QUECTEL

Build a smarter world

Single board computers white paper

Accelerating design of intelligent edge IoT devices – a guide to faster development and deployment

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INTRODUCTION

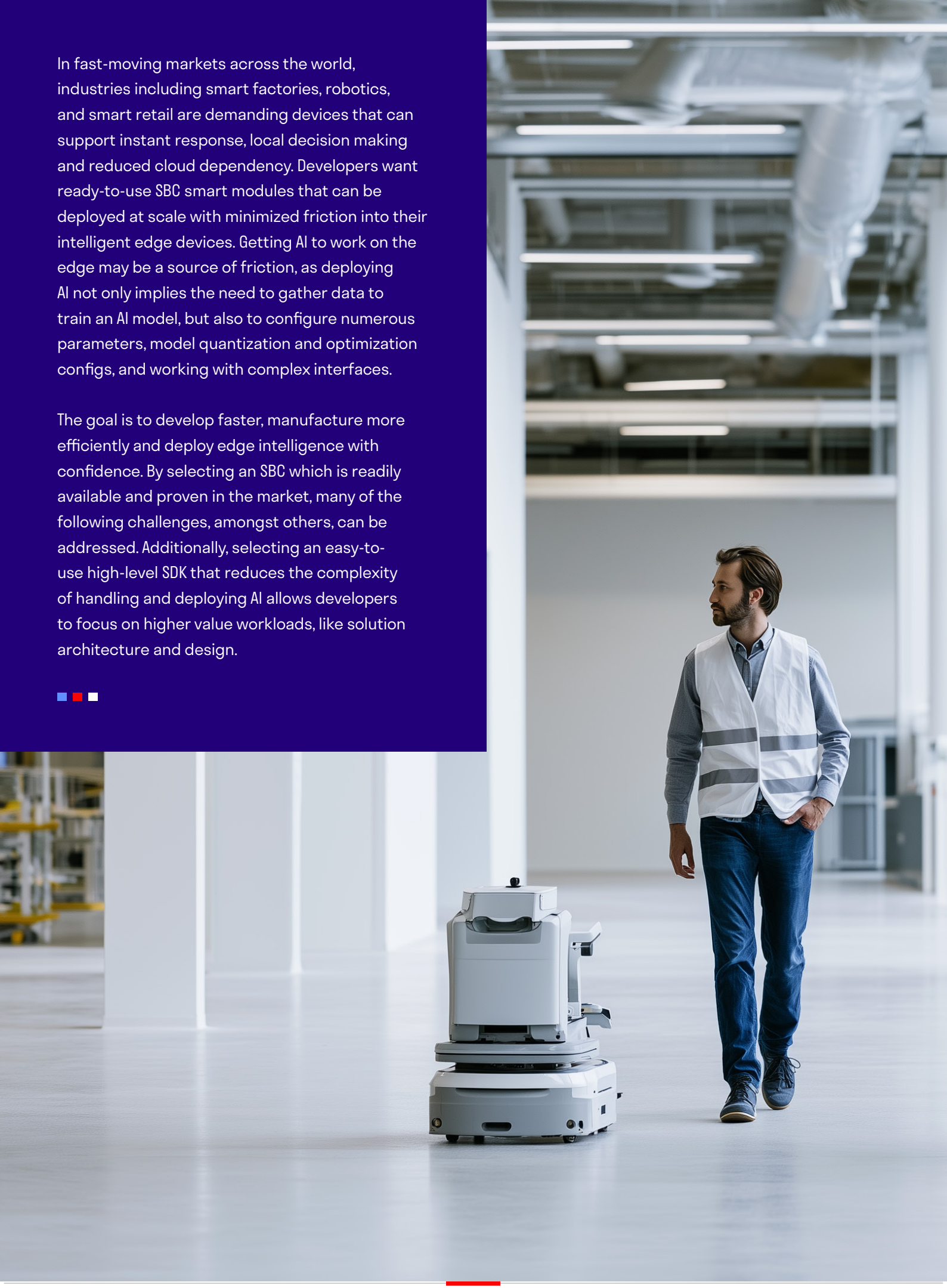
As greater intelligence at the edge becomes a baseline requirement for IoT devices, developers need to address real-time processing demands, power efficiency and requirements for low latency in their designs. Traditional cloud architectures struggle to meet applications' low latency needs due to the need for edge-cloud communication and is negatively associated with vendor lock-ins. As a result, organizations are looking to reduce latency, cloud dependency, and communications traffic by integrating greater intelligence into their devices.

By implementing artificial intelligence (AI) on the edge, devices gain greater autonomy and can eliminate latency because decisions can be made in the moment on the device. However, incorporating intelligent functions into devices adds complexity and can add to devices' overall costs. The situation is compounded by the shortage of specialized edge and device intelligence engineers as well as the increased workload and complexity involved in integrating multiple components to achieve greater on-device intelligence.

