Networking Sensors with CANopen for some AmI applications

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Tecnalia Automoción is working on an ECG sensor integrated into the steering wheel as one of several concepts following Ambient Intelligence (AmI) principles. This work is related to a previously developed prototype of a sensorized active headrest which was designed to maintain desired horizontal and vertical safety distances from the head.

A networked solution, with smart sensors and actuators integrating the IEEE 1451 standard group, is being designed to be applied to the active headrest prototype and this ECG sensor. Following this standard, Tecnalia-Automoción has selected CANopen high level protocol to network this ECG sensor and obtain data about the car-driver, adding the plug & play feature with the mentioned IEEE 1451 standard.

The concept of "Ambient Intelligence" (AmI), defined by ISTAG (Information Societies Technology Advisory Group) as a guiding vision to give an overall direction to Europe's Information Society Technology programme, stresses the importance of social and human factors as well as developing the base technologies on which aspects of the vision are founded. It is the edge of a process which introduces technology into peoples' lives in such a way that it never feels like a conscious learning curve: no special interface is needed because human experience is already a rich "Manual" of ways of interfacing with changing systems and services.

Nowadays, an average car has between 50 and 100 sensors. This number is increasing and with the implementation of AmI based solutions such as those described above, the number of car sensors and actuators will increase substantially. This means that solutions related to network sensors and additional features on the sensor side (smart sensors) are being considered as strategic ways for the future.

Tecnalia-Automación is researching intelligent sensor networks and their availability and application in car systems and devices. All sensors and actuators mentioned would be integrated within a networked system taking the IEEE 1451 standard for a "plug & play" system into account.

This paper shows how both the previously mentioned applications (the active headrest prototype and ECG sensor) are being designed to integrate a solution, and how some CANopen protocol services can help us to network sensors, mainly ECG.

Active Headrest

One of the previously mentioned applications is a developed prototype of a sensorized active headrest which was designed to maintain desired horizontal and vertical safety distances to the driver's head.

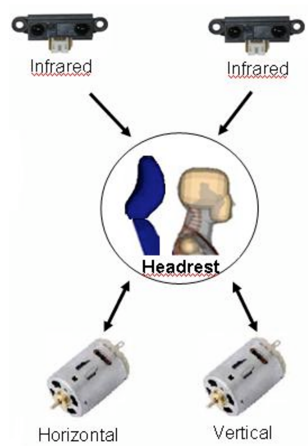

Figure 1: Active headrest

All sensors (4) and actuators (2) of this application, designed to be integrated within a networked system, aim to adjust the headrest to the optimal safety position using two independent motion controls for the horizontal and vertical direction (actuators).

Related to sensors, two infrared sensors placed in the headrest detect the position of the user's head using measured information by contact-free devices. One of these is a presence detecting sensor and the other one is an analogue sensor to measure the distance from an object. With these, we can pinpoint the outline of the head and find out the distance from the headrest to the head.

Besides, two further sensors send information to find out the current position for both independent motion controls (horizontal and vertical).

ECG sensor

Since heart rate measurement is not very complex, the ECG signal needs little amplifying (about 10 to 20 times less than EEG) and electrode placement is not very critical if measurement is limited to R-wave detection and registration. The following solution has therefore been selected by Tecnalia-Automación to integrate an ECG sensor into a car.

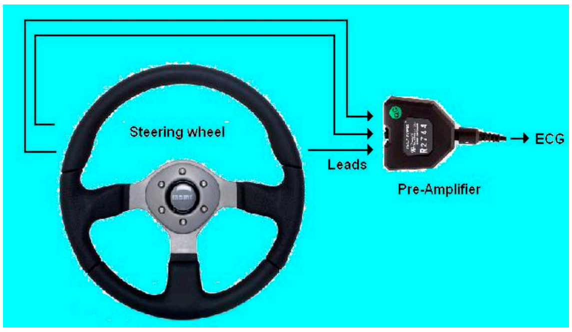

Figure 2: ECG sensor

Drivers change their hand position while driving the car, so this solution takes into account the lack of a continuous ECG signal. Nevertheless, it would be possible to sample this information and find out how some **particular parameters** are change during the driving activity, such as those based on HRV (Heart Rate Variability).

Plug & Play

IEEE 1451 is a group of seven standards, some of them in revision phase, concerned with smart transducer interfaces for sensors and actuators which will let us have plug & play feature on the sensor-actuator side within a distributed control system.

