SPARK MICROSYSTEMS

The Wireless Transceiver Reimagined

Executive Summary

Short-range wireless communication is a core component of almost every electronics-based design today, no matter what the application. As smartphone users, we are familiar with pairing a variety of tech to the phone, from cordless headphones and fitness wearables to answering our smart doorbell. As our relationship with wireless devices grows, we also start to become aware of some of the limitations, of which battery life is probably the most prominent daily challenge. Embedded developers have become very adept at tweaking and optimizing hardware for the best balance of user responsiveness versus use time. Despite these enhancements, many tech-savvy users like gamers seek a more engaging and immersive technology experience through the use of low-latency headphones or VR/AR headsets that, today, have to be wired. Imagine the enhanced cable-free gaming experience achieved using a sophisticated headset that is wirelessly connected, that the battery life is not limited to a single game, and the VR headset doesn't need a bulky battery pack strapped to the gamers belt to operate.

From another perspective, in an industrial IoT deployment, a vast army of sensors are used to acquire data across the factory floor. To avoid the prohibitive cost of wiring these to line power, particularly in a retro-fitted implementation, many of these are battery-powered. While these may be convenient and easy to install, the legacy to plant managers is committing maintenance staff to an ongoing battery-replacement regime. Imagine deploying sensors where the battery-life is significantly extended, or even better still, their power requirement is so minute that it can use energy-harvesting techniques.

In this white paper, we investigate the current methods used to establish short-range wireless communication together with some of the challenges that are holding back the

next generation of product designs. SPARK Microsystems' ultra-wideband (UWB) communication method is a new implementation class of UWB that extends it well beyond the existing UWB-based ranging applications in use today. It is a viable contender to address the limitations of current wireless techniques such as Bluetooth, while introducing a high quality of service (QoS) data transfer approach that offers a significant reduction in power consumption and much lower latency companied to traditional wireless technologies.

Wireless communications at the core of every electronics design today

Wireless communication has become so ubiquitous that we probably take it for granted. In many cases, we only need to know what wireless protocol a device uses when we configure it for the first time; after that, we forget about it. Our early experiences with wireless communication probably involved pairing Bluetooth headsets to our cellular phone and connecting our laptop to a Wi-Fi network. Since then, we've significantly expanded the number of different applications that use wireless connectivity wherever we are, whether in our car, at home, at work, at the gym or on the move. There is now an almost endless list of consumer electronic devices that we can buy and connect to, from smart speakers, smart home 'white-goods' appliances, gaming consoles, fitness bands, and smart doorbells. The same is true in the factory office environment. Market trends such as the Industrial Internet of Things (IIoT) are accelerating the pace of deployment of wireless connected sensors and actuators within production and manufacturing environment. In recent times, the rise of the connected car has also propelled the use of in-car wireless technologies for streaming infotainment services, navigation, as well as the emerging use of vehicle-to-vehicle (V2V), and vehicle-to-infrastructure (V2X) applications for road safety and improved traffic flow purposes.

The technical standards for both the initial Bluetooth and Wi-Fi wireless communication protocols were ratified in 1998 and have continued to evolve ever since. Bluetooth has seen its role as a short-range, low power communications link become ever more defined, while Wi-Fi has become the defacto high throughput wireless alternative to using wired networks. Each can be found on most wireless-enabled consumer electronic devices, such as a smartphone. For example, a smartphone serves as a hub between Bluetooth attached devices, say, a fitness wearable, to a Wi-Fi router or a cellular connection, to a cloud-based application service. These technologies face limiting challenges however in order to address the requirements of new applications.

Wireless Communication Challenges

As the variety and diversity of wirelessly connected devices grow, so do the constraints under which they need to operate. For example, virtual and augmented (VR/AR) reality headsets are becoming the latest must-have device for gamers looking for a more immersive gaming experience. For the VR/AR headset product designer, the development challenges are many. Headsets are densely packed with technology from compact video display screens, eye and head tracking sensors, and AI-based gesture detection algorithms. Unfortunately, a VR headset that offers such an immersive real-time experience consumes a lot of power and needs to have a high-bandwidth low-latency data link to the player's computer. Today's wired connectivity approach of the headset to the host meets many of the design requirements but restricts a player's movement and can be cumbersome and uncomfortable. Increasingly, gamers want to enjoy their gaming experience free of a multitude of cables, typically there are at least one each for the headset, keyboard, and mouse. Initially, implementing a wireless communication protocol to remove the cables would appear a prudent step; however, on closer inspection, several challenges appear. In this particular scenario, the impact of latency introduced by the wireless link and associated protocol on the overall user experience is significant. Compared to a USB wired connection that typically has a latency of 1 ms, a Bluetooth Low Energy (BLE) link introduces latency in the range 20 – 100+ ms. Such a dramatic increase in latency would be very noticeable by the user and result in a poor gaming experience. A BLE headset link, while technically feasible for a VR headset, would suffer from unsuited low-res video quality and low refresh rate, loss of game sync, and incorrect positioning accuracy when interacting with the virtual objects. It would also require significant power hungry processing in the headset device to reduce wireless data exchange to the PC, exacerbating the power consumption power.

