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DESIGNING AN INTERNET OF THINGS (IoT) READY DEVICE FOR MACHINE TOOL MONITORIZING

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Abstract: *Nowadays more and more companies are using active monitoring systems for predictive maintenance of the manufacturing systems. With Industry 4.0 revolution almost all modern production systems are able to monitor the production systems and to send data values to monitoring platform. The main issue appears when using older machines that lack the basic communication capabilities, in this case sometimes supplementary equipment are needed to connect the required machine. The IoT platforms represents an alternative to the classical monitoring platforms as usually integrates tools and utilities needed to facilitate some common actions like sending emails and SMS alerts. This paper presents research results regarding an IoT ready device for industrial environment capable of connecting machines and production equipment through the internet to a smart process monitoring platform based on IoT.*

Key words: *Internet of Things (IoT), monitoring platform, industrial communications, Industry 4.0.*

1. INTRODUCTION

Nowadays one of the most important component of a production facility is the production monitoring system. Starting from classical SCADA systems to more evolved monitoring platform those systems are responsible with collecting usage data from machines, displaying alarms, and even with the breakdown prevention.

As we passed from unplanned maintenance to predictive maintenance and latter to preventive maintenance the role of the monitoring systems has grown even more. In this context is essential for all the production systems to be included in one integrated monitoring platform even the one that lack the required communication protocols.

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Regarding industrial monitoring platforms there are several approaches wide used. The simplest method is to use dedicated SCADA platforms this method is suitable especially for new facilities where the same compatible equipment's are used. The second method implies that the monitoring platform is custom made to accommodate all the equipment that are available at a certain time in a production system. This method has the several disadvantages like the price required to integrate new machines and the maintenance difficulties.

With the continuous growth of the IoT concept a third approached of using general IoT platforms for machines monitoring arises. Generally, an IoT platform is used as front end or a dashboard to present and process machines data, the platform is also capable of handling large amount of data and usually came with predefined snippets of code which can be used to automate some tasks like sending email or GSM alerts thus simplifying the maintenance cost.

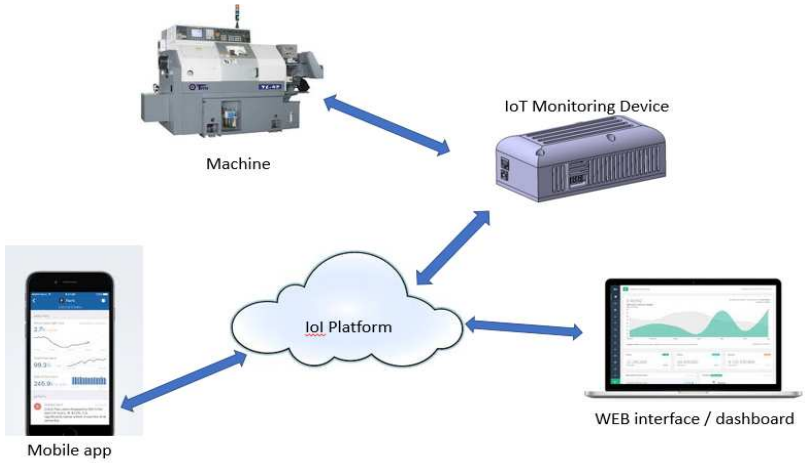

Fig. 1. Device integration within the IoT monitoring architecture.

Most IoT platforms support basic web communications protocols like: HTTP GET or HTTP POST and Java Script data-interchange format (JSON) as those are the most common protocols nowadays connecting various devices is simple. Another advantage of IoT platforms is the ease with which they can be programmed and configured.

As most of the new machines and production equipment have at least one of those two protocols implemented it is easy to integrate them in any monitoring platform based on the IoT. The main issue is that we can find often in common production systems also machines that lack the communication components.

There are two ways of dealing with equipments that do not have the ability of transmitting data to monitoring platforms the first method implies the use of wireless sensors [1] while the second method (Fig. 4) suppose that the machine will be equipped with a smart device that can solve communication issues. This paper focusses on the second approach.

2. STATE OF THE ART

Nowadays there are many IoT ready devices on the market but almost all of them are user consumer products like smart washing machines or coffee makers. With the development of the Industrial Internet of Things (IIoT) more companies like Schneider, Bosch Rexroth or Echelon try to adapt their product for the IoT platforms.

There are several industrial IoT products on the market like flexi1 (Fig. 2) [2] that can be configured to work with different sensors for different applications but they have a limited number of Inputs and inputs accept a single type of signal so, from this point of view, they have limited connectivity possibilities.

There is also a second category of industrial products available on the market that can be used as a gateway for IoT platforms. An IoT gateway facilitate the connection between various sensors and the internet but it doesn't change sensor data.

