International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 12 | Dec 2019 www.irjet.net p-ISSN: 2395-0072

Cyber Physical Systems (CPS) and Design Automation for healthcare System: A new Era of Cyber Computation for Healthcare System

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Abstract - *Cyber Physical System (CPS) is a Cyber System integrated with physical processes, the new generation technology supporting cyber security for physical processes and physical systems. Cyber physical system can be described as a system that integrate various physical elements with computing elements and processes. CPS has became area of interest in academia, industry and research institutes due to various potential impacts of CPS on environment, economy, Industry growth, societal development and security. In this paper, CPS design parameters, application areas, comparison with other ICT devices and analytical study is presented.*

Key Words: **Security, Traffic, Safety, WSN**

1. INTRODUCTION

Cyber physical systems characteristics or working behavior is defined by the physical and computation parts of CPS. The physical processes monitored and controlled by cyber devices using the feedback loop. The feedback loop helps control the physical processes and in turn affect the computation. CPS is an integration of cyber devices and physical processes, and not the union of these two.

CPS is also know as Internet of Everything, Embedded Systems, the Industry Internet etc. Cyber physical Systems were in existence since long time, but recently it has come together as an new era of intellectual system or discipline. CPS design and integration is to curtail as we cannot just integrate physical processes and cyber computational components directly. Before integration of cyber components and physical components, we must understand their integration requirements and design of integrated system. The integration involves integration of computation, physical processes and networking environment & devices. Even though CPS is in existence for long time, many tools & techniques exist for CPS automation, a design methodology for wide utilization is not in existence for all tools. CPS is more complex as compared to integrated circuits in many parameters. One cannot find a single design space or methodology for CPS as we can find for digital circuits, embedded systems and software design. This article is about the Cyber-physical system design, security aspects, challenges while designing system automation, and some application areas of CPS.

CPS is a result of advancements in technology, technology for design and fabrication at micro level and nano level, fundamental components available in required size & with required features. Some fundamental components are wireless networking devices, sensors, processors which are small in size but efficient in processing, and actuators. The developments in software design methods for complex applications, computing system software advancements like high performance computing system ,real time embedded operating systems, sensor based operations, programming languages with high level library support are also important in development of CPS. The wireless devices are feasibly connected to each other through the Internet across the world.

Some major application areas for CPS are Smart city traffic control, automobile sector, robots, aircraft for traffic control, smart power grid design, manufacturing plants for management and control of machinery, construction, medical system and many more. CPS are working in highly dynamic environment with distributed operating system, heterogeneous cyber and physical entities like software hardware, electronics devices, challenging dynamic objectives. CPS need to be adaptive for such dynamic environment. Many CPS are operated by human, which in turn require considerations of human aspects for CPS design. The considerations of human aspects need extreme advancements in theory, technology and tools for automation of CPS. The automation community has extended opportunities with this need of advancements in technology. The automation process gives opportunity to entire design process stages, which include system specification, modelling, programming language design, simulation, system validation and system components verification, parameter mapping, design of interface, analysis of performance, networking, application debugging & testing, any repairs and so on. Each of the stages or categories need more advances in technology and tools for CPS automation. Two main applications researchers worked on are smart power system and smart transportation system.

1.1 Structure of CPS

CPS is in development phase, that is its under analysis, study and research phase. It need to be clearly specify the structure and methodology of CPS for industrial implementation. To fulfill the demand of industrial implementation of CPS, a unified system framework is designed. Collaborative algorithms and technologies at each layer are proposed for enhanced efficiency, reliability and quality of product. This collaboration can determine expected functionalities from each layer of CPS structure. Cyber physical system works as feedback system throughout application areas of CPS. The industrial implementation of CPS needs advancements in design tools, design methodologies and strong security in terms of cyber context.

CPS need cyber security for physical devices or systems connected using Internet based network. The cyber security provided to devices should monitor malicious attacks, intrusion and privacy parameters of systems. CPS algorithms should be designed by considering such security concerns. Privacy of data or metadata should be maintained while performing network communication. CPS systems work as feedback systems for complete architecture. CPS may work in collaboration with humans to provide some intelligence to decision system of CPS. Based on economical efficiency and environmental results, CPS may provide feedback to central or distributed server. CPS feedbacks are based on real time monitoring and analysis of sensed data. System can be designed using adaptive or predictive algorithms for better prediction and understanding of environmental decisions.

1.2 Challenges in CPS Design

The combination of characteristics of CPS system are the reason for various challenges in CPS design:

Heterogeneous components: The cyber-physical system has various types of components. These components work in collaboration with each other and we need to interface different platform for interaction among these various components.

Hybrid Systems: CPS is combination of computation system and physical processes. The combination of discrete and continuous dynamics require advanced theory and tools which can model, design and analyse the CPS.

Dynamics: The working environment of CPS is dynamic. To account the changes in environment CPS design and operations must respond in such a way. The environment may behave adversarial to disturb the operation and may violate desired properties.

Distributed components: In cyber physical systems, components are connected to each other, but may be separated from each other physically, geographically, or logically.

Large-scale system: the number of components in cyber physical system are growing rapidly. The number of sensors, actuators, computational processes and communication devices are generating large amount of data.

Adaptive to changes: The dynamic nature of environment need to be understood and CPS must understand the dynamics of system. To adapt the changes in environment designer can use machine learning.

