Monitoring and controlling of smart equipments using Android compatible devices towards IoT applications and services in manufacturing industry

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Abstract - *The ever increasing requirements for information being accessible at any time, from any place, regardless the type of remote device or planned operation, together with the need of complete control of a specific scenario or device has paved the way towards the next technological revolution: Internet of Things (IoT) and led to several major research projects. Within this paperwork the authors' vision regarding the architecture of an IoT network and an experimental testing bench for one of the first steps leading towards implementing the IoT vision is briefly introduced. The first part presents an overview of the Internet of Things. In the second part, authors' concept regarding an architecture for IoT and the vision towards implementation it into manufacturing environments are presented. The third part illustrates the implementation and testing of the chosen solution for connectivity between a smart equipment and Android compatible devices. In the last part, conclusions are highlighted and the roadmap regarding to concept implementation is defined.*

Keywords - IoT, Android, embedded design, manufacturing processes, smart equipments

I. WHAT IS INTERNET OF THINGS?

The term *Internet of Things* was introduced by K. Ashton in the context of supply chain management and it describes a system where the digital world is connected to the physical world forming a global network [1], [2]. A report of McKinsey Global Institute regarding the disruptive technologies defines Internet of Things as to the "use of sensors, actuators, and data communication technology built into physical objects – from roadways to pacemakers – that enable those object to be tracked, coordinated, or controlled across a data network or internet" with the goal of creating value [10].

Over the last years IoT is foreseen as the solution for the ever-increasing demand for connectivity between peoples, organizations, companies, gadgets and devices and it was born from the desire to achieve software real-time control and access to information.

Based on machine-to-machine (M2M) concept, fuelled by the development of smart sensors and actuators, together with communication technologies (Wi-Fi, Bluetooth, RFID) and supported by cloud computing technologies, IoT becomes a reality and its goal is to make "things" more aware, interactive and efficient for a better and safer world. Therefore, any smart device that can be addressed by means of a communication protocol can be part of the Internet of Things.

European Union research cluster on Internet of Things, defines 'Things' as active participants in any kind of "business, information and social processes where they are enabled to interact and communicate among themselves and with the environment, by exchanging data and information 'sensed' about the environment, while reacting autonomously to the 'real/physical world' events and influencing it by running processes that trigger actions and create services with or without direct human intervention" [3].

Therefore, the Internet of Things is both a reactive (react to changes) and proactive (initiate changes) layer of digital information, covering the real world and connecting to it.

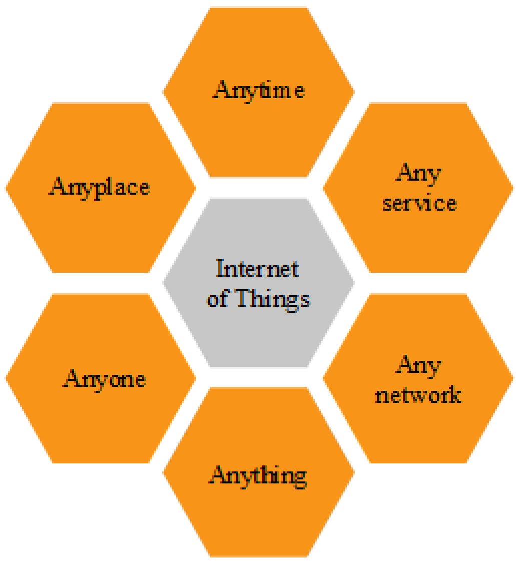

Fig. 1. Internet of Things (4)

A. *Facts about IoT*

Extensive research and great amount of time and financial resources have been invested by corporations and governments into this concept, which is also refereed as the next technological revolution [4]. In Gubbi [16], opinion about IoT

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is composed out of three main parts, linked by communication networks:

- Things: physical devices with an identity that can be accessed, monitored and controlled.
- Middleware, the layer that links the physical world with the virtual world.
- Monitoring and control / Information systems.

