MATTER FOR CE PRODUCT MANUFACTURERS

MAKING PRACTICAL, PROFITABLE SMART HOME PRODUCTS

Consumer electronics (CE) product decision-makers worldwide are evaluating the strategic impact of Matter, a new smart home connectivity standard from the Connectivity Standards Alliance (CSA). Matter makes CE products interoperable over existing residential networks, but its effects on CE product strategy, architecture, and design extend beyond improving device communication. Universal connectivity elevates the smart home value proposition from simple transactional controls to higher levels of human interaction and whole-home process automation. This white paper offers a top-down analysis of Matter's transformative effects on CE product strategy.

Over the past three years, some of the biggest computing and CE brands invested hundreds of thousands of person-hours[1] in Matter. At the time of this writing, Matter is in its third release, version 1.2, with more than 1,214 certified products[2]. Adoption barriers are low because Matter didn't start from scratch. The specifications incorporate widely deployed standards for networks, protocols, security, and device communication semantics instead of creating new ones. Please refer to the first paper in this series, "Matter – Making Smart Homes Smarter," for a thorough introduction.

Situation: Chaotic connectivity

Smart home technology began about 25 years ago with the advent of various device connectivity protocols capable of simple remote control functions. Ten years later, smart homes became "smarter" as hubs (gateways) extended local device connectivity to web services and smartphones. Today, connected products such as thermostats, lighting controls, smart plugs, security devices, appliances, and AV equipment are commonplace, providing compelling user experiences on phones, tablets, and smart speakers. However, with no unifying connectivity standard, products from different manufacturers behave differently and rarely work together. The resulting hodgepodge of device families, networks, hubs, cloud services, mobile apps, user IDs, and passwords divide the smart home market into non-interoperable product silos that confuse consumers, impede product sales, preclude the economies of scale that come from standardization, and block the evolutionary path of new smart home use cases. Matter aims to solve these problems.

[1] Tobin Richardson, CEO of the Connectivity Standards Alliance – interview with Bill Curtis – CES 2023
[2] CSA Matter 1.2 press release, 23 October 2023 https://csa-iot.org/newsroom/matter-1-2-arrives-with-nine-new-device-types-improvements-across-the-board/

Solution: Simplicity and interoperability

Matter founders realized that undifferentiated product diversity increases smart home complexity without adding value. Consumers prefer simplicity, and for connected devices, that means using existing networks like Wi-Fi and Thread and mainstream smart home ecosystems like Alexa, Google Home, Apple HomeKit, and SmartThings.

CE manufacturers also want simplicity. Unified connectivity maximizes total available market (TAM) while eliminating the need to develop and support nonstandard networks and protocols. Matter simplifies product design and development for manufacturers while making connected devices easy for consumers to buy and use.

A product manufacturer's point of view

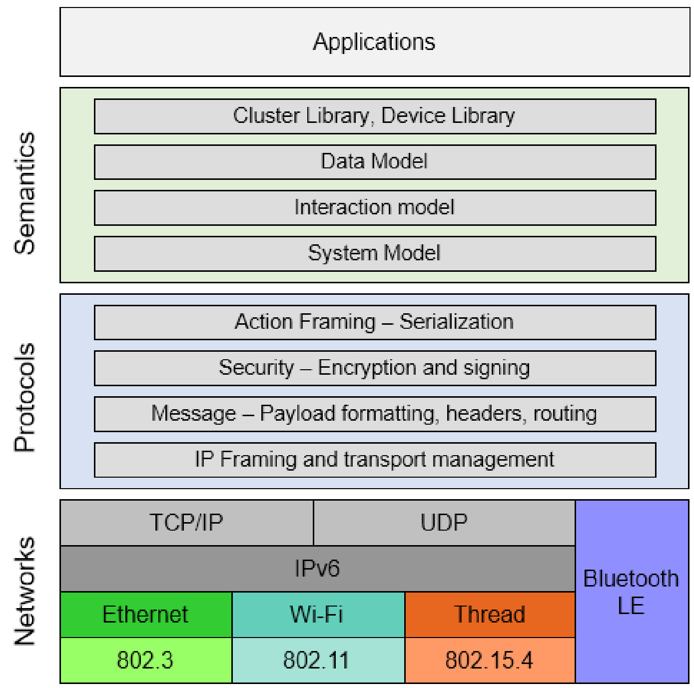
This research paper analyzes Matter strategies from a CE product manufacturer's point of view. First, we examine Matter architecture from the top down, highlighting what Matter standardizes and how manufacturers can add more value as connectivity becomes standardized. Then, we predict Matter's transformative effects on the smart home marketplace and recommend appropriate product strategies. Next, we dig into Matter platforms and suggest efficient ways to develop standards-based products with differentiated features. We also list best practices for manufacturing secure Matter products and show how platform suppliers streamline the consumer product supply chain. Finally, we address some common questions about transitioning to a Matter-based product strategy.

MATTER OVERVIEW

As shown in Figure 1, Matter's layered architecture standardizes networks, protocols, and semantics. After reviewing each layer, we'll show how applications use the whole stack.

Network layer – Traditional low-power CE devices use non-IP mesh networks such as Z-Wave, Zigbee, Insteon, and other proprietary schemes, each with unique protocols and hubs. Matter uses standard IP protocols, so it natively supports any IP-based network such as Wi-Fi, Thread, or Ethernet with no intervening hubs or gateways. Many hardware and software platforms already support these networks, so product developers can use them as-is. Matter also uses Bluetooth Low Energy for device installation (commissioning) but not for network transport.

FIGURE 1: MATTER'S LAYERED ARCHITECTURE



Source: Moor Insights & Strategy

Protocol layer – Above the network layer is the IP protocol stack that constructs, secures, formats, frames, sends, and receives all IP messages. The protocol layer uses a proven, industry-standard architecture optimized for connected devices.

Semantics layer – This layer defines Matter's "language" for device communication. Like the network and protocol layers, the semantic layer leverages technologies proven on millions of devices over many years. System, interaction, and data models define the device hierarchy, transactions, and persistent relationships that automate data and control flow. The Matter 1.2 Device Library includes lighting, plugs, switches, sensors, closures, HVAC, media devices, robot vacuums, refrigerators, room ACs, and appliances such as washing machines and dishwashers. The list grows with each new release, currently on a six-month cadence. Matter's Application Cluster Specification defines device attributes, commands, and events common to many device types. For example, an on/off light switch uses the on/off cluster, while a color dimmer switch uses on/off, level control, and color control clusters. Matter is on track to provide clusters modeling the behavior of most mass-market CE products over the next few years. However, the specs also allow developers to use manufacturer-specific extensions to provide advanced functionality before standardization.

