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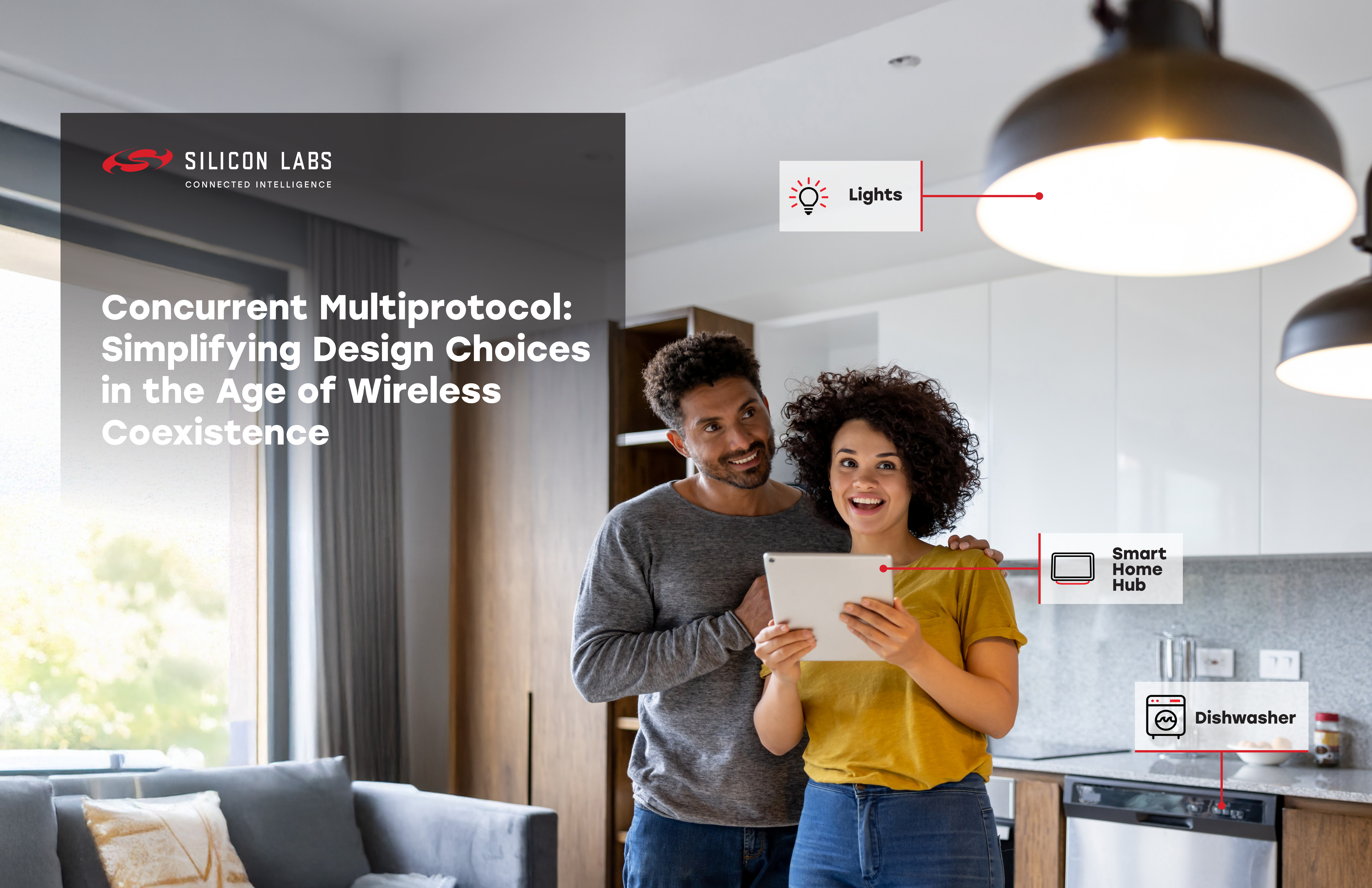
Concurrent Multiprotocol: Simplifying Design Choices in the Age of Wireless Coexistence



Introduction

Wireless Coexistence is No Longer Optional

The rise of the IoT and, maybe more directly, the incredible usefulness connectivity has brought to our devices has transformed how we interact with technology. There are more devices in more places, and consumers expect a single product to support multiple wireless technologies and perform multiple functions. The result of this is that today's networks often include a variety of devices from different manufacturers, all using different wireless protocols. This presents a significant challenge to achieving seamless interoperability, particularly as the demand grows for devices that can operate on multiple protocols and deliver various services simultaneously.