It has been estimated that the connected things will reach a number above 50 billion [7] by 2020 and they will bring value to almost any society related activity [12], [13]:

- Energy savings by 20-30% ,
- Increase parking revenue by 20-30%,
- Reduce urban traffic by 30%,
- Reduce water consumption with up to 50%,
- Crime rates will decrees by 20%.

Also, the importance of this concept is depicted in the table below, as perceived by different corporations:

TABLE I. HOW IOT IS PERCEIVED

Corporation	How IoT is perceived
Rockwell Automations	IoT will help us improve the standard of living for everyone [6]
Cisco	Re-defining what's possible…connecting the unconnected [7]
Cisco	IoT is driving the evolution to an intelligent orchestrated network
Schneider Electric	IoT has the potential of delivering a quantum leap in operational efficiency for a fraction of the cost of existing control and enterprise systems [8]
Intel	The IoT starts with intelligence inside [9]

Even if there are great challenges to overcome, roadmaps and strategic research planning are established and the Internet of Things is about to become "the nervous system of the planet" [11].

B. Financial importance of IoT

The value of the network is given by the following equation: Network value = #Connections^2 [7]. Considering the tremendous number of things that will be connected, the financial importance of IoT is of great significance to any kind of business. Figure 2 represents the distribution of revenue within the IoT business.

Implementing IoT in the field of manufacturing will generate revenue of 3.9 trillions of dollars out of an estimate value at stake of $ 14.4 T. As a fact, manufacturing (27%) is considered one of the most important fields where IoT can be implemented and exploited [6].

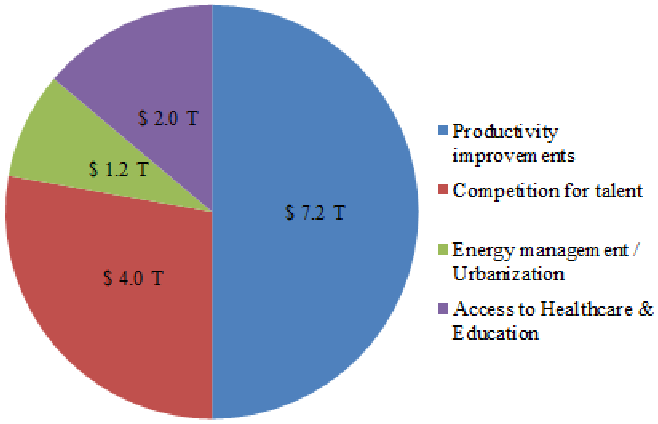

Fig. 2. Distribution of financial revenue within IoT [12], [13]

II. PROPOSED ARCHITECTURE TOWARDS IOT

Several architectures of how the implementation of IoT should be done are proposed in [13], [14], [15] and [16]. Nevertheless, most of them can be summarized by a simplistic view as presented in figure 3.

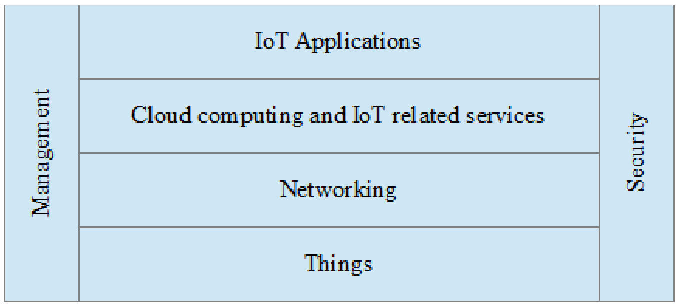

Fig. 3. Simplified generic IoT Architecture

The European IoT research cluster gathered under a strategic research roadmap the technology enablers and the issues that need to be addressed towards achieving the actual goals of IoT concept [3].

The goal of the research project introduced in this paper is to deliver connectivity to smart manufacturing equipment in order to allow them to be controlled and monitored by software applications running on Android compatible devices. Therefore, among the identified enablers and issues that need to be addressed, the ones of interest for this project are listed below:

- Networks of smart equipment enhanced with embedded distributed intelligence to deal with scalability challenges [3],
- Micro-electromechanical systems and sensors for augmented applications [17] or foreknowledge and awareness of things to come [3],
- Plug – and – produce and interoperable thins for efficient things communication [3],
- Extended communication capabilities for intermittent network connectivity and unique identification [3],

- Energy efficient and reconfigurable things [3],
- Remote human machine interaction and interfaces; maintenance service and support [3],
- High computational power and information processing, data storage and data availability [3], [17],

Authors' vision and proposed architecture concept for deploying IoT into the manufacturing field are presented in figure 4, based on several connected research topics in the area of the above mentioned IoT enablers and challenges [17], [18] and [19].

