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INFORMATION SOCIETY TECHNOLOGIES (IST)  
Specific Targeted Research Project (STREP)**



IST-2004-004042



**BETSY**

# **BEing on Time Saves energy**

## **Summary Final Activity Report**

**Project Month 1 to 30**

**1 September 2004- 28 February 2007**

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# 1 Publishable Executive Summary

## 1.1 Introduction

This Executive Summary comprises the objectives, the progress of the work and the dissemination activities within the Specific Targeted Research Project IST-2004-004042 Betsy – Being on time saves energy.

### 1.1.1 Contractors

The following table shows all Partners involved in the IST-2004-004042 Betsy Project.

Partner No.	Partner acronym	Partner name	Country
1	PHI	Philips	Netherlands
2	CSEM	CSEM	Switzerland
3	IMEC	IMEC	Belgium
4	ISI	ISI	Greece
5	MDH	MDH	Sweden
6	C-LAB	Siemens C-LAB	Germany
7	TUE	TU/e	Netherlands
8	UOC	University of Cyprus	Cyprus
9	TUK	TUK	Germany
10	NXP	NXP	Netherlands

**Table 1 Partners in the Betsy Project**

MDH was part of the consortium from 01/09/2004 to 31/12/2005.

TUK was part of the consortium from 01/01/2006 to 28/02/2007

Philips was the BETSY coordinator from 01/09/2004 to 28/09/2006.

NXP was the BETSY coordinator from 29/09/2006 to 28/02/2007.

### 1.1.2 Coordinator contact details

The following table shows the contact details of the Project Coordinator.

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### 1.1.3 Public Project Website

The Public Project Website can be found on: <http://www.extra.research.philips.com/euprojects/betsy>

## 1.2 Objectives and Results

### 1.2.1 Project Objectives

The aim of the BETSY project is to have multimedia streams on wireless hand-held devices seamlessly adapted to fluctuating network conditions and available terminal resources while reducing the energy consumption of the stream processing. This way the user can enjoy true multimedia experiences with freedom of movement in a networked home or at any hot-spot.

To achieve this, we need to be able to make trade-offs between the use and consumption of network and terminal resources, such as bandwidth use, CPU consumption, memory needed and power consumption by the terminal, while guaranteeing end-to-end timeliness - required for streaming data. The results of the BETSY project will make this possible.

The main topics, which are to be addressed by BETSY, according to the descriptions in section 6.1 of the project work plan in the DoW, can be summarized as follows:

1. The identification and study of the trade-offs between timeliness, saving energy in the terminal and utilising network and terminal resources.
2. The definition of an end-to-end timing model along with decomposition methods for the timing behaviours of all involved entities in the path, in order to move from a "closed-box embedded devices" to a "networked embedded devices" system design and implementation paradigm.
3. A high-level model which can describe a system in functional entities and their needed resource, temporal and power consumption characteristics without actual hardware characteristics to make re-use possible at this level.
4. A low-level model which captures the actual devices and components and their hardware/software resource and power consumption properties.
5. The definition of a common resource model to be used as an abstraction layer to hide lower level system parameters from higher-level temporal descriptions and QoS strategies. This will clearly reveal and capture the relationships between the model mentioned in 3 and 4 and make trade-offs during system design possible.
6. Finally, the common resource model will be delivered to the system for dynamic trade-offs during run-time in the form of a well-defined framework interface, or set of interfaces, which will transparently service requests for optimising the quality experienced by a user.

### 1.2.2 Work performed and Results achieved

WP1:

Refined scenarios and use cases were defined. A SOTA inventory of energy-power aware research, MPEG codecs, mobile devices and networking technology was conducted. Much time was spent to define the different concrete, physical and functional components that will be used in WP2 and WP3. To clarify the end-to-end concept for the researchers involved that so far usually looked at part of streams, the key concept of Breeze was also introduced to describe the multimedia streams that are controlled by a user. An overview of the BETSY system composed of Functions and Data Types, based on identified components. Finally evaluation criteria for the technical work performed in WP2-4 were defined.

WP2:

In order to provide user centric QoS on an end-to-end basis, the following issues have to be addressed.

- Analysis and expression of the semantic dependencies within a video encoded bitstream, e.g. as inter-frame and stream packet relations
- End-to-end timing specification in the delivery chain processing.

- Identification of functional component parameters having an impact on the end-to-end timing, such as CPU load, available network bandwidth (in exchange with WP3)
- Decomposition of end-to-end specification into low-level system parameters for the individual functional components involved and tradeoffs.

The BETSY framework (WP4) will use this information both for resource allocation decisions and as input to enforce end-to-end constraints locally on the involved entities.

The results of this work have been described in deliverables D2b, D2e and D2f. D2e and D2f are public deliverables. The next objective in WP2 is to provide for end-to-end decomposition of the BETSY breezes, based on the previous work in the work package.

Previous results of work-packages 2 and 3 eroded the border between the work-packages even more. Consequently, with approval by the reviewing team, the continuation work in this period - tasks 2.3 and 3.4 – have been carried out together for integrated model composition and end-to-end decomposition. The results are reported in deliverable D7 (which comprises D2d and D3d).

From the WP2 perspective, system wide trade-off methods have been developed to enable end-to-end decomposition for the models described in WP3 by using Pareto spaces.

These have been integrated with the framework implementation work of WP4.

#### WP3:

Within this period, the work package objective was to come up with the modeling of the elements. Starting from the set of functional components and devices selected by WP1, the different types of resources available on the devices were listed and classified. This list and the devices involved were to be used both by task 3.2 and by task 3.3.

