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Web Service and Serial Input based Agricultural Machine's Management

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Abstract

This study presents the K-AgriLink system that combines ICT and agricultural machine technology to manage agricultural machines not equipped with remote management functions. The K-AgriLink system consists of a smart manager, a smart adapter attached to an agricultural machine, and a smart aider that performs hybrid app of agricultural machine's management. Agricultural machine's management interface (AMMI) was defined to manage agricultural machines based on RESTful web service, WebSocket and push service. Agricultural machine's sensing interface was also defined on the smart adapter for status information monitoring. The K-AgriLink system was constructed as a laboratory model and confirmed that the status information of the agricultural machine collected from the smart adapter is transferred to the aider and manager using AMMI. Also, it is confirmed that the proposed power circuit for stable power supply from the agricultural machine to the smart adapter and the circuit for detecting the engine speed operate normally. This study defined reliable agricultural machine's status notification mechanism and analyzed the WebSocket and push service based notification delays from smart manager to smartphone.

Keywords*: agricultural machine management, smart manager, smart adapter, smart aider, web service, push service, serial input*

1. Introduction

In order to improve productivity and prevent accidents through advance management, development of agricultural machine's management technology combined with ICT is actively under way [1-3]. Global agricultural machine companies combine ICT technology with tractors, combine, and soil separator to provide remote monitoring and diagnostics, engine utilization and fuel consumption, battery management, supplies replacement and periodic maintenance management services. Jone Deere's JDLink [4], New Holland's PLM [5] and Yannmar's SmartAssist [6] are typical agricultural machine management systems. However, domestic agricultural machine companies have not yet introduced a remote agricultural machine's management system.

This study describes the design and implementation of the K-AgriLink system that combines ICT and agricultural machine technology for management of agricultural machines that do not have remote management functions. The K-AgriLink system consists of a smart manager, a smart adapter attached to an agricultural machine, and a smart aider that performs hybrid app of agricultural machine's management. AMSI (Agricultural Machine Sensing Interface) was defined between the smart adapter and the sensor of the agricultural machine for status information monitoring. This study also defined the AMMI (Agricultural Machine Management Interface) among the smart

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adapter, the aider and the manager to manage agricultural machines based on RESTful web service [7], WebSocket [8] and push service [9]. The K-AgriLink system was constructed as a laboratory model and confirmed that the status information of the agricultural machine collected from the smart adapter is transferred to the smart aider and manager using AMMI. Also, it is confirmed that the proposed power circuit for stable power supply from the agricultural machine to the smart adapter and the circuit for detecting the engine speed operate normally. This study defined reliable agricultural machine's status notification mechanism based on FCM-API [10] and AMMI. We also measured and analyzed the notification delay from smart manager to smartphone. This study also compared WebSocket [8], web's push service technology with existing polling and Comet technologies in terms of waiting time of status notification.

2. Related Research

2.1. Agricultural Machine's Management

Recently, domestic agricultural machine environment has been suffering from lack of labor force, decrease of agricultural land, and natural disasters. In order to solve the problems and develop sustainable agriculture, it is necessary to innovate on agricultural technology through fusion with advanced science and technology. YoonHee [1] emphasizes the necessity of constructing integrated agricultural information system that collects and utilizes diverse information by applying ICT technology to an agricultural machine. The hardware / software implementation for control and sensing of an agricultural machine ECU (Electronic Control Unit) is useful with the CAN Bus [11].

Fabrizio [2] proposed a development method for control and sensing of an agricultural machine ECU using a WinCE6.0 mobile OS based board (MPC2500 CAN module) equipped with S3C6400 MCU. The TRAKTnet.one project of the Free University of Bolzano aims to identify and develop new solutions to remotely monitor the efficiency of farm-tractor engines. Engines are monitored by measuring rpms, exhaust gas's temperature and oxygen content and then analyzing and inferring the monitored data [2]. Khodabakhshian [3] reviews condition monitoring system and application of it to agricultural machinery. The main problems facing the designers of condition monitoring systems for agricultural machinery obviously continue to be:

- Selection of the number and type of sensors for data acquisition step;
- Selection of effective signal processing methods associated with the selected sensors;
- Design of a sufficient and efficient maintenance decision mechanism.

