Options of radio based industrial CAN communication

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Mobile communication in industrial automation systems is an increasing field of interest. Radio based fieldbus extensions are investigated in several projects. Approaches for CAN are also known. Nevertheless, the known solutions are still far from becoming a standard. This paper provides an overview of the necessary technical and economical preconditions of a radio based CAN standard. The standard can follow several objectives concerning the mobility, flexibility or network topology which are discussed. The technical problems of a radio based CAN standard are shown in this paper. Consequences for the level of specification as well as solutions which could be the basis of a future standard are also introduced.

Introduction

Technological developments open up new possibilities even in application fields which they were not developed for. The Controller Area Network (CAN), developed for car communication - used in industrial networks, is an excellent example of this.

Today, radio technologies are in a state to be introduced into new fields of application, thus e. g. into industrial communication. However, the integration in applications and devices as well as the usage conditions follow special rules in industrial automation systems. First experiences show that modifications are necessary, since the radio technologies and standards are not made for the usage in industrial environments. The today known implementations of industrial radio systems solve special communication problems by adapting selected radio solutions, but a common approach, covering a broad field of application, can not be seen. However, even if a specific radio solution for a communication task in an automation system may spare costs, the objective of a widely usable specification is suggested.

The community of CAN in automation experienced the importance of standardised interfaces and behaviours with the CAN Application Layer specifications and their profiles. Especially for small and medium sized companies, standardisation is an important topic to save their investments.

A common approach described in a specification document and ready for standardisation is necessary.

Applications for different radio CAN solutions which can serve as a basis are known (/1/, /2/, /3/).

In this paper, the prerequisites and conditions for a common radio CAN approach are discussed. Several objectives are presented which have to be considered in a radio CAN standard. These objectives are discussed taking account of the current status of CAN and radio implementations. In the conclusion, suggestions for a first standardisation approach are made.

Even if the first documents are specifications rather than standards, the term standard will be used in this paper. Another convention is that the term wireless is used as a synonym for radio in this paper. Other types of wireless communication such as infrared are out of the scope in this paper.

Prerequisites and conditions for a radio CAN standardisation

Before discussing standardisation details, the prerequisites and conditions for a radio CAN standard shall be considered.

Even if the interest in wireless communication in the automation is growing, the reasons, motivation and requirements are all very different. The most important requirement is the request for communication with mobile devices such as handheld or moving robots. Also options to obtain a greater flexibility or open up new application fields are possible reasons to look for a wireless communication.

Before starting specification activities, it is necessary to find interested parties who share a common aim. Who could be interested in such an activity? No doubt that end users in any case would have advantages of a standardisation. On the other hand, end users do not normally participate in standardisation. Providers of radio technologies, such as chip manufacturers and radio modem manufacturers could also participate in expecting a growing market. For the providers, however, the margin seems to be too small as these activities would need to be shared. So normally system integrators and device manufacturers deal with this kind of specification.

A communication standard is a formal description of objects, services, protocols and coding. The question is what is the appropriate standardisation body for wireless extensions of a wired communication system. Since several technologies are involved (Bluetooth, CAN, Wireless LAN, etc) there are several options for standardisation. In the given case it seems reasonable to add a document to the CAN specification family instead of forcing one of the radio specification bodies to regard a special wired protocol. However, CAN and Bluetooth for instance could be regarded as short distance communication networks. Thus, even a CAN profile for Bluetooth is imaginable supposing that the support by companies is large enough to form an interest group.

In any case, the expectancies and requirements in a standard must be formulated in advance. Some objectives for a radio CAN specification are discussed in the following chapter.

Objectives of a Specification

Figure 1 shows a communication architecture which is used to discuss some objectives for a radio based CAN specification.

In principle two kinds of networks are imaginable. On the left side you can see a so called ***direct link network*** and on the right there are two ***base station networks***. The direct link network is characterised by a direct communication between each wireless station, while in a base station network the communication is relayed via a base station. A direct communication between two stations is not possible. A special case of a direct link network is a point-to-point connection. Of course, two wireless stations residing in one and the same wireless domain (radio cell) must not have a wired connection. Otherwise a doubling of messages would result.

