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Wireless Sensor Networks – an Important Part of Current Automotive and Building Automation Tasks

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Abstract*— *In the areas of building automation and automotive applications the use of systems of (embedded) systems is very common. However, until recently, in many cases the communication between the participating systems was cable-based. Due to developments in the area of wireless sensor networks, the communication can be converted step-by-step to be wireless. This leads to many advantages, like reduced space requirements, less weight, etc. On the other hand it introduces new problems like possible occasional connection problems, vulnerability in terms of data security, etc.

This survey paper gives an overview on current activities and works in the area of wireless sensor networks for automotive and building automation applications.

Index Terms*—*Wireless sensor networks, WSN, Building Automation, Automotive

I. INTRODUCTION

The use of wireless sensor networks is growing in many areas, two of which are the automotive area and the building automation area. This development however not only brings advantages, but also introduces problems that are unknown or uncommon when only cable-bound communication is used.

II. THE USE OF WIRELESS SENSOR NETWORKS

The topic of wireless sensor networks is a keystone in smart buildings. In modern constructions and private homes, many devices like lighting, heating and cooling (with temperature sensors), elevators, windows, data displays, and even household appliances like dish washers and refrigerators have to be able to communicate in order to coordinate their functionality. All of these devices can be controlled in a centralized manner if the required environment data (e.g. room temperature, number of present persons in a room, open-state of windows, doors, and refrigerator doors, etc.) is available. This data can then be used to enhance security (mostly in terms of theft protection) and safety (e.g. by setting a foundation for ambient assisted living (AAL) applications).

Another very active area of research is automotive communication. Many systems are changed from cable-based to wireless in order to save cables and thereby weight and in the end fuel. Examples are many comfort systems like distance sensors or safety related systems like tire pressure monitoring [1,2].

his trend was extended recently when *Car2X* [3,4] moved into focus of many research groups. This research is intended to help lowering the number of car accidents (and thereby the number of traffic deaths and injuries) worldwide.

Car2X is an umbrella term for *Car2Environment* and *Car2Car*; the former meaning communication between cars and stationary objects, e.g. street signs, traffic lights, bridges, etc. Typical data to be communicated could be information about current traffic jams, dangerous bends, frozen-over bridges, routing changes, or traffic congestions. The latter [5,6,7] focuses on communication between cars themselves. Typical data to be communicated could be information about car crashes ahead, cars braking ahead (being the electronical equivalent of the brake lights the driver can see), burst tires, and many more.

The data needed for control is collected by numerous specialized sensors and transferred to the central unit (of a car) or distributed local central units.

Fig. 1 shows a typical situation of a car passing other cars, resulting in an overlap of their network. This can lead to needed resends due to network congestion, or even security problems, e.g., if a warning message about a rapidly falling pressure in the tire sent out by one sensor is received by the central unit of another car, making this other car react (and probably stop).

Nowadays, mainly two channels are used for this, namely power-line-communication (PLC) [3,4] and wireless communication. The former is easily applicable for devices which have to be connected by cable to the power grid, anyway. However, a large number of connected PLC devices lead to diverse problems from channel congestion to security issues [5]. More commonly, wireless communication is used. Wireless sensor networks (WSN) do not need physical cable infrastructure and can even connect ad hoc to devices currently in reach.

One of the most important scientific questions is the energy consumption of wireless sensors, since many of them are implemented in the form of battery-powered embedded systems. Obviously, it is important to design cheap, small devices with a long battery life. This can be achieved by a clever chip design or by power management in the running system itself [9,10], the use of smart compression schemes [11] for communications, or even network-topology-based optimizations [12]. In some approaches, the extension of battery life is achieved by means of energy harvesting.

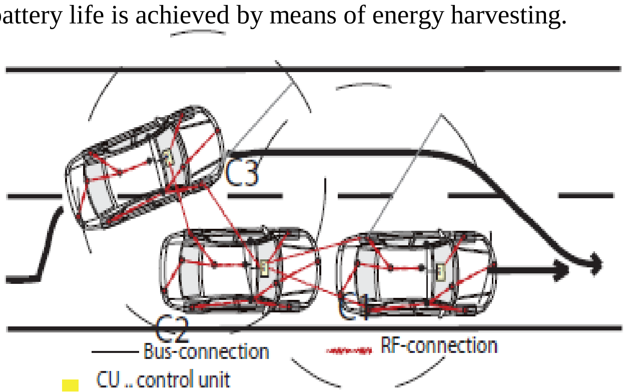

Fig.1

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Simulation scenario, consisting of two cars (C1 and C2) driving in a goose line and a third car C3 doing a take over maneuver. Communications from sensor nodes in the tires of nearby vehicles might overlap and thereby conflict, as shown here (see the dashed circles): Car C2's CU receives not only messages from its own tires but also from C3 and C1. (taken from [8])

This means that energy is taken from the environment to partly or fully fuel the device in question. In buildings, e.g. ambient light can be harvested [14,15]; in the automotive area, e.g. vibrations of the tire on the street can be exploited [16]. Other approaches try to compare different possible designs and choose the most energy-saving approach (design space exploration); this is mostly done by energy consumption estimation in simulations [17]. In some cases, only single chips are simulated and optimized, other approaches simulate and monitor the energy consumption of specific messages throughout the whole sensor network [18,19].

Another field of research is the analysis of the data sent throughout the network. There are many available wireless protocols like ZigBee, OneNet, EnOcean, 6LoWPAN, etc., so the designer of a wireless sensor has to decide which protocol to use [20,21,22], see Fig.2. In many cases, a specific routing is proposed to enable real-time operation [23,24].

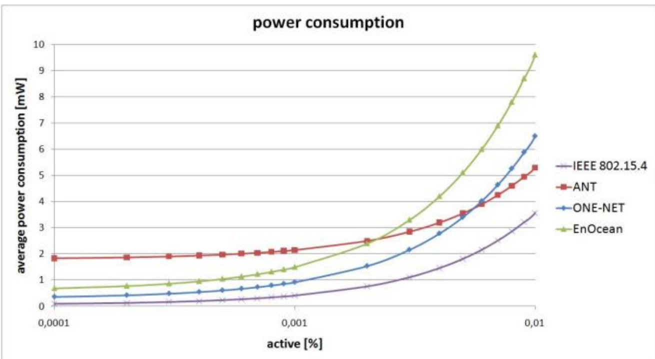

Fig. 2: Average power consumption of some low-power sensor protocols (taken from [22])

In order to be able to monitor the energy consumption of devices used in building automation environments, even software-in-the-loop approaches are interesting. Typically a complete experimental set-up of a building or apartment containing household devices like refrigerators, washing machines, air conditioners, etc. is expensive and bulky, therefore specific devices are replaced by real-time simulations [25,26] (see Fig. 3). Another more recent approach is the simulation of complete buildings using simulators which were intended for systems on chip by setting the simulation period to seconds instead of picoseconds [27].

Fig.3 Simulator main screen on a Motorola Xoom tablet PC.

The screen shows twelve virtual household appliances which can be selected for simulation. The simulation then returns realtime consumption data, i.e., in terms of energy consumption reporting, the tablet behaves just like a real household appliance.

III. CONCLUSION

All these optimizations make sensor networks in buildings and automotive applications useful and help enhance safety and security.

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Jan Haase received the Diploma degree in computer sciences at Goethe University, Frankfurt, Germany. He then became a Research Assistant at the Department of Technical Informatics, Frankfurt University. There he focused on the field of computer architectures, dynamic and distributed parallel computation, middlewares, and embedded systems, resulting in his Ph.D. thesis on the scalable, dataflow-driven virtual machine (SDVM).

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