Thread for Pro Home and Buildings

February 2024

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Revision History

Revision	Date	Comments
1.0	September 2019	First Public Release
2.0	September 2022	Fully Revised Version
3.0	February 2024	Fully Revised Version & Title Change

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2. Introduction

Today, most building networks consist of technology silos, which also require separate security and maintenance efforts. Thread connectivity aims to provide a common IP (Internet Protocol) networking solution for easy integration with enterprise networks. This integration enables more flexibility in functionality planning, better system features, easier maintenance, and lower cost.

Thread is an open standard for wireless communication, offering a native IP (Internet Protocol) solution for reliable, low power, secure, mesh, application-agnostic communication. It is the premier IPv6-based solution running on existing and broadly supported IEEE 802.15.4 radio technology.

Thread offers several benefits compared to other solutions. Its IPv6 base enables flexible set-up, monitoring, data analysis, provisioning, and a direct connection without compromising encryption and security, from local networks up to the cloud. Thread also offers flexibility in choosing which application protocols to run, even allowing multiple application standards to run concurrently, enabling flexible integration with other technologies, and maintaining an open path towards future developments.

Since Thread is based on IPv6, the application layers can also run on existing IP infrastructure like Wi-Fi and Ethernet, allowing the most suitable networking technologies to be used together. For example, a network could consist of lighting end points connected with Thread and lighting end points connected via PoE, all operating in one fully integrated environment.

Thread scales to thousands of wireless robustly connected IP devices and handles both local communication between devices as well as cloud connectivity over the Internet. In terms of self-configuring and re-configuring, it brings a familiar way of setting up and managing the network for system administrators, without the need to worry about address and topology assignment. End-to-end routing and addressability allow IPv6 packets to securely move from one end point to the other, whether on the same Thread mesh network or via the Internet across the world. Its 6LoWPAN foundation is

based on low power, widely deployed, proven, and low-cost IEEE 802.15.4 radio technology that supports sleepy nodes and reduces network overhead.

Thread is a seamless part of the enterprise network and allows the usage of various application-level protocols to integrate with existing infrastructure while maintaining the security and flexibility to commission and maintain end devices. It also allows for the creation of various individual and group profiles and domains, even spanning multiple individual Thread mesh networks.

3. The IP Protocol and its Adoption in IoT

At the beginning of 2023, we celebrated 40 years since the precursor of the Internet officially moved to the TCP/IP protocol. Designed to be a flexible, versatile protocol to transmit data over large networks of networks, it marked the beginning of what would become an essential part of how we communicate, learn, and work today.

As the use of computers at work expanded in the 1980s and 1990s, so did the need for connecting them. After a period of mostly proprietary and incompatible protocols for doing so, it became clear that a universal solution would make things far easier, from a maintenance, cost, and interoperability standpoint. And with the increased usage of the Internet as an essential business tool, it made sense to base the local office networking on the IP protocol. IP had proven to work with a host of different applications, and it would make integration and communication with the greater Internet far easier. Office networks eventually transitioned to IP, and with it, ease of maintenance, versatility, and interoperability vastly increased.

3.1 Connected Devices

Fast forward a couple of decades, and we enter a period in which there was a demand to connect other devices beyond traditional office equipment like computers and printers to a network. Centralizing things like lighting and climate control would allow for much more efficient and optimized operation and use.

It became evident that IP could also serve as the foundation for these networks of connected devices. However, the available technology at the time didn't make this feasible. Computer chips and components did not allow for the full, versatile IP protocol to be used on these constrained, low cost and often battery-operated devices.

As a result, specific protocols that could work within the technical constraints were developed. Some of them were optimized to work as cable replacements (for example audio), and others were based on tightly defined clusters or profiles for specific usage, requiring different implementations for each application. None of them were based on IP, but instead relied on application-specific protocols and networking technologies.

3.2 Becoming IoT Devices

This approach worked well for these clearly defined single-purpose applications. However, with devices tied into siloed networks, connecting them to allow for fully integrated and multi-domain solutions was no simple task.

