Fundamental Development and Application of the Next Generation Edge Devices

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ABSTRACT

There is a growing need for IoT systems to minimize the use of cloud systems and enable data collection and analysis to be completed in the field. Fuji Electric is developing a platform for "edge devices" that collects data from on-site equipment and relays them to cloud systems. This next-generation device has hardware that delivers enhanced processing power and diverse connectivity in wired and wireless networks, allowing it to be used for a broad range of products. It also includes highly scalable business application frameworks and other convenient software.

1. Introduction

Conventional Internet of Things (IoT) systems were built around cloud systems, but recently, there has been a growing need to minimize the use of cloud systems and complete the process from data collection to analysis on site at factories and other locations where IoT systems are applied. With that comes changing requirements for edge devices that collect data from on-site equipment and relay them to cloud systems.

Fuji Electric is developing an edge device platform aimed at meeting these new requirements. This paper describes the development of this next-generation edge device platform and its application to Fuji Electric's products for the food and beverage distribution field.

2. IoT System Technology Trends

2.1 Expectations for edge computing

Conventional IoT systems are based on a configuration in which various types of information is collected from equipment on site at factories and other locations and stored in a cloud system on the Internet via edge devices. The collected data are analyzed using applications that use artificial intelligence (AI) or other technology on the cloud system.

For some customers, this conventional configuration gave rise to the following concerns, which posed a barrier to the adoption of IoT systems.

(a) Increased communication costs between edge devices and cloud systems
(b) Increased processing time from data collection to completion of data analysis on cloud systems due to communication-related overhead (making real-time analysis difficult)
(c) Concerns about data leaks and other security risks arising from sending data to cloud systems

To address these concerns, the focus is now on "on-site completion" IoT systems that do not involve sending data to cloud systems. For example, these systems feature a configuration in which a server PC is installed in a customer factory in place of a cloud system to collect and analyze data on site. This type of data processing using server PCs installed in the field is called edge computing.

These new IoT systems that use edge computing are expected to utilize edge devices as its computing platform. In particular, edge devices, which are installed in environments close to the on-site equipment, may be capable of realizing real-time data collection and analysis. Because edge devices are so-called embedded devices, they cannot completely replace cloud systems or server PCs, but by sharing the appropriate functions and performance, they may enable a reduction of overall system costs by minimizing the required performance of server PCs or by reducing the number of PCs required.

2.2 Computing technologies for edge devices

Computing technologies available for edge devices have evolved significantly in recent years. This owes largely to the widespread use of smartphones, and the increasing density, multifunctionality and energy saving of computing devices are remarkable. Systems on chips (SoCs) on which the elements necessary for computing (such as the CPU, the GPU, security and multimedia) are integrated have been improving in functionality and performance and have been getting smaller. In addition, systems on modules (SoMs) on which these SoCs are integrated together with memory and wired communications

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(such as USB*1and Ethernet*2), wireless communications (such as Wi-Fi*3, Bluetooth*4 and cellular*5) and other components into a single module have also evolved significantly, and their application is becoming more widespread. For these SoMs, international standards have been established for interfaces for these modules, and competition among module vendors has led to lower prices, making them easier to adopt for various embedded devices.

On the other hand, the adoption of SoCs and SoMs has its disadvantages. Because they are multifunctional, the number of man-hours required to develop their firmware (software for controlling hardware) can be enormous. However, it has become common for SoC and SoM vendors themselves to provide firmware samples, which users can leverage to speed up product development. In addition, most of these firmware applications are made into license-free open-source software (OSS) applications, which allows users to easily modify the firmware according to their product designs, and in terms of software development, they have come to be adopted for SoC and SoM embedded devices.

3. Recent Challenges in Retail Businesses

Fuji Electric provides supermarket and convenience store business owners operating brick-and-mortar stores with showcases, counter fixtures and store systems to be installed in their stores. We also provide beverage manufacturers, operators and other clients with vending machines that can sell beverages and various other goods unattended and around the clock. The business environment surrounding these retail businesses has changed significantly in recent years, and new challenges have emerged.

3.1 Strengthening efforts to address social issues

Traditionally, the main challenge in store operations has been to eliminate labor shortages by improving operation efficiency, which in turn increases profits.

Recently, the Sustainable Development Goals (SDGs) have become widely recognized. Moreover, corporate social responsibility (CSR) has become a major pillar of corporate evaluation, and both general consumers and investors are placing importance on corporate CSR initiatives. Consistent with this trend, convenience stores are also working to reduce greenhouse gas emissions and food loss. To realize this initiative, further energy saving in store operations is essential. The systems we have developed in the past, which are self-contained within in a single store fixture or the store, are insufficient. For example, there is a need for lighting and air conditioning that is linked between the inside and outside of the store, optimal control of each fixture and synchronization with demand response, as well as energy management for all of these features.

