DA8.6: Implementation of the PLM Process model for the Demonstrator

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ABSTRACT	This deliverable DA8.6 summarises the implementation of the PLM process model for the demonstrator, in terms of scenes, PROMISE components and technology implemented, as described in DA8.3 and DA8.4. The motivation for eventual discrepancies is given, together with the detailed results of the activities performed for the implementation.

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Abbreviations

Abbreviations used in this document:

PEID	*Product Embedded Information Device*
SA	*Smart Adapter*
ULP	*Ultra Low cost Powerline communication technology*
PC	*Personal Computer*
PDA	*Personal Digital Assistant*
DA	*Digital Appliance*
DSS	*Decision Support System*
PDKM	*Product Data Knowledge Management*

1 Introduction

1.1 Purpose of this deliverable

This deliverable (DA8.6) summarises the implementation of the PLM process model for the demonstrator, in terms of scenes, PROMISE components and technology implemented, as described in DA8.3 and DA8.4. The motivation for eventual discrepancies is given, together with the detailed results of the activities performed for the implementation.

1.2 Objective of demonstrator

The objective of Indesit Demonstrator is to show a household appliance (refrigerator) able to generate data useful for remote assistance and preventive maintenance purposes, and to send such data to a proper remote service centre (simulated by a PC) without adding significant costs to its digital control system.

To do this, a particular PEID is included inside the same control system of the refrigerator and an inexpensive proprietary communication technology is used to send data to the outside.

2 Description of the demonstrators

Figure 1 shows the Indesit Demonstrator architecture.

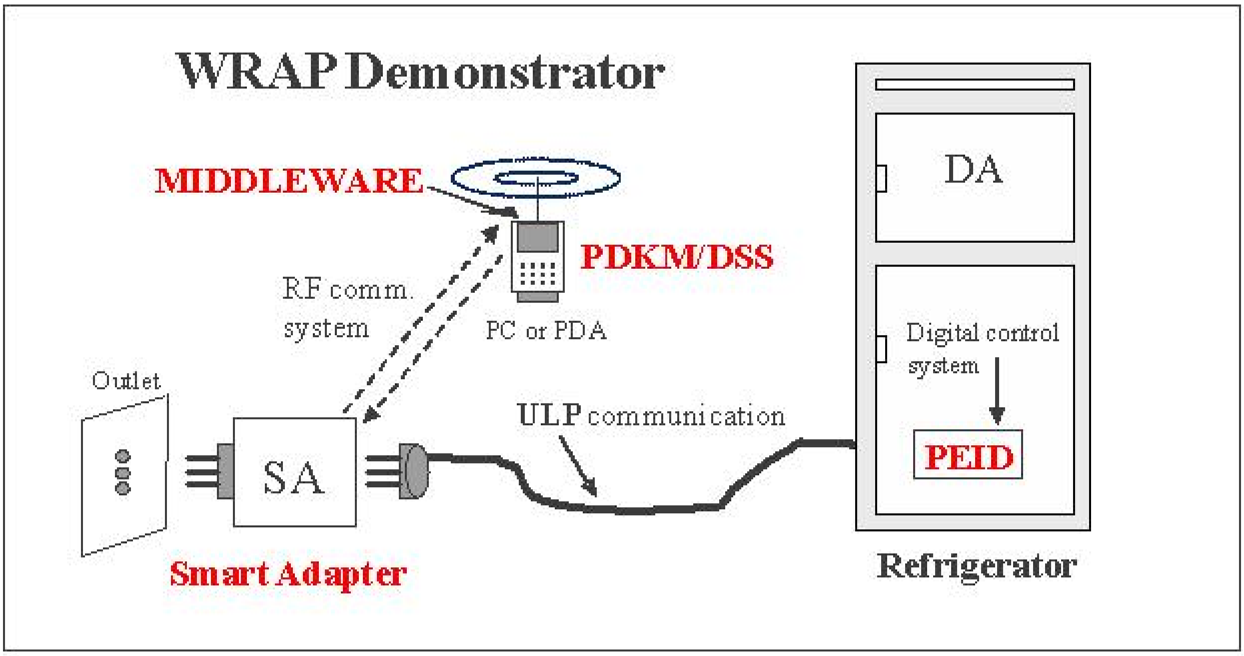

Figure 1 Indesit demonstrator scenario

The main parts of the Demonstrator are:

- a refrigerator DA (Digital Appliance) having a specific digital control system including PEID functionalities,
- an inexpensive communication system (ULP) using as transmission media the same power cable of the product (refrigerator),

- an interface device SA (Smart Adapter) placed between the power cable of the household appliance and its electric plug (Outlet),
- a proper standard communication link between said SA device and a remote monitoring centre (PDKM/DSS, simulated by a PC), where predictive maintenance activities are performed.

With respect of DA8.3 and DA8.4, no significant variations have been added.

2.1 Scenes implemented

DA8.3 and DA8.4 describe the following three scenes:

- Refrigerator in-line test
- In-house installation process of the refrigerator
- Predictive maintenance operations.