Fortunately, advancements in chip design and component manufacturing ushered in a new era that enabled the possibility of applying IP networking technology across all application domains for all kinds of devices. And since the IP protocol allows for a seamless integration with office network infrastructure and the Internet, we are truly moving towards the "Internet of things."

4. Thread's IP Foundation Offers Flexibility and Security

Wi-Fi is for data-intensive applications like video and audio streaming, Thread is for low bandwidth, battery, and power-efficient devices. Like Wi-Fi, Thread is fully based on IP and therefore not constrained to any single usage protocol or application type, and, like Wi-Fi, it can be seamlessly integrated with the rest of the IP network, both in the home and office.

It is not surprising that modern application protocols are based on IP, given that the technical constraints are no longer an issue. The new Matter standard, defined by Google, Apple, Amazon, and hundreds of other companies is part of the Connectivity Standards Alliance for the future of Internet of Things devices and is fully based on IP. It can leverage existing Ethernet and Wi-Fi networks, and it has chosen Thread as its low power wireless network foundation.

Likewise, in the professional building automation world, well-established and proven solutions like KNX and DALI are now offering IP-based versions of their popular protocols and have selected Thread as the wireless low power network of choice.

4.1 IP Brings Endless Benefits for Installation

Typically, individual infrastructures for various applications require a lot of cabling combined with significant maintenance costs. The current push to move towards a single network infrastructure, driven amongst others by costs, increased security requirements, and environmental and carbon footprint concerns has led many building owners to fully converge on IP technology. This results in fewer cables and complex wireless solutions. It also provides an easy pathway into compliance with the European Union's EPBD directive that starts to include Building Management and Energy Management requirements from 2025 onwards.

Growing and extending a network is much easier in an IP-based world. It's easy to combine different physical transport technologies like Ethernet, Wi-Fi, or Thread in one network. Furthermore, one can use well-known and proven networking scaling methods, such as routers and switches to create subnets. This allows updates to the network architecture without breaking the application.

4.2 Maintenance and Usage

When all applications leverage the same IP infrastructure, it becomes easier to reach the faraway spots in buildings or plants, by tying them into cabling or wireless networks that are already present in the building. Individual

devices on a wireless Thread network act as mesh network extenders that can be leveraged by all applications.

For example, lighting benefits from the HVAC systems running on the same, IP-based Thread networks. And if at some point new applications or application protocols are needed, IP offers the flexibility to easily integrate them into the existing network infrastructure.

An IT administrator does not need to have knowledge that is specific to legacy network technologies that were commonly used for the various application domains. IP means that familiar maintenance tools can be used to administer the network. And because IP networks do not require network protocol gateways, a manufacturer or service company can have a direct connection to any device on the network and remotely monitor its usage or tailor it to specific user needs.

In addition, with an IP infrastructure, device manufacturers have a direct connection to their devices and the users give them valuable insight into how their devices are being used.

4.3 Security

On an IP-based network, data packages remain encrypted as there is no need for gateways or converter boxes. With traditional solutions, these gateways require specific care since they often form a vulnerable spot that might lead to security concerns. The network can leverage state-of-the-art and proven security methods that are used on the Internet and corporate networks.

Security domains can be defined to restrict access to specific subsets of devices. What's more, on an IP network, every device can be reached by standard equipment using familiar concepts in IT networking, enabling maintenance and operation to be executed remotely.

4.4 A Logical Move at a Logical Time

All the pieces have come together: the new unified smart home standard Matter and new versions of proven smart building standards like KNX IoT and DALI+ are based on IP. With Thread, there is now for the first time a powerful

low-cost wireless mesh networking technology fully based on IP, and there is a wide availability of components and silicon, and even open source software stacks, to speed up the development process of devices and solutions for a world of IP-based connected devices.

With previous constraints out of the way, the time to fully embrace IP networks for both traditional office equipment and smart connected devices is now!