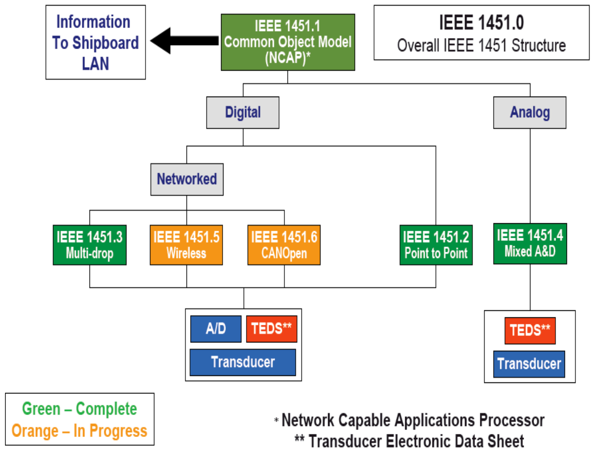

Figure 3: IEEE1451

Only the following two standards from the IEEE 1451 group has been considered in this work:

IEEE P1451.0: providing a uniform set of commands, common operations, and TEDS (Transducer Electronic Data Sheet) for the family of IEEE 1451 smart transducer standards. This command set allows access to any sensors or actuators in the 1451-based networks. This standard will be used to assure uniformity within the family of IEEE 1451.x interface standards.

IEEE P1451.6: defining a transducer-to-NCAP interface and TEDS using the high-speed CANopen network interface. It defines a mapping of the 1451 TEDS to the CANopen dictionary entries as well as communication messages, process data, configuration parameter, and diagnosis information. In any case, IEEE1451.6 status is currently only in a draft version and it has not been considered overall in this work.

TEDS definition is the key feature of this family of standards and it would be a memory device attached to the transducer having information such as transducer identification, calibration, correction data, measurement range, manufacture-related information, and so on.

Hardware Architecture

Both developments, the active headrest and ECG sensor, will be integrated into a system with one NCAP (Network Capable Application Processor) and two STIM's (Smart Transducer Interface Module):

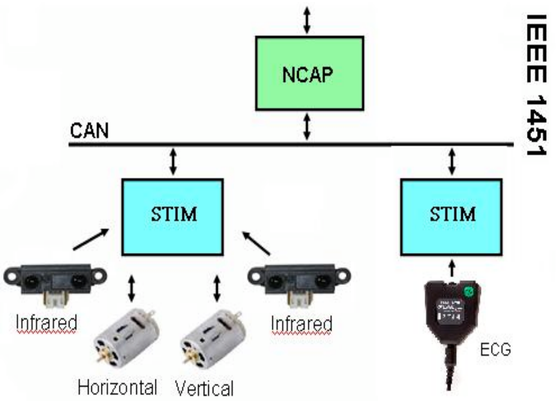

Figure 4: Architecture

As shown in the figure, one STIM will collect information from four different **sensors** (Infrareds, Horizontal and Vertical). In the same way, the STIM will be connected to the two **actuators** of the headrest system (horizontal and vertical).

On the other hand, one more STIM will be dedicated to the ECG sensor getting data from a pre-amplifier & filter device. So, all sensors' data and actuators' control will be accessible from a NCAP device.

Software Architecture

Software architecture, related to the previously explained hardware architecture, is shown in the following paragraphs.

NCAP: Three general modules will work together to carry out NCAP functions:

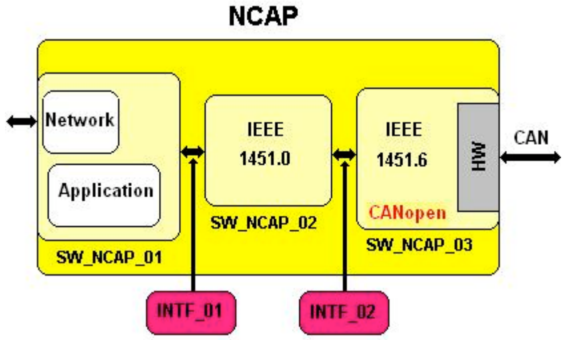

Figure 5: NCAP SW-Architecture

SW_NCAP_01 has been designed to connect all sensors and actuators with a networked application by means of a particular LAN (Network), or directly with the related application (Application).

SW_NCAP_02 will implement the 1451.0 standard to provide a set of common commands and operations, to access any sensors or actuators in the 1451-based networks assuring uniformity within the family of IEEE 1451.x.