JONH Deere's JDLink system, which provides agricultural machine management, provides location information, operating area and time limit service for agricultural machines, and vehicle diagnostic services using Diagnostic Trouble Codes (DTCs) notified to the control center on agricultural machines. It also provides information on consumables and periodic maintenance of the agricultural machine, utilization of the agricultural machine, and fuel information [4]. New Holland uses Precision Land Management (PLM) to help improve productivity by managing agricultural machines and attaching various sensors. The sensor attached to the agricultural machine performs the functions of measuring the yield, sensing the humidity of the crop to be harvested, determining the cutting length of the harvest according to the humidity, and determining the weight of the haystack and additives according to the humidity [5].

2.2. Push Service and Web Service based Management

Polling technique is to deliver message if requested by a client, while pushing technique is to deliver message without request. In the previous HTTP requesting/responding model, polling is that web browser requests data to server in a constant cycle. Comet is that server responds when data is created upon request from web browser. Polling and Comet techniques suffer network overhead making it difficult to support real-time service according to stand-by time of data produced in the server [12]. In order to solve such issues, W3C has defined WebSocket API of HTML5, a bi-directional communication technology between web-server and web browser, and IETF has standardized protocol with RFC 6455 [8].

Push system is comprised of provider server, push server, and smart devices. Provider server produces message to notify and deliver it to the push server, while push server delivers received message to the smart device. As for examples of push servers, there are FCM (Firebase Cloud Messaging) from Google, APNS from Apple, AOM (Always on Management) from SKT, and nPush supported by NHN [13]. Li [9] compares push and polling as well as push techniques of each company, length of message, message format, and preservation period of message.

Table 1. Comparisons of Push Services

push service	transport technology	message length	message format	preservation period
FCM	TCP/IP	4kB	JSON	4 weeks
APNS	TCP/IP	256bytes	JSON	unlimited
MPNS	TCP/IP	3KB	XML	30 days
BBPS	WAP	8KB	XML	8 hours

SNMP (Simple Network Management Protocol) is the Internet management protocol using the connectionless transport layer [14]. Thus, it can hardly respond effectively to an increase in network size and management information due to the limited data expression, limited message length and reliability. Twente University proved that web service was as good as SNMP (Simple Network Management Protocol) in terms of bandwidth, memory use, CPU usage time and round-trip delay [15].

SOAP based web service was initiated for the inter-working of applications in a business environment. In contrast, RESTful web service was initiated for the purpose of allowing Internet service providers to offer data conveniently to application developers. SOAP based web service is developed through the strict standard and well-equipped infrastructure of W3C. RESTful web service, which requires only the basic Internet standards, can access those resources allowing for various expressions (XML, JSON, HTML, image, *etc.*) only with the basic types of HTTP [7]. Furthermore, it's another distinctive feature is that the state information of client is not managed at the server. CoRE (Constrained RESTful Environments) working group of IETF proposed RESTful web transmission protocol that redesigned several functions of HTTP for M2M application in a small-sized device such as a sensor node [16].

3. K-AgriLink System

The K-AgriLink system, which is a fusion of ICT and agricultural machine technology, provides productivity improvement and safety through advance management of agricultural machine. The K-AgriLink system consists of a smart manager, a smart adapter attached to an agricultural machine to monitor status information, and a smart aider as shown in Figure 1. Smart aider provides hybrid app of agricultural machine's management that operates Android phone or Apple phone.

