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Different Perspectives of The Upcoming Industrial Era and Current Trends in Cyber-Physical System: A Review

Ahmad F.A. Md. Hezam
Department of Mechanical and Production Engineering (MPE)
Islamic University of Technology (IUT)
Boardbazar, Gazipur, Dhaka, Bangladesh
ahmadfatehi@iut-dhaka.edu

Abrar Sobhan Chowdhury
Department of Mechanical and Production Engineering (MPE)
Islamic University of Technology (IUT)
Boardbazar, Gazipur, Dhaka, Bangladesh
abrarsobhan@iut-dhaka.edu

Muhammad Waqas
Department of Mechanical and Production Engineering (MPE)
Islamic University of Technology (IUT)
Boardbazar, Gazipur, Dhaka, Bangladesh
muhamamdwaqas@iut-dhaka.edu

Abstract
The consecutive improvement in industry has caused us to move towards the ongoing industrial revolution "Industry 4.0". Yet, the concept of the "Smart Industry" lacks a clear understanding and proper knowledge. This review paper aims to provide an overview of the modern industrial revolution, "Industry 4.0" referred to as the "Fourth Industrial Revolution", the ongoing automation of traditional manufacturing and industrial practices using modern smart technology. Based on several authors' perspectives the terms related to "Industry 4.0" and its components will be highlighted in this literature. In this paper, the aspects of implying modern technology in the core components industry are highlighted. The structure and evolution of Cyber-Physical System (CPS), Industrial Internet of Things (IIoT), Information Communication Technology (ICT) via the Internet of Service (IoS) which has taken place in the procedures, control, logistics management, design and efficiency of the industry products reducing time, cost and human intervention are discussed in the light of different authors. The integration and correlation of the several key components of Industry 4.0 for an overall development of the industrial sector is being analyzed. The end of this paper focuses on the current challenges faced in implementing Industry 4.0.

Keywords
Cyber-Physical System, Industry 4.0, Fourth Industrial Revolution, Industrial automation and control systems.

Introduction
In this paper, the current technological advancement and automation taking place in the industrial and production system, which is known as Industry 4.0 (Fourth Industrial Revolution) and related used technology are being elaborated and defined from different perspectives of Authors (Research Articles and Journal Papers). The main target of this paper is to shade off the mystery of the recently used industrial terminologies and their framework using the method of comparing the existing definitions, relevant details, gaps, and challenges which may lead to better handling of applying the technology in the industry. The terminology that this paper discusses is Industrial Internet of Things (IIoT), Cyber-Physical Systems (CPS), and Industry 4.0.

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Continuous development of wireless technologies has shaped a new concept called the Internet of Things or simply IoT. In 1998, Kevin Ashton introduced this concept of IoT which was meant to connect things and objects to the Internet [1]. Besides impacting sectors like healthcare, environment, transportation, IoT has a major impact on the industries by increasing their efficiency through optimized supervision and control management. It was mentioned by Soumaya et al. [2] the demand for a sustainable product by customers has made the industries focus more on after-sales service which requires the implementation of modern technologies. The continuous improvement for optimization and control of the industrial processes has caused the emergence of Industry 4.0 by the combination of several components. The implementation of IoT in the industry sector has emerged a whole new concept called Industrial Internet of Things (IIoT). IIoT allows the industries to assemble large data and utilize them in the improvement of the overall performance of the company by reducing costs and increasing productivity. Another significant paradigm in the evolution of Industry 4.0 is the Cyber-Physical System (CPS). CPS has the potential to ensure the physical world to be supervised, regulated, and impacted both adaptively and logically [3]. Researchers have assumed that the implementation of CPS in the world of engineering will have far-reaching outcomes. The development of CPSs interlinks both the opportunities and challenges of technology, the economy, and society.

Industry 4.0

Germany which has been one of the greatest leaders in the manufacturing industry has launched the entire idea of "Industry 4.0" in 2011 as a major part of their strategy to create a high-tech integrated manufacturing industry. Kagermann et al. [4] suggests that developed nations like Germany will be the most successful ones if they could actively take part in the entire initiative of Industry 4.0. To be more concise, it refers to the automated process of operation and production, the systems based upon knowledge, sensor, and information. A very crucial part of the industrial environment is the logistics. The implementation of CPS and IoT into this field would be able to enable a real-time tracing of inflow of raw material, managing the supply chain better along with precise risk management. Hoffman and Rusch [5] have argued that the vision of Industry 4.0 can only turn into reality if the logistics could make it possible to supply the production system with the correct amount of material at the correct time. Again Herman et al. [6] suggested that not only IoT but also IoS has the potential to enter into the functioning of the industries. Due to the introduction of such automated technology these factories are also named "Smart Factories". The concept of Industry 4.0 is so unique and diversified that even the researchers tend to argue over the related facts. Though Industry 4.0 is a reality cherished by the industrialists still it is uncertain when this could turn into a real situation and how much time will it require. Herman et al. [6] has determined 4 elements of the Industry 4.0 concept from extreme research over various business publications. These elements include all the systems we have been discussing till now namely – Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services (IoS), and Smart Factory. With the integration of these 4 factors, it is expected that the concept of Industry 4.0 will ultimately revolutionize logistics management by decentralizing, self-regulation, and higher efficiency.

