
The Matter Protocol as a Solution to Ecosystem Fragmentation in Smart Home Environments: Architecture, Capabilities, and Implementation Challenges

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Abstract:

Purpose: This study examines the development of the Matter standard as a response to interoperability challenges in the smart home market. It focuses on the extent to which Matter can overcome the fragmentation associated with proprietary ecosystems and heterogeneous communication protocols, while identifying the technical limitations that may constrain its wider adoption.

Design/Methodology/Approach: The study employs a qualitative analytical approach based on an examination of the Matter architecture, its communication and commissioning mechanisms, and its interoperability features. Particular attention is given to the application layer, network technologies, local communication, Multi-Admin functionality, and the technical requirements associated with device commissioning and certification.

Findings: The analysis indicates that Matter provides a unified application layer operating over IPv6 and supporting Wi-Fi, Ethernet, and Thread, thereby creating a common framework for communication between devices from different manufacturers. Its local-network architecture reduces dependence on mandatory cloud intermediation, while the Multi-Admin feature enables devices to operate across multiple smart home platforms. However, implementation constraints remain, particularly the computational requirements associated with certificate-based commissioning over Bluetooth Low Energy and continued fragmentation arising from differences in platform orchestration logic.

Practical Implications: The findings highlight the need for manufacturers and platform providers to consider the computational capabilities of low-cost devices when implementing Matter. Further optimisation of cryptographic processes, broader interoperability at the platform level, and greater convergence of certification requirements could facilitate adoption and reduce implementation costs. These developments may contribute to a more open and flexible smart home market.

Originality/Value: The study contributes to the discussion on smart home interoperability by examining Matter not only as a technical standard but also in terms of the practical constraints affecting its implementation. It demonstrates that the introduction of a common application layer can reduce traditional forms of ecosystem fragmentation while simultaneously creating new challenges related to device resources, platform orchestration, and certification.

Keywords: Matter, smart home, interoperability, Internet of Things, IoT, smart home ecosystems, IPv6, thread, multi-admin, cloud computing.

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1. Introduction

The building automation market has evolved into a collection of closed ecosystems, commonly referred to as walled gardens. Purchasing a device forced consumers into complete brand loyalty, with integration heavily dependent on external cloud servers and proprietary voice assistants. Regaining local control over hardware often required physical intervention, such as the necessity of overwriting firmware with unofficial versions in popular communication modules².

Incompatibility equally burdened hardware manufacturers, as open IEEE 802.15.4 standards competed with proprietary protocols like Z-Wave³. These proprietary systems imposed strict certification requirements that directly increased the market price of devices⁴. Developing universal sensors required funding parallel validation processes, and attempts to mitigate this through multi-mode hardware gateways only forced the installation of additional hubs⁵.

Ultimately, smart home development was hindered by the lack of a unified language rather than physical hardware limitations.

In response to this implementation paralysis, market rivals within the Connectivity Standards Alliance released the Matter standard specification in late 2022. Matter's core architectural premise is that it acts as a universal application layer operating natively over the classic internet stack, rather than defining a new radio interface. Utilizing IPv6 as the communication foundation alongside proven transport networks Ethernet, Wi-Fi, and the low-power Thread protocol, this approach significantly lowers entry barriers and hardware introduction costs⁶.

²Khan, M.A., Ahmad, I., Nordin, A.N., Ahmed, A.E., Mewada, H., Daradkeh, Y.I., Rasheed, S., Eldin, E.T., & Shafiq, M. (2022). *Smart Android Based Home Automation System Using Internet of Things (IoT). Sustainability*, 14(17), p. 5.

³Orfanos, V.A., Kaminaris, S.D., Papageorgas, P., Piromalis, D., & Kandris, D. (2023). *A Comprehensive Review of IoT Networking Technologies for Smart Home Automation Applications. Journal of Sensor and Actuator Networks*, 12(2), p. 6.

⁴*Ibid.*, p. 6.

⁵*Ibid.*, p. 24-25.

⁶Madadi-Barough, S., Ruiz-Blanco, P., Lin, J., Vidal, R., & Gomez, C. (2024). *Matter: IoT Interoperability for Smart Homes. arXiv preprint arXiv:2405.01618*, p. 1, 6.