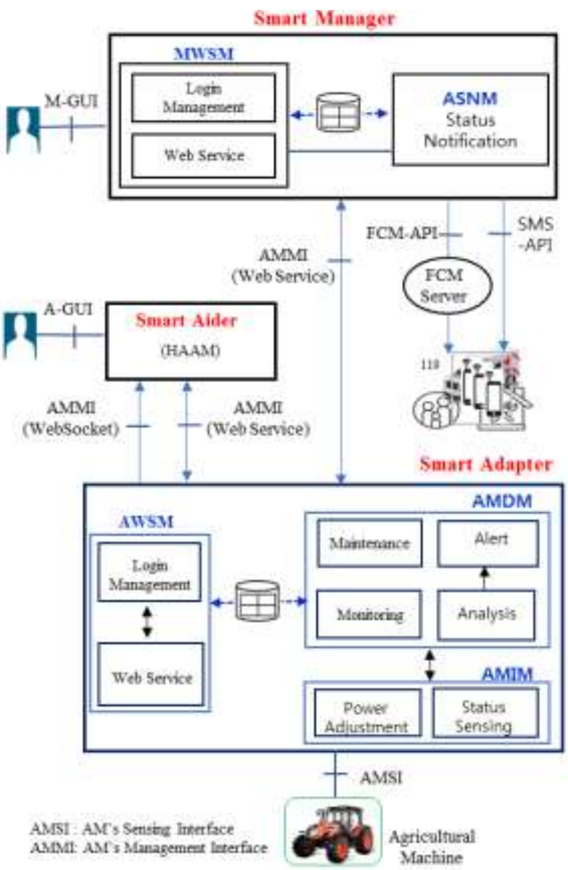

Figure 1. K-AgriLink System's Configuration and Interfaces

3.1. Smart Manager and AMMI

3.1.1. Agricultural Machine's Management Interface

In order to manage an agricultural machine, web service, WebSocket and push service-based AMMI is defined between the manager and the adapter, centering on the smart aider. AMMI includes the following management functions:

- Login management to a smart adapter
- Query and modification of a smart adapter's configuration information
  o password, monitoring period of machine's status
  o criteria of safety status (*e.g.* gyro sensor's safe degree)
- Query of machine's status
- Notification of machine's warning or failure status
- Notification of machine's safety status
- Supplies replacement and periodic maintenance management
- Query of machine's location
- Query of event log generated for machine's status

The smart adapter periodically monitors the status of the agricultural machine and automatically notifies the smart manager and the smart aider of any failures or warnings through AMMI, which is implemented as WebSocket. The smart aider operates as HAAM (Hybrid App for Agricultural machine Management) on the driver's smartphone. The smart aider includes a user interface (A-GUI) function and displays status information of the agricultural machine received through WebSocket based AMMI. The smart aider uses AMMI, which is implemented as RESTful web service [7], to log into a smart adapter and manage an agricultural machine. RESTful web service based AMMI uses GET, POST, PUT and DELETE request types of HTTP for inquiry and generation of agricultural machine management information, change and deletion of configuration information, and applied usage rule of URL defined in research [17]. The response of the inquiry to the agricultural machine status information includes the status of the sensors installed in the agricultural machine (normal, warning, and critical) and the measured value. Table 2 shows typical request types, URLs, and status codes of web service based AMMI applied among smart adapter, smart aider, and smart manager.

Table 2. Request Types, URLs and Status Codes of Web Service based AMMI

request type	URL(http://smart adapter's address)	status code	
		normal	error
POST	/driver-login/tel-number/{tel-number}: driver’s login /manager-login/id&passwd/{id&passwd}: manager’s login	201	400
DELETE	/driver-logout/tel-number/{tel-number}: driver’s logout /manager-logout/id/{id}: manager's logout	204	400
POST	/driver-info: registration of driver's information	201	400
GET	/driver-info/all: query on driver account information	200	400
DELETE	/driver-info/tel-number/{tel-number}: deletion of driver's account	204	400
GET	/machine-status: query on machine’s statuses	200	400
PUT	/adapter-conf/passwd: modification of manger’s password /adapter-conf/sensing-period/{sensing-period}: modification of sensing period /adapter-conf/gyro-safety-degree/{gyro-safety-degree}: modification of gyro’s safety degree /adapter-conf/time-after-oil-change/{time-after-oil-change}: modification of the operating hours after engine oil change	200	400
GET	/event-log/start-time&end-time/{start-time&end-time}: query on events as to a designated duration	200	400
	URL(http://smart manager's address)		
POST	/notificationConfig: activation and registration of push service for status information	201	400
POST	/pushAck: acknowledgement of push message	201	400

3.1.2. Smart Manager

The manager's web service module (MWSM) handles RESTful web service based user interface (M-GUI) and CoAP [16] based AMMI. The smart adapter notifies the smart manager of the agricultural machine's status information to the smart manager using the CoAP based AMMI. MWSM module uses Apache Tomcat and Jersey, the JAX-RS reference implementation to process RESTful web service based user interface [18]. The ASNM (Agricultural machine's Status Notification Module) will notify the family or the agricultural machine repair shop of the status of the agricultural machine using Google's FCM-API [10] or SMS-API.

