Nordic Semiconductor technical article

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TITLE: **Low-power RF beyond Bluetooth**

STANDFIRST: A proprietary alternative to Bluetooth extends sports watch battery life.

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TEXT:
Short-range, relatively low speed wireless communications in consumer electronics have become almost synonymous with IEEE 802.15 (Bluetooth). This is partly due to the backing of an ambitious Special Interest Group (SIG), and partly due to the simple fact that Bluetooth works.

Indeed, from the efforts put into defining the standard and producing a protocol that ensures backwards compatibility, to the existence of numerous "Bluetooth Unplug Fests", Bluetooth has undoubtedly helped to simplify the incorporation of wireless comms into a vast range of applications. These include, for example, wireless comms between a PDA, headset, mobile phone and laptop PC in a WPAN or "piconet" arrangement.

Yet despite its advantages, Bluetooth is not without drawbacks either. These become particularly evident for "power and cost critical" battery applications such as wireless mice, keyboards, joysticks, intelligent sports equipment (e.g. watches) and toys. In these types of product, designers should avoid being blinded by Bluetooth's high profile, because established, proprietary RF alternatives do exist and can be far more suitable.

Picture 1: Proprietary RF alternatives such as Nordic Semiconductor's nRF24xxx family are superior to Bluetooth for wireless connectivity in coin cell devices such as sports watches

Listening carefully

The underlying reason is that Bluetooth's strength – the ability to easily form and manage an *ad-hoc* "piconet" of up to eight devices (one master and seven slaves) – also turns out to be a weakness in point-to-point battery-powered applications.

The master determines the 1600 frequencies to be used each second across the nominal 2.4 GHz band. In operation, the master sends a 160-bit packet every 675 μS (1600 packets/s, or a net data rate of 256 kbit/s) to maintain the link, whether the target device is in use or not.

This synchronisation scheme was developed to avoid the inevitable clashes that would occur in a piconet if the master were to randomly transmit to the slaves. And even though the IEEE802.15 standard does provide for missed or corrupted packets to be resent, this further compromises the data transfer rate and power consumption.

The reality is that while synchronisation is a distinct advantage for maintaining data transmission when several devices are communicating over a single piconet, it's a real drawback in point-to-point applications. The simplicity of these applications doesn't demand synchronisation, yet this feature is forced into use because it's a part of the Bluetooth standard. As a result, the link is slowed by unnecessary synchronisation packets, and the transmitter uses more power because of the increased duty cycle.

Lower power RF link

There are proven alternatives to Bluetooth, however, that claim to solve this problem. The nRF24L01, 2.4GHz integrated transceiver from Trondheim-based, Norwegian company Nordic Semiconductor, for example, is said to consume up to 75 percent less power than comparable Bluetooth devices in typical point-to-point applications (from a 1.9 to 3.6V supply). It also offers a maximum air data rate of 2Mbit/s compared to Bluetooth's nominal 1Mbit/s in its lowest power mode.

A proportion of this power economy comes from employing a more efficient data packet overhead, as well as a data payload up to 8x larger than Bluetooth's. The packet structure comprises 8bit preamble, 40bit address, up to 256bit payload and 8/16bit CRC (cyclic redundancy check). This can be used to perform a message transfer in 256bits, yielding an overhead of 56bits, and giving a raw packet data-efficiency of 82 percent.

By comparison, Bluetooth's packet structure comprises 68 or 72bit access code plus 56bit header and 32bit data payload – requiring 160bits, with an overhead of 128bits and an efficiency of 20 percent. This difference is largely a by-product of ensuring compatibility with a wide range of devices.

The proprietary device integrates a GFSK transceiver, OSI link layer in hardware, standard SPI interface for programming output power, frequency channels and protocol setup, plus CRC calculation and verification in 0.18μm CMOS. By presenting an SPI interface to the application MCU and allowing it to dictate its own interface speed (fig. 1), the digital part of the application can run slower and the data rate on the bi-directional RF link faster. The result is that the end application consumes less power on average and permits the use of a lower performance external MCU.

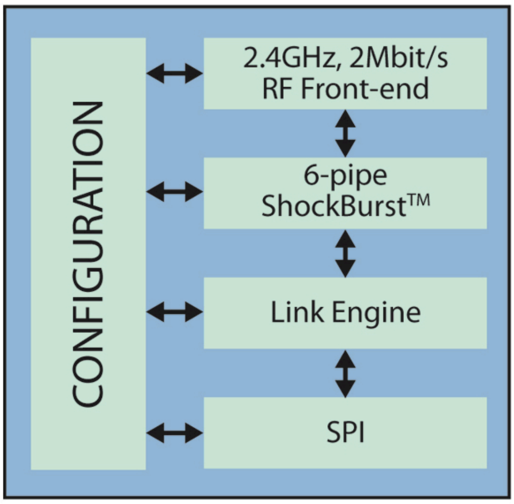

Figure 1: By presenting an SPI interface to the application MCU and allowing it to dictate its own interface speed the digital part of the application can run slower and the data rate on the bi-directional RF link faster

It also means acknowledgement of received packets and retransmissions of lost packets do not require involvement from the application MCU used to manage this task in Bluetooth. After a data packet has been sent, the receiver expects an acknowledgement to arrive from the terminating part within 250μs. If this doesn't arrive it will keep retransmitting until it gets an acknowledgement (for a user specified number of retries). Compared with Bluetooth, this results in more aggressive timing changeovers and reduced transmission time.

