connectBlue

From idea to a Bluetooth based product

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Abstract

Enabling of Bluetooth in products has a high threshold depending on many different factors. For many developers this is the first time a radio technology is used in the product. Focus on new problems like antennas and making the electronic design "radio-aware" is then required. A radio design also needs to be type approved witch implies the need for special knowledge and involves substantial costs. Bluetooth is currently a rather complex technology involving time and cost consuming issues like purchasing or developing a software stack and the mandatory Bluetooth qualification procedure. Several different partitions are possible between the Bluetooth part of the system and the application part of the system.

This paper will address these issues and discuss different possibilities and methods of how to enable Bluetooth in a product depending on anticipated volumes and constraints on size, costs and time-to-market. Using different levels of ready-made, already type approved and Bluetooth qualified components, the time-to-market and development cost may be lowered at the expense of a higher product cost. Using ready-made components you do no even need to be member of Bluetooth SIG (Special Interest Group) to put the Bluetooth trademark on your product..

Radio technology and antennas

Involving radio technology in an electronic design will put focus on new issues and may require changes to an already existing product.

The electronic designer must be aware of the presence of a radio in order to avoid bad radio performance or that the radio interferes with other parts of the product electronics.

Antenna issues needs to be considered very early in the design. The antenna to choose is depending on requirements like range, type of housing and where the circuit board is mounted in relation to other parts of the device (for example metallic parts may interfere with the radio field). One option is to mount the antenna directly on the circuit board. This is a cheap solution and another benefit is that the antenna is hidden from the user but it may on the other hand result in bad performance with regards to range and "radio shadows". An internal antenna is also very sensitive to the type of housing. A metallic housing or even a housing using a metallic paint may out-rule this

option. An external antenna may be directly mounted on the circuit board or mounted on a wire, away from the board. Mounting it directly on the circuit board will give a minimum of losses but is less flexible than an antenna on a cable. Figure 1 shows some examples of different antenna solutions.

Figure 1 - Alternative antenna solutions

Sometimes an antenna with a specific type of radiation pattern is the correct choice, for example for a device that is mounted on a wall an antenna with radiation pattern of 180 degrees may be the right choice. A more directional antenna will enable you to extend the range of your antenna due to the antenna gain (see Figure 2 for an example of two different radiation patterns with different antenna gains).

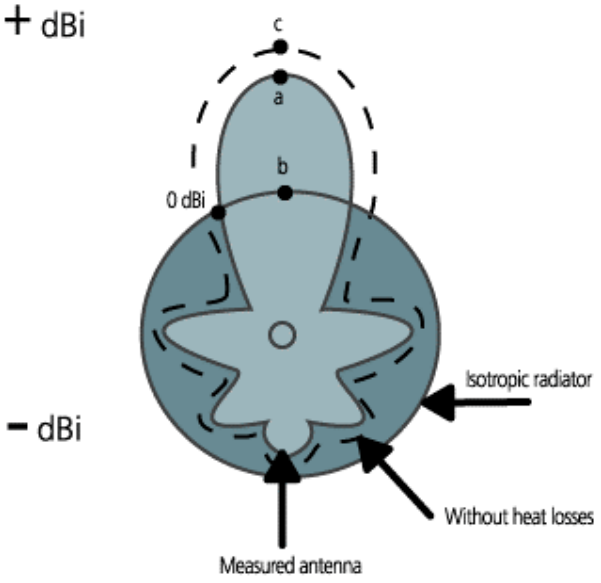

Figure 2 - Radiation patterns

Type approval and Bluetooth qualification

Type approval and Bluetooth qualification are additional tests and certifications required for a Bluetooth product. These are added to the traditional EMC tests and certifications.

Bluetooth is using the ISM (Industrial, Scientifical and Industrial) band. This is an unlicensed band but *type approval* is mandatory (for regulatory reasons). Authorities in different countries have to approve the use of a radio in this band. In order to do this certain measurements needs to be done, reported to and approved by the authorities. For all EC countries only one central approval is required. For USA, a FCC approval is required. For many other countries these approvals are sufficient but some countries have exceptions of how to use the ISM band and additional type approval is required. The Bluetooth community is actively working on this matter, trying to get the same regulatory rules valid all over the world.