5. Topology of Thread in an Enterprise Network

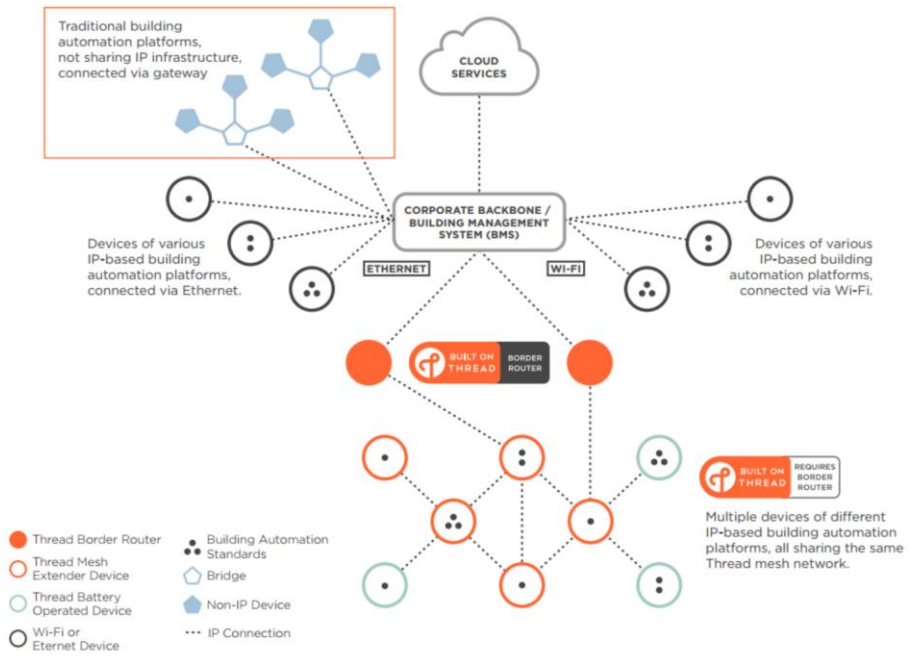

Figure 1: Topology of Thread in an Enterprise Network

Figure 1 shows an example of how Thread can be implemented in an enterprise network environment. The diagram illustrates Thread's key advantage over other networking technologies: it is fully based on IPv6. Thread's IPv6-based foundation brings many advantages to the Smart Building. Not only can it leverage widely proven cyber security mechanisms, but it can also integrate seamlessly into the existing building network infrastructure. Contrary to legacy automation systems, which are usually

siloed in separate networks for each application, multiple applications - even those based on different standards and protocols - can share the same network at the same time and use the most appropriate physical network type for each device. Thread's low power mesh network is ideal for power-constrained device types covering wide areas in a building.

5.1 Thread Mesh Extender Device

Thread is a mesh network technology, which means a device on the network can not only receive data but also pass data along to other devices. In this way, these devices act as Thread Mesh Extender devices. This results in a very stable network with a large reach, without the need for additional repeaters that rebroadcast wireless signals to devices that are located further away.

5.2 Thread Battery Operated Device

Thread Battery Operated Devices, also known as Thread Sleepy End Devices, are devices on the network that generally only operate when requested, like light switches. They don't reroute data and can be sleepy devices to save energy, only to be activated and immediately become part of the Thread network upon use.

5.3 Thread Border Router

A Thread Border Router is the device that forms the link between the enterprise network, to the IEEE 802.15.4 energy-efficient wireless radio standard that is being used by Thread. It can be a dedicated device, or this functionality can be part of a powered device with another function. A Border Router does not need to convert data packets, since Thread uses the same IPv6 protocol as the enterprise network, making Thread Border Routers straightforward devices. Thread supports having multiple Border Routers on the same network that dynamically take over the function, so there is no single point of failure. Manufacturers of wireless base stations offer products that combine Wi-Fi and Thread radios in a single device, even further reducing the complexity of extending an enterprise network with a secure and wireless network for low power devices.