Table 3. AMMI for Notification Registration

request type	URL(http://smart manager's address)
POST	/notificationConfig

{ "NotificationConfig":{
"mobilePhone": "010-1111-1111",
"fcmInfo": "xxxxxxxxxxxxx",
"apnsInfo": "xxxxxxxxxxxxx",
"mobilePlatform": "android",
"notifyFilter": "xxx",
"pushAckFlag": "yes",
"smsFlag": "on"
}
}	

Table 3 shows the AMMI, which registers the notification of status information of an agricultural machine. This AMMI contains telephone number of the smart device, type of mobile platform, report filter, acknowledgement flag of push service incoming, and activating flag of SMS. FcmInfo contains register ID for Android platform, while ApnsInfo contains device ID as well as register ID for iOS. If the verification of AMMI efficacy for notification registration is successful, the information on push service and SMS would be established in the entry of UserTbl which corresponds to the phone number. Telephone number, FCM/APNS information, and the type of mobile platform among AMMI information for notification registration are generated with the related information on the smart device in the hybrid application automatically, and the others are set with default information. Using M-GUI which performs the amendments of user account information, it is possible to change report filter, acknowledgement flag of push service incoming and activation flag of SMS.

3.2. Smart Adapter and AMSI

The smart adapter, which collects the status information of the agricultural machine, is implemented using a single board computer, Raspberry Pi 3B [19]. AMMI interface with smart aider uses Wi-Fi communication, and AMSI interface with sensor installed in the agricultural machine uses serial input. The agricultural machine interface module (AMIM) as shown in Figure 1 consists of a power adjusting unit and an agricultural machine status sensing unit. The power adjusting unit provides a stable power supply of 5V from the 12V or 24V agricultural machine power to the smart adapter. The agricultural machine status sensing unit periodically monitors the status information from the sensors installed on the agricultural machine through the AMSI interface based on the serial input.

The AMDM (Agricultural machine's Monitoring and Diagnostic Module) periodically monitors the status of the agricultural machine and analyzes the status (normal / warning / critical) of the sensors to diagnose the fault or safety condition. The AMDM module also manages consumables and periodic inspection cycles using the operation time of the agricultural machine measured by the smart adapter. The inquiry of the consumable management / inspection cycle is requested at the time of login from smart aider to smart adapter, and is guided to the driver.

The status of engine oil was defined as Normal state in case of operation duration less than 95 hours, Warning state in case 95 to 110 hours, and Critical state in case over 110 hours. In addition, the temperature of engine cooling water was defined as Normal state at less than 90 degree Celsius, Warning state at 90 to 110 degree, and Critical state over 110 degree. Figure 2 shows the defined state diagram to diagnose the agricultural machine in AMDM module. With detections of two consecutive warning statuses in Normal state, it is transformed into Warning state. Upon detections of two consecutive normal statuses, it is transformed into Normal state. In any cases of critical status occurrence, it is transformed into temporary Pseudo-C state, and into Critical state once critical status is detected again. With detection of warning or normal status under the Critical related state, it is transformed into temporary Pseudo-W or Pseudo-N state.

