connectBlue®

Shaping the Wireless Future with Low Energy Applications and Systems

by: Rolf Nilsson, CEO of connectBlue

With the increased use of mobile devices and the increased need for information exchange with small devices such as sensor nodes, new requirements are placed on connectivity options. The below paper covers the new trends with Internet of Things, the demands on low power and mobile connectivity, wireless technology options, wireless coexistence and potential low energy applications.

Internet of Things, the Web of Things, or the Embedded Web

There is a clear trend that information exchange between various apparatus and devices is growing. For instance, there is a rising need to continuously monitor equipment usage, energy consumption, stock supply, and remote control of devices. These increased needs are seen across multiple industries including the following examples of needs on the rise:

- Medical applications: create customized medications, remote monitoring and alerts, etc.
- Buildings: track energy consumption, security surveillance, etc.
- Industrial applications: remote control, information exchange with tracking systems, etc.
- Infrastructure & environment: monitor traffic, air and water pollution, etc.

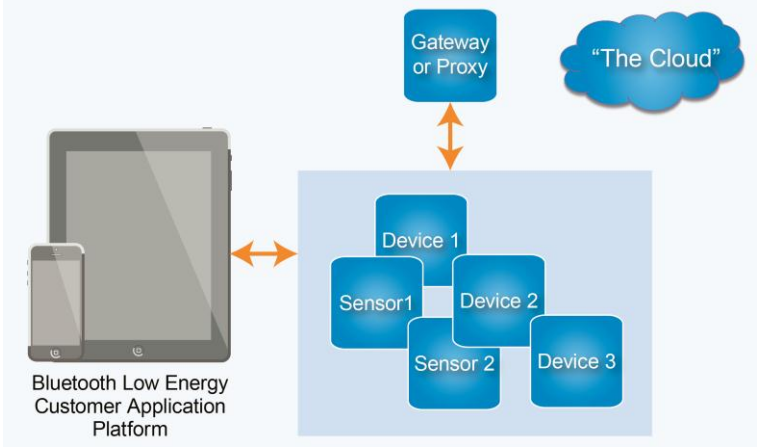
With yearly shipments of more than 10 billion microcontrollers that all can exchange information locally or through the Internet, a huge variety of so called “intelligent devices” are enabled. These devices include motion sensors, pool pumps, gas/electric meters, and street lights.

Based on the rapid infrastructure coverage and Internet access all these devices can be accessed over the Internet. This evolution is called “Internet of Things,” “Web of Things,” or “Embedded Web” and typically requires a local low power wireless connection besides the Internet connection. For most such applications and solutions, a gateway is required to connect sensor nodes to the Internet via a local infrastructure or over a cellular network.

Low Power Wireless Devices and Sensor Connectivity

A cellular connection is a good alternative for many applications but requires a substantial power source and is relatively expensive both to purchase and to operate in relation to the cost of smaller devices or sensors. In these cases preferred is a local low power wireless technology that covers the distance between the device and a gateway connected to the existing infrastructure or the cellular network.

There are several low power wireless technologies available including Ant+, EnOcean, ZigBee and proprietary technologies operating in the 2.4 GHz and sub 1 GHz bands. Low power Wireless LAN versions are also available but for many applications they consume too much power.



Caption: *A key requirement in the Internet of Things vision is an easy to deploy and cost efficient low power wireless solution. Connecting all small devices and sensors directly to the fixed or cellular networks would be too costly.*

Especially when it comes to a new installation of sensors or other smaller devices, it is of interest to go wireless. Going wireless also includes “wireless power” which is typically achieved through batteries. For many smaller devices a coin cell battery would be enough for several years of operation. When a battery solution would not fulfill the requirements there are several energy harvesting alternatives. Energy harvesting alternatives include solar light, temperature differences and movement (e.g. rotation or vibration) as power sources.

In addition to cloud connectivity there is rising need for wireless in personalized Human Machine Interface (HMI) pertaining to local monitoring and control via smartphones or tablets. Such a mobile device can also act as a gateway to the cloud. The operating systems (Apple iOS, Android or Windows) require low power wireless technologies and built-in connectivity to these types of devices.

