

Using Bluetooth in an Industrial Environment, Reliability and Robustness

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Using radio technology in an industrial system requires special care depending on the type of usage. Some examples of user scenarios:

1. Use Bluetooth to access a built-in user interface based on WEB/WAP technology. Mainly used for configuration and maintenance. These are not normally mission-critical applications.

2. Use Bluetooth to transfer live process information between different parts of an industrial system. This may be used for more or less mission-critical applications.

For the more mission-critical applications the radio link reliability is very important in order to reach high demands on deterministic behavior and real-time performance.

Important issues are e.g. interference with other Bluetooth nodes, other radio standards like 802.11 and other radiating sources like certain types of machinery (might be industrial devices or commercial devices like microwave ovens).

Another issue is communication error detection and automatic correction.

This paper will discuss this issue from two perspectives; the Bluetooth architecture and studies done on these issues.

Bluetooth architecture and reliability

Bluetooth is initially designed with reliability in mind and there several concepts used helping to achieve this.

Frequency-hopping Code Division Multiple Access (FH-CDMA). The chosen radio band (2.45 Ghz) is divided into 79 1Mhz wide slots and new frequency slot is chosen each 625 μ S. Each communicating pair of devices has its own frequency-hopping schema decided when initially

connected and chosen in order to avoid conflicts as much as possible. This technique minimizes possibilities for interference within a Bluetooth system and interference with other radio-based systems (e.g. Wireless LAN – 802.11b, see reference 1).

Error Correction. Bluetooth includes both Forward Error Correction (FEC) and packet retransmission. There are two different FEC codes used, 1/3 rate code and 2/3 rate code. The 1/3 code is always used for the packet header. For application data the 2/3 rate is used (if requested by the application). This is a shortened Hamming code and able to automatically correct all one bit errors and detect all two bit errors.

An ARQ packet retransmission scheme is applied. Each packet payload contains a CRC checksum to check for errors. Each transmitted packet contains an ACK/NAK bit to indicate the status of previous received packet. Retransmission is done if packets are lost or NAKed. This allows for safe transmission of data.

Received Signal Strength Indicator (RSSI)-based power control is mandatory for the high-power radio (20dBm) and optional for the low-power radio (0dBm). This ensures that excessive power not is used to fulfill communication between a pair of nodes. This has a positive effect on the interference problem. Several independent Bluetooth networks in the same neighborhood will less likely interfere with each other.

For a short summary on the Bluetooth radio technology see reference 1.

Interoperability with other radio networks

The radio band chosen for Bluetooth is the 2.4 Ghz ISM unlicensed band. Several radio-operated devices

and standard networks are using this band. The most important is the probably the IEEE 802.11b standard. It is today widely used in both office and industrial environments.

Reference 2 and 3 are two theoretical investigations of the interoperability between 802.11b and Bluetooth. Reference 2 seen from the Bluetooth perspective and reference 3 from the IEEE 802.11b perspective.

802.11b influence on Bluetooth is very dependant on the distance between the Bluetooth nodes. If the Bluetooth distance is 1.5 meters is the probability for more than 10% throughput reduction 1.5% and with 10 meters distance 24%.

Note! Due to limited frequency overlap in the radio protocols used (only 17 Bluetooth hop channels can be effected by 802.11b) the absolute maximum throughput reduction is 17/79 or 22%, although this maximum scenario probably never will occur.

Of course some practical test is needed to verify the theoretical calculations.

Other interoperability issues

There are interference on a Bluetooth systems from other sources than radio frequency networks e.g. from unintentional radiators like industrial equipment or commercial devices like microwave ovens.

Reference 4 is a white paper describing microwave oven influence on the 2.4 GHz ISM band. This paper mainly discusses influence on the 802.11 standard radios but some of the general conclusions may be used for Bluetooth too. In general the conclusion are that radiators like microwave ovens does interfere with Bluetooth but the distance between the oven and Bluetooth has to be short. More detailed analysis may be done using data from this paper but this is out of scope for this white paper.

ABB Corporate Research in Norway has done some research on radio system use (and specifically Bluetooth) in the industrial environment (see reference 5). Measurements have been performed in real life environments like pulp and cable factories and nuclear plants. The general conclusions are that an RF system works very well in this type of environment. Received power as function of receiver location shows even better results than the theoretical results, this due to multipath reflections from the installed industrial equipments. Multipath fading that normally is a enemy can in a factory become a friend. Of course, care has to be taken when installing RF equipment

e.g. the antenna position is a very important issue. For more information see the paper.

Coexistence Working Group

The Coexistence Working Group is one of the Bluetooth SIG official working groups. It works in close cooperation with the Radio Working Group. The group objective is to investigate interference problems with other RF sources and propose changes to the standard in order to minimize the problems.

So far simulations has been done investigating interference with Bluetooth itself, IEEE 802.11b, HomeRF and WBFH NPRM. HomeRF is a low-cost 2.4 GHz based standard aimed for the home market. WBFH NPRM is a newly FCC approved method of a wide-banded frequency hopping technique allowing for higher bandwidths in the 2.45 GHz band.

Some conclusions from these simulations are; interference will not be an issue for Bluetooth for low QoS applications, but voice applications may see some problems in certain environments. More details in reference 6.

The group will continue its simulations to DECT (wireless phones) and microwave ovens (to be published later).

Proposal to changes to the standard is also an issue for the group. One proposal is to use "Adaptive Frequency Hopping", that is a frequency hopping technique that will notice interference on certain frequencies and avoid the use of them.

Conclusions

The Bluetooth protocol is generally constructed for robustness. Techniques used like "aggressive" frequency hopping and advanced error correction ensures this.

Both theoretical investigations and practical test has proven Bluetooth's reliability, but it has to be understood that Bluetooth is a RF-system and care has to be taken when creating products and installing Bluetooth products e.g. antenna position, and encapsulation.

There is a lot of focus on the interference issues within the Bluetooth SIG and changes to the standard minimizing these problems will come in future versions e.g. adaptive frequency hopping.

References

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About the author

Mats Andersson is a senior advisor of connectBlue AB, Sweden. connectBlue is specializing in integrating Bluetooth based solutions in industrial and commercial devices. The company's services include consulting, training and complete solutions including hardware and software.

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.