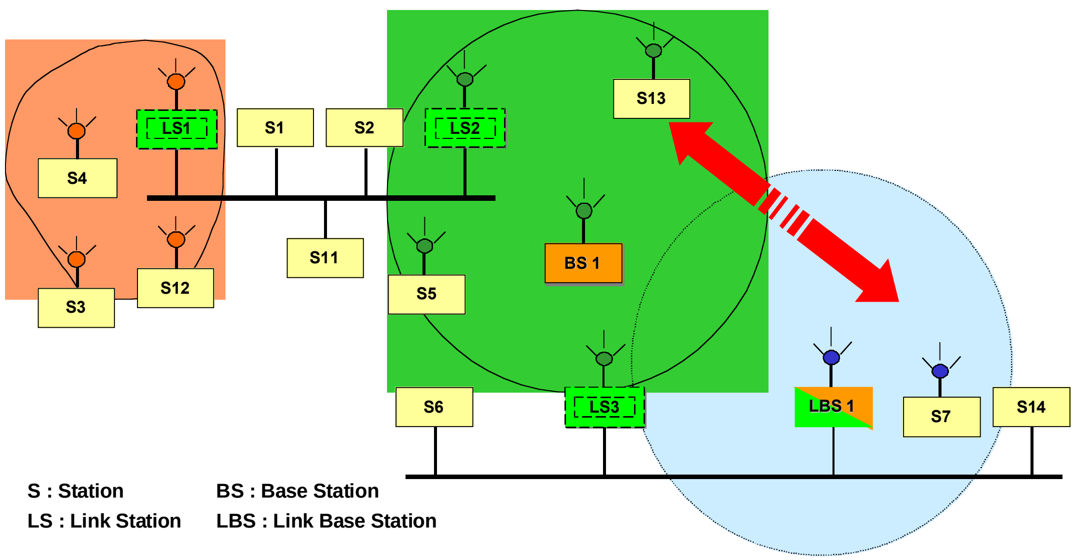

Figure 1: Wireless Communication Architecture

For a direct link network, mainly the link between the wired and the wireless part is to be specified. These link stations can be implemented as a ***cut through*** or ***store and forward*** repeater. The same is valid for the link stations in a base station network. Here needs also to be clarified how to separate the ***uplink*** and ***downlink*** transfer. This is possible by different frequency channels, by time slots or by different spread codes in code division multiple access networks

(CDMA). Another subject in base station networks is the ***mobility*** between two radio cells. How does the channel assessment work and how does the channel switching function?
Both network types have advantages and disadvantages which shall not be further discussed in this paper.
At taking a closer look at the communication structure of a CAN device (see Figure 2), the question arises on which ***communication layers*** can be used in the wireless version of a CAN device. At the very least the Medium Dependent Interface has to be exchanged and the application layer must remain unchanged. The position of the intermediate layer in a link device (device with wired and wireless interface) depends on this decision.
With a new medium (radio), additional devices and parameters are introduced. It has to be decided which ***parameters*** must be handled by the system management and by the layer management. Examples of these parameters are:

- the physical layer address for remote configuration (e. g. transmission power)
- operation modes
- power thresholds for channel assessment
- channels (frequency, time, code)
- timeouts

