NEW POSSIBILITIES OF REDUNDANT DATA TRANSMISSION FOR INTELLIGENT SENSOR NETWORKS

Wojciech STASZEWSKI, Adam JABLONSKI and Tomasz BARSZCZ

AGH University of Science and Technology
Department of Mechanical Engineering
Aleja Adama Mickiewicza 30
30-059 Kraków, Polska
Telephone: (48) 509-805-483
ajab@agh.edu.pl

Abstract: Condition monitoring systems (CMS) that are currently available offer many types of tools, such as stationary monitoring systems, portable on-site instrumentation, and finally wireless, autonomous systems. Nowadays, the technology related to electronic systems is developing rapidly resulting in the overall improvement within division of data processing (clock speed and number of processing cores), data transfer (speed and power efficiency of communication), and energy consumption. Unfortunately, this development is not being transferred into Condition Monitoring Systems, probably because the complexity of installation and cost of such systems is holding its manufacturers from introducing significant changes in its architecture. A potential point where all modern technologies will culminate is in a technology initiative that is already underway - this is the “Industry 4.0”. It leverages existing and emerging technologies to improve the efficiency, effectiveness, and service that need to be provided in order to be competitive in the future. Recently developed MEMS technology, ongoing trend to create smaller, more energy efficient electronics, followed by rapidly growing tendency for non-traditional devices being connected to the Internet (IoT) made it possible to design novel, small-size measurement units, which are capable of working autonomously as an individual device or in a set of connected devices, as a distributed system. Such a system might utilize ordinary smart phone device as a part in data transmission chain, as end-user device that allows monitoring current state of machine or as a gateway that can transmit measurements further, into the cloud system. Introducing redundant data transmission for such a device allows creating autonomous CMS, which can react to changes in machines operation and changes of the condition of the device itself. The redundant data transmission allows developing different scenarios including priorities for: extending operation time on battery source, maximizing measurement rate or data transmission rate, prolonging the range of sensors network. Ultimately, these new possibilities might lead to self-learning distributed system and intelligent sensors network.

Key words: Distributed condition monitoring system; diagnostics; IoT; micro data acquisition system; portable machine health management tools; wireless vibration sensors

Introduction: The accuracy of parts that are produced by machining systems is strongly related to the quality their subsystems (e.g., feed-drive systems and spindle units) and therefore if performance degradation due to wear in is not identified, monitored and controlled it may lead into serious production failures. That is why choosing the appropriate maintenance actions is very important as it may delay the possible deterioration and minimizes the machine downtime. Moreover, measuring and monitoring the condition of a machine tool has become increasingly important due to the introduction of agile production, increased accuracy requirements for products and customers' requirements for quality assurance. Condition Based Maintenance (CBM) and Condition Monitoring Systems (CMS) practices, such as vibration monitoring, are becoming attractive, but still challenging. CBM and CMS is usually being used to plan the maintenance action based on the condition of the machines and to prevent failures by solving the problems in advance (before they occurs) as well as controlling the accuracy of the machining operations. By increasing the knowledge in this area it becomes possible to can save money through fewer breakdowns, reduction of inventory cost, reduction of downtime needed for repairs, and an increase in the robustness of the manufacturing processes. The process of monitoring the state of machinery needs the contribution from an early fault and malfunction detection, in order to succeed in prevention of machine failure. Keeping the machine working point at the conditions that are the most optimal leads to machine downtime reduction, which results in economic loss reduction [1][2]. Nowadays, the purpose of monitoring the conditions of an engineering system, especially machinery has become a concern that requires great affection. A Condition Monitoring System (CMS) that bases on vibration monitoring may play a very important role in pushing out the maximum potential of all kinds of machinery by minimizing the downtime. In this paper, the authors try to compare the possible architectures and types of possible communication protocols that can be used for each architecture in order to assess their strengths and weaknesses, which will lead into identification of the threats and opportunities that may have an influence on modern Condition Monitoring Systems. Figure 1 presents scheme of a typical embedded device used for data acquisition for condition monitoring system.