Finally, **SW_NCAP_03** will develop the 1451.6 standard to communicate with a CAN network where several STIM modules can be connected. Two interfaces are considered in this solution as can be seen in the previous figure **(INTF_01** and **INTF_02**).

STIM: In the same way, three modules have been designed on the STIM side to carry out their respective functions:

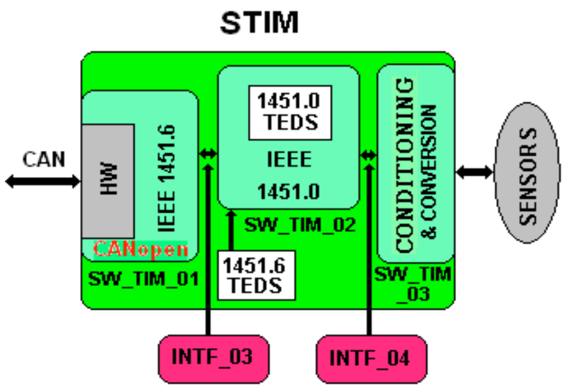

Figure 6: STIM SW-Architecture

SW_TIM_01 will be an implementation of IEEE 1451.6 standard but on STIM side.

SW_TIM_02 will have the 1451.0 standard implemented for the sensor/actuator side and will manage TEDS (Transducer Electronic Data Sheet) with all information related to sensors connected to this STIM.

Finally, **SW_TIM_03** will do conditioning and conversion tasks for data received from sensors. As shown in the previous figure, two more interfaces are considered in this solution (**INTF_03** and **INTF_04**).

CANopen Solution

Following on from the previously mentioned architectures, Tecnalia-Automoción has selected CANopen high level protocol to network these applications. In particular, the following pharagraps explain how the SW_NCAP_03 and SW_TIM_01 modules above implement CANopen services for the ECG sensor to obtain parameters about the car-driver, adding the plug & play feature with the IEEE 1451 standard quoted above.

CANopen: NMT (Network Management)

Focussing on the ECG sensor, the corresponding STIM device shown in the previous figure will work like a "slave" meanwhile NCAP device will be the "master":

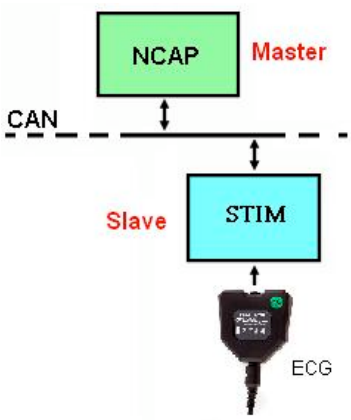

Figure 7: Master/Slave

NCAP (Master) and STIM (Slave) devices will follow a minimal boot-up according to the typical "State diagram" shown here:

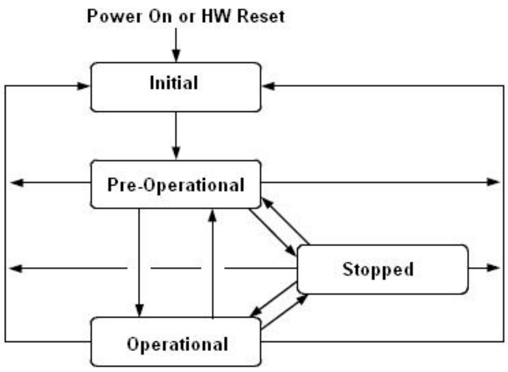

Figure 8: State diagram

Every "Power On" or "Hardware reset" NCAP will complete its initialization process and from its "Pre-operational" state will send a broadcast "Start_Remote_Node" message binding itself to go to "Operational" state.

In the same way, after its "Power On" or "Hardware reset", each STIM will finish its initialization process and will be in "Pre-Operational" state sending the corresponding NMT message according to the "Bootup protocol".

Then, every STIM in "Pre-Operational" would be entered into "Operational" when the NCAP sends the broadcast message to start all remote nodes. Failing this, the STIM would be started by the NCAP when the last one receives a "Bootup protocol" NMT message from the previous one, once the corresponding STIM has become "Pre-Operational" and completing its "Initialization".

In any case, the NCAP will be able to start/stop every STIM if necessary through the NMT messages (Start Remote Node and Stop Remote Node protocols).

CANopen: SDO (Service Data Object)

SDO services will be mainly used to read and write TEDS information, mapped in the object dictionary of each STIM device, from the NCAP. Therefore, it would be sufficient to only consider one SDO object in the "peer to peer objects of the predefined connection set" ([1]: table 34).