In modern IoT deployments, devices are often in close RF proximity to one another. This is putting pressure on manufacturers to build devices with interoperability and long-term flexibility in mind. Adding to this challenge is manufacturers' tendency to optimize competitive advantages through higher power and bandwidth. While this boosts performance, it often prioritizes proprietary solutions over universal compatibility. The landscape becomes even more intricate when devices are required to operate under multiple protocols while constrained by battery-dependent or low-power operations.

As a result, demand for devices that support multiple protocols simultaneously is growing. This capability, known as concurrent multiprotocol (CMP), makes it possible for a device to run multiple wireless protocols, like Zigbee and Thread, at the same time, as long as they're based on the IEEE 802.15.4 standard. By doing this, CMP reshapes how IoT devices interact within an RF environment and paves the way for new frontiers in connectivity, device performance, and user experience.

The main benefit of concurrent multiprotocol is its simplicity—it supports multiple networks simultaneously with no performance impact when operating on the same channel beyond normal channel congestion. Silicon Labs first introduced CMP as a feature in our Series 2 MG21 and MG24 devices in RCP mode targeting Gateway applications. However, this is now also supported on our MG26 series of System-on-Chip (SoC) devices, and the SiMG301 Series 3 SoCs, which feature the flash and RAM requirements needed to support Zigbee and Matter over Thread on a single end device.This marked a significant step forward in enabling accessory devices to operate efficiently while supporting interoperability on a single radio.

This whitepaper explores the relevance of concurrent multiprotocol technology in addressing protocol fragmentation, its practical applications in IoT networks, and its role in optimizing device performance without compromising on interoperability. We'll also look at how the SiMG301 Series 3 system-on-chip (SoC) will help make seamless device coexistence a reality.

Managing Wireless Coexistence on the Shared 2.4GHz ISM Band

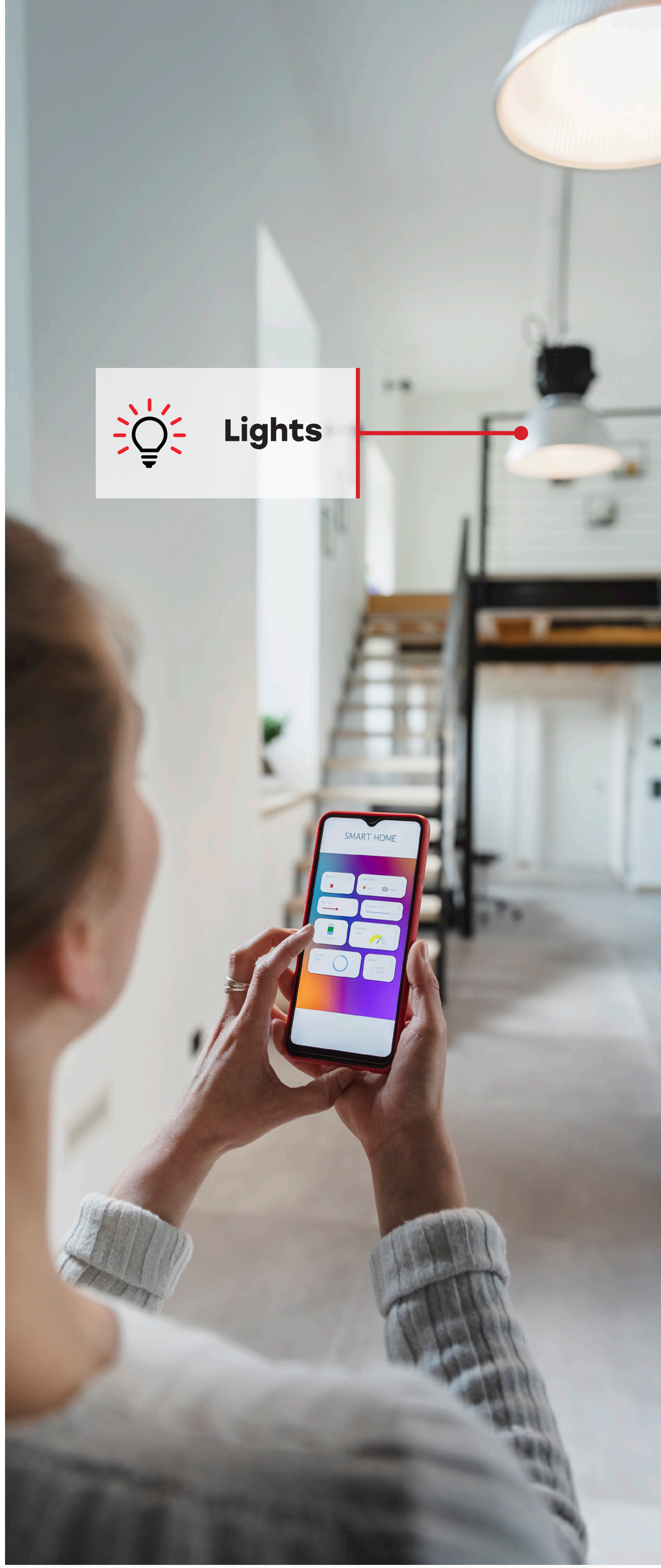
Coexistence among popular wireless technologies such as Wi-Fi, Bluetooth, Zigbee, and Thread presents unique challenges due to their shared use of the 2.4 GHz frequency band. These technologies often operate within overlapping segments of the spectrum, utilizing different frequencies, modulation techniques, and bandwidths. However, their simultaneous activity within close proximity can create unintended interference, with one technology's transmission appearing as noise to others. For end devices, this interference typically manifests as missing or corrupted data packets, increased retry rates due to failed transmissions, and shortened battery life as devices expend more energy attempting to re-establish communication. Gateways and hubs, which play a critical role in aggregating and managing multiple devices within a network, may experience missed device events, delays in response times, or dropped connections. These consequences are particularly concerning in environments where reliability is paramount, such as smart homes, industrial systems, healthcare devices, and other mission-critical applications.