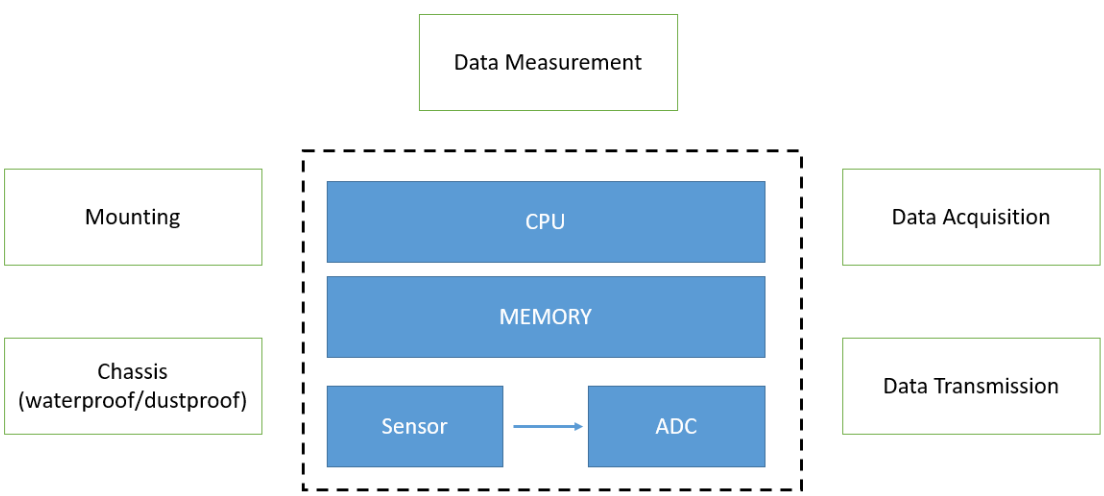

Figure 1: Scheme of an embedded device for modern condition monitoring system.

Condition Monitoring System: Condition monitoring (CM) can be shortly described as a process of monitoring a parameter of condition in machinery, like vibration, in order to identify a significant change in the range of this parameter which usually may indicate a progression of ongoing fault. As this process is a major component of well-known predictive maintenance, the use of CM allows scheduling maintenance or undertaking other actions to prevent further failure as well as avoid its consequences. Condition Monitoring has a benefit in compare to other techniques (breakdown and preventive (or scheduled) maintenance) – deterioration of the crucial parameters that would shorten a typical lifespan of a component can be addressed before they could develop into a major failure [3], causing an unplanned downtime. Condition monitoring techniques are usually used on rotating machinery and other equipment like pumps, electric motors, internal combustion engines, presses, while periodic inspection using non-destructive testing techniques are used for stationary plant equipment such as steam boilers, piping and heat exchangers. The advantages that have been offered by the application of predictive maintenance techniques have in a past few years led to the increase in the development of a number of methods for condition monitoring/fault-diagnostic systems [4]. After detection of possible failure (significant change of monitored parameter), mostly the diagnostic staff is responsible for taking the necessary actions in order to verify the condition of the machinery and later on act accordingly to prevent from machine failure. Those activities may require further data measurement in order to gather more data that might be necessary in order to make appropriate decision regarding machines condition, but at the point where the failure starts to develop it is necessary to notify the engineers that the condition of machinery is changing. Figure 2 presents embedded device that allows End-User to communicate with the device directly, without the use of a gateway.

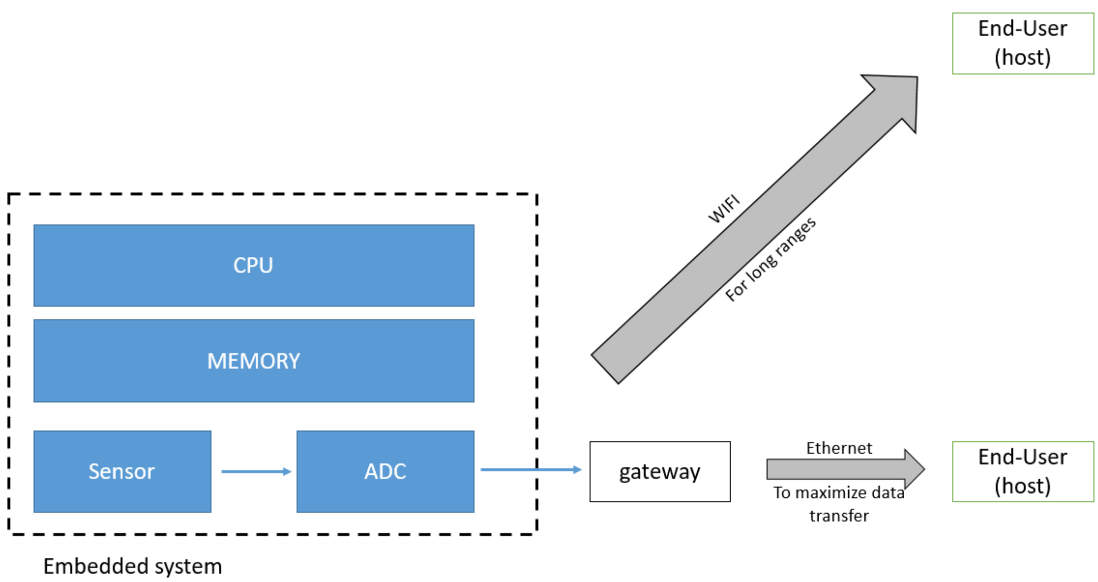

Figure 2: Scheme of an embedded device including direct communication with End-User.

