Comparing smart-home devices that use the Matter protocol

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***Abstract*—This paper analyzes Google Home, Apple HomeKit, Samsung SmartThings, and Amazon Alexa platforms, focusing on their integration with the Matter protocol. Matter is a connectivity standard developed by the Connectivity Standards Alliance (CSA) for the smart-home industry. By examining key features and qualitative metrics, this study aims to provide valuable insights for consumers and industry professionals in making informed decisions about smart-home devices. We conducted (from May to August 2024) a comparative analysis to explore how Google Home Nest, Apple HomePod Mini, Samsung SmartThings station, and Amazon Echo Dot platforms leverage the power of Matter to provide seamless and integrated smart-home experiences.**

keywords: smart-home; cyber security; Privacy; Matter Protocol

I. Introduction

The idea of a 'smart home' dates back to the late 20th century when visionaries and inventors imagined a future where technology would automate and enhance our domestic lives [1]. The MIT House_n [2] and the Georgia Tech Aware House [3] were notable early smart home projects that built on that vision. It was not until recent decades, however, that advancements in computing power and connectivity led to the proliferation of Internet of Things (IoT) devices, enabling the realization of the modern smart-home concept.

Today smart homes are moving away from being primarily focused on basic automation tasks of the past such as lighting control and security, toward a wider range of functionality [4], [5]. Homeowners can now enjoy features like voice-controlled assistants, whole-home energy management systems, and interconnected information systems integrated into a cohesive smart-home ecosystem [6], [7], [8]. At least they can in theory. In practice, we found the picture is not as rosy.

A key to implementing these features involves communication between devices. The industry has developed various communication protocols, such as Z-Wave, Zigbee, Wi-Fi, classic Bluetooth, and Bluetooth Low Energy (BLE), each intending to achieve seamless communication and interoperability among smart devices [9]. Historically, however, no universal standard has provided easy and secure integration of heterogeneous devices. This problem is particularly apparent for devices that provide different features, with dissimilar setup procedures, and with heterogeneous requirements. The result has commonly been a patchwork of one-off solutions vendors implement to suit their specific needs.

Rather than continue this disjointed state of affairs, major technology companies such as Apple, Google, Samsung, and Amazon banded together as part of the Connectivity Standards Alliance (CSA) to solve these issues. The result was the *Matter Protocol*, which aims to establish a universal standard for smart-home connectivity and interoperability [10]. By promoting interoperability, Matter simplifies the integration of smart devices, regardless of their brand or manufacturer [11], [12]. This unified approach ensures that consumers have the flexibility to choose devices that best suit their needs without focusing on compatibility issues.

Since it was first released in Fall 2022, Matter has been the focus of several studies that explored the Matter testbed construction and reviewed security features [13], [14], [15]. As far as we know, none of the existing work has studied the Matter integration of the smart-home devices sold in the current market. In this paper, we conducted experiments between May and August 2024 to perform a comparative analysis of how Google Nest, Apple HomePod Mini, Samsung SmartThings, and Amazon Echo platforms leverage the power of Matter to provide seamless and integrated smart-home experiences. This paper makes three major **contributions**:

- We conducted a systematic qualitative study of Matter's integration in the products manufactured by major IoT companies, focusing on different Matter features suggested in the Matter specification and how they are supported by different products.
- We built a testbed and illustrated its potential to explore the features of IoT devices and their Matter integration.
- We identify Matter's integration challenges and identify future directions for the IoT industry.

II. Background on Matter

Formerly known as the "Connected Home over IP" (CHIP) project, Matter is an industry-standard connectivity protocol developed by major technology companies. It aims to establish a unified standard for smart-home devices, allowing them to work together effortlessly, regardless of the manufacturer or brand. Matter promotes interoperability, security, and reliability, ensuring a seamless user experience within the smart-home ecosystem.

The standard seeks to promote the longevity of smart devices. Matter supports interoperability across devices from different manufacturers, simplifies development for manufacturers, and increases compatibility for consumers than previous

technologies [10]. In this section, we highlight some of the main features of Matter, characterized by its emphasis on simplicity, interoperability, reliability, as well as security and privacy. We also introduce the Matter device commissioning process.

A. Simplicity, Interoperability, and Reliability

In pursuit of simplicity, Matter strives to make smart device implementation and usage straightforward through standardized lifecycle processes such as commissioning and device operation. Interoperability is a core feature, allowing seamless communication between diverse devices within the IoT ecosystem. Matter supports backward compatibility by supporting non-Matter protocols (such as Wi-Fi, Bluetooth, or Zigbee) through a Matter bridge. The bridge provides a mechanism for devices that conform to a protocol such as Wi-Fi to communicate with devices that conform to Matter, even though the Wi-Fi device may be unaware of Matter.