To address these coexistence challenges, developers have implemented a range of methodologies to minimize interference and optimize wireless communication.

Unmanaged coexistence is the simplest approach to running multiple wireless protocols. This is when you let the device and use case dictate behavior instead of actively managing the interaction. For example, you might rely on features like signal identifiers, detecting Wi-Fi interference via RSSI, improved adjacent channel rejection, or enhanced MAC-layer features such as retries. But you're not actually coordinating the two protocols in real time.

Another approach is **frequency planning**, which is strategically arranging frequency bands, enhancing band agility to adapt to interference, and employing techniques like frequency hopping. Frequency hopping enables devices to dynamically switch between channels to avoid conflicts in the spectrum, reducing the likelihood of prolonged interference.

Time slicing is also an option, which enables dynamic multiprotocol (DMP) operation by allocating specific time slots for each protocol. This ensures multiple communication standards can operate within the same environment without overlapping transmissions. Components such as selective RX diversity (which allows devices to prioritize certain signals over others) and packet traffic arbitration further enhance this approach by enabling intelligent decision-making at the device level, ensuring smoother communication and less contention.



In more advanced systems, **concurrent methodologies** are employed to allow simultaneous multiprotocol communication. These strategies often rely on multi-chip designs, integrating multiple ICs to handle different protocols independently, or leveraging advanced features such as MIMO (multiple input, multiple output). MIMO technology uses multiple antennas and signal paths to enhance communication reliability, speed, and capacity, even in environments with high interference. This allows devices to operate concurrently without significant degradation in performance, ensuring robust and reliable operation.