Bluetooth Qualification is enforced and supported by the *Bluetooth SIG* (Special Interest Group). The SIG (or more correctly the SIG company, Bluetooth Inc.) is the owner of the Bluetooth patents. In order to use the patents, a development company signs an agreement stating that it will comply to the Bluetooth specification and interoperability rules. The SIG has defined several usage scenarios and for the usage scenarios are *Profiles* defined. A profile specifies how a device shall use the Bluetooth protocol stack in order to be interoperable with other devices. The Bluetooth qualification program tests and verify the compliance with the protocols and the profiles that is used in the product. The SIG is accrediting persons called BQBs (Bluetooth Qualification Bodies) as agents allowed to qualify a product and list it on the list of qualified products (found on the Bluetooth SIG homepage http://www.bluetooth.com/).

Several of the type approval, Bluetooth qualification and EMC tests may be performed at the same test house and at the same instance in time. But still, we estimate an additional cost for about 30 – 50 kUSD for the type approval and the Bluetooth qualification (if the Bluetooth solution is developed from the ground up). These costs may be considerably lower if already qualified components (hardware and software) are used (see the “ Software and hardware partitioning” section later in this document).

Software and hardware partitioning

When designing and integrating Bluetooth in a device, different hardware and software partitioning methods may be used.

To understand this I will give a short description of the Bluetooth software stack.

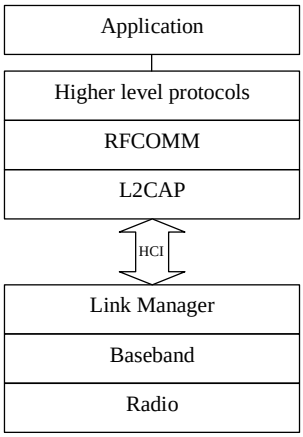

Figure 3 - Bluetooth software stack

Figure 3 shows the main layers of the Bluetooth communication stack. Traditionally the layers below the HCI (Radio, Baseband and Link Manager) have been delivered in hardware from the manufacturer of the Bluetooth chip sets. HCI (Host Control Interface) is an interface defined in the Bluetooth specification defining a standard method to communicate between the L2CAP and Link Manager (on different physical interfaces like UART, USB, PCI and others). The higher-level protocols (L2CAP, RFCOMM etc) are often called the "Upper Level Stack".

A Bluetooth chip set is normally based on two chips or on a single chip. A typical two-chip configuration is shown in Figure 4. In a one-chip configuration the radio is incorporated in the same chip as the baseband. There is also Multi-Chip-Modules (MCM) available that integrates a two-chip solution in one easy-to-use package.

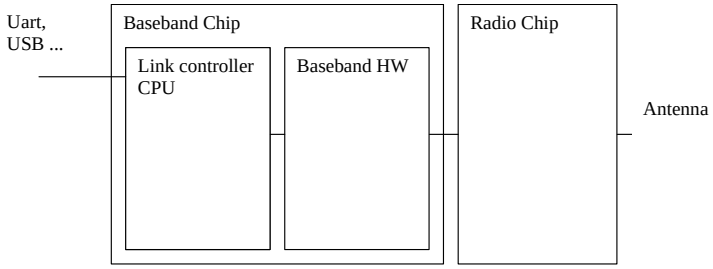

Figure 4 – A typical Bluetooth chip set

Using this as a background different partitioning methods may be used.

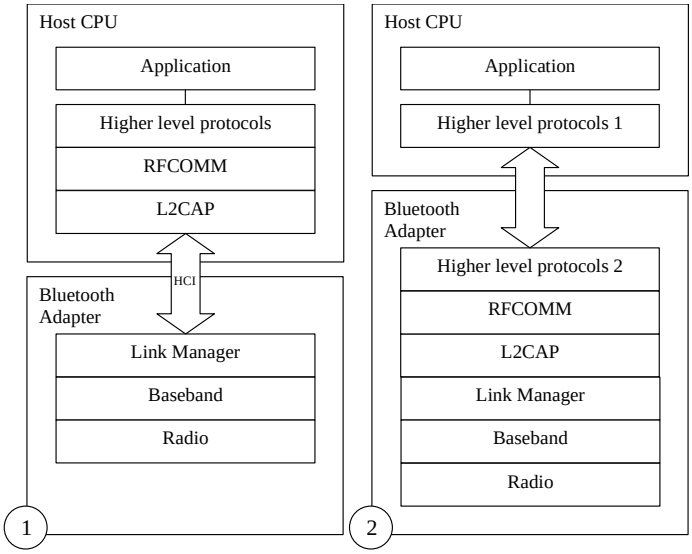

Figure 5 – Two partitioning alternatives

In alternative 1 the upper stack is executing on a host processor. This is the most commonly used way of doing it. Bluetooth adapters (for example PC Cards or USB adapters) focusing on the PC area normally operates like this but also many "embedded" devices are using Bluetooth in this way. An adapter of this type consists of the Bluetooth chip set, an antenna and a few other components.