Another source of power saving is a low peak RX and TX current of 12.5 and 11mA respectively at 0dBm 2Mbit/s transmit speed. This compares with 40 and 65mA for a typical Bluetooth device in full 1Mbit/s stride.

In standby and powerdown modes, the nRF24L01 consumes 32μA and 400nA respectively. These are comparable to Bluetooth devices, but under typical usage conditions it is the RX and TX figures that dominate power consumption and battery recharge cycles, as the following example illustrates.

Intelligent sports watch example

Let's consider a sports watch designed to monitor and record data from a wireless pulse rate monitor in contact with the user's wrist or chest. A typical usage pattern is 10 percent active and 90 percent sleep, with a communications cycle of transmission and reception every 500ms of operation when in the active part of the duty cycle. Given a 32bit payload, the proprietary packet length will still be around half that of a Bluetooth packet (88 versus 160bit).

In addition, Bluetooth runs at a nominal maximum of 1Mbit/s compared with the proprietary solution's 2Mbit/s. Consequently, it can be seen that Bluetooth has a bandwidth demand 4 times that of the proprietary solution to do the same job boosting power consumption.

The sequence diagram (fig. 2) for the proprietary design shows that the heart rate part of device is active for 130 + 64 + 130 + 24 = 348μs, and the wristwatch part of the device for 130 + 64 + 130 + 24 +130 + 64 = 542μs.

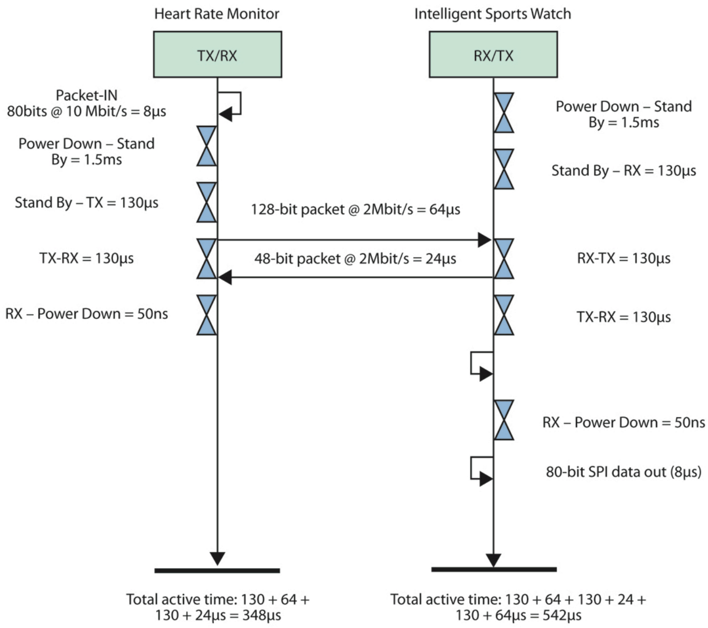

Figure 2: Sequence design for proprietary device communication between heart rate monitor and sports watch

For the typical 500ms communications cycle this gives an actual duty cycle of 1:922. Because the active time during the 500ms communications cycle is relatively low, the average current consumption when in "constant" use is 13μA. (This is lower then the standby current because between packets the transceiver is put into the 400nA powerdown mode).

Although Bluetooth also has an average current consumption of 45mA when active, it continues to run at 15mA in "idle" mode to maintain synchronisation. This means the current consumption is dominated by the RF part. Given that a typical 3.0V lithium coin cell can deliver no more than 20mA maximum, a Bluetooth-based design would require AAA battery in both the watch and pulse sensor, adding significant bulk and weight to the application.

In RX mode, the proprietary device can also receive data through up to six data pipes (each assigned with a 40bit address on the same frequency channel) to form a wireless hub for up to six simultaneously communicating devices. This means it could also be used to monitor up to six parameters (e.g. heart rate, speed or torque sensors) in the above application. This could prove impractical for Bluetooth given that each channel compounds the power consumption.

The bottom line is that Bluetooth has proven to be a very successful way to build wireless connectivity into devices such as mobile phones where short duty cycles and universal compatibility are the norm. And adhering to the IEEE standard certainly eliminates much of the design challenge. But for many portable applications with low duty cycles, Bluetooth can be far more demanding of the batteries than alternative approaches.