Developers are increasingly turning to single board computers (SBC) to unify multiple functions in a single device, provide the intelligence they need in current generation edge devices, and hold the expectation of working with AI SDKs that "just work" without going through endless documentation. There are significant advantages to this approach which allows organizations to streamline investment in R&D and achieve faster time-to-market. The key benefits of using SBCs for development include reducing the hardware complexity, where developers can immediately plug-and-play an SBC out of the box and start developing immediately on an SDK that does what it needs to.

In fast-moving markets across the world, industries including smart factories, robotics, and smart retail are demanding devices that can support instant response, local decision making and reduced cloud dependency. Developers want ready-to-use SBC smart modules that can be deployed at scale with minimized friction into their intelligent edge devices. Getting AI to work on the edge may be a source of friction, as deploying AI not only implies the need to gather data to train an AI model, but also to configure numerous parameters, model quantization and optimization configs, and working with complex interfaces.

The goal is to develop faster, manufacture more efficiently and deploy edge intelligence with confidence. By selecting an SBC which is readily available and proven in the market, many of the following challenges, amongst others, can be addressed. Additionally, selecting an easy-to-use high-level SDK that reduces the complexity of handling and deploying AI allows developers to focus on higher value workloads, like solution architecture and design.



REAL-TIME PROCESSING AT LOW LATENCY

By enabling data to be processed, analyzed and acted upon within the device, IoT organizations remove the need for data to be transmitted to the cloud for centralized processing. This eliminates network latency and time taken within central servers to assess the data, make a decision and issue an instruction to the device, which can involve further network latency. Deploying AI on edge devices allows data to be processed in real-time with minimal latency in the decision-making process.

On-device AI can reduce the volume of data sent to the cloud for processing and enables cloud expenses to be controlled. In addition, greater embedded AI processing capabilities allow for greater flexibility for devices once in deployment, by enabling new functions to be added and supported during the device service lifecycle and helps to future-proof devices.

COMPLEX INTEGRATION CHALLENGES

For smart manufacturing, transportation, robotics, smart retail, healthcare and smart city systems providers, the need to integrate all of these components into a single stable system is the key to unlocking efficiency. By selecting SBCs, they can achieve pre-integration of a set of hardware functions alongside the software systems that are essential for smooth device operation. Attempting to design efficient devices that rely on individual components from multiple vendors supported by separate software systems creates a convoluted, complex architecture that is both time-consuming to design and complex to operate. Integration complexity today is one of the greatest time-to-market bottlenecks faced by developers of intelligent edge devices.

Traditional cloud architectures struggle to meet expectations for instant response times, local decision-making, reduced cloud dependency and real-time analytics which is why edge computing, on-device AI, edge intelligence and local data processing are becoming important priorities in the global IoT modules market.

Key integration challenges for global IoT developers include integrating SoCs and chipsets, operating systems, such as Linux, Android, connectivity technologies from 5G and LTE to Wi-Fi, Bluetooth and GNSS, cameras and displays, AI frameworks and edge processing tools, and cloud platforms. These need to come together into a single reliable and scalable system. This need is especially acute in industrial automation, robotics, smart kiosks, medical devices and AIoT applications.

Today, integration complexity is one of the largest barriers to faster product launches, development efficiency and cost optimization.

PRIVACY, SECURITY AND COMPLIANCE

As intelligent IoT devices process more sensitive data, developers have encountered growing pressure to reduce cloud dependency and process data locally. They also need to strengthen endpoint security to ensure they comply with regional regulations. This need is critical in more sensitive sectors such as healthcare, smart surveillance, financial systems, industrial automation, connected vehicles and smart retail.

Global IoT trends are driving demand for secure boot, hardware root of trust, encrypted communications, device authentication and edge-based processing.

CONSTRAINTS TO SCALABILITY

The relative newness of the current focus on edge intelligence means developers are struggling with fragmentation as different chipsets, operating systems and classes of devices are utilized across their deployments. They struggle to maintain consistent performance, inter-device compatibility and deployment stability as a result. And, as volumes increase into mass scale IoT, edge devices, smart modules and intelligent systems continue to proliferate and diversify, increasing the scope and size of the challenge across the entire lifecycle.

Cloud ecosystems, software compatibility and varying global network standards need to be considered and these issues become more complex as smart modules, AI-enabled edge devices and connected systems continue to diversify rapidly. Enterprises increasingly want standardized development environments, modular platforms, scalable ecosystems and simplified deployment workflows to ensure they can develop and bring new products to market quickly and efficiently.