Caption: *Increasingly important is connectivity to smartphones and tablets where an “App” can serve as a local HMI as well as an access point or gateway.*

What is Bluetooth Low Energy?

Bluetooth low energy technology becomes particularly interesting as a wireless technology option due to its ultra-low power consumption and connectivity possibilities with smart phones and tablets.

Bluetooth low energy is substantially different from Classic Bluetooth technology which is ideal for continuous, streaming data applications including voice. Classic Bluetooth has successfully eliminated wires in many consumer as well as industrial and medical applications. Bluetooth low energy technology is ideal for applications requiring episodic or periodic transfer of small amounts of data. Bluetooth low energy has unique characteristics and new features that that are not practical with Classic Bluetooth. For instance, coin cell battery-operated sensors and actuators can now smoothly connect to Bluetooth low energy enabled smartphones, tablets or gateways.

Power consumption is kept to a minimum as a Bluetooth low energy device is kept in sleep mode most of the time and only wakes up when a connection is initiated. The actual connection times are a few ms only, the maximum/peak power consumption is less than 15 mA and the average power consumption is as low as 1 uA. It is possible to power a small device with a coin cell battery – such as a CR2032 battery – for several years. Otherwise, one can use alternative energy sources.

In order to obtain a very low power consumption Bluetooth low energy uses a lower data rate. In theory, this data rate is 1 Mbps but in practice the transfer rates for Bluetooth low energy technology are less than 100 kbps.

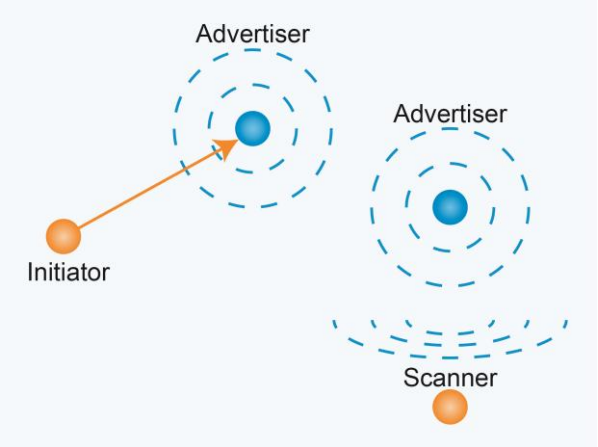
	Classic Bluetooth technology	Bluetooth low energy technology
Data payload throughput (net)	2 Mbps	~100 kbps
Robustness	Strong	Strong
Range	Up to 1000m	Up to 250m
Local system density	Strong	Strong
Large scale network	Weak	Good
Low latency	Strong	Strong
Connection set-up speed	Weak	Strong
Power consumption	Good	Very strong
Cost	Good	Strong

Software and Structure
Bluetooth has a determined set of “profiles” that in essence are application defined behaviors that Bluetooth devices use to communicate with other each other. Examples of Classic Bluetooth profiles include headset (HSP), object exchange (OBEX), audio distribution (A2DP), video distribution (VDP), file transfer (FTP), serial port (SPP) and personal area networking (PAN).

Bluetooth low energy technology profiles are different from those used in Classic Bluetooth and are based on the Generic Attribute Profile (GATT). GATT includes service groups, attributes, declarations and descriptions. Described in the Generic Access Profile (GAP) is device discovery, connections and bonding. In this way, a number of basic services and profiles are set up such as time, battery condition, automation I/O, building automation (e.g. temperature, thermostat, humidity, lighting, on/off switch, dimmer), remote control, fitness (e.g. step counter or heart beat monitor), medical devices (e.g. glucose meters), etc.

Unlike Classic Bluetooth, product developers can develop their own profiles and services to add to those from the Bluetooth SIG. For example, connectBlue has developed the Low Energy Serial Port Service which is a GATT-based service that offers transparent serial communication and thus is an ideal solution for devices with lower data rate and episodic transmission.

Just as Classic Bluetooth, Bluetooth low energy is based on a master connected to a number of slaves. However, in Bluetooth low energy the number of slaves can be very large; how large depends on the implementation and available memory. The new “advertising” functionality makes it possible for a slave to announce that it has something to transmit to other devices that are “scanning.” “Advertising” messages can also include an event or a measurement value.