Industrial Internet of Things Definitions

The definition of the IIoT proposed by (Hugh Boyes) [4] that Industrial Internet of Things: A system comprising networks, smart objects, cyber-physical assets, associated generic information technologies, and optional cloud or edge computing platforms, which enable real-time intelligence. And autonomous access, collection. Analysis, communications, and exchange of process, product, and /or service information, within the industrial environment, to optimize overall production value. This value may include; improving product or service. Delivery. Boosting productivity. Reducing labor costs, reducing energy consumption, and reducing the build-to-order cycle. (W.Z.Khan) [5] proposed that IIoT could be defined Industrial IoT (IIoT) is the network of intelligent and highly connected industrial components that are deployed to achieve high production rate with reduced operational costs through real-time monitoring, efficient management, and controlling of industrial processes, assets, and operational time.

Framework of IIoT

The Basic Structure of the IIoT gives the ability to analyze the system security and other arising affairs. The proposed Framework by (Hugh Boyes) [4] is characterizing the devices based on six categories, with each category having several subcategories:

1. Industry sector;
2. Device location;

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3. Connectivity;
4. Device characteristics;
5. Device technology;
6. User type

1. Industry sector:

The industry sectors illustrated in Fig. 1 are relevant to the severity and nature of threats to an organization and the IIoT devices deployed in the organization's operational systems, the sub-categories listed above are generally recognized as the critical infrastructure of developed economies.

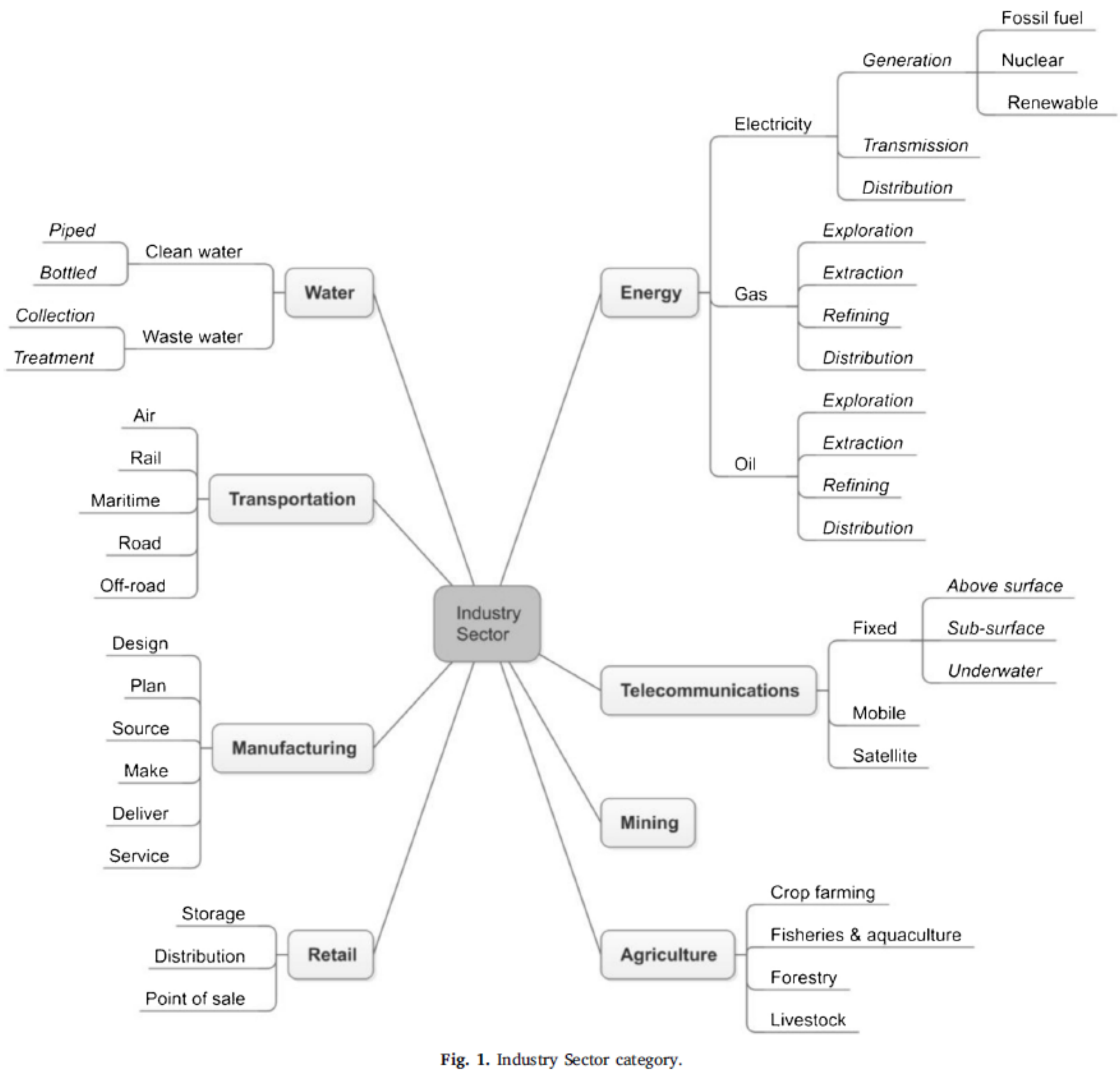

Fig.1. Industry Sector Category [4]

2. Location:

Four sub-categories are proposed as described in Fig.2:

