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Managing Multiple Wireless Standards for Smart Home Applications

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Lighting, security cameras, garage doors, appliances – the list of home-based systems that you can control with your mobile device is growing. The Internet of Things (IoT) is quickly bringing new conveniences to our home lives that we could only dream about a decade ago. Designing systems on chip (SoCs) to support these smart home systems, however, can be challenging given the multiple, evolving wireless connectivity standards and the need to get to market quickly. How can you future-proof your design? This paper examines how configurable digital signal processing technology can meet current and emerging demands in this space.

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Introduction

It's dawn and you awaken to the chirps of your smartphone alarm. With a few taps on your phone, you start your coffeemaker and turn on your heating system, plus a few lights.

Fast-forward a few hours, when a nagging thought flits in and out of your mind—"Did I shut the garage door?" You put your mind at ease by checking the smartphone app for the door – it is, indeed, closed. And, for good measure, you also make sure your home security system is set properly.

Smart devices are pervading the home, bringing conveniences and capabilities that are making life a little easier and more secure, and helping us save time, energy, and money. Inside each of these devices and systems are sophisticated systems on chip (SoCs) that enable them to do what they do.

Designing SoCs for the smart home is becoming increasingly challenging – the chips themselves are complex, often large, and must meet the power and cost budgets of consumer electronics. They also must keep up with the latest wireless connectivity standards. Not only do the standards continually evolve, but there are also multiple standards in place that are relevant for smart home applications. So, you have to design for now and for the future.

Common Wireless Connectivity Standards

Let's take a brief look at some of the more common wireless connectivity standards that SoCs for smart home applications need to meet.

Wi-Fi

Tapping into 2.4 GHz and 5 GHz ISM radio bands, Wi-Fi brings computer networking to electronic devices such as smartphones, tablets, digital cameras, and video-game consoles. According to the Wi-Fi Alliance, Wi-Fi chips can meet requirements for low cost and power, compact form factors, fast connection setup times, and scalable deployments.[1] Most recently, the

IEEE has been developing a new WiFi standard known as 802.11ah. It operates in license-exempt, sub-1GHz bands and attempts to reduce the complexity of implementation as well as extend the range due to the use of lower frequency bands.

There is the question of which Wi-Fi standard—the more established IEEE 802.11n or IEEE 802.11ah—will prevail. IEEE 802.11n[2], while ubiquitous, is only as effective as the nearest access point. Users with large homes often find that they need more than one access point to adequately provide service throughout the home. Extending coverage to a mailbox at the curb, a driveway monitor, or to a detached garage is typically outside the usable range of an IEEE 802.11n device. IEEE 802.11ah is an ultra-low power version of the standard that provides a longer range and easier connectivity and, as a result, is attractive for IoT applications. However, as a developing standard, IEEE 802.11ah has a long way to go to reach the broad adoption that IEEE 802.11n and its variants have today.

ZigBee

The ZigBee specification is for networking and application layers, using the IEEE 802.15.4 standard (2.4GHz or sub-GHz) for MAC and PHY communications protocol. The specification was first standardized in 2003 and is already popular for smart meters. The ZigBee Alliance is pushing the standard for home-based devices, from temperature and lighting systems to security monitors and smoke detectors. According to the Alliance, the ZigBee specification is suited to these systems because of its reliability, interoperability, and low power consumption. However, there remain concerns over addressing and managing the number of ZigBee variations that are available.

Thread

Launched by Nest and Samsung, Thread is a new low-power wireless mesh standard for the smart home. The protocol supports IPv6 using 6LoWPAN. The idea behind Thread is resolve reliability, security, power, and compatibility issues that often arise when connecting products around the home. Because Thread is built on the 802.15.4 physical layer (which is the basis of ZigBee devices), an OEM can easily update its ZigBee devices to support Thread with a software update. By providing upper layer protocol support including full Internet access via IPv6 and using a mesh topology for robustness and extended range, Thread offers a more complete solution than previous low-power wireless standards.

Bluetooth Low Energy

Marketed as Bluetooth Smart, Bluetooth Low Energy is described by Bluetooth Special Interest Group (SIG) as the intelligent, power-friendly version of the wireless technology for point-to-point communications. Bluetooth offers an infrastructure of direct connection from smartphones and tablets, allowing users to control home appliances from their mobile device.

Recently, the Bluetooth SIG put forward a proposal for defining a Bluetooth mesh protocol. A mesh protocol would increase the physical range of devices using the Bluetooth network while potentially reducing the power consumption.