A detailed explanation of what a Border Router is and how it works can be found in the next chapter.

5.4 Building Automation Standards

As indicated in Figure 1, various Building Automation Standards can be used on a Thread network. As with other IP-based applications and devices (e.g. printers, servers, or copiers), multiple application types (e.g., lighting, access control, or climate systems) can share that same network, and these applications can be based on different protocols, like DALI+, KNX IoT, or Matter.

5.5 Building Management System

A Building Management System (BMS) may be part of the enterprise network. A BMS can directly address each Thread device, as Thread's IPv6 connectivity is fully transparent to the existing enterprise network. Likewise, authorized PCs, laptops, and mobile devices like smartphones and tablets are directly connected to the enterprise network and can also immediately access Thread devices using the existing IPv6 networking protocol.

5.6 Cloud Connection

IP makes the life of system maintainers and IT staff much easier. All devices, including those on the Thread wireless mesh, can be remotely configured and maintained using familiar tools and technologies. It offers easy remote control, data collection, and monitoring from anywhere in the world, while maintaining full end-to-end encryption.

5.7 Bridge to Traditional Non-IP Systems

Many buildings have legacy building automation systems in place that will over time make the full transition to IP and unlock the many benefits described above. They are either based on other physical network standards or non-IP-based application protocols. These systems can be integrated with

the rest of the network using a gateway that allows access to the respective network technology and application protocol.

6. Thread Border Router vs “Hub”, “Gateway”, or “Bridge”

Thread is changing the way we think about low power wireless connections for smart devices in both home and commercial building applications. Whereas wireless technologies for IoT devices have existed for quite a while, Thread is different in several significant ways, resulting first and foremost in the fact that it does not require a dedicated hub or bridge to operate. Let’s dive in and have a look at how this works.

6.1 IP-Based: Thread Natively Fits in the Network

Thread is based on the ubiquitous IP protocol, the same protocol that is used on the Internet and in existing networks in homes or buildings. That means that it acts as a low power, wireless mesh network extension to the network, comparable to how Wi-Fi serves the high-bandwidth wireless needs of a network. Neither technology needs to “translate” IP packages to serve them from one physical infrastructure (i.e., wired Ethernet cables) to the other (i.e., the wireless network).

Traditional wireless IoT solutions typically rely on a bridge or hub to translate the IP packages to their native technology, and vice versa. This often requires a dedicated box that performs these complex operations. In most situations, the vendor of a specific product offers their box to serve this function, resulting in several boxes for each type or brand of application (e.g., lighting, climate control, door locks, window shades, etc.)

Since Thread does not require any form of translation, a Thread Border Router's sole function is to send packages between the low power wireless mesh and the rest of the network. The Border Router function is not brand or application-specific and therefore can be performed by many types of mains-powered Thread devices. It might be present for example in smart speakers or displays, set-top boxes, or even in lighting products.

If the network consists of multiple devices that can perform the Thread Border Router functionality, communication between the low power mesh network and the rest of the network remains possible even if one of those devices go offline. They just seamlessly switch actions. Figure 2 provides a comparison of this to the traditional wireless technologies: if their dedicated hub or bridge goes down, all the connected devices stop functioning.

	BUILT ON THREAD BORDER ROUTER	Traditional "Bridge" or "Hub"
Purpose	Let the network access low power IP-based Thread devices	Translate between hub's protocol and IP (and vice versa) to make devices usable on the network
Functionality Location	Can be a function in many types of existing devices 	Typically a dedicated box 
Application Types (Ex: Lighting, Locks, Shades, Etc.)	Works with multiple brands and types of Thread devices	Typically requires individual hub per type or brand 
Single Point of Failure	A network may have multiple Thread Border Routers - Seamless switching	Typically one hub - All devices go offline if hub goes offline

Figure 2: Thread Border Router comparison to traditional wireless technologies

7. The Thread Difference: A Universal Low Power Mesh Network

With traditional wireless technologies for smart devices, there is typically a dedicated device that serves as a hub or bridge to control the connected devices. Figure 3 shows that a separate box is usually needed for each type of application, and often for every brand. This results in many separate boxes that need to be individually configured and kept up to date with security updates.

