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Influence of Industrial Internet of Things on Mechatronics

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***Abstract*— In the last decade the Industrial Internet of Things (IIoT) has been growing in all manufacturing plants, but in the last couple of years connectivity has taken a startling leap forward. Connecting sensors to a plant-wide network enables control engineers and plant managers to monitor the entire plant on a set of SCADA/HMI screens from a central location or locally on a machine. Also, industrial connectivity has moved outside the plant. All these facts have a huge impact on mechatronics, especial on design of mechatronics devices. In this paper is presented a brief overview of the impact of IIoT in different area in Mechatronics.**

***Keywords*— IIoT, Mechatronics, Production, Supply Chain Management, Transportation**

I. INTRODUCTION

Multidisciplinary field of mechatronics basically combines mechanical and electrical engineering and control, but also involve other aspects of engineering such as: computing, sensing and networking. The term mechatronics, introduced in the late 1960s by Japan's Yaskawa Electric Company, was derived from the observation of the synergy achieved through the integration of mechanical and electronic technologies Yaskawa, subsequently released trademark rights to the name. Since then it has been used in education and industry to describe systems derived from this heritage [1]. As mechanical, electronic, and control systems for a product is becoming more complex, a development environment needs much more mechatronics knowledge. Also, another technology increases demand for mechatronics knowledge - Internet of Things (IoT). In many definitions of IoT, following are most common:

- The interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data [2].
- IoT is a recent communication paradigm that envisions a near future, in which the objects of everyday life will be equipped with microcontrollers, transceivers for digital communication, and suitable protocol stacks that will make them able to communicate with one another and with the users, becoming an integral part of the Internet [3].
- IoT is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment [4].

An illustration of the IoT with interconnection of different devices is shown in Fig. 1.

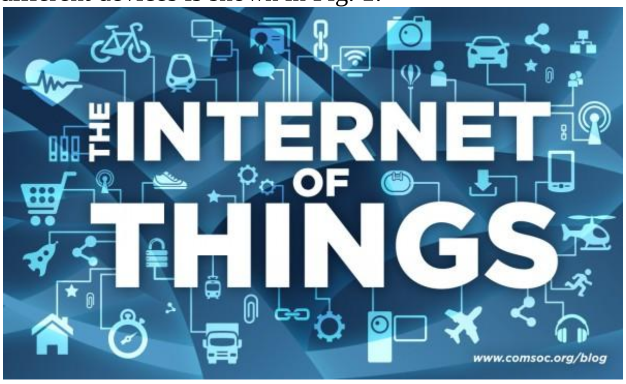

Fig. 1 Illustration of the IoT with interconnection of different devices (Image source: http://www.comsoc.org/blog)

It is obvious that IoT is requiring the design of devices using engineering skills and knowledge in multiple domains: electronics, mechanics, control systems, computers, software, telecommunications, transportations, logistics, etc. In other words, Mechatronics is essential part of the IoT.

The Industrial Internet of Things (IIoT) has its focus on how networking of field devices will transform manufacturing operations and efficiencies. Understanding the complexities of how different field devices will operate within the IIoT, is the most important for modern manufacturing. Different field devices include: sensors, actuators (with embedded technology), Programmable Logic Controllers (PLC), control stations, Supervisory Control and Data Acquisition/Human–Machine Interface (SCADA/HMI) devices, and fieldbus technologies used for establishing communication between them.

After leaving manufacturing facility, many products will have capability to continue its connectivity and be part of another network [5]. Also, industrial connectivity has moved outside the plant. Wind farms, smart grids, monitoring critical truck components in mines are good examples of how IIoT move outside the plant. The rest of

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the paper is structured as follows. Chapter 2 provides the background of the IIoT and possible applications in everyday life, as well as its future development. Chapter 3 presents relationship between the IIoT and mechatronics. Chapter 4 considers the issues and challenges that mechatronics systems designers are facing in relation to managing the dynamics of the changes required by IIoT. Section 5 gives conclusions and identifies areas for further research.