RELIABLE CONNECTIVITY WITH GLOBAL COVERAGE

While the connection itself was always critical with traditional cloud architectures, it is now important that intelligent edge devices are supported with flexible connectivity, often involving multiple protocols. Modern IoT deployments increasingly require always-on connectivity, seamless roaming, low-latency communication and high uptime reliability. Use cases such as logistics and fleet management, industrial IoT, remote monitoring, smart cities and connected healthcare all rely on these attributes.

Developers therefore now need multi-mode connectivity comprised of 5G, LTE, Wi-Fi and LPWAN along with satellite communication options and redundancy and failover capabilities to ensure uninterrupted device operation globally.

MEET THE TIME-TO-MARKET CHALLENGE

Developers and IoT companies are under more pressure than ever before to launch new products faster, to reduce development complexity, minimize certification effort and accelerate prototyping. Traditional embedded device development cycles are often too slow to enable companies to succeed in competitive markets.

A new approach is therefore needed to accelerate development and demand for pre-integrated smart modules, development kits and SBCs, pre-certified connectivity solutions, simplified software ecosystems and low-code or Python-based development tools is growing significantly. Developers need to simplify architectures so they streamline processes and reduce the number of components used and move forward with confidence. Adoption of an SBC smart module can address many of the pressures and concerns developers face as they respond to the need for speed.

THE SBC AND EDGE AI APPROACH

SBC smart modules encompass a rich and wide range of functionality extending from entry-level products that combine lower processing power with lower resolution cameras and video support to premium modules with a wider choice of connectivity, including 5G cellular and multiple GNSS bands, and greater computing, camera and video capabilities. Developers are faced with deployment issues such as crashing apps, high latency, excessive memory consumption, incorrect results, inability to quantize and unsupported operators as they design in CPUs, GPUs and NPUs to support greater intelligence. These challenges fit in three main categories: getting started, achieving performance across many devices and rapid iteration.

Getting started presents obvious difficulties because there is a need to carefully define how development of on-device intelligence should progress. SBCs make this easy because it is usable immediately out-of-the-box and supports a wide range of AI algorithms developed by Quectel with robust performance that have gone through multiple iterations of improvements. Next, the performance needs to be made consistent so the same outcome is experienced across many devices.

A standardized line of SBC products by Quectel helps achieve this, together with a standardized SDK across Quectel's range of AI algorithms. Finally, developers need to be able to manage rapid iteration so new functionality can be added and distributed across devices at scale. SBCs are simple yet they contain all the tools and interfaces and support a developer needs to quickly test out new ideas, and when coupled with easy-to-use high-level AI algorithm APIs accessible through standardized SDKs, developers can achieve separation of concerns between their solution application and the AI algorithm easily, and update either one or both without worrying about dependency due to the standardized interface layers.

Traditionally, intelligence at the edge is enabled by the combination of modules, platforms, connectivity and services that integrate and interact with each other to manage the data flows and communications that power the intelligent edge. Intelligent edge IoT devices process data either directly within the device or via local servers, allowing them to generate insights and potentially take action closer to the data source. This on-device intelligence can enable significant efficiency benefits in comparison to traditional cloud which relies on sending device data to the centralized cloud for processing and then communicating back to the device on what action to take.

In addition to saving on the expense of communicating, intelligent edge systems deliver far more rapid decision-making capabilities thanks to minimizing latency. Intelligent edge is especially valuable in IoT for industries operating in remote locations with limited connectivity.

The addition of edge capabilities is helping to make intelligent computing available everywhere from wearables to robots to laptops, tablets and smartphones. In IoT, increasingly intelligent applications and use cases are being powered by this greater intelligence at the device level and every product, application and device can now be designed with embedded intelligence to enable appealing new services.

For example, functions such as dictation, text recognition and machine translation can be added alongside optimized battery charging, video calling, phototagging and feature-rich cameras. On-device intelligence is helping developers balance costs and performance with the privacy and regulatory requirements of use cases and users.

HOW QUECTEL HELPS

To help developers achieve their goals, all Quectel smart modules are system-on-chip platforms and offer Open Android, Linux or Ubuntu operating systems. The smart modules contain high performance CPUs, GPUs, NPUs and DSPs and offer built-in Wi-Fi and Bluetooth in addition to cellular connectivity which includes 5G, LTE, UMTS, GSM and GNSS. The modules have global certifications and a wide range of peripheral interfaces are on offer. In addition, various multimedia functions are supported including LCD, audio, cameras and video. Finally, all Quectel smart modules are backed by Quectel's excellent customer service.

Quectel helps developers address common intelligent edge design challenges by reducing the complexity of hardware, software and connectivity integration. Through smart modules, evaluation kits, software support, certification assistance, PCBA services and JDM/ODM cooperation models, Quectel enables faster prototyping, driver development, board bring-up, simplified global deployment, and a clearer path from concept to mass production.