Human aspects: some CPS are working in concern with human interaction or systems controlled by humans. Eg: surgical robotics which are controlled by doctors to achieve their objectives.

2. Applications

Traffic Congestion:

Recent growth in industry and businesses has affected the road transport system. Growing rate of vehicles on road has increased number of accidents resulting in injuries and fatality. Today's transportation facility is at its peak for services to vehicles. Further it is not possible to construct transportation infrastructure without environmental losses. The infrastructure construction is not an feasible solution. Instead we need to think about smart, intelligent, safe and energy efficient transport system. Developments in wireless communication, intelligent intersection systems and autonomous self driven vehicles for V2V and V2I is essential.

Energy Generation:

In many countries electricity is generated from fossil fuels like coal and natural gas. Many of those power plants are too old, may be operating for last 40 to 45 years. More than 40% of greenhouse gas emission is from these power plants, which may increase in next few years. The demand of electricity will increase in future and which will contribute to emission of more and more greenhouse gas. The aged power plants and electricity distribution techniques are not upgraded by considering the current

environmental requirements and financial losses. The power grid has became less reliable. More than 600 million people were affected due to largest blackout experienced by India in July 2012.

The electricity / power generation plants and electricity distribution infrastructure built in last few decades are not realizable, ecofriendly, efficient and economic to satisfy the increasing demand. We need to develop smart power grids that can manage efficient power distribution and detect power losses in any circle. Research using CPS is carried out to design a system with sensors, monitoring features, control over power generation and consumption, analysis and prediction of power generation and utilization for optimization of loss due to extra power generation or power cut, identification system/circle where infrastructure failure may occur, recovery of failed system, etc. This research has became crucial for future smart grid.

Green Ecofriendly Buildings and states:

Most of the Cars and Industry are running on gasoline and electricity generated from fossil fuel. By considering environmental effect of using gasoline and fossil fuels, society need to transit from current traditional fuel utilization methods to renewable energy sources. Many researchers are working on this issue. Research is carried out to for use of alternative energy sources like solar energy, wind energy and geothermal. Vehicle manufacturers are designing electrical cars as an alternate to existing gasoline vehicle. The sustainability of new design depends on efficiency, performance and cost of vehicles. CPS research need to be carried out to optimize energy utilization by using smart meters, real time billing & communication system between user and supplier, smart monitoring of electricity utilization.

Medical and healthcare system with reliability, intelligence and flexibility:

According to various surveys and reports across the world, it is explored that large number of population aged more than 65 years , old people, are living alone and many of them are suffering from some type of disability. With the leading growth in population against decrease in well trained and experienced doctors, healthcare faculties are becoming costlier. The challenge in healthcare system is to design a cost efficient system. CPS research in this area is about to design a smart sensing system which will monitor health, predict further condition of patient, suggest some remedial to patient based on condition of patient, telemedical system for remote healthcare service, semi-automated robots to assist patient physical activities, call emergency services based on critical conditions and so on.

CPS research is required as their is drastic change in confidence of people in healthcare system operated manually by doctors. Various reasons behind this loss of confidence are surgical error, wrong diagnostics, medicine prescription errors and patient handoff errors. CPS technology with computerized physical order entry system and automated clinical decision support systems can reduce up to 75% adverse drug cases in primary health care. Proper diagnostics and real time embedded system can help to control and monitor proper diagnostic decisions, patent handoff and development of smarter safer system.

Security Analysis

CPS need to satisfy three S: Safety, security, and sustainability. The embedded system with its feedback loop can be used to design healthcare system to take control of all physical processes and can generate computational results. Usual security mechanisms are concerned about access rights, cyptography, stegnography, anomaly detection, intrusion, and many more solutions. Security mechanism ensure safe and reliable communication between cyber physical devices through network. Numerous anomalies are in existance which has resulted in delay and performance degradation. Anomalies are detected with patient records available publically. In patient data these anomalities are observed due to abnormality in patient, movements by patient, transmission errors, device malfunctionality and device disconnection.

Austin Jones et al proposed unsupervised learning algorithm. The device records were used to identify patient behaviour. STL formula was used to find this behaviour. Xin Sun et al proposed a hybrid system with anomaly traffic detection in high-loaded networks. With this approach, static and dynamic traffic analysis methods are combined. Cross platform behaviours are observed in this method. On social networks fraudulents are capturing private data of users. These anomalies are detected using intelligent sensing model for anomalies detection (ISMA).

Future Scope

In the era of IoT, WSN and high range sensors, we can design more secure and trusted systems on which users will be reliable. Current systems in healthcare are limited in features, less user friendly and is limited in terms of accessibility. Using CPS, it is possible to design a system where patient can trust on system through which he/she will transfer any medical data for precautionary suggestion. More reachability can be added by designing mobile apps and UI for use by any non-medico user. In healthcare system, more and more hospitals and doctors can be added for best results. In terms of technology and deployment,

we need to design a prototype which will connect number of sensor based devices to central server, can process a big data, and provide security over data transmission and reliability to patients.

3. CONCLUSION

Healthcare is emerged as one of the most important research area for technology designers and developers. Researchers are working for embedding more security to data and communication in network. Any single change in patient data may result in extreme treats to patient life. The cyber-attacks on medical data motivates researchers to study various security systems like multi layered data cryptography, steganography, and so on. In future we need faster and more secure algorithms as slow and less secure systems can cause more havoc.

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