II. Industrial Internet of Things

The term "Industrial Internet of Things" started to use in 1999. by Kevin Ashton in order to explain linking the new idea of Radio-frequency identification (RFID) in P&G's supply chain management and the Internet [6]. The Industrial Internet of Things (IIoT) is made up of a lot of devices that are connected by fieldbus. The resulting systems can collect, analyze, exchange data, and instantly act on information to change their behaviour or their environment. All this can be done without human intervention as real time activity. The focus of the IIoT is industrial environment like shown in Fig. 2.

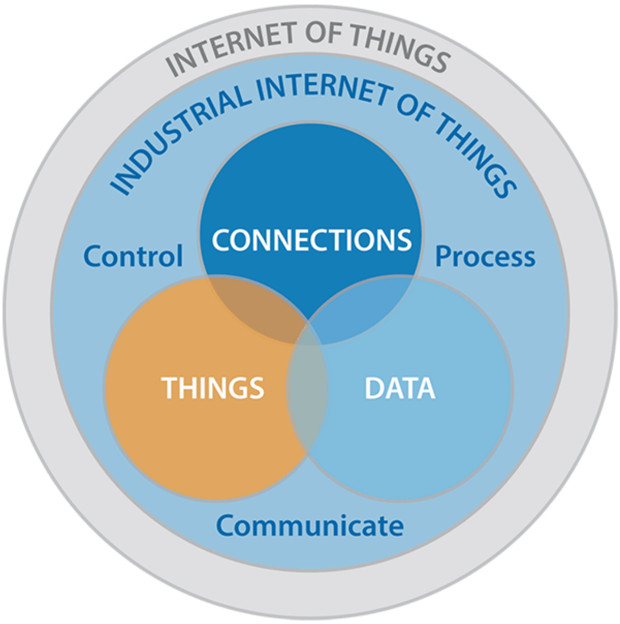

Fig. 2 Illustration of the IIoT (Image source: rti.com, 2015)

The connection of sensors, machines, devices and things allows increasing operational efficiencies of production systems. Also, analyzing of data can improve structure and organization of the business model.

From the first day when the Internet was developed, people and companies realised potential of communication over Internet. There was a desire to connect more devices to it. The number of internet users has increased tenfold from 1999. to 2015. [7]. From this statistics an "Internet User" is therefore defined as an individual who can access the Internet, via computer or mobile device, within the home where the individual lives. On the [7] it can be seen a current number of individuals who has access to the Internet at home. That number is over 3.1 billion.

But the "Internet User" is not only the individual who access to the Internet using different communication devices. Actually, the Internet user is every physical object which communicates over the Internet. This approach to definition of "The Internet user" lead to new term: "The Internet of Everything (IoE)" instead of term "The Internet of Things". Relationships inside the Internet of Everything are shown in Fig. 3.

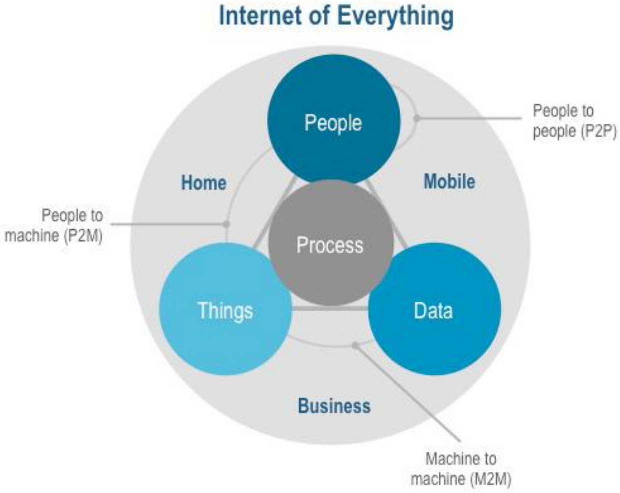

Fig. 3 Relationships inside the Internet of Everything (Image source: Cisco IBSG, 2012)

The Internet of Everything can be viewed as a network of networks with billions/trillions of connections between things. Those connections create unprecedented opportunities as well as new security and other risks. The estimated number of things that are connected via the Internet from 1995. to 2020. is shown in Fig. 4.