Within a Client/Server architecture, the following SDO **download** and **upload** services will be implemented:

- Initiate Block Download.
- Download Block.
- End Block Download.
- Initiate Block Upload.
- Upload Block.
- End Block Upload.

When TEDS in any STIM (server) is to be modified from the NCAP (client), the NCAP will request the STIM (server of SDO and owner of the object dictionary) to prepare for downloading TEDS to the STIM (Initiate Block Download). This service must be confirmed by the STIM. When it is done the NCAP will start sending data-blocks with “Download Block” conformed protocol.

Once every block of TEDS has been sent from the NCAP to the STIM, the “End Block Download” protocol is requested to finish TEDS download process:

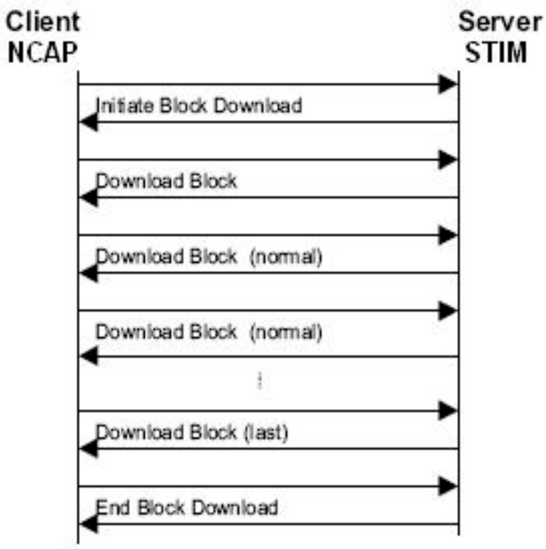

Figure 9: SDO Block Download

A similar process is carried out to read (upload) the mapped TEDS in the STIM’s object dictionary from the NCAP, using “Initiate Block Upload”, “Upload Block”, and “End Block Upload” protocols:

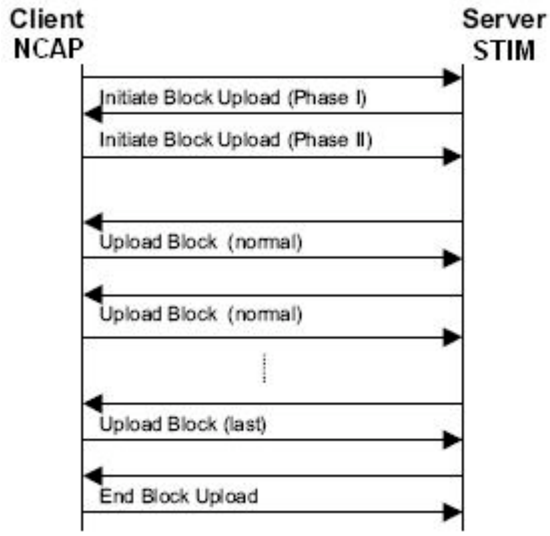

Figure 10: SDO Block Upload

This set of SDO services will let TEDS data be read and modified to configure STIM for a particular transducer. In any case, any modification of TEDS should stop the STIM sending the proper NMT service from the NCAP to put the STIM in “Pre-Operational” state, then change TEDS, and finally re-start STIM sending “Start Remote Node” service from the NCAP.

CANopen: SYNC and PDO

When the NCAP is in “Operational” state it will start sending SYNC messages to define a fixed time window and synchronize PDO messages. So, every STIM connected to sensors will send its data by “Write PDO” protocol according to its PDO mapping information. Through this service the STIM of ECG sensor (PDO producer) sends the data of the mapped application object to the NCAP (PDO consumer) every “SYNC”.

Summary

- Tecnalia-Automación is researching intelligent sensor networks and their availability and application in car systems and devices.

- The number of car sensors and actuators will increase and solutions related to network sensors (smart sensors) are being considered as strategic ways for the future.

- Two AmI applications, the active headrest and ECG sensor, are being integrated into a system with one NCAP (Network Capable Application Processor) and two STIMs (Smart Transducer Interface Module) according to the IEEE1451 group of standards.

- Only two standards from the IEEE 1451 group, IEEE1451.0 and IEEE1451.6, have been considered in this work. In any case, IEEE1451.6 has not been considered overall in this work.

- Taking these standards into account, Tecnalia-Automoción has designed a hardware and a software architecture selecting CANopen high level protocol to network these applications.

- Default CANopen configuration is being used taking basic NMT, SDO, PDO and SYNC related services into account.

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