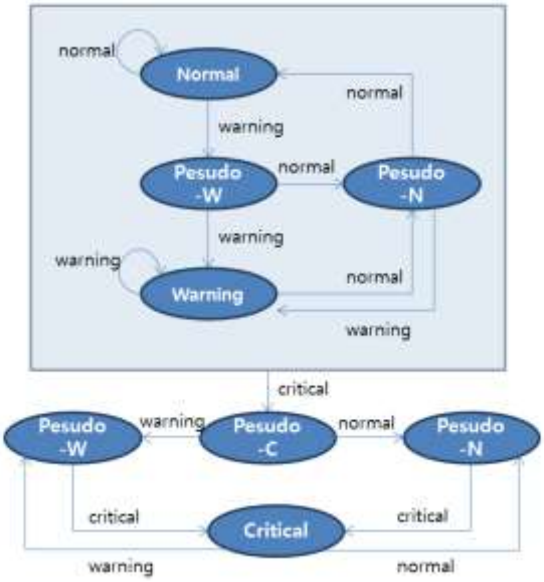

Figure 2. State Diagram for Diagnosis of Agricultural Machine

The AWSM (Adapter's Web Service Module) of the smart adapter handles RESTful web service based AMMI requested by the smart aider. When a user requests management of an agricultural machine using a hybrid application-based A-GUI, the smart aider transmits a web service based AMMI interface request to the smart adapter. This study also uses AMMI, which is implemented as Apache Tomcat's WebSocket [8], to notify the smart aider asynchronously of important status information diagnosed by the smart adapter.

3.2.1. Agricultural Machine's Sensing Interface

AMSI interfaces with sensors on the agricultural machine via serial input with the general purpose input / output (GPIO) pins of the Raspberry Pi Board [19]. The AMSI defined in Table 4 shows the types of sensors, operation methods, measurement values and pin assignments of GPIO for agricultural machine management services.

Table 4. AMSI and Agricultural Machine’s Management Service

management	sensor	operation method	GPIO
fuel filter humidity	level	on, off	23
battery	level	on, off	4
engine’s water degree	thermistor	register's value	24
anti-freeze amount	level	on, off	25
safety	gyro	angular velocity	10
transmission oil	level	on, off	18

Since noise and chattering are generated when monitoring is performed by relay operation of an agricultural machine that is operated with level sensor, inaccurate level sensing might be occurred. For the accurate level sensing, we adopted photo-coupler that was operated by contactless switch rather than relay. An 8-channel A-D converter converts the analog signal detected by a potentiometer to a digital signal for sensing the status of the agricultural machine. The sensor detects the displacement and uses this signal as an input. The engine's temperature sensor uses a thermistor, which is a semiconductor element with a negative resistance characteristic, and the resistance value decreases linearly from 100 kΩ to 150 Ω. The temperature gauge operates by detecting the resistance value at 18.8 KΩ ± 12.6% at -20 ° C, 1.136 KΩ ± 8.4% at 40 ° C, and 150 Ω ± 4.5% at 100 ° C.

In order to monitor the status of the engine, a circuit that detects the engine speed (RPM) by reading the AC voltage generated by the ring gear of the engine is shown in Figure 3. Input into the electric circuit is the alternating current voltage that is generated by magnetic pickup sensor of ring gear, and outputs are voltage and frequency that are used for RPM detection in Raspberry Pi board.

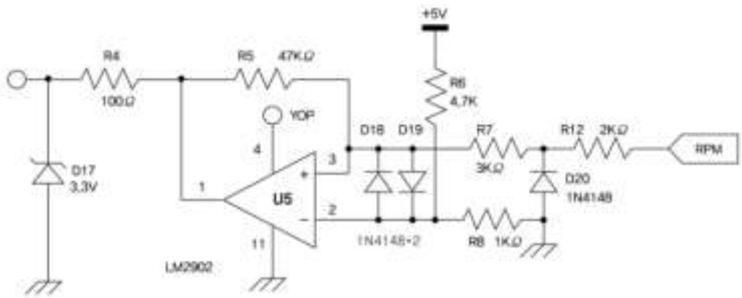

Figure 3. RPM Detection Circuit

To generate normal output of frequency in RPM detection circuit, input of alternating current voltage should be Vp-p 3V or more in ring gear. To generate output of 3.0V voltage required in Raspberry Pi, Zener diode was connected at the output terminal of OP-AMP with 3.3V. Figure 4 shows the graph of output measurements including voltage and frequency in RPM detection circuit, which is connected to Kuboda engine, V2203-M-EBH.