Applications – From a device developer's point of view, Matter is an abstract interface to other devices – a way to send and receive commands, attributes, and events. The Matter stack is the same regardless of device type, network connection, or function (client or server). Developers often refer to the entire Matter stack as an "application layer" because it connects applications running on various devices. However, Matter is not an application. Calling it an "application *connectivity* layer" would be more accurate, but the "app layer" moniker is probably here to stay.

MATTER PRODUCT STRATEGY

Smart home "interoperability" means products from any manufacturer can use the same networks, communicate with one another, and participate in multiple smart home ecosystems. Device interoperability is Matter's "killer feature" because it levels the playing field, making CE products easier to build, buy, and use.

CE product sales should increase as interoperability decreases market friction, but how much? Metcalfe's Law tells us that the *financial value* of a network is proportional to the square of the number of connected devices. However, suppose Matter is just a better way to do the same home automation functions we've been doing for the past 25 years. In that case, the *consumer value* of the network is demand-limited, and so is device sales growth. Will interoperable products open up innovative new smart home use cases that consumers value? To answer this question, let's review home automation technology trends and predict upcoming business opportunities.

We're now on the threshold of the autonomy era, where people manage complex home systems by declaring intent and outcomes rather than actions and schedules.

EXPANDING SMART HOME BUSINESS OPPORTUNITIES

Over the past 25 years, smart home technology evolved from simple "remote control" to higher levels of automation using smartphones and personal assistants. We're now on the threshold of the autonomy era, where people manage complex home systems by declaring intent and outcomes rather than actions and schedules. MI&S defines four phases of smart home evolution.

- **Phase 1 – Remote control**
  Smart home technology began in the late 1990s[3] and early 2000s with the introduction of low-power, low-bandwidth wireless device communication

[3] Although the X10 powerline protocol dates back to the 1970s, the advent of wireless mesh networks beginning with Z-Wave in 1999 made home automation commercially viable.

frameworks for controlling residential lights and other electric loads. Z-Wave, Zigbee, Insteon, and other frameworks enabled the first smart home use case – remote control. These isolated device frameworks use different radios, protocols, and semantics.

- **Phase 2 – Home automation**
  In the late 2000s, smartphone apps introduced higher levels of home automation. Device frameworks added proprietary hubs and web services, enabling smartphones to manage device connectivity, events, scenes, and schedules. Mains-powered Wi-Fi devices such as thermostats, cameras, garage door openers, and appliances followed the same pattern, creating many proprietary frameworks, web services, and apps. Although home automation makes smart homes smarter, managing multiple frameworks, hubs, web services, apps, user IDs, and passwords frustrates users and slows technology adoption.
- **Phase 3 – Ambient control**
  In the 2010s, cloud service providers (CSPs) created virtual assistants like Alexa, Google Assistant, and Siri. The CSPs linked assistants to multiple home automation ecosystems (Alexa, Google Home, Apple Home) and created APIs for integrating multiple device frameworks. Layering an ecosystem with a virtual assistant on top of multiple device frameworks creates an appearance of interoperability, but it's just an illusion. Users still have to deal with the reality of connecting ecosystems to multiple device frameworks with unique user IDs, passwords, and semantics.

Today, state-of-the-art smart homes use CSP ecosystems to control home devices via smartphone apps, smart speakers, and hubs. The result is ambient smart home control, and it's very compelling. "Alexa, turn on the porch lights." "Hey, Google, show the driveway camera." "Siri, close the garage door." In September 2023, Amazon claimed, "Customers have connected over 400 million smart home devices to Alexa and use Alexa hundreds of millions of times each week to control those devices[4]." That's an impressive number, but it's a small fraction of the market. There are over 500 million Alexa-enabled devices[5]. Each home could have dozens of smart home

[4] Amazon press release, 20 September, 2023 – "Introducing a new era for the Alexa smart home" https://www.aboutamazon.com/news/devices/amazon-smart-home-announcements-2023
[5] Amazon press release, 17 May 2023 – "Amazon introduces four all-new echo devices; sales of Alexa-enabled devices surpass half a billion" https://press.aboutamazon.com/2023/5/amazon-introduces-four-all-new-echo-devices-sales-of-alexa-enabled-devices-surpass-half-a-billion

devices and several mainstream ecosystems, so the market potential is tens of billions of devices.

The Matter effect: In 2024, CSPs plan to enhance virtual assistants with large language models (LLMs), enabling conversational interactivity that makes ambient computing more like natural human speech. Matter accelerates this trend by replacing the illusion of device interoperability with actual industry standards that enable CE manufacturers to build connectivity into every product, ultimately extending ambient controls to every device in the home.

Users specify outcomes, not actions.

- **Phase 4 – Autonomy**
  New AI capabilities take ambient computing to the next level – autonomy. Residents control the home via LLM-based user interfaces (UIs), combining conversational voice, proximity, gestures, facial expressions, and behavior patterns within a situational context derived from connected sensors and systems. Users specify outcomes, not actions. This higher level of abstraction enables AI-enabled applications to optimize whole-home security, safety, health, convenience, comfort, and energy costs.

  The Matter effect: Matter enables autonomy by making it easy to connect and manage enough home devices and systems to achieve whole-home automation. Without Matter, installing and managing multiple incompatible smart home device frameworks would remain challenging for most consumers, limiting the number of connected devices below the level required for whole-home automation. So, business cases for autonomous homes depend on Matter.

Autonomous Home Use Cases

Autonomy can make our homes more efficient, comfortable, personalized, secure, safe, and healthy. Here are a few examples to show what's possible.

- Energy management – Optimize energy use and minimize cost across all electrical loads and sources.
- HVAC optimization – Sense and model the whole-home heating and cooling situation – zonal occupancy, activity, schedules, weather, HVAC performance, and thermal mass – and control HVAC systems within the home's energy management context.

- Security – Confirm identities and authorize access to the home and its control systems. Detect intrusions and react appropriately, given the home's current occupancy situation.
- Safety – Monitor all sensors and control systems to detect anomalies and protect occupants and property.
- Health and wellness – Monitor air quality, optimize lighting, and integrate personal sensor information. The CSA already has a Health and Wellness working group.
- Aging-in-place – Monitor activity and motion, detect anomalous behavior, sense unsafe situations, integrate health monitoring devices, and assist residents with managing home systems.
- Ease of use – As homes become more complicated, autonomy and AI have the potential to simplify operations of multiple interdependent systems and reduce maintenance costs.