Matter prioritizes reliability, ensuring consistent and dependable performance across various devices and scenarios with measures in place for protection, detection, and recovery. Matter supports different transports, including Wi-Fi, Ethernet, and Thread, which build on Internet Protocol (IP) to support reliable device-to-device local communication. Integrating a Distributed Compliance Ledger (DCL) enhances reliability and scalability. DCL works as a trusted store of information about different devices and their certification status, which is important for device attestation.

B. Security and Privacy

Security is a paramount concern, and Matter employs robust measures, including strong cryptographic standards, authentication, and attestation, to safeguard user data and device integrity. Matter offers a foundation for developing safe IoT devices and was developed with security and privacy as core design principles [16], [17].

The Matter network employs a comprehensive and layered security approach during commissioning, ensuring authentication and attestation for each device. All inter-device communication is safeguarded with the AES-CCM and AES-CTR algorithms. Secure over-the-air firmware updates enhance device integrity. The security framework is robust, using a cryptographic suite based on established standards, such as Deterministic Random Bit Generator (DRBG) and True Random Number Generator (TRNG), and incorporating passcodes, certificates, and device attestation for secure sessions. Additionally, the network is agile, featuring crypto-flexibility to adapt to emerging developments and address evolving threats. For example, Matter nodes support changing IPv6 addresses and ports throughout the lifetime of a commissioned device in the face of evolving underlying IPv6 networks.

Matter prioritizes data privacy by incorporating principles into its framework to safeguard consumers' personal information during device interactions. These principles encompass confidentiality and integrity, using high-level cryptographic standards to prevent unauthorized access or tampering of data exchanged between Matter devices. Proof of identity is mandatory for devices with cryptographic certificates, ensuring that data is shared exclusively among recognized Matter entities. Because Matter is an open standard, it allows scrutiny of the protocols for interaction among legitimate Matter nodes. Data minimization is a key tenet, reducing the risk of unintended information leakage within Matter interactions. Additionally, data shared between Matter nodes serves a defined purpose, aligning strictly with the operations required by the Matter protocol. Privacy-preserving mechanisms, including encryption, further guarantee that messages and identities remain secure and undisclosed on the network.

C. Matter Commissioning Process

In Matter, *commissioning* refers to the process of adding new devices to a smart-home network. It involves the use of Bluetooth Low Energy (BLE) for device discovery, secure key sharing, and communication with the border router. In this section, we delve into the intricacies of Matter commissioning, outlining the step-by-step process, and highlighting its significance in creating a robust and interoperable smart-home environment.

Matter commissioning typically involves a device (such as a smart light bulb or a sensor) that needs to establish a secure connection with the smart-home network, allowing it to interact with other Matter-certified devices. The primary components involved in commissioning include the new device, a commissioner device (such as a smartphone or tablet), and the Thread Border router that serves as the central hub for the smart-home network. We summarize the key steps involved in the commissioning process as follows:

1) A device enters the commissioning mode, e.g., when directed by the user or when it is first powered on.
2) Depending on the network topology, device discovery occurs with BLE, Wi-Fi, or over IP if the new device is already on an IP network.
3) Password Authenticated Session Establishment (PASE) is used to establish a secure channel for commissioning between the commissioner and the new device.
4) Device attestation is performed by the commissioner validating device information from the DCL.
5) The commissioner generates a Node Operational Certificate (NOC) and installs it on the new device. Devices use the NOC to identify themselves within a Matter fabric, which defines a security domain for node identification and communication.

III. Comparison of Matter smart-home hubs

To compare smart-home platforms, we examined hub devices within major IoT ecosystems: the Google Nest Hub (Google Home), Apple HomePod Mini (Apple HomeKit), Samsung SmartThings Station (Samsung SmartThings), and Amazon Echo Dot (Amazon Alexa). We start by introducing each platform's integration capabilities with Matter, followed by a set of qualitative metrics for comparing Matter integration across these ecosystems. Our metrics include device compatibility, ease of setup, privacy and security measures, central

control features, automation functionality, and the impact of the Matter protocol on overall performance. This analysis is based on a qualitative review of technical specifications, user feedback, industry reports, and official documentation provided by the respective companies.