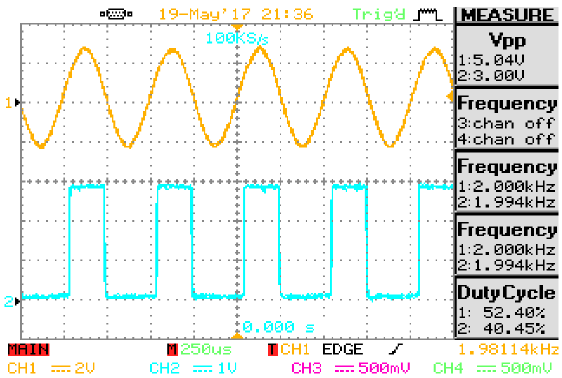

Figure 4. Input and Output of RPM Detection Circuit

Formula 1 calculates RPM using the number of ring gear (rgear) and frequency occurred at the magnetic pickup sensor (f_p) for V2203-M-EBH engine [20].

$$\frac{f_p}{t}\times\frac{2\times 60}{rgear} = 1000\times\frac{120}{127} = 944rpm \qquad (1)$$

Formula 2 calculates the number of engine revolutions using the number of ring gear and the frequency of output wave form (f_{Vo}) in Figure 4. In case of Vo frequency with 1.994kHz, the number of engine revolutions is as follows.

$$rpm = \frac{f_{Vo} \times 60}{rgear} = \frac{1994 \times 60}{127} = 942rpm \quad (2)$$

Little difference could be found between the measured RPM using output frequency in the RPM detection circuit and the calculated RPM by formula 1.

3.2.2. Power Adjustment

Because the agricultural machine has a poor operating environment and high load, overvoltage may be generated by the generator, which can have a serious effect on various electronic parts. In order to provide a stable power supply from the 12 / 24V agricultural machine to the smart adapter, a power supply circuit as shown in Figure 5 was developed. Raspberry Pi board with input voltage of 3.3V cannot use TTL type of input voltage directly. In order to provide a stable power supply from the 12 / 24V agricultural machine to the smart adapter, a power supply circuit as shown in Figure 5 was developed. Raspberry Pi board consumes the alternating current of 230mA, and 370mA when it is connected with keyboard and mouse [19]. 1,600mA is consumed for monitoring of agricultural machine's status information by serial input of GPIO and for operation of AD converter that is used during the temperature measurement. For status monitoring of an agricultural machine and operation of Raspberry Pi board, internal circuit was organized to output 3A from DC-DC converter.

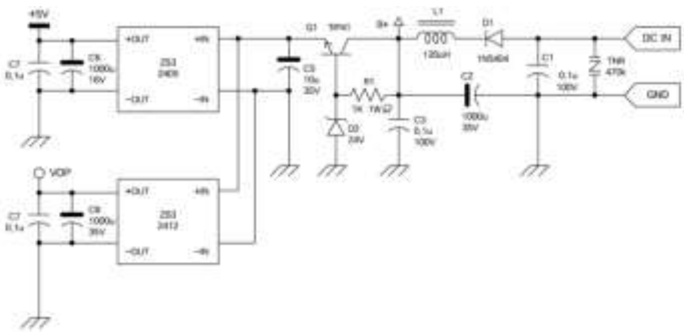

Figure 5. Power Circuit for Smart Adapter

The voltage at the GPIO input was limited to 3.3V by using OP-AMP to adjust the voltage and Zener diode at the output. The VOP is limited to 12V and the output voltage to 5V. When an agricultural machine's battery is connected, the polarity is often changed, so diode D1 is connected to protect the smart adapter's internal circuit. The ZS3 2405 is a DC-DC converter that converts 24V input power to 5V. We checked out the normal 5V output even when the input was 12V. Temporary overvoltage over 40V was measured in the generator of the agricultural machine. To protect the internal circuit of smart adapter from this overvoltage, TNR-470 surge protector was used which could protect it up to 47V.

4. Notification Test of Agricultural Machine's Status Information

In order to test the notification of agricultural machine status, as shown in Figure 6, we constructed a test environment composed of smart manager, smart adapter, adapter simulator, and smart aider. The smart adapter simulator generates status information and transmits it to the smart manager through AMMI. The smart manager used in the test runs on an 8GB memory capacity, a 2.80GHz (quad core) CPU and Windows 7 64bit operating system. Smart adapter made use of Raspberry Pi 3B with embedded Linux, smart aiders run on Android and iOS platforms.