Connecting a gaming headset by wireless introduces the need for it to be battery-powered, further impacting the space and weight envelope requirement in a product enclosure that is already constrained. Up until now, BLE probably represents the best combination of data rate and low power consumption available, the reason why it has proved to be popular for many wireless speakers and headphones. However, the total anticipated power budget for a gaming headset needs to include the displays, media controllers, wireless connectivity, and other functions such as gesture and head tracking. Whether a rechargeable battery solution or a replacement regime is chosen, either approach can impact the available time the headset can be used for its purpose.

There are many other examples where today's wireless connectivity impacts the evolution of product designs. The power consumption and latency challenges exist across most wireless-based peripherals, wearables such as health and fitness straps, smart home sensors, and industrial automation/machine-to-machine equipment. Depending on the amount of data to be transferred, data rate, can also present a challenge.

It is also important to note that there are data rate limitations imposed on the designer when using low power wireless protocols such as BLE. These force the design team to consider trade-offs in audio quality, for example, or the need to limit the type of functions the wireless link can provide to relatively low data rate sensors or light data streams, such as highly compressed audio or sub-par microphone uplink quality. In turn, these factors can result in further trade-offs at the system level, such as requiring an increase in the compute resources required to compress and decompress the data stream. Naturally, these come with their own cost, power consumption, and board-space constraints.

The consequence of the above limitations is the need for wireless communication technology to evolve so that the products that use it can advance too.

An Introduction to Ultra-wideband Technology

The concept of ultra-wideband communication was first established in the mid-1980s, although it was early 2000s until the interest in commercialization gathered momentum. However, due to several factors such as standards definition, over-engineered technical complexity, and, at the time, the market growth of Wi-Fi, UWB never gained sufficient market traction. That said, UWB was selected as an ideal candidate for high-resolution pulse-based RADARs for military applications. More about that shortly.

To understand the basics of UWB, we need to understand the relationship between time and frequency covered by the Fourier Transform, which states that, for a given signal, bandwidth is the inverse of time. Hence an extremely short duration impulse signal exhibits a very high bandwidth. This is illustrated in Figures 1 and 2. UWB uses this time and frequency duality to transmit a short signal burst over a very wide radio spectrum. This approach brings several direct benefits that SPARK Microsystems uniquely leverages. Firstly, the SPARK UWB transmitter and receiver are ON for a very short period of time, and since transmitting any radio signal requires significant amounts of power, the power consumption profile is much smaller due to this reduced duty cycle. Other popular wireless protocols, for example, Wi-Fi and Bluetooth, require the transmitter to be on for relatively long periods. Also, the modulation techniques used by those protocols are based around orthogonal frequency division multiplexing (OFDM) and frequency shift keying (FSK) principles that use power consuming carriers, sub-carriers and demodulator architectures. Secondly, by significantly minimizing the transmitter and receiver ON time, SPARK UWB minimizes the power consumption but also the link latency. SPARK UWB also ensures that synchronization is maintained regardless of the aggressive duty cycling of the transmitter and receiver.

