Advanced Power Line Communication for Multisensor, First Responder Applications

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Abstract — Fighting fire is a very difficult task, firefighters a regularly risking their lives doing their dangerous job. Intelligent support systems are urgently needed. This paper describes a new approach, using a PLC (Powerline Communication) and RFID-based alert and location system.
Using Renesas Electronics state-of-the-art systems, environmental data – tempreature, smoke intensity, firefighter location – is collected and send to a local computer system, using the emergency power line infrastrucuture installed in the buildings. The data is visualized using a dedicated Graphical User Interface (GUI), so that supervisers can continuingly receive information about their teams' situation.
The system presented in this paper was successfully tested in a building with very harsh and noisy power line infrastructure.

Index Terms — Power Line Communication (PLC), Firefighter Localization, First Responder System, active RFID.

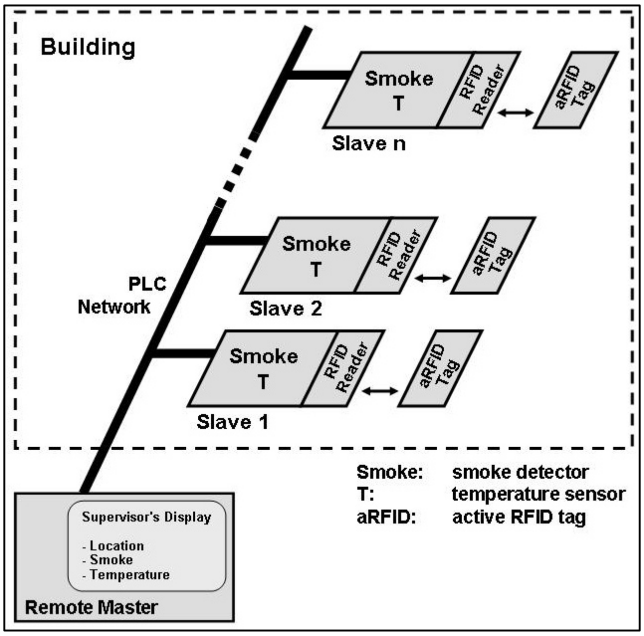

Fig. 1: General Setup

INTRODUCTION

Fire is one of the most dangerous elements on earth, causing the loss of material goods and – more important - lives. This project has the goal to support and protect those people who fight against it: the firefighters. Firefighters risk their lives whenever they enter a burning building to rescue people or to extinguish the fire. To support their work and to monitor them continuosly is the basic idea of this project.
To achieve the goals two fundamental technologies have been applied: power line communication (PLC) to implement a reliable communication path and active radio frequency identification (aRFID) employed for location detection. Temperature sensors and smoke detectors add basic sensoric elements to complete the experimental setup (Figure 1).

POWER LINE COMMUNICATION

Various PLC-systems are available nowadays operating in different frequency bands, applying different modulation techniques, and allowing a wide range of data transmission rates.
Problems arising with this type of data communication systems include high error rates and limited transmission ranges, and this strongly depending on the power wiring usind in the building.
The project discussed here employs the state-of-the-art PLC-technology developed by Renesas Electronics Corporation, using an advanced DCSK (Differential Code Shift Keying) spread spectrum modulation technique.

Configurable to support worldwide regulations and frequency bands compliance (CENELEC A&B, FCC, ARIB)

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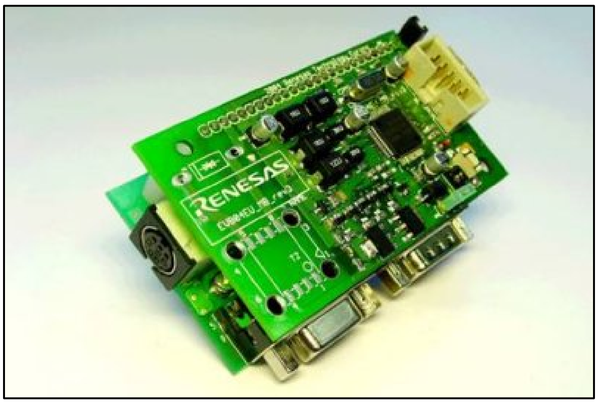
With the help of Renesas' Spread Spectrum Technology (SST) implemented on their EVB04 – EU development boards, a Powerline Communication Network is developed to collect environmental data such as temperature and smoke and also the location of firefighters via active Radio Frequency Identification. Sending this information to a local computer that displays everything on a graphical interface allows the firefighter chief to have an overview over the environmental conditions and the teams inside the building.
Earlier projects at the Texas A&M University to build a Power Line Communication Network were not successful. The reasons for this may be found in the inadequate power line infrastructure available in the building and the noise on the power line caused by every switching power supply. For this project, Fermier Hall, the building of the Engineering Technology and Industrial Distribution (ETID) Department at Texas A&M University, provides an additional challenge for the test bed under development.

The proof of concept for this Power Line Communication network is the most important task. Additionally, a network of one Master and three Slave devices will be created. Sensors for temperature, smoke and active Radio Frequency Identification will be connected to the Slaves devices to collect the environmental data and send this data values to the Master device that will be directly connected to a local computer. A graphical interface will be created to have a quick and easy access to the Power Line Communication Network and to display all values in a clear manner.