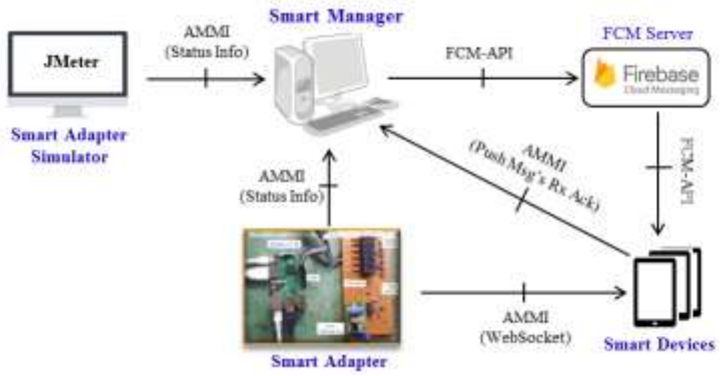

Figure 6. Test Environment for Status Notification

4.1. Notification Test of Status Information based on Push Service

When a hybrid application for an agricultural machine management is executed in Android and iOS platforms, the smart aider registers the push service of status information using AMMI to the smart manager. When the smart manager receives the AMMI (status information) request message from the adapter, the smart manager transmits the push message with status information and push acknowledgment flag to the FCM server. The flag is set at the time of registering the push service. The FCM server [10] pushes the received status information to the smart device that registered the push service. Whether or not the push message has been transmitted from the smart manager to the FCM server can be checked by FCM-API response from the FCM server, but whether the status information is pushed from the FCM server to the smart device cannot be known in real time. In this study, the reliable notification procedure of state information is defined as shown in Figure 7.

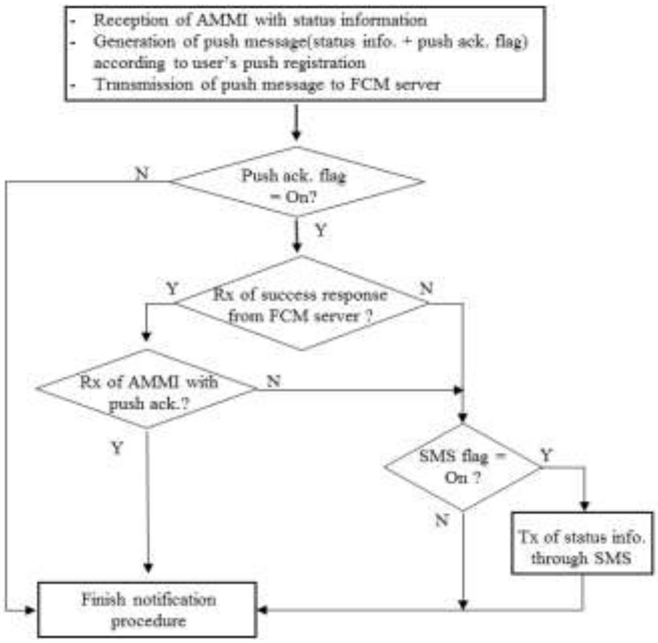

Figure 7. Reliable Notification Procedure based on AMMI and FCM-API

Upon receipt of the status information to which the confirmation flag is added, the smart device confirms reception of the push message to the smart manager through AMMI. The smart manager accomplishes notification procedure upon receipt of AMMI with push acknowledgment. If the smart manager receives FCM-API response with failure or does not receive acknowledgment from the smart device within the specified time, it checks whether the SMS transmission flag is set for the user. If the SMS transmission flag is set, status information is transmitted to the smart device through the SMS transmission method.

This study used five Android smartphones and three iOS smartphones in the same environment to measure the notification delay of agricultural machine's status information from the smart manager to the smart device. The notification delay is defined as the time from when the smart manager transmits the push message to the FCM server until the arrival time of the AMMI (push acknowledgment) from the smart device. The smart adapter simulator built on the Apache JMeter [21] generates AMMI (status information of an agricultural machine) every 20 seconds and sends it to the smart manager. Table 5 shows the average, deviation, maximum and minimum notification delays, which were measured 40 times for each smart device.

