Realtime Automation Networks in moVing industrial Environments

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ABSTRACT

The radio-based wireless data communication has made the realization of new technical solutions possible in many fields of the automation technology (AT). For about ten years, a constant disproportionate growth of wireless technologies can be observed in the automation technology.

However, it shows that especially for the AT, conventional technologies of office automation are unsuitable and/or not manageable. The employment of mobile services in the industrial automation technology has the potential of significant cost and time savings. This leads to an increased productivity in various fields of the AT, for example in the factory and process automation or in production logistics. In this paper technologies and solutions for an automation-suited supply of mobile wireless services will be introduced under the criteria of real time suitability, IT-security and service orientation.

Emphasis will be put on the investigation and development of wireless convergence layers for different radio technologies, on the central provision of support services for an easy-to-use, central, backup enabled management of combined wired / wireless networks and on the study on integrability in a Profinet real-time Ethernet network [1].

Keywords: Wireless Networks, Bluetooth, 802.15.4, Industrial Automation Technology, Distributed Control Systems, PROFINET

Introduction

Radio communication has been convincing through its advantages within the private sector for a long time and also within the office range it has become generally accepted. WLAN [2] and Bluetooth [3] demonstrate their efficiency in this area on a daily basis. The increasing confidence and the worldwide spreading of radio solutions as well as the continuously falling prices for radio components have led to the fact that by now different products are being used in the industry.

The requirement to link mobile machinery or plant parts to a wired communication system is an important reason for the use of wireless technologies in the AT. This requires an appropriate mobility support. It is necessary to consider, on the one hand, the speed in which the component moves, and, on the other hand, the radius in which the plant part moves. Both characteristics are determined by the application. A typical example is a driverless transport system which moves with a speed of 10 – 15 mph and operates in a radius of up to several hundred meters.

Unfortunately, there is no radio technology which can be used unrestricted in any kind of surrounding or circumstances. But there are radio technologies that work for respective uses and circumstances. Apart from the different stages of development, none of these technologies are able to meet all requirements of the AT. Therefore, it is not surprising that today different wireless technologies have become established in practice. The companies PHOENIX CONTACT [4] and WAGO Kontakttechnik

[5] for example, have been integrating Bluetooth components in their portfolio for some time now.

Due to different features, every standard includes more or less specialized or supplementing applications. Concerning the wide-area radio coverage of many participants for example, Wi-Fi has become established. Bluetooth is mostly used as a cable replacement solution and for sensor networks, 802.15.4 [6] has gained acceptance.

To use the advantages of all radio technologies in the industrial surrounding field, it is often necessary to use proprietary solutions from different providers, e.g. IWLAN of Siemens. No automation technology system is currently able to integrate the different radio technologies usefully into one automation system. Therefore, it was absolutely necessary to develop a gateway (GW), which, on the one hand offers an interface for the different radio technologies and on the other hand presents itself as I/O-device for RT-Ethernet.

Overall system

As can be seen in Figure 1 a RT-Ethernet is used as backbone of the distributed automation system, here with the example of PROFINET. This technology is already established in the automation technology and is consequently widespread.

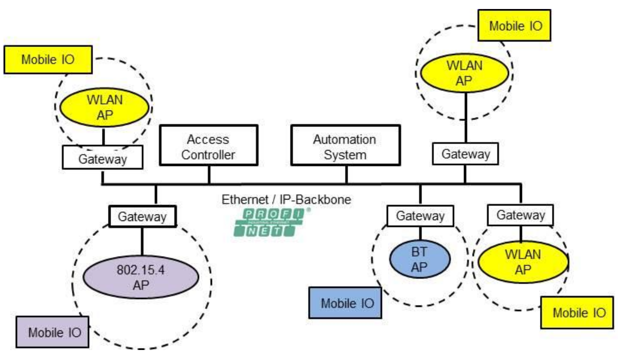

Figure 1: Structure of the overall system

In addition to the standard POFINET devices, new PROFINET I/O-devices have been developed, which make a connection to different autonomous wireless networks possible. These gateways provide on the one hand the communication with PROFINET and thereby to the programmable logic controller (PLC), and on the other hand they provide the communication with the respective Access Point of the respective wireless sensor network (WSN).