(a) Ecosystem
(b) Purdue Model
(c) Physical
(d) Mobility

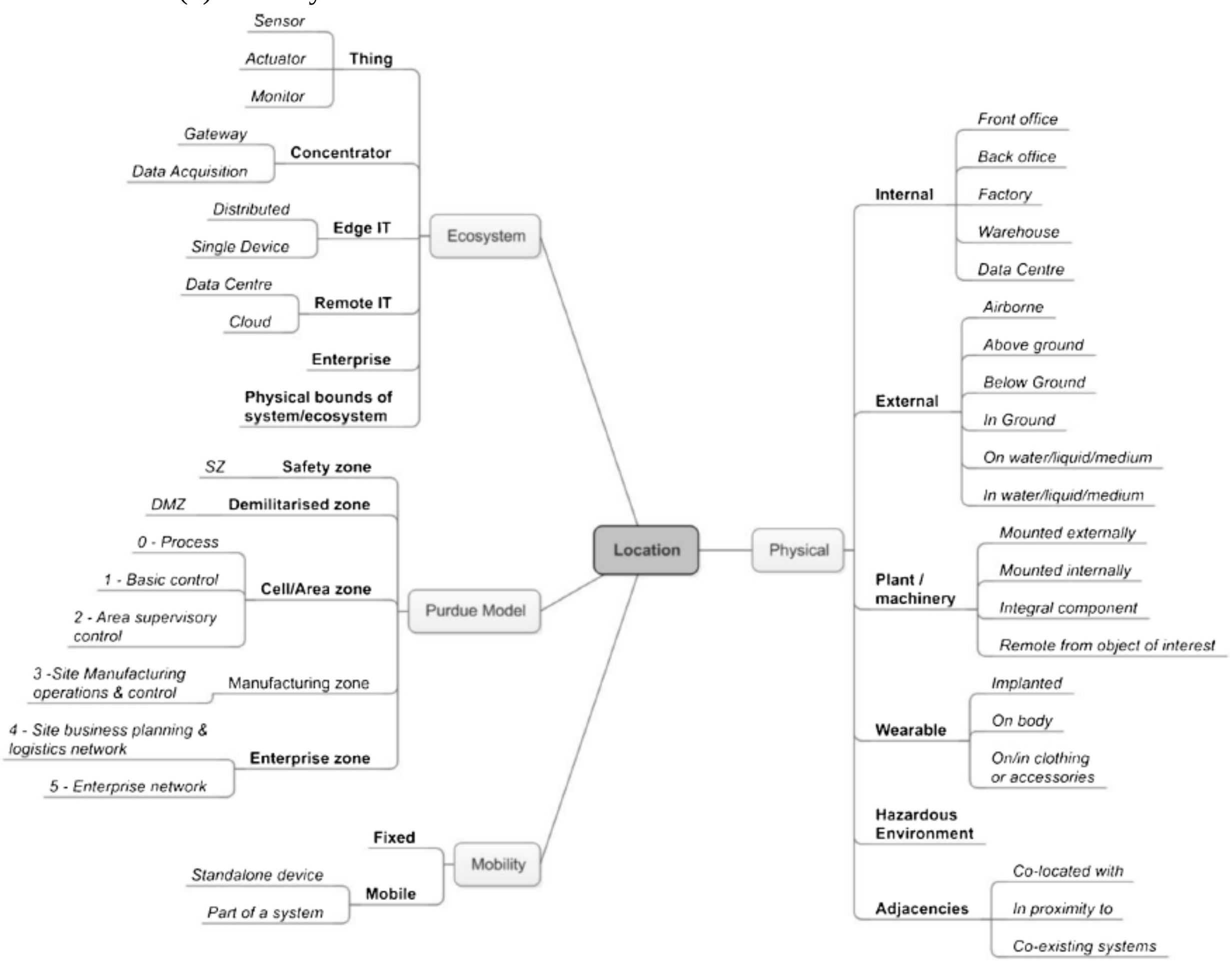

Fig.2. Location Category [4]

3. Connectivity:

The proposed connectivity characteristics are illustrated in Fig.3, the aim of using these is to identify the essential features of the networking or communications connectivity between the device and the IIoT system within which it operates.