To develop devices and enable intelligence at the edge, Quectel offers a series of platforms to help developers address the challenges outlined earlier. Quectel's smart module evaluation kit includes the module, the test equipment adaptor (TEA) and the evaluation board (EVB). This includes interfaces such as UART, USB Type-C, LCM, audio, camera, SIM and SD card. Supported accessories include antennas, earphones, adapters, USB Type-C connections, RF cables, USB to UART cables and U-disk. The kit is further supported by an evaluation (main) board schematic, the TE-A (carrier) schematic, the evaluation and TEA board bill of materials and a smart module SDK.

To assist developers, Quectel offers a portfolio of value-added services. These include component sourcing and support for functions such as hardware board light-up, camera integration, LCD bring-up and tuning of the device. Quectel also offers generic or customized PCBAs and offers software customization including customizing of the device tree and customized algorithms and functions. Quectel can also streamline certification with existing carrier certifications for its modules and antennas and RED and CE certifications for devices.

Quectel also offers PCBA and device service co-operation models. Taking the joint development manufacturer (JDM) model, Quectel takes specifications from the customer and jointly designs the system, hardware and software with the customer. Design validation is also undertaken jointly and, once final approval has been received from the customer, Quectel performs the manufacturing.

In contrast, the original design manufacturer (ODM) model sees Quectel design the system, hardware and software to the customer's specifications. Quectel also performs design validation. Final approval is given by the customer and Quectel does the manufacturing.

Quectel has highly automated manufacturing capability with its ISO 9001, IATF 16949, ISO 14001 and ISO 45001 certified facility. The factory features an automatic de-panelling machine and optical inspection system, an automatic download and RF calibration test station and an automatic module flatness inspection system. In addition, the factory offers a convection oven for module dehumidification, an automatic tape and reel packaging system and a real-time monitoring system for quick response at the production line. Quectel is putting intelligence at the edge on its manufacturing lines, with automated defect detection which can detect empty, cracked or wrapped tin as well as warping, pin foot skew and tin slag. Quectel also provides shield cover defect detection to address issues such as oil stains and scratches.

REAL-WORLD USE CASES

SMART MANUFACTURING AND INDUSTRIAL AUTOMATION

Industry 4.0 adoption is accelerating worldwide as industrial environments require robust and reliable modules. There is a growing reliance on local processing to reduce latency and downtime. Mordor Intelligence has reported that on-premises deployment models accounted for 57.63% of Industry 4.0 solutions deployed in 2025.[2] Use cases such as industrial human-machine interface (HMI) panels, machine vision systems and predictive maintenance are turning to intelligent SBCs. In addition, autonomous mobile robots (AMRs), edge AI quality inspection, factory monitoring gateways and industrial handheld terminals are driving adoption of greater intelligence at the edge.

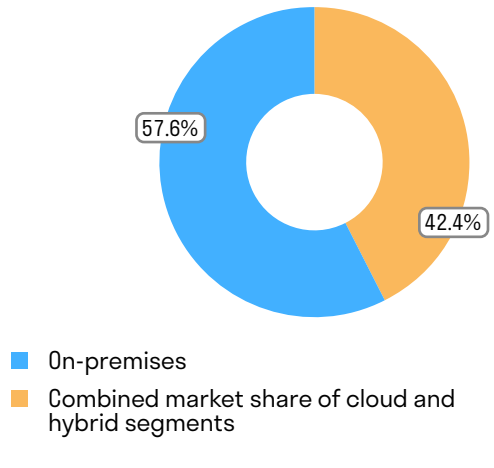
ROBOTICS AND AUTONOMOUS DEVICES

Adoption of robotics is accelerating globally both in enterprise and consumer sectors. For many robots, edge AI is a critical enabler of autonomous operations and robots that require real-time decision-making are increasingly dependent on reliable, low-latency connectivity. Use cases include service, delivery and cleaning robots, warehouse automation, sensor fusion platforms and companion robots.

SMART RETAIL

Smart retail has transformed in recent years with a new generation of smart vending machines, self-checkout kiosks, retail cameras and digital signage driving richer customer interactions and more efficient retail. The ability for these machines, interactive PoS systems and customer analytics terminals to operate autonomously and process interactions and requirements at the edge is improving customers' retail experiences and providing retailers with greater automation and better insights into customers. AI and multimedia processing are supporting several easy-to-visualize use cases for customers.