This article systematizes knowledge of Matter's architecture and critically evaluates its actual degree of application layer unification. Subsequent sections analyze the communication stack, unified data model, cryptographic security, and comparative capabilities against earlier smart home systems.

2. Technical Architecture and Security Model

Matter eliminates translating gateways by assigning globally routable IPv6 addresses to every smart home device, allowing direct communication across diverse hardware. Older protocols like Zigbee, Z-Wave, and Bluetooth Mesh lack IPv6 support and rely on distinct routing mechanisms.

Consequently, integrating distinct ecosystems previously required complex semantic conversion and dedicated software to map commands between stacks. By unifying the network layer, common IPv6 addressing guarantees end-to-end reachability regardless of the underlying radio technology ⁷.

Since the network layer is unified, Matter pragmatically offers both classic internet protocols for data transport. Most operational traffic uses lightweight UDP, supplemented by the Message Reliability Protocol for assured delivery without the overhead of full connection establishment. TCP remains an option for restricted network paths or when transmitting larger data blocks is required.

This dual approach adapts to both simple sensors and video streaming cameras. Importantly, the entire mechanism operates on devices with merely 128 kB of RAM and 1 MB of Flash memory, proving the standard's lightness and enabling deployments in the simplest market sensors ⁸.

Below the network layer, Matter defines three access technologies. Wi-Fi and Ethernet support devices with unlimited power supplies requiring high bandwidth and low latency. Thread occupies the opposite spectrum as a 250 kbit/s IEEE 802.15.4 mesh network designed for battery-powered sensors and thermostats⁹. To handle smaller radio frames, Thread implements the 6LoWPAN adaptation layer for packet fragmentation and header compression¹⁰. A Thread mesh utilizes mains-powered routers, allowing energy-efficient devices to remain asleep and poll for packets periodically. If polled less than once every five minutes, a node's battery life

⁷*Ibid.*, p. 6.

⁸*Ibid.*, p. 2.

⁹Algrøy, J. (2020). *Latency in Mesh Networks*. University of Bergen, Department of Informatics, p. 3.

¹⁰Vandervelden, T., Deac, D., Van Glabbeek, R., De Smet, R., Braeken, A., & Steenhaut, K. (2024). *Evaluation of 6LoWPAN Generic Header Compression in the Context of a RPL Network*. *Sensors*, 24(1), p. 1-2, 5.

can reach up to a decade¹¹. Thread border routers bridge this low-power subnetwork to the central Wi-Fi or Ethernet IPv6 network.

Additionally, the classic Bluetooth Low Energy protocol, designed for single-hop star topologies is excluded from carrying primary application traffic¹². Instead, it serves exclusively as a secure channel for commissioning new nodes¹³. This strict division of roles allows each technology to focus on its strengths.

A unified network layer requires a common language, a role fulfilled by Matter's Data Model. Every physical device acts as a node containing endpoints for specific services. These endpoints organize functionality into client-server clusters that exchange attributes, events, and commands based on the ZigBee Cluster Library, ensuring optimal message sizes for Thread networks. Operating above this is the Interaction Model, defining four exchange types: reading attributes, writing, invoking commands, and subscribing¹⁴. Subscriptions are crucial as they allow state monitoring without continuous polling, minimizing mesh network traffic.

Consequently, a manufacturer deploying a new thermostat simply implements the appropriate cluster. Any Matter-compliant controller can then read the state and issue commands without custom communication protocols or additional integration. Security in Matter is integral to every transmission. Application data exchanges are protected by cryptographic sessions established via the CASE protocol for mutual authentication and symmetric key agreement.

