan for the use and dissemination of the foreground developed in the project was produced during the third year, including amendments to the original exploitation plan and market background and a description of the mechanisms needed to promote the project results in relevant markets, the Consortium Agreement for use of foreground developed in the project and IPR handling, as well as a Technology Implementation Plan showing the impact and planned take-up of project results. In the Technology Implementation Plan we summarize what we have already developed in the project, the maturity level of the various components which will need to demonstrate a robust and trouble-free operation in a real deployment, the lessons learned, what is missing from the prototype system in order to reach the maturity level of a product system, as well as a product development plan starting from M36 accompanied with a commercial feasibility study and a SWOT analysis.

Regarding standardization, we have presented some proposals for contributions to standards based on promising results of the project. These proposals refer to architectures, methods, individual components and subsystems. Furthermore, several open source developments were made available to the community (e.g. UPnP library, STEM, Adaptive Spoken Dialogue Manager etc).

1.5 Main Results of the Project

First Period

Five dimensions of adaptation have been identified to be necessary to form an ATRACO system: Artefact Adaptation (AA), User Behaviour Model Adaptation (UBA), User Interaction Adaptation (UIA), Sphere Adaptation (SA) and Network Adaptation (NA). The research done so far to comply with those dimensions is described in detail in D13 “Research Results on adaptation & evolution”.

Another main result of the first year was the development of the basic concept and the fundamental system design of a working 1st Year Prototype, which uses the iSpace at the University of Essex as deployment platform. The identification and collection of both technical and user requirements was essential to guide the development process. The definition and engineering of ontologies and the first network adaptation component together with user interaction adaptation studies perfect the outcome of ATRACO.

Second Period

The five dimensions of adaptation mentioned above have been implemented to form an ATRACO system. Several components have been developed to realize all the dimensions: Artefact Adaptation Component for AA, User Behaviour model Adaption Component for UBA, Interaction Agent for UIA, Sphere Manager, Ontology Manager, and Planning Agent for SA, and a final version of the Network Adaptation Component for NA. An update of the research done so far is described in detail within the public deliverable D13 “Research Results on adaptation & evolution”.

Another main result of the second year was the development of the Privacy Components and the final versions of ATRACO Upper Level Ontology, Generic Device and Service Ontology, UPnP Device Ontology, User Profile Ontology, and the Privacy Policy Ontology. The development and the integration of the second year prototype in the iSpace and the AmInOffice are major milestones that have been fulfilled. Results of the social evaluation provided insights into the way users perceive pervasive systems such as ATRACO and into the broader concepts of ATRACO.

Third Period

The main task of the third year was to integrate the final integrated ATRACO system into the iSpace. In particular, we have implemented AA functionalities that focus on medium to long term adaptation of artefacts. UBA provides rapid learning of user behaviour in order to allow for a more user-centred approach of adaptation. In the third year SA utilises the Category Theory and incorporates a final version of the ATRACO alignment strategy. The most important enhancement regarding NA is based on an OSGi-UPnP bridge that has been implemented called as a component called STEM. For IA we have integrated the extended WWHT model and an adaptive Spoken Dialogue Manager into the ATRACO system. Furthermore trust aspects have been introduced by digital certificates and signatures. Further trust level refinement can be achieved by combining this credential-based mechanism with reputation-based trust assessment mechanisms.

Overall, the evaluation efforts of WP7 have highlighted the strength of the AS concept and the importance of user control particularly in defining, setting up and managing AS groupings. A major dissemination activity is the ATRACO book entitled “Next Generation Intelligent Environments: Ambient Adaptive Systems” published by Springer.

1.6 Expected Results & Impact

The potential impact of the ATRACO project is very considerable in the following key areas:

- ATRACO will provide an integrated approach to resolve the adaptation requirements of intelligent environments in terms of artefact operation, user behaviour, sphere composition, network selection and man-machine interaction with respect to user context and behaviour
- ATRACO will implement privacy management components which enable consistent privacy assurance in intelligent environments by introducing “content-sensitive” and “process-sensitive” privacy policies, which can be used to integrate different platform components in a trustable manner.
- ATRACO will integrate a combined adaptation strategy, with a sophisticated user interaction and privacy enforcement policy and measures the technology capability as well as the user acceptance through a number of prototypes that will be tested and evaluated in iSpace testbed.

This project will form a very important step towards the realisation of full ambient intelligent pervasive environments which are occupied by multiple users. The project will address many of the social, theoretical and practical research issues that will enable the creation of adaptable environments that can evolve in a lifelong learning mode to satisfy the user objectives. A wide range of application domains may benefit from research in this project including Health, Managed Public Environments, and Practice Skills Training.