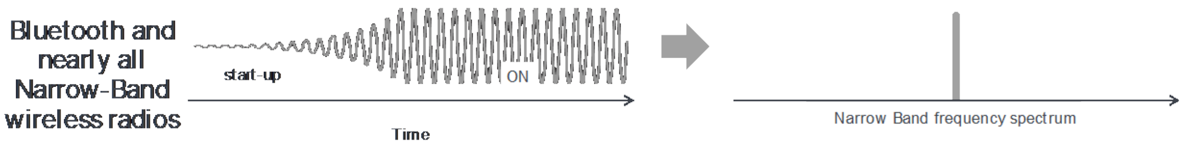

Figure 1 – Bluetooth and Narrow-Band radio architecture time and frequency representations

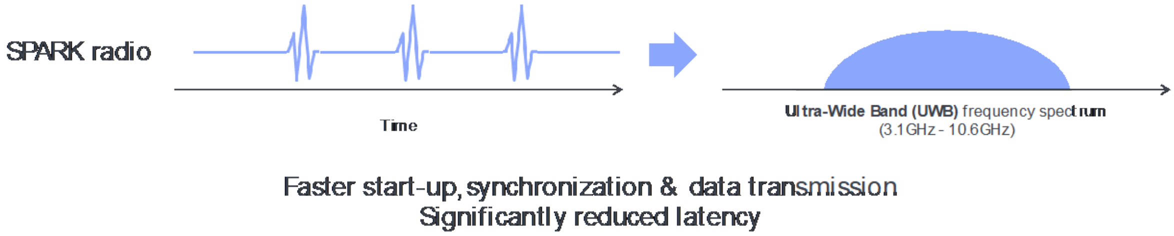

Figure 2 – SPARK Microsystems radio architecture time and frequency representations

Moreover, UWB lends itself to use in ranging and positioning applications. The extremely short pulse operation of a UWB transmitter, like the RADAR application mentioned earlier, is ideal for measuring distances with centimeter accuracy using a time-of-flight (TOF) approach. TOF functions by measuring the time taken for the signal to leave the transmitter, be reflected by an object and arrive back at the receiver. The Apple iPhone 11 is the first smartphone to incorporate a UWB-based distance measurement function, and will no doubt unleash the innovation of a host of new applications across many markets.

SPARK Microsystems UWB development

UWB is re-emerging as not only a viable method of precise ranging and positioning but, thanks to the development and innovations pioneered by SPARK Microsystems, a credible high quality of service, high-speed, short-range, ultra-low power, and low latency data communications method not possible with conventional radios or other UWB radios.

SPARK's innovations make full use of the wide frequency spectrum that UWB offers and operates in the unlicensed spectrum from 3.1 GHz to 10.6 GHz. In addition, the average output power used for transmitting is lower than most conventional methods, and typically below the sensitivity of other radios, being perceived as noise to most. The benefit of being perceived as noise to other users of the spectrum is that SPARK Microsystems UWB technology gains a notable coexistence advantage. This is particularly the case for the congested WLAN 802.11 spectrum centered on 2.4 and 5 GHz. With a low electromagnetic inference, as illustrated in Figure 3, the SPARK UWB signals are also hard to detect, and as a consequence, make them difficult to intercept and tamper with, further improving wireless link security.

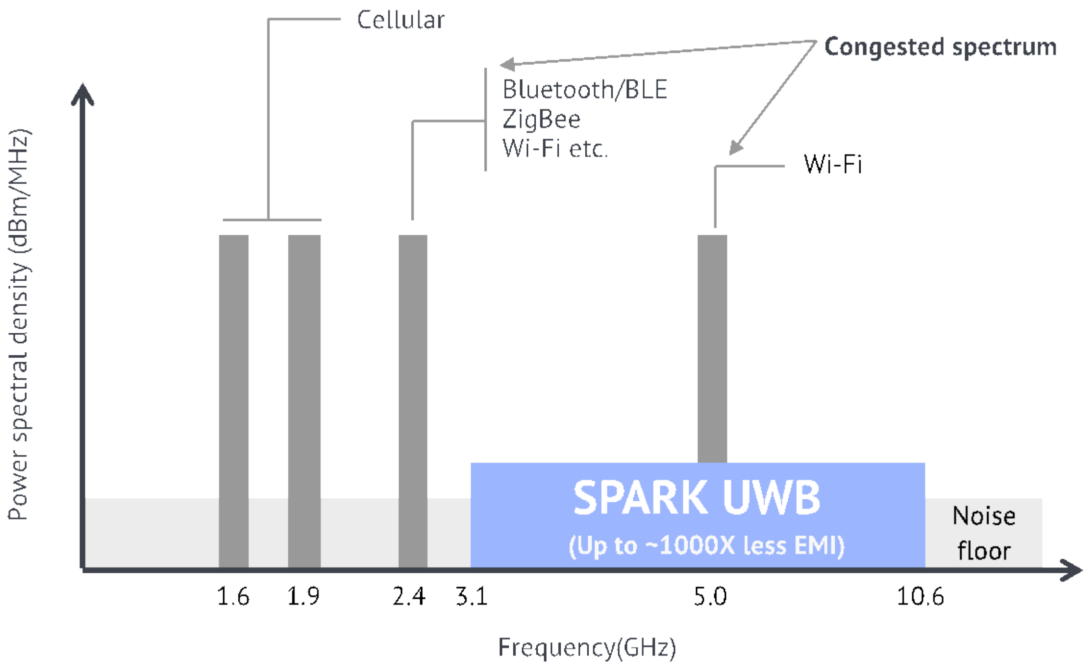

Figure 3 – The Frequency Advantage of UWB (source SPARK Microsystems)