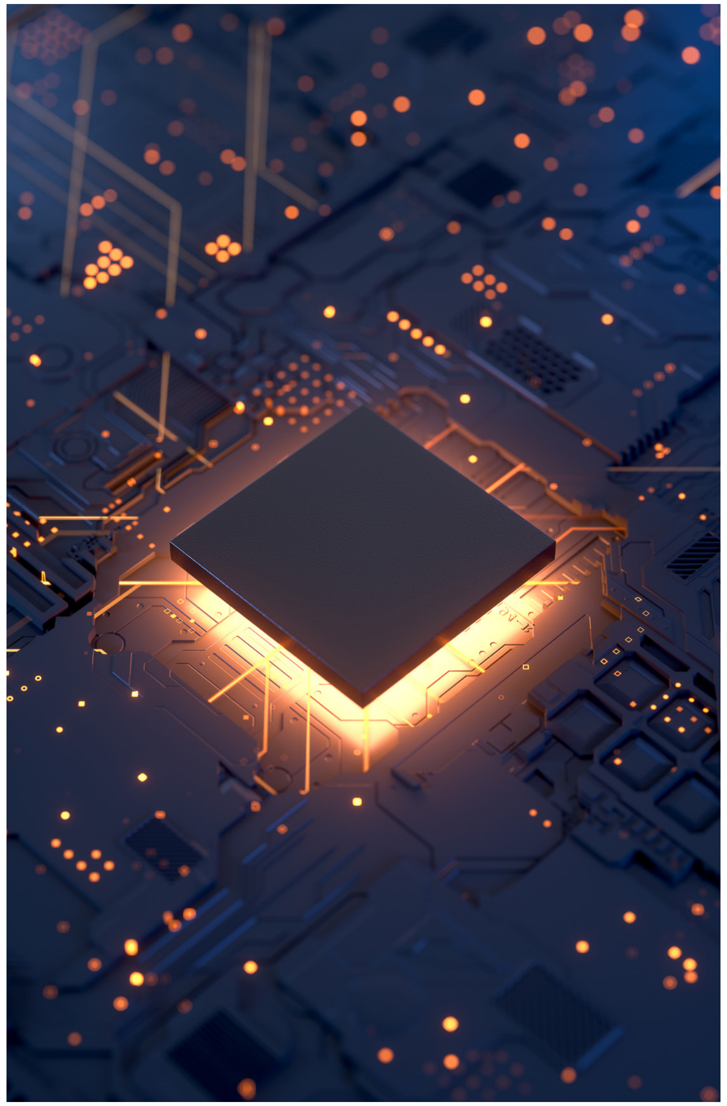
The development and application of these strategies aim to optimize wireless performance by reducing interference and ensuring compatibility between devices and networks. By addressing coexistence challenges effectively, these methodologies not only resolve common performance issues but also enhance the overall user experience. As wireless ecosystems become increasingly complex and interconnected, with more devices relying on seamless communication, managing coexistence is critical to maintaining reliability, efficiency, and user satisfaction in both consumer and industrial applications.

Techniques for Achieving Wireless Multiprotocol Functionality

Switched multiprotocol, dynamic multiprotocol, and concurrent multiprotocol represent distinct approaches to enabling multiple wireless protocols on a single device.

Switched multiprotocol is the simplest and most straightforward technique. It operates on single-radio devices and supports switching between two firmware images. For instance, a deployed device operating on one protocol can be updated via OTA to switch to another protocol. While relatively easy to implement, switched multiprotocol introduces latency due to the process of reloading new firmware and restarting the device. This solution is ideal for scenarios requiring occasional protocol changes, such as field updates, provided the latency is acceptable and the device has sufficient flash memory to accommodate multiple firmware images.

Dynamic multiprotocol takes a step forward by time-slicing a single radio to support two protocols within one operational period. This approach integrates advanced scheduling to manage the radio's resources effectively, ensuring that both protocols get sufficient airtime. For example, a device could alternate between Bluetooth LE and Zigbee or Thread. This technique has been widely adopted in applications where direct connectivity is crucial, such as connecting to mobile phones over Bluetooth LE. The advantage lies in the capability to maintain links with different ecosystems simultaneously, albeit with a slight trade-off in timing precision. The process depends heavily on efficient management via the real-time operating system (RTOS) and a multiprotocol radio abstraction layer. Dynamic multiprotocol is common in lighting solutions. For example, a smart light bulb may need to connect to a mesh network using Zigbee or Thread, while also using Bluetooth for commissioning. Similarly, modern gateways often support multiple protocols simultaneously, such as Bluetooth, IEEE 802.15.4, and Wi-Fi.



Concurrent multiprotocol, introduced by Silicon Labs, enables **simultaneous operation** of two or more protocols. Unlike dynamic multiprotocol, which relies on alternating sessions for airtime allocation, concurrent multiprotocol enables **actual multitasking at the stack layer**. This is significant for devices sharing the IEEE 802.15.4 standard, such as Zigbee and Thread, but operating on their distinct PAN IDs. This method when employed with concurrent listening technology (for example, the ability of single radio to rapidly switch between two channels within microseconds) further enables the 15.4 Zigbee and Thread stacks to operate on independent channels. This allows a device to support three wireless protocols, Bluetooth, Zigbee, and Thread, for example, simultaneously. Bluetooth continues to operate in a time-sliced mode, sharing the radio with the 802.15.4 protocols. When handling 802.15.4 traffic, the radio uses concurrent listening to enable simultaneous support for both Zigbee and Thread on separate 15.4 channels.