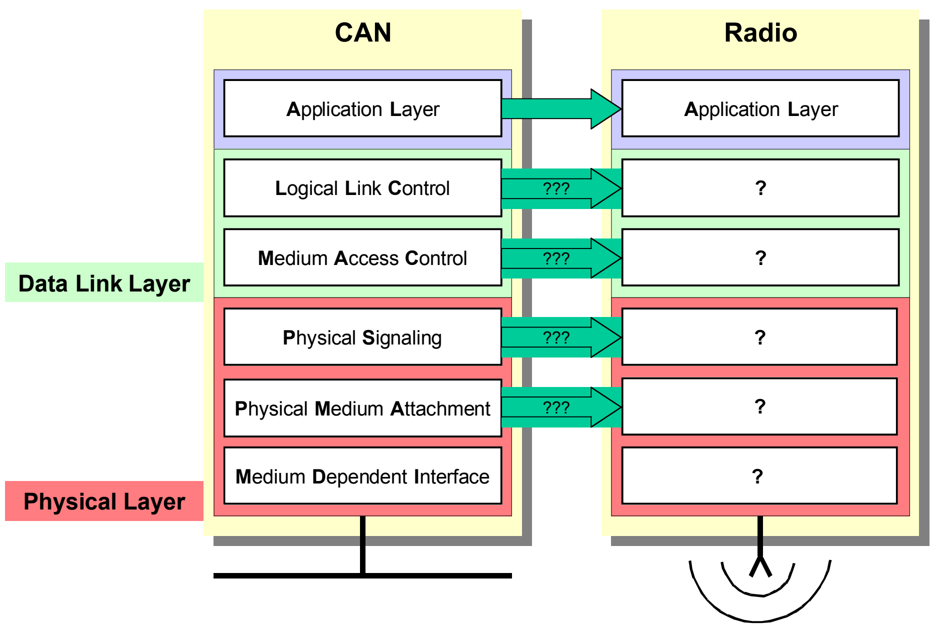

Figure 2: Transforming a CAN device into a radio CAN device

Some of the above mentioned decisions depend on a certain radio technology or their implementations. Therefore, Bluetooth offers e. g. only a defined interface to the user, so that there is no degree of freedom concerning the communication layers which can be used or which can not be used. Wireless LAN implementations probably offer more flexibility at this point. Therefore, one of the main decisions in a radio specification for CAN is which ***radio technology or technologies*** shall be considered by the specification.

The specification has to take into account of the special industrial environmental conditions which differ from the requirements which the radio solutions are normally made for. It has to consider if the ***characteristics of radio solutions*** such as data throughput (baud rate, media access mechanism, error handling, channel capacity) and reliability (bit error rate) fit the requirements of the communication in industrial automation. If this is not the case, additional measures must be specified. Which of the listed objectives should be taken into consideration for a radio CAN specification? Some ideas are expressed in the following chapter.

Radio CAN Approaches

Even if point-to-point connections are sufficient for many applications in industrial automation systems today, the market would grow essentially if the specification would focus on ***network architectures***. This is usually the precondition to implement mobility covering a larger area. Talking about mobility, two options are possible: the intra-cell mobility and the inter-cell mobility. The inter-cell mobility requires a hand-off mechanism to be able to move from one cell to another cell without losing the connection. In the case of CAN, ***hand-off mechanisms provided by the radio solutions*** should be used.

The question 'which kind of link devices should be considered?' is closely related to the implemented CAN communication layers. This is the reason for this subject being discussed first.

Just by exchanging the CAN Medium Dependent Interface by a radio physical layer would require that this layer supports the CAN medium access control mechanism. The crucial point of the CAN media access control is that it is event driven, resolving collisions by a bit aligned arbitration. Implementing these mechanisms requires the reception of a symbol still during the transmission. This results in three main problems:

- the coding of the recessive and dominant state of a symbol
- the transmission delay between transmitter and receiver
- the simultaneous transmission and reception (near-far problem)

The most critical problem is the last one. The signal attenuation is a significant characteristic of radio communication. A station near the transmitter receives a strong signal while a station far away could assume the media free. In networks with a base station (access point), the problem is solved e. g. by protocol measures (media access control) or by transmission power control. These solutions are not suitable for CAN because it is, like all industrial communication networks, a broadcast network. A radio CAN could be considered as an ad-hoc network. In conventional ad-hoc networks, the attenuation can remain disregarded as long as none of the transmitters is located directly beside one of the receivers, which is the case with a discussed CAN solution. Thus, in radio CAN where clear communication relations are missing, it seems impossible just to exchange the physical layer. This means a radio CAN solution also needs another media access control layer.

However, what about Data Encapsulation and Decapsulation, Frame Coding (Stuffing, Destuffing) and Error Detection, Acceptance Filtering, Overload Notification and Recovery Management? These services could remain unchanged. Since the interface of these services are inside today's CAN chip implementations, this approach is unrealistic for now. However, with the development of application specific integrated circuits (ASICs), it becomes interesting to merge CAN VHDL descriptions with that of radio base band controllers.

In any case, the CAN application layers can be used unchanged. Therefore, an ***intermediate layer*** is necessary in radio CAN devices which provides interfaces to the CAN controller as well as to the application layer and controls the interface to the chosen radio module. In the link devices, the intermediate layer controls the CAN controller interface as well as the interface of the radio module and optionally provides an interface to the application layer (see Figure 3). This also means that a radio CAN link device is a ***store and forward repeater***. Firstly, the entire CAN Object (including Identifier, Frame Length Code ect.) is received (and stored) completely before it is transmitted via the other media.