The last two scenes are confirmed as in the previous documents. Regarding the first scene, the results of the factory in-line test are stored in the PEID based control system of the appliance.

2.2 PROMISE components used

According to DA8.3 and DA8.4, the following PROMISE components are confirmed:

- PROMISE MIDDLEWARE, developed by Helsinki University of Technology.
- PROMISE PDKM, developed by INMEDIA SP.
- PROMISE DSS, developed by POLIMI.

2.3 Eventual other modifications with respect to DA8.3 and DA8.4 (e.g. workflow)

With respect to DA8.3 and DA8.4, no significant modifications have been introduced.

3 Analysis of results obtained in the Activities A8.6

Regarding Indesit, all the main hardware and firmware activities related to PEID and SA (Smart Adapter) and specified in PROMISE project has been positively concluded.

Such main activities are listed below:

PEID Main Activities::

- hardware design of the refrigerator electronic control system including PEID functionalities;
- first prototypes implementation (safety version of PEID suitable for firmware development);
- firmware development according to PROMISE specifications;
- PEID hardware and firmware debugging session;
- implementation and debugging of PEID-side ULP communication system (involving SA)
- implementation and debugging of firmware for supporting the refrigerator in-line test;
- PEID hardware and firmware final version;

- integration of PEID and SA with PROMISE Middleware for demonstration purposes.

SA Main Activities::

- hardware design of SA;
- first prototypes implementation (safety version of SA suitable for firmware development);
- hardware and firmware debugging phase;
- SA hardware and firmware debugging session;
- implementation and debugging of SA-side ULP communication system (involving PEID)
- implementation and debugging of firmware for supporting the refrigerator in-line test;
- SA hardware and firmware final version;
- integration of PEID and SA with PROMISE Middleware for demonstration purposes.

3.1 Development and test of the stand-alone DSS

In this application the DSS aims at evaluating the ageing of the products under analysis and to allow the Indesit's personnel to manage the maintenance missions. So the DSS is a code that is able to esteem the ageing using the field data coming from the refrigerators, but a very relevant part of the scenario is achieved through the PDKM functionalities and Graphic User Interface.

In the application, the parameters are measured continuously. In order to avoid the necessity for an unreasonable amount of storing memory for a fridge, statistics are computed and only aggregate data can be sent along the network connection and hence used in the diagnostic process that is at the basis of the Indesit DSS. Moreover, the on-board control system is capable of masking particular faults emulating the behaviour of properly working products starting from statistics regarding the near past. If this prevents anomalous behaviours with a substantial advantage for the user, it masks the ageing process inducing the diagnostic module to attribute constant ageing levels to fridges operating according to statistical data even for a long period. This is clearly undesirable since in such a situation the diagnostic module cannot produce reliable results. The solution to the problem was found in the development of an expert system made of two separated modules. The first one uses defined variables to estimate the ageing of the thermodynamic circuit, while the second takes as inputs some particular measurements plus all the warning and fault signals generated by the on-board control system, and uses them to compute an estimate of the reliability of the ageing value. Operating this way, the expert system produces an ageing estimate and a measurement of its reliability, letting the user understand whether the ageing value is representative of the real condition of the thermodynamic circuit or rather induced by a specific operation mode triggered to protect the fridge from particular failures.
The two modules will be briefly described in the following.
The first stages of the development were aimed at the design of the part of the expert system responsible for estimating the ageing of the thermodynamic circuit.
The idea was to monitor some particular variables describing the operation of the compressor and others describing the thermodynamic characteristics of the system (different temperatures and the like) in order to verify the presence of compressor operation modes not consistent with the values expected, assigning different ageing values to different degrees of inconsistency. Fuzzy logic was chosen for its flexibility which allowed to deal both with uncertainty due to the absence of experimental data and to the uncertain classification of some of the measurements evaluated.
Moreover, in this case, the interaction of the user with the good is something important.

An user can for example open the fridge door several times in a minute, causing the compressor to work more than the average expected time. This should not obviously affect the ageing estimate

since the working condition is caused by the user and not by inefficiencies of the thermodynamic circuit. Fuzzy logic was used to deal with this unmodelled interaction, giving flexibility to the classification of observed variables.
Considering that both severe modifications of the operating modes due to users behaviour or abnormal environmental conditions, and normal operation induced to mask system failures could not be dealt with effectively only using fuzzy logic, a second part of the expert system aimed at predicting the reliability of the ageing estimate was designed. In order to spot abnormal situations either caused by users or by unusual environment conditions, this second module monitors a set of variables which can clearly highlight their presence, for example the environment temperature, and some warning signals generated by the on-board control system such as the warning for excessive cumulative door opening. To detect the presence of working modes based on statistical data and caused by the absence of specific measurements, failure signals (e.g. environment temperature sensor fault) coming from the fridge are considered. It is clear that the two different situations cause opposed trend in the ageing value which results respectively over and under-estimated.
The two modules were developed with the use of XFuzzy and codified in Java to grant flexibility and customisation.
The structure of the java code of the two modules is shown in the following figure.