For a better clarity, some layers of the proposed architecture are not presented, among them being: security, middleware and overall information management.

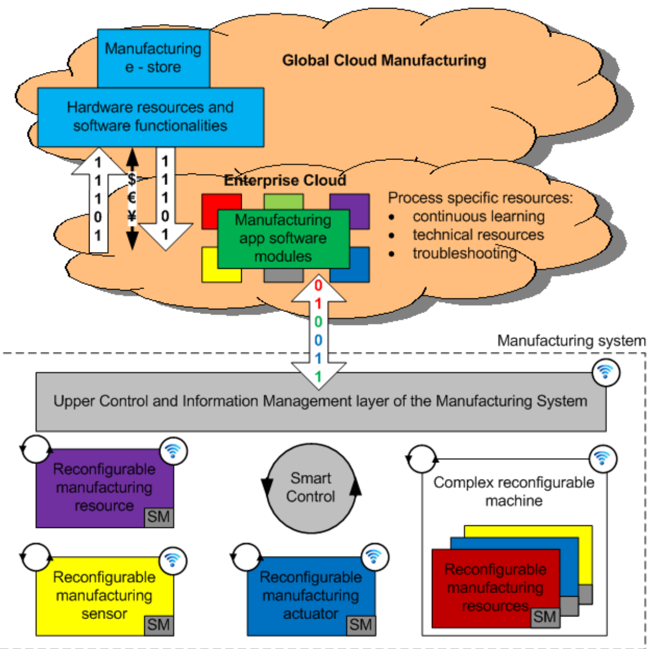

Fig. 4. Simplified view of the proposed IoT architecture for manufacturing

A. *Brief description of the proposed architecture expected outputs*

As depicted from figure 4, a manufacturing system is built out of smart reconfigurable manufacturing resources that are linked by means of wired or wireless communication between them and to the manufacturing system control and information management layer. Sensors and actuators are part of reconfigurable manufacturing resources, which, if joined together, can create more complex resources obtaining extended functionalities.

Smart reconfigurable resources can be considered things because they are addressable by using a communication network (wired or not) and they have the ability to process, store, send and receive data and monitor or control devices (sensors, actuators, etc.). Even more, they have the ability to communicate with other reconfigurable manufacturing resources and react to changes in order to maintain a specified process parameter set-point by different means.

A smart reconfigurable manufacturing resource is enhanced with distributed intelligence, providing local control for the physical manufacturing resource, plug – and – play capability and high computational power. Even more, the hardware and software building blocks of a reconfigurable manufacturing resource can be rearranged in order to obtain a different then before functionality with a minimum effort and delay.

Figure 5 presents an overview of a conceptual architecture for smart manufacturing resources.

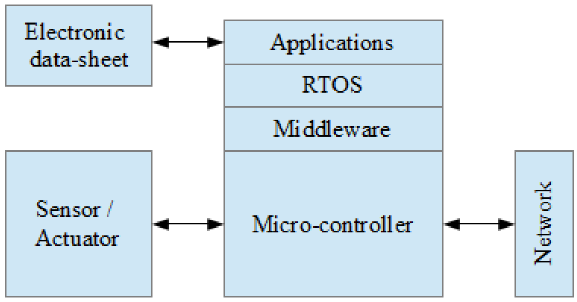

Fig. 5. Smart manufacturing resource architecture for IoT

Several experimental developments for deploying smart reconfigurable manufacturing equipment and control architectures were done by the authors in [17], [18] and [19].