Sometimes, a IoT gateway is used to facilitate connection to one platform (Fig 3) for sensor of many types and brands.

There are also several products that use Modbus and can be connected to IoT platforms like BACnet/IP Energy meter [6].

Fig. 2. Flexi1 industrial IoT device

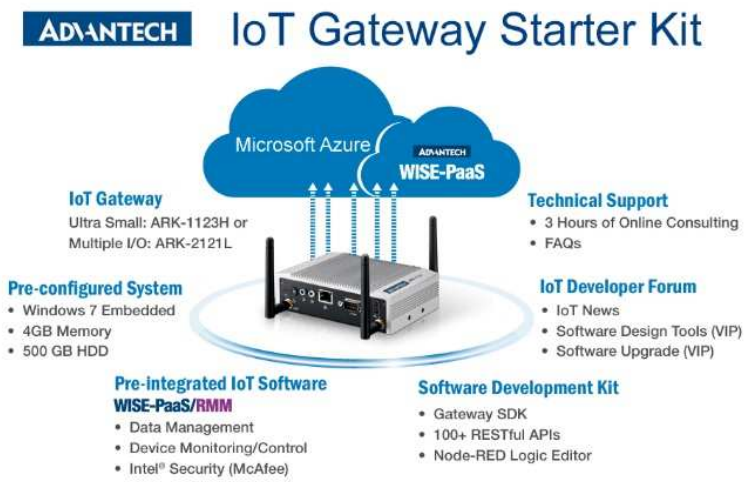

Fig. 3. Advantech gateway for Microsoft Azure [3].

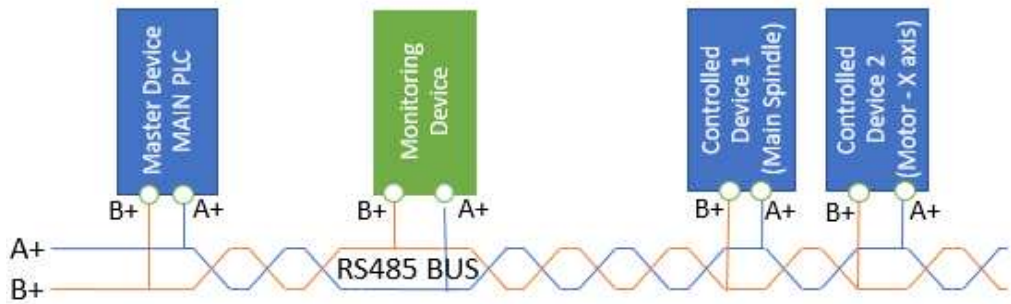

Fig. 4. RS485 network architecture.

3. PRODUCT DESIGN

There are several well-known IoT platforms, like Azure from Microsoft, ThingWorks from PTC, that can be used for industrial application for this case study we've used ThingWorks but the product can be adapted to connect to any platform that uses the same WEB communication protocols.

The main purpose of the designed device is to read functional parameters from a machine and send them to the IoT platform by using an internet connection. Usually machines are controlled by a PLC so parameters are read through serial communication using the RS-485 standard directly from the PLC [4].

To develop a device for the industrial environment several key elements should be considered:

- All industrial machines use standard 24V CC as control voltage, the power supply requirements are high as the stability of all microcontroller board depend on the power supply.
- The serial communication in industrial environment usually use the RS485 standard as it can connect more than 2 devices for longer distances.
- In industrial environments, several wired and wireless connections are available mostly devices are connected through the RJ-45.
- Digital I/O uses 24V DC and analog I/O uses 0–24V DC.

3.1. Hardware

For this case study, we propose a modular approach (Fig. 6) consisting of five mandatory and three optional modules.

The main element of the proposed device is the microcontroller board. The microcontroller board is based on the atmega328 processor (Fig. 5) it operates at 5V DC and require between 5–12V DC.

The main microcontroller board characteristics are:

- 14 digital I/O with 6 PWM output;
- 6 analog inputs (0-10 V);
- 32kb Flash memory;
- clock speed 16 Mhz.

The power supply module (Fig. 7) is used to power the device using 24V DC as input voltage and providing 5V at 3Amp. The power supply is based on the LM2596 chipset and it support a maximum of 40V DC as input.

For wired network access, the device will include a LAN adapter shield (Fig. 8) with RJ-45 connection based on the W5500 chipset. The Wiznet W5500 provides a network (IP) stack capable of both TCP and UDP it can accommodate up to eight simultaneous socket connections.

Fig. 5. Microcontroller board.

