Protocol Evaluation and Recommendation for Alarm.com

Final Report

ENGM 178- Technology Assessment

Master's in Engineering Management- Thayer School of Engineering

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1. Introduction

The global home automation market has witnessed a remarkable surge due to drawing demand for energy efficiency, convenience, and enhanced household security. With increased accessibility to the internet and improved standard of living, homeowners have started embracing the concept of interconnected home appliances, enabling them to control temperature, security, and entertainment with the click of a few buttons.

Fig 1. Projected CAGR of the Home Automation Industry in the next 10 Yrs

Alarm.com, founded in 2000, has played a pioneering role in developing home security and automation. Over the years, it has continually innovated cloud-based smart home technology and services and enabled its users to remotely monitor and control their security, energy management, and home automation systems through a user-friendly app. However, uncertainty due to rising hardware costs and a limited technical roadmap has made it difficult for Alarm.com to solely support its current integrated protocol- Z-wave. Z-wave offers Wireless Communication, Low Power Consumption, and Interoperability, making it convenient for households and small businesses.

Some products of Alarm.com are:

1. Doorbell with Camera: Doorbells are embedded with motion sensors and send a notification to the Alarm.com app, enabling live communication.
2. Crash & Smash Technology: The system detects a series of “crash” and “smash signals and sends signals to Alarm.com’s monitoring center to send dispatchers immediately.
3. Scenes: Enables users to control multiple devices using a single click, for eg- in ‘night mode’, the drapes go down and lights turn off.

2. Situation overview

2.1. Current Situation of Alarm.com and Clients' Needs

In response to the evolving landscape of home automation and the need to strategically position Alarm.com in the US Market, we need to comprehensively analyze, evaluate, and build a matrix of existing and emerging home automation protocols to determine the protocol best suited for the existing user base and with maximum potential for future growth. We also need to assess the compatibility of the protocols with the existing Alarm.com systems and their potential for seamless integration. ***Post-evaluation, we recommend Thread to Alarm.com.***

Further, we evaluated and proposed a strategic roadmap for the implementation of the same. The strategy will encompass the existing commercial and residential vertical opportunities, including home automation solutions such as lights, locks, thermostats, and similar functionalities, within the domestic market. We also conducted a financial analysis to estimate the switching cost from z-wave to threads and the implementation cost of threads. Lastly, we proposed a strategy for alarm.com to penetrate new markets by leveraging its existing technology and by innovating new technologies.

3. Protocol review and assessment

3.1. Assessment Process

Our interdisciplinary team conducted in-depth analyses as part of our strategic engagement with Alarm.com to identify the key elements necessary for the project's implementation. We chose nine crucial evaluation criteria with a strong emphasis on precision and excellence: Security, Network Topology, Cost, Compatibility and Interoperability, Power Consumption, Data Rate, Latency and reliability, Range and coverage, and Operating Frequency. To ensure a comprehensive approach to the project's development, these criteria were created to include every aspect of the client's requirements.

We created a sophisticated Google form that was intended to record precise, in-depth preferences of Alarm.com’s products. The client filled out this form, giving us a thorough insight into their goals and expectations. The carefully collected data had a key role in the development of the protocols being examined. Our protocols were not only technically sound because we incorporated the client's insights from the Google form, but they were also carefully honed to perfectly match Alarm.com's goal with the team brainstorming and researching. We then meticulously examined the 6 most important criteria that perfectly corresponded with the client's goals at Alarm.com for the following reasons.