FIGURE 1 Industry 4.0 market: market share by deployment model, 2025



Source: Mordor Intelligence

1 https://www.iea.org/reports/global-ev-outlook-2026/executive-summary

2 https://www.mordorintelligence.com/industry-reports/industry-4-0-market

SMART HOME AND CONSUMER DEVICES

Consumer IoT adoption continues to rise globally driving demand for seamless connectivity and AI features. Analyst firm Berg Insight predicts that by 2029 about 90.9 million homes in North America will be smart, equal to about 59% of all homes in the region.[3] The European market is still behind North American in terms of market penetration with the number of smart homes in the region forecast to reach about 102.8 million at the end of 2029, representing a market penetration of close to 42%. The growing smart ecosystem integration with popular, leading global brands is seeing devices such as smart home hubs, voice-controlled appliances, smart panels, home gateways, smart displays and multimedia control systems increasingly operate with embedded intelligence. Users want multi-protocol devices that can interact across multiple ecosystems within their homes and value devices with intelligent edge capabilities that can immediately control functions in their homes.

HEALTHCARE AND MEDICAL DEVICES

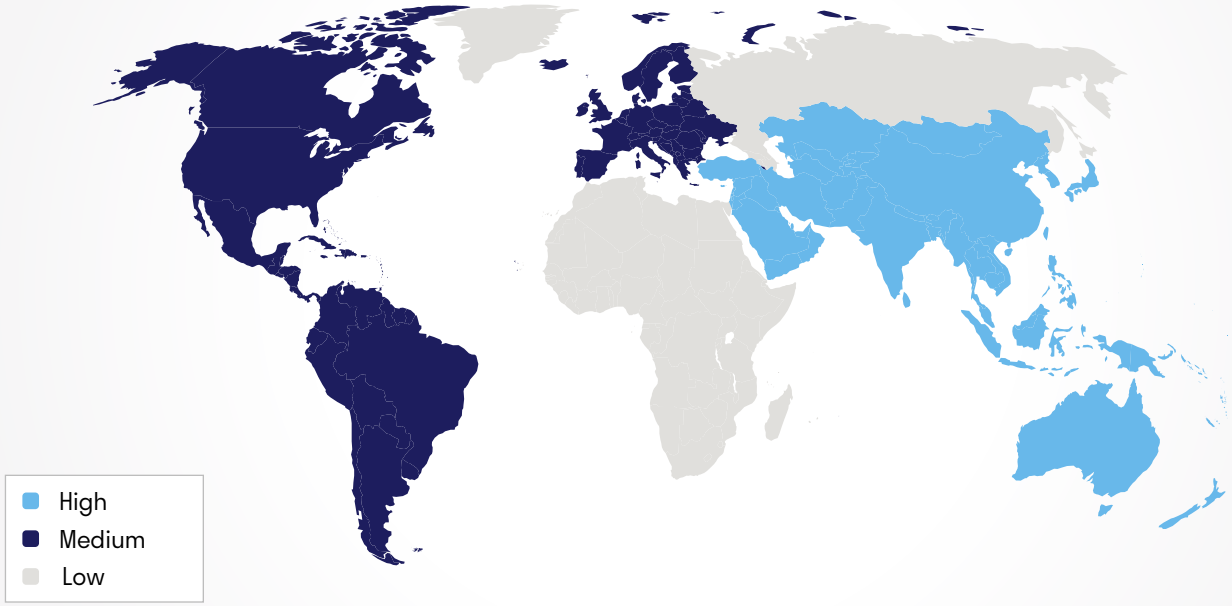
Healthcare is both a mission-critical and privacy sensitive market so having to communicate patient data over the cloud presents obvious challenges, costs and delays. Greater intelligence at the edge means data can remain on the device and edge processing can be utilized to deliver immediate decisions without transmitting private information. Connected healthcare adoption is growing rapidly so there is a high need for secure and reliable IoT systems. Devices such as patient monitoring systems, smart diagnostic terminals, telehealth devices, medical image processing systems and elderly care monitoring are all benefiting from on-device intelligence.

SMART SECURITY AND SURVEILLANCE

Systems that support security and safety increasingly rely on video to enable remote management of locations. Demand for real-time local video analytics is increasing and there is a need to reduce the bandwidth and cloud processing costs associated with traditional architecture. Systems such as smart network video recorders (NVRs), access control terminals, facial recognition devices, edge video analytics and safety monitoring systems benefit from enhanced intelligence at the edge because they can eliminate the need to transmit video to the cloud. Security applications require low latency and reliability. Substantial savings in bandwidth costs can be made and organizations can reduce their dependency on cloud services.

3 https://www.berginsight.com/more-than-190-million-european-and-north-american-homes-will-be-smart-in-2029

FIGURE 2 Smart homes market CAGR (%), growth rate by region, 2026-2031



Source: **Mordor Intelligence**

SMART AGRICULTURE AND ENVIRONMENTAL MONITORING

The growth curve is well-established in smart farming and analyst firm, Berg Insight, has predicted the market for precision agriculture systems will hit €9.5 billion in 2028 as technologies from telematics to variable rate technology are adopted.[4] Innovations in remote connectivity and edge intelligence have come together to help address the growing focus on sustainability and efficiency in farming. By enabling more information to be processed at the edge, intelligent smart farming gateways, livestock monitoring devices, irrigation monitoring and crop analytics systems all are able to act with greater autonomy and reduce bandwidth consumption and cloud usage. For environmental sensing stations, for example, the ability to process data on the device and act on it in near real-time provides compelling advantages over cloud-based systems.

