State-of-the Art and Trends in Cyber-Physical Systems (CPSs)

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Abstract
There have been a number of important developments in information technology and computer technology. In the second half of the 20th-century, desktop computers and Internet were invented. Today, many experts from different fields are paying increased attention to the rise of a new engineering system known as Cyber-Physical System (CPS). CPS is an instrumentation of physical and computers systems. Embedded computers control and monitor the physical process, including feedback loops where computations affect physical processes and vice versa, CPSs have been used in automotive systems, medical devices, manufacturing, military systems, traffic control, power generation, energy conservation, etc. The objective of this paper is to review literature related to current state-of-art and trends in CPSs in general and within the UAE. The paper will elaborate the CPS concept, factors that have fueled use of CPSs, challenges affecting CPSs, use of CPSs in the UAE and potential of CPS technology in this country.

Keywords: CPS, Technology, system, Cyber

I. INTRODUCTION

The proliferation of communication and computing technologies has made it possible to create societal-scale systems that have transformed societal infrastructure in various sectors such as healthcare, transportation, and energy. The opportunity provided by advanced societal infrastructure has been exploited through the introduction of effective Cyber-Physical Systems (CPSs). This a term that is used to describe a wide range of multi-disciplinary and complex engineered systems that integrate various computing inventions into the real world. CPSs serve to bring the benefits of Internet-scale computing and network to physical systems like buildings and transportation infrastructure. The emergence of CPS has been fueled by significant advancements in many technology areas, particularly modern nano-scale, and micro-scale design as well as fabrication technologies [7].

This paper provides a literature review on the current state-of-the-art and trends in CPSs and Internet of things in general and within the U.A.E in particular. The paper is sub-divided into four sections. The first section will provide a survey of the general factors that have culminated in the increased use of CPSs. The second section will highlight some of the main challenges hampering the development of CPS technology while the third section will show how CPSs technology has been used in the UAE. The last section will highlight the potential of CPS technology in the UAE. CPS technology has the potential of covering various aspects of economic and social life bring about a broad influence in the development of computer science. Nonetheless, restricted by the existing technology and theory of communication, control technology, and computation, the growth of CPS technology is facing various challenges. Breakthrough in CPS technology will enable the UAE to take a leading position in CPS development.

II. CPS CONCEPT

Lee defined CPS as the integration of physical and calculation process, which include embedded networked and computerized controlling and monitoring physical process [24]. The physical processes impact computation through feedback loops. J. F. He considered CPS as credible, controllable, and scalable networked physical equipment systems with in-depth integration of communications, computation and control ability [25]. The feedback loop of mutual effects between physical and computing process, real-time interactions and in-depth integrations are attained. These integrations and interactions help in expanding and increasing the functions of physical systems and networks and to control or monitor a physical entity in an efficient, safe, reliable and real-time manner.

Wireless Sensor Network (WSN), CPSs, and the Internet of Things (IoT), are all physical network systems derived from electromechanical and software systems. However, the three are different. WSN only function to sense signal instead of stressing on the identification of the object. Therefore, WSN is ineffective in identifying a particular object from many objects sensed. It emphasizes the perception of information and gives data support for different specific application through data collection, processing, integration and routing. On the other hand, IoT interconnects different Internet information sensing devices like radio frequency identification (RFID) and wireless sensor through Internet technology and wireless network to achieve overall perception, intelligent processing of information and reliable transmission.

CPSs in a credible, controllable, scalable and credible network physical equipment system which intensely integrates the ability of communication, computing and control on the basis of information transmitted by IoT. Generally, IoT promotes the perception, but not the ability to control the physical world while CPS has not only the ability to sense the physical world, but also has strong ability to control it. Therefore, the computing capability of CPS exceeds that of WSN and IoT.

In CPSs, there is a higher coordination and combination between computational and physical elements. CPSs range from phone applications to self-driving cars, from home energy meters to airplane controls. Currently, CPSs are of interest in industries, academia, and government because of their potentially significant impact on environment, society, and economy. Generally, CPSs

should be seen as the next generation of engineered systems that need tight integration of communication, computing, and control technologies to attain performance, stability, robustness, reliability, and efficiency when it comes to dealing with physical systems of many application domains like energy, transportation, defense, and medicine [6]. It is forecasted that CPSs can possibly revolutionize how scientists operate, interact, and construct many engineered systems that people in the current world critically depends on like automobiles, power grids, aircrafts, buildings, medical systems, and manufacturing plants.