Caption: *An advertiser periodically sends and will always act as a slave when it is connecting. A scanner is waiting for an advertisement and is always a master when connecting.*

Bluetooth low energy uses a simple star topology which simplifies the implementation work significantly. This topology fits very well with the commonly used system architecture with several small devices connected to a master in a production island. In most cases, infrastructure or Ethernet networks are available and there is no need for mesh networks to extend the geographical coverage.

A unit is always either a master or a slave, but never both. The master communicates with the slaves and it can also communicate simultaneously with multiple slaves.

Connectivity and Compatibility
Because the two technologies are fundamentally different, there are the following two implementation options:

- **Single-mode Devices:**
  Traditional Classic Bluetooth implementations are single-mode implementations. But with the addition of Bluetooth low energy there are also single-mode Bluetooth low energy devices known as Bluetooth Smart devices. These devices are optimized for small battery-operated devices with low cost and low power consumption in focus. Typical single-mode

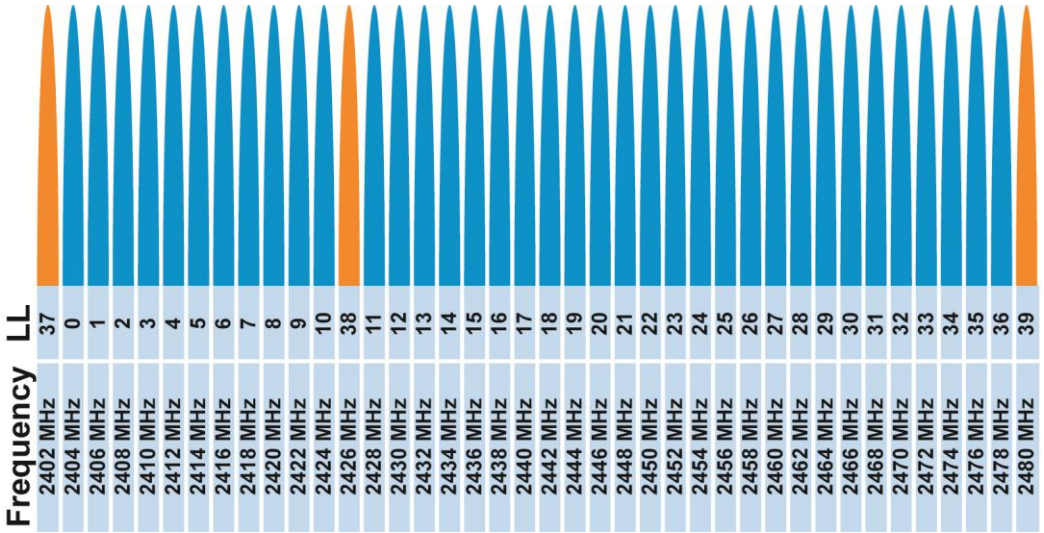
low energy devices include heart rate sensor accelerometers, temperature and pressure sensors.

- **Dual-mode Devices:**
  These devices, also known as Bluetooth Smart Ready devices, include both Bluetooth low energy and Classic Bluetooth technologies. Dual-mode devices will rarely gain in power saving since they need to support both technology implementations; the power savings will only be achieved with the single-mode option. Examples of dual-mode devices include smartphones, computers and industrial platforms.

Caption: *Examples of Bluetooth modules (connectBlue) covering Classic Bluetooth and Bluetooth low energy technologies. There are single-mode Classic Bluetooth solutions and single-mode Bluetooth low energy solutions while dual-mode solutions provide the bridge between the technologies.*

Easy Installation and Superior Coexistence to other Wireless Technologies
Many features of Classic Bluetooth are inherited in Bluetooth low energy including Adaptive Frequency Hopping (AFH) as well as part of the Logical Link. This inheritance makes Bluetooth low energy very easy to set up and robust and reliable in tough environments.

