IoT Edge Platform Trillion-Node Engine Project

The rapid spread of IoT sensor nodes is expected in recent years, and predictions are that one trillion nodes will be connected to the internet by the 2030s. In the world of IoT, each one of the applications is small. This means that many sorts of applications must be spawned in order to create a market for one trillion nodes and that a platform where created IoT sensor nodes are not only small and achieve low power consumption but are also easy to customize is necessary. Toshiba Electric Devices & Storage has participated in the research and development of Trillion-Node Engine, which is a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO), along with the University of Tokyo, Zuken Inc., D-Clue Technologies Co., Ltd., and Susubox Co., Ltd., since 2016. Here we introduce the activities of Toshiba Electric Devices & Storage in this project.

1. Introduction

The rapid spread of IoT sensor nodes is expected in recent years, and predictions are that one trillion nodes will be connected to the internet by the 2030s. To create and make this situation come true, many sorts of applications must be spawned. To this end, it is important to ensure that not only those who are engaged in the development of electronic devices but also individuals and those who are called makers (sole entrepreneurs who produce products) reflect their own ideas easily in IoT sensor nodes so as to expand and develop the IoT market further as shown in Fig. 1.
For terminals, such as sensor nodes for IoT, a platform realizing both small size and low power consumption, because they are required by the restrictions of the installation location to be small in size and low in power consumption, and that is easy to customize IoT sensor nodes so as to easily realize the functions, is necessary. In this project, PC boards called a leaf measuring typically 20 mm x 20 mm in size were developed that realize various functions, such as MCUs, sensors and so on, as shown in Fig. 2 and a module structure that materializes functions by combining the leaves with a method of using a rubber connector to connect each leaf without solder was developed. The HW architecture is compatible with Arduino, which has spread widely in the market, so that development can be made in a development environment of Arduino IDE. Leaves having various functions were developed in this project, and the practicality and reliability of the platform have been verified. We report the result of verification of its practicality and reliability in this paper.

Fig.1. Future of the IoT Market

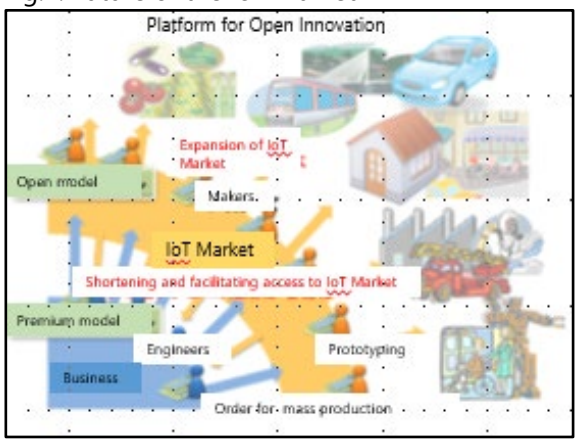
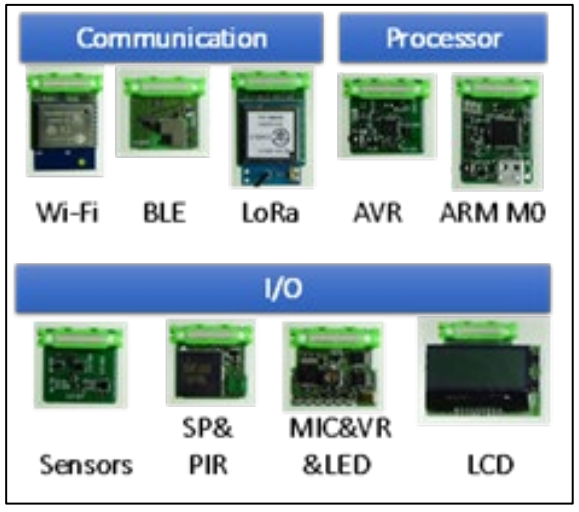


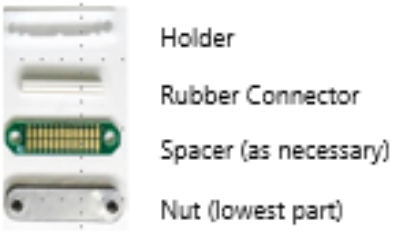
Fig. 2 Examples of leaf PCB



2. Practicality and reliability of Trillion-Node Engine

The structure of the module connection of the platform is shown in Fig. 3. The leaves are piled up and screwed up with a rubber connector and holder, nut, and screw to secure the connection between the leaves.

Fig.3 Connection Structure



To verify practical use, examinees not related to this project were selected, and an assembly test that implemented from assembly to operation of an application was conducted.
The attributes of the examinees were as shown in Fig. 4. Five examinees of different ages and sex were selected. As assembly issues, not only the assembly issues but also issues, such as operations of an application and wireless communication, were included as shown in Fig. 5.