ENERGY, UTILITIES AND SMART INFRASTRUCTURE

Utilities and energy providers are increasingly digitalizing their infrastructure in markets across the globe. This mission critical infrastructure requires secure, reliable, always-on connectivity to support increasingly complex use cases from EV charging to bi-directional grids that accommodate customers' generation of power from renewables. Devices that need greater on-device intelligence include smart meters, renewable energy monitors, EV charging stations, smart grid gateways and remote utility monitoring systems.

MULTIMEDIA, EDGE AI PROTOTYPING AND DEVELOPER ECOSYSTEMS

Developers increasingly need to design devices that integrate edge intelligence with multi-protocol connectivity and processing capabilities. Priorities are security, cost efficiency, low power consumption, compact form factors and flexibility. There is strong alignment here with smart SBC and AI module ecosystems that are powering AR and VR devices, videoconferencing systems, AI edge development kits and rapid prototyping. To achieve these aims, developers need systems that enable rapid proof-of-concept development, edge application testing, environments to optimize models and systems that help with embedded Linux or Android development. Quectel's Pi ecosystem has huge applicability here, enabling developers to access new capabilities and accelerate their time to develop.

4 https://www.berginsight.com/the-precision-agriculture-market-to-reach--95-billion-worldwide-by-2028

OUTCOMES

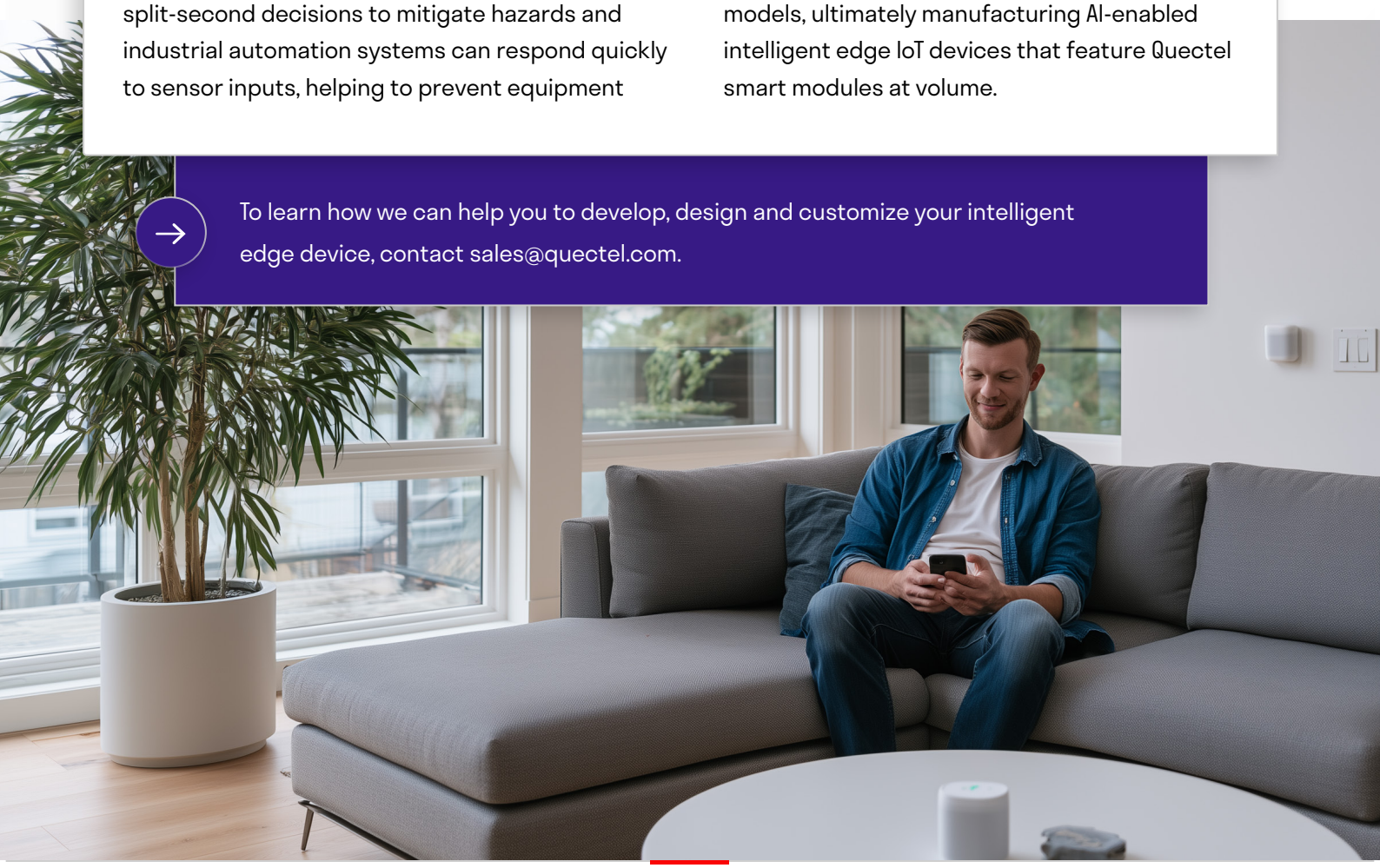
Intelligent edge capabilities enabled by smart modules are powering faster, safer, more responsive operations across all sectors. The benefits of adopting edge intelligence in IoT go well beyond operational efficiency as scalable, resilient and responsive systems are created. Edge devices distribute decision-making capabilities, so if one unit fails, the network remains operational and is therefore making this approach suitable for critical infrastructure like power grids, healthcare facilities and smart city environments.