Encryption and integrity checks rely on AES-CCM with a 16-byte key and a 16-byte message integrity check field. This is a deliberate departure from older protocols like Bluetooth Low Energy, which limited the MIC to just 4 bytes¹⁵. Prioritizing robust security akin to internet TLS over transmission overhead, Matter intentionally imposes a heavier burden on constrained devices. Trust relies on a public key infrastructure where every device carries a factory-provisioned authenticity certificate. During commissioning, a verified device receives a 64-bit identifier and an operational certificate binding its keys to the local trust domain¹⁶. This

¹¹Madadi-Barough, S., Ruiz-Blanco, P., Lin, J., Vidal, R., & Gomez, C. (2024). *Matter: IoT Interoperability for Smart Homes*. *arXiv preprint arXiv:2405.01618*, p. 4, 6.

¹²Gomez, C., Oller, J., & Paradells, J. (2012). *Overview and Evaluation of Bluetooth Low Energy: An Emerging Low-Power Wireless Technology*. *Sensors*, 12(9), p. 11735, 11737.

¹³Madadi-Barough, S., Ruiz-Blanco, P., Lin, J., Vidal, R., & Gomez, C. (2024). *Matter: IoT Interoperability for Smart Homes*. *arXiv preprint arXiv:2405.01618*, p. 2.

¹⁴*Ibid.*, p. 3.

¹⁵Gomez, C., Oller, J., & Paradells, J. (2012). *Overview and Evaluation of Bluetooth Low Energy: An Emerging Low-Power Wireless Technology*. *Sensors*, 12(9), p. 11739.

¹⁶Madadi-Barough, S., Ruiz-Blanco, P., Lin, J., Vidal, R., & Gomez, C. (2024). *Matter: IoT Interoperability for Smart Homes*. *arXiv preprint arXiv:2405.01618*, p. 1-2.

asymmetric cryptography uses the secp256r1 elliptic curve¹⁷. While the resulting energy load can be critical for battery-powered sensors, using dedicated hardware secure elements reduces the session agreement energy expenditure in Thread networks by over 60%, measurably extending the node's maintenance-free operation time¹⁸.

3. Interoperability, Local Control, and Comparative Analysis

Older smart home systems required mandatory cloud intermediation, generating dependence on internet connectivity and manufacturer policies. In Matter, device communication occurs natively over the local IPv6 network, with the cloud serving merely as an optional remote access channel. This relies on the fabric concept, a security domain where nodes share a common root of trust.

Through the Multi Admin function, a device can simultaneously belong to multiple fabrics, handling commands from platforms like Apple Home and Google Home in parallel without external server communication. This reverses the walled garden paradigm, allowing a physical device to accept commands from different platforms equally based on operational certificates¹⁹. Consequently, the market entry barrier is lowered as a single device no longer requires separate platform integrations.

To provide a migration path for millions of installed Zigbee and Z-Wave devices, Matter introduces a bridge element that translates older protocols into the unified Data Model. This ensures legacy devices participate in the network as fully fledged endpoints without requiring software modifications, replacing earlier market attempts to mitigate fragmentation through multi-mode hardware gateways²⁰.

For native Thread and Wi-Fi networks, a border router fulfills the integration role by connecting the low-power IEEE 802.15.4 mesh to the central home IPv6 subnetwork²¹.

These architectural benefits are backed by measurable performance. In Thread networks, device response times range from 60 to 170 ms, with delays primarily stemming from processor overhead rather than the 6 ms maximum radio transmission. In energy-saving modes, sleeping devices experience forwarding

¹⁷Nosedá, M., Zimmerli, L., Schl  pfer, T., & R  st, A. (2022). *Performance Analysis of Secure Elements for IoT*. *IoT*, 3(1), p. 4.

¹⁸*Ibid.*, p. 3, 16.

¹⁹Madadi-Barough, S., Ruiz-Blanco, P., Lin, J., Vidal, R., & Gomez, C. (2024). *Matter: IoT Interoperability for Smart Homes*. *arXiv preprint arXiv:2405.01618*, p. 1-2.

²⁰Orfanos, V.A., Kaminaris, S.D., Papageorgas, P., Piromalis, D., & Kandris, D. (2023). *A Comprehensive Review of IoT Networking Technologies for Smart Home Automation Applications*. *Journal of Sensor and Actuator Networks*, 12(2), p. 25.