Autonomy requires situational context

Autonomous home use cases need situational context – the ability to perceive, understand, and respond to complex situations in real-time. Perception requires AI-based applications to connect with multiple home systems such as lights, doors, windows, cameras, security sensors, HVAC, appliances, AV, plumbing, irrigation, pools, cars, and energy sources. Situational context may include other inputs such as wearables, pet trackers, family schedules, presence detectors, weather sensors, electric grid status, and real-time utility rates.

The need for multisensory situation analysis is not unique to homes. Autonomous vehicles combine inputs from 2D and 3D cameras, ultrasonic sensors, LIDAR, GPS, accelerometers, and dozens of mechanical and electrical systems to synthesize the car's dynamic situation and drive the vehicle. Autonomous homes also require many sensor inputs, but connectivity is a significant barrier – more so than vehicles. Here's why.

For vehicles, design teams specify sensors and actuators that work together over standards-based in-vehicle networks. In contrast, home design isn't centralized, and home connectivity isn't standardized (yet). Over the life of a home, various architects, builders, remodelers, contractors, and homeowners select home controls, appliances, and other devices with little or no consideration for connectivity. Without a unifying connectivity standard for residential products, the proliferation of non-interoperable devices makes multisensory integration impractical. That's where Matter comes in. Autonomy and ambient control require situational context, and standardizing product interoperability makes it practical. That is how Matter's killer feature, interoperability, enables the autonomous home.

Autonomous Home Business Cases

Each use case example offers compelling benefits, and some provide measurable financial returns. As a case in point, let's look a few years into the future and predict how whole-home, autonomous energy management can generate significant cost savings.

For most energy customers, the cost per kWh is stable during a monthly billing cycle. However, many wholesale and industrial customers already have time-variable pricing (TVP) with rates that change frequently, sometimes in real-time, reflecting variable generating costs and grid conditions. It's only a matter of time until utility companies extend TVP to residential users, opening the possibility for significant time-dependent savings – and penalties. TVP optimization is an excellent use case for autonomy. Here's how it would work.

TVP complicates calculating the best times for energy-intensive tasks such as charging cars, heating water, or running pool pumps. It's cheaper to do these things when energy prices are low, but there are also time constraints. So, rather than tell the car when to charge, users should specify when the car must be ready to drive and let the AI figure out the best times to charge. Optimizing whole-home energy costs requires orchestrating all large electrical loads, energy storage systems, solar cells, and generators to use electricity when it's cheap, sell it to the grid when it's worth more, and always maximize residents' comfort and quality of life. In a resource-constrained world, TVP is inevitable, and investments in autonomous home technologies pay back rapidly.

New Software Opportunities

This section explained how Matter elevates smart home business opportunities from remote control gadgets to ambient, autonomous use cases, creating the potential for step-function increases in consumer demand for smart home products. That's *why* CE product companies should build Matter products. The following section covers *how* to build them.

Matter Product Architecture

Matter enables the situational context that makes autonomous homes possible. That's a bold claim, but we're already on the road to that vision. Ambient controls are here now, and 2024 product roadmaps include LLM-based human interaction, digital assistants with ambient intelligence, and a groundswell of Matter-enabled products. CE manufacturers can expect autonomous use cases to evolve in 2024 and 2025 as Matter-enabled devices proliferate.

This section discusses architectural strategies for CE manufacturers to leverage industry-wide investments in Matter ecosystems and device platforms, enabling a new generation of smarter, higher value, higher margin products that align with autonomous use cases. We break the problem down into three critical architectural decisions: (1) software design and ecosystem options, (2) platform selection, and (3) secure manufacturing.

MATTER ECOSYSTEMS

Implementing the Matter strategies defined in the previous section requires developing application software for microprocessor (MPU) and microcontroller (MCU) embedded devices. But Matter applications extend beyond devices to smart home ecosystems comprising cloud services, smartphones, hubs, speakers, and other Matter Controllers. Manufacturers are no longer just building gadgets. New CE products are increasingly software-defined, with components running not just on devices but also on cloud ecosystems with local interactive controllers and smartphone apps.

For devices, the Matter open-source software stack is readily available from GitHub and pre-integrated with hardware platforms from multiple suppliers, making it easier for developers to start quickly and make rapid progress. At the time of this writing, there are four Matter-enabled ecosystems – Amazon Alexa, Google Home, Apple Home, and Samsung SmartThings. Here's how Matter ecosystems work and how to decide which ecosystem strategy is best for your company – none, one, multiple, or DIY.

Matter device and ecosystem interoperability

Interoperability is the foundation of Matter's value proposition, and Matter enables two distinct types of interoperability – *devices* and *ecosystems*. Consumers expect any device with a Matter logo to work correctly with all other Matter devices. Likewise, consumers expect all Matter devices to work correctly with any Matter smart home ecosystem, such as Alexa, Google Home, Apple Home, or SmartThings. Matter's detailed specifications and thorough certification procedures assure reliable multivendor device interoperability. Unfortunately, the specifications do not thoroughly address ecosystem interoperability. Many consumers deploy multiple ecosystems concurrently, so this interoperability gap complicates deployment and frustrates users.

Matter ecosystems

A Matter ecosystem provides the administrative domain manager (ADM) for a set of Matter devices. An ADM creates and manages a unified device "fabric" with trustworthy devices stitched together by common operational credentials, a unified namespace, and persistent device bindings (device-to-device connections). The ADM also provisions each low-power Thread device with credentials that create a unified mesh network. From a user's perspective, the ADM is Matter's administrative control panel. Architecturally, an ADM can run on a local device but is often implemented as a cloud service with an in-home presence – a Matter Controller – that creates the Matter fabric and interacts with devices and users. Controllers are software components that run on local devices, typically mass-market, interactive, locally networked CE products such as smartphones, tablets, touchscreen panels, smart speakers, video hubs, and AV equipment.

Matter specifications do not adequately address multi-ecosystem interoperability, so supporting more than one is often confusing for consumers and costly for OEMs. Here's a key quote from the Matter 1.2 specification:

> *"The algorithmic details and policies within the Administrative Domain Manager are out of the scope of the specification as long as the allocation of all identifiers obeys the uniqueness and scoping criteria.[6]"*

This carefully worded sentence means Matter specifications define the interface between the ADM and Matter devices but do not address ecosystem-to-ecosystem interoperability. This policy is intentional, not an oversight, because Matter's scope cannot, and should not, include the internal architecture of a CSP ecosystem. The specs include a workaround called "multi-admin," a way to use multiple ADMs in the same home. CSA members are working on better solutions, but here's how it works.

