

Elegantly Connecting Your Smart Home Network

September 2023

This Thread Technical white paper is provided for reference purposes only. The full technical specification is available publicly. To gain access, please follow this link: <https://www.threadgroup.org/ThreadSpec>.

If there are questions or comments on these technical papers, please send them to help@threadgroup.org.

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Revision History

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Table of Contents:

1. Authors: Sujata Neidig, Jonathan Hui, Kyle Sporre	3
2. Introduction	3
3. Overview of IoT Communication Protocols	4
3.1. Wi-Fi	4
3.2. Bluetooth	4
3.3. Zigbee	5
3.4. Z-Wave	5
3.5. Thread + Matter	5
4. The Advantages of Thread Technology	6
4.1. Reliable and Robust	6
4.2. Years of Battery Life	6
4.3. Secure Communication	7
4.4. Interoperability with other Thread-enabled Devices	7
5. Better Together: Matter + Thread	7
6. The Thread Ecosystem	8
7. Parting Thoughts	9

1. Authors: Sujata Neidig, Jonathan Hui, Kyle Sporre

2. Introduction

Smarter homes and buildings deliver better experiences to all involved, from occupants to managers and owners. The need to automate responses, have ambient awareness, and manage energy usage are just a few examples of why smarter homes and buildings are critical. A foundational element for the industry to deliver these solutions is wireless connectivity. Devices must be connected to communicate and take action as needed.

Smart home tech can save money and make everyday tasks more convenient, like turning on the lights, adjusting the temperature, or seeing who's at your front door. With smart home technologies, you can relax with all your products and devices — from everyday appliances to your home thermostat and security system — simply, reliably, and securely. That's the purpose of Thread, a low-power, wireless networking protocol with one goal: to create the best way to connect and control products in the home and buildings.

Wirelessly connecting and controlling products is more complex than it seems. Connections can be spotty, slow, and power-hungry, which is why the Thread Group created Thread. Thread enables direct, end-to-end, secure, and scalable connectivity between Internet of Things (IoT) devices, mobile devices, and the internet. The technology is based on the widely used Internet Protocol (IP) and seamlessly integrates with many environments.

In this white paper, we will outline the challenges with using some IoT communication protocols that led to Thread's creation and the advantages of Thread technology for targeted types of IoT applications. We will also explore the [Matter](#) smart home standard and why the Thread networking protocol enables Matter to work better by making connected smart devices lower power, stronger, and faster. Finally, we will introduce you to the thriving Thread ecosystem: its make-up, collaboration initiatives, and plans. Ultimately, you will see how Thread is shaping the future of the IoT

communication protocol and positively influencing how we live in our homes and buildings.

3. Overview of IoT Communication Protocols

First, you may wonder why Thread exists when there are many other traditional smart home communication protocols, including Wi-Fi, Bluetooth, Z-Wave, and Zigbee. Although each protocol fills a need, none are ideally suited for communication among a range of IoT devices. Thread is designed specifically for low power, low-latency, and reliable use cases.

3.1. Wi-Fi

Wi-Fi provides high-bandwidth communications and enables smart home networks to link up to the wider world over the internet. It was designed for high bandwidth data such as streaming audio or video and is implemented as a point-to-point or star network. Wi-Fi is essential for the home network but presents challenges for devices that need reliable and robust local connectivity and extended battery life.

Think of Thread as a complement to your home Wi-Fi. Your devices will work faster and more reliably across a larger area, and they'll use less power than they would on Wi-Fi. Since Thread connects smart devices using a local mesh network, Thread-based devices will continue working, glitch-free, even if there are hundreds of devices on the network, the internet goes down, or one device fails.

3.2. Bluetooth

Bluetooth was created to provide point-to-point connectivity with short ranges from a mobile device to another device. Like Thread, Bluetooth uses a 2.4GHz radio. The key difference is that Thread natively supports IPv6 over an IEEE 802.15.4 mesh. For product designers, this makes it straightforward to build Thread-based solutions that can interoperate with devices from other vendors.