Criteria	Significance	Assessment
Operating Frequency	The operating frequency of the protocol should be widely recognized and should not interfere with other wireless devices.	Ensures compatibility between regions and reduces interference problems to enable smooth communication in a variety of settings.
Compatibility & Interoperability	Device compatibility means that products from many manufacturers can coexist, supporting a diversified environment.	An emphasis on compatibility and interoperability in a protocol enables a large range of devices to connect and communicate successfully, supporting a unified home automation system.
Latency	A responsive and effective automation system is made possible by low latency, which assures minimal delays in command execution.	Low latency protocols are essential for real-time applications because they allow for speedy user command responses and improve user experience.
Power Consumption	Low power consumption extends battery life and lowers energy expenses for devices.	For battery-operated devices to function for lengthy periods of time without needing replacement or recharging, protocols with optimized power usage are crucial.
Data Rate	(Low data rate) LDR protocols effectively manage modest amounts of data, making them appropriate for the majority of home automation applications.	High data rates are not necessarily required for home automation. LDR protocols efficiently manage sensor data and control signals while using less bandwidth and energy.
Network Topology	Physical arrangement of the different devices in a network to be able to easily communicate	As devices may be added, removed, or moved during home automation, protocols with hybrid topologies are desirable. This flexibility guarantees network functionality even if the configuration of the automated devices evolves over time.

Table 1. Evaluation criteria and their significance

3.2. Data Collection and Comparative Analysis

We shortlisted 7 protocols that are popular in the home automation market, including Z-Wave, Thread, Matter, Bluetooth, WIFI, Zigbee, and Wi-SUN. We did research for each and found that Thread, Matter, Zigbee, and Wi-SUN are suitable for integration into Alarm.com's ecosystem.

For each protocol, we found the data of each criterion and the highlights and potential problems they have. At the same time, we kept in mind the requirements of Alarm.com including the protocol should be able to operate under 2.4 GHz and the company provides solutions for both households and small and medium size companies.

To compare and contrast these 4 protocols, we aggregated their data into an explicit summary table (Fig 3.) that provides an outlook of 6 protocols and then transformed them into a weighted final decision matrix table (Fig 4.).

Criteria	Criteria ranking	Thread	Matter	Zigbee	Wi-SUN	Condition
Operating Frequency	6	2.4	2.4/5	2.4	2.4	2.4 better than 5
Compatibility & Interoperabiity	5	Higher & can upgrade to matter	High	Low	Lower than Zigbee	Higher the better
Latency (ms)	4	80-100	20-150	80-130	20	Lower the better
Power consumption (mA) resting/listening	3	0.0016/0.037	0.1/0.5	26.5/28.5	0.002/8	Lower the better
Data rate (Kbps)	2	250	250	250	300	Higher the better
Network Topology	1	Mesh	Mesh	Star/mesh/ cluster-tree	Star/Mesh	Case dependent

Decision Criteria
6 - Most Important Criteria
1 - Least Important Criteria

Fig 2. Explicit summary of protocol evaluation matrix

To do that, we first gave performance rankings for the data of each criterion on a scale of 1-4, where 1 is the worst and 4 is the best because there are 4 protocols in total; the Condition column from Fig 3. explains the logic we used for the ranking. Secondly, we divided each criterion ranking by the sum of the rankings to get the percentage weighting for each criterion and stored it in column Weights. Lastly, we summed up the products of each criterion weight and the corresponding performance ranking to get the total score of each protocol. The condition column represents the priorities of each criterion in the given case, i.e. whether the higher the value the better, or the lower the value the better. For example, for latency, lower values are preferred more as the delay in data transmission in this case is expected to be less for immediate actions to be taken by the control unit, owner, or dispatchers. Our results show that Thread and Wi-SUN received the highest scores: 3.52 and 3.29

Criteria	Criteria ranking	Weights	Thread	Matter	Zigbee	Wi-SUN
Operating Frequency	6	0.29	4	4	4	4
Compatibility & Interoperabiity	5	0.24	4	3	2	1
Latency (ms)	4	0.19	2	2	1	4
Power consumption (mA)	3	0.14	4	3	1	4
Data rate (Kbps)	2	0.10	3	3	3	4
Network Topology	1	0.05	4	4	4	4
Scores			3.52	3.14	2.43	3.29
4-being the best, 1-being the worst						

Note : Weights = Ranking of each criteria / Sum (All criteria rankings)

Fig 3. The final decision matrix with Thread & Wi-SUN with the highest score

Based on our research on these protocols, they have different highlights and different network designs. We decided to study both of them to see which one best suits the current strategy of Alarm.com.