Why Is Meshing Important in the Home?

A mesh network (as depicted in Figure 1) combined with a simple way to connect new devices into a system makes for a more robust, easier to use network than traditional wireless systems. As mentioned earlier, the coverage issues of a WiFi network, as well as an authentication scheme where you first select a network and then enter a password can be quite problematic on an IoT device that lacks a display and a keyboard and may need to operate off a battery for up to a year. New network identification and authentication schemes, as implemented by systems such as Thread and IEEE 802.11ah, are key to broad user adoption.

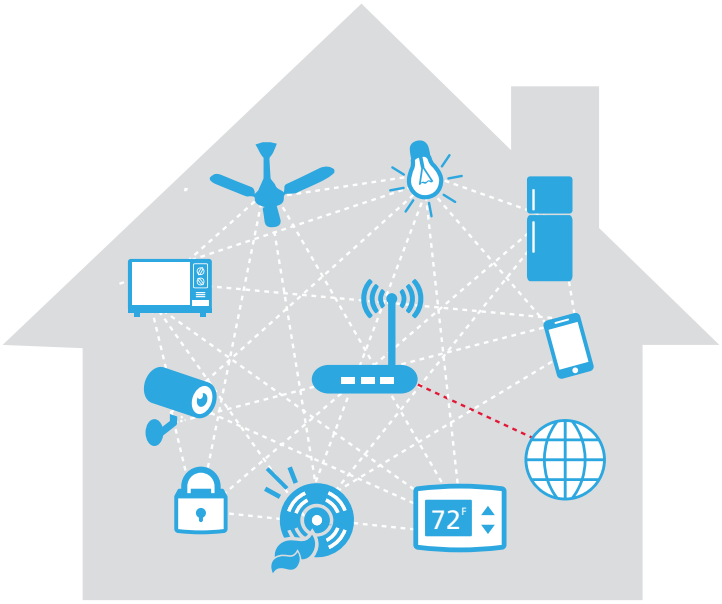

Figure 1: Simplified mesh network

Building the Infrastructure for Smart Home Connectivity

What really builds a market and the number of end-node connection points? The answer is: a defined and stable infrastructure. Without this infrastructure, the connection scheme and development platform aren't there. For smart homes, where will the defined infrastructure come from?

Looking at existing connection schemes in the house, the main one is Wi-Fi, largely driven by PCs and handheld devices. Wi-Fi traditionally has a high data rate and consumes power at a level consistent with either wall power or large batteries with frequent recharging intervals. While a "cut down" version of IEEE 802.11n with a single antenna system has the potential to keep power consumption at lower levels and maintain interoperability with existing access points and routers, it does little for the range problem associated with the use of the 2.4 and 5GHz bands.

As mentioned earlier, recently, there has been a push towards a new IEEE802.11 standard just for IoT applications: IEEE 802.11ah, which offers longer range at a lower data rate and power.

ZigBee offers another option for connected devices. ZigBee has found its way into a variety of products such as light bulbs, smart meters, thermostats, and even electric vehicle charging stations. Now we can add Thread, which is being pushed by big market players for mesh connectivity and network authentication.

Muddling the picture further, the proposed Bluetooth mesh protocol may play a role in the smart home, supporting extended-range connectivity for smartphone and tablet users and devices that may need multi-device connectivity.

Bottom line, all of these options add up to an unclear infrastructure for wireless communications in the smart home. If you're a developer of a smart home product, which communication protocol is the right one for your next device?

Preparing for a Wave of Opportunities

Indeed, the smart home might be the next frontier in terms of Internet of Things applications. Once the infrastructure and communications standards supporting these types of applications has been solidified, the potential volume of end-node devices could be huge and with this comes big opportunities. SoC companies will want to be ready to capture the opportunities that are expected to emerge.

Appliances and other devices in the home are types that homeowners generally don't change for many years. Smart devices, therefore, should be designed such that they can be upgraded in the field in order to keep them operationally up to date. Most "white goods", such as refrigerators, washers/dryers, and dishwashers, will likely use some form of Wi-Fi connectivity. Power consumption and cost won't be big issues, however, the range issue may drive the adoption of IEEE 802.11ah once router/access points begin to support 802.11ah on to top of 2.5GHz and 5GHz WiFi.