A Reimagining of The Wireless Transceiver

SPARK Microsystems UWB technology developments have yielded a short-range, typically 50-100 meters, innovative wireless transceiver architecture that, compared to Bluetooth Low Energy, has an energy efficiency profile and link latency that is more than an order of magnitude better, and a 10x higher payload data rate of up to 10 Mbps. The performance metrics of SPARK Microsystems' UWB technology are summarized in Figure 4.

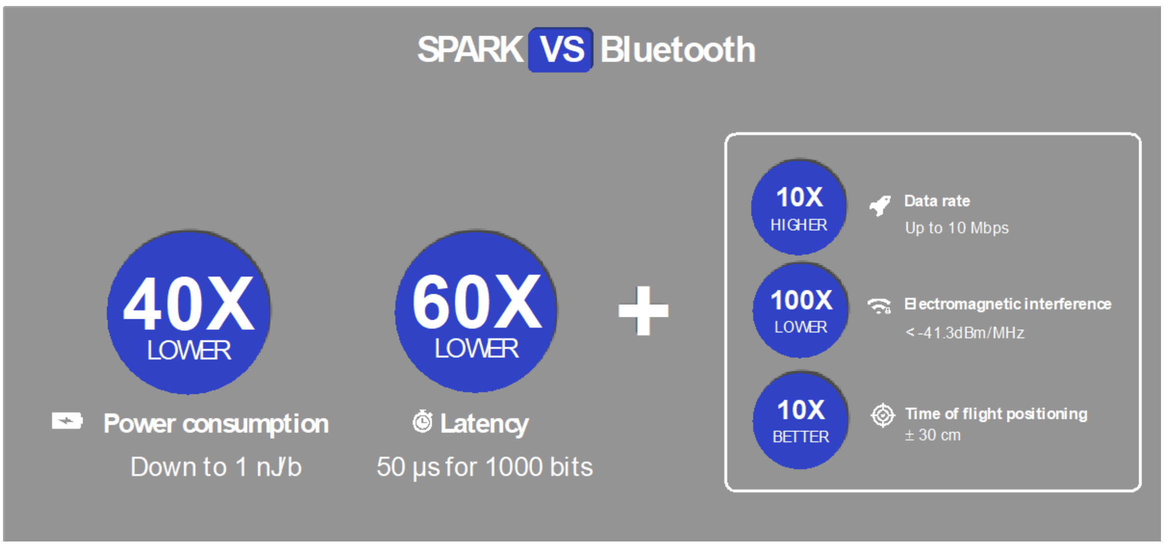

Figure 4 – Reimagining the wireless transceiver (source SPARK Microsystems)

With such performance credentials, more data can be transferred, battery life can be extended, and the low latency characteristics will open up a raft of new applications, such as live media wireless streaming. The transceiver can support a variety of network topology configurations from device-to-device, star, and mesh. Hundreds or thousands of devices can operate within the same space.

Figure 5, below, highlights the ultra-low power consumption profile of the SPARK Microsystems approach, comparing the amount of energy used to transfer one bit for ZigBee, BLE, and the SPARK UWB. This power consumption profile is also illustrated compared to the data transfer rate in Figures 6 and 7. The SPARK Microsystems uses so little energy that it could be used in a battery-less device that employs energy harvesting techniques to convert, say vibration, or ambient light into energy. An energy-harvesting approach is well suited to the army of simple sensors, motion, temperature, humidity, vibration etc. used by the industrial internet of things (IIoT). Batteries represent a significant maintenance cost in deployed IoT devices. Their removal from systems, using the SPARK transceiver with energy harvesting technology, represents a paradigm shift.