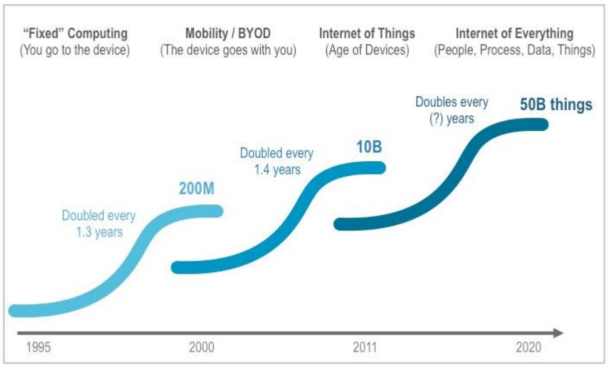

Fig. 4 Estimated numbers of things that are connected via the Internet (Image source: Cisco IBSG, 2012)

For many products, the IIoT is starting point for acquisitions first data which will be used in a product life cycle. Many of these data are using forward and backward exchange of information. It can help increasing efficiency, and most importantly continuing to improve production, because most businesses are focused on getting products to market more quickly. Engineers and managers are still at the beginning to imagine the possibilities that may be achieved by taking advantage of billion devices that can communicate and act in real time, based on information they exchange amongst themselves. As the IIoT becomes better understood, defined and developed, more impactful IoT/IoE applications can and will be created. As developing of the IIoT require multidisciplinary engineering knowledge, involving mechatronics engineers is good approach to overcome a lot of problems which arise during networking of different devices.

III. IIoT and Mechatronics

There are several definitions of Mechatronics. Usually, Mechatronics is defined as an interdisciplinary field which includes mechanical engineering, electrical engineering, computer science and control engineering. Very often, this definition is modified by adding/changing some engineering disciplines. One of these adoptions is shown in Fig. 5. This definition of Mechatronics is interesting because it includes Information systems as one of key parts [8]. The IIoT produces a lot of data and without an information system collected data is useless. More complex representation of Mechatronics is shown in Fig. 6.

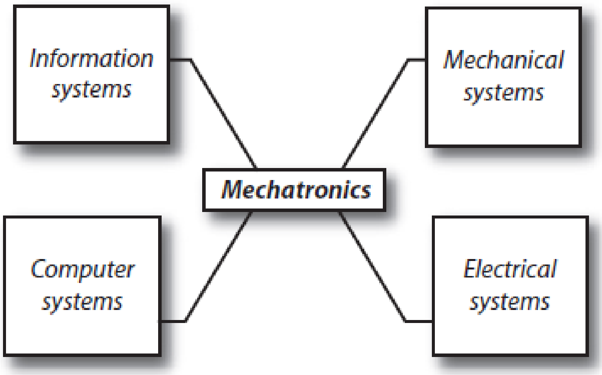

Fig. 5 Mechatronics constituents (Image source: Devdas Shetty, 2012)

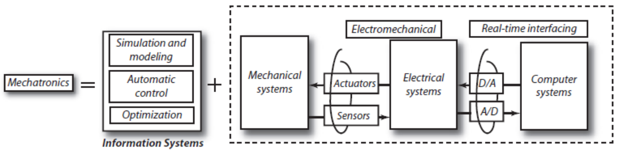

Fig. 6 The key elements of the mechatronics (Image source: Devdas Shetty, 2012)

Mechatronics is continuously changing its contents. Particular developments in information technology and electronics influence on increasing diversification of both content and concept of Mechatronics. This can be seen by reference to Fig. 7 which shows the spread of topics identified as mechatronics in a keyword search using Web of Knowledge and IEEE Xplore [9].