3.3. WI-SUN protocol review

The WI-SUN technology is applicable to 2 areas: Home Area Network (HAN) and Field Area Network (FAN). Its Home Area Network usually applies to smart meters and smart home appliances in connecting them to the smart city. Its Field Area Network has more applications in smart cities such as smart cities, smart utilities, smart grids, smart meters, and other IOT applications. Its current stakeholders are enterprises, universities, municipalities, and government organizations. So, we concluded that WI-SUN is more extensively used in smart cities, industries, and enterprises rather than at home.

In addition, WI-SUN is not suitable to be integrated into Alarm.com's current landscape. The reasons are that it is designed for large-scale deployments with a focus on utility companies and industrial applications, Wi-SUN devices and infrastructure are more expensive to implement than other alternatives, high power consumption for households, and is a complex and highly secure protocol, which may be unnecessary for most home automation systems. Also, WI-SUN's current market is in smart cities and enterprise applications, its goal to master home automation is in the next 5 years which is not desirable and mature enough for Alarm.com to adapt now.

3.4. Thread protocol review

The Thread technology has the following characteristics: low-power, secure, and ipv6-based wireless mesh protocol; it operates in the 2.4 GHz band which is desired by Alarm.com and is license-free; one big highlight is its self-healing technology–if one node goes down, the network reconfigures itself in which the communication is simply rerouted through another point; also it is a mature home automation protocol that has already been in the

market since 2014 and is promoted by Thread Group which is backed by big players: Google, Amazon, Samsung, Apple, etc. Implementing it can bring in many customers from these partner companies. Thus, ***Thread is well-suited to integrate into Alarm.com's ecosystem.***

4. Strategy

We conducted a market analysis to understand the nature of buyers and suppliers in the market. Dealers, Installers, and Homeowners are some of the key buyers of Alarm.com and they possess moderate control over the market. On the other hand, Thread Group, and Hardware component suppliers are some of the key suppliers and they possess a high control on the market because they possess high control over the components installed in home automation devices and a shortage of these components has a high impact on the price. The threat of substitutes is moderate because Alarm.com has an established market share. Additionally, it's hard to create a significant product differentiation, hence buyers are price sensitive and hence the substitution is moderate. The threat of new entrants is relatively low because of high setup costs and expensive protocol licensing costs.

After thoroughly evaluating the market we propose the following strategy:

Stage 1: Capability Assessment

1. **Cost Analysis**
    - Conduct a thorough cost analysis of implementing threads.
    - Evaluate the potential return on investment (ROI) for adopting Thread.
2. **Internal Evaluation**
    - Assess the current capabilities, strengths, and knowledge gaps within the organization.
3. **Workflow Upskilling**
    - Develop a training program to upskill the existing workforce.
    - Consider hiring new personnel with expertise in Thread technology.

Stage 2: Coordinate with Stakeholders, Implement, and Test

1. **Supply Chain Analysis**
    - Identify potential vendors and evaluate the existing supply chain for the distribution of Thread-based devices.
2. **Coordinate with Vendors**
    - Collaborate with vendors to integrate Thread components into Alarm.com products.

3. **Pilot Project and Launch**
    - Conduct a small-scale pilot project to validate the performance of Thread devices.
    - Gather feedback from users and make necessary improvements.
    - Roll out Thread-enabled products based on the successful pilot.

Stage 3: Marketing and Rollout

1. **Partnerships**
    - Incentivize partners by offering discounts to switch to Thread technology.
2. **Affordable Devices**
    - Introduce cost-effective Thread-based devices and highlight long-term benefits to encourage adoption.

Stage 4: Monitoring and Maintenance

1. **Collaboration with Local Vendors**
    - Partner with local vendors to enhance after-sales services for Thread-enabled devices.
2. **Z-Wave Support**
    - Maintain support for Z-Wave devices to cater to existing customers.
3. **Continuous Improvement**
    - Regularly monitor the performance of Thread-enabled devices.
    - Gather customer feedback and make continuous improvements to both products and services.