Multi-admin

ADMs operate independently by design. Each ecosystem in a home creates a unique fabric with its own root of trust, operational credentials, namespaces, device bindings, user interface, and operational procedures. Matter's "multi-admin" feature allows multiple ecosystems to coexist and use the same devices simultaneously. Multi-admin specs only cover the basics of creating multiple ecosystem-specific Matter fabrics and stop short of making those fabrics work together smoothly. Not surprisingly, managing multiple fabrics in the same home is tricky, and the resulting user experience is often

[6] Matter 1.2 specification https://csa-iot.org/developer-resource/specifications-download-request/

confusing and frustrating. CSA members are working to improve this situation, but it remains unresolved at the time of this writing.

Matter 1.2 currently has four authorized ecosystems – Amazon Alexa, Apple Home, Google Home, and Samsung SmartThings – and more are under development. Matter specifications require devices to support a minimum of five simultaneous ecosystems. A quick survey reveals that most devices have a hard limit of five for two reasons – memory constraints and performance – so the five ecosystem limit is unlikely to change.

Until CSA members resolve multi-admin problems, MI&S recommends that new Matter consumers start with a single primary ecosystem and add others only as required for unique, highly desirable features. For CE product companies, supporting all ecosystems maximizes TAM, but that strategy also increases development and support costs. Let's look at some specific ecosystem options.

Using existing ecosystems

All Matter ecosystems perform routine tasks such as device onboarding, creating and maintaining the device fabric, and controlling devices – on/off, light dimming, door unlocking, and hundreds of other functions defined by the standard. However, many product companies are highly motivated to add value on top of these "generic" functions and build specialized controls that require application code on phones, cloud services, and Matter Controllers.

Each ecosystem provides rich APIs for building solution-specific apps with Matter capabilities. Developers can use these APIs to build specialized, differentiated apps that (1) provide solution-specific user experiences, (2) create brand awareness, (3) expose manufacturer-specific device capabilities, and (4) orchestrate sets of devices to focus on complex use cases. For instance, an energy management app might connect with dozens of sensors from multiple vendors to create a whole-home context for optimizing HVAC, window coverings, car charging, water heating, and energy storage.

Each ecosystem has a comprehensive set of APIs, services, tools, and reference apps that simplify building and maintaining developer-branded apps on Android, IOS, and other platforms. However, these extensions require ecosystem-specific application software and, in some cases, device software. Development and support costs motivate developers to minimize the number of supported ecosystems, but that limits TAM. Hence, the Matter ecosystem dilemma and the need for a rational strategy.

Four ecosystem options

Product developers are confused about ecosystem options for good reasons. Most products need ecosystem-based software, leveraging a single smart home ecosystem limits TAM, supporting multiple ecosystems is costly and problematic, and building bespoke ecosystems is extremely expensive. Developers should evaluate each of these options before deciding on an application architecture.

- **No specific ecosystem – generic device, no app**
  - If Matter's device definitions and cluster library support everything your device needs to do, it'll work with any Matter-certified ecosystem.
  - Some Wi-Fi-based products already have apps. Adding a Matter software stack to these devices enables any Matter ecosystem to control basic device functions while an existing non-Matter app controls advanced features.
  - ***Analysis:*** *"Generic" devices plug and play with any ecosystem, so this is the right choice for simple, high-volume products and a great way to add basic Matter support to existing Wi-Fi products.*
- **One ecosystem**
  - You select one Matter ecosystem vendor. The vendor's Matter app provides onboarding, device management, and basic operation. Your developers can use the ecosystem vendor's native APIs to build a custom app with additional capabilities and branding.
  - ***Analysis****: Integration is straightforward, but product TAM is limited to customers who use the chosen ecosystem.*
- **Multiple ecosystems**
  - Repeat the "one ecosystem" option to add more ecosystems.
  - ***Analysis:*** *This option increases TAM but adds complexity and increases development, testing, and maintenance costs.*
- **Custom ecosystem**
  - You build a new ecosystem with a unique ADM and controller.
  - ***Analysis:*** *This approach maximizes opportunities for domain-specific value-add, manufacturer-specific device capabilities, end-to-end branding, and closed-ecosystem product strategies. However, developing domain-specific ecosystems is impractical for most CE companies until the CSA fixes multi-admin. See "The Matter Multiverse" section for more details.*

Until the CSA solves the multi-admin problem, most CE manufacturers should use existing ecosystems and avoid building new ones. Let's dig a little deeper into this critical issue.

Ecosystem divergence – the Matter multiverse

Motivated by opportunities for domain-specific value-add, branding, competitive differentiation, and minimizing external dependencies, some product companies want to create proprietary ecosystems despite Matter's multi-admin limitations. This approach is problematic for three reasons.

1. **Multiverse** – Suppose the CSA eventually solves the ecosystem interoperability problem by enabling a single, unified multi-ecosystem fabric or by enabling multiple Matter fabrics to behave as one. In either case, multiple ecosystems could peacefully coexist on a unified Matter fabric. Until then, creating lots of specialized ecosystems is not practical for reasons previously described in this section. We call fragmented fabrics the "Matter multiverse" – parallel, independent Matter universes with little or no interoperability. The Matter multiverse is a new version of the walled garden landscape that Matter aims to unify.
2. **Cost, TTM, and focus** – Building and maintaining a full-function Matter ecosystem is expensive and doesn't always add practical value. For mainstream consumer applications, using one or more existing CSP ecosystems minimizes cost and time-to-market while allowing developers to focus on adding value.
3. **Next-level features** – CSPs like Amazon, Apple, Google, and Samsung are investing heavily in AI and embracing ambient controls and autonomy. Developing applications on mainstream ecosystems aligns product companies with industry-wide smart home technology investment profiles.

The exceptions are situations that require manufacturer-specific ecosystems. Examples include function-focused applications such as energy management, safety-related applications, and fit-for-purpose, single-vendor commercial installations. In cases like these, mainstream CSPs add little value, and the costs of building and supporting new Matter ecosystems might be easier to justify. Still, MI&S advises manufacturers to carefully research multi-ecosystem limitations before proceeding and to work directly with the CSA to improve multi-admin capabilities.

Matter Device Platforms

Traditional embedded software development requires writing procedural code in C (or assembly) for purpose-built hardware with minimal processing power, memory, and storage. In these environments, every CPU instruction and every byte has a cost, and developers need specialized embedded knowledge, skills, and experience.