POWER LINE COMMUNICATION

"A spread spectrum data communication system utilizing a modulation technique referred to as differential code shift keying (DCSK) transmits data in the form of 5 time shifts between consecutive circularly rotated waveforms of length T known as spreading waveforms. A plurality of bits are transmitted during each symbol period which is divided into a plurality of shift indexes with each shift index representing a particular bit pattern. The spreading waveform is rotated by an amount in accordance with the data to be transmitted or is conveyed in the difference between two consecutive rotations. A correlator employing a matched filter having a template of the chirp waveform pattern is used to detect the amount of rotation of the chirp within the received signal for each symbol. The received data is fed into a shift register and circularly rotated. For each rotation shift, the matched filter generates a correlation sum. The shift index chosen for each symbol corresponds to the shift index that yields the maximum correlation sum. Differential shift indexes are generated by subtracting the currently received shift index from the previously received shift index. The differential shift index is then decoded to yield the originally transmitted data." [1]



Frequency Bands: [2]
"The CENELEC—standard EN 50065–1 applies to electrical equipment using signals in the frequency range 3 kHz to 148,5 kHz to transmit information on low voltage electrical systems, either on the public supply system or within installations in consumers premises.
It specifies the frequency bands allocated to the different applications, limits for the terminal output voltage in the operating band and limits for conducted and radiated disturbance. It also gives the methods of measurement.
[...] The object of the standard is to limit mutual influence between signal transmission equipment in electrical installations and between such equipment and other equipment. In addition this standard is intended to limit interference caused by signal transmission equipment to sensitive electronic equipment. However, complete freedom from such interference can not be assured."
The Canelec C band supports CSMA / CA (Carrier Sense Multiple Access with Collision Avoidance).
"It is used [...] to allow several systems to operate on the same, or electrically connected, mains networks."

Band	Frequency	Usage	Access protocol
A	9*kHz* to 95*kHz*	Outdoor, reserved for energy suppliers	No
A+	70*kHz* to 95*kHz*	Outdoor, reserved for energy suppliers	No
B	95*kHz* to 125*kHz*	Indoor without access protocol	No
C	125*kHz* to 140*kHz*	Indoor with access protocol	CSMA / CA
D	140*kHz* to 148.5*kHz*	Indoor for alarm and security systems	No
FCC	100*kHz* to 400*kHz*	US	No
ARIB	100*kHz* to 400*kHz*	Japan	No

TABLE 1
PLC BANDS [3]

Conclusion

Power Line Communication has always been a problem at Texas A&M University, especially at the Engineering Technology and Industrial Distribution Department. The

power lines in this department are very noisy, so that other PLC solutions were not able to work.
Another problem is that no schematics about the power lines inside the build are available. That has been caused by several renovations during the last decades and the failure of updating the appropriate schematics. With the help of Renesas Spread Spectrum Technology with Differential Code Shift Keying, that is implemented in its M16C/6S microcontroller, a last attempt to build a Power Line Communication network was started. This project was directly supported by Renesas in Germany. They provided four EVB04 – EU PLC development kits and the needed software to program the microcontroller. It was the last chance to build this kind of network because the Differential Code Shift Keying technique is not the fastest, yet it is the most robust one on the market.

At the beginning, it was important to find out whether Power Line Communication at
Texas A&M University is possible or not. After sending some characters and signs over the power line in a direct connection, a Power Line Communication network was created, and all EVB04 – EU modules were connected to it as one Master and three Slaves. Afterward, the temperature sensor, the smoke detector and in the last step the RFID Reader were connected to that network. To minimize the traffic on the power line, special messages were developed.

After successfully testing and controlling the Power Line Communication network via
Terminal software, a graphical interface was created. This interface displays the measured sensor data and is able to identify the RFID messages. Every firefighter has his unique Tag ID and the graphical interface is able to refer firefighter names to Tag IDs.

The test–set up was built on breadboards. To have a professional solution and to show the project to potential companies, there was a desire for a Printed Circuit Board (PCB). This board allows the user to connect all sensors to the EVB04 **–** EU. It also provides free input / output pins for the microcontroller. The PCB solution can be put in an appropriate plastic box to be placed in a room or hallway.

This project proves that Power Line Communication at Texas A&M University is possible. The smoke detector, the temperature sensor and the RFID Reader are successfully connected to the network. The firefighter chief is now able to locate areas in a building where smoke is present and identify that the temperature in a room is more than it should normally be. More importantly, he is able to trace his colleagues inside the building to better coordinate them.

This project still has components to be improved or expanded. The RFID technique by Tagsense is very powerful and allows more options for the Tags to be used, like connecting sensors to it or implementing a panic button for the firefighters.
The connection between Master and PC can be replaced by a bluetooth module, connected to the Master, because nowadays, not many PCs provide an RS232 interface. The collected experience during this project has shown that a USB–to–RS232 adapter might have driver problems with Windows 7.
Furthermore, a small plastic box for the RFID Tags should be built, considering they are just sold as PCBs and not protected from environmental influence, which could be very critical in case of high humidity or worse by extinguishing water.

During this project, Renesas released a newer version of the M16C/6S. It is called M16C/6S1. It provides the same robustness combined with a higher data rate (up to 500 *kbps* in FCC/ARIB band).

ACKNOWLEDGEMENTS

This project has been supported by Renesas Electronics Europe GmbH, Germany, providing the basic PLC modules and technology.

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