3.2 Responding to changes in markets and consumption preferences

The main challenges in the vending machine operation business have traditionally been increasing sales per unit and reducing costs. To address these challenges, Fuji Electric has been developing sales promotion functions for stand-alone vending machines by using digital signage and functions for operation efficiency improvement using IoT technology.

While the existing beverage vending machine market was greatly affected by changes in consumer behavior caused by the current COVID-19 pandemic, renewed attention has been paid to the characteristics of vending machines, which allow customers to purchase items 24 hours a day without face-to-face contact, leading to a new need for multipurpose vending machines. It is more important than ever before to quickly materialize new services that take into account these market changes. In order to achieve this, a system that can efficiently conduct a proof of concept (PoC) is required.

4. Features of Next-Generation Edge Devices

As a means of achieving the challenges described in Chapter 3, the introduction of a new IoT system that utilizes edge computing is thought to be effective. We believe that edge devices can be installed in store equipment or vending machines to autonomously collect and analyze the necessary information, perform coordinated control of equipment units in the store, and display the digital signage of the vending machines while adjusting the content as necessary according to certain conditions. These edge devices should have the following features.

(a) Advanced connectivity including wired and wireless connections with easy access to a variety of surrounding facilities and content on the Internet
(b) High processing capacity that enables image data to be captured from cameras to analyze them in real time using AI
(c) Provision of a versatile application development environment that enables quick changes and additions of functions as needed, as well as easy replacement of applications

To provide these features, we redefined the hardware and software requirements to develop a platform

*1 USB is a trademark or registered trademark of USB Implementers Forum
*2 Ethernet is a trademark or registered trademark of FUJIFILM Business Innovation Corp.
*3 Wi-Fi is a trademark or registered trademark of the Wi-Fi Alliance
*4 Bluetooth is a trademark or registered trademark of Bluetooth SIG, Inc.
*5 Refers to cellular communication systems

for next-generation edge devices. The following sections present the details.

4.1 Hardware platform

Next-generation edge devices require flexible hardware that can fulfill various customer needs. Therefore, we considered the functions required for new services to fulfill customer needs and defined the specifications for next-generation edge devices, assuming future technological trends.

Figure 1 shows the appearance of the edge device (prototype), and Table 1, its main specifications.

The following describes the hardware features of the next-generation edge device.

(1) Diverse connectivity

The device is equipped with wired and wireless network communication capabilities for connection to the cloud and enables the construction of IoT systems according to needs. It also has a variety of external communication interfaces and inputs and outputs for video and audio signals to connect to various devices. Regarding wireless communication functions, for which technology is rapidly evolving, the device has been modularized, making future upgrades easy. It has also been configured to allow installation of built-in antennas for Wi-Fi and cellular communications. External antennas can also be mounted depending on the installation environment.

(2) High processing capacity

A high-performance SoC and high-speed, large-capacity memory are installed as standard equipment in order to significantly improve processing capacity as compared with conventional products. In addition, the device uses a hardware architecture that allows SoC upgrades and memory expansion to meet product requirements. For example, AI functions can be achieved by swapping processors for those with AI accelerators. The embedded multimedia card (eMMC) is expandable up to 64 GB and the Low-Power Double Data Rate 4 (LPDDR4) is expandable up to 8 GB for high-capacity applications.

(3) Usability in a variety of applications and environments

The device has been designed to be compact in size, making it easier to mount on a variety of equipment. It also uses industrial-grade parts to enhance its environmental endurance.

- Size: W153 × D30 × H100 (mm)
- Temperature (installation environment): –20°C to +70°C

Fig.1 Edge device (prototype)

Table 1 Main specifications of edge device (base model)

Component		Specification
Processor		Cortex*1-A53 Quad Core + Cortex-M7
Memory		eMMC 32 GB
		LPDDR4 1 GB
Storage		SD card
Clock		RTC
Interface	Ethernet*2	Gigabit Ethernet (GbE)
	Wireless communication	Bluetooth*3 5.0
		Wi-Fi*4 4
		cellular*5 4 G CAT-4
	USB	USB*6 3.0 Host
		USB 2.0 Function
	Serial	RS-232C, RS-485, I2C, SPI
	Video	LVDS, HDMI
	Multimedia	MIC, speaker
	I/O	LED, SW, DIO

*1 Cortex is a trademark or registered trademark of Arm Ltd.
*2 Ethernet is a trademark of FUJIFILM Business Innovation Corp.
*3 Bluetooth is a trademark or registered trademark of Bluetooth SIG, Inc.
*4 Wi-Fi is a trademark or registered trademark of the Wi-Fi Alliance
*5 Cellular refers to a cellular communication system
*6 USB is a trademark or registered trademark of USB Implementers Forum

4.2 Software platform

While cloud computing IoT systems are based on providing standardized services regardless of where they are applied, edge computing IoT systems have the advantage of services that are easily built and optimized for the specific challenges of each site where they are applied. To achieve this, a variety of software applications (business applications) must be built for services that meet the needs of each site, and improving the efficiency of their development is a challenge. The edge device to be developed takes the form of an embedded device, but unlike software development for PCs and the cloud, software development for embedded devices requires expertise such as knowledge of hardware and the know-how to utilize it, making it difficult. In addition, replacement of software is often difficult in that a dedicated tool is required to install the created software in embedded devices, for example.