Embedded device

An embedded device is a type of device that is highly specialized for one or very few specific purposes, and is embedded or included within another object or as element of a larger system that serves a greater purpose than the embedded device itself. Data Acquisition Unit (DAQ) is a hardware that acts as the interface between a computer (end-user or host) and signals from the considered machine. Its primary function as a device is to digitize incoming signals so that a computer can interpret them. Many DAQ devices include other functions for automating measurement systems and processes. Figure 3 presents embedded device that allows End-User to communicate with the device with the use of a communication gateway.

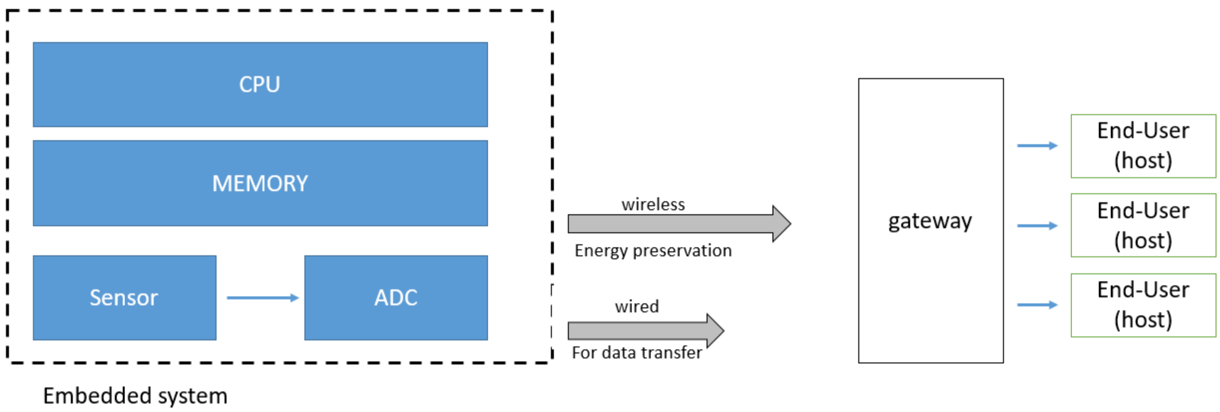

Figure 3: Scheme of an embedded device including communication with End-User using gateway device.

Embedded device and communication protocols

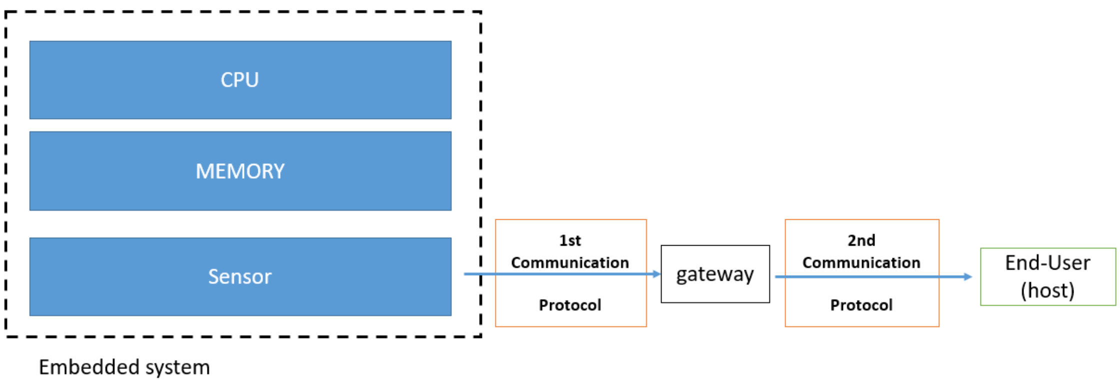

Figure 4: Scheme of a typical communication chain in condition monitoring system.

Figure 4 presents communication chain in condition monitoring system, where different communication protocols are used to connect DAQ with the gateway and the gateway with End-User.