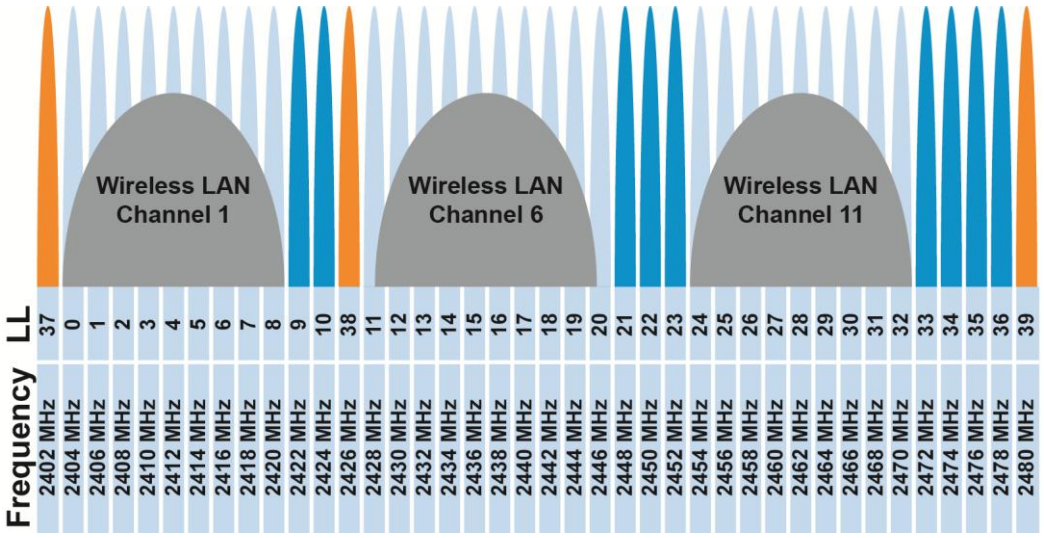
To obtain simpler and cheaper radio chipsets, Bluetooth low energy uses only 40 two MHz wide channel while Classic Bluetooth uses 79 one MHz channels.



Caption: *In the 2.4 GHz band, Bluetooth low energy technology uses 40 channels instead of the 79 channels used in Classic Bluetooth.*

Bluetooth, Wireless LAN, IEEE 802.15.4/ZigBee, Wireless HART, and many proprietary radios use the unlicensed 2.4 GHz ISM (Industrial Scientific Medical) band. Therefore, in order to get a robust and reliable communication, it is essential for many wireless technologies to utilize frequency planning. However, Bluetooth technology has already solved these issues thanks to its built-in AFH feature and high tolerance for interference. These features also make Bluetooth low energy technology co-exist smoothly with other wireless technologies in the 2.4 GHz band as Bluetooth

will not use frequencies occupied by other nearby wireless technologies. In addition, there is also a possibility to apply the principle of not using designated channels via the so-called channel blacklisting.

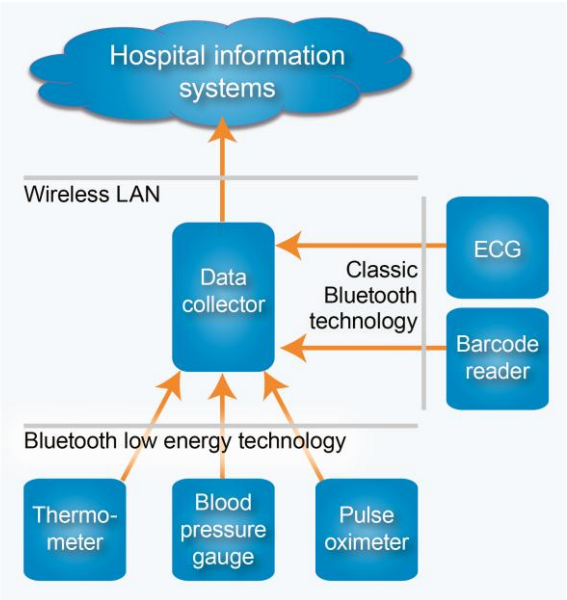


Caption: *Out of the three advertising channels and the 37 data channels, the three advertising and nine of the data channels are located between the three most commonly used Wireless LAN channels in the 2.4 GHz band.*

Thanks to a modified modulation, Bluetooth low energy has an approximately 3 dB better link budget compared to Classic Bluetooth. A Bluetooth low energy unit can thereby offer a range of 200-300 meters in line-of-site without the need of an additional power amplifier. Although industrial sensors and actuators often only need a range of only 20-50 meters, it is important in the aspects of robustness and reliability to have a large reserve in order to bridge temporary obstacles and interference.