²¹Madadi-Barough, S., Ruiz-Blanco, P., Lin, J., Vidal, R., & Gomez, C. (2024). *Matter: IoT Interoperability for Smart Homes*. *arXiv preprint arXiv:2405.01618*, p. 2.

delays up to their 200 ms polling interval, while Matter over Wi-Fi delays distribute evenly up to the 100 ms beacon interval²².

For comparison, Zigbee technology exhibits typical latency of 0.1 to 0.2 seconds depending on the topology²³. Enabling 128-bit AES encryption and multi-hop topologies in Zigbee drastically exacerbates these delays, increasing time overhead by hundreds of percent compared to direct, unencrypted transmission²⁴.

Cloud-based systems present an entirely different scale of latency, with REST and MQTT interfaces generating typical round-trip delays between 1 and 3 seconds²⁵. The high variance in server data transmission clearly indicates significant cloud-side processing overhead, which only drops below 250 ms when directly communicating with the MQTT broker while bypassing analytical layers²⁶. These results confirm the validity of Matter prioritizing local processing without mandatory cloud intermediation. The table below summarizes the key parameters of the three smart home communication paradigms.

Table 1. Comparison of key parameters of Smart Home systems

Criterion	Matter	Zigbee	Cloud Systems
Cloud dependency	None. Local IPv6 communication ²⁷	None. Local communication ²⁸	Full. Commands pass through the server ²⁹
Network topology	Star or mesh with a border router	Star, mesh, or tree ³⁰	Star with a hub to the cloud ³¹

²²*Ibid.*, p. 5.

²³Sojoyo, S., & Ashari, A. (2017). Analysis of Zigbee Data Transmission on Wireless Sensor Network Topology. *International Journal of Advanced Computer Science and Applications*, 8(9), p. 150-151.

²⁴Haque, K.F., Abdelgawad, A., & Yelamarthi, K. (2022). Comprehensive Performance Analysis of Zigbee Communication: An Experimental Approach with XBee S2C Module. *Sensors*, 22(9), p. 18.

²⁵Viegas, V., Dias Pereira, J.M., Girão, P., & Postolache, O. (2021). Study of latencies in ThingSpeak. *Advances in Science, Technology and Engineering Systems Journal*, 6(1), p. 342, 345-346.

²⁶*Ibid.*, p. 346.

²⁷Madadi-Barough, S., Ruiz-Blanco, P., Lin, J., Vidal, R., & Gomez, C. (2024). Matter: IoT Interoperability for Smart Homes. *arXiv preprint arXiv:2405.01618*.

²⁸Sojoyo, S., & Ashari, A. (2017). Analysis of Zigbee Data Transmission on Wireless Sensor Network Topology. *International Journal of Advanced Computer Science and Applications*, 8(9).

²⁹Viegas, V., Dias Pereira, J.M., Girão, P., & Postolache, O. (2021). Study of latencies in ThingSpeak. *Advances in Science, Technology and Engineering Systems Journal*, 6(1).

³⁰Sojoyo, S., & Ashari, A. (2017). Analysis of Zigbee Data Transmission on Wireless Sensor Network Topology. *International Journal of Advanced Computer Science and Applications*, 8(9).

Typical latency	60 to 170 ms in Thread, up to 100 ms in WiFi	100 to 200 ms depending on topology ³²	1 to 3 s via cloud API ³³
Encryption	AES CCM 128 bit with 16 byte MIC field	AES 128 with 4 byte MIC field ³⁴	TLS with cipher suites dependent on the broker ³⁵
Interoperability	Native via IPv6 and a common Data Model	Limited to Zigbee devices or a bridge ³⁶	Dependent on manufacturer integration with the platform ³⁷
Multi platform support	Multi Admin allows connecting multiple ecosystems	Requires separate gateways per ecosystem ³⁸	Requires an account in every service ³⁹

Source: Own study.

Beyond latency reduction, Matter's most critical benefit is hardware independence from external servers. Traditional smart home systems become useless during internet outages or cloud shutdowns. By forcing local IPv6 communication, Matter completely eliminates this central point of failure. Furthermore, the Multi Admin mechanism allows simultaneous control by multiple platforms strictly within the

³¹Khan, M.A., Ahmad, I., Nordin, A.N., Ahmed, A.E., Mewada, H., Daradkeh, Y.I., Rasheed, S., Eldin, E.T., & Shafiq, M. (2022). *Smart Android Based Home Automation System Using Internet of Things (IoT). Sustainability*, 14(17).