Bluetooth - is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz) from fixed and mobile devices, and building personal area networks (PANs). Invented by telecom vendor Ericsson in 1994, it was originally conceived as a wireless alternative to RS-232 data cables. It can connect up to seven devices, overcoming problems that older technologies had when attempting to connect to each other [5].
Bluetooth operates at frequencies between 2402 and 2480 MHz, or 2400 and 2483.5 MHz including guard bands 2 MHz wide at the bottom end and 3.5 MHz wide at the top. This is in the globally unlicensed (but not unregulated) Industrial, Scientific and Medical (ISM) 2.4 GHz short-range radio frequency band. Bluetooth uses a radio technology called frequency-hopping spread spectrum. Bluetooth divides transmitted data into packets, and transmits each packet on one of 79 designated Bluetooth channels. Each channel has a bandwidth of 1 MHz. It usually performs 800 hops per second, with Adaptive Frequency-Hopping (AFH) enabled. Bluetooth low energy uses 2 MHz spacing, which accommodates 40 channels.

WiFi – is a technology for wireless local area networking with devices based on the IEEE 802.11 standards. 802.11 is the "radio frequency" needed to transmit Wi-Fi, it was defined by Vic Hayes who created the IEEE 802.11 committee. Devices that can use Wi-Fi technology include personal computers, video-game consoles, smart phones, digital cameras, tablet computers, digital audio players and modern printers. Wi-Fi compatible devices can connect to the Internet via a WLAN network and a wireless access point. Such an access point (or hotspot) has a range of about 20 meters indoors and a greater range outdoors. Hotspot coverage can be as small as a single room with walls that block radio waves, or as large as many square kilometers achieved by using multiple overlapping access points [5].
Depiction of a device sending information wirelessly to another device, both connected to the local network, in order to print a document Wi-Fi most commonly uses the 2.4 gigahertz (12 cm) UHF and 5 gigahertz (6 cm) SHF ISM radio bands. Having no physical connections, it is more vulnerable to attack than wired connections, such as Ethernet.

Zigbee

It is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs, designed for small scale projects which need wireless connection.
The technology defined by the ZigBee specification is intended to be simpler and less expensive than other wireless personal area networks (WPANs), such as Bluetooth or Wi-Fi. Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that require short-range low-rate wireless data transfer.
Its low power consumption limits transmission distances to 10–100 meters line-of-sight, depending on power output and environmental characteristics. ZigBee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. ZigBee is typically used in low data rate applications that require long battery life and secure networking (ZigBee networks are secured by 128

bit symmetric encryption keys.) ZigBee has a defined rate of 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device.

Modbus

Communication interface is built around messages. The format of these Modbus messages is independent of the type of physical interface used. On plain old RS232 are the same messages used as on Modbus/TCP over Ethernet. This gives the Modbus interface definition a very long lifetime. The same protocol can be used regardless of the connection type. Because of this, Modbus gives the possibility to easily upgrade the hardware structure of an industrial network, without the need for large changes in the software. A device can also communicate with several Modbus nodes at once, even if they are connected with different interface types, without the need to use a different protocol for every connection. Serial Modbus connections can use two basic transmission modes, ASCII or RTU, remote terminal unit. The transmission mode in serial communications defines the way the Modbus messages are coded. With Modbus/ASCII, the messages are in a readable ASCII format. The Modbus/RTU format uses binary coding which makes the message unreadable when monitoring, but reduces the size of each message which allows for more data exchange in the same time span. All nodes on one Modbus network segment must use the same serial transmission mode. A device configured to use Modbus/ASCII cannot understand messages in Modbus/RTU and vice versa.

Table 1: Communication protocols

	1st Communication protocol			**2nd Communication Protocol**			
	I²C	**SPI**	**UART**	**Bluetooth**	**WiFi**	**ZigBee**	**Modbus**
Data rate	1 Mb/s	20 Mb/s	460 kb/s	1 Mb/s	54 Mb/s	250 kb/s	1 Gb/s
Channels	27	n/a	2	8	2000	65000+	254
Range	2m	10m	1m	10m	100m	100m	1000m
Power consumption	6.1 mW	4.5 mW	6.0 mW	7.0 mW	100.0 mW	75.0 mW	600.0 mW
Advantages	Simple addressing, flow control	Full duplex, push-pull mechanism	Simple	Simple	Range, Data transfer	Fixed data rate	Long range
Disadvantages	Half-duplex interface, processing overheads	No flow control, Hardware complexity	Communication between two devices	Range, Number of nodes	Energy consumption	Middle range	Hardware and software complexity

Table 1 presents comparison of properties of available connection protocols that can be used in order to connect DAQ to the gateway and gateway to the End-User. Further analysis will not be conducted since it is not the intention of the authors. The intention is to present the separation between characteristics of protocols in different parts of CMS.