Bluetooth Low Energy Technology Use Cases

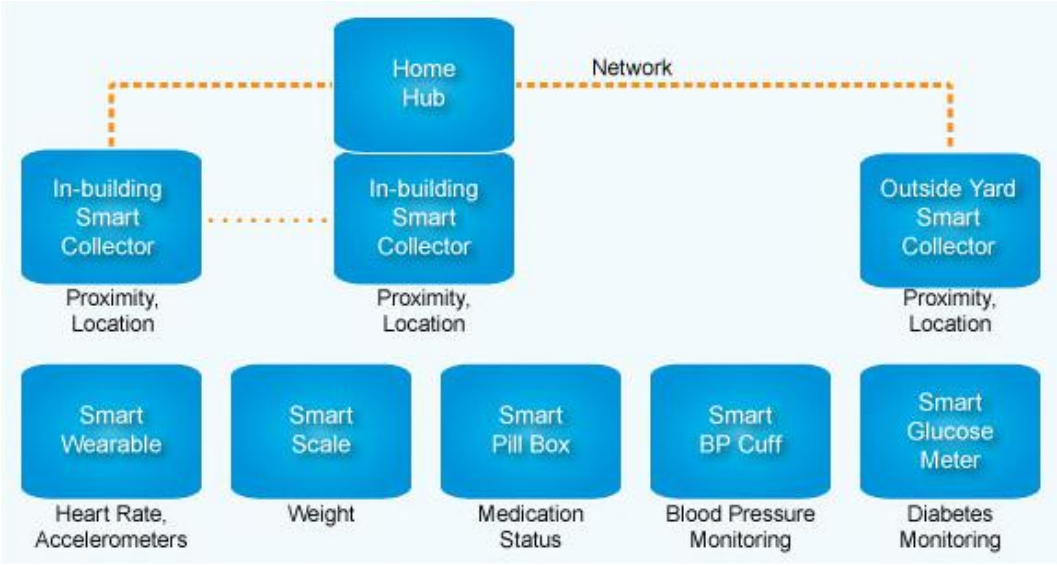
To get a better idea of what use case Bluetooth low energy is ideal for the below examples cover both theoretic and live use cases in medical and industrial applications.



Monitoring of Unmonitored Patients

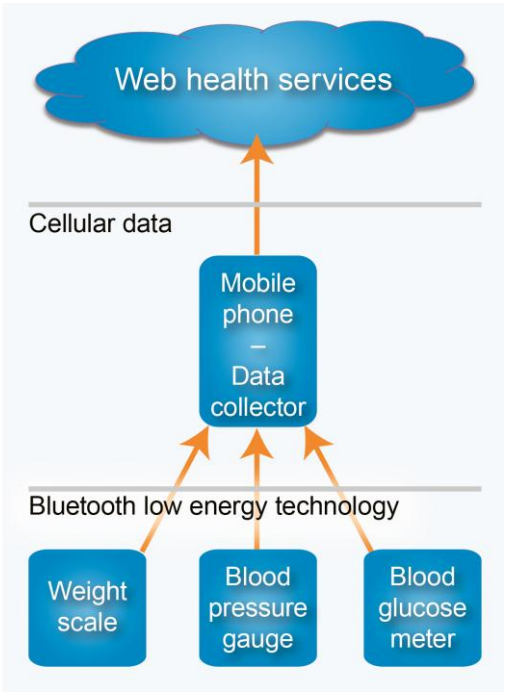
Many patients are not monitored and reports rely on manual vital signs entry for their EHR (electronic health records). This manual process results in increased workload and potential issues from unmonitored patients or transcription errors.

The solution is a Wireless Bedside Hub where Wireless LAN is the preferred choice for the connection to hospital IT systems. Bluetooth technology provides for local connectivity to patient connected and data collection devices. Classic Bluetooth is used for higher data rates, streaming devices and Bluetooth low energy gives longer battery life to intermittent and lower duty-cycle patient worn sensors.