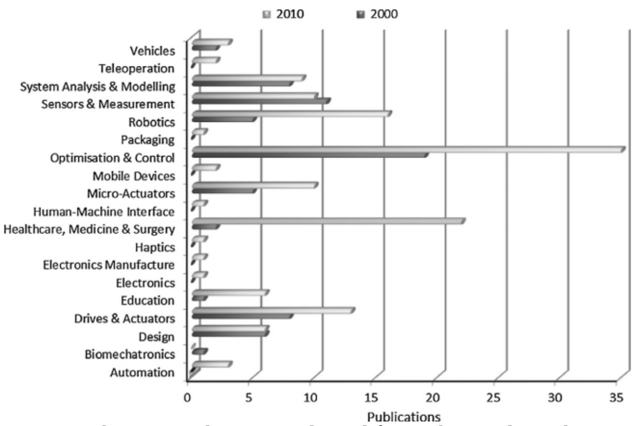

Fig. 7 Mechatronics subject areas derived from a keyword search using Web of Knowledge and IEEE Xplore for the years 2000 and 2010. (Image source: Breadly David, 2015)

The differential rate of development in the core mechatronics subjects of information technology, electronics and computing and mechanical engineering is suggested by Fig. 8.

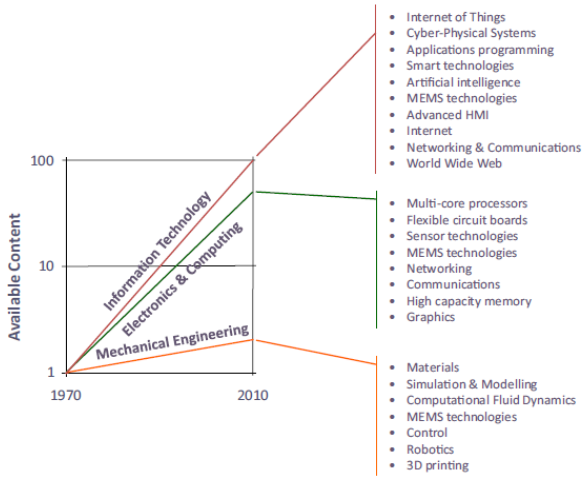

Fig. 8 Development and diversification of core mechatronics technologies in the period 1970–2010. (Image source: Breadly David, 2015)

Mechatronics is involved in many application areas. Therefore, IIoT has different interaction between things and a variety of levels. Industrial communication is much more complex then office communication. It is not only one type of network and one type of protocol that is used. It can be very simple like an AS-i network which needs only one cable to connect to the sensors and actuators, the input and output modules from any manufacturer. The power supply to the sensors and actuators is also provided by this cable. AS-i users do not need thorough knowledge of industrial systems or communication protocols. Unlike other digital networks, the AS-i network does not need terminators or equipment description files. Simplicity is its strong point for networks like AS-i [10]. Other industrial communication networks like: Profinet, Indutrial Ethernet, CANbus are much more demanding. Now, within industrial communication exists hundreds of protocols and networks. Industrial network shares, according to HMS are shown in Fig 9 [11].

Many users of industrial communication networks believe that main reason to the large amount of network standards is that large companies use the communication technology to tie their customers to their company. On the other hand, specific technologies are often more filled with features which have more advantages in particularly process. Also, to overcome difficulties in interconnection between networks it can be used open network standards like OPC (Open Platform Communications) standard [12]. Implementation of this standard gives a degree of interoperability.

Application areas of Mechatronics are numerous. Some important application areas are indicated in Table I with typical ways of communication in IIoT/IoT environments. Referring to Fig. 3, abbreviations of M2M, P2M and P2P is following:

- M2M indicates Machine to Machine communication, which actually means communication between devices (sensors, actuators, PLC, ...), P2M indicates Person/People to Machine communication, which actually means communication between person/people and machine using SCADA/HMI, or any kind of

GUI (Graphical User Interface) for beginning processes on machines,

- P2P indicates People/Person to People/Person, which actually means communication between people using personal connected devices.

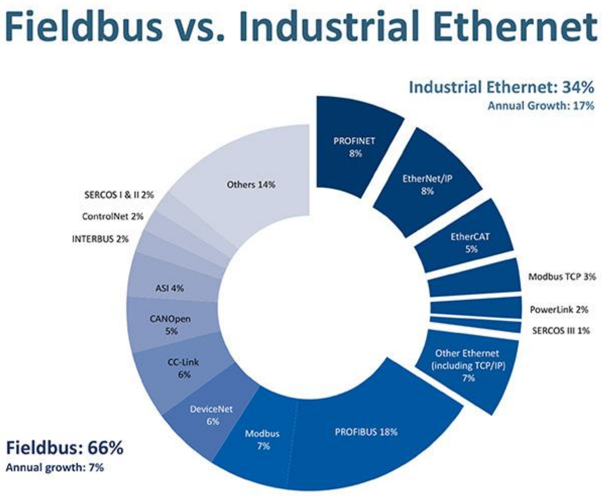

Fig. 9 Industrial network shares according to HMS (Image source: HMS Industrial Networks, 2015)