III. ARCHITECTURE OF CPS

CPS architecture includes models that developed, modified and integrated into existing physical system, computer system, and network system. Modeling and abstraction of computation, communication and physical dynamic in different sizes and scales are also important in CPS development. == indicated that CPS system structure model can be divided into three segments: the physical layer, information system layer and user segment. The physical system layer includes a big number of sensor networks, embedded and smart chips, etc. The role of a physical system is collecting and transmitting information and signals, thus it serves as the foundation of the CPS. The main role of information system segment is processing and transmitting data obtained from the physical system. The last segment, user layer mainly completes the work like data query and safety that should be guaranteed to all CPS users,

Majority of CPSs are used to support real-time application, like real-time monitoring, real-time observation, real-time forecasting, and real-time control, with to keep the user updated on the latest situation of physical devices as well as to make necessary intervention and control of physical devices and intervention of environments and physical equipment by way of network control. In this regard, CPS data processing is needed to meet real-time requirements to make sure proper results are provided within a limited span of time. Lee emphasized the importance of CPSs reliability, security, and real-time ability, and considered the efficient combination of primitive models required by software and hardware process [26]. Kremer pointed out that real-time ability can greatly influence the demand for CPS application systems from hard real-time to soft real-time perspective [27]. In CPS technology, heterogeneity results in challenges of the network in large-scale system design, such as time jitter, time-varying delay, packet loss, data rate limitation, etc. To address these limitations, [28] proposed the application of single-path delay variation to deal with the impact of delay jitter in CPS.

Studies on practical problems of CPS, like wireless network transmission errors, complex environmental interference in distributed systems, data processing errors related to storage raise problems like outliers, noise, loss of data, randomness, concreteness, and data dispersion, and other uncertainties have declined because of the dominant factors the influence the reliability of test information and the credibility of systems. Bujorianu *et al*. established a self-learning uncertainty reasoning model applicable in the automotive control system, helping in solving problems of rapid response, automatic sensing, and control of automobile in different scenarios [29]. However, even though the design of external information acquisition is ideal, it ignores the network test environment, particularly the certainty of information collected and the uncertainty of data in the network layer and transport layer in a complicated environment.

Data reliability is another import factor in CPS data processing. CPS includes a big number of embedded computing systems which has computation role and are needed to automatically acquire

real-time reliable data. Andrei *et al.* studied the automatic optimization challenge in developing and realizing exceedingly reliable real-time embedded system. Using tightly and loosely coupled system specification security assertion theory, Andrei *et al.* also proved that the optimization methods may be used to a large-scale real-time logic processing [30].

IV. FACTORS THAT HAVE INFLUENCED INCREASED USE OF CPSS

Today, the production and dissemination of CPSs are driven by three main factors: the rise of smart embedded systems, internet-based business, and growing social networks and communities [18].

Rise of smart embedded systems

Intelligently embedded systems constitute one part of CPSs. Embedded systems are used to address a number of potentially conflicting design constraints like heat, cost, resilience, performance, energy, security, among others, in the face of modern highly dynamic operational behaviors and environmental conditions. By including elements of intelligence, 'smart' embedded systems function better despite dynamic changes in the applications and the environment as well as changes in the underlying hardware/software platforms [10]. Localized assistance services are predominantly available in aeronautics and automobile industries. They are used in automation, and telecommunications technology. Increase in interaction and networking has made such services more sophisticated and versatile.

Internet-based business transactions

Networked objects such as Radio Frequency Identification (RFID) are increasingly being used in modern business processes [19]. Companies are adapting easily to software-controlled business interactions and are interacting with their target audiences and existing customers using the web. For instance, the internet is now being used to track a parcel in a logistics chain. Such information technology services are often outsourced from external sources making their operation autonomous from the data center of a particular location. More progressively, cloud computing services are being given to end users with the help of computer operating system – Google Chrome – that depend on cloud resources. This trend is relevant for CPSs because the business web creates an opportunity for the embedded system to be utilized as services through the internet, thereby facilitating various web-based business models.

Social networks and communities

Social networks – whose main purpose is facilitating social interactions and communication – bundle huge quantities of information and data. They are also used in open knowledge networks as companies often apply wiki systems for the extensive provision of knowledge and information. For companies, potential customers are the users and thus, social networks are mainly used as a marketing and advertising podiums. growing establishment of profiles and increased specialization of participants. Devices using Web 2.0, mainly tablets and smartphones, implicitly and plainly account for increased use of sensors. Therefore, CPUs based on social networks are being developed to cater for this particular market need.

V. CHALLENGES OF CPS

Technical challenges

To reduce the cost of developing applications, it is important to reduce the developer burden and promote reuse of applications. In addition, an infrastructure needs to be developed that serve to support the development of CPS applications. Balaji *et al.* proposed that models need to be created that include domain particular complexity, and uncover information related to abstractions to developers [2]. Such models may be user-centric, design-centric, information-centric, or centered toward controls or operations. Model development may be complex. Therefore, development of these models can be delegated to competent entities to minimize errors. They should be certified by standardized bodies [12]. Based on these models, tools for simulation, debugging, and emulation may be developed.

