Bluetooth in Automotive Applications

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ABSTRACT

There is a potential for 50 - 400 million per year Bluetooth nodes within the car market if Bluetooth can be integrated into the car controller network. This paper deals with some of the features that can be achieved with such an integration, and some of the problems.

1 Introduction

Bluetooth is developed primarily for linking two mass markets together; telephone and PC. This is really thrilling and anybody realizes that this opens up for a huge chip volume and then low prices can be expected. But what about the third volume market; cars? Will Bluetooth fit in there too and make the volumes even bigger? The answer is "Certainly Yes!" As soon as we imagine that the car system can be connected via Bluetooth a whole row of services can be identified. The car owner would firstly expect any service he has at home, that also make sense when in the car, to be delivered. What first comes in mind are phone and audio services and they do not need to be discussed further at this time. Next comes car dedicated services as using the mobile phone for locking and unlocking the car, adjusting seats and climate according to settings in the mobile phone, etc. Once you start thinking about the possibilities to connect car information and control systems to personal information carried in a mobile phone, and further to the Internet, you will find an unlimited number of possible services. Now, this calls for one Bluetooth set in each car, a potential additional market of about 50 million units per year. But this market might be expended with up to an order of magnitude if Bluetooth could be made suitable for CAN!

2 CAN

There are three major reasons for using networks in a car:

1) To replace mechanical control systems, e.g., throttle linkage, speedometer wires, etc.
2) Provide diagnostics information
3) Reduce wiring harness

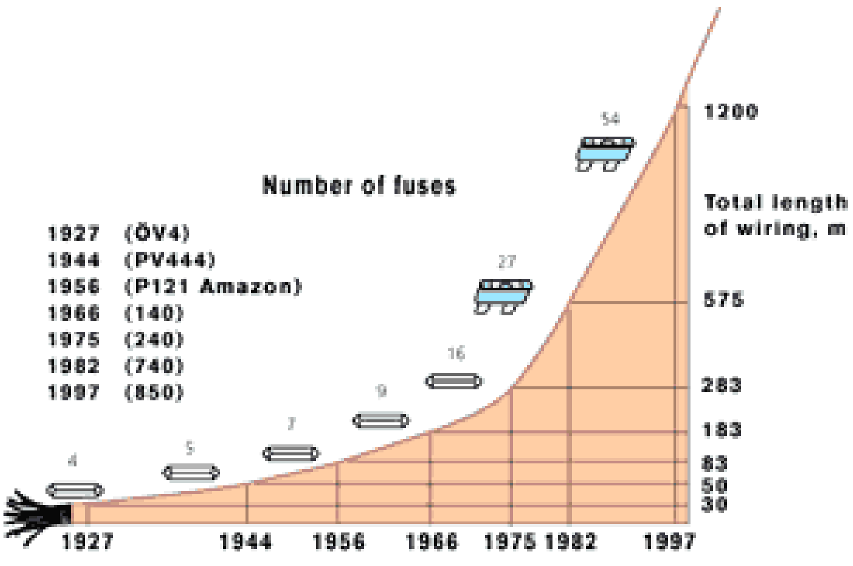

Figure 1 Fuses and cables in Volvo cars over the years

Most new cars of today have an electronic system consisting of several micro controllers distributed in the car and connected to each other via a serial bus. This technology has evolved during the past ten years and now there is a well established basic protocol for such networks, the ISO 11898 Controller Area Network, in short "CAN."