Intelligent edge IoT can also enable highly personalized user experiences. Smart home devices can tailor interactions to individual user preferences in real-time and retail kiosks can recognize returning customers and offer customized product suggestions.

Low latency is a particular strength of intelligent edge IoT. This is vital in systems that require split-second decisions to mitigate hazards and industrial automation systems can respond quickly to sensor inputs, helping to prevent equipment failures and downtime. Privacy and security are also enhanced since sensitive data is kept on-site rather than sent to the cloud. Healthcare monitors, for instance, can store patient data locally, while security systems can keep video feeds within premises. This builds user trust while helping to resist data breaches and ensuring compliance with privacy laws.

Recent technological advances are seeing increasingly powerful edge devices developed with the computing power to process greater amounts of information in the device and then take action without the need for back-and-forth communications to centralized intelligence. Greater intelligence enables faster, more automated decision-making to enhance the user experience and support safer, more secure operations. Quectel's role is to help developers navigate the complexities and create optimized devices across various models, ultimately manufacturing AI-enabled intelligent edge IoT devices that feature Quectel smart modules at volume.

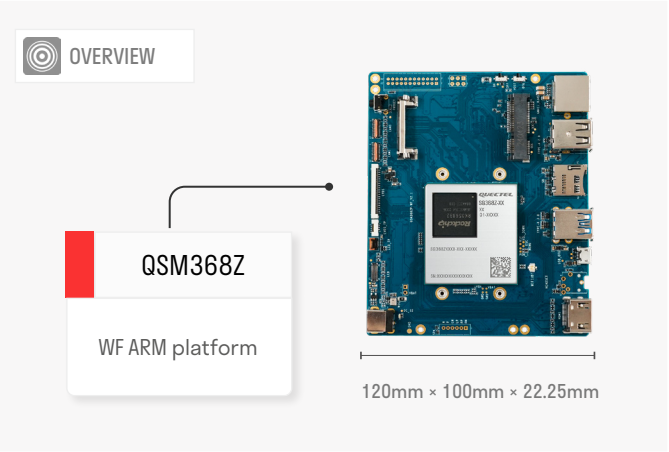
To learn how we can help you to develop, design and customize your intelligent edge device, contact sales@quectel.com.



APPENDIX I – QUECTEL PRODUCTS

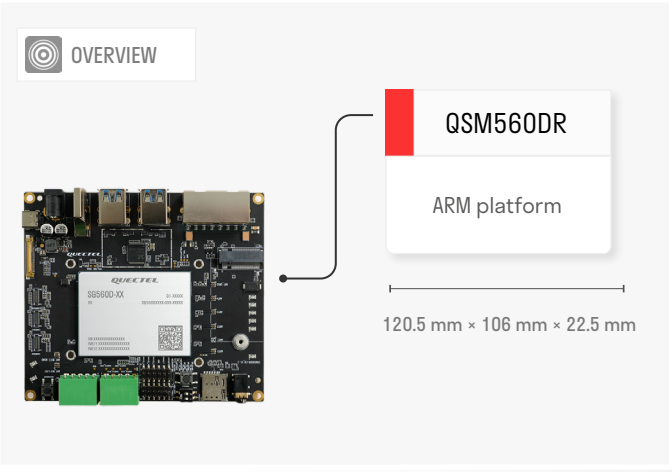
The SBCs

Powered by the Rockchip RK3568 processor, the QSM368Z combines a quad-core Cortex-A55 CPU, Mali G52 GPU, 1 TOPS NPU and HDR ISP to deliver balanced edge computing and multimedia performance. Supporting Linux and Android, it offers triple-display support, 4K video encoding, Gigabit Ethernet, Wi-Fi, Bluetooth and optional LTE, Wi-Fi 6 and GNSS connectivity for industrial gateways, smart displays, machine vision and automation applications.