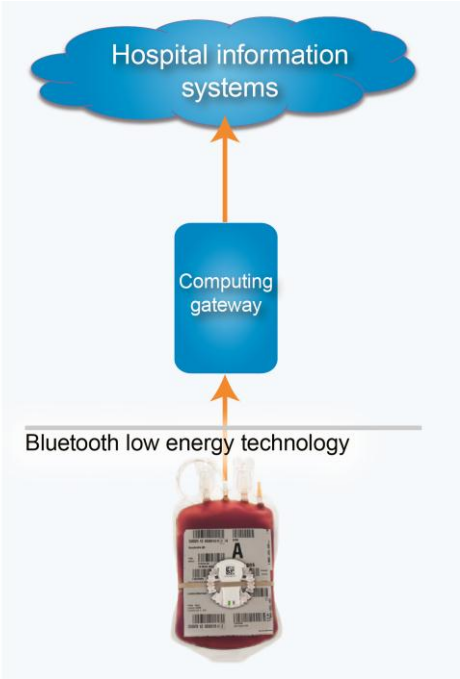
Aging-in-Place

As population ages it is needed to provide for a safe environment as well as optimize the use of healthcare resources. Bluetooth low energy technology and home network connectivity provide the building blocks that allow older people to safely stay in their homes by monitoring daily living. Bluetooth low energy provides a robust technology at a price and power point to allow several data collection points to be spread throughout the home and networked through a power line or other robust, low cost networking technologies. Via the Home Hub medication monitoring and activity, food intake, fluid retention, proximity sensing providing location information alleviates concerns about wandering or mishaps outside the home environment.

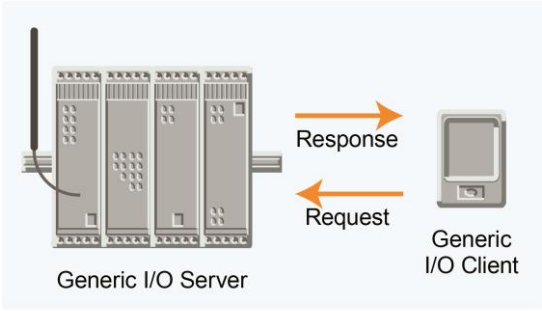


Web Health Services

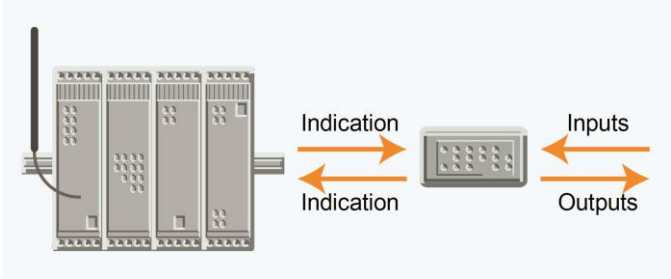
The reduced power and cost of Bluetooth low energy enable many medical use models from the home to the hospital. The example model in the home could be used to log data and establish trends for a Congestive Heart Failure (CHF) patient using several types of sensors and the patient's mobile phone.



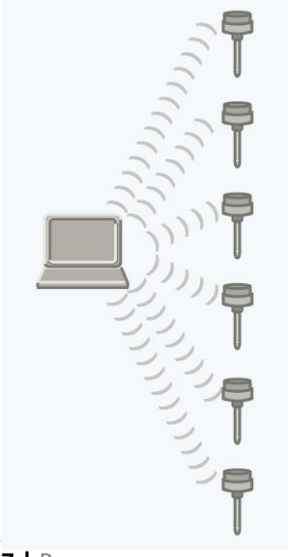
Blood Bank Monitoring System
Blood components must be stored at 2-6°C, at 20-22°C or in a frozen state. Deviation from those requirements will result in reduced shelf life or even discarding of the specific blood unit. The PC based gateway collects the data from the Bluetooth low energy tracer. One could also potentially use a smartphone for information upload or read-out. The Bluetooth low energy module in the tracer also handles temperature logging, calculations and user information indications.