³²Sojoyo, S., & Ashari, A. (2017). *Analysis of Zigbee Data Transmission on Wireless Sensor Network Topology. International Journal of Advanced Computer Science and Applications*, 8(9).

³³Viegas, V., Dias Pereira, J.M., Girão, P., & Postolache, O. (2021). *Study of latencies in ThingSpeak. Advances in Science, Technology and Engineering Systems Journal*, 6(1).

³⁴Haque, K.F., Abdelgawad, A., & Yelamarthi, K. (2022). *Comprehensive Performance Analysis of Zigbee Communication: An Experimental Approach with XBee S2C Module. Sensors*, 22(9); Madadi-Barough, S., Ruiz-Blanco, P., Lin, J., Vidal, R., & Gomez, C. (2024). *Matter: IoT Interoperability for Smart Homes. arXiv preprint arXiv:2405.01618*, p. 6.

³⁵Gentile, A.F., Macrì, D., Carnì, D.L., Greco, E., & Lamonaca, F. (2024). *A Performance Analysis of Security Protocols for Distributed Measurement Systems Based on Internet of Things with Constrained Hardware and Open Source Infrastructures. Sensors*, 24(9).

³⁶Orfanos, V.A., Kaminaris, S.D., Papageorgas, P., Piromalis, D., & Kandris, D. (2023). *A Comprehensive Review of IoT Networking Technologies for Smart Home Automation Applications. Journal of Sensor and Actuator Networks*, 12(2).

³⁷Khan, M.A., Ahmad, I., Nordin, A.N., Ahmed, A.E., Mewada, H., Daradkeh, Y.I., Rasheed, S., Eldin, E.T., & Shafiq, M. (2022). *Smart Android Based Home Automation System Using Internet of Things (IoT). Sustainability*, 14(17).

³⁸Orfanos, V.A., Kaminaris, S.D., Papageorgas, P., Piromalis, D., & Kandris, D. (2023). *A Comprehensive Review of IoT Networking Technologies for Smart Home Automation Applications. Journal of Sensor and Actuator Networks*, 12(2).

³⁹Khan, M.A., Ahmad, I., Nordin, A.N., Ahmed, A.E., Mewada, H., Daradkeh, Y.I., Rasheed, S., Eldin, E.T., & Shafiq, M. (2022). *Smart Android Based Home Automation System Using Internet of Things (IoT). Sustainability*, 14(17).

local network. This solves the issue of forced brand loyalty, ensuring purchased devices remain fully operational regardless of future manufacturer business decisions.

4. Implementation Challenges and Standard Limitations

The Matter Data Model stems from the ZigBee Cluster Library, whose lightweight architecture suits simple actuators but struggles with complex hardware. While a basic lightbulb requires only a few attributes, certifying complex devices like autonomous vacuum cleaners reveals uneven functional coverage across clusters.

Consequently, advanced hardware manufacturers must choose between waiting for specification updates or implementing custom, non-compliant control logic. The Matter roadmap explicitly anticipates the need to simplify application layer formats and operations⁴⁰. The current design ultimately imposes a complexity that realistically slows the adoption of advanced product categories.

Integrating millions of older devices introduces backward compatibility challenges via bridge translation. This semantic translation is rarely lossless, as attribute granularity discrepancies often strip specific source device functions. Furthermore, bridging exposes drastic differences in cryptographic architecture. Older stacks like Zigbee and Z-Wave utilize 4-byte and 8-byte message integrity check fields, whereas Matter imposes a much heavier 16-byte requirement⁴¹.

Similar overhead savings were used in early Bluetooth Low Energy systems⁴². Reconciling these incompatible protection levels incurs continuous software maintenance costs for manufacturers, leaving users with basic control rather than full capabilities and only partially fulfilling the promise of protecting previous hardware investments.