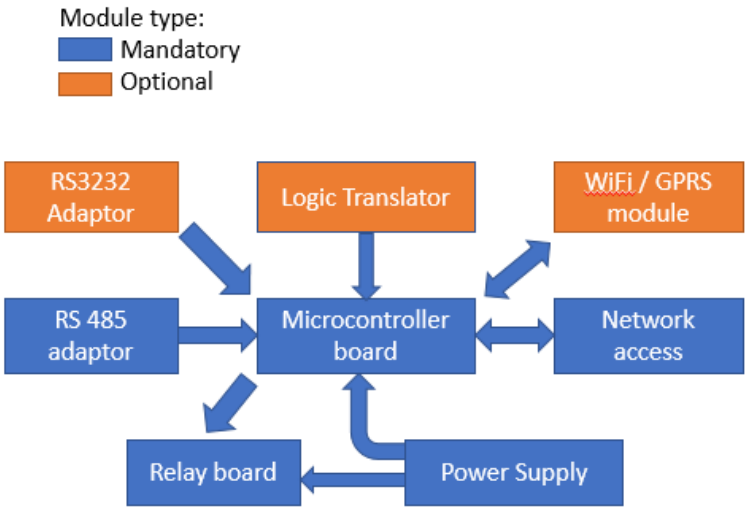

Fig. 6. Proposed device architecture.

Fig. 7. Power module.

Fig. 8. Network access module.

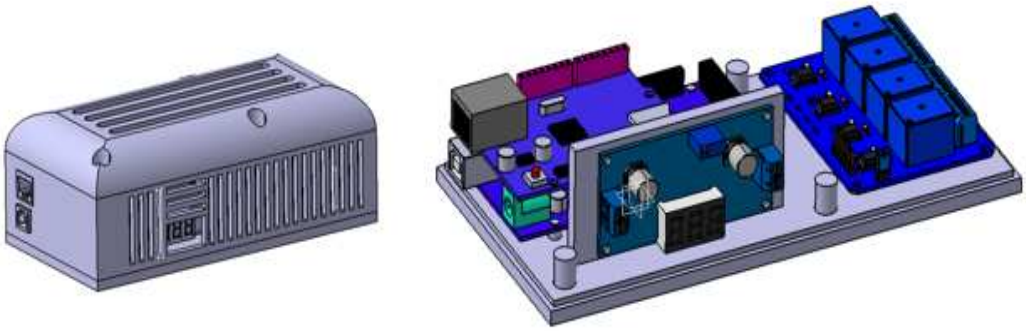

Fig. 9. CAD model of the IoT ready device.

The module includes also an onboard micro-SD card slot, which will be used to store configuration files. Usually industrial serial communication protocols are different than the one used by microcontroller architecture. The RS485 module includes an adaptor from the industrial RS485 serial to the most common TTL serial that can be directly read by the microcontroller board [4].

Another main element for the IoT ready device is the relay board. The relay board is used to control industrial equipment, it can be used to trigger visual alarms, emergency stops and motors.

The relay board can switch high voltage elements it can be used at 220V / 6A AC it can even be used to control contactors for devices that are working at 400 V AC. The relay board can also be used as general I/O for the IoT ready device.

The Wi-Fi 33 optional module ca be used for machines that can't be connected to a wired LAN. The WIFI can be connected by using SPI serial interface. The GPRS module is based on the M10 Quectel chipset. The M10 is a Quad-band GSM/GPRS modem that works at frequencies GSM850MHz, GSM900MHz, DCS1800MHz and PCS1900MHz. It supports TCP/UDP and HTTP protocols through a GPRS connection.

The logic translator module is used to connect the microcontroller I/O to the industrial command circuits. Its main purpose is to transform the 24V DC to 5V DC.

The RS232 optional module is based on the max 232 chipset and is used to transform the industrial serial signal to TTL serial voltage.

3.2. Software

One of the main purpose of the microcontroller is to read parameters send via the RS-485 protocol into serial values that can be published on the IoT platform.

The RS-485 use the Modbus RTU or Modbus ASCII protocols, the Modbus is the main protocol implemented on almost all HMIs (Human Machine Interface) and PLCs (Programmable Logic Controller).

The Modbus uses the query/response cycle – in the Modbus architecture one or more devices play the role of the master device and communicate with the slave device by sending query requests (Fig. 10) [4]. The main difference between the RTU and the ASCII version is that in ASCII each 8-bit byte in a message is sent as two ASCII characters while in the RTU version each 8-bit byte in a message contains two 4-bit hexadecimal characters.