CPS applications have been developed across different domains. Balaji *et al.* presented two case studies with automobiles and buildings, and drew some similarities across various applications they examined [2]. Balaji *et al*. held that large-scale application of CPS is still in its infancy phase and a number of challenges need to be addressed in order to promote its growth [2]. Large-scale application of CPS will be incomplete without the right environment in which applications can be deployed safely and models can co-exist. The architecture for a CPS system may be metaphorically described as the infrastructure given by a city for its daily operations [8]. The city gives necessary services like real estate for different businesses to operate, safety, transportation, and an environment in which businesses give services to each other. Likewise, the CPS architecture should provide mechanisms for communication, protection, reliability, timing, and consistency. Just like in a city, the architecture should be designed to guide beginners to understand the infrastructure for models to be upgraded and services to be tested so that the system adapts to the changing requirements of the applications.

Integrity and confidentiality are part of main technical challenges of CPS. Integrity is the ability of a system to ensure information within it is protected from illicit modification or manipulation to preserve accuracy. A highly confidential system is able to provide extensive approval and constancy check mechanisms. Outstanding integrity is among essential properties of a CPS. Therefore, CPSs need to be created with a greater guarantee by giving integrity check mechanisms on particular occasions. It is for this reason that CPS developers should have a deep understanding of properties of the cyber and physical processes to be able to define the needed integrity assurance [9]. In regard to confidentiality, data discretion is a crucial matter that should be upheld in almost all CPSs. Confidentiality is the principle of permitting only the authorized parties access to delicate information found in a system. A system with high integrity uses the most secure mechanisms of protecting data from unauthorized access, tampering or disclosure. CPSs developers thus need to be awake to the fact that confidentiality of information transmitted via sensor nodes may be manipulated. Moreover, malicious/false data can be introduced into to the system through fake nodes.

Mission-critical CPS applications operate even in the event of disruptions at any system level (e.g. network connections, software, hardware, and other underlying infrastructure). Thus, an exceedingly resilient CPS needs to be designed. In this context, resilience is the capability of a

system to persist in its delivery of services and operations when it is exposed to internal or external difficulties such as rising workload, malfunctioning components, sudden defects etc. A decidedly resilient system needs to be self-healing and includes early recognition of failures and fast recovery mechanisms that enable it to deliver mission-critical services such as oxygen and airflow control over an automatic medical ventilator, automated brake control in vehicular CPS. Developing mission-critical resilient CPS necessitates a thorough understanding of the likely disruptions and failures, resilience properties of the relevant applications, and system evolution because of the fluctuating nature of the operational environment [5].

Enabling planetary-scale deployment of actuators and sensors to measure major environmental parameters and make local collections is a major challenge when it comes to using CPSs. These sensors need to be networked for data collection, aggregation, and response. They must be self-sustaining and environmentally friendly [13]. Moreover, they must be easy to program in bulk, yet resistant to failures, malicious attacks, and false data feeds. For these networks to be sustainable without significant maintenance costs, they must form a symbiotic relationship with their physical environment. In this relationship, natural processes like bird migration, wind, solar energy, and everyday human activities can be manipulated to help various work functions. In turn, network output should result in optimization of environmental processes. The resulting interactions can lead to new cyber-physical phenomena that can be more efficient than their purely physical or natural counterparts [13].

Political challenges

Politicians are experiencing several challenges associated with CPSs. This necessitates the establishment of clear rules to regulate CPSs. CPS technology deals with big volumes of data. The storage and management this data necessitates a high degree of information security. This is important because public acceptance of CPSs is influenced by data security, privacy, and trust that citizens have in these systems. In this regard, it is essential to bring about legal conditions, especially with an objective of promoting the safety of important infrastructure and to elucidate liability issues. Particularly, the issue of property rights in data issues is relevant for CPSs. This includes third parties' right to access data and all the legal issues associated with such access. The primary data created by CPSs, which is logged in the right time, raises the question about who should collect this data and use which methodology, who is allowed to access this data and under what conditions.

It is practically and economically impossible to record data on a particular subject several times. This raises a question related to the openness of database. Besides, CPSs involve huge investments in systems' technical infrastructure. In this regard, financing needs to be lobbied by the government. Moreover, politicians are required to create the economic conditions to get the technical design and to make sure the number of qualified specialists is sufficient. Consequently, to a great extent, CPS technology has been involved in economic and social processes. The political class should introduce a social discourse with an aim of promoting awareness on the different dimensions of CPSs and to make the general public aware of the risks and opportunities associated with CPSs.