For devices such as light switches, fan controls, and the like, the connectivity scheme is less clear—ZigBee (Thread), Wi-Fi (including IEEE 802.11ah), and Bluetooth are all possibilities. In many cases, some of these devices may need to be compatible with more than one of these wireless standards. Sensors—such as those that measure movement or climate conditions—will likely use a meshing scheme for connectivity. However, sensors that are placed outside of the home may need to connect via a different wireless scheme than a sensor inside the home.

What is Needed to Future-Proof a Smart Home Device?

What if you didn't have to choose the standard for which you should develop your design? What if your design could support many standards, even as they evolve? In order to truly future-proof your SoC design and extend its roadmap with differentiated versions, there are a few requirements you'll need to meet.

Programmability is one of the most important requirements. Beyond just the application layer, programmability in the MAC layer, extending into the PHY, will be important for long product lives.

In the PHY and MAC, where complex digital signal processing calculations take place, you'll need to consider:

- Support for the computationally intensive but spectrally efficient OFDM-based waveforms including fast Fourier transform (FFT) processing and MIMO operations
- Computationally intensive forward error correction (FEC), error detection, and RLP schemes such as Viterbi and Turbo decoding
- Efficient packet assembly and disassembly schemes associated with transmitting the minimum amount of information in the smallest channel possible

In upper levels of the design, it will be important to have support for encryption and authentication, such as AES and SHA. Low power consumption for battery and/or coin cell applications is another key consideration. You'll want your device to run at as low a clock frequency as possible while maintaining your performance requirements for the lowest energy consumption. At the same time, some elements of the system design might perform better when operated in a burst mode – waking up on a scheduled interval to perform a task as fast as necessary before going back to sleep in a near total power shutdown mode.

In addition to the communications requirements, a major part of keeping IoT device costs down is the ability to do more with fewer cores. For many applications, the communications may not be that demanding, but the sensor processing can be intense. Or, the sensor processing might be light but the security requirements high, or the device may need to access a network such as WiFi that needs to support low-latency, high-throughput communications.

Being able to scale your platform to meets the needs of a variety of different application and communication requirements is a key element in technology selection.

Configurable Core for IoT Designs

Cadence's Tensilica® Fusion DSP, based on the proven Xtensa® configurable processor, provides scalability for IoT applications. The Xtensa processor lets you configure parameters and add predefined or custom instructions to your processor in a way that is fully blended and verified in the final processor.

Providing ultra-low energy with low clock rate requirements, while reducing code size, the Tensilica Fusion DSP is a dual issue DSP. Its base structure supports a variety of precisions and throughputs being capable of multiplier accumulator (MAC) operations of one 32x32, two 32x16, two 24x24, or two 16x16 real and complex operations every clock cycle. You can also choose the following options as needed during the configuration process to be tightly integrated into the final processor:

- Single-precision floating-point unit (FPU), where floating-point instructions are issued concurrently with 64-bit load/store, speeding software development of algorithms created in MATLAB or in standard C code
- Audio/voice/speech (AVS), which has software compatibility with the Tensilica HiFi DSP and is backed by access to more than 140 HiFi audio/voice software packages
- 16-bit Quad MAC (adds a four 16x16 operation), which further accelerates communications standards like Bluetooth Low Energy and Wi-Fi, along with voice codec/recognition algorithms
- Encryption acceleration for Bluetooth Low Energy/Wi-Fi AES-128 wireless operations
- Advanced bit manipulation, which accelerates implementations of baseband MAC and PHY, including LFSR (linear feedback shift register), CRC (cyclical redundancy checking), convolutional encoding, and bit select operation for interleaving/de-interleaving
- Flexible memory architecture that works with caches and/or local memories of various sizes, depending on application

To meet requirements for low power, you can scale up the performance of the processor by adding in options for different wireless communications standards. All of the necessary computations are performed at low clock frequency with the same architecture—no additional digital signal processors (DSPs) are required.

Summary

There are many unanswered questions surrounding wireless connectivity for smart home applications. There has not yet emerged a prevailing wireless standard, and different smart home devices have different connectivity requirements. However, what remains clear is that once the market for these devices opens up, SoC designers will need to be ready to capitalize on the opportunities.

Using a configurable processor for IoT applications—such as Cadence's Tensilica Fusion DSP—provides a flexible option to meet the requirements of a burgeoning, evolving market.

For Further Information

Learn more about the Tensilica Fusion DSP at http://ip.cadence.com/fusion/

References

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