While the traditional approach is still appropriate for small, standalone embedded devices, higher-value use cases such as ambient UI and autonomy require larger embedded platforms with IP networking, interoperable protocols, faster processors, high levels of security, more memory, more storage, and for some products, ML acceleration. These modern platforms run multi-tasking embedded OSes that support software development tools, languages, and DevOps practices similar to those used for PCs and mobile devices. Mature software environments reduce development costs, shorten time to market (TTM), improve product quality, and open embedded device development to a larger software engineering talent pool. Critics correctly point out that traditional embedded practices produce efficient code for lower-cost hardware platforms. However, that's like comparing a feature phone to a smartphone – the additional capabilities are worth the cost. Smart home use cases are moving beyond simple "remote control" applications, so it's time to upgrade the device platforms.

Emergence of embedded platforms

Within the context of this paper, a "platform" is all the hardware and software in a smart home device – processors, memory, storage, networks, OS, development tools, board support packages, a Matter stack, and any function blocks necessary for a manufacturer's application. NXP and other silicon companies offer Matter-ready platforms with processors ranging from battery-powered MCUs to desktop-class MPUs. Some platforms consist of a single chip, complete with wireless networking and security subsystems, while others are chipsets that offer mix-and-match configuration flexibility.

Silicon companies provide evaluation kits (EVKs) for each processor family, complete with pre-tested, open-source distributions of operating systems, board support packages, network stacks, the Matter stack, and security components. Developers download the open-source system code from GitHub, fire up the OS, and write applications in high-level languages like C++, JavaScript, or Python. Developing software for fully supported embedded platforms is becoming more like writing an app for a PC, Mac, or phone. Let's run through the whole Matter development process – determine the product's Matter role, select a development platform, and specify the production platform. In the next section, we'll cover planning for secure manufacturing.

Matter platform characteristics

The first step in choosing a product development platform is classifying its role in Matter fabrics and device networks. Matter roles use various combinations of two IP-based wireless networks – Wi-Fi for higher bandwidth and Thread for lower power. Every role also uses Bluetooth LE for wireless setup.

We'll provide more detail on Thread because it's a new mesh technology with more configuration options. There are four distinct device roles in a Thread mesh network:

- **Border router** – These always-on devices connect the Thread mesh network to the primary home IP network.
- **Router** – These always-on devices route packets within the Tread mesh.
- **Minimal** – These always-on devices do not act as Thread routers, typically because of resource constraints – memory, CPU, or other limitations.
- **Sleepy** – Battery-powered devices are usually asleep, can only communicate when awake, and never serve as routers.

Processing requirements and network options define seven distinct device roles. Table 1 lists each role from highest to lowest processing power. We divide the roles into two categories. *Infrastructure nodes* manage the Matter fabric, host higher-level applications such as user interfaces, and connect legacy networks. Thread border routers are infrastructure nodes required by Thread but are not part of the Matter specification. *End nodes* are the Wi-Fi and Thread devices that reside at the edge of the Matter fabric and interact with "things" and people in the home.

TABLE 1: DEVICE ROLES AND PLATFORM CHARACTERISTICS

	Matter and network role	Processor	Radio integration	OS	Radios			Platform notes
					Wi-Fi	Thread	BLE	
infrastructure	Matter Controller	MPU	Hosted	Linux	Y	Y	Y	Optional accelerators, graphics, audio
	Matter Legacy Bridge	MPU	Hosted	Linux	Y	Optional	Y	3rd party radio required for legacy networks. See text for configuration options
		MCU High perf	Hosted	RTOS				
		MCU High perf	Standalone	RTOS				
	Thread Border Router	MPU	Hosted	Linux	Y	Y	Y	May also act as controllers or end nodes
		MCU High perf	Standalone	RTOS				
End node	Wi-Fi	MPU	Hosted	Linux	Y	Optional	Y	Thread router (optional) May have accelerators
		MCU High perf	Standalone	RTOS				
	Thread	MCU High perf	Hosted	RTOS	n/a	Y	Y	Thread-only high-performance MCUs are hosted
		MCU Low power	Standalone	RTOS				
	Minimal	MCU Low power	Standalone	RTOS	Y	Y	Y	Always on, limited CPU, memory Cannot be a Thread router
	Sleepy	MCU Low power	Standalone	RTOS	Y	Y	Y	Battery powered, Thread preferred Cannot be a Thread router

Source: Moor Insights & Strategy

Here's more detail about each of the seven Matter and network device roles:

Infrastructure device roles:

- **Matter controllers** typically host the ADM functions that create and manage Matter fabrics and commission new devices. Controllers may be in-home agents of Matter-enabled cloud ecosystems (Amazon, Apple, Google, Samsung, and soon more) or may create local ecosystems. Controllers may also enable cloud applications (and local proxies) to use devices on the Matter fabric. Users typically interact with ecosystems via smartphone apps and local UIs (smart speakers, video hubs). Controllers may also host third-party software components created by CE manufacturers using ecosystem APIs and services, but each ecosystem does this differently.
  Example products: Smart speakers, home hubs, AV devices, security panels, and energy management panels
- **Matter legacy bridges** are protocol translators that connect simultaneously with legacy networks (i.e., Z-Wave, Zigbee) and Wi-Fi (or Ethernet). Bridges may also serve as end nodes or Thread border routers.
  Example products: Legacy network hubs, dedicated bridges
- **Thread border routers** are MCU- or MPU-based devices that connect simultaneously with Thread and Wi-Fi (or Ethernet) and route Thread traffic to and from the primary home IP network. Matter controllers and Wi-Fi end nodes often integrate Thread border router functions.
  Example products: Smart speakers, TV streaming boxes, thermostats

End node device roles:

- **Wi-Fi** end nodes are MCU- or MPU-based devices at the edge of the home network with configurations ranging from battery-powered to high-performance.
  Example products: Edge devices requiring Wi-Fi connectivity and bandwidth.
- **Thread** end nodes are typically MCU-based devices with characteristics similar to Wi-Fi end nodes but with Thread's lower power and mesh networking advantages.
  Example products: Edge devices that benefit from low-power mesh technology and fit Thread's bandwidth limitations.
- **Thread minimal** end nodes are MCU-based, always-on, resource-constrained devices that cannot act as Thread routers. The additional cost of a Thread Router configuration is minimal, so this configuration is rare.
  Example products: Cost-constrained devices.
- **Thread sleepy** end nodes are MCU-based, battery-powered devices that sleep most of the time, waking only in response to events or timers. Sleepy

nodes cannot serve as Thread routers.
Example products: Anything with batteries, such as window or door sensors, thermometers, and door locks.

NXP's Matter product portfolio enables developers to implement these seven roles with four distinct silicon configurations. Table 1 uses four colors to highlight processor family and radio subsystem combinations that meet each role's requirements. Before diving into the details, let's clarify NXP's terminology.