5. Economic analysis

To assess the economic value of this transition from Z-wave to Thread, we considered various factors in which Alarm.com has to invest and compared it with the current portfolio:

1. **R&D-** This involves the research and development of Thread protocol, its products and how should the configurations of the current products be changed in order to make it compatible, the various suppliers, the best deal offered and new market expansion etc. As Thread would require additional research work, an extra amount is added to the usual average of Alarm.com.
2. **Marketing-** It includes promotions and advertisements to promote the new products as an upgraded version. It ranges from advertisements and personal recommendations to personal selling with the main focus being on the benefits of Thread. As it is a new product, it would require more investment compared to the usual average.

3. **Software-** It involves the cost of the cloud storage and user interface which remains significantly the same in both the cases.
4. **Hardware-** The cost of various components being used in the home automation devices like microcontrollers, central hub, sensors, actuators and batteries. As the cost of chips for Thread is 10$ and Z-wave is 15$, this transition saves the majority of the hardware costs (~ around $2M), thereby justifying the need of the transition.
5. **Labour**- Apart from the current workers, Alarm.com would require additional Hardware (2), Radio Frequency (1) and Firmware engineers (3) for around 4 months to ensure the change in system and configuration design, integration of the protocol with devices and proper functioning of them. The current worker's salary is assumed to be X with an adder of the additional labor costs.
6. **Licensing & Certifications-** To ensure that the standards are met, Alarm.com would need to get a Thread Certification. Thread being an open source protocol has no licensing fee as such.

The table below shows the comparison of the before and after transition costs with an assumption that Alarm.com gets 10,000 orders per year.

FACTORS / PROTOCOLS	Z-WAVE	THREAD
R&D	$150,000	$200,000
HARDWARE	$9,240,000	$7,290,000
SOFTWARE	$4,200,000	$4,200,000
LABOUR	x	x + $220,000
LICENSING & CERTIFICATIONS	$1,000	$3,000
MARKETING	$75,000	$100,000
TOTAL	$13,666,000	$12,013,000

Table 2. Comparison of Z-wave and Thread costs

The total cost of Z-wave is $13,666,000 and that of Thread is $12,013,000 with a difference of around $1.7M. Therefore, Alarm.com can get profits instantaneously after switching from Z-wave to Thread. While this process seems easier than before, it is still going to be challenging to convince prospects to switch to Thread. We therefore

propose that Alarm.com uses the economic savings from the transition (~ $1.7M) to incentive customers who opt for Thread devices in the following form:

1. **Introductory discount-** For every order of the upgraded version, Alarm.com can provide a discount of around $170.
2. **Enhanced version-** The company can market the new products as an Enhanced version of the old ones focusing mainly on the benefits when compared to the previous ones such as improved security, self - healing etc.

Customers would now get a better version of the products with a discount, thereby convincing them to indirectly switch from Z-wave to Thread.

This transition will overall have the following benefits-

1. **Cost reduction-** Hardware costs, Operating costs, Overall costs by ~ $1.7M
2. **Increased value proposition-** Up-to-date products, Higher compatibility and security, Increased revenue, Reduced price of products

6. Risk assessment and mitigation

The risks and corresponding mitigation strategies involved in seamlessly integrating Threads into the Alarm.com ecosystem have been meticulously outlined. A comprehensive analysis has been undertaken by our team, identifying potential risks such as security vulnerabilities, compatibility issues, data privacy concerns, user acceptance challenges, and regulatory compliance. Corresponding mitigation strategies have been proposed, encompassing rigorous testing, stringent security measures, and user education initiatives. This collective effort ensures a secure and efficient integration of Threads into the alarm.com ecosystem while safeguarding against potential threats.

A comprehensive breakdown of identified risks, categorized based on their probability and potential impact, is provided as part of our assessment for integrating Threads into the alarm.com system. Additionally, each risk is accompanied by a strategic mitigation plan, outlining proactive measures aimed at minimizing both the likelihood and impact of these identified risks.