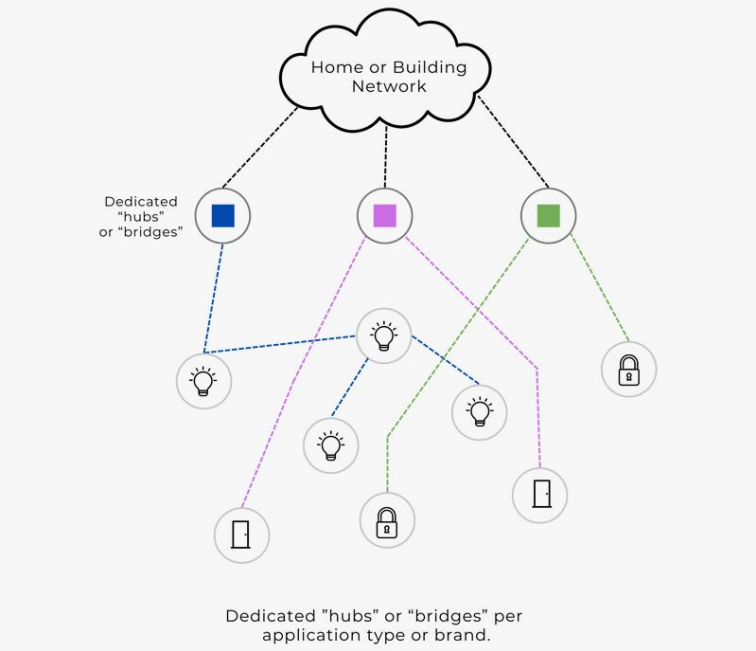

Figure 3: Hubs and Bridges per Application Type or Brand

Because all these wireless connections are separate and serve a single or limited function, they are not aware of each other's existence. The result is many different wireless networks that need to be maintained.

7.1 How Thread is Different: Universal Mesh

As explained above, Thread only needs Border Router-functionally to send data to and from the Thread low power wireless mesh network. There is no need for protocol conversion or any other dedicated actions. Therefore, the Thread network is used by all Thread devices, regardless of their purpose or brand.

This makes it very simple to include Thread Border Router functionality in existing mains-powered Thread devices, eliminating the need for separate boxes. Thread Border Router functionality can be found in many devices such as lighting panels, smart speakers, or set-top boxes.

If a Thread device performs Border Router functionality, it may have this logo:

And because Thread is a mesh technology, this means that all Thread devices can benefit. Every mains-powered Thread device (such as a light bulb) serves as a Thread Mesh Extender, rerouting data from one device to another. Fully seamlessly and automatically, without any user actions. These devices also communicate with battery-powered “sleepy” Thread devices that only wake up when needed (e.g., window sensors or door locks), enabling many years of battery usage.

As Figure 4 illustrates, the more main-powered Thread devices you add to the network, the wider the area that you can serve, and the more reliable the network becomes.