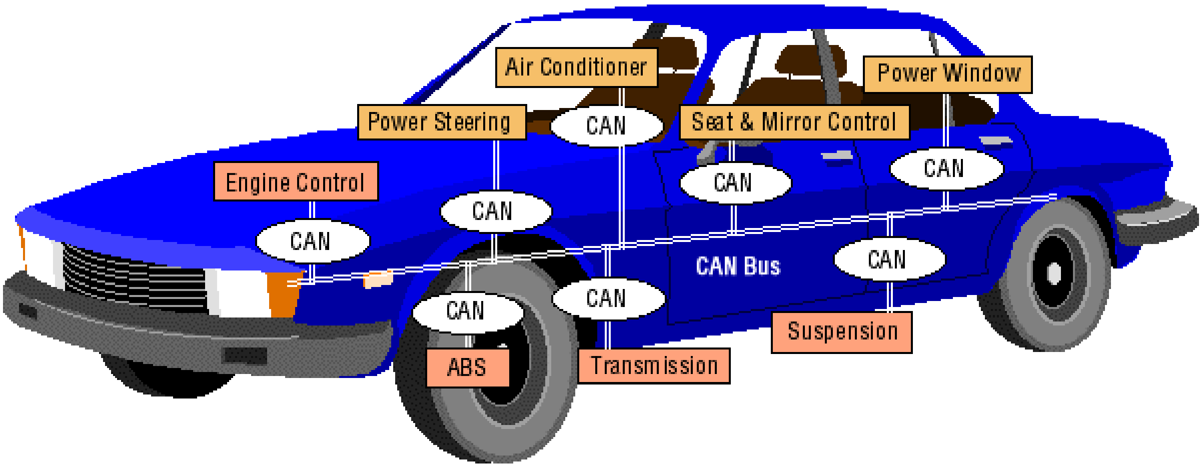

Figure 2 CAN network in a car

Some CAN characteristics:

Bit rate	Adjustable, ≤ 1Mbit/s	Depending on cable length and oscillator quality. Maximum bus length is 40 m at 1Mbit/s
Transmission type	Broadcast	Every node receive every message and participate in error checking
Raw message length	47 - 150 bits	
Usable message length	11 - 94 bits	Usually 0 - 8 byte data
Buss access	Collision Detection Multiple Access / Collision Resolution by Bitwise Arbitration	Each message has a unique priority. When the bus is free, any transmitter is allowed to transmit. If collision occurs, the message with highest priority wins the bus. The losers tries again when the ongoing message is completed
Error detection	CRC-, bit-, bit stuff-, frame- and acknowledgment- errors	Extremely low probability for undetected erroneous messages
Data consistency within the net	Guaranteed	All nodes have received a message and found it error free before it is accepted
Latency time	Predictable	Depends on message priority and scheduling method. The maximum latency of a message can often be kept below 1 ms.

CAN is a very robust and efficient protocol for wire transmission but unsuitable for radio transmission. The very reason for this that CAN fundamentally relies on a mechanism of simultaneous transmission and reception of bits, zero being dominant and overwriting one. This bitwise behavior of the protocol requires that nodes are synchronized to each other within a fraction of a bit time. Thus, the minimum bit length (maximum bit rate) is coupled to the signal path. When transmission takes place on a wire the signal path is known and constant and this ideal for CAN. Usually the signal path for radio waves is variable within a wide range and this makes radio less attractive for CAN. Further, to achieve the bitwise arbitration, a radio for CAN has to be true full duplex. This leads to an architecture where radios are used as bridges or gateways.

As Bluetooth has a maximum bit rate of 1 Mbit/s and that there is no bit-by-bit transfer of the CAN messages, it is obvious that we have to face that the radio transmission will be a bottleneck. Thus, in order to make Bluetooth attractive for the car industry, it must be possible to minimize this drawback.

3 Bluetooth in cars

The new generations of cars will have an increasing number of micro controllers connected via two or more networks. An advantage of this is that the cars can be individually customized by software, another that the car to a great extent can have self diagnostic functions. To fully use such features, it is necessary to have a bi-directional communication between the car system and production tools as well as service tools for downloading new software and parameters and uploading of status and diagnostics messages. These production and service tools will, to a great extent, be based on PC technology. The connection between the car system and the tool is made via a cable, either directly to the CAN bus or via a gateway. The cheapest way is to connect the PC directly to the CAN bus by a drop line but this has to be short: According to the CAN standard it should be less than 30 cm at 1 Mbit/s bit rate. In practice it can be somewhat longer but still impractically short. In new designs, most probably a CAN/USB gateway will be used and then Bluetooth can be considered an alternative as it would be a great advantage to have a wireless communication between the car and service tools. Let us take a look at the pros and cons of USB and Bluetooth:

	USB	Bluetooth
Data throughput	+ +	-
Latency	++	--
Security	+	-
Mobility	-	+++
Price	+	_
Versatility	-	+++

We can see that the main advantage of Bluetooth is the wireless connection and that it can be used not only for car production and service but also for other services appreciated by the car owner. The major disadvantages are latency and security. Bluetooth is developed to be an open connection between any item but for car systems dedicated connections are preferred in most cases.