The enterprise cloud is designed to be a service that will connect the manufacturing system or a manufacturing resource to a plant. It is envisaged to provide access to computing services, manufacturing information, manufacturing software applications and to support data sharing with the served process, but, not restricted to this. Enterprise cloud will allow one to remotely connect to a specific manufacturing resource, monitor its status, enhance software algorithms or download new ones.

Global manufacturing cloud represents the global network of manufacturing, whereas an enterprise could sell or buy products, raw materials software and hardware manufacturing resources, technical support and data.

There are three major expected outputs from the proposed architecture at the end of the project. First, the development of smart reconfigurable resources, allowing to rearrange their building blocks in order to fit process needs by selecting the right software applications from the enterprise or manufacturing cloud within the constraints of the available hardware modules. Out of these resources, more complex reconfigurable manufacturing resources can be achieved, leading also to reconfigurable manufacturing systems. Their development will be supported by highly interoperable modular hardware and software blocks, generic embedded systems, real time embedded operating system, intelligent information management algorithms and informational-electrical-mechanical interfaces.

The second output: the graphical human-process interface will provide a more enjoyable user experience to the manufacturing processes by means of PCs, smart phones and tablets. The interface will be used to design control algorithms for reconfigurable resources or to its modules, by using the software functionalities and technical resources available in the enterprise cloud or manufacturing e-store. The control algorithm will be transferred to the resource for which it was designed throughout the computational resource of the upper control and information management layer of the manufacturing system. This layer will be responsible for several activities: to auto-integrate the newly connected reconfigurable manufacturing resources, to support the operator in the configuration process of the newly connected resource, to provide the framework for designing control algorithms, to transfer control algorithms to the manufacturing resource, to monitor the data received from the manufacturing resources and to take over the control of manufacturing resources if needed.

Third, the manufacturing cloud will be the virtual space of the manufacturing industry. It will provide an enterprise with access to a manufacturing e-store, allowing it to acquire, sell, test and develop manufacturing technical, hardware or software resources and know-how. The enterprise cloud will be the virtual model of a specific enterprise that will link the manufacturing cloud with the enterprise facilities. It will host information related to the enterprise and its manufacturing processes, a database with available software functionalities that can be downloaded into hardware resources and a knowledge base with technical resources and troubleshooting actions.

III. TESTING THE CONNECTIVITY SOLUTION

Among the first steps towards implementing the proposed architecture concept is the implementation and testing of the chosen connectivity solution. Therefore, this paper work and experiment is focused on testing the efficiency of controlling and monitoring actions on smart equipment by using Android compatible devices with respect to performances of the developed embedded design and the selected connectivity solution.

At this stage, we expect to successfully deliver at least the following IoT characteristics as presented in figure 1: anytime, anyplace, anyone and partially any network.

Therefore, for this step, an embedded system was design around an ATmega32U4 microcontroller running at 8 MHz at which several sensors and actuators can be connected with respect to hardware constraints and specific characteristics. By deploying specific software algorithms and an intelligent information management, the connected sensors and/or actuators will become smart equipment [18].

The UART communication protocol of the microcontroller was configured to work at a baud rate of 115200 bits per second 8 bit data, without parity and flow control and 1 stop bit. On the UART communication interface a wireless shield from Roving Networks (RN-171ek) was connected as a data gateway from the embedded design to a wireless network, as depicted in figure 6.

An LM35 temperature sensor and a 5VDC fan are connected to the embedded design. When an android compatible device is connected to the embedded design, the user can monitor the: temperature value, the runtime of the system and the due time to maintenance.

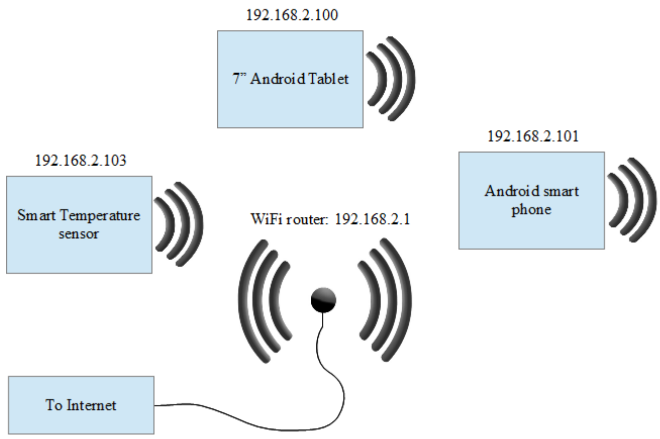

Fig. 6. Wireless connection diagram

Also the user can trigger actions like: starting or stopping the fan by sending specific commands like: fan on or fan off.