Commissioning introduces a third layer of complexity. Matter utilizes Bluetooth Low Energy solely for initial credential exchange, followed by the CASE protocol establishing an encrypted session via asymmetric key exchange⁴³. These stringent requirements push cheap microcontrollers to their limits, as complex TLS session negotiation can take over two seconds on typical IoT chips⁴⁴. While dedicated hardware secure elements reduce energy consumption, they incur additional material

⁴⁰Madadi-Barough, S., Ruiz-Blanco, P., Lin, J., Vidal, R., & Gomez, C. (2024). Matter: IoT Interoperability for Smart Homes. *arXiv preprint arXiv:2405.01618*, p. 7.

⁴¹*Ibid.*, p. 6.

⁴²Gomez, C., Oller, J., & Paradells, J. (2012). Overview and Evaluation of Bluetooth Low Energy: An Emerging Low-Power Wireless Technology. *Sensors*, 12(9), p. 11739.

⁴³Madadi-Barough, S., Ruiz-Blanco, P., Lin, J., Vidal, R., & Gomez, C. (2024). Matter: IoT Interoperability for Smart Homes. *arXiv preprint arXiv:2405.01618*, p. 1-3.

⁴⁴Salles, R., & Farias, R. (2023). TLS Protocol Analysis Using IoTST—An IoT Benchmark Based on Scheduler Traces. *Sensors*, 23(5), p. 13-14.

and design costs⁴⁵. Moreover, these cryptographic delays compound BLE link layer limitations during service discovery, which heavily depends on smartphone operating systems.

For instance, Android prevents explicit BLE connection interval definitions, restricting transmission predictability⁴⁶. Consequently, slow sensor-side cryptographic negotiations often collide with aggressive mobile OS timeouts, causing the exact same device to pair smoothly in one environment but fail in another.

These technical barriers are magnified by business challenges, as effective interoperability requires continuous specification refinement, adherence to security standards, and environment scalability⁴⁷. Major platforms interpret the specification through the lens of their proprietary ecosystems.

While the protocol layer remains common, the vendor-specific orchestration of commissioning and hardware sharing leads to paradoxes where fully compliant sensors work seamlessly in one ecosystem but fail in a competing one. Ultimately, Matter flattens integration costs almost exclusively for new certified devices, while divergent platform policies and the older hardware base sustain fragmentation under a new name.

5. Summary and Development Perspectives

The Matter standard marks a turning point in building automation by proving that a unified application layer operating directly on IPv6 can replace closed proprietary platforms. This architecture eliminates the need for hardware translators and external cloud servers.

However, the promise of completely seamless interoperability remains only partially realized as network layer unification collides with business realities. Major platform manufacturers maintain divergent certification policies and distinct commissioning logic. Furthermore, the slow expansion of the unified Data Model for complex devices means full market harmonization will require subsequent specification iterations and close competitor cooperation.

From a long-term perspective, Matter's greatest value lies in transforming the control paradigm from walled gardens toward local edge computing. Shifting the computational burden away from centralized cloud servers drastically lowers

⁴⁵Nosedá, M., Zimmerli, L., Schl  pfer, T., & R  st, A. (2022). *Performance Analysis of Secure Elements for IoT*. *IoT*, 3(1), p. 1, 20.

⁴⁶T'Jonck, K., Pang, B., Hallez, H., & Boydens, J. (2021). *Optimizing the Bluetooth Low Energy Service Discovery Process*. *Sensors*, 21(11), p. 15.

⁴⁷Magara, T., & Zhou, Y. (2024). *Internet of Things (IoT) of Smart Homes: Privacy and Security*. *Journal of Electrical and Computer Engineering*, 2024, p. 12.

latency, increases responsiveness, and provides a much higher level of end-user privacy⁴⁸.

Nevertheless, the standard's future trajectory must address critical research challenges. The most urgent needs are optimizing cryptographic overhead for cheap chips and resolving protocol instability during the BLE service discovery phase⁴⁹.