1. **Risk intensity: High Probability, High Impact**

   One identified risk involves clashes detected between various building elements during the technological integration of Thread. This risk poses a high probability of occurrence and carries a significant impact on the integration process.

   Mitigation Strategy:

   To address this risk, a multi-pronged mitigation approach is being implemented. Firstly, a strategic product redesign is underway to minimize potential conflicts between different building elements within the integration framework. Additionally, automated testing frameworks are being implemented to detect and resolve clashes at an early stage. Furthermore, rigorous code reviews are being conducted to ensure compatibility and streamline the integration process, minimizing the likelihood and impact of clashes during the Thread integration.

2. **Risk intensity: Medium Probability, Medium Impact**

   Another identified risk involves the potential delay in securing certifications for new hardware or software, posing moderate operational and timeline challenges during the integration process.

   Mitigation Strategy:

   To mitigate this risk, proactive measures are being taken. Regulators are engaged early in the certification process to ensure a smoother and more efficient approval timeline. Additionally, documentation processes are being optimized to streamline certification requirements, expediting the approval process. Moreover, robust contingency plans are being established to mitigate any potential setbacks, allowing for flexible adaptations and minimizing the operational and timeline challenges associated with certification delays during the integration of Threads.

3. **Risk intensity: Medium Probability, High Impact**

   There's a moderate likelihood of facing supply chain disruptions while procuring essential semiconductors and hardware components. Such disruptions could lead to significant delays in the integration process and may incur increased costs due to scarcity or price fluctuations of these critical components.

Mitigation Strategies:

Mitigation measures include diversifying our supplier base, and working with multiple vendors for essential components, to mitigate disruptions from a single source. Additionally, implementing a strategy to stockpile critical components in advance aims to create reserves to alleviate the impact of potential shortages. Furthermore, establishing long-term contracts with select suppliers secures a steady and consistent supply of crucial components, reducing the risk of sudden shortages and offering a more predictable procurement process.

4. **Risk intensity: Low Probability, Medium Impact**

There is a low probability of potential delays in the interface launch due to factors influenced by customer requirements or preferences. While the likelihood of occurrence is low, such delays could moderately impact schedules and costs associated with the integration process.

Mitigation Strategies:

To mitigate this risk, clear and achievable milestones are being established in collaboration with customers. These milestones serve as benchmarks to track progress and ensure alignment with agreed-upon timelines, minimizing the likelihood of delays caused by ambiguous or evolving customer needs. Additionally, encouraging early and continuous feedback from customers throughout the integration process allows for addressing concerns or modifications promptly, reducing the potential for delays caused by late-stage revisions or misunderstandings.

7. Recommendations and Conclusions

We created a 10-year comprehensive roadmap to enhance Alarm.com's longevity via Thread integration. Basically, Alarm.com should leverage the existing technology while entering the new market. In the first three years, Alarm.com will start doing research and development to prepare integrating Thread into Alarm.com. Meanwhile, it should also continue servicing Z-wave products to ensure the company's revenue. In the next two years, Alarm.com can update all products to Thread and expand into new markets such as financial institutions, healthcare, IT firms and retail stores with existing solutions. In the next five years, Alarm.com should already be in the new market and constantly doing research and analysis on consumers and the market to come up with new solutions. The company can leverage those solutions to expand into new markets and enable smart agriculture, inventory management, quality control inspection etc. In the end, Alarm.com will be completed with Thread integration and mature in the home automation market. It can consider whether or not to integrate WI-SUN for enterprise solutions to expand the business.