- **Standalone** wireless SoCs are complete, single-chip Matter platforms with built-in radios and security subsystems.
- **Hosted** wireless SoCs are multi-chip Matter platforms that "host" external network chips for various combinations of Wi-Fi, Thread, Bluetooth LE, and NFC. Externally hosted security chips such as the EdgeLock SE05x Secure Element or A5000 Secure Authenticator provide additional functionality, as explained in the next section on secure manufacturing.
- **MPU** processor SoCs are available in many configurations, but all use "hosted" radio integration.
- **MCU** processor SoCs also come in a wide variety of configurations. For Matter applications, we split them into two categories – lower power, suitable for battery-powered devices, and higher performance. Lower-power MCUs are standalone, and higher-performance MCUs are standalone or hosted.

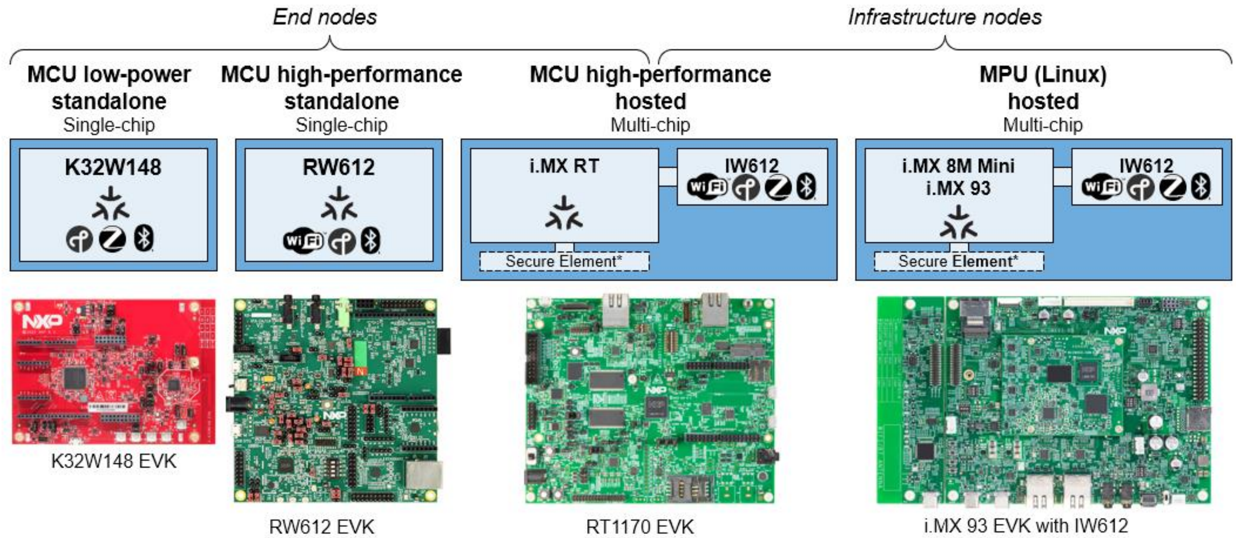
Thus, we define four NXP SoC platforms that can implement all seven Matter roles:

- **MPU (Linux) hosted** platforms offer maximum processing power and configuration flexibility for all infrastructure roles and high-performance Wi-Fi end node roles.
- **MCU high-performance hosted** platforms have Cortex M7 processors (as of this writing) and are ideal for legacy bridges and high-performance Thread nodes.
- **MCU high-performance standalone** single-chip platforms have Cortex M33 processors (as of this writing) and are ideal for Thread Border Routers, legacy bridges, Wi-Fi end nodes, and Matter Controllers – but not ideal for Thread end node roles because the chips also have Wi-Fi.
- **MCU low-power standalone** single-chip platforms are ideal Thread sleepy and Thread minimal end nodes, including battery-powered configurations.

Matter software development platforms

After determining a new product's role (or roles) in the Matter fabric, the next step is to pick an appropriate software development platform. Developers may implement all seven Matter roles using the four NXP Matter-enabled platforms defined above. Figure 2 is a simplified view of these four platforms, showing NXP part numbers for typical SoC families, hosted network chips, and evaluation kits (EVKs).

FIGURE 2: NXP MATTER-COMPLIANT PLATFORMS AND DEVELOPMENT KITS



Source: Moor Insights & Strategy

Each platform has an EVK, a development board that exposes all platform features and works with NXP's Matter-tested open-source software. After downloading all platform software from GitHub, NXP's "Getting Started" documentation walks developers through connecting the hardware, configuring the OS, setting up the Matter development environment, and building example applications. Application programmers can perform all these steps without specialized embedded knowledge or assistance from system programmers. Software development in high-level languages begins immediately after setting up the platform environment.

Matter production platforms

While applications take shape on the development boards, requirements for processor performance, networks, memory, flash, and I/O come into focus. The four NXP Matter SoC platforms offer many options for processors, radios, security chips, and accelerator subsystems. However, for Matter developers, processor, radio, and security subsystem choices are the most consequential. Table 2 drills down into each SoC platform to show some popular NXP options for Matter-enabled SoCs and radio chips.

TABLE 2: MATTER NETWORK RADIO OPTIONS

Matter SoC Platforms			Radio Subsystems				
Processor type	**Radio type**	**Part #**	**Chip**	**Wi-Fi**	**Thread**	**BLE***	**NFC**
MPU (Linux)	Hosted (Multi-chip)	Various i.MX 9, 8, 6	IW612	6	Y	Y	
			K32Wx	n/a	Y	Y	Optional
MCU High performance	Hosted (Multi-chip)	Various i.MX RT	IW612	6	Y	Y	
			IW611	6	n/a	Y	
			K32Wx	n/a	Y	Y	Optional
MCU High performance	Standalone (Single-chip)	RW612	On-chip	6	Y	Y	
MCU Low power	Standalone (Single-chip)	K32W148	On-chip	n/a	Y	Y	

* Bluetooth Low Energy

Source: Moor Insights & Strategy

Moor Insights & Strategy offers the following observations about Matter SoC options based on conversations with experts at NXP. Please refer to readily available online documentation and contact NXP for more information.

- Bluetooth LE is in every radio subsystem. Matter can use Bluetooth LE for commissioning (installing) new devices but does not need the radio after installation.
- Tri-radio – The IW612 (hosted, multi-chip) or RW612 (standalone, single-chip) Tri-Radio should be part of every Matter product requiring Wi-Fi, Thread, and Bluetooth LE. Integrating all three radios in a single chip simplifies product design while solving critical coexistence issues from sharing the 2.4 GHz band.
- Wi-Fi-based Zigbee-Matter bridges don't necessarily need Thread, so a tri-radio chip such as NXP's IW612 with the 802.15.4 radio configured for Zigbee should work very well. However, adding Thread connectivity to a Zigbee bridge might require an additional hosted Thread radio chip like the K32Wx, depending on performance requirements and how Thread is used. Bridges are complicated, so MI&S recommends contacting NXP for design assistance.
- Near-field communication (NFC), an option on the K32Wx, is a convenient and secure alternative to a QR code for starting the Matter commissioning process. It's a helpful addition for many consumer products where the printed label isn't visible after installation. Most smartphones have NFC, so there are no significant deployment barriers.