These gateways were implemented as prototypes with the help of the evaluation board ERTEC 200 of Siemens [7]. The Access Points (AP) were connected on their part with the ERTEC 200 by a serial interface.

The RS232-interface seemed to be perfectly suitable for a prototype, but should be replaced in the next step by a faster and higher performing interface like the Serial Peripheral Interface (SPI). Through the access points of the different radio technologies the respective WSN can now be developed. Over a Wireless Convergence Layer, as shown in Figure 2, the data of the individual WSN and their wireless devices are mapped onto PROFINET and are then available in the entire network.

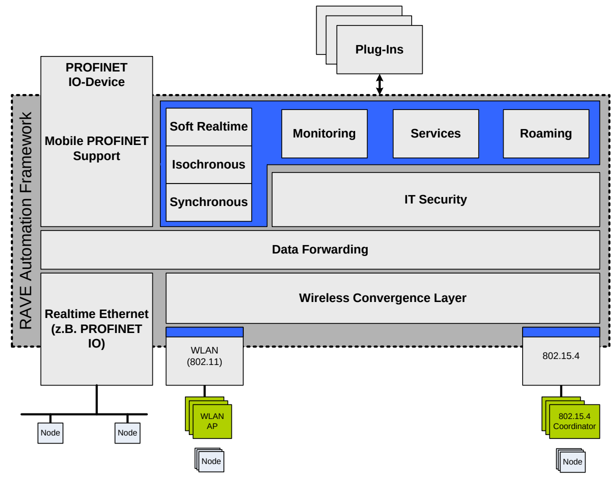

Figure 2: RAVE layer model

As can be seen in the illustration of the layer model, the RAVE Automation Framework has been structured into several levels, in which the different hardware components are embedded. Various standard protocols secure the communication between the individual sections that a cross-technology functionality is ensured.

The overall system provides a network-spanning communication in the engineering and the process phase. The design as well as the configuration of the logic, which is needed for the operation, is still done in the engineering tool. For the configuration of the WSN, the Access Controller (AC) is responsible. In a preliminary discovery phase, the AC creates a GSDML-file [8], in which the entire WSN is depicted, and provides it to the engineering tool. Thus, all the required I/O-addresses are known and the engineering tools e.g. PC WORX can integrate all radio components into the automation system.

Access Controller (AC)

The configuration of the WSN (I/O-devices, security, etc.) is accomplished centrally by an Access Controller through Ethernet during the configuration phase. The AC presents a PC based software solution and offers several possibilities to be able to configure the radio networks. On the one side by “guided finding” and on the other side by “automatic finding”. With guided finding and by using a GUI with drag & drop, the entire WSN can be configured and afterwards be checked. During the check the AC connected itself to the respective access point through the gateway. Following now, the AP checks the status of its slaves and reports it to the AC. Thereby, the entire network with all its devices can be checked whether the I/O-nodes are available and fully operating. In this version of the configuration it is also possible e.g. to define temporary Devices for different 802.15.4 Networks and thereby enabling roaming between two or more WSN.

For automatic configuration, the situation is different; here only those devices can be added which are found by the respective radio master. In addition, temporary devices can be added by hand or the network can be corrected manually. As with the guided finding the currently configured wireless network can then be monitored and evaluated by the AC.

These wireless subnets can consist of an arbitrary combination of I/O-nodes, which cannot be determined exactly in advance. In addition, extensions of the WSN should be as easily accomplishable as possible by new I/O-devices. For this reason, every device has programmed into it its own specific GSDML-file. The access controller reads this information during the discovery phase and puts it afterwards into a large GSDML-file which is standardized according to ISO 15745-3. This file contains the device-specific information, such as component ID and hardware description of the individual I/O-nodes, which are then passed to the configuration tool for the configuration of the RT-Ethernet.