- In task 3.2, focus was made on the video related components to find out how resource requirements could be met by changing the parameters of the listed functional components of the breeze and to map them onto the concrete resources of the devices.
- In task 3.3, focus was made on the transporting functional component in a similar approach as task 3.2 to find out how the changing of parameters could influence the usage of resources both on the interface side (the WLNIC) as well as on the processing side.

The final objective of those two tasks was to come up with a clear enough model and ways to build it so that not only we could move to task 3.4 to study the composition of those models but also to describe ways of building these models, i.e. the methods, so that it can be reproduced at a later stage.

The results of this work are described in D3a Parameter and resource requirements equivalence classes, D3b Device functional component models and D3c Network functional component models.

The final objective of WP3 was to take devices as a set of functional components and see how resource sharing could be described. Given the fact that the network in itself is shared between resources, it has been taken aside and considered as one independent element.

In Task 3.2 and 3.3, focus was made on individual components to find out simple models of resource usage listed in Task 3.1. During this last period, as part of Task 3.4, the goal was to take all those models and see what were their relationships. Those relationships were used to come up with possible trade offs on the involved resources.

The results of this task are described in the WP2 and WP3 joint deliverable D7, Model Composition and End-to-end Prediction.

#### WP4:

The objectives for the reporting period were:

- Take the scenarios to design a test-bed and demonstrators, which will make it possible to evaluate the BETSY results
- Specify the BETSY framework interfaces in such a way that this control framework can be used on different platforms, with different control algorithms to modify dynamically the critical parameters for power, network bandwidth and memory consumption and timing behaviour.

The main results of the reporting period were:

- The specification of the BETSY framework interfaces
- The design of the test-bed and the demonstrator
- The first version of the reference implementation of the BETSY framework interfaces on the test-bed

These results have been described in deliverable D4a: Specification of the BETSY framework interfaces and D4b Design report of the test-bed and demonstrator

The objectives for the reporting period were:

- Take the scenarios to design a test-bed and demonstrators, which will make it possible to evaluate the BETSY results.
- Specify the BETSY framework interfaces in such a way that this control framework can be used on different platforms, with different control algorithms to modify dynamically the critical parameters for power, network bandwidth and memory consumption and timing behaviour.

The main results of the reporting period were:

- The Betsy Framework (BFW) had been revised and used by the partners, leading to an improved version used in the final demonstrators.
- The BFW was successfully used on desktop / laptop computers as well as on portable devices like the IPAQ, the Nokia 770, and the NXP prototype NPP 2.0.
- Elements to determine available bandwidth and bandwidth fluctuations have been implemented as modifications of driver software and networking software.
- A fully adaptive encoder that allows parameter changes on the fly has been integrated as an element into the BFW.
- Elements to control the encoding parameters of an USB camera as well as a mobile wireless camera (AXIS) have been successfully implemented.
- Elements for laptop battery monitoring have been implemented.
- Graphical user interfaces for control of the BFW have been implemented using the BFW and controlling elements like the master controller (MC).
- The demonstrators for bandwidth fluctuation as well as for energy restrictions were revised and built.

These results have been implemented and described within deliverable D4.c (Reference Implementation of the BETSY framework) and D4.d (Demonstrator Implementation).

WP5:

An initial promotion plan and promotion package was made, a draft market and business plan was created, a BETSY public and internal website were set-up. Also an inventory of relevant conferences and journals to publish the BETSY results in was made and a list of relevant other research projects in the same field.

For easier daily project management, a project handbook (part of WP6) containing all information needed for the day-to-day execution of the project was created. This includes procedures for publications, meetings etc. that were agreed upon within the consortium.

The objectives for the reporting period were

- Creation of the dissemination and exploitation plan
- Active dissemination via conference presentation, publications and journal papers

This result has been described in D5e the dissemination and exploitation plan. During the reporting period members from the BETSY consortium gave 3 invited talks and 4 conference presentations. 9 conference papers, 2 standard proposals, 2 book papers and 1 book were published. As the BETSY project targets the very well-known problem in embedded systems for better performance and lower power consumption external visibility is also high. This can also be seen in the very recent mentioning of the BETSY project in the ACM TechNews of Friday, March 17, 2006.

The objectives for the reporting period were

- Revision of the dissemination and exploitation plan
- Active dissemination via conference presentation, publications and journal papers

This result has been described in the revised D5e, dissemination and exploitation plan. During the reporting period members from the BETSY consortium gave 17 conference presentations and papers, 2 standard proposals, and 2 journal papers.

WP6:

Daily project management.

### **1.2.3 Expected End Results**

The BETSY project will deliver all the theory, models and design methodology to make well-founded trade-offs between time-constraints, terminal and network resources and energy consumption possible during design time. The project will also deliver a framework implementation that makes dynamic adaptations in this trade-off possible at run-time. To verify the timing and resource model, the framework will be populated by selected components or modules, for example configurable codecs, bandwidth allocation controllers for WLAN cells and display drivers, which use the framework's mechanisms to adapt the processing chain to changes in the resources mentioned above. The framework and its components will be implemented in a streaming server and mobile clients (or equivalent evaluation boards), and evaluated against the scenario definitions and their evaluation criteria. The possible saving of energy consumption in the terminal in a dynamic way compared with traditional methods will be measured as well. The expectation is that the terminal energy savings, depending on the situation, can be in the order of 20%.

## **1.3 Use and Dissemination**

During this period dissemination via conference contributions and journal papers took off. Many publications are planned for 2007 and published in 2006. An update of the exploitation plan was written, in which the exploitation and dissemination plans became conclusions. Though it will be after the finalisation of the BETSY project before its results will be used in actual products, the roadmap towards transferring results in the business lines of the industrial partners has been laid out and first actions have been taken towards realisation.