3.1 Bluetooth in car production

In the car production a lot of software is downloaded as a final step in the production line. This is an application where Bluetooth would be ideally suited. A Bluetooth base station is connected to the production fieldbus. When the car on line gets connected to the Bluetooth base station, it uploads it serial number. The production computer then downloads the software for this very car via the fieldbus to the base station, who in turn transmit it to the car. However, this is a dedicated use and no other Bluetooth units than those installed in the cars should get connected to the cell. This might need some changes in the MAC layer.

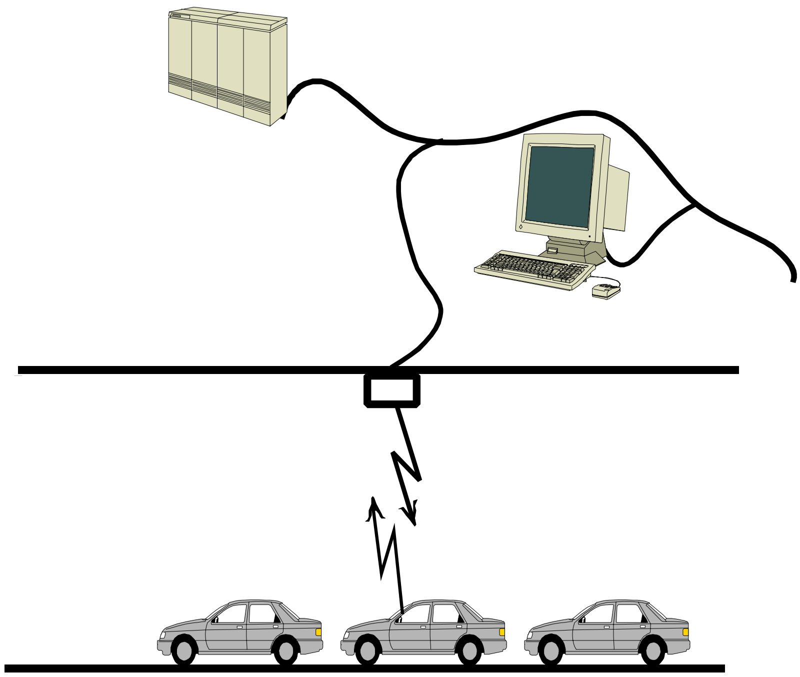

Figure 3 Bluetooth in a car production line

3.2 Bluetooth for car service

A scenario for using Bluetooth could be:

1) When the car enters the service station, its Bluetooth station gets contact with the service stations main computer. This has previously exchanged information with the car computer via the cell phone system.

2) The service station main computer alerts the service man allotted the task and his PC establishes contact with the car and downloads any information needed.

3) The serviceman gets any work instructions needed on his PC. When servicing the car, he can control and adjust several functions via the PC, e.g., any lights, windows, climate control, engine parameters, etc. He can also download the latest software versions to any Electronic Control Unit (ECU)

The two first items above are not very controversial. They are not time critical but maybe the car manufacturer would like to hide or control some information so they cannot be altered by unauthorized people. But the third item is more tricky. To really utilize the potential of the technique, both hard realtime requirements and privacy has to be met. In future, the car could actually be driven by remote control via a PC! Thus, we can distinguish two modes:

1. Connection mode
2. Control mode

In the connection mode, the ordinary Bluetooth MAC layer will probably work fine. Maybe the density of Bluetooth stations in a parking house will cause some problems. In the control mode however, the Bluetooth MAC layer is not very well suited. When connection is established, then only a fast point-to-point link is needed. Any other services, like roaming, neighborhood connection, etc. will only cause problems. As the qualities of a Control Mode MAC are car-maker specific, there must be a possibility to switch from the Bluetooth MAC layer to a custom design MAC layer. There is no need for the Bluetooth consortium to redesign the current MAC layer or to provide a hard realtime MAC alternative. This will be made by the car manufactures themselves or by their organizations. But in order to make it more attractive for the car manufacturers to include a Bluetooth node in each car, i.e., to get the additional 50 million per year market, there should be a way to temporarily substitute the Bluetooth MAC for a custom design MAC.