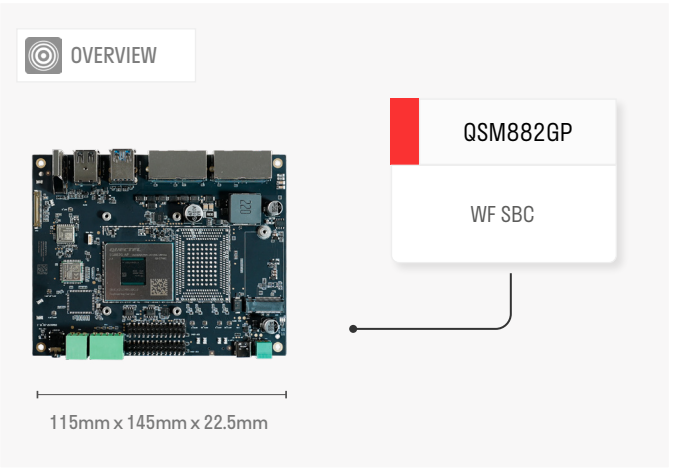


The QSM560DR is a high-performance edge computing platform featuring up to 12 TOPS AI processing and support for Ubuntu, Android and Windows. With multi-mode 5G, Wi-Fi 6E, Dual Band Simultaneous technology and industrial-grade operation from -35°C to +75°C, it is ideal for smart manufacturing, robotics, retail analytics, safety monitoring and connected infrastructure requiring low latency and high bandwidth.

Designed for versatile IoT deployments, the QSM668SR combines LTE Cat 4, Wi-Fi, Bluetooth 5.0 and optional multi-constellation GNSS positioning. Extensive interfaces including HDMI, Ethernet, USB, UART, CAN, RS232 and RS485 enable integration with sensors and peripherals. Its compact, rugged design makes it suitable for gateways, logistics, industrial control, vehicle systems, smart homes and safety monitoring solutions.



Based on the Qualcomm QCS8550 platform, the QSM882GP delivers flagship-level performance with an octa-core Kryo CPU, Adreno graphics, advanced multimedia engines and up to 48 TOPS AI processing.

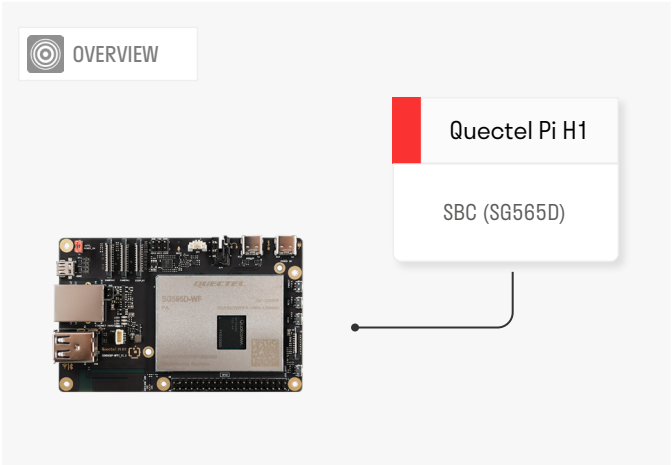


Supporting Ubuntu and Android, plus Wi-Fi, Bluetooth and extensive I/O, it addresses demanding applications including robotics, AR/VR, video conferencing, gaming, live streaming, smart retail and edge AI computing.

The Quectel Pi M1 is a compact SBC powered by the Qualcomm SM6115 processor, featuring LTE Cat 4, Wi-Fi 5, Bluetooth 5.0, Gigabit Ethernet and optional GNSS. With Linux, Android and Ubuntu support, plus Raspberry Pi compatibility, it provides a flexible platform for IoT development, embedded systems, edge computing and rapid prototyping.

Built on the Qualcomm QCM2290 processor, the Quectel Pi L1 combines LTE Cat 4, dual-band Wi-Fi, Bluetooth 5.0 and optional GNSS in a compact form factor. Featuring Raspberry Pi compatibility, dual SIM support and Linux-based development flexibility, it is ideal for connected devices, smart IoT applications and cost-sensitive embedded projects.

The Quectel Pi H1 delivers advanced computing performance through the Qualcomm QCS6490 processor, Adreno 643 GPU, 8GB LPDDR4x memory and 128GB UFS storage. Supporting Linux, Debian and Ubuntu, alongside Gigabit Ethernet, Wi-Fi and Bluetooth, it enables AI-powered edge computing, robotics, computer vision and industrial IoT application development.



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