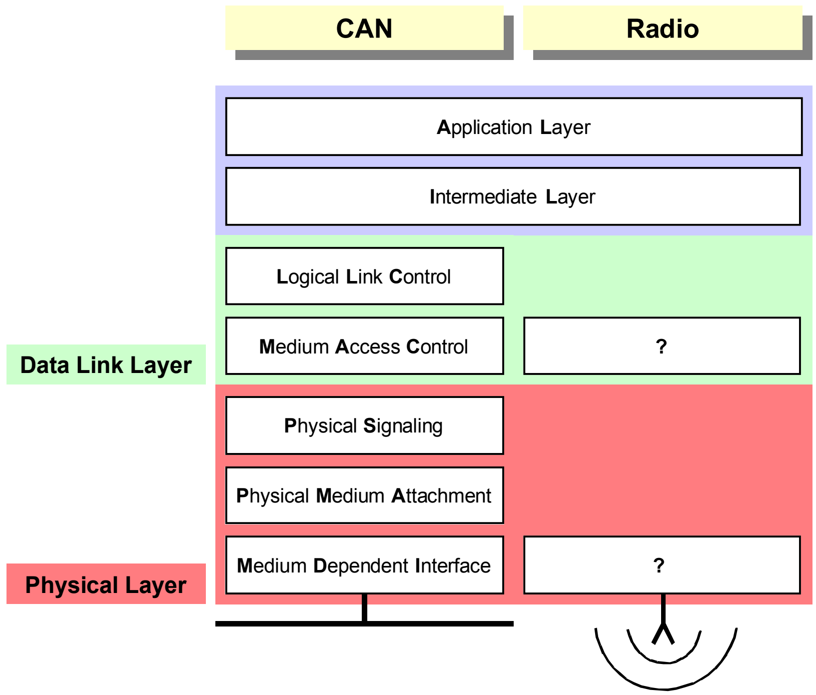

Figure 3: Radio CAN link device

In this case, the question arises if each CAN object can be transmitted immediately, contained in a wireless protocol data unit. Due to the required synchronisation of the radio receivers, the overhead of such a transmission can easily be as long as the data field. That is why the effort and consequences of a packed data transfer (3 or more CAN objects with one radio transmission) should be investigated. This will be especially interesting if wireless data rates of more than 5MBit/s are used.
In contrast to a link device, a base station could be a cut through repeater, because in this device the CAN objects are only data without a special (CAN) meaning. It depends on the used radio solution whether it is a cut through repeater or not.
Concerning the ***radio technology,*** there is ***no favourite solution*** depending on the CAN architecture. Moreover the application field determines the requirements in the radio solution. Investigations were made to assess radio solution regarding the special requirements of communication in industrial automation (/4/, /5/). Most probably ***solutions using the ISM Band*** such as Bluetooth or Wireless LAN or Wireless LAN based solutions will be used for industrial radio communication as long as no

frequency band is reserved exclusively for industrial automation. Comparable with the CAN implementations, most of the radio solutions are so highly integrated that it is difficult to find an implementation which properly fits to a good communication architecture. In contrast to CAN where a certain saturation in controller implementation is reached, the stage is still open for radio controller implementations. This means it is still a field of further investigations and developments.

Subjects of further investigation are the additional required ***parameters and services*** contained in the ***layer and network management***. A common model of a system management is described in /6/. However, additional work has to be done to specify in detail the management extensions necessary because of the radio transmission. It would be a challenge to specify a common layer and network management extension independent of the wired or wireless systems. First experiences are available (/4/, /7/) which have to be analysed together with other solutions in order to obtain an appropriate solution.

Furthermore, experiences are necessary concerning the use of radio solutions in industrial environments. Here we have not spoken about the robustness (according to German classification IP65) or availability of radio devices (10 years and more of support), but in particular the ***propagation conditions*** which are different to that of offices or homes. Results of these investigations will of course influence the specification work in terms of improvement of the timing behaviour and improvement of the reliability compared to the original radio solution. However, even if the improvements are implemented, the application layer deals with two different medium with a different Quality of Service. This has also to be taken into consideration in the specification.

A first approach to a radio CAN specification could be the definition of the interfaces and the behaviour of an intermediate layer located beneath a CAN application layer. Concerning the radio part, a generic interface should be aimed considering available solutions such as Bluetooth, HIPERLAN 2 and IEEE 802.11b. System and layer management services must be taken into account.

Conclusions

There is a growing interest in wireless access to Controller Area Networks. To avoid a wide variety of proprietary implementations, a standardisation of a radio CAN solution is required even if the market potential is not yet available to force comprehensive changes in CAN or radio implementations. A realistic specification today can not deal with poor physical layer replacement. Nevertheless, the already available experiences can be focused and the field can be prepared for future developments. The market potential of industrial radio implementations has to be demonstrated. Therefore, co-operation with other industrial communication systems could be helpful. Common to all these systems is the requirement for a high performance and high reliable radio solution on the one hand and a limited number of pieces for a specialised solution on the other hand. Standardisation in this context not only introduces new possibilities to industrial communication but also opens up new application areas for the wireless industry.

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