A software application from roving networks is used as a terminal for monitoring and controlling the embedded design via the WiFly wireless shield.

In figure 7 it is presented a screenshot from a 7” Android compatible device with information sent from the embedded design. The TCP/IP connection partner IP is 192.168.2.103 and the listening port is: 2000.

Fig. 7. Terminal screenshot from Android compatible device

The above mentioned wireless shield incorporates a 2.4 GHz radio processor, full TCP/IP stack, real-time clock and supports FTP client, DHCP, DNS and HTML client protocol. Secure Wi-Fi authentication with WEP, WPA-PSK and WPA2-PSK and configuration over ASCII codes via UART interface.

Figure 8 presents the experimental workbench composed out of an embedded design having an LCD (4) for local display of process information, together with an Android compatible smartphone (1). Within figure 8, one can also observe: a custom made embedded system (2), a Wi-Fly module (3), a LM35 temperature sensor (5), a board with two relays for loads control (6) and a 5 VDC fan.

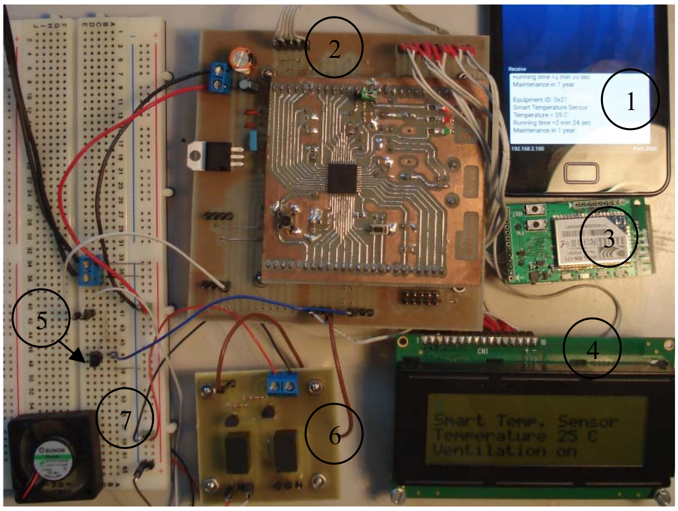

Fig. 8. Experimental workbench

Considering the fact that this paperwork wishes to test a new connectivity solution that can provide a better modularity, flexibility and scalability of a system, no other hardware and software options were experimented. Authors' research in software and hardware re-configurability of smart equipment is presented in other research papers like (18), (19) and (20).

IV. CONCLUSIONS AND FURTHER RESEARCH DIRECTIONS

Conclusions that can be extracted out of this paperwork and experimental project denote the fact that the proposed connectivity solution between a manufacturing resource and a monitoring device meets our needs at this moment. Still, for using the Wi-Fi module at its full performances a microcontroller with better processing power and memory must be selected.

Process data, in this case temperature, has been successfully transferred using the Wi-Fi shield (from Roving Networks) from an embedded design and two Android compatible devices, used for monitoring. Also by sending specific commands, a small fan can be turned on or off by an Android compatible device via the Wi-Fi shield. As it can be seen from figures 7 and 8, the user or operator has access to additional useful information like: the time since the embedded design or manufacturing resources is on, and information about maintenance of the resource.

Based on the result of this work and our vision about how IoT can be implemented into the manufacturing field, the following future research directions are established:

- Developing an intuitive, use-centered graphical human-machine interface for Android devices that can provide extended access and control to information stored within the embedded design and to its functionalities.
- Development of software applications that can be downloaded from enterprise cloud to a manufacturing resource and used by this resource for process control and monitoring.
- Development of a network of manufacturing resources for scalability testing.

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