Table 5. Notification Delays to Smart Devices

smart device	notification delay(sec)			
	average	deviation	min	max
sm-g930s(Galaxy S7)	0.933	0.205	0.423	2.212
sm-g920l(Galaxy S6)	0.632	0.037	0.419	1.511
sm-n916k(Galaxy Note4)	0.673	0.183	0.31	2.912
sm-a800s(Galaxy A8)	0.873	0.190	0.382	1.67
sm-a5000(Galaxy A5)	0.486	0.047	0.314	1.327
A1688(iPhone 6S Rose Gold)	2.027	0.248	1.189	3.347
A1688(iPhone 6S Space Gray)	1.77	0.328	1.143	3.461
A1429(iPhone 5)	1.999	0.218	1.289	3.48

The average delay of five Android smartphones was 0.719 seconds, and that of three iPhones was 1.932 seconds. There was a slight difference in notification delay depending on the phone model. It has the advantage of pushing status information to Android phone and iPhone by implementing only FCM-API in the smart manager. However, since the FCM server is used instead of the APNS server [13] dedicated to the iPhone, the average notification delay of iPhones is 1.213 seconds larger than that of Android phones.

4.2. Notification Test of Status Information based on WebSocket

The polling method and the WebSocket method are possible to transmit the status information of the agricultural machine sensed by the smart adapter to the smart aider. The WebSocket method and the polling method are compared in terms of the notification waiting time of the agricultural machine status information. Figure 8 shows the notification waiting times for WebSocket, Comet and polling methods.

The notification waiting time of the status information is defined as the time from when status information is generated in the smart adapter until it is transmitted to the smart aider. The polling method is divided into Polling-A (10-second request period) and Polling-B (20-second request period) according to the request period, and 500 status information is randomly generated in 0 to 10 seconds. In the polling method, the waiting times increase in proportion to the size of the request period, which are 4.3 and 10.1 seconds. The waiting time of the Comet method is 2.2 seconds, and the WebSocket is measured as a waiting time close to 0 second. The waiting time of WebSocket was closer to 0 second, it is feasible to minimize overhead of network and achieve notification in real-time.

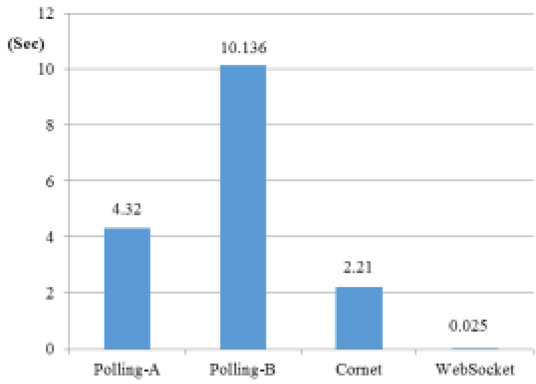

Figure 8. Waiting Time of Status Notification

5. Conclusion

The K-AgriLink system, which is a fusion of ICT and agricultural machine technology, provides productivity improvement and safety through advance management of agricultural machine. Unlike the products of global companies that have built-in remote management functions on the agricultural machine, The K-AgriLink uses attached smart adapters to enable management of agricultural machines without remote management functions. The smart aider works as a hybrid app on the driver's smartphone, and the smart adapter works on a single board computer, the Raspberry Pi 3B.

We constructed a test environment of the K-AgriLink system and confirmed that the status information of the agricultural machine collected from the smart adapter's AMSI is transferred to the smart aider and manager using AMMI. Also, it is confirmed that the proposed power circuit for stable power supply from the agricultural machine to the smart adapter and the circuit for detecting the engine speed operate normally. We compared WebSocket, web's push service technology with existing polling and Comet technologies in terms of waiting time of status notification. Waiting time of WebSocket was closer to 0 second, it is feasible to minimize overhead of network and achieve notification in real-time. We defined reliable agricultural machine's status notification mechanism based on FCM-API and AMMI. We tested status notification toward smart devices and measured notification delay from smart manager to smartphone. The average delay of five Android smartphones was 0.719 seconds, and that of three iPhones was 1.932 seconds. Since push service is provided for iPhone through FCM server from Google instead of APNS server, delay in status notification of iPhone turned out to be higher than that of Android phone.

As a next step, this research plans to compare the delay of notifying in the case of using the APNS server and the FCM server for iPhones.

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