Alternative 2 is an alternative partitioning. Most parts of the upper level stack is executing inside the Bluetooth adapter. The adapter is exposing a high-level easy-to-use application interface to the host hiding Bluetooth details from the application integrator. For simple applications, all of the logic in the application may execute inside the Bluetooth module allowing for a small, low power and low cost solution.

In this scenario the Bluetooth chip set may be used in two different models. In the first model the lower level stack is as well as the upper level stack executing inside the Baseband chip CPU. This will give a small, low power and low cost adapter but the somewhat limited resources of the Baseband CPU will limit its capabilities. In the second model an external CPU is added executing the upper level stack and talking to the baseband CPU using the HCI interface. This model allows for a more capable adapter but to a higher price with a larger size and higher power consumption.

How to Bluetooth enable a product?

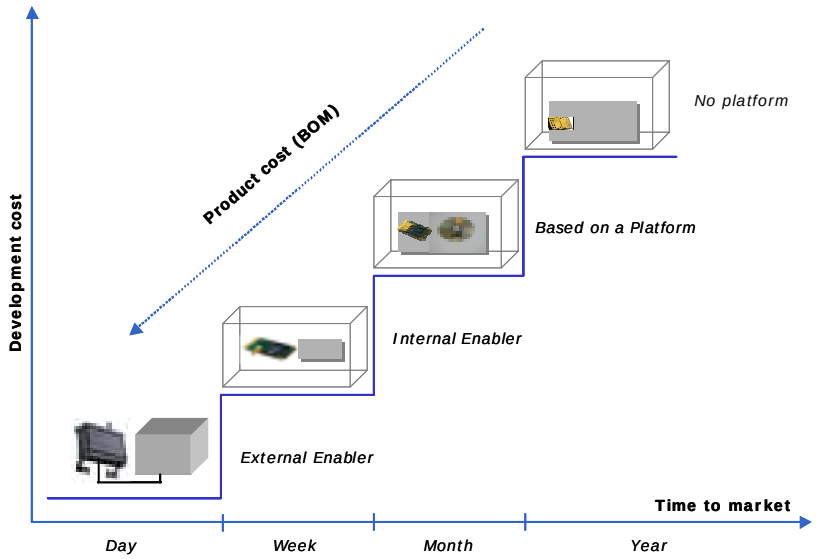

Figure 6 - Development ladder

Figure 6 is a schematic figure describing different approaches to enabling Bluetooth in a product.

The lowest step on the ladder is to use an external, fully qualified and ready-to-use Bluetooth adapter for example acting as transparent RS232 cable replacement. No extra qualification and type approval is required, the development cost is close to zero but the cost per unit will probably be rather high. Chose this solution if time-to-market is the most essential requirement for example if you want to do a case study for a limited volume, or if the enabling of Bluetooth in your product is delivered as an option for limited number of the users.

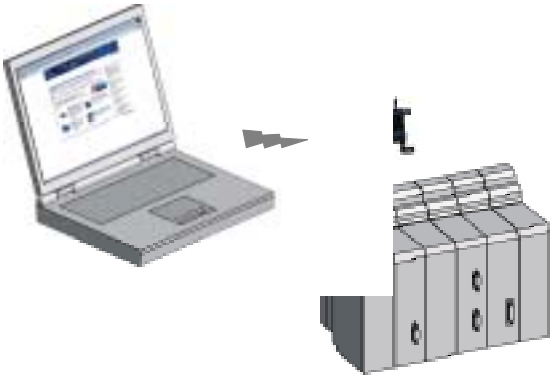

Figure 7 - Ex1 - Industrial control system

Figure 7 is an example of using an external adapter. An already available control system is programmed via a serial port from a laptop PC. The cable is replaced with a standard PC equipped with Bluetooth and an external Bluetooth adapter connected to a RS232 port on the control system. The Bluetooth is sold as an option in small volumes and the product owner did not want to modify the current product.