Switched multiprotocol is advantageous for simplicity and basic use cases, while dynamic multiprotocol excels in fine-tuning resource allocation for dual-protocol applications. However, concurrent multiprotocol represents true multitasking capabilities for complex and high-performance systems.

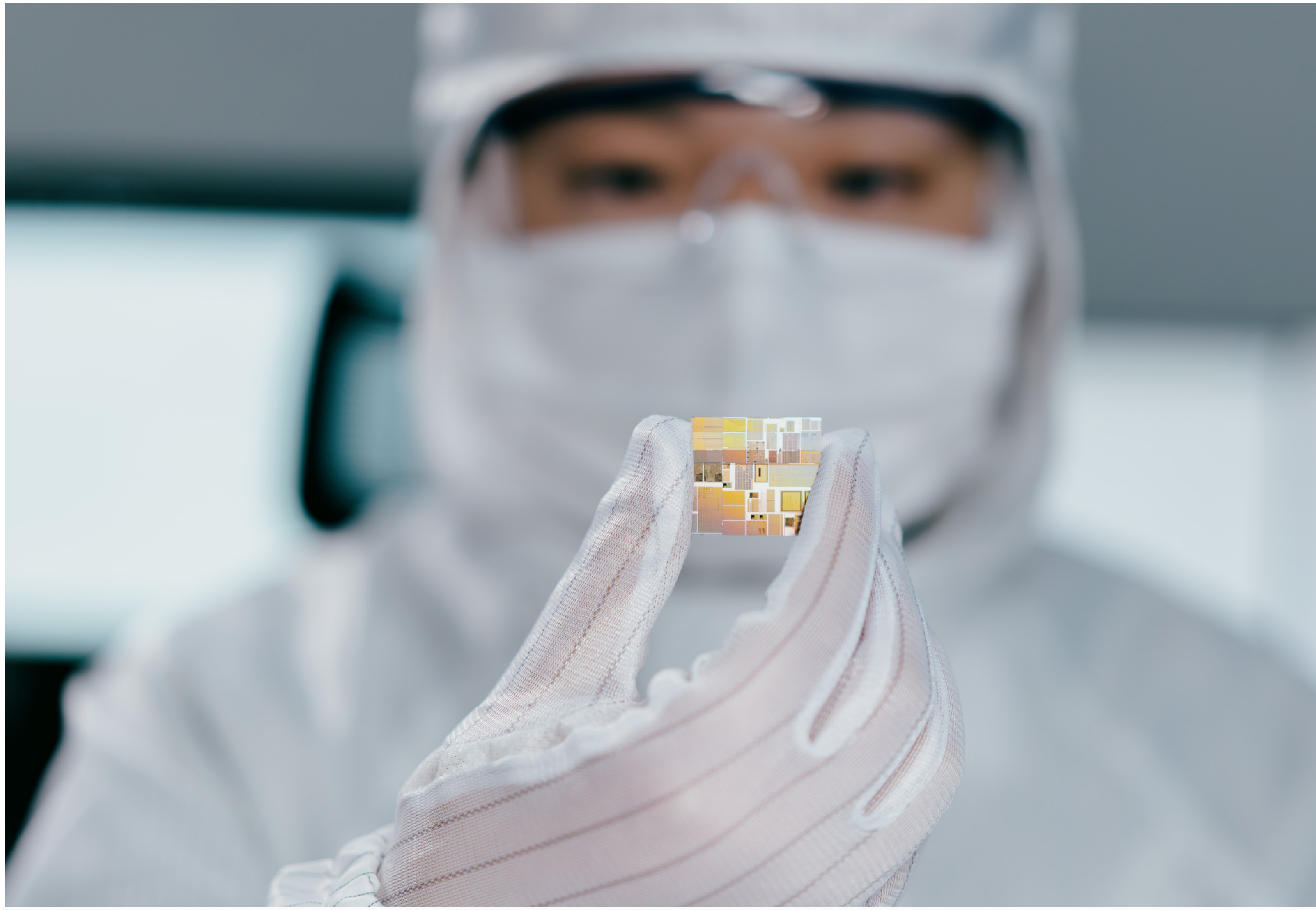
CMP Concurrent Multiprotocol Makes Life Easier for Manufacturers, Developers, and Consumers