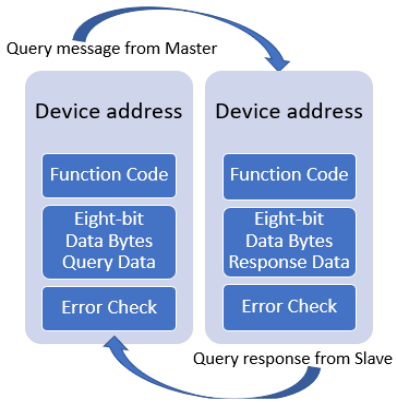

Fig. 10. Modbus query/response cycle [4].

Table 1

Modbus start motor request

Add.	Funct.	Reg. Hi	Reg. Lo	State Hi	State Lo	CRC
05	06	20	00	00	01	43CA

Request from the master device are sent to all connected devices but only the one specified in the query address will send a response back.

Broadcasted messages can be "read" by any device connected to the RS485 bus in this way the microcontroller can see all the parameters that are sent (start/stop command for the motor, speed of the motor, the current of the motor etc.) and can sent those parameters to the IoT platform.

Once the functional parameters are published on the IoT platform they must be interpreted (translated) into useful information.

As an example, the following request (Table 1) is addressed to the device number 5 an AC inverter, the function is 6 (set parameter [5]) and the command 2000 followed by the value 0001 will issue a start forward action to the motor. The first time when the command is received a new thing is created on the IoT platform. The newly created thing will have a property called prop06 with the value 0001 [5].

3.3. IoT platform setup

The IoT ready device is designed to work with any ThingWorx IoT platform so the initial set-up must include the server web address, a security app key, a thing name, and a service that will be further used to create or update all the required things for monitored devices (Fig. 11).

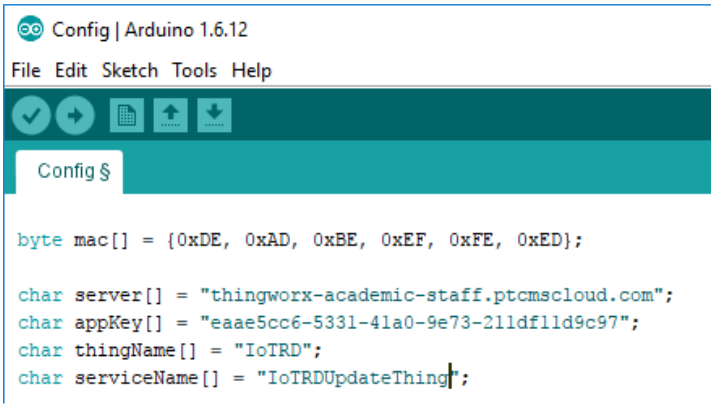

Fig. 11. Initial configuration of the microcontroller.

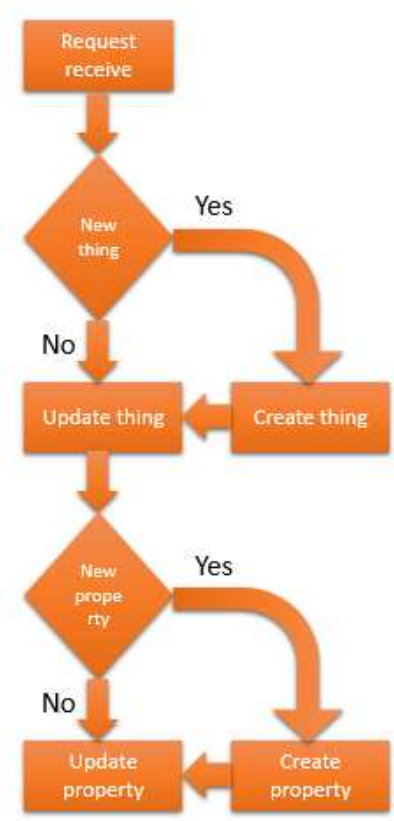

Fig. 12. Thing update property algorithm.

For the IoT platform the initial design will include a single thing and a service. Every time when a new request is received, if the request is for a new thing or for a new property, the service will create the required object (Fig. 12).

The main difficult is to map all the things and properties that are automatically created to real world devices, by using this approach is easier to include machines on the IoT monitoring platform, the difficult task is to build monitoring dashboards.

4. COCLUSIONS

An IoT platform is a good alternative to the classical monitoring devices as it usually includes a lot of predefined functions that can be used to automate tasks.

By using IoT platforms several computational algorithms can be implemented to predict maintenance operations and to eliminate failures.

Working with IoT platforms, big data can also facilitate developing of machine learning technique for predictive maintenance.

From a programmer point of view, this procedure is difficult but from an engineering point of view it saves time as the equipment can be installed with ease.

5. FURTHER RESEARCH

The next step in developing this IoT ready device is to include more optional modules that can be used to connect devices that are using other communications protocols and standards.

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