Machine-to-Machine:
Machine-to-Machine SIM (or M2M SIM) – refers to the technologies that enable devices and sensors to communicate with each other – and with other Internet-enabled devices and systems. Even though M2M refers to ‘non-human’ communication, devices still should have an interchangeable protocol which is used for receiving and sending data. Connectivity is achieved by either inserting or embedding a Machine-to-Machine SIM in the device that is later configured with the home server where all the usage data is collected and can be analyzed for company’s beneficial purposes.

Host – universal system with redundant communication protocols:
A network host is a computer or other device connected to a computer network. A network host may offer information resources, services, and applications to users or other nodes on the network. A network host is a network node that is assigned a network layer host address.
Computers participating in networks that use the Internet Protocol Suite may also be called IP hosts. Specifically, computers participating in the Internet are called Internet hosts, sometimes Internet nodes. Internet hosts and other IP hosts have one or more IP addresses assigned to their network interfaces. The addresses are configured either manually by an administrator, automatically at start-up by means of the Dynamic Host Configuration Protocol (DHCP), or by stateless address auto-configuration methods.
Every network host is a physical network node (i.e. a network device), but not every physical network node is a host. Network devices such as modems, hubs and network switches are not assigned host addresses (except sometimes for administrative purposes), and are consequently not considered to be network hosts. Devices such as network printers and hardware routers have IP addresses, but since they are not general-purpose computers, they are sometimes not considered to be hosts.
Network hosts that participate in applications that use the client-server model of computing are classified as server or client systems. Network hosts may also function as nodes in peer-to-peer applications, in which all nodes share and consume resources in an equipotent manner.

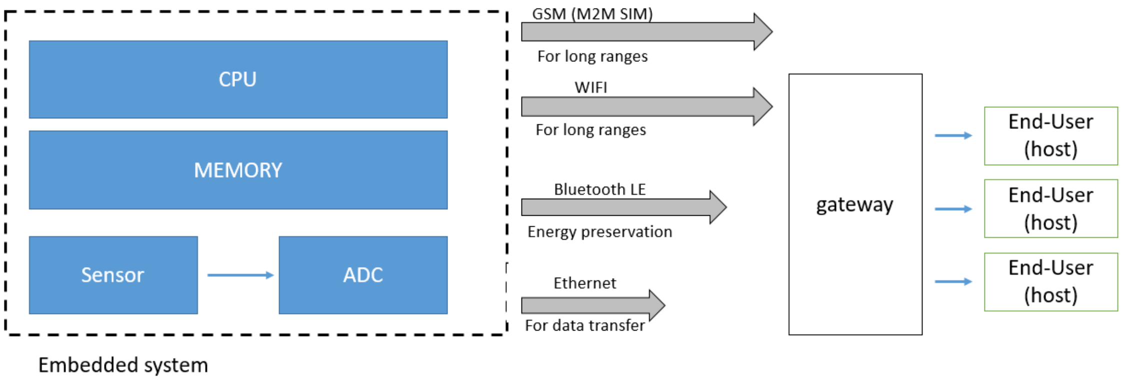

Figure 5: Scheme of proposed communication for condition monitoring system

The host PC serves as the control center of the CMS system. It can be used to:

- control the DAQ,
- provide a graphical user interface (GUI) for the user to operate the system (with use of web gui based on http protocol)
- store the acquired information on mass storage devices
- provide the tools to display and/or analyze the acquired data in real or non-real time

The host computer is also used to define and implement the algorithms performed by the CMS system.

Conclusion: Nowadays, that technology related to electronics systems is developing rapidly – this trend could be observed by looking into the direction of mobile devices development. The Internet of Things (IoT) is the rapidly growing trend of non-traditional devices being connected to the Internet. Industry analysts from International Data Corporation (IDC) suggest that the IoT devices and their ecosystem is expected to create $8.9 (a five-year annual growth rate of 16,8%) trillion market in 2021 with an estimated 20 billion devices [6]. A point where all modern technologies are being culminated is already underway in the industry - this is the Industry 4.0. It leverages existing and emerging technologies to improve the efficiency, effectiveness and service that must be provided in order to be competitive in the future. Presented approach allows creating modern – Industry 4.0 ready – devices that could be integrated into a complex Condition Monitoring System. By now, everyone uses modern devices for ex.: smart phones, wearable accessories like smart watches or smart bands, wireless headphones and speakers or smart ecosystems like smart home automation. Each of those devices provides different ways of communication, usually redundant ones in order to allow their users the most possible functionality. The authors want to point out that by now such a trend is not visible in the industry, but within following years it might be the direction of changes in different branches of industry.

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