(a) Mechanism
(b) Nature
(c) Initiation
(d) Protocols
(e) Link security

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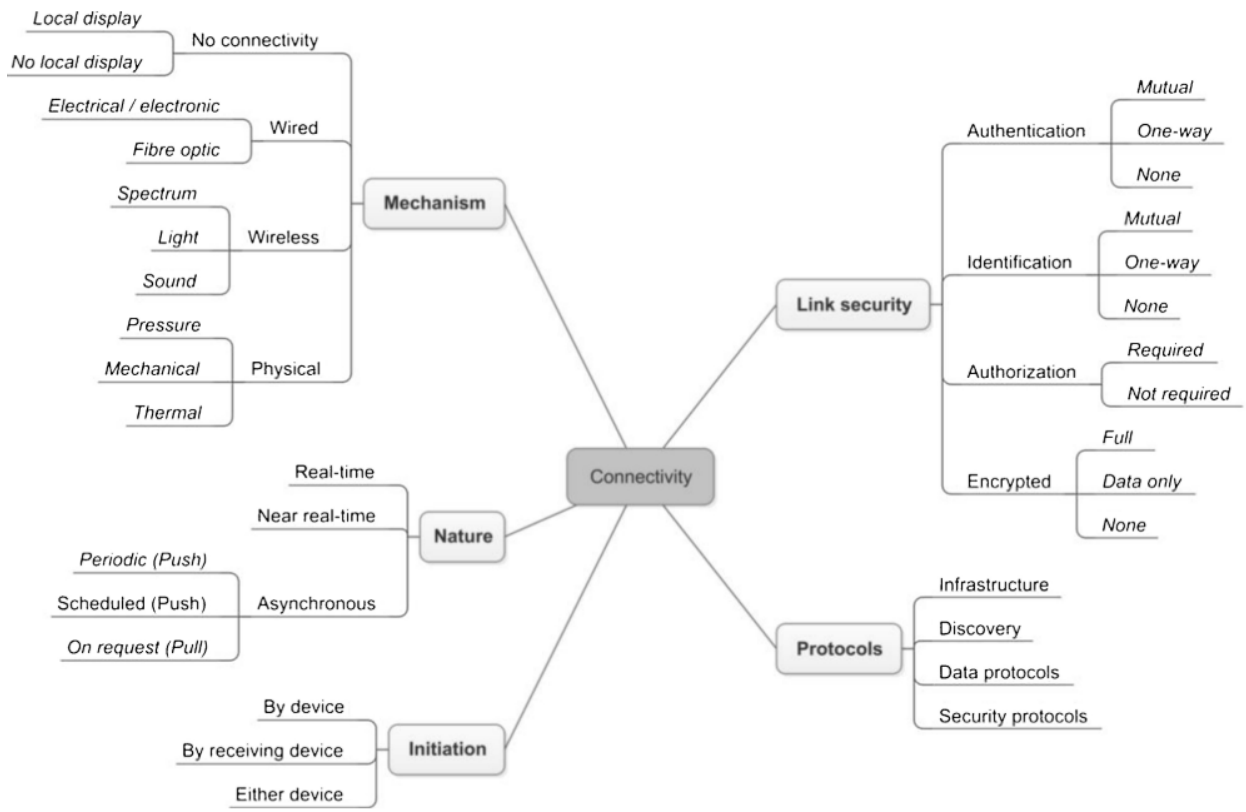

Fig.3. Connectivity Category [4]

4. Device characteristics:

The proposed device characteristics, illustrated in Fig. 4, is on the functionality of the device, specifically how important it is to the system, it is part of, the function the device provides, and how it is managed.

The proposed sub-categories are:

(a) Criticality
(b) Function
(c) Relationships
(d) Management interface

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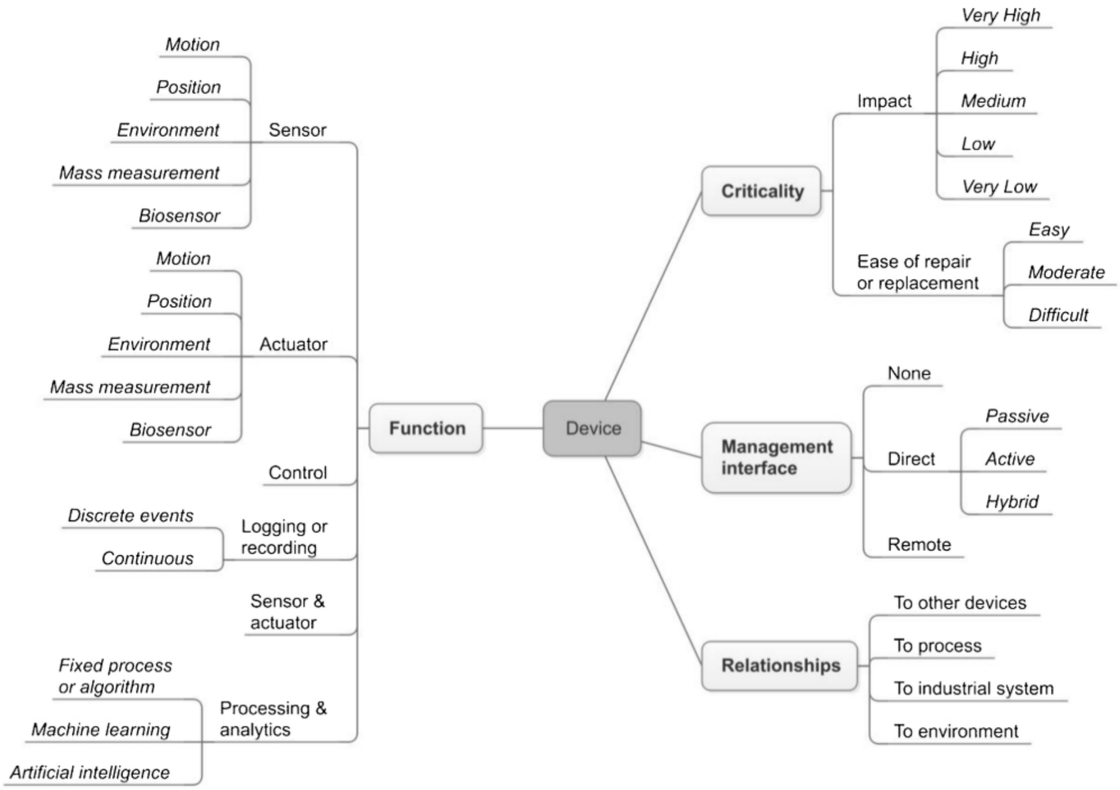

Fig.4. Device category [4]

5. Device technology:

The proposed technology characteristics of the IIoT device are illustrated in Fig. 5. These focus on technical features that may constrain or influence device design or the ability to address vulnerabilities once the device has been deployed. The power source, energy use, and hardware characteristics are relevant as they can constrain the processing capacity of the device, which in turn affects the design of security mechanisms used for protection.