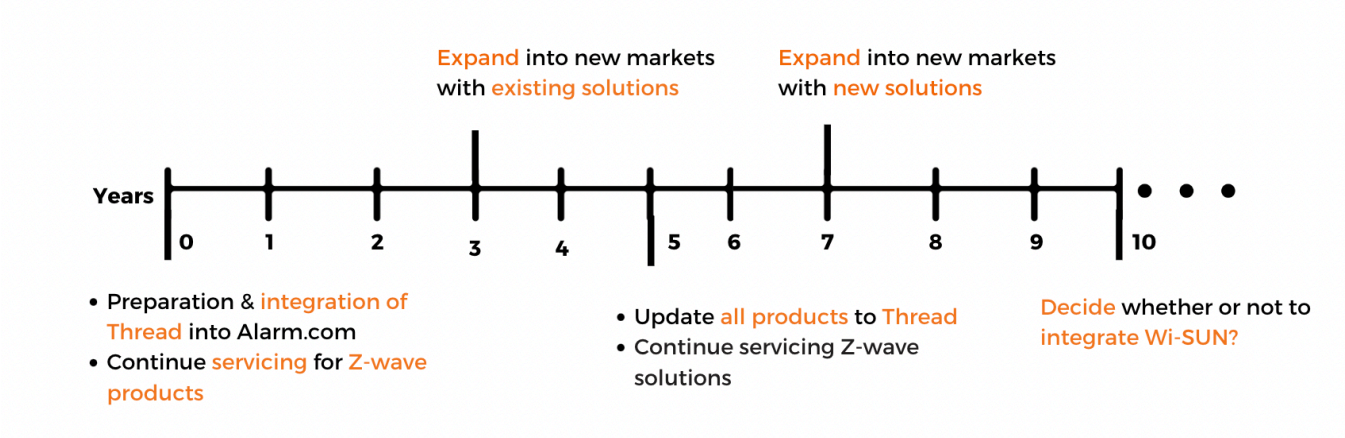

Fig 4. 10 Yr Strategy for Alarm.com

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- https://www.youtube.com/watch?v=pwi1fEUFn7M
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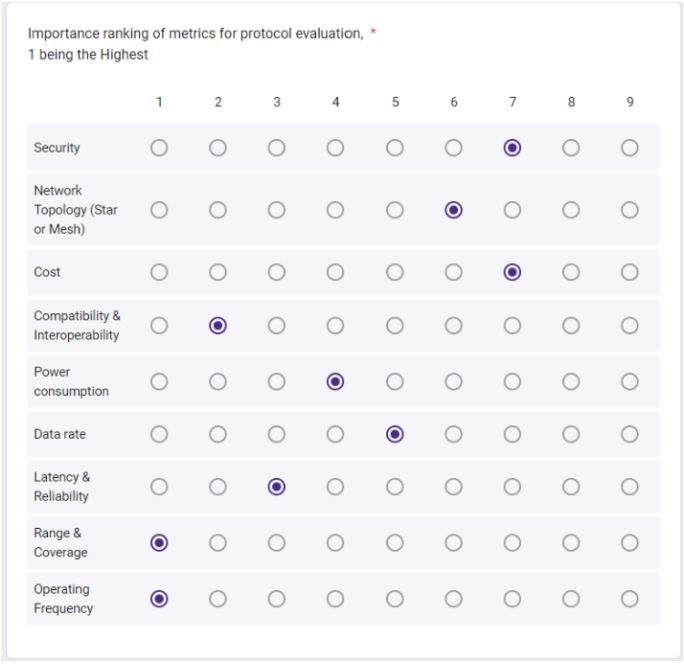
Appendix:

Clients priority of Decision Criteria:



Importance ranking of metrics for protocol evaluation, *
1 being the Highest

	1	2	3	4	5	6	7	8	9
Security	○	○	○	○	○	○	◉	○	○
Network Topology (Star or Mesh)	○	○	○	○	○	◉	○	○	○
Cost	○	○	○	○	○	○	◉	○	○
Compatibility & Interoperability	○	◉	○	○	○	○	○	○	○
Power consumption	○	○	○	◉	○	○	○	○	○
Data rate	○	○	○	○	◉	○	○	○	○
Latency & Reliability	○	○	◉	○	○	○	○	○	○
Range & Coverage	◉	○	○	○	○	○	○	○	○
Operating Frequency	◉	○	○	○	○	○	○	○	○

Wi-Sun in Detail :

Incorporated as Not for profit organization - Delaware, US, 2012

Field area network (FAN) & Home area network (HAN)