Social challenges

Social readiness to accept CPS as a new technology, develop it, and use it appropriately is pivotal for their effectiveness. Toward this end, the willingness of end users is an important precondition for the application of CPSs. Acceptance implies that users have a positive perception of technologically developed systems, agree to take them, and are enthusiastic and ready to use them. History has demonstrated that it is extremely difficult to foresee acceptance. Moreover, acceptance is highly reliant on good human-machine interaction. In this regard, acceptance matters need to be dealt with expansively and comprehensively from the very first steps of designing CPSs [11].

VI. INTERNET OF THINGS (IOT) IN THE UAE

The ability to efficiently and effectively manage the increasing urbanization in the world today is crucial. Modern cities must therefore heighten the efficiency of new and existing facilities. Nowadays, the quality of life for city inhabitants is mainly influenced by the degree of user-friendliness and smartness of the different services provided by the city authority. Technology plays an important role in the attainment of this efficiency and smartness. The world has witnessed an unprecedented rise of smart cities. These cities benefit from the power of communication networks such wi-fi to augment daily life for businesses and residents as well as support sustainability. The UAE is marching toward a period of improved quality of life. The smart cities idea has been abstracted under the idealistic leadership of Shaikh Mohammad bin Rashid Al Maktoum, the Prime Minister and Vice-President of the UAE and the Ruler of Dubai [20].

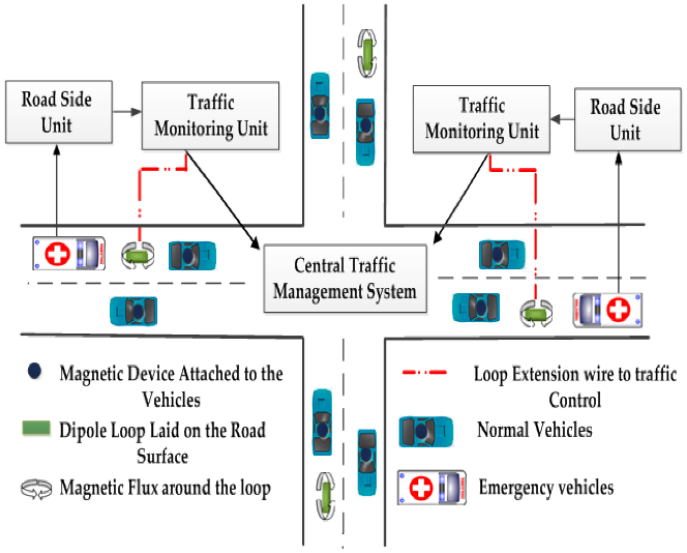
Markets are growing at a faster rate in the Middle East than in any other region in the world. It is predicted that the regional spending on IT will rise to USD 243 billion by 2019 driven by such factors such as smart governments, big data, mobility and CPSs [16]. When it comes to CPSs, the momentum is being driven by business and consumer demand, continuing development of smart cities and homes, enhanced connectivity infrastructure, and an increasingly connected culture. The UAE has become a regional hub and an important gateway for investors trying to access the Far East market. Local governments in this country, especially in Dubai and Abu Dhabi, are striving to change the whole country into one smart city connected using smart sensors. The use of technology has been applied to streamline three main fields, namely: telecommunication, transport, utility management, education, and tourism.

Telecommunication

Telecom connectivity is seen as the backbone of every smart city [5]. End-to-end connectivity is crucial in all aspects of a smart city. Therefore, cities are striving to introduce reliable, high capacity and high-speed networks. These networks have the potential of facilitating internet usage, and machine-to-human and machine-to-machine communications – commonly known as the "internet of things" that the smart cities rely on. Cisco projected that about by 2020, 50 billion devices will be linked to the internet in the world, necessitating reliable and fast network infrastructure [4]. To promote network connectivity in the UAE, Du, the leading telecom provider has created 5,000 hotspots to provide Wi-Fi at about 100 locations in both Abu Dhabi and Dubai. This company has promised to provide unlimited, fast, and free access to government applications, paid a premium, high-bandwidth Wi-Fi and low-bandwidth Wi-Fi.

Transport

Transport is a major challenge in modern cities. City residents depend on transportation systems for people to travel, and transport essential goods. CPS technology has enabled the use of smart sensors placed along the roads to detect traffic flows and send signals to central traffic management system as shown in the figure below. Smartphones and apps are also being used to provide real-time traffic updates to road users. Kaur & Maheshwari noted that Moscow, Russia a TrafiCam x-stream system has been introduced to serve as a smart traffic solution [16]. The Roads and Transport Authority (RTA) is making efforts to implement smart transportation solutions in major towns across the UAE. According to the RTA, the number of vehicles in Dubai was 1.4 million by the end of 2014. The RTA is implementing smart transportation solutions to deal with the high demand for transportation infrastructure in Dubai [20].