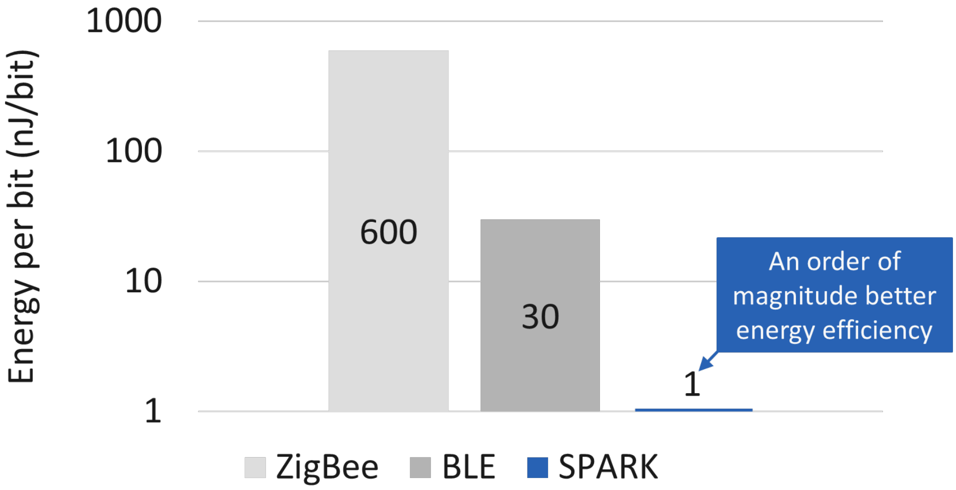

Figure 5 – Energy efficiency comparison of energy used to transfer one bit for ZigBee, BLE, and SPARK UWB. Logarithmic scale. (source SPARK Microsystems)

This advantages also carries over at high data rates where SPARK Microsystems UWB can provide high data throughput at a fraction of the power consumption of other technologies, yielding significant battery life improvements in many potential data streaming applications.

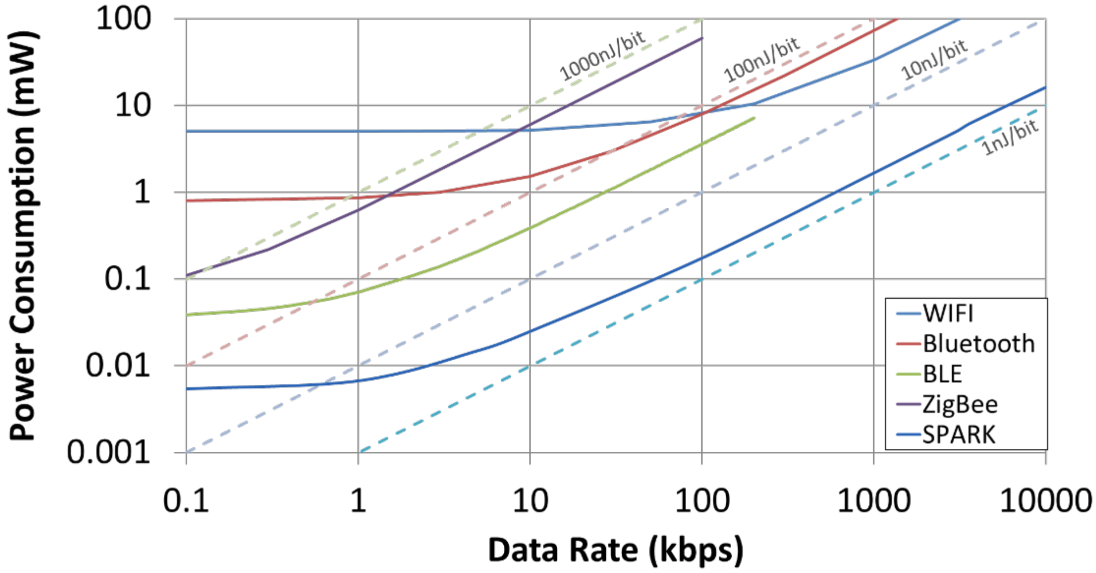

Figure 6 – Transmit + receive power consumption profiles of WiFi, Bluetooth, BLE 4.2, ZigBee, and SPARK UWB against data rate. Logarithmic scale. (source SPARK Microsystems)