A. Google Home Nest

Google Home Nest, a popular smart speaker and assistant, integrates with Matter to create a cohesive and interconnected smart-home environment. It ensures compatibility with a wide range of smart-home devices, regardless of their brand or manufacturer. This interoperability allows users to mix and match devices from different manufacturers, creating a customized smart-home ecosystem tailored to their needs. Additionally, Matter simplifies the setup process by providing a unified standard for device configuration, eliminating the need for multiple apps or complex procedures. It also enhances security by encrypting communication between devices and safeguarding user data and privacy.

B. Apple's HomePod Mini

The HomePod Mini is Apple's compact smart speaker. In addition to audio capabilities and support for Apple's voice assistant, the HomePod Mini serves as a central hub for controlling HomeKit-enabled devices. With Matter integration, the HomePod Mini expands its functionality as a hub, enabling communication and control between Matter-compatible devices within the smart-home ecosystem. The advantages of HomePod Mini with Matter are listed as follows.

1) Effortless Connectivity: The HomePod Mini simplifies the setup and connectivity process for Matter-compatible devices. It also has 802.11n Wi-Fi, peer-to-peer discovery for easy guest access, Bluetooth 5.0, Thread networking technology, and Ultra Wideband for device proximity. In addition, it provides easy connectivity with Apple devices via the Apple's HomeKit App.

2) Voice Control and Automation: With the built-in Siri voice assistant, the HomePod Mini enables convenient voice control of Matter-compatible devices. For example, users can simply issue voice commands to adjust lights, and change temperatures.

C. Samsung SmartThings

Samsung's SmartThings platform harnesses the power of Matter to create a connected home environment that seamlessly integrates devices from different manufacturers. Matter ensures expanded device compatibility, allowing users to choose from a wide range of smart-home devices to build their ideal ecosystem. It uses the SmartThings App to simplify the management and automation of connected devices, offering a user-friendly experience. With Matter, SmartThings users can create customized automation routines that span devices and platforms, maximizing convenience and efficiency within the smart-home environment.

D. Amazon Alexa Echo

Amazon's Alexa Echo devices support both the Matter protocol and Amazon Sidewalk [18], which enhances their versatility in smart-home ecosystems. Matter integration enables streamlined control of various smart-home devices through voice commands, facilitating cross-platform compatibility and interoperability. The inclusion of Amazon Sidewalk extends connectivity beyond the home Wi-Fi network, supporting functionalities such as device tracking, connections to third-party services, and a broader range of smart-home capabilities. Additionally, the advanced voice recognition technology of Alexa devices allows for precise, voice-controlled interactions, contributing to a more responsive and user-centered smart-home experience.

IV. Comparison Metrics of Matter Integration

Based on our examination of different hubs' features related to Matter integration, we use the following comparison metrics for qualitative analysis:

- how easy it is to set up and commission a Matter device to the network,
- how much it supports backward compatibility by allowing customized automation rules involving Matter-certified and non-Matter-certified devices.
- how much it supports the multi-admin feature that allows the hubs from different brands to monitor and control the same Matter device.
- how easy it is to manage, monitor, and control Matter devices through the user interface from the hub or controller app (e.g., voice control, remote control, automation routines, and guided development for routines).

Quantitative metrics (such as latency and response time) are not considered in this work. However, we noted that the expiration times of setup codes are the same, 15 minutes as described in Section VI. In addition, Matter over Thread has better reliability, less power consumption, and better range compared to Wi-Fi networks [19].

V. Commercial Devices Testbed

In this section, we provide a description of a Matter-based smart-home testbed we built. The testbed employs commercial Matter devices, as shown in Table I and Figure 1. We next describe the basic setup of the testbed.

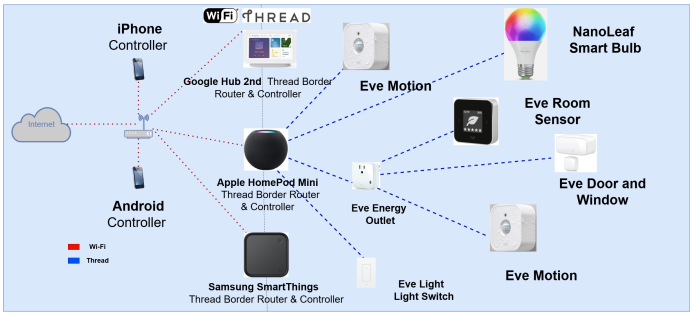

Fig. 1. Commercial Matter Devices Testbed.