Source: Nellore & Hancke [21]

The drastic increase in urbanization over the last few years in the UAE has created the need for efficient, sustainable, efficient, and smart solutions for governance, transportation, quality of life etc. This is because this drastic increase in urbanization serves as the driving force behind the increased consumption of resources resulting in resource shortages as well as climate changes. Electric Vehicles (EVs) have been considered as an important step toward economic and green environmental transportation. EVs are driven by electric energy stored in special devices such as rechargeable batteries. In the UAE, EVs are being used for considerable reliability. It is against this backdrop that they have gained high popularity. They are also environmentally friendly as renewable energy based on the fact that EVs' have the potential of addressing the shortage of fuel as well as reducing emissions of harmful gases. In this regard, EVs are seen as one of the main components of the transportation system in modern cities.

Healthcare

CPS technology involves the integration of physical processes into computation and communication. It helps in the introduction of intelligence in social life [14]. In healthcare, CPS technology has the potential of changing the means of delivering efficient and effective healthcare services, resulting in longer and healthier lives for citizens as well as improving their overall

wellbeing. In the UAE, the use of electronic health records has replaced paper-based records enabling patients and doctors to access complete information on a diagnoses, tests, treatments, and prescriptions online on demand. Cities with CPSs that function across all government agencies, doctors, and hospitals make medical services more efficient and accurate. In the UAE, the increasing demand for modern and advanced healthcare facilities has pushed the health department to build efficient infrastructure and to introduce smart healthcare programs. For instance, in 2013, Dubai introduced a smart healthcare program with three key initiatives – smart operations, smart applications, and smart infirmaries. Dubai has also implemented electronic medical records and hospital information system, which have enabled healthcare providers to access patients' health records. These systems also enable healthcare providers to send medical instructions to other departments in the hospital like pharmacies and laboratories as they interconnect all hospital sections and departments.

Utilities management

Smart cities employ CPSs to allow for better waste and water management. Although water is one of the basic resources, the majority of the modern cities are facing water issues such as declining quality of water, water shortages, and aging water infrastructure. Smart water leak detector (shown in the figure below) can be used to gauge pipe flow rates to detect water leakages. Other sensors may be used to measure the quality of water using parameters such as pH, conductivity as well as dissolved oxygen and turbidity. Sensors can then send information in real-time to a central system. The central water management system may then use information provided by sensors to identify water pollution and leakages. Data from sensors can indicate pipe problems, chemical spills and treatment plant concerns or the effectiveness of water sanitization systems.

Source: Markham [22]

Energy

Energy is another basic and essential resource that needs to be managed. Smart cities not only need to deal with increasing energy demand but they are also supposed to make sources of energy green and more environmentally friendly. One of the smart energy programs is the introduction of smart grids and smart meters in towns. Smart electricity meters make use of sensors that are capable of monitoring energy consumption and serve customers with information on their patterns of energy usage. Smart meters adopted in every factory, home, and office send this usage data in time to smart grids. Then, a smart grid responds in real-time to information collected from energy

consumers and suppliers. It gives real-time evaluation and monitoring. This way, it increases dependability. Smart grids are self-healing and have an ability to separate parts of the network experiencing failure, which in turn helps in averting blackouts and outages. They can effortlessly be connected to renewable sources of power such as solar and wind plants, which helps in facilitating distribution and storage of energy through the city. The UAE has started using these smart meters. For instance, DEWA has planned to install over 250,000 sensor-based meters in all industrial, commercial, and residential properties by 2018. DEWA will install smart grid in order to systematize grid-control and to deliver quality services to customers, enabling them to monitor their power consumption.

The demand for electricity following increased use of EVs has imposed the UAE to extra energy burden that can have negative effects on the grid system. Therefore, EVs technology needs to be managed while putting into consideration the diverse requirements of customers. IOT is the main technology that can be used to manage EVs to save energy resources and save money [1]. Actuators and sensing devices are major constituents of an IoT-enabled system along with network and communication devices. These sensing devices help in real-time detection and monitoring in different scenarios [15]. Therefore, the changing management of the system using IOT provides an automated and smart system, and includes core features like billing, charging, scheduling etc. IoT can also help EV customers to identify the optimal solution for their charging requirements within a specific budget. In a nutshell, an efficient charging management based on IoT is indispensable for the future smart cities in the UAE.

Tourism

Tourism is a main source of revenue for many governments. Smart tourism relies on the CPS technology to connect real and physical objects to the internet. CPS may also be utilized as an extrapolative tool for developing and managing tourist destinations in a smart manner. For example, a tourists tracking system can be used to coordinate transport services. To meet the increasing challenges, smart tourism systems have been implemented in the UAE. For example, a tour guide system is known as "Nahaam" has been introduced. It gives tourists data about geographical routes and landscapes. Another development is the Dubai Airport's smart gate system shown below. This system has significantly reduced the waiting time for visitors through microelectronic identification.