Fig. 4 Attributes of examinees

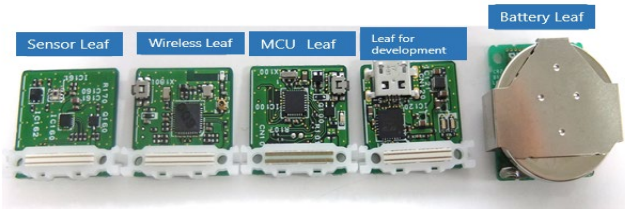
	Age	Sex	Occupation
Examinee 1	60s	Male	System engineer
Examinee 2	30s	Female	Product planning
Examinee 3	50s	Male	Quality management
Examinee 4	40s	Male	Production
Examinee 5	20s	Male	Sales

Fig. 5 Test issues

Issue 1	Runs an application that turns LED on/off by using an MCU leaf and a leaf for development. Also changes the blinking cycle of the LED.
Issue 2	A sensor leaf and a wireless leaf are added to the leaves used for issue 1 to display data obtained from a sensor on a smartphone.
Issue 3	A battery leaf is added to the leaves used for issue 2 to power the sensor with battery and display sensor data on a smartphone.

As a preparation for this test, a sample sketch of Arudino, which is operated by the MCU leaf, and application software for smartphones that displays sensor data on the smartphone were installed beforehand.
In addition, a video showing the assembly method would be created and shown to the examinees before the evaluation.
The five types of leaves shown in Fig. 6 were used. As the wireless leaf, a leaf equipped with IC, TC35678, conforming to Toshiba Electronic Devices & Storage's 2.4 GHz wireless communication Bluetooth® V4.2 low energy standards was used.

Fig. 6 Test leaves



The test result is as shown in Fig. 7. All the examinees finished one issue within 10 minutes, completed assembly within 4 minutes, and ran the application within 6 minutes. That all the examinees could achieve all the issues bears out high practicality, given that only one examinee did the assembly again and one additionally tightened the screw.

Fig. 7 Result of assembly time measurement

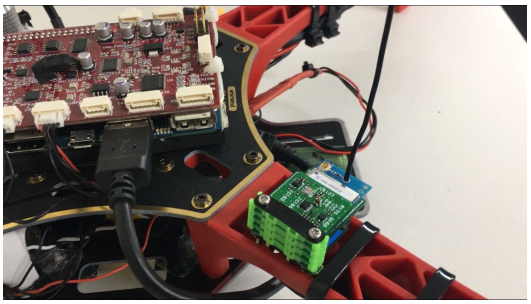
		Examinee 1	Examinee 2	Examinee 3	Examinee 4	Examinee 5
Issue 1	Assembly	151	238	138	141	228
	Execution	168	119	114	107	138
Issue 2	Assembly	111	141	141	103	200
	Execution	215	234	317	171	145
Issue 3	Assembly	190	191	195	188	220
	Execution	92	116	57	67	48

To verify reliability, several reliability tests on the connection resistance of rubber connectors were conducted. The results of these test were favorable in that an increase in connection resistance was not seen in two of three types of rubber connectors when stability of connection resistance was tested under the conditions of high temperature and high humidity (85℃, 85%), low temperature (-40℃), and thermal cycle test (-40℃ to 85℃, changed over 2 hours). Details are shown in the published IEEE paper, "Connection Structure Using Rubber Connectors in the IoT Edge Platform, Trillion-Node Engine" (K. Agawa, et al., IEEE CPMT Symposium Japan (ICSJ) 2018, November 2018).

3. Conclusion

In this project, Trillion-Node Study Group aimed at spreading the result of research was launched in 2016 to provide leaves actually developed, as well as to report the situation of research and development (https://www.trillion-node.org/). As a result, even non-project members started conducting a demonstration experiment using the Trillion-Node Engine, and seven examples of experiments were reported at a workshop held on February 1, 2019.
These examples included the case shown in Fig. 8 where a wireless performance demonstration experiment was conducted with a leaf mounted onto a drone, making the best use of the small size and low power consumption of the Trillion-Node Engine, and a case shown in Fig. 9 where the platform was used for a hackathon.
In the future, the functions of the platform should be reinforced and its ease of use should be enhanced so that the platform will spread widely and can be used as a tool that appeals the usefulness of Toshiba Electronic Devices & Storage's products.

Fig. 8 Use of LoRa for a drone (JASA & MCPC drone WG @KES, Tedorigawa River, Ishikawa)



JASA: Japan Embedded Systems Technology Association
MCPC: Mobile Computing Promotion Consortium
KES: Kanazawa Engineering Systems Co., Ltd.

Fig. 9 Use for Hackathon (MCPC Nano-computer Application Promotion WG)

Acknowledgement
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