The next step in the ladder is to use a fully qualified OEM adapter designed for integration in a device. This type of adapter contains a full Bluetooth stack inside the adapter and very little or none type approval and qualification is needed. The development work is limited to calling high level API. The unit cost may not be the optimal but reasonable low. Use this solution if you need an integrated solution where volumes are medium sized and your requirements on price, size etc. fits within the attributes for this type of solution.

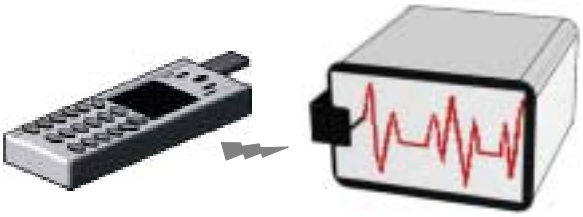

Figure 8 - Ex 2 - Portable medical equipment

Figure 8 is an example of use of a built-in OEM adapter. The portable defibrillator or patient monitoring device is using the built in Bluetooth adapter to dial-in to the hospital using a standard Bluetooth phone for transferring of patient data. Is of medium sized volumes and the product cost is not of major importance.

The third step in the ladder indicates a more integrated solution but the starting point is a Bluetooth platform (software and/or hardware) with ready-made components. This requires less implementation work than starting from basics. Using pre-qualified components may lower the costs for type approval and qualification. The final result is close to an optimal solution with regards to size and unit cost. In this case you may consider any of the two partitioning alternatives described in earlier sections. For real small devices, for example sensors, headset or similar, the Bluetooth platform may be the base for the whole application. Use partitioning type alternative 2 and include your application into the Bluetooth adapter.

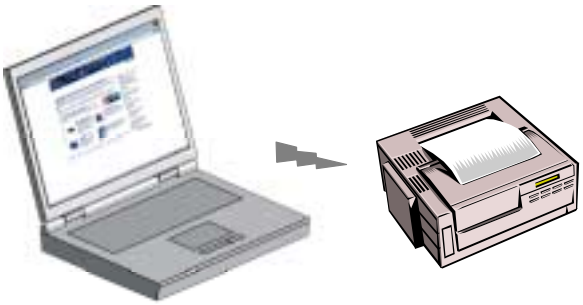

Figure 9 - Ex 3 - Special purpose thermo-transfer printer

Figure 9 shows a special purpose thermo-transfer printer with medium-sized volumes. First version, used for trying out the market, was built on an OEM adapter. In the second generation was a solution based on a Bluetooth platform used in order to create a more cost-optimised solution.

If the other three steps, described above, do not solve all requirements the last step in the ladder might be the only solution. In this case the optimal hardware and software components are chosen or developed. The drawback is of course longer time-to-

market and higher development costs. Use this for high volume products and when there are specific requirements on for example size, power consumption or product cost.

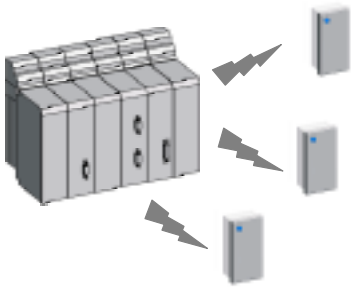

Figure 10 - Ex 4 - Small battery-operated sensor

Figure 10 is small, battery-operated sensor in high volumes. This requires a solution optimised for size and power consumption. The product cost is of most importance. This is developed from the ground-up choosing the optimal components for this products specific requirements.

Summary

Enabling Bluetooth in a product has to be carefully planned and decision needs to be taken on which development strategy to use. The strategy to choose depends on the product volume and requirements on parameters as size, power consumption and product cost. The right strategy makes it possible to enable Bluetooth in all types of products, products with small as well as products with large volumes.

Bluetooth also introduces new elements to product design for example radio and antenna issues, radio type approval and Bluetooth qualification that need to be considered in the product design.

About the author

Mats Andersson is the CTO (Chief Technology Officer) at connectBlue AB, Sweden. connectBlue is specialized in integrating Bluetooth based solutions in industrial and commercial devices. The company's services include consulting, training and complete solutions including hardware and software. connectBlue is also developing and marketing Industrial Bluetooth Products.

Mats Andersson has more than 20 years experience in the field of industrial automation. This includes managing development of industrial automation products at AlfaLaval Automation and ABB Automation Products.