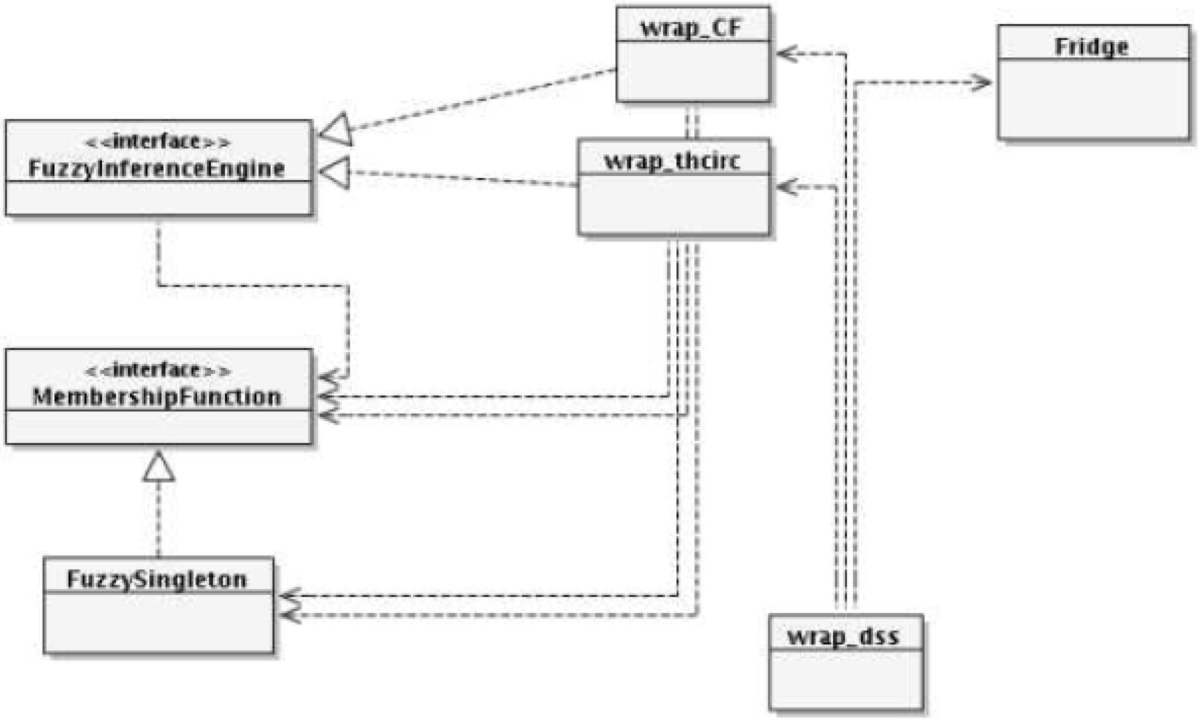

Figure 2 Indesit DSS structure

The Fuzzy expert system has been tested as a stand alone component both during the development of the system using a white box testing approach and verifying the functionalities of all the rules using a specific interface of Xfuzzy, and after, when the DSS has been completely coded into Java and prepared as a stand alone jar file using specific code to run it and pass all the required data simulating the way the PDKM should interact with it. A black box testing approach has been used in this second case and the data used for the test has been acquired during a long run test held in

Intesit on two refrigerators; one perfectly efficient, the other with some faults. The DSS proved to be able to work and provide results compliant with the status of the analyzed refrigerator.

3.2 Integration tests

All the components of Indesit system has been developed.
The integration between the PEID and the Middleware has been executed and tested.
The PDKM is in place and the PDKM's Indesit-specific data structure has been completely defined and tested with a first set of sample data.
The user interface, which is particularly important in this application since is needed to manage product fleets, has been designed, verified with Indesit's team, implemented and now is running on SAP server.
The integration of the Middleware with the PDKM is ongoing and the tests of the DSS working within the PDKM will start after it will be finished and data will start populating the PDKM. Due to the results of the white and black box tests done in the DSS-testing phase, we are confident it will work correctly and provide correct evaluations of the ageing of the refrigerators that will be connected with the PROMISE architecture.

4 Conclusion

A new approach in developing digital systems for white goods, where PEID functionalities are included without adding significant costs to the appliance (objectives fully compliant to DA8.3/DA8.4 specifications), has been created and validated. According to PROMISE general objectives, such approach is suitable to be easily extended to each Indesit product line (Cooling, Washing and Cooking lines).

Due to the particular application (domestic refrigerator), PROMISE components have required proper adaptations, but without overcoming their specifications.

PROMISE results extension to Indesit mass production is presently under evaluation, including technical and marketing issues: a Service Marketing team is going to conclude by April 2008 the exploration of all the business opportunities coming from Preventive Maintenance services, while a Technical team is working on PEID and "smart adapter" industrialization.

A first "preventive maintenance trial" based on two products (refrigerator and washing machine) and referred to UK market is planned by the end of this year (2008). Depending on the results of such trial, the official offer of Preventive Maintenance services is planned in two years.

5 References

DA8.3
DA8.4