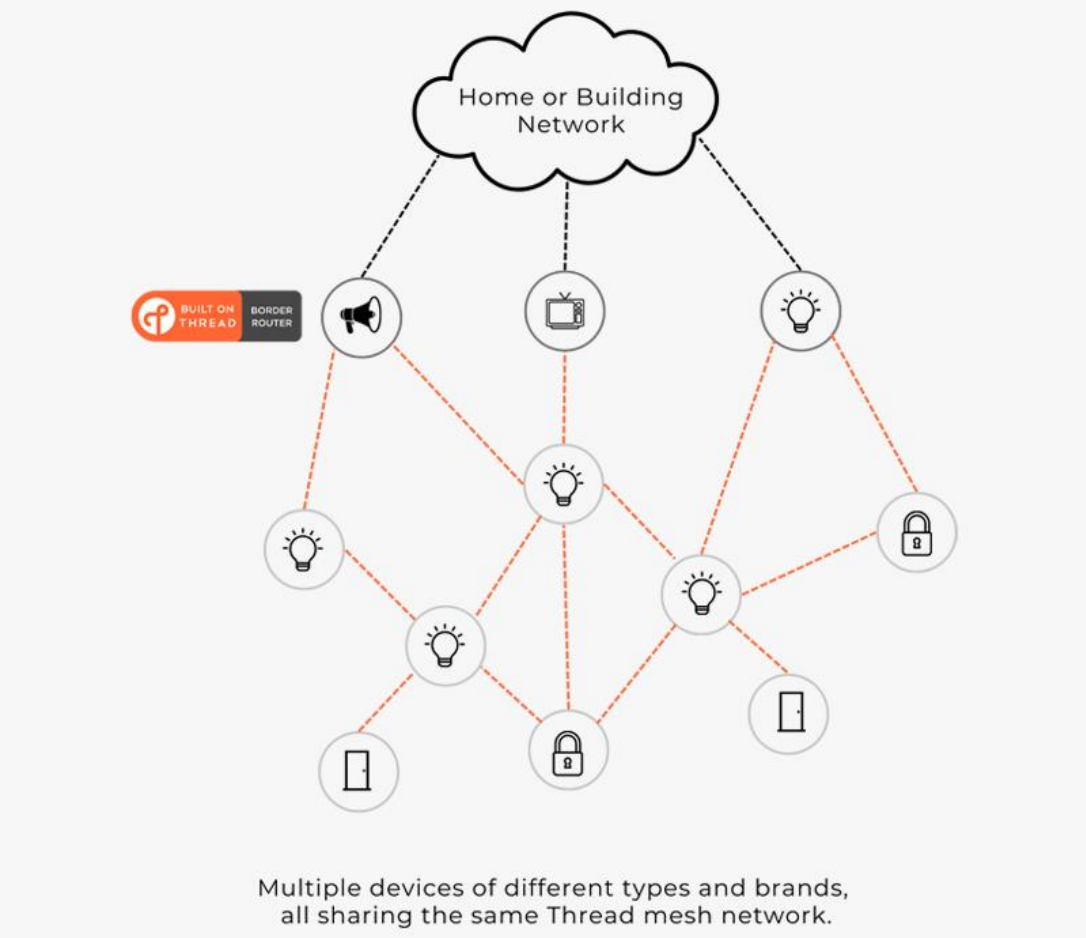

Figure 4: Thread Mesh Network

By using Thread devices, you can benefit from a secure, reliable, wide area covering wireless mesh network that, due to the Thread Border Router, seamlessly becomes part of your existing building network.

8. Thread Supports Multiple Application Layers

Thread's application support is comparable to the way Wi-Fi works with multiple applications. By simply joining one Wi-Fi network, due to the common Internet Protocol we can access every service, regardless of who is offering it or from wherever it is being provided.

Today's wide offering of IoT solutions often requires that we set up and maintain a network for every protocol we want to use. This not only requires surveillance and maintenance to keep them up and running, but networks might also interfere with each other. Furthermore, since they are separate networks, devices do not "talk" to each other and there is no way to control them effectively from a single location, monitor and analyze their data, or provision them over various locations and users, in an end-to-end secure manner.

This is where Thread comes in. Like Wi-Fi, it can run every modern IoT application that runs over IP, using a common physical network.

Having one single network for all your IoT devices provides major benefits. These devices do not interfere with each other but instead can work together to extend the reach of the network by forming a mesh. Since the entire network is IPv6-based and does not need "conversion" of application data, encryption of data packets remains intact throughout the entire chain, all the way from the individual device up to the cloud. Every device is uniquely addressable, making it easier for system administrators to commission them individually or as a group, and to flexibly change those arrangements. All devices can be managed and monitored from a single location, opening the possibility for powerful data analysis.