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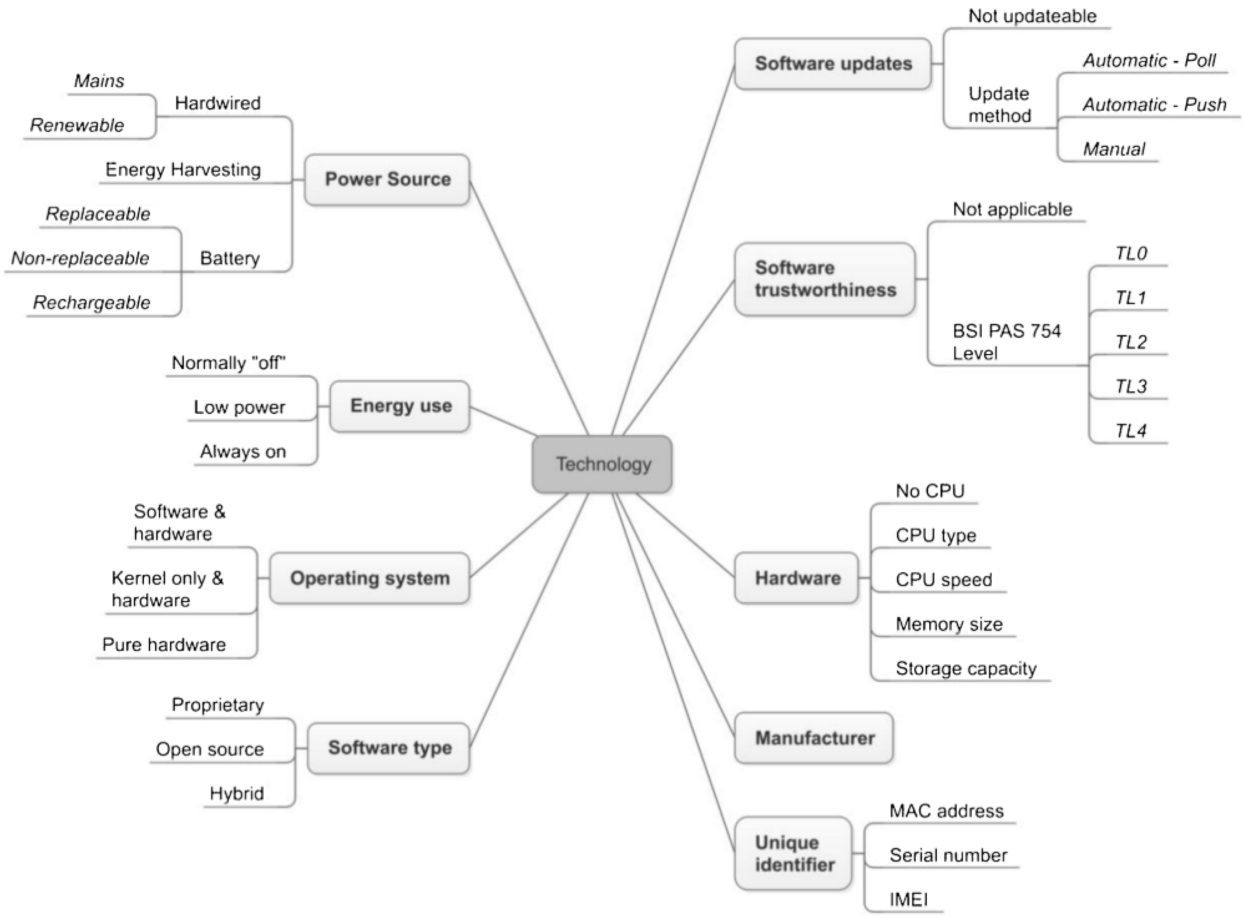

Fig.5. Technology category [4]

6. User type:

The proposed user characteristics, as illustrated in Fig. 6, are intended to allow identification of who or what the device is interacting with. The proposed user types are either human or machine, for example where the device is sensing and providing machine-to-machine communication for system control or monitoring purposes.

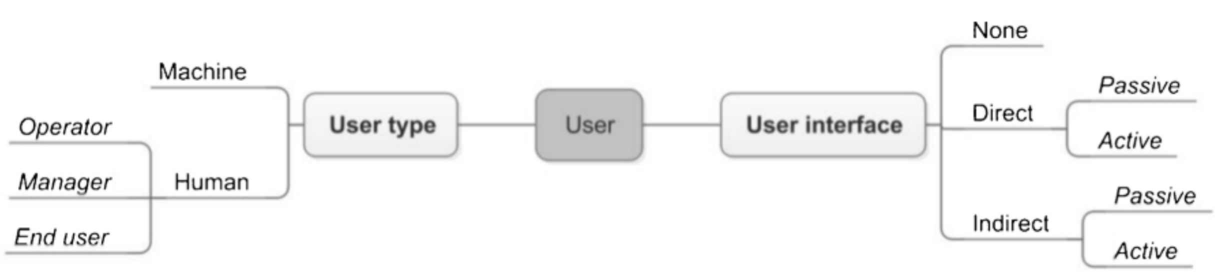

Fig.6. User Category [4]

Secondly, the IIoT architectures and frameworks proposed by (W.Z.Khan) [5] are presented in Fig. 7, whereby IIoT devices and industrial data sources generate continuous data streams at Layer-1 while the edge servers and cloud computing systems empower IIoT applications at Layer-2 and Layer-3, respectively. The enterprise applications are depicted at Layer-4. Fig. 9 2also shows the flow of data and information among different layers as well as exhibits the orchestration flow for resource management and operational flow for managing assets in the industrial networks.