3.3 A Bluetooth network in the car

Flexible cables are always a source of problems. In a car you find them at least at each door, in the front seats and at the steering wheel. Here a short range wireless cable stretcher would be handy. As it is difficult, even for very short ranges, to make a reliable bit-by-bit wireless connected section in a CAN network, the cable stretcher will not be a repeater but a bridge. The effect of this is that the cable stretcher will divide the CAN net into two nets, even one of the nets will consist of one node only. This ends up in high complexity and cost.

As a short range point-to-point cable stretcher would require fourteen radio units, still requiring network-to-network capability, such an architecture would not be attractive. A solution with one base station connected to the CAN network and radio nodes in the doors, seats and the steering wheel hub is more probable as this would require only eight stations. Further, the base station would be the same as for the PC and mobile phone connection. The cell stations will only have to communicate with the base station and any other Bluetooth features will only create problems. Thus, it would be an advantage to have customized MAC layer from a technical point of view. The cost for these stations has also to be low and the reduced MAC layer might also lead to cheaper hardware. If Bluetooth hardware can meet the requirements, we have a potential market of and additionally 350 million units per year.

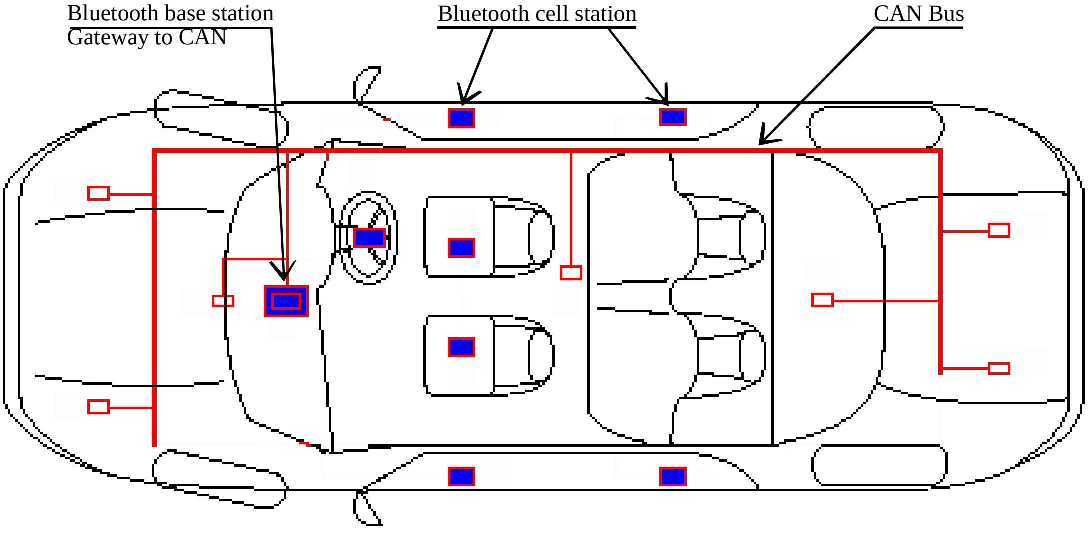

Figure 4 A CAN/Bluetooth network

4 Timing requirements and eavesdropping

In order to make Bluetooth really attractive, it must be possible to switch between the standard Bluetooth MAC layer and a customer specific one. The need for a customer specific MAC is primarily to achieve better realtime performance but also to simplify solutions to avoid eavesdropping and interference by other Bluetooth stations. The main timing requirement is to exchange CAN messages with a rate of 1000 to 5000 messages per second, i.e., 100 - 750 kbit/s data rate and a 5 - 10 millisecond turnaround time for short messages of 10 - 20 byte data packets.

5 Conclusion

There is a potential additional market of about 50 million units per year for Bluetooth in the car industry as a gateway to the Controller Area Network. To reach this market there has to be a possibility to store a car specific alternative to the Bluetooth MAC layer and to switch between the two by command from the CPU.

The car market could be even bigger, maybe an additional 350 million units per year, for Bluetooth radio chips combined with a custom design MAC layer. These units would mainly be placed at positions now requiring flexible cables and would only communicate with the Bluetooth/CAN gateway mentioned above.

The custom design MAC layer would allow for a 100 - 750 kbit/s data rate (not including radio overhead) and a turnaround time of 5 - 10 millisecond for short messages of 10 - 20 byte data.

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