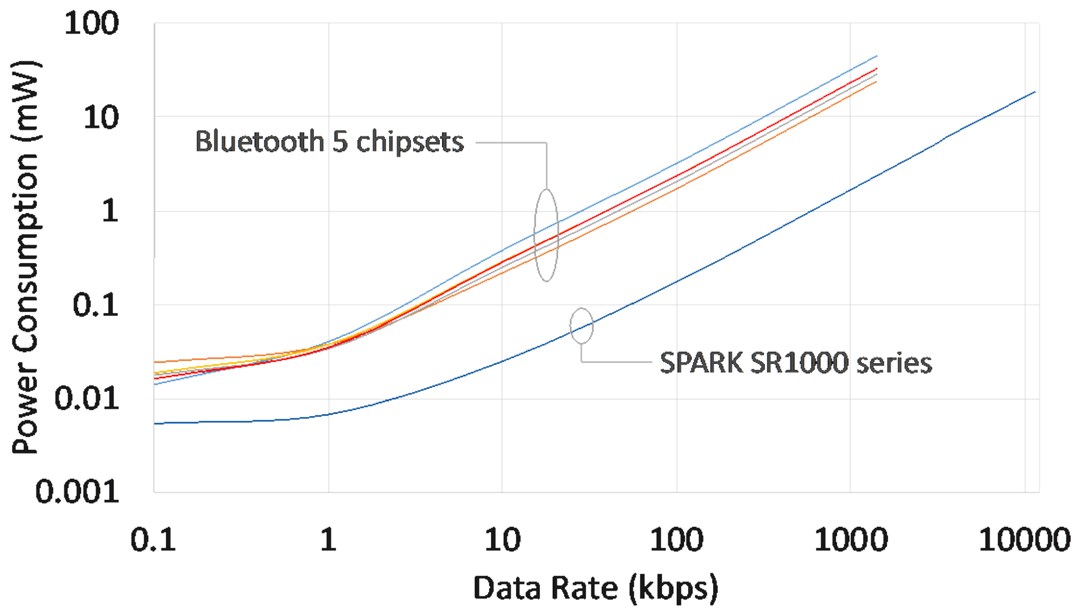

Figure 7 – Transmit + receive power consumption profiles of different Bluetooth 5 chipsets and SPARK UWB against data rate. (source SPARK Microsystems)

Latency has proved to be one of the biggest challenges to provisioning wireless-based connectivity for battery-powered media headsets and headphones. As Figure 8 indicates, the SPARK UWB architecture provides a combined frame and MAC latency characteristic that is sixty times lower than BLE when communicating a 20-byte payload.

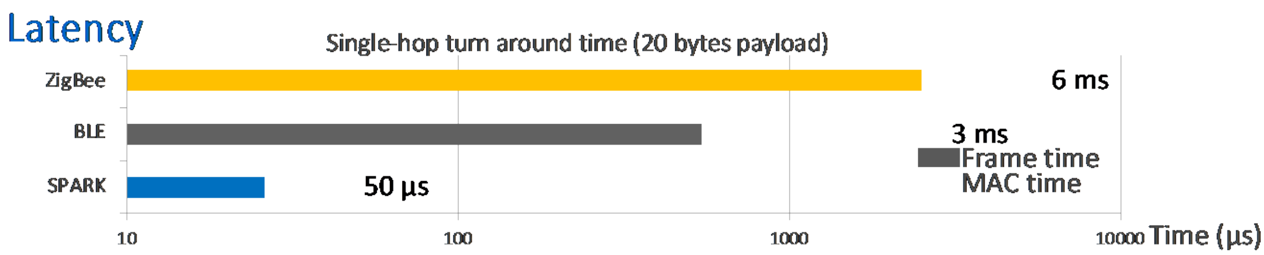

Figure 8 – The latency performance provided by the SPARK Microsystems UWB transceiver architecture. (source SPARK Microsystems)

The SPARK Microsystems SR1000 Series of UWB Wireless Transceivers and Development Tools

The SPARK Microsystems SR1000 series comprises two ultra-low power, low latency UWB wireless transceiver ICs, the SR1010 covering 3 GHz to 6 GHz, and the SR1020 covering 6 GHz to 9.3 GHz. With a 10 dBm peak transmit power output, the series integrates the UWB transmitter and receiver, antenna switch, digital baseband circuitry, clocks and timers, and a power management and regulator function – see Figure 9. Communication with a host microcontroller is through SPI, and the only additional key components are a low-cost ultra-low-power external industry-standard 32.768 kHz crystal and a PCB antenna. The need for solely a 32.768 kHz low cost and low power crystal is a significant paradigm shift in wireless transceivers which typically require relatively high cost and power consumption tens of MHz crystals. This helps further decrease the cost and power consumption at the system level. The transceiver is capable of accommodating a 1.71 VDC to a 3.6 VDC supply voltage, the SR1000 series consumes only 45 nA during hibernation mode, and 750 nA in deep sleep mode which maintains synchronization. An off-chip MCU operates the network stack and application layer.