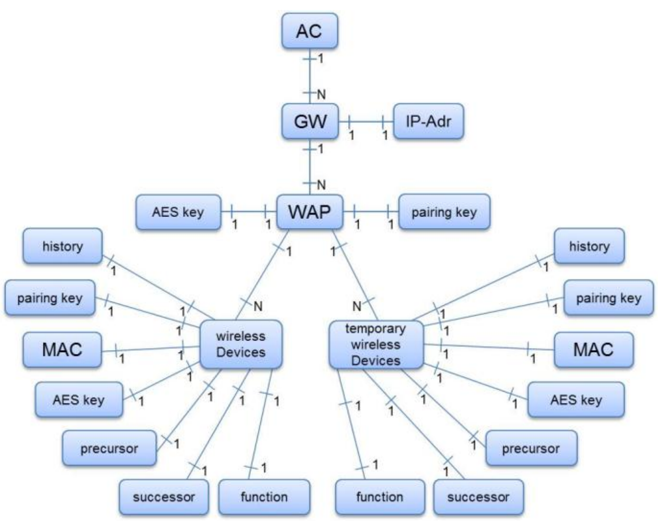

Figure 3: Logical Data Model

The AC may therefore reflect the entire wireless network. The required data structure is shown in Figure 3. For this reason, it is also very easy to replace and exchange defective devices quickly by the help of this system. The AC directly provides all necessary information to configure the replacement device and thus, to integrate it into the appropriate wireless network. Besides the device information such as data types, addresses and hardware ID required for the function classification, safety and service-related data such as AES keys, Pairing keys and history are recorded.

Beside the described functions, the security requirements which are demanded from a WSN, are also fulfilled, e.g. the securing of the network through authentication of the devices or AES encryption of process data, to name just a few.

Wireless Convergence Layer

Different wireless technologies come with specific characteristics, communication characteristics, and network topologies, in addition to their specific advantages and disadvantages. Bluetooth works with a star topology, while 802.15.4, for example, uses a meshed topology.

To integrate these wireless sensor networks together into an AT, a way must be found to show these different properties on the defined interfaces of the automation system. This task is performed by the Wireless Convergence Layer. It is based in the RAVE Framework between the data forwarding and the various wireless technologies, as is represented in Figure 2. The major task of this abstraction layer is thus, to illustrate the data of the WSN in such a way that they can be mapped onto the data model of the automation system.

As can be seen I/O-nodes are mapped onto the in the Figure 4 individual slots of the automation system. In addition, administrative functions have to be providing for each node, e.g. security and routing information. Depending on the used radio technology, the number of parameters and services may vary significantly. With Bluetooth, for example, it is not possible to build a multi-hop network and only one transmission channel exists.

In the engineering phase, the radio network is booted during its initial operation and lines of communication are established. Here, internal routing structures are identified and profiles are recorded. The access controller triggers the coordinator to determine its network structure and transmit it to the AC. By using a broadcast message, the AP initiates each I/O-nodes to transmit its device description.

If, for example, 802.15.4 is used, it may be possible that the present networks might be multi-hop networks. Therefore, the communication channels or the network structures are logged and also transmitted to the AC. The network structure e.g. can be determined in the way that each node remembers its predecessor and its successor.