The steps required to complete Matter device commissioning are described as follows:

TABLE I
LIST OF EQUIPMENT IN THE MATTER TESTBED

Product Name		Software/Firmware
Border Routers	HomePod Mini	18.1(22J580)
	Nest Hub 2nd Gen	3.25.101
	Amazon Echo Dot (5th Gen)	11040827012
	SmartThings	1.7.21.21
Commissioners	Android Tablet	TB125FU_S100140_240227_ROW
	iPhone 13 Pro Max	iOS 15.8.3
	iPad Tablet	iPadOS 17.7.1
Sensors	Eve Motion	6650.0
	Eve Door and Window	0.0
	Eve Indoor Air Quality	2.1.4(2877)
Actuators	NanoLeaf Smart Bulb	0.0

a) Device Preparation: Place the device in commissioning mode; for new devices, this may be occur when they are first powered on.

b) Setting Up Commissioning Tools: Start the commissioning process with a Matter-compliant commissioning tool. This tool could be a physical device intended for commissioning, a software program, or a mobile application.

c) Network Information: Give the commissioning tool network credentials (such as the network name and security key) and specifics regarding the commissioning procedure itself.

d) Communication Setup: Create a communication channel between the device and the commissioning tool, using Matter-compliant wireless protocols such as Bluetooth or NFC (Near Field Communication).

e) Provisioning Security Credentials: To guarantee safe communication within the Matter network, the commissioning tool can send security credentials, like cryptographic keys, to the device.

f) Network Establishment: The commissioning tool shares crucial network settings and security data to link the Matter device to the home network.

g) Device Verification: Confirm that the smart-home device has joined the Matter network successfully. This could entail making sure it has the right network settings, verifying its identity, and checking that it is present in the network.

h) Completion and Reporting: The user receives a confirmation from the commissioning tool once the device has been successfully commissioned and connected to the Matter network. Information regarding the item that was successfully commissioned may be included in this confirmation.

VI. PLATFORM COMPARISON

In this section, we compare the four vendor products.

A. Commissioning Devices

The first step for the user to add a Matter device to the network is to scan QR codes, NFC tags or manually enter pairing codes. These are onboarding payload for the commissioner, which includes important information to ensure interoperability. All platforms – Amazon, Apple, Google, and Samsung – support QR code scanning and manual pairing code entry. However, only Samsung supports retrieving the onboarding payload from NFC tags. Amazon, Apple, and Google do not support NFC tags, which limits their commissioning options. The Matter specification outlines NFC support as one of the commissioning mechanisms, but this is not uniformly implemented across all platforms. It appears that NFC support remains inconsistent and less available on commercially available Matter devices.

B. Integration with Legacy Devices

Based on the integration tests with legacy devices, the results reveal distinct differences in how each brand supports automation rules involving both Matter-certified and non-Matter-certified devices. Amazon, Apple, and Google do not support creating automation rules directly, as indicated by the lack of native support for such features. However, Apple's announcement at WWDC 2024 introduced Shortcuts, a version of IFTTT, which allows Siri to interact with third-party applications, providing a potential workaround for automation. In contrast, Samsung supports creating automation rules but requires the use of third-party apps linked through a Samsung account. This requirement adds an extra step for users but enables the integration of legacy Wi-Fi devices with Matter-certified devices. Overall, while Apple and Samsung offer some level of support for creating automation rules, Amazon and Google lack direct mechanisms, highlighting the variability in ecosystem capabilities for integrating and automating legacy and Matter devices.

C. Multi-Admin Features

The Matter Protocol's multi-admin feature allows for devices to be commissioned and managed across multiple hubs, providing flexibility and interoperability in smart-home ecosystems. Our experimental observations highlight significant differences in how this feature is supported by Amazon, Apple, Google, and Samsung.

1) Amazon Echo as the Primary Hub: Amazon Echo did not fully support the multi-admin feature. While Alexa could generate setup codes for commissioning devices onto secondary hubs like HomePod Mini and SmartThings, we found that it consistently failed with Google Home. Although Alexa settings displayed other assistants and apps the device was shared with, secondary hubs could not change the status of the device. For instance, a smart bulb turned off from Alexa could not be turned on from a secondary hub, though

TABLE II
AUTOMATION RULES SUPPORT BY BRAND

Brand	Automation Rules Created?	Notes
Amazon	no	
Apple	no	Apple's WWDC 2024 announced their own version of IFTTT called 'Shortcuts', allowing Siri to interact with third party applications.
Google	no	
Samsung	yes	Requires third party Apps linked by creating a Samsung account

brightness adjustments updated across hubs. HomeKit could remove devices from Alexa, SmartThings, and HomePod Mini, demonstrating a partial control but not complete integration.