3.3. Zigbee

Like Thread, Zigbee is a wireless protocol that lets smart home devices talk to each other. One key difference is that Thread is built on IP, enabling devices to connect directly to each other. It is also focused on the network layer, which is how devices connect. Zigbee, however, is a full-stack protocol for networking and application. Also, since Zigbee is not based on IP, Zigbee devices require a central hub to do translations when integrating with any other communication technology. Thread devices communicate end-to-end across IP networks, making them faster and more secure over more extensive networks.

3.4. Z-Wave

Like Zigbee, Z-Wave is a smart home device protocol that requires a central smart home hub to control your smart devices. A critical difference between Z-Wave and both Thread and Zigbee is that it uses sub-GHz frequencies, which differ worldwide, complicating SKU management and certification. Thread and Zigbee use 2.4 GHz radios, allowing for global SKUs. Sub-GHz systems enable longer point-to-point range than 2.4 GHz to support extended range use cases. Thread and Zigbee address extended-range use cases using the mesh network to mitigate range limitations and extend network coverage.

3.5 Thread + Many

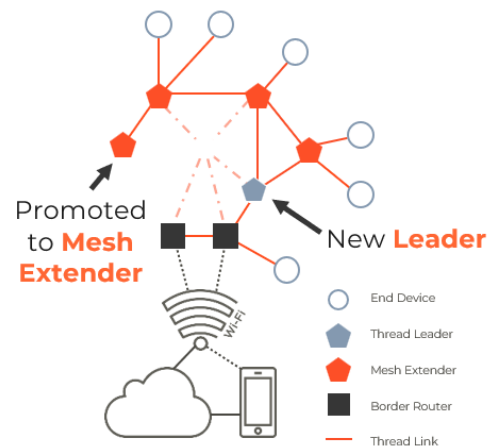
It's key to understand that Thread complements other IP-based technologies, including Wi-Fi, Ethernet, and cellular. There are a variety of applications, and multiple wireless protocols serve different use cases. Here are a few examples:

- Thread Border Router - Thread Border Routers, which connect the smart home mesh network to the broader internet, can be embedded in always-powered applications such as lighting panels, smart speakers, smart TVs, and set-top boxes.
- Wi-Fi + Thread - In this instance, Wi-Fi is used for high data-rate applications such as video and audio streaming, and Thread is used for low data-rate communications.

4. The Advantages of Thread Technology

4.1. Reliable and Robust

Thread is dependable. As a mesh network, the more Thread devices that are added to the network, the more robust the network becomes. Each Thread Mesh Extender device will automatically route data traffic from one point to another using the most efficient path through the mesh network, so you don't have to deal with third-party hubs or Wi-Fi extenders. And, if one or more devices on the network fail, a Thread network "self-heals" so there is no disruption in service to users.



Thread devices connect without a single point of failure. So, if one device goes down or a connection becomes spotty, the network can adjust to maintain connectivity. Because the Thread network has a self-healing mechanism, if any router fails, another router will automatically take over and continue routing data, ensuring the network stays up.

4.2. Years of Battery Life

Thread is power-efficient, resulting in exceptionally long life in battery-powered devices and a small energy footprint in powered devices. The Thread network protocol was designed with low-power performance in mind from the ground up. Thread uses the asynchronous mode of operation within the 802.15.4 specification – making it a good fit for battery-operated peripheral devices (also known as “sleepy end devices”). These devices keep their radios mostly off and transmit only when an event occurs. For example, door and window sensors or smoke detectors wake up only when there is a triggering event, like an intrusion. Lighting, window shades, actuators, and remote controls operate efficiently through the asynchronous network, waking up only to send commands like open/close to other devices one or

multiple hops away in response to user-triggered operations such as a button press.

Better power performance increases convenience. No one likes getting on a ladder to fix a smoke detector's low-battery beep. Efficient power performance also reduces overall system costs because homeowners do not have to replace batteries as often.

4.3. Secure Communication

Thread uses versions of the same types of security technologies that make applications across the internet safe, the ones that keep financial transactions, purchases, and social media sessions secure. These security technologies have been adapted to the unique situation of consumer devices that must automatically maintain network security with little or no user interaction.