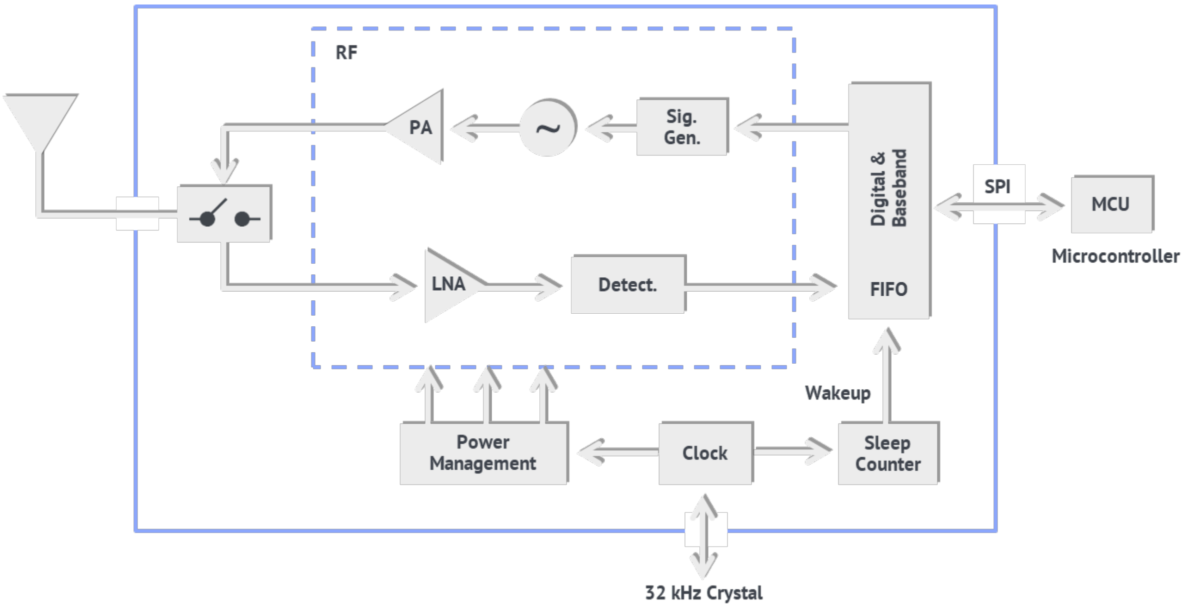

Figure 9 – The SPARK Microsystems SR1000 series UWB transceiver functional block diagram. (source SPARK Microsystems)

To showcase the transceiver's capabilities, and to speed-up the prototyping of an initial design, SPARK Microsystems provides a range of demonstration boards, evaluation kits, and reference designs. Tailored for specific application use cases, from an IoT battery-less sensor through to a gaming hub, supporting an uncompressed low latency audio headset and HID devices, the evaluation boards provide a means of measuring many of the key operating parameters such as link margin, latency, and power consumption. Further details on these boards can be found on the SPARK Microsystems website: sparkmicro.com.

Summary

Wireless connectivity is everywhere, so much so that we take it for granted. It links our headphones to our smartphone, controls our smart appliances, and monitors our environment. However, the wireless protocols in use today, while fulfilling the tasks expected of them, are limiting the evolution of products and preventing many new technology ideas coming to market. Reducing latency, increasing data-rate, lowering power consumption and enhancing wireless coexistence are key drivers for any wireless-based design.

Just as the technology we use everyday advances, adding new features and functionality, so must the wireless technology that underpins the unseen communications. SPARK Microsystems has spent more than 10 years developing high-speed, ultra-low power, low latency Ultra-wideband transceiver technology to make the products of tomorrow meet our expectations.

About SPARK Microsystems

SPARK Microsystems is a fabless semiconductor company leading the way towards ultra-low power, ultra-low latency wireless communications. With its patented technologies, SPARK Microsystems delivers order-of-magnitude better bandwidth, latency and power consumption compared to legacy wireless protocols. The company also seeks to bring battery-less operation to the market.

For more information about SPARK Microsystems visit sparkmicro.com.