NXP offers a broad Matter silicon portfolio that engineers can assemble in dozens of combinations. This flexibility has little or no software impact because NXP abstracts the hardware characteristics in the board support software layers and presents a consistent API across all configuration options. Application developers can work independently using the EVKs, while hardware engineers choose the processors, network subsystems, security hardware, memory, flash, I/O, and accelerators for production deployment. Simultaneous hardware-software development is a significant advantage of developing on platforms with fully integrated and tested software stacks.

Planning for Secure Manufacturing: Matter Security, Privacy, and Attestation

Product security is a first-order concern for CE manufacturers because consumer perceptions of safety and privacy affect purchase decisions and brand reputation. Security and data protection are fundamental Matter design tenets – built into the specification from the start. Matter adapts standardized, proven, widely deployed security technologies for consumer product applications in residential environments. This approach ensures that Matter security is comparable to the devices we use daily for communication, e-commerce, work, and entertainment.

The MI&S white paper "Matter – Making Smart Homes More Secure" explains Matter security in detail. In this paper, we'll summarize the three steps every manufacturer must take to build secure Matter products: (1) design products to meet Matter security standards, (2) certify that the product performs as designed, and (3) prove the validity and provenance of each product. Only products that meet these requirements may display the Matter logo and join Matter Fabrics.

Designing and developing secure Matter products

Matter security is technically complicated but easy to use. Much of the densely worded 951-page version 1.2 specification is about security. Despite its underlying complexity, Matter devices are easy for consumers to set up, usually with a single tap on a phone. Matter also makes it easy for developers without deep security expertise to build compliant products.

For developers, GitHub repositories provide thoroughly tested open-source implementations of the complete Matter software stack, including security software, networks, and Matter-ready silicon platform security features such as secure enclaves, secure elements, and protected memory. Manufacturers that use Matter-enabled silicon platforms avoid costly and risky security engineering and focus on value-added application development.

NXP has all the Matter security ingredients required for successful development and rapid product certification. As a board-level member company of the CSA, Thread Group, and Wi-Fi alliance, NXP helped define the specifications and was one of the first semiconductor companies to offer Matter-certified platforms with everything developers need to create secure products – silicon, software, development boards, reference designs, and sample applications. NXP's broad platform portfolio, platform-independent software implementations, and deep expertise in Matter, Thread, and Wi-Fi simplify development and reduce risk. The company's Matter-ready platforms are about as close to plug-and-play as Matter can be.

Matter product certification

The Matter logo on a product means it has passed tests by independent, accredited labs, confirming compliance with Matter specifications. The logo assures consumers that products are genuine – functionally secure, easy to install, and interoperable with other Matter products.

To certify a product, manufacturers must do three things:

1. **Join the CSA** – Besides other benefits, membership provides access to pre-released specs, intellectual property, test tools, the Matter certification process, and the distributed compliance ledger (DCL). DCL is a blockchain-based distributed database that lists the certification status and roots of trust for all Matter products.
2. **Develop products using trusted software** – Use open-source software from Matter, OpenThread, and a trusted silicon supplier such as NXP. Using platforms already certified in other products minimizes certification risk.
3. **Certify products** – The CSA authorizes a global network of independent laboratories to test products for compliance with Matter specifications. When a product passes all tests, the labs notify the CSA. The CSA then issues a certificate declaration (CD) and updates the DCL with the corresponding CD ID.

Matter product attestation

Matter manufacturers must factory-install a device attestation certificate (DAC) into every device on the production line to attest that it is genuine, certified, and trustworthy. When customers install the product on home networks, Matter's automated commissioning process validates these credentials and provisions the operational certificates that enable network participation. Please refer to the previously mentioned security white paper – "Matter – Making Smart Homes More Secure" – for detailed information about certification, attestation, and the commissioning (device deployment) process.

NXP EdgeLock 2GO

Generating and managing DACs is a rigorous process. Only CSA-authorized product attestation authorities (PAAs) may generate these certificates, and the CSA defines strict requirements for this vital role. Becoming a PAA requires costly and ongoing security and privacy protocols, operational controls, physical security, and regular audits. Most product manufacturers should outsource this function to a vendor-independent (non-VID Scoped) PAA, such as NXP. NXP generates DACs for multiple manufacturers, even for products that do not contain NXP silicon.

NXP offers a comprehensive service for managing this process – EdgeLock 2GO. This service provides two options for managing DAC distribution: (1) inject DACs into products on the production line or (2) pre-install DACs directly in Secure Element or Secure Authenticator chips during silicon manufacturing.

Secure Element and Secure Authenticator chips offer enhanced system security beyond the basic Matter requirements. These chips eliminate the need for downloading and injecting DACs in device factories and have Common Criteria EAL 6+ certification for protection against advanced hardware attacks. These external components require hosted platforms (described in the Matter Platforms section of this paper), precluding standalone (single-chip) SoCs. Standalone SoCs such as the RW612 and K32W148 have Matter-compliant on-chip secure enclaves but no option for pre-installing DACs and are not EAL 6+ certified.

MATTER SUPPLY CHAIN

Our investigation into Matter platforms predicts significant restructuring of CE supply chains. Traditionally, connected embedded device developers cobbled together silicon and software components to create unique product designs with limited interoperability. With Matter, the "cobbling" comes to an end. Developers start with Matter-ready silicon and development boards, download open-source software from GitHub, compose applications in high-level languages using mainstream toolchains, and build products that address large-scale use cases spanning products from multiple manufacturers.

> **Matter transforms CE supply chains into a platform model.**

Matter transforms CE supply chains into a platform model, enabling product companies to focus development resources on applications and minimize undifferentiated system-level engineering. NXP and other silicon companies are already aligned with this trend, supplying off-the-shelf Matter platforms that immediately support application development and rapidly scale up to production designs. ODMs typically emerge in this environment, designing semi-custom platform-based hardware and manufacturing product components at scale.

Product companies that worry about losing competitive advantages in this new OEM / ODM world are not getting the big picture. Standardized platforms make connectivity, system-level code, and old-school "home automation" use cases table stakes. MI&S recommends that CE companies use Matter-based platforms to create high-value applications that align with industry-wide, AI-powered smart home technology investments.