Thread uses AES-128 encryption, which closes holes that are present in other networking protocols. Although Zigbee and Z-Wave also use AES-128 encryption for data communication, Thread was designed to always require all data frames to have security enabled.

4.4. Interoperability with Other Thread-enabled Devices

Thread-enabled devices are interoperable by design. Thread uses open standards like IPv6 and DNS as a foundation. Translation: all your Thread-enabled devices, no matter the manufacturer, talk to each other.

5. Better Together: Matter + Thread

[Matter](#) is a wireless protocol created and maintained by the Connectivity Standards Alliance that enables smart home devices to work with each other across brands and smart home platforms, e.g., Amazon, Apple, Google, and Samsung SmartThings.

Matter is the “Application Layer” responsible for defining common functions on various device types. It is the standard language for smart devices to speak. As an IP-based technology, Matter leverages proven and deployed IP-based network transport technologies to define how devices connect. Thread is a wireless mesh network transport designed to support IP technology. Thread is designed for lower-bandwidth use cases with long-range, resilient, and low-power applications. One of the most critical functions of a smart home is automatic control between devices, and the Thread protocol provides a secure, reliable, and faster connection for Matter devices.

Along with Matter, Thread is the foundation for manufacturers to deliver devices that seamlessly connect across a wide range through its mesh network. The enablement of Matter devices through Thread brings the full functionality of IP routing and service discovery to Thread networks so that Matter can operate seamlessly across networks comprising Thread, Wi-Fi, and Ethernet, allowing manufacturers to focus on innovation and less on the “plumbing,” and resulting in richer user experiences.

With Matter and Thread together, smart devices respond more quickly to commands such as “Turn on the lights.” Plus, they require less power to operate – making them ideal for battery-powered devices like smoke detectors, door locks, and motion sensors, enabling them to run for years without needing a new battery.

6. The Thread Ecosystem

Thread is backed by hundreds of members, from innovative startups to leading brands defining the connected home lifestyle. Member companies use it across the connected home landscape, from home automation and appliances to climate control, lighting, security, and healthcare. Among the primary benefits delivered to Thread Group members is the opportunity to shape the Thread roadmap based on market pain points and needs.

Members include esteemed companies across the IoT spectrum, including Amazon, Apple, Bosch, Google, Nordic Semiconductor, Qualcomm, Siemens, SmartThings, Wyse, Yale, and many others. They offer a variety of products and services to help ecosystem members build Thread solutions. These include end-device manufacturers, semiconductor and systems companies,

RF module manufacturers, and service suppliers. In addition, Thread Group offers a rigorous testing and certification program to ensure that products using Thread connect effortlessly and securely.

Thread Group works with other industry alliances to ensure Thread continues to deliver on the promise of providing the best way for manufacturers and consumers to connect products around the home. Partnerships with other standards organizations and alliances, such as the Connectivity Standards Alliance, advance connectivity and interoperability for all devices connected to the IoT.

As a result of membership and robust alliances, the availability of Thread-enabled products and services continues to grow, ranging from Thread Border Routers to sensors. Examples include the Amazon Echo Gen 4, Apple HomePod Mini, Google Nest Hub Max, Samsung SmartThings station, Nanoleaf, Eve Energy, Aqara, and Samsung. With over 200 certified Thread products, most smart homes already have Thread implemented. You can check a list of up-to-date Thread devices [here](#).

7. Parting Thoughts

The IoT aims to transform people's lives through smart homes. In the home, the goal is to make life easier by creating new experiences and reimagining old ones through a network of connected appliances, lights, climate controls, security, entertainment systems, and various innovative products and services. Thread is at the center of this transformation. Thread technology improves IoT efficiency, functionality, automation, comfort, and safety — the fundamental technology shaping the future of the IoT communication protocol.

Consumers and users of smart home technology can look for the Built on Thread badge to see how Thread is enabling the smart home, and visit www.threadgroup.org to learn more.

Smart home product manufacturers can join us in shaping and advancing the future of the smart home today. To join the Thread Group, complete the online [Membership Application Form](#) or send the completed Membership Agreement to help@threadgroup.org.