Figure 2 shows the overall configuration of a software platform to be installed on the next-generation edge device platform intended for facilitating software development. The platform comes standard with firmware that covers the basic functions of edge devices, and on top of it is installed a business application framework for facilitating the development of software, or business applications, to address individual issues. Table 2 shows the components of the software plat-

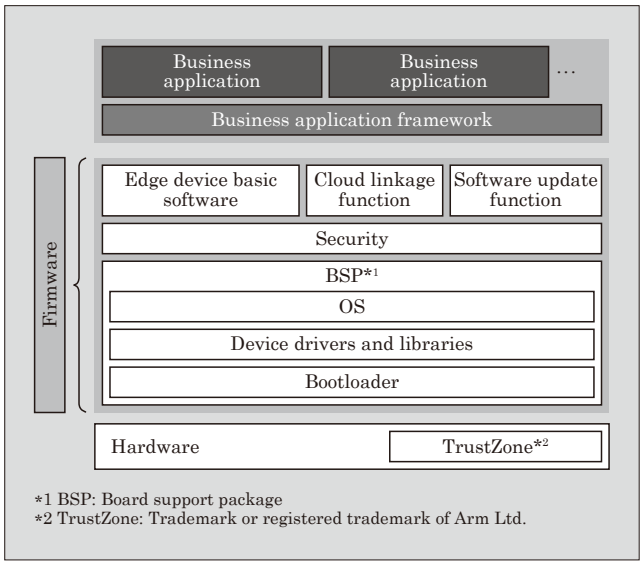

Fig.2 Overall configuration of the software platform

Table 2 Components of the software platform

Component	Overview
Board support package (BSP)	Built-in software suite for running hardware: ○ Bootloader Software that runs immediately after power-up Supports secure startup to prevent malware from running ○ Device drivers and libraries A collection of drivers and libraries to utilize each device on the hardware (platform) ○ OS Linux*1 5.15 installed
Security	Secure software execution environment using TrustZone*2 available on Arm microcomputers
Edge device basic software	Software that integrates basic features of edge devices ○ Data collection function ○ System monitoring function ○ Network management function ○ Clock function, log function ○ System maintenance function and other functions
Cloud linkage	Function for communication and data linkage with edge devices and cloud systems (various clouds provided by various IT vendors)
Software updates	Offline or online software update capabilities
Business application framework	Framework to manage and run business applications

*1 Linux is a trademark or registered trademark of Linus Torvalds in Japan and other countries
*2 TrustZone is a trademark or registered trademark of Arm Ltd.

form. Its features are as follows:

(1) Linux*6 OS installed

As the operating system (OS) of the platform, we have adopted the Linux OS, which is OSS widely used around the world. This makes it easier for software developers to build a development environment and take advantage of their software development know-how for PCs and the cloud, which is expected to improve the efficiency of business application development in particular.

(2) Full support BSP installed

To make all hardware functions included in the hardware platform readily available to software developers, components including device drivers for initializing and using the hardware applications have been put together into one package, and a board support package (BSP) that meets Fuji Electric's quality standards is installed as firmware.

(3) Business application framework that uses container technology

In order to improve the development efficiency of business applications and facilitate their installation, we have adopted a technology called a container to virtually build an operating environment of applications. Figure 3 shows the structure of the business application framework, and Table 3, its components.

Using a typical PC as an example, container technology can be explained as a technology that creates a virtual PC inside the PC and runs applications on the virtual PC, managing the individual virtual PCs in units called containers. This software platform adopts Docker*7 Engine, which is standard for the cloud, as container management software for creating and man-