2) Apple HomePod Mini as the Primary Hub: Apple's HomePod Mini exhibited robust support for the multi-admin feature, albeit with some caveats. To commission a device to a secondary hub, pairing mode had to be enabled on the primary hub, generating a setup code for the secondary hub. Devices could be removed from the HomePod Mini smart home while remaining part of secondary hubs like Google Home. However, removing a device from all services on HomePod Mini also removed it from secondary hubs and iCloud credentials. Issues arose with Samsung SmartThings, where commissioning via setup code failed, despite the device appearing in iCloud. This appears to have been due to SmartThings adding the device to iCloud before completing the setup, causing a failure.

3) Google Home as the Primary Hub: Google Home supports multi-admin features with notable limitations. It could generate setup codes for secondary hubs like HomePod Mini, though pairing mode was not explicitly needed. Devices commissioned on Google Home remained controllable even when removed from the secondary hub, although status updates were shared between hubs. Samsung SmartThings faced similar commissioning issues as observed with HomePod Mini, failing to register the device despite it appearing in iCloud. We found that pairing codes expired after 15 minutes, necessitating timely actions.

4) Samsung SmartThings Station as the Primary Hub: Samsung SmartThings showed promising but inconsistent multi-admin support. It generated both setup and QR codes for device sharing, expiring after 15 minutes. HomePod Mini could commission devices without manual code entry, by leveraging iCloud keychain integration. However, devices commissioned via SmartThings failed to appear on Google Home, highlighting compatibility issues. Samsung supported turning devices on and off as a secondary hub, and could detect and copy setup codes generated by other hubs, streamlining the commissioning process.

D. User Interface

The usability and effort required for users to coordinate and interact with their smart-home ecosystems varied significantly across different brands, as illustrated in Table III. We view each UI screen as one step. Amazon's ecosystem required the highest number of steps for both QR code and manual commissioning, with 16 steps each. This finding indicates a more complex and potentially cumbersome process for users, which may lead to a less intuitive and more time-consuming setup experience. Despite this, the steps for checking device status and controlling devices were minimal, suggesting that once devices are commissioned, interaction with them is straightforward. In contrast, Apple and Google demonstrate a more streamlined approach, with 7 steps for QR code commissioning and 8 for manual commissioning, indicating a more user-friendly setup process compared to Amazon. Similar to Amazon, Apple and Google require only 1 step to check device status and 2 steps to control devices, indicating ease of use in daily interactions once the initial setup is complete.

Samsung's ecosystem fell between Apple/Google and Amazon in terms of complexity. It required 13 steps for QR code commissioning and 14 steps for manual commissioning. While fewer than Amazon, SmartThings had significantly more steps than did Apple and Google, indicating a moderately complex setup process. However, like the other brands, Samsung also requires only 1 step to check device status and 2 steps to control devices, suggesting that daily interactions remain user-friendly despite the more involved setup. This finding highlights that, while Samsung offers a better experience than Amazon, it still required more effort from users compared to Apple and Google.

Overall, Apple and Google stand out as the easiest ecosystems to use in terms of commissioning devices, at least in the sense that they required the fewest steps. This simplicity can enhance user satisfaction by providing a more efficient and less frustrating setup experience. However, we found that all ecosystems required minimal steps for checking device status and controlling devices, indicating that once devices are set up, the interaction with them is consistently straightforward across all brands. These findings highlight the importance of minimizing the steps required for initial device setup to improve the overall user experience in smart-home ecosystems. Brands that simplify their commissioning processes can potentially attract more users who prioritize ease of use and efficiency in managing their smart-home devices.

VII. CONCLUSION

In this comparative analysis, we explored how Google Home Nest hub, Apple's HomePod Mini, Samsung's SmartThings, and Amazon's Alexa Echo leverage the power of the Matter Protocol to enhance the smart-home experience. These protocols enable seamless connectivity, interoperability, expanded device compatibility, and advanced control capabilities, ensuring users can create a truly connected and integrated smart-home ecosystem. By considering qualitative metrics and the impact of these protocols, consumers and industry professionals can make informed decisions when choosing

TABLE III
COMMISSIONING AND CONTROL STEPS BY BRAND

Brand	Commissioning Steps (QR)	Commissioning Steps (Manual)	Device Status Steps	Control Device Steps
Amazon	16	16	1	2
Apple	7	8	1	2
Google	7	8	1	2
Samsung	13	14	1	2

smart-home devices. As the smart-home landscape continues to evolve, the adoption of robust connectivity standards like the Matter Protocol paves the way for a more interconnected and convenient future.

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