OTHER CE PRODUCT MANUFACTURER CONCERNS

Here are the top five questions MI&S hears as CE companies consider transitioning to a Matter-based product strategy.

Complexity and cost

Q: Matter devices with Thread or Wi-Fi are much more complicated and costly than my existing home automation designs, so why should I move to Matter?

A: Although technological progress adds complexity, standardizing connectivity reduces platform variability. For platform suppliers, fewer SKUs means higher volume production at lower costs. For CE manufacturers, standard platforms simplify application software development and enable higher-value use cases such as ambient computing and autonomy. The platform cost is decreasing as the software benefits increase.

Competitive differentiation

Q: Does commoditizing connectivity reduce my competitive differentiation opportunities?

A: No. To consumers, connectivity is plumbing. Features and experiences differentiate products, not connectivity. Commoditizing connectivity enables product companies to directly address consumer requirements by creating innovative user experiences and building higher-level solutions that amplify the totality of a consumer's investment in interoperable smart home products. The alternative, continued investment in isolated connectivity schemes, ensures rapid obsolescence.

Many companies express concern that Matter standards might not support innovative new product features, but the specifications address this issue head-on. Manufacturer-specific extensions allow product-specific enhancements that do not have to wait on industry-wide standardization. Matter accelerates innovation velocity by providing a clear path for new features while providing industry-wide interoperability for existing commands and queries.

Legacy transition

Q: My company has a large installed base of products that use a "legacy" connectivity scheme. Can I migrate to Matter over the next few years, preserve my customers' investments in older technology, and offer a smooth migration path?

A: Yes. There are two ways to do it – bridges and adding Matter to Wi-Fi devices.

Matter specifications include bridges to ease the transition. A Matter bridge is a hub that connects to a legacy ecosystem using its native radios and protocols and translates messages to and from Matter, mapping legacy device functions to equivalent Matter device definitions and clusters. The mapping is good enough for basic functionality, but never perfect.

The other approach applies to Wi-Fi devices that already have cloud services and a smartphone app. Manufacturers can enhance the device to add Matter support, enabling it to join a Matter fabric while still functioning with the manufacturer's existing app. Manufacturers can sometimes add this Matter support to Wi-Fi devices via software updates.

Development teams

Q: What software skills should I recruit and retain to build smart home products in the Matter era?

A: Developers skilled at squeezing OSes and applications into small, embedded platforms are in demand today, and that isn't changing. However, off-the-shelf, standards-based embedded platforms empower embedded engineers to operate at a higher level – configuring OSes instead of customizing them, validating network stacks instead of assembling them from scratch, and adding specialized I/O and accelerator components instead of constructing complete device platforms. Platforms with integrated, pre-tested hardware and system software let embedded engineers work more efficiently, while application developers use mainstream languages and toolchains to write advanced applications. In other words, Matter platforms up-level system engineering roles and open up embedded application development to a larger population of engineers.

Customer demand

Q: When will we see a spike in demand for Matter products? We're seeing interest but no "hockey stick" demand curve.

A: At the time of this writing, a year has passed since the CSA released Matter 1.0. According to the Matter 1.2 press release (23 October 2023), 1,214 products are now certified, and the number of companies in the working group has grown by 24%. The new update adds nine new device types, including high-volume products such as "white goods" appliances (refrigerators, ACs, dishwashers, laundry equipment, robotic vacuums, smoke alarms, air quality sensors, air purifiers, and fans). Industry take-up is impressive, and MI&S expects significant acceleration in 2024 as Matter and Thread support become "standard equipment" in more mass-market products.

This is how Matter arrives in most consumer homes. It's not something consumers go out and shop for. Instead, Matter comes pre-installed on name-brand CE devices and appliances. Like Thread – most US homes already have it, but few consumers know it.

Bottom line

Matter is essential for the next generation of smart home use cases, and we see no significant adoption barriers. Developers should base new product designs on Matter and develop comprehensive strategies for adding customer value with smarter, AI-enabled, and increasingly autonomous applications.

Matter Strategy in a Nutshell

Let's summarize some of this paper's key points.

- **Matter is delivering as promised.**
    - Evidence includes ongoing support from major CE brands, impressive membership growth, over 1200 certified products, and increasing device coverage.
- **Matter's diffusion model is now apparent.**
    - It's not something that consumers shop for and buy. It's integrated into hundreds of millions of mainstream CE products.
- **AI is making smart homes smarter, and Matter plays an important role.**
    - AI-enabled use cases such as ambient and autonomous computing are driving smart home growth for the foreseeable future.
    - Advanced AI use cases need situational context – the ability to perceive, understand, and respond to complex situations in the world

all around us. In each home, the context includes dozens (potentially hundreds) of CE products – lights, plugs, appliances, systems, sensors, controls, actuators, and other connected devices.
    - Universal device interoperability is Matter's killer feature.
- **Off-the-shelf Matter platforms make advanced, AI-enabled edge application development practical.**
    - Suppliers like NXP provide off-the-shelf platforms with Matter-ready hardware, pre-integrated open-source software, and comprehensive security services.
    - Matter platforms enable CE companies to shift development resources from undifferentiated system engineering to value-added application software development.
    - System-level customization increases technical debt. Whenever possible, CE developers should use platform software as-is.
    - Mainstream languages and DevOps practices commonly used on cloud, PC, and mobile platforms are increasingly practical on embedded devices[7]. CE companies now have more flexibility in recruiting and hiring application programmers to focus on AI-enabled ambient and autonomous use cases.
- **Matter-enabled smart home ecosystems**
    - CSPs provide advanced smart home ecosystems with footprints in the hundreds of millions. These companies invest heavily in AI, so mainstream CE manufacturers can leverage these widely deployed ecosystems rather than building new ones from scratch.
    - While CSPs focus on mainstream consumers, some manufacturers must create new ecosystems for function-focused applications and vertical markets other than smart home. This process becomes more practical as the CSA improves Matter's multi-admin capabilities.

The confluence of AI and Matter is an inflection point in the evolution of smart homes. CE companies embracing Matter can leverage connectivity ecosystems already present in hundreds of millions of homes. As connectivity becomes table stakes, applications transcend simple use cases like remote control and "if this, then that" home automation to embrace the full potential of AI-enabled ambient interaction and whole-home autonomous controls. This is how smart homes finally become truly smart.

[7] "There’s now enough computing power available on a US $0.70 CPU to make Python a contender in embedded development." IEEE Spectrum – Top Programming Languages 2023

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