Moreover, Thread is designed so that in networks consisting of devices that use different application protocols, all these benefits remain in effect. Thread can run multiple application layers concurrently on the same network. This is simply not possible with other IoT solutions on the market today. If you use multiple devices based on different systems, all devices require their network which often creates maintenance issues. And if in the future you want to replace or add an application layer, you do not need to replace the underlying wireless network. As with Wi-Fi, Thread allows you to simply start using the new application on the existing network.

All popular IoT standards for building automation control recognize the importance of moving towards a universal, secure, and interoperable IPv6-based network. And most of them have chosen Thread to be their future-proof solution. This includes DALI+, KNX IoT, and Matter. And since Thread is fully agnostic to the application layer, it is even possible to design and

develop a custom application layer to suit specific needs (e.g., for unique factories and machinery, or medical applications).

Application standards will continue to focus on compelling new use cases, satisfying new IoT application requirements, and interoperability aspects between different applications on the same network.

An IP-based network is an innovation enabler. A common IP-based network makes it very low-cost and easy to introduce new applications. It is a large reason for the Internet's success.

Instead of developing yet another IoT protocol, Thread combines current and proven Internet-based technologies into a standard that is optimized for security and mesh networking in low-cost, low power devices. Thread is transparent to the applications that run on the network which makes it the only future-proof choice for modern IP-based networks for IoT devices.

9. Parting Thoughts

Thread's wireless mesh IPv6 solution offers specific advantages to a variety of pro home and building applications:

- Professional building owners will be able to install both small networks (such as a quick-fix retrofit RF solution) and very large building networks (thousands of nodes) using the same networking technology, simplifying, and streamlining network installation and management processes and overhead.

- Wireless IPv6 technology is forward-compatible, more sustainable, and offers greater economies of scale than alternative technologies, so networking solutions become more cost-efficient and add functionality more easily. It can easily be combined with other physical network transports in one single network.

- Network managers, application managers, and system integrators can independently execute tasks on the system, easing network management bottlenecks.

- IP networks like Thread can leverage proven and constantly evolving security and encryption technologies.

- A native IP system can collect and process vast amounts of data, from a broad range of intelligent connected devices, in near real-time. System data can then be accessed directly or via the cloud. Unique values can be extracted through advanced analytics.

- The flexibility of the application stack enables more sophisticated occupant individual control possibilities, increasing the levels of convenience, productivity, and operational efficiency.

- The network is easier to reconfigure than alternative technologies, implying decreased refurbishment costs and lower churn costs in buildings.

- The technology further enables remote and predictive maintenance, provides more opportunities for notifications on maintenance tasks, and simplifies system-wide fixes, software updates, and network reconfigurations.

- During building refurbishing, wireless technology requires less physical alteration of the site, reducing installation costs and offering increased flexibility and installation speed.

In the ever-expanding universe of IoT applications, Thread Group sees a great market opportunity in the smart building sector—and more specifically, the building automation, energy management, and lighting control markets.

Thread Group's global membership, and the various industry alliances with which Thread Group collaborates, are committed to standardizing on a common, cost-effective, secure, IP-based mesh networking infrastructure that supports interoperability for resource-constrained devices. With an established base as the leading IP mesh networking protocol in the residential IoT space, Thread is ready to scale from residential to large businesses and is well-positioned to provide a strong foundation for robust and secure wireless networks in critical building infrastructures.

Thread delivers the features and functionality required by the building automation market. As the standard for smart buildings, Thread is a cost-effective, reliable, secure, scalable mesh IP solution that is essential for any automated building system. With Thread's incorporation of next-generation IPv6 and low power technologies, the groundwork is laid for an open, routable IPv6 mesh network infrastructure with end-to-end security for the connected building.

Thread allows building owners to create an effective open network infrastructure that will not only support the heterogeneous devices and applications of today but, as with the Internet at large, the heterogeneous devices and applications of tomorrow that will develop and evolve, all operating on the same IP network.