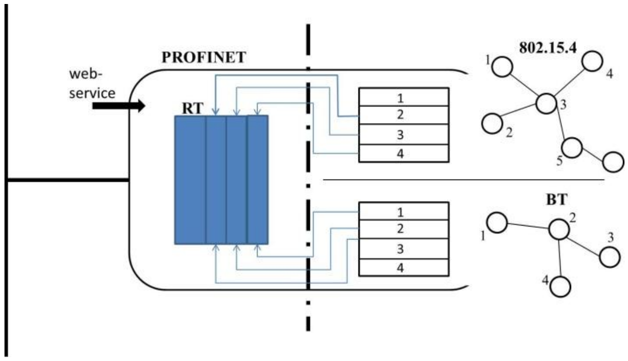

Figure 4: Wireless Abstraction

Mapping

The advantages of several different radio systems can only be used appropriately in a RT-Ethernet-based automation system, if a gateway performs the mapping of process data and forwards the data. The data transmission between the I/O-controller and the wireless sensor network is processed in the gateway and implemented on the appropriate protocols. Since the cyclic data traffic of the RT-Ethernet and the traffic of the WSN are asynchronous to each other, a cache must be set up which synchronizes the two cycles. A process image in the Gateway could resolve the matter by adopting the appropriate data and by providing it to the respective other process.

With the RT-Ethernet used in this project the addressing is accomplished through the principle of the slot/subslot and index addressing as is shown in Figure 5.

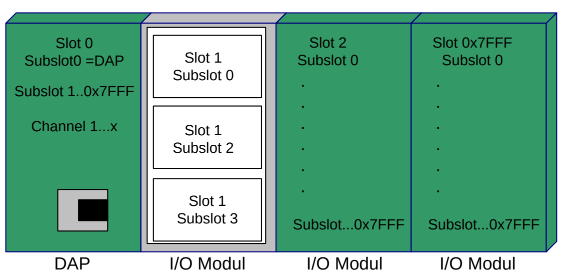

Figure 5: Addressing I/O-Device

As described above, all field devices with their technical and functional characteristics are described in the GSDML-file.

Among other things, the device model is defined by the Device Access Point (DAP). In order to manage the actual process data traffic, a multiplicity of periphery components can be assigned to the DAP. With field equipment it is necessary to be able to address all I/O-signals separately, and therefore the following definition was established:

1. The field equipment is addressed as single unit by the DAP.
2. Individual periphery components are addressed by slots.
3. Subslots contain the actual interfaces to the process (in/out).

A physical card location of a periphery component is marked by a slot, and this means in a WSN that each radio knot represents a slot. These slots in turn contain one or more subslots for the actual data exchange. For a quadruple digital output radio knot this would mean that its 4 tracers are represented in the subslots.

The DAP is, according to the standard, addressed over slot 0/subslot 0. Slot 0x1 - 0x7FFF are available for the projectable periphery components.

Cyclic I/O-data are addressed by a slot/subslot combination. The number of subslots determines the access options of different I/O-controllers. Only one I/O-controller can access per subslot while writing, when reading, several are permitted.

With acyclic data traffic, the data is also specified exactly by a slot/subslot. However, the index is user-specificly added, which defines the function that is triggered by the combination of slot and subslot [8].

For the addressing of data sectors that are read or written in an acyclic way, the following is true:

- INDEX 0x0000 – 0x7FFF free for the user
- INDEX 0x8000 – 0xFFFF reserved for PROFINET

In summary, this means for the system presented here that each gateway together with the AC is a DAP. The individual radio operators are perceived through the slots, and the individual inputs and outputs, namely the process data, are in turn presented in the sub-slots.

The engineering system receives the collected GSDML assembled by the access controller and is able to configure the automation system based on the contained information. Similarly, every respective gateway receives the relevant data for each radio network and extracts the necessary information in a dynamic way. At this point, the node between the component ID and the corresponding knot are known, therefore, the GW is able to map the relevant data of an I/O node onto the appropriate slot.

Conclusion

In this paper, the topic of wireless technologies in automation has been discussed, and a possible solution for the integration of different radio technologies has been shown.

A particular advantage of using different technologies, especially in the area of factory automation, is that depending on application and local conditions, the most appropriate wireless technology can be used. Thus, all advantages of wireless data transmission can be used without their respective disadvantages.

So far, only very few proprietary wireless solutions for the automation field exist, and therefore, the solution that has been demonstrated here represents a significant innovation in the field of automation technology.

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