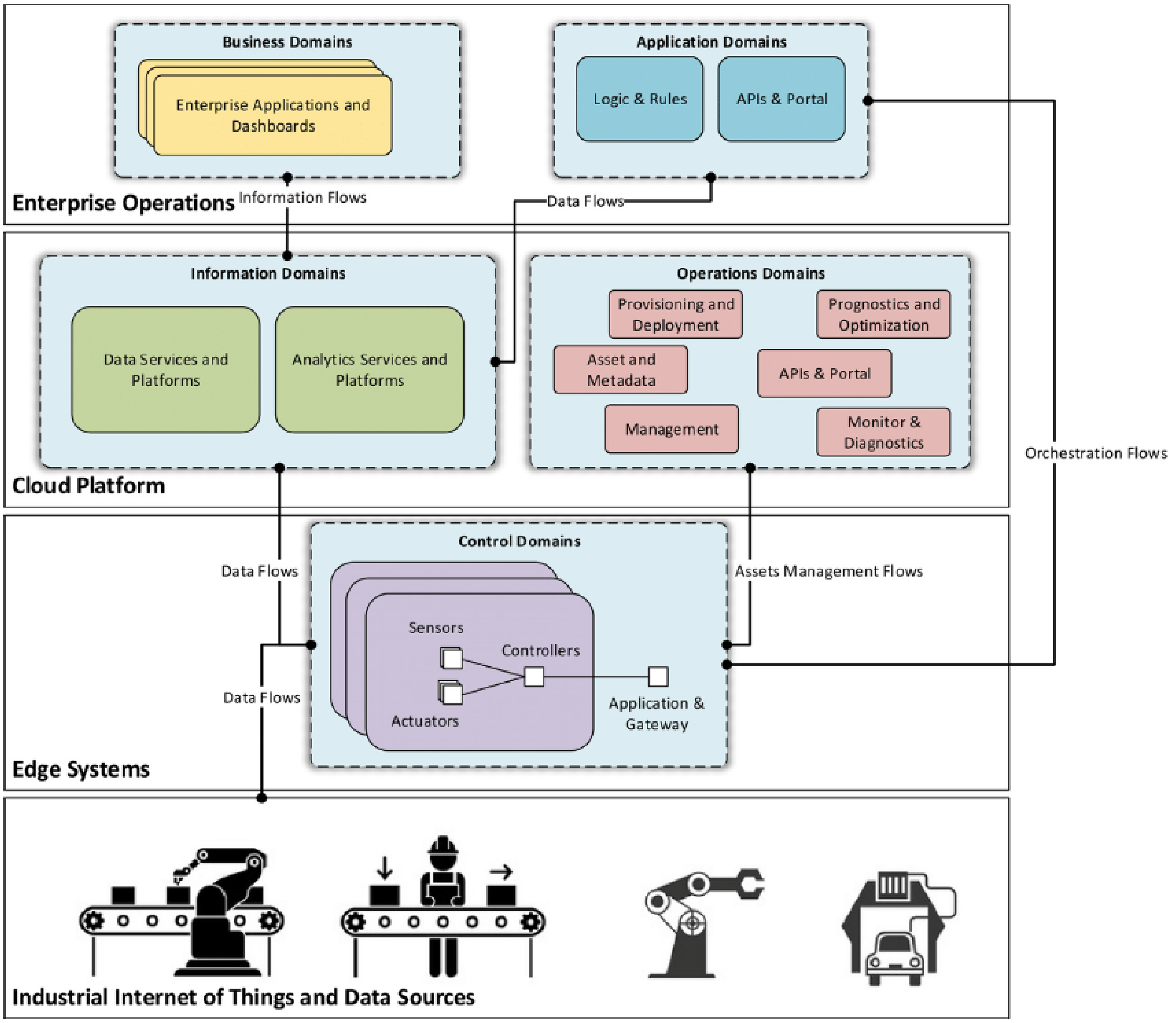

Fig. 7. A general architecture for IIoT systems [5]

Cyber-physical systems (CPSs)

Cyber-physical systems (CPSs) perfectly integrate computation with physical processes and provide abstractions, modeling, design, and analysis techniques for the integrated whole [1]. According to Erik Hofmann [3], the technology depends on multiple disciplines, such as computing science, control theories, and communication engineering. CPSs range from relatively small systems, such as aircrafts and automobiles, to large systems such as national power grid stations. There are several definitions of a Cyber-physical system,[2] "A system comprising a set of interconnecting physical and digital components, which may be centralized or distributed, that provides a combination of sensing, control, computation and networking functions, to influence outcomes in the real world through physical processes." While CPS and ICT systems process data and information, the focus of CPS is on the control of physical processes. CPS uses sensors and actuators to receive information, including measurements of physical parameters, and actuators to control physical processes. For example, CPS often can determine whether to change the state of an actuator or to draw a human operator's attention to some feature of the environment being sensed.

Cyber-physical systems (CPS) and Industry 4.0:

The Fourth Industrial Revolution (or Industry 4.0) is the ongoing automation of traditional manufacturing and industrial practices, using modern smart technology. Large-scale machine-to-machine communication and the internet of things (IoT) are integrated for increased automation, improved communication and self-monitoring, and the production of smart machines that can analyze and diagnose issues without the need for human intervention [1]. More precisely, "cyber-physical systems are integrations of computation with physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa". In the manufacturing context, this means that information related to the physical shop floor and the virtual computational space is highly integrated.