TABLE I MECHATRONICS APPLICATIONS AREAS WITH TYPICAL WAYS OF COMMUNICATION

Applications areas	Communication		
	M2M	P2M	P2P
Automation	X		
Automotive engineering	X	X	
Biomechatronics		X	X
Computer aided and integrated manufacturing systems	X	X	
Computer Numerically Controlled machines	X	X	
Consumer products			X
Control engineering	X	X	
Diagnostic, reliability and control systems techniques	X	X	X
Engineering design		X	X
Engineering and manufacturing systems	X	X	
Expert systems	X	X	X
Games technologies			X
Health technologies and systems		X	X
Industrial engineering	X	X	
Intelligent Machines	X	X	
Machine vision			
Manufacturing technologies		X	
Mechatronics systems	X	X	
Medical technologies and systems		X	X
Packaging technologies	X	X	
Power production and generation	X	X	
Robotics		X	X
Sensing and control systems		X	X
Servo-mechanisms and control	X	X	
Space technologies		X	
Structural dynamics		X	
Systems engineering	X	X	
Transportation and vehicular systems	X	X	X

As mention previously, industrial connectivity has moved outside the plant. Wind farms can be monitored and adjusted to optimize the use of wind. Connectivity is allowing wind farms to coordinate all of the turbines to gain optimum energy production. An increase in airflow read by the front turbine sends a signal to the rest of the farm to adjust for changed velocity, as represents in Fig. 10. Also, wind farm structured energy harvester can perform well in wireless forest fire monitoring application. [13]-[15].

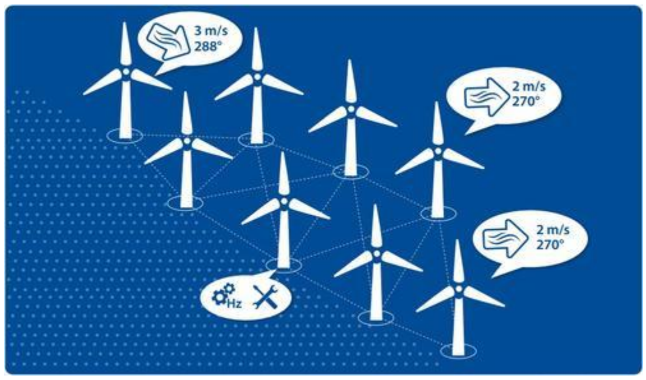

Fig. 10 Internet of Wind farm (Image source: rti.com, 2015)

The transportation and construction industry, have started to deploy smart equipment that can let users know position, fluid levels, battery condition, and temperature inside transportation vehicle (Fig. 11). These sensors information with position information have a big influence not only on a supply chain management. Fleets that use Global Positioning System (GPS)/ global navigation satellite system (GNSS) tracking technology, have been able to increase productivity and efficiency, reduce costs, improve safety and overcome many other business challenges. Integrating GPS/GNSS into consumer products is widely used (smart phone, camera, watch ...). Consumers' reliance on positioning and identification technologies is growing [16]-[17]. These facts confirm the predictions of further expansion of the IIoT.

Fig. 11 Monitoring truck components (Image source: fool.com 2015)

Also, in everyday life we are surrounded with a large number of sensors as shown in Fig 12. This diagram shows the extensive range of sensors involved in IIoT connectivity applied in smart homes/cities [18]. Ultimately the connected system connects to other connected systems, thus improving performance and reducing waste from the grid to the plant to the supply chain to the home (Fig. 13).