Source: Shouk [23]

Education

The use of CPS technology in education has opened the door to deeper learning and facilitated the creation of a more engaging learning and teaching environment. This is because CPS technology allows increased accessibility of information because of efficient interconnection attained through cloud computing. A smart education system also serves as a tool for collecting and submitting accurate data such as school projects, grades, essays etc. Parents and teachers can use such data to assess the academic progress of their children. Realizing the importance of CPS technology in the education system, the UAE government has allocated money to support smart education. Recently, Dubai's Knowledge and Human Development Authority (KHDA) implemented a smart e-services portal for institutions of higher learning and a modernized system for training. There are also schools that allow users to connect with KHDA directly, saving paperwork and time, which in turn increases customer satisfaction.

Public safety

In the UAE, crime rates are relatively low especially when compared to global averages. This is why the UAE is considered one of the safest countries in the world. One of the many smart initiatives launched in the UAE includes the Dubai Police application. This app includes some of the most important online services that the public can access using their mobile phones. Other smart initiatives include the sandstorm and visibility application. This is a mobile app that contains features that are able to forecast sandstorms. The UAE could implement CPSs that are capable of enabling various government departments to share information related to public safety and to collaborate when it comes to handling various public safety matters.

VII. POTENTIAL OF CYBER-PHYSICAL SYSTEMS

CPSs are being used to find solutions to the main challenges facing the modern society. They are increasingly becoming pertinent for many companies in different fields of operation. CPS technology provides companies with the support needed in process optimization, thus, saving time and cost. They also enable companies to save energy, thus minimizing the release of toxic gases. For private users, CPSs are important as they provide a high degree of comfort. For instance, in self-medication, in assistance with mobility, in networked safety, and caring for the aged, CPS technology comes in handy. CPSs have a high potential of addressing challenges in energy, mobility, health and industry and automated production.

CPSs for Smart Energy Grid

Today, decentralized and volatile energy has been subject to prominently different consumption levels contingent on regions and seasons. Nonetheless, for sustainable provision of energy, the supply in the electricity network must outweigh energy demand at all times. Decentralized energy and unstable availability necessitate a far-reaching management system. In this regard, energy conversions may be used and energy rates can be flexible depending on the existing power. Nevertheless, this calls for far-reaching information management, which documents consumer data, manages appliances and creates forecasts about consumption. This will help in assuring people of sustainable energy supply in future. The electricity grid must however be made "intelligent." This means that in the energy storage and energy production in the country should be networked with each other. Strong networking through communication and information technology as part of the

electricity grid will further assist in the provision of services as well as in sustainable energy supply.

CPSs for Networked Mobility

In the transport sector, effective working of various means of transport can only be achieved through CPS technology. Networking in CPS has the potential of creating new means of evading accidents, limiting consumption of energy resources as well as minimizing environmental pollution. In the modern electro-mobility field, CPSs are playing a crucial role because they are providing the basis for charge, energy and battery management. Nonetheless, the capacity of CPSs can go beyond this. For instance, they can be used as a coordination and planning tool to be used in the transport management, and can serve as a solution to unexpected situations like traffic jams. This necessitates individual systems to constantly exchange information such as instantaneous weather information as well as information concerning transport breakdown, road situations, and availability of alternative routes by means of transport.

The other likely importance of CPS technology in transport management includes sharing information about obstacles and risks. This will ensure the UAE has an efficient transport management system, and, ultimately, help in dealing with traffic congestion. CPSs have the potential of increasing the level of coziness for every road user. Moreover, CPSs have the potential of improving the ecological balance through lowering environmental pollution due to improved transport management, leading to lower emissions of harmful gas following lower consumption of fuel. In the end, CPSs have the potential of improving the economy because of better exploitation of transport infrastructure and means of transport as well as avoidance of road accidents and car damage based on the services and information delivered.

CPSs in the Health Industry

The rapid inventions in the information and communication sector have also benefited the health industry. CPSs have the potential of promoting health care delivery by allowing doctors to provide extensive medical care without restricting the independence of a patient. CPSs have enabled aged people to independently and actively care for themselves for long, and allowing them to continue participating in societal matters. This substantially increases the quality of their life and considerably reduces the cost of care. They enable doctors to provide better primary and support care in medical emergencies, especially when traveling. In addition, CPSs can be seen as a fundamental precondition for high-performance answers in remote medical and telemedicine diagnosis. Besides, CPSs health portals can provide more comprehensive and all-encompassing consultation and support in health issues than mere information forums. Rajkumar *et al.* argued that CPS technology is useful in caring for the aged, particularly in telemonitoring and assistance, even though it is important to put into consideration universal privacy needs and the relationships between family members and caregivers with the CPS design [13].