Smart factory:

Till now, CPS, the (Internet of things) IoT, and (Internet of services) IoS were introduced as main drivers of Industry 4.0. These "concepts" are closely linked to each other since CPS communicate over the IoT and IoS, therefore enabling "smart factory", which is built on the idea of a decentralized production system, in which "human beings, machines, and resources communicate with each other as naturally as in a social network". [3] The close linkage and communication between products, machinery, transport systems, and humans are expected to change the existing production logic. Therefore, smart factories can be considered another key feature of Industry 4.0. In the smart factory, products find their way independently through production.

The Development of the cyber-physical system

This section provides an overview of different types of systems and the transition process from mechatronics to CPS and Internet of things (IoT) systems. Mechatronics can be considered an interdisciplinary field of engineering science that aims to interconnect mechanical engineering, electrical engineering/electronics, control engineering, and computer science such that their interactions form the basis for the design of a range of products and product types Interaction between product developers from different fields is often hindered by an insufficient understanding across disciplines, and by a lack of shared platforms for the modeling of complex systems.

In such a context Lee [3] defined CPSs as the "integration of computation and physical processes". Embedded computers, networks monitor and control the physical processes usually through feedback loops in which physical processes affect computations and vice versa. Fig. 8 shows the transition process beginning from a mechatronic system to CPS and the IoT in which the horizontal axis represents the driving forces/necessary technologies and the vertical axis the level of the system.

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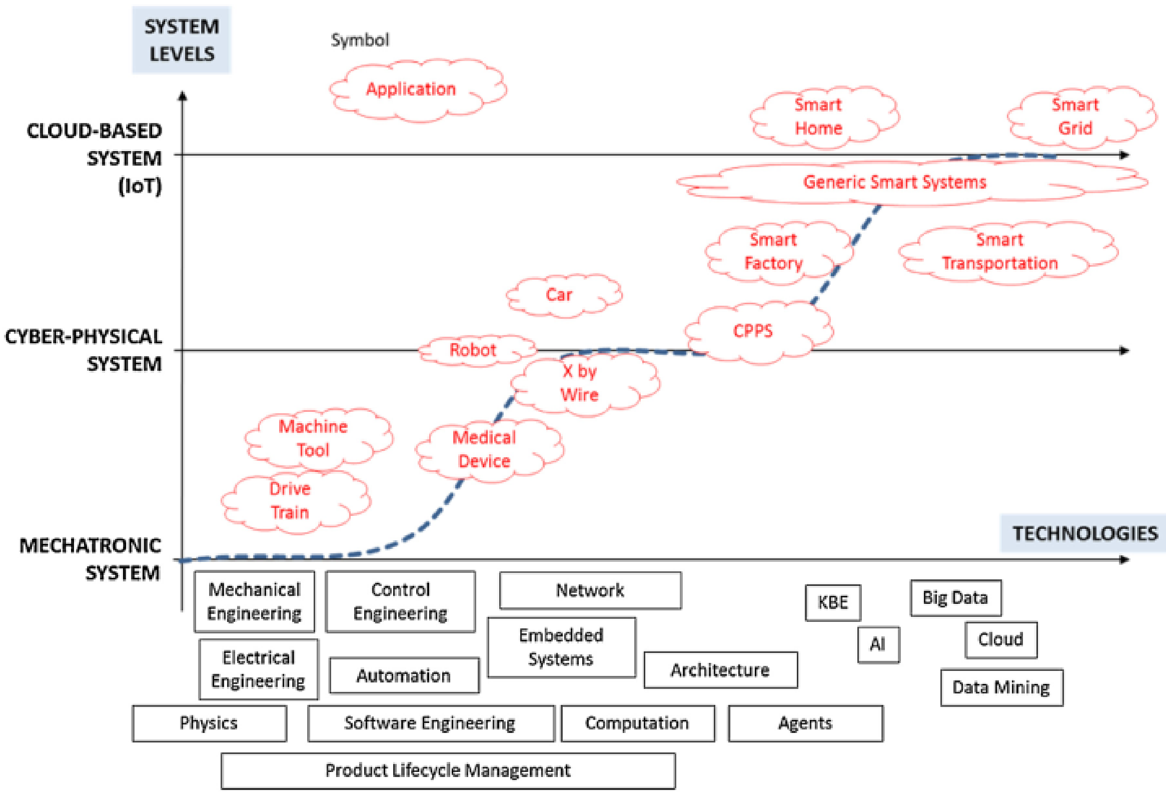

Fig.8. The transition process from Mechatronics to CPS to Internet of Things [3]

Correlations of the components of the Upcoming Industrial Era

The Internet of things (IoT) describes the network of physical objects that are installed with sensors, software, and other technologies to connect and exchange data with other devices and systems over the Internet. IoT is the technology enabling the interconnection of all types of devices through the internet to exchange data, optimize processes, and monitor devices to generate benefits for the industry, the economy, and the end-user. It is composed of a network of sensors, actuators, and devices, forming new systems and services. The term "Industrie 4.0" refers to the fourth industrial revolution. It originates from a project in the high-tech strategy of the German government, which promotes the computerization of manufacturing. That includes the integration of logistics and production. If IoT is the basic infrastructure, then on top of that comes CPS, CPPS, and IoS, and the whole is Industrie 4.0 the relationship is illustrated in a layered Model.

Referring to Fig. 9, the relationship between the various system layers of mechatronics, Cyber-Physical Systems, and the Internet of Things (IoT) can be expressed in terms of increasing levels of abstraction.