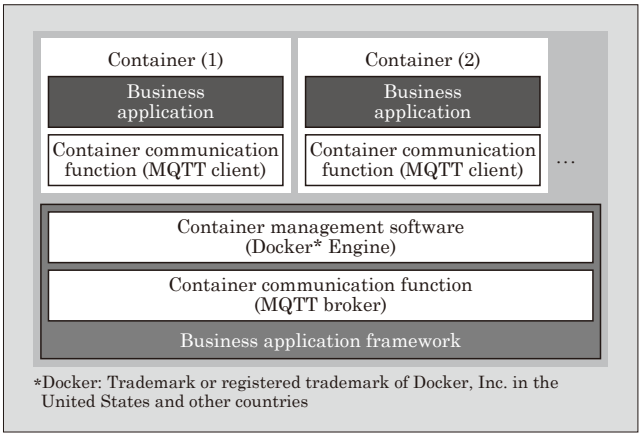

Fig.3 Configuration of business application framework

Table 3 Components of business application framework

Component	Overview
Container	Virtual edge device that runs business applications
Business application	Application that exclusively occupies an edge device and runs alone
Container management software	Management software for managing and running containers (e.g. Docker* Engine)
MQTT brokers and clients	Communication functions and protocols for data communication between business applications and functions outside the container

* Docker is a trademark or registered trademark of Docker, Inc. in the United States and other countries

*6 Linux is a trademark or registered trademark of Linus Torvalds in Japan and other countries

*7 Docker is a trademark or registered trademark of Docker,Inc. in the United States and other countries

aging containers. This business application framework allows developers to create business applications without the need for detailed hardware knowledge or consideration for firmware or other business applications. Applications can also be easily updated using the Docker Engine feature.

(4) High security

A mechanism has been built to prevent unauthorized software from running by performing security authentication on the bootloader (the first software application started after power-up), the OS and other software applications at startup.

4.3 Examples of application to products for the food distribution sector

(1) Vending machine

We are currently conducting research for next-generation vending machines that apply next-generation edge devices. Figure 4 shows the system configurations of vending machines. We believe that we can create new value by completely renewing the system configuration of conventional vending machines that has been in use for more than 20 years. For example, by using wireless communication functions of next-generation edge devices to connect machines to smartphones owned by operators in charge of tasks such as replenishing vending machines, remote control functions used to input various settings for vending machines can be implemented on smartphones. These remote controllers are much easier to use than the remote controllers for operation included with conventional vending machines. Many other new features can be achieved using next-generation edge devices.

(2) Stores

In order to save further energy in stores in the future, it is necessary not only to link together various facilities and equipment inside stores, but also to link together various systems outside stores to enable energy saving measures that could not be implemented previously. The requirements for the next-generation store controllers, which form the core of this system, include the ability to perform advanced information processing at high speeds, through means such as wired and wireless communication functions for network communications, with external systems, and communication functions for connecting to various facilities and equipment in the store. We believe that the application of next-generation edge devices will satisfy these requirements, which could not be achieved with conventional store controllers.

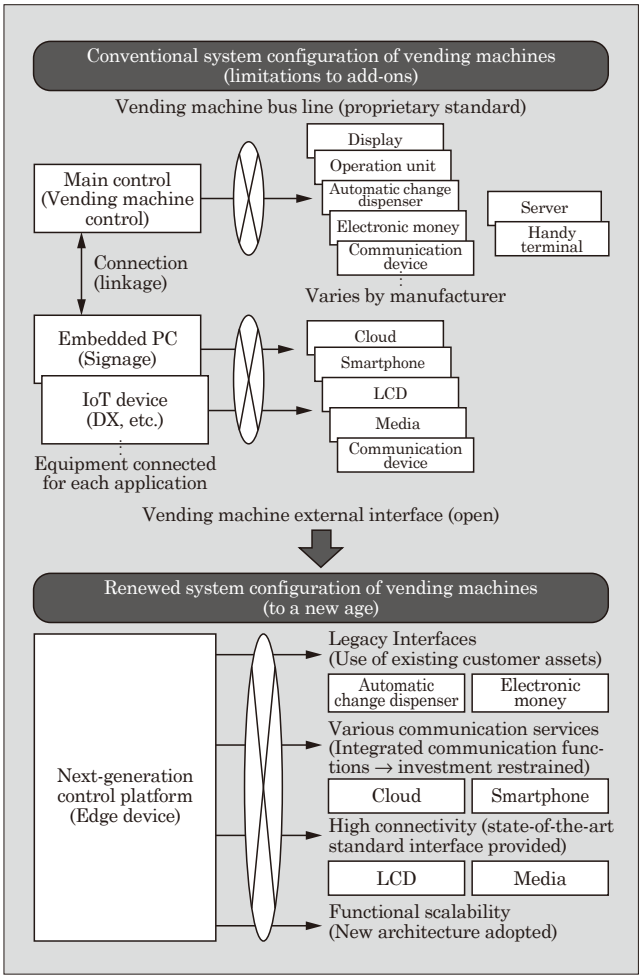

Fig.4 System configurations of vending machines

5. Postscript

This paper has described the development of a next-generation edge device platform and its applications.

In addition to products for vending machines and stores, we are studying its applications for a variety of products, including factory automation applications, and will continue to respond swiftly to the increasingly diverse needs of our customers.

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