Properties-

- Open standards based mesh network - useful for home automation as interconnected nodes allow entire smart home to be integrated with a central controller
- Running on Sub GHz - useful for long range and low power communications (< wifi, bluetooth which functiion on 2.4GHz)
- Based on IEEE 802.15.4g
- Based on IPV6 protocol
- Robust & Self-healing networks
- Uses frequency hopping to increase robustness
- Designed for large scale networks up to 1000 nodes
- Line powered + border routers -> gateways to other layers of networks
- Ensures scalability, interoperability

Usage-

- Large scale network, ranging up to KMs.
- Mainly for smart city network- smart lighting, metering & EV charging
- In Home automation-
    - Smart lighting- Dimming, scheduling, occupancy sensing
    - Smart metering- Monitor to reduce cost and increase energy efficiency
    - Smart thermostats- Control temperature
    - Home security- Cameras, motion detectors, door/window sensors- ensures security over a long range
    - Smart water management- Controls leaks, irrigation system and water usage
    - Environmental monitoring- Temperature, humidity and air quality outside home
    - Smart appliances- Connect washing machine, ovens and refrigerator
    - Asset tracking tag- Helps track keys or wallets

Disadvantage of Wi-SUN for home automation

-
    - Complex setup- Not user friendly for average consumers
    - Limited device compatibility- Compared to Zigbee and Zwave
    - Interference- Can work with wifi, but intereference from devices with sub GHz can affect performance
    - Security- Requires appropriate encryption and authentication

- Cost- Can be expensive compared to other protocols, not suitable is home owner is not very rich
- Limited data throughput- Due to focus on long range communications and power efficiency, no high speed data transmission

Wi-SUN and home automation

Linkedin

- The Wi-SUN Alliance is a global non-profit member-based association made up of industry leading companies. Its mission is to drive the global proliferation of interoperable wireless solutions for use in smart cities, smart grids and other Internet of Things (IoT) applications using open global standards from organizations, such as IEEE802, IETF, TIA, TTC and ETSI. With more than 180 members worldwide, membership of the Wi-SUN Alliance is open to all industry stakeholders and includes silicon vendors, product vendors, services providers, utilities, universities, enterprises and municipalities and local government organizations. For more information, please visit: www.wi-sun.org.
- Wi-SUN NICs play a crucial role in enabling reliable and secure communication for smart meters. The technology provides advantages such as open standards based, self-healing mesh capabilities, and interoperability for large-scale outdoor IoT networks.
- In a new blog President and CEO Phil Beecher for Wi-SUN Alliance talks with Abhijit Grewal, Senior Marketing Director Smart Cities at Silicon Labs, about the company's work with the International Institute of Information Technology in Hyderabad, India and the role of Wi-SUN mesh technology in supporting its Smart City Living Lab project.

SINBON

The Wi-SUN technology is applicable to the 2 following areas:

Field Area Network (FAN):

An indispensable technology in smart cities. Common application scenes include smart factories, smart street lights, smart buildings, and so on, to connect public infrastructures and achieve interoperability.

Home Area Network (HAN):

Through the home energy management systems (HEMS) controllers, users can link the smart meters with smart appliances (such as a Roomba or an air conditioner, etc.). Besides monitoring their live power consumption, users can also integrate smart households into the smart city by connecting the smart meter and FAN-based smart city applications.

Wi-SUN eBook

https://wi-sun.org/wp-content/uploads/Wi-SUN-eBook-Smart-City-and-IoT-r21.pdf

Where do you see Wi-SUN FAN applications in the next five years?

Wi-SUN's goal is to support Smart utilities, Smart cities, Smart home, and M2M. Even though there is already a lot of activity in all four of these areas, we are still only at the very early stages of the growth curve. Historically the technologies used to service these use cases have been very fragmented. We think Wi-SUN will be the one of the technologies that brings all these applications together. These applications all need network infrastructure that provides reliable, secure communications at scale – and Wi-SUN can provide all of that.