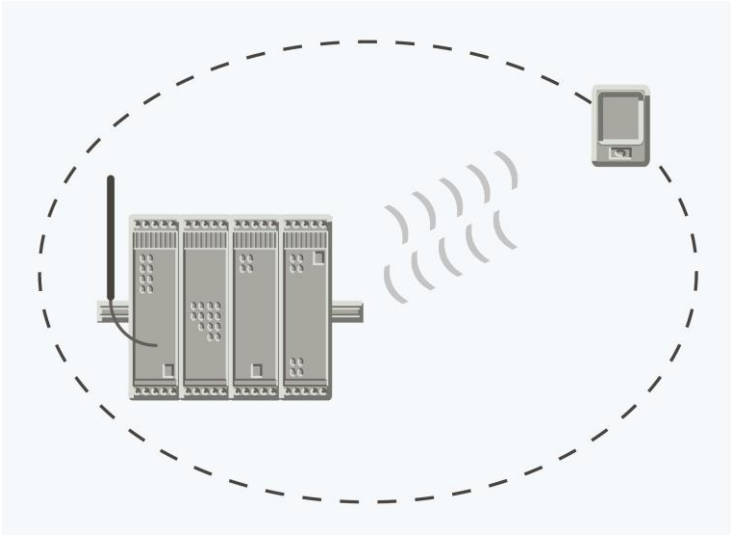
Portable Monitoring and Control
A portable HMI unit can be based on an iPhone or Android smartphone / tablet. Read/write variables can be exchanged with a device such as a Programmable Logic Controller (PLC) and lighting. Smartphones also offer new opportunities using the Internet connection to get access to spare part lists, obtain user instructions, present visual data, alarm lists, and trend curves.



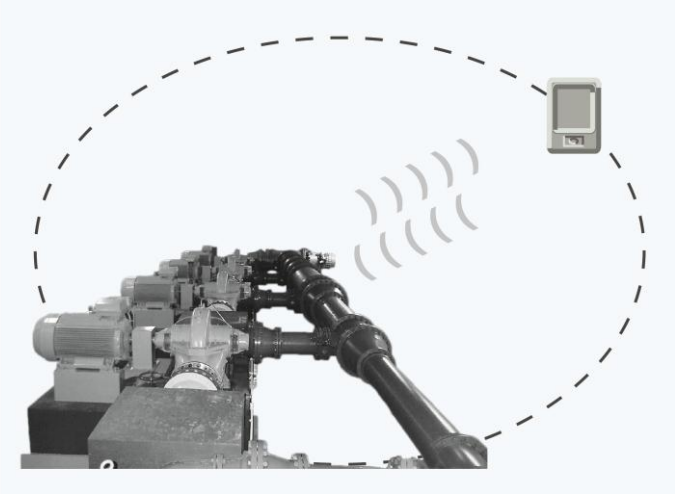
Simple Remote Control Unit
A simple remote controller can be an I/O-unit with push buttons and LED's. Bluetooth low energy handles the data exchange (I/O-transfer) between two devices like a PLC and an I/O-device or HMI-panel. The digital and analog signals are mirrored from one side to the other.



Data Acquisition
The Bluetooth low energy gateway reads the sensor values at a specific time interval or the sensor devices transmit the sensors values upon a specific temperature change. The Bluetooth low energy node could include software for calculations, logic as well as store historical values.



Device Access
A fast and secure connection set-up is used as a key in order to allow a mobile operator's panel to get access to the automation cell or machine. In addition, the proximity feature can send a message if the user is within the production cell or not in order to allow for elective interaction.



Asset Management
Device maintenance and device information usage is increasing. It is possible to store information concerning device type, run-time, last inspection, overload, etc. in the Bluetooth low energy node. The information can be accessed when an operator gets in close proximity of the device.

About the Author
Rolf Nilsson is the CEO and founder of connectBlue with over 30 years of thorough insight and know-how from industrial automation and communication. Before founding connectBlue, Rolf was the President of Eurotherm Scandinavia and before that he was in leading positions at Alfa Laval Automation/ABB Automation Products.

About connectBlue
connectBlue® is a leading provider of robust Industrial and Medical wireless solutions, designed and tested for the most demanding applications and environments. Based on Classic Bluetooth technology, Bluetooth low energy technology, Wireless LAN (WLAN) and IEEE 802.15.4 / ZigBee, connectBlue provides ready-to-use products and modules as well as custom design solutions. connectBlue has its head office in Sweden and local offices in Germany and USA. For more information, please visit www.connectblue.com.