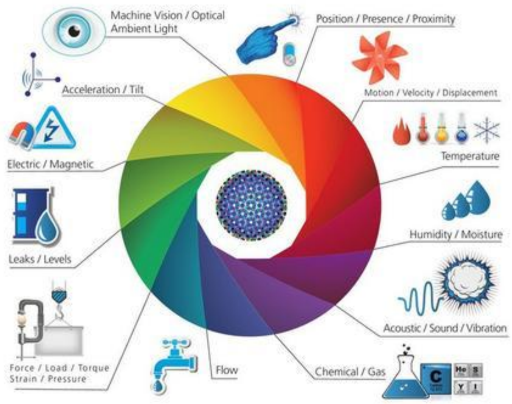

Fig. 12 Sensors in smarts home/city (Image source: www.educatingplanet.com)


Fig. 13 Connection of different connected systems (Image source: e2e.ti.com, 2015.)

According to research and estimation of CISCO, Garnter and GE companies, market potential IIoT is enormous as is shown in Fig. 14.

Fig. 14 Market size of IIoT (Image source: sliceshare.net, 2015)

It is clear that the Mechatronics has to be ready to accept all the changes and opportunities of the IIoT. Many challenges that mechatronics systems designers are facing is related to managing dynamics of changes that the IIoT generates.

IV. Mechatronics Challenges

If we have in mind the changes both in engineering and information technology which are brought by the IIoT, mechatronics has to provide the bridges between the information oriented world and the physical world. For the successful construction of these bridges it is necessary to have good education of mechatronics engineers. Experiences in education of Mechatronics are over thirty years old. In this paper is given only one experience from University of Novi Sad. Mechatronics study program at University of Novi Sad is established 2002. In this study program subjects are mainly divided in four engineering disciplines as shown in Fig. 15. [19].

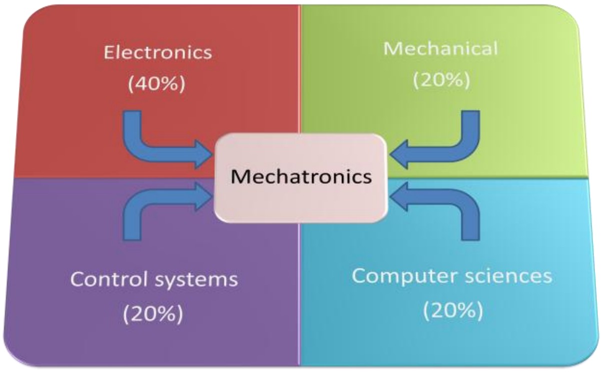

Fig. 15 Structure of the Mechatronics curriculum at University of Novi Sad

The synergistic combinations of such divided subjects enable future engineers to follow main trend in Mechatronics, which can be described as: Developing smart devices which characterised by high degree of concurrency and decentralisation with self-coordination [1], [20]-[22]. Other key trends in Mechatronics are:

- Greater precision,
- Newer materials and
- Miniaturization.

These trends lead towards mechatronics units which are significantly smaller size, at level of nano size.

At the same time as results of globalization of markets, we have global distribution of the processes of product realization (concept development, design, prototyping, manufacture, and servicing). In other words we are applying concept of the IIoT to enable further grow of the economy.

Pace of innovation around the world is increasing dramatically in recent years owing to technological developments especially in filed communications and the IoT. These developments have a big influence in the designing of a mechatronics product. In this context, following phases of the mechatronics design process have bigger significance:

- Sensor and actuator selection,
- Control system design and
- Deployment of embedded software.

These phases are critical for the successful implementation of IIoT and life cycle of products.

Successful mechatronics design can lead to products that are extremely attractive to the consumer in terms of quality and cost effectiveness.

The above challenges are not the only one, but in this paper are pointed out. There are various views on the other challenges that can occur between the IIoT and Mechatronics which will affect both fields.

V. Conclusions

The Internet is one of greatest innovation of the late 20th century. The development of the Internet has resulted in a radical expansion and transformation of many processes in manufacturing, service industry, e-commerce, transportation ... Connection of identification technology and the Internet in production is enabled development of the IIoT. Also, this connection has a big influence on Mechatronics, especially in education of mechatronics engineers and the mechatronics design process. Therefore, many challenges are in front of Mechatronics. The successful resolution of these challenges enables further development and Mechatronics and the IIoT, with industrial progress and grow of economy.

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