What new application opportunities do you see for Wi-SUN technology?

There are opportunities for Wi-SUN HAN network solutions to integrate with Bluetooth Low Energy (BLE) and offer more versatility for smart home applications than is possible with Wi-Fi and Zigbee. We have begun preliminary research and development on products that would employ a new version of Wi-SUN technology as the LPWANs and related sensors used in water and gas metering.

Why is Wi-SUN not being preferred for home automation ?

- Wi-SUN is designed for large-scale deployments with a focus on utility companies and industrial applications. For most home automation scenarios, simpler and more cost-effective wireless protocols like Wi-Fi, Zigbee, Z-Wave, or Bluetooth are sufficient.
- Complexity: Wi-SUN is a complex and highly secure protocol, which may be unnecessary for most home automation systems. Simplicity and ease of use are often preferred in consumer applications.
- Power Consumption: Home automation devices often require low power consumption to maximize battery life, especially for battery-operated devices like sensors. Other wireless standards like Zigbee and Z-Wave are optimized for low power usage, while Wi-SUN may be less efficient in this regard.

Interoperability: In the context of home automation, there's a significant focus on interoperability between different devices and ecosystems. Wi-SUN may not have the same level of compatibility and interoperability as more established home automation standards.

Financial Analysis Calculation

Labour costs-

Labour costs	Duration(months)	Amount	Salary/year	Salary for project
Hardware engineers	4	2	98574	65716
Firmware engineers	4	3	117451	117451
Radio frequency engineers	4	1	98574	32858
			Total	216025

Software costs-

	Data usage/month in GB	Data usage/year in GB	Quantity/house	Cost of data storage in cloud ($)
Security camera	60	720	7	292.32
Thermostat	0.05	0.6	2	0.0696
Doorbell	175	2100	1	121.8
Smart plugs	0.05	0.6	15	0.522
Smart bulbs	0.05	0.6	20	0.696
				415.4076
			Total cost of storage	$420
			Total cost for 10,000 orders	4200000

Cost of data per GB = $0.058

No. of microcontrollers-

	No. of microcontrollers
Sensors - Door & Windows	8
Smart bulbs and switches	20
Smart thermostats	1
Smart hubs	3
Security cameras	7
	39

Hardware costs-

	Z-wave	Thread	
	unit cost	*unit cost*	*Quantity*
Microcontroller	15$	10$	39
Batteries	$4	$4	6
Actuators	$315	$315	1

	Z-wave	Thread
Microcontroller	$585	$390
Batteries	$24	$24
Actuators	$315	$315
Total cost	$924	$729
Total cost for 10,000 orders per yr	$9,240,000	$7,290,000

Exhaustive list of hardwares-

	Z-wave	Thread
Hardware	unit cost	unit cost
Microcontroller	15$	10$
Sensors		
Motion Sensors	$35	$35
Door/Window Contact Sensors	$35	$35
Temperature Sensors	$20	$20
Light Sensors	$20	$20
Smoke and Carbon Monoxide Detectors	$50	$50
Actuators		
Servo Motors	$20	$20
Electric Linear Actuators	$200	$200
Solenoid Actuators	$30	$30
Motorized Valves	$20	$20
Stepper Motors	$25	$25
Relays	$20	$20
Batteries		
Alkaline Batteries	$0.50-$2	$0.50-$2
Lithium Batteries	$1-$5	$1-$5
Rechargeable Batteries	$2-$10	$2-$10
Coin Cell Batteries	$1-$3	$1-$3
Button Cell Batteries	$1-$3	$1-$3

R&D and Marketing-

Departments					Average cost	Additional cost for Thread	Total cost
Sales and marketing	23,861	23,057	74,278	69,182	47,595	50,000	~100,000
Research and development	61,014	55,581	183,840	161,227	115,416	80,000	~200,000

Discount calculation-

Z-wave total cost	$13,666,000
Thread total cost	$12,013,000
Switching profits	$1,653,000
Reduction in additional initial projects labour	$220,000
Discount	$1,873,000
Discount for each order	$187