CPSs for the Future of the UAE Industries

CPSs are also relevant in industrial production as they help in the implementation of customer demands. In-house production processes may be augmented, resulting in enhancement of the ecological balance sheet. Using CPS production systems can help in responding in time to changes

in the supply chain and market fluctuations. This makes rapid production in accordance with specifications of individual customer possible as well optimizing production procedure with companies through a network of adaptive, cooperating, self-organizing, and evolutionary production units owned by different operators. The likely innovation and savings in such companies are enormous [3].

CPSs and Environmental Conservation

Natural resources in the modern world are some of the most important national assets that must be protected for sustained economic development. Common agricultural practices, urbanization, and deforestation have severely reduced the natural ecological diversity. This has brought about cumulative side effects. For example, global warming has resulted from the melting of polar ice caps at a rate of about 8 per cent in the recent past. In two decades to come, the cumulative side effects will be much more pronounced, creating the need for long-term solutions to avert a global environmental crisis. These solutions will include substantial investment in a new infrastructure for urban, ecological, and industrial monitoring that models and observes the use of natural resources, infers global effects on different natural cycles, and serves as the basis for correction, including the use of legal measures to postpone or avert encroaching environmental mega-catastrophes. Ubiquitous networks of actuators and sensors will provide access to large expanses of the environment at unprecedented temporal and spatial resolutions. This makes CPSs important infrastructure that the UAE can use to counter mega environmental catastrophes.

VIII. SUMMARY OF LITERATURE REVIEW

Cyber-Physical System (CPS) technology involves a wide range of multi-disciplinary and complex engineered systems that integrate various computing inventions into the real world. CPSs serve to bring the benefits of Internet-scale computing and network to physical systems like utility management, buildings, environmental conversation etc. The use of CPSs has increased mainly because of the rise of smart embedded systems, internet-based business, and growing social networks and communities. Despite the increased use of CPSs, developers are still facing a number of challenges. These challenges are mainly technical, political, and social. Technical challenges include the need to develop the resilient and highly confidential system. A resilient system should be a system that is capable of delivering services and operations even when it is exposed to internal or external challenges. In regard to confidentiality, CPSs need to have a mechanism that only allows authorized parties unfettered access to delicate information found in a system. One of the political challenges is the creation of a legal environment that promotes the safety of important CPSs infrastructure.

The UAE is one the countries in the world making increased use of CPS technology. For example, smart sensors and devices have been used in a number of sectors such as utility management, energy, communication, education, health, and transport. For instance, the Road Transport Authority (RTA) is implementing a smart transportation solution to deal with the high demand for transportation infrastructure in Dubai. The RTA has undertaken several initiatives to create intelligent transportation systems with an aim of enhancing transport services and network and to deliver integrated transportation experience to customers. In tourism, Dubai Airport’s smart gate system has been introduced. This system that has significantly reduced the waiting time for visitors

through microelectronic identification while in utility management, smart grids have been installed to systematize grid-control and to deliver quality services to customers, which in turn had enabled them to monitor their power consumption.

REFERENCES

[1] A. Fachechi, L. Mainetti, L. Palano, L. Patrono, M. Stefanizzi, R. Vergallo, P. Chu, and R. Gadh, "A new vehicle-to-grid system for battery charging exploiting not protocols," in IEEE International Conference on Industrial Technology (ICIT), (Seville), pp. 2154–2159, IEEE, Mar. 2015.

[2] B. Balaji, et. al. Models, abstractions, and architectures: the missing links in cyber-physical systems. In Proceedings of the 52nd Annual Design Automation Conference 2015 Jun 7 (p. 82). ACM.

[3] B., Vogel-Heuser, Embedded Systems: Erhöhte Verfügbarkeit und transparent Produktion, Kassel: university press GmbH 2011

[4] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021 White Paper.

[5] E. Tranos, D. Gertner. Smart networked cities?. Innovation: The European Journal of Social Science Research. 2012 Jun 1;25(2):175-90.

[6] K.-D. Kim and P. R. Kumar, "Cyber-Physical Systems: A Perspective at the Centennial," Proceedings of the IEEE, vol. 100, no. Special Centennial Issue, pp. 1287–1308, 2012.

[7] K.D. Kim, P.R. Kumar. An Overview and Some Challenges in Cyber-Physical Systems. Journal of the Indian Institute of Science. 2013 Jul 19; 93 (3):341-52.

[8] L. Northrop, P. Feiler, R. P. Gabriel, J. Goodenough, R. Linger, T. Longstaff, R. Kazman, M. Klein, D. Schmidt, K. Sullivan, et al. Ultra-large-scale systems: The software challenge of the future. Technical report, DTIC Document, 2006.

[9] M. Yilin & S. Bruno, "Integrity Attacks on Cyber-Physical Systems," in Proc. of the 1st ACM international conference on High Confidence Networked Systems (HiCoNS), pp. 47-54, 2012.