Concurrently, this architecture requires fortification against quantum computers, as the ability of IoT devices to migrate to post-quantum cryptography will directly determine home network security in the coming decade⁵⁰. Ultimately, while Matter does not solve all integration problems, it provides a scalable foundation that successfully orders the communication layer and sets the primary IoT development vector for the coming years.

References:

- Algrøy, J. 2020. Latency in Mesh Networks. University of Bergen, Department of Informatics.
- Gentile, A.F., Macrì, D., Carnì, D.L., Greco, E., Lamonaca, F. 2024. A Performance Analysis of Security Protocols for Distributed Measurement Systems Based on Internet of Things with Constrained Hardware and Open Source Infrastructures. *Sensors*, 24(9), p. 2781.
- Gomez, C., Oller, J., Paradells, J. 2012. Overview and Evaluation of Bluetooth Low Energy: An Emerging Low-Power Wireless Technology. *Sensors*, 12(9), p. 11734-11753.
- Haque, K.F., Abdelgawad, A., Yelamarthi, K. 2022. Comprehensive Performance Analysis of Zigbee Communication: An Experimental Approach with XBee S2C Module. *Sensors*, 22(9), p. 3245.
- Khan, M.A., Ahmad, I., Nordin, A.N., Ahmed, A.E., Mewada, H., Daradkeh, Y.I., Rasheed, S., Eldin, E.T., Shafiq, M. 2022. Smart Android Based Home Automation System Using Internet of Things (IoT). *Sustainability*, 14(17), p. 10717.
- Madadi-Barough, S., Ruiz-Blanco, P., Lin, J., Vidal, R., Gomez, C. 2024. Matter: IoT Interoperability for Smart Homes. *arXiv preprint arXiv:2405.01618*.
- Magara, T., Zhou, Y. 2024. Internet of Things (IoT) of Smart Homes: Privacy and Security. *Journal of Electrical and Computer Engineering*, p. 1-17.
- Noseda, M., Zimmerli, L., Schläpfer, T., Rüst, A. 2022. Performance Analysis of Secure Elements for IoT. *IoT*, 3(1), p. 1-28.
- Orfanos, V.A., Kaminaris, S.D., Papageorgas, P., Piromalis, D., Kandris, D. 2023. A Comprehensive Review of IoT Networking Technologies for Smart Home Automation Applications. *Journal of Sensor and Actuator Networks*, 12(2), p. 30.
- Salles, R., Farias, R. 2023. TLS Protocol Analysis Using IoTST - An IoT Benchmark Based on Scheduler Traces. *Sensors*, 23(5), p. 2538.

⁴⁸*Ibid.*, p. 13.

⁴⁹T'Jonck, K., Pang, B., Hallez, H., & Boydens, J. (2021). *Optimizing the Bluetooth Low Energy Service Discovery Process*. *Sensors*, 21(11), p. 1-2, 20.

⁵⁰Schöffel, M., Lauer, F., Rheinländer, C.C., & Wehn, N. (2022). *Secure IoT in the Era of Quantum Computers—Where Are the Bottlenecks?* *Sensors*, 22(7), p. 1-2, 5.

- Schöffel, M., Lauer, F., Rheinländer, C.C., Wehn, N. 2022. Secure IoT in the Era of Quantum Computers - Where Are the Bottlenecks? *Sensors*, 22(7), p. 2484.
- Soijoyo, S., Ashari, A. 2017. Analysis of Zigbee Data Transmission on Wireless Sensor Network Topology. *International Journal of Advanced Computer Science and Applications*, 8(9), p. 145-151.
- T'Jonck, K., Pang, B., Hallez, H., Boydens, J. 2021. Optimizing the Bluetooth Low Energy Service Discovery Process. *Sensors*, 21(11), p. 3812.
- Vandervelden, T., Deac, D., Van Glabbeek, R., De Smet, R., Braeken, A., Steenhaut, K. 2024. Evaluation of 6LoWPAN Generic Header Compression in the Context of a RPL Network. *Sensors*, 24(1), p. 73.
- Viegas, V., Dias Pereira, J.M., Girão, P., Postolache, O. 2021. Study of latencies in ThingSpeak. *Advances in Science, Technology and Engineering Systems Journal*, 6(1), p. 342-348.