Another benefit of concurrent multiprotocol is its ability to simplify SKU management by abstracting end-user complexities. Manufacturers no longer need to worry about whether a device will be compatible across multiple ecosystems. This compatibility is particularly essential for hubs and end devices within smart home ecosystems, enabling them to coexist without compromising functionality. For example, CMP can seamlessly support both Zigbee and Thread protocols operating on the same IEEE 802.15.4 channel, enabling TX/RX operations through a single radio. The multi-PAN mechanism plays a key role in keeping the protocols distinct by differentiating PAN IDs. In comparison, concurrent listening takes CMP further by leveraging hardware-level robustness and enabling fast channel switching on the radio, allowing protocol coexistence across independently operating channels.

When creating end devices, manufacturers can either stick to Zigbee-centric hardware platforms while incorporating OTA updates for future migration to Matter or commit directly to Matter using Thread from the outset. However, with CMP, manufactures can take it a step farther and introduce products that support both Zigbee and Matter over Thread on an single device out of the box. This simplifies things for the manufacture, retailer and user.

The MG26 and MG301 features enhanced memory capacity, sensitivity, and security, making it ideal for more demanding applications. These advancements underscore how CMP-capable devices offer a performance advantage in multitasking environments, ensuring greater interoperability and maintainability within the rapidly growing IoT market.

By offering interoperability between Zigbee and Matter ecosystems, concurrent multiprotocol empowers device manufacturers to cater to regions where Matter adoption might be nascent while maintaining compatibility with Zigbee's widespread infrastructure. For instance, a Zigbee-only smart bulb can be equipped with CMP capabilities, enabling both legacy Zigbee functionality and future Matter support without requiring significant overhauls. This forward-thinking approach helps manufacturers future-proof their products while simplifying the supply chain with a smaller BOM (bill of materials).



From a competitive perspective, Silicon Labs' concurrent multiprotocol solutions are paving the way forward by delivering performance metrics that far outstrip competitor offerings. Enhanced RF sensitivity, for example, ensures devices perform consistently and reliably in complex environments, with sensitivity outperforming comparable solutions by 4-5 dB.

Silicon Labs recently performed simultaneous Thread and Zigbee throughput validation testing for the Concurrent Multiprotocol RCP, running both OpenThread and Zigbee. The tests were conducted in our Boston office, home to our Connectivity Lab, and the results show that the solution delivers throughput and latency comparable to single-protocol SoCs, with excellent reliability across single- and dual-channel scenarios. The comprehensive results from this testing are included in our Application Note, AN1385: Performance Results for Concurrent Multiprotocol RCP for OpenThread and Zigbee."

Silicon Labs' concurrent multiprotocol offering not only benefits current IoT applications but also opens doors to expansive possibilities as ecosystems evolve. The adaptive design assures that devices can stay relevant without frequent replacements or expensive upgrades. CMP's optimized use of resources, coupled with its ability to handle dynamic and concurrent protocols, positions it as the go-to standard for manufacturers aiming to build resilient products in a competitive, fast-changing market.

Implementation of Concurrent Multiprotocol Technology

Practical integration begins with leveraging tools like the MG26 and MG301 development kits. These kits simplify development for multiprotocol applications by offering robust hardware and software solutions, complete with easily accessible resources and documentation to guide you through the process. They provide developers with the tools to configure and switch seamlessly between Zigbee and Matter as part of their designs. Whether you're designing for smart lighting systems or bridging networks, these resources serve as reliable foundations for complex multiprotocol implementation.

This integrated development environment of [Silicon Labs' Simplicity Studio] equips developers with advanced analytics, debugging capabilities, and a suite of configuration tools tailored for multiprotocol support. It simplifies the challenges associated with channel access and frequency planning, ensuring smoother coexistence of multiple protocols.

Design considerations should also center around multiprotocol scheduling and efficient resource allocation. Using the Silicon Labs Radio Scheduler, for instance, developers can ensure that tasks like packet arbitration and time-slicing are managed seamlessly. Tools like [FreeRTOS] enable dynamic and concurrent operations, ensuring tasks such as Bluetooth LE advertising, Zigbee messaging, or Thread transmissions work harmoniously, without interference or excessive energy consumption.