[10] N. Dutt, A. Jantsch, S. Sarma. Toward smart embedded systems: A self-aware system-on-chip (soc) perspective. ACM Transactions on Embedded Computing Systems (TECS). 016 Jun 7; 15 (2):22.

[11] O. Herzog, O, & T. Schildhauer. (Ed.): Intelligence Objekte: Technische Gestaltung – Wirtschaftliche Verwertung – Gesellschaftliche Wirkung (acatech DISKUTIERT), Heidelberg et al.: Springer Verlag 2009.

[12] P. Derler, E. A. Lee, and A. S. Vincentelli. Modeling cyber-physical systems. Proceedings of the IEEE, 100(1):13–28, 2012.

[13] R. Rajkumar, I. Lee, L., Sha, J. Stankovic. Cyber-physical systems: the net computing revolution. InProceedings of the 47th Design Automation Conference 2010 Jun 13 (pp. 731-736). ACM.

[14] S. A. Haque, S.M. Aziz, & M. Rahman. Review of the cyber-physical system in healthcare. International Journal of Distributed Sensor Networks. 2014 Apr 27;10(4):217415.

[15] A. El-Mougy A, M. Ibnkahla, & L. Hegazy. Software-defined wireless network architectures for the Internet-of-Things. InLocal Computer Networks Conference Workshops (LCN Workshops), 2015 IEEE 40th 2015 Oct 26 (pp. 804-811).

[16] M. J. Kaur, & P. Maheshwari. Building smart cities applications using IoT and cloud-based architectures. industrial Informatics and Computer Systems (CIICS), 2016 International Conference on 2016 Mar 13 (pp. 1-5). IEEE.

[17] R. Buyya, & A. V. Dastjerdi. Internet of Things: Principles and paradigms. Elsevier; 2016 May 11.

[18] L. Monostori. Cyber-physical production systems: Roots, expectations and R&D challenges. Procedia CIRP. 2014 Jan 1;17:9-13.

[19] K. Finkenzeller. RFID handbook: fundamentals and applications in contactless smart cards, radio frequency identification and near-field communication. John Wiley & Sons; 2010 Nov 4.

[20] U. Sahib. M-governance: Smartphone applications for smarter cities—Tapping GPS and NFC technologies. InE-Governance for Smart Cities 2015 (pp. 245-306). Springer Singapore.

[21] K. Nellore & G.P. Hancke. A survey on urban traffic management system using wireless sensor networks. Sensors. 2016 Jan 27;16 (2):157.

[22] D. Markham. This intelligent Water Leak Detection System turns off your water if a pipe bursts. Retrieved from https://www.treehugger.com/gadgets/water-hero-wireless-leak-detection-system.html

[23] A. A. Shouk. Smart gates. Retrieved from http://gulfnews.com/news/uae/transport/new-smart-gates-set-to-cut-queues-at-dubai-airport-1.2065806

[24]. E. A. Lee, "Computing foundations and practice for cyber-physical systems: a preliminary report," Tech. Rep. UCB/EECS-2007-72, University of California, Berkeley, May 2007.

[25] J. F. He, “Cyber-physical systems,” Commun. China Comput. Feder., vol. 6, no. 1, pp. 25−29, 2010.

[26]. E. A. Lee, “Cyber-physical systems: design challenges,” in Proc. the 11th IEEE Int. Symp. Object and Component-Oriented Real-Time Distributed Computing (ISORC), Orlando, FL, 2008, pp. 363−369.

[27]. U. Kremer, “Cyber-physical systems: a case for soft real-time”, Accessed on: May 1, 2013. [Online]. Available: http://www.research. rutgers.edu/∼uli/Sarana/documents/CPS-Uli.pdf

[28]. H. Al-Omari, F. Wolff, C. Papachristou, and D. McIntyre, “Avoiding delay jitter in cyber-physical systems using one-way delay variations model,” in Proc. 2009 Int. Conf. Computational Science and Engineering, Vancouver, BC, 2009, pp. 295−302.

[29]. M. C. Bujorianu, M. L. Bujorianu, and H. Barringer, “A unifying specification logic for cyber-physical systems,” in Proc. 17th Mediterranean Conf. Control and Automation, Thessaloniki, 2009, pp. 1166−1171.

[30]. S. Andrei and A. M. K. Cheng, “Optimizing automotive cyber-physical system specifications with multi-event dependencies,” in Proc. 10th Int. Symp. Symbolic and Numeric Algorithms for Scientific Computing, Timisoara, 2008, pp. 475−479.

[31]. Liu, Y., Peng, Y., Wang, B., Yao, S., & Liu, Z. (2017). Review of cyber-physical systems. *IEEE/CAA Journal of Automatica Sinica*, *4*(1), 27-40.