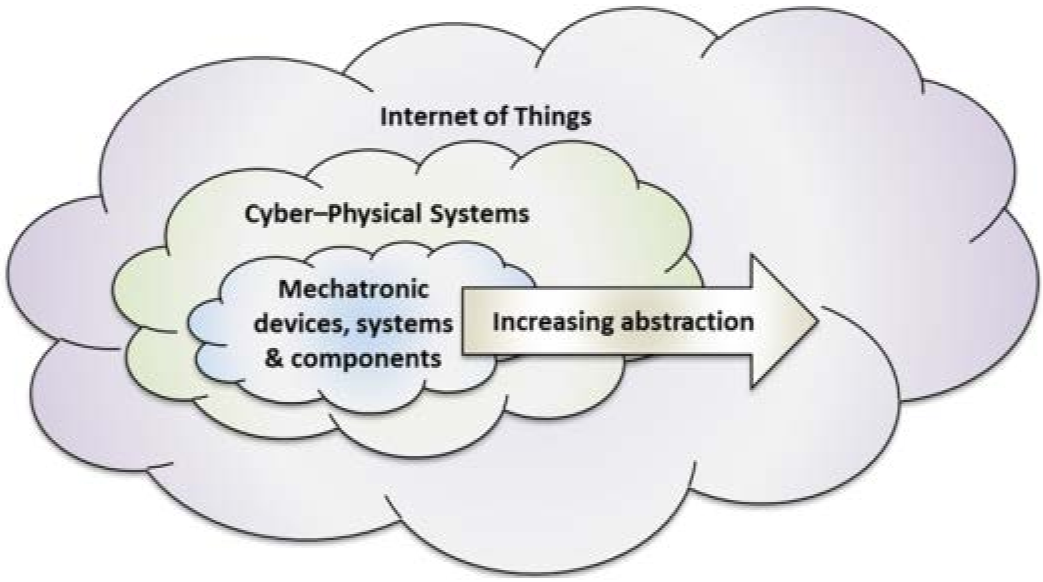

Fig. 9. Relationships [3]

The design processes and procedures are reasonably well defined and understood, supporting a transfer into physical systems. At the level of Cyber-Physical Systems, the relationship between the physical components and the cyber level is largely defined by function.

Main challenges facing the implementation of components of the New Industrial Era

(a) Integrating CPSs

CPS-design requires a multi-disciplinary development process during which designers should focus not only on the separate physical and computational components but also on their integration and interaction. Challenges related to CPS-design are therefore considered here from the perspectives of the physical process, computation, and integration respectively [3]. The success of the CPS depends primarily on its ability to process and transfer data in real-time between a network of large and complex systems while maintaining security.

(b) Challenges of IIoT

According to (W.Z. Khan)[5], The heterogeneous and complex nature of IIoT systems has brought together many technical challenges, such as interoperability, security, and privacy, scalability, heterogeneity, reliability, and resource management. However, some important challenges are still needed to be resolved. Herein, we discuss these challenges

(a) Efficient data management schemes
(b) Collaborations between heterogeneous IIoT systems
(c) Robust and flexible big data analytic technologies
(d) Trust in IIoT systems
(e) Coexistence of wireless technologies and protocols in IIoT
(f) Enabling decentralization on the edge
(g) Emergence of IoT specific operating systems
(h) Public safety in IIoT

(c) Challenges of EIS

According to Soumaya et al. [2] the 4 major challenges of Enterprise Information System (EIS) are:
(1) data value chain management;
(2) context-awareness;

(3) usability, interaction, and visualization; and
(4) human learning and continuous education.

Conclusion

The integration of CPS and IIoT for the automation and advancement of the traditional manufacturing system will reshape the future involving less human activities. The focus should be on designing, modeling CPS using the proper methodology. The collaboration and framework development of IIoT after analyzing the whole system should be considered with proper importance. A smart industry requires heavy data processing depending on the size of the system and complexity. As a result, proper tools for combining different subsystems, data analysis should be implemented for the smooth operation of future industries. Considering the growth and utilization of computers applied in the industries, there exist several determinants that shape the systems of the next generation. For example – the current economy is shifting from being product-oriented to information centered with the addition of wireless technologies like CPS, IoT, ICT, or 5G. In this economy, the way to access, transfer and share the appropriate data depending on the context and need is most likely to redefine the system types if combined with "production on demand" technologies such as 3D printing. One of the challenges of the emerging digital technologies is that engaging humans with their short-term attention into a working environment that is dominated by the control of computers results in the loss of skill and decision-making power also results in a disability to innovate.

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Biographies

Ahmad Hezam is an undergraduate engineering student of mechanical engineering specialized in energy in the Department of Mechanical and Production at Islamic university of technology, Dhaka, Bangladesh. He has worked on different energy-related projects such as solar tracker and biogas digester, and recently he is developing an interest in Industrial and Production Technologies.

Muhammad Waqas During my undergraduate studies in Mechanical engineering at the Islamic University of Technology, I began taking a keen interest in smart manufacturing and industrial revolution challenges engaged myself in several related activities. As I wanted to further educate myself on the modern industrial revolution, I decided to pursue an MSc in the manufacturing process at the University of Glasgow. In parallel, my interest in modern industry revolution entrepreneurship led me to join the smart industry group and the research-related program.

Abrar Sobhan Chowdhury, an undergraduate student in the Islamic University of Technology has worked on several projects regarding production and manufacturing like the color sorter. Despite being specialized in energy, he developed his interests in the field of production and manufacturing and the industry 4.0. His research interests are based on modern technology in the industry and its heat transfer characteristics.