During the development process, common challenges such as latency, channel interference, and certification must be addressed. By integrating simulation tools within Simplicity Studio, developers gain insights into the real-time operation of their applications, enabling optimization during the early stages of development.

We've seen that multi-protocol support is no longer a luxury—it's a necessity given the diverse applications we work with today. Whether you're future-proofing your product, supporting emerging ecosystems like Matter, or simply aiming to deliver a better user experience, coexistence is the path forward.

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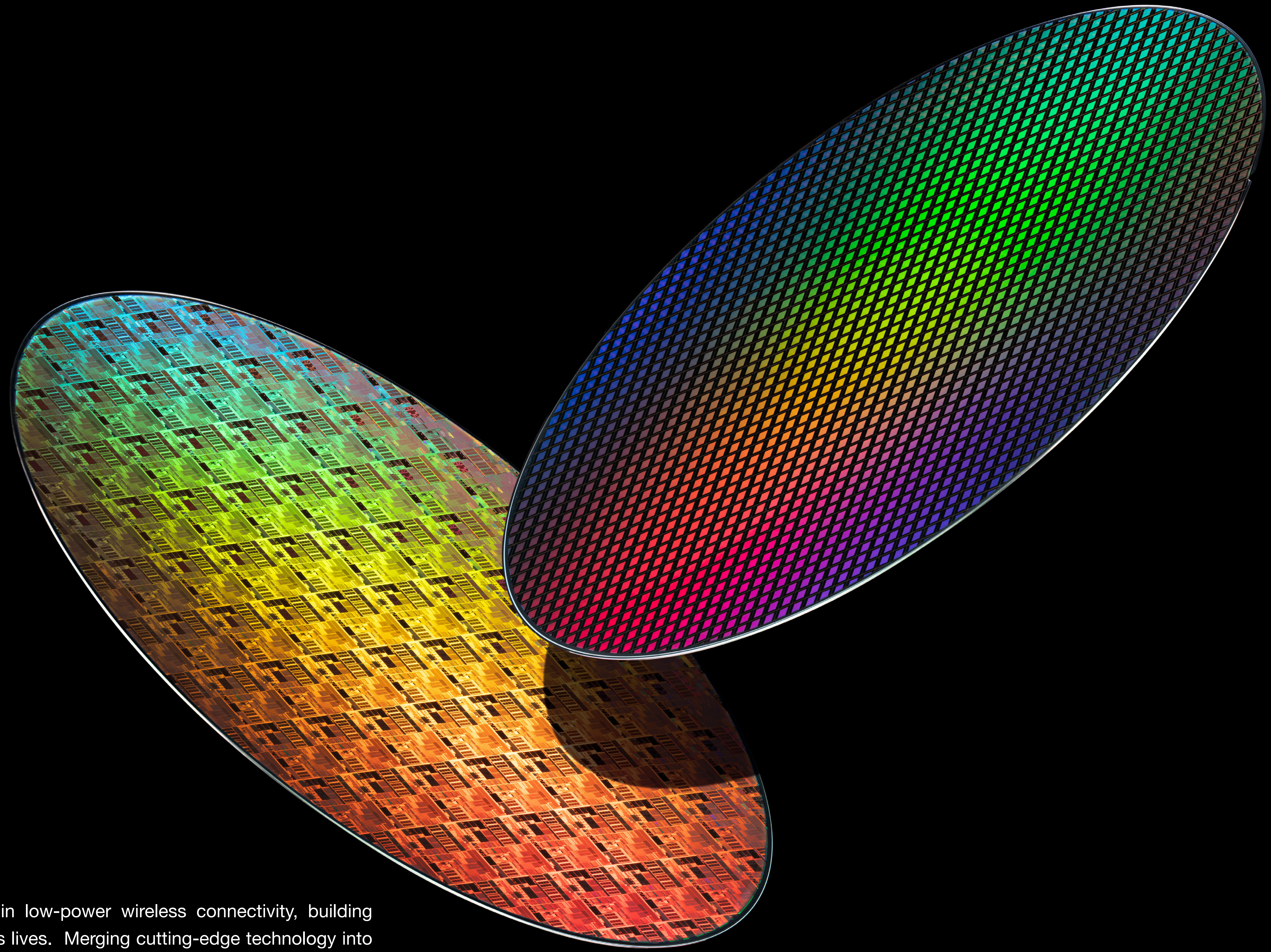

Silicon Labs

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