An Review of Medical Cyber Physical System Architecture and STP Issues

[1]Zhonghe Zuyan
[1]College of Electronic Information and Optical Engineering, Nankai University, Nankai District, China.
[1]zuyanzho@gmail.com

Correspondence should be addressed to Zhonghe Zuyan: zuyanzho@gmail.com.

Article Info
Journal of Computing and Natural Science (http://anapub.co.ke/journals/jcns/jcns.html)
Doi: https://doi.org/10.53759/181X/JCNS202202019
Received 25 May 2022; Revised form 20 June 2022; Accepted 27 July 2022.
Available online 05 October 2022.

Abstract – Medical Cyber-Physical System (MCPS) is a system of diagnostic instruments that is vital to healthcare. Hospitals are increasingly using these technologies to ensure that patients get high-quality treatment at all times. To name just a few, the MCPS system software confronts high assurance requirements, inoperability, security and privacy, and a host of other issues. There is an assessment and discussion of the CPS infrastructure in the present work. The study into interconnected medical device systems (MDs) to improve healthcare safety and efficiency was improved by this article. In addition, experts in medical device design may benefit from this software, which can aid them in overcoming critical obstacles and challenges in the design of the healthcare device's networks. Wireless Sensor Networks (WSNs) and networking are both discussed, as well as their respective security. After that, the CPS technologies and frameworks were built, and greater attention was paid to CPS-based healthcare.

Keywords – Cyber physical system (CPS), Medical Cyber-Physical Systems (MCPS), Wireless Sensor Networks (WSNs).

I. INTRODUCTION

Cyber Physical System (CPS) alludes to a networked system that combines the cyber realm (i.e., computer systems) with the physical phenomena. Machines and networks embedded in the physical phenomena are also used to constantly monitor them. There are several reasons why embedded systems precede all of the preceding concepts that came to light in the last century, such as automation control, to mention just a few. It is impossible for end users to easily change (i.e., reprogramme) the specified functionality provided by embedded systems in one or more functionalities. The basic objective of embedded systems is to control and manipulate the physical environment. While IoT and CPS have expanded the scope of embedded systems, the initial focus of these technologies was on controlling physical phenomena, while embedded device had a narrow focus.

An increasing requirement for dynamic embedded systems to handle increasingly complex systems led to the development of Networked Embedded Systems. The RUNES project, which was supported by CORDIS, conducted important work in this area. This research looked at a "hybrid network of systems," or a system of systems [1]. The development of CPS was sparked by a shift away from standalone systems to more sophisticated networks. Sensor Networks evolved in the 1980s as a consequence of this evolution, and they have since become an important feature of current CPS. Sensor networks are often made up of several sensors strategically positioned throughout a certain area with the express goal of gathering data. Smart Objects, which are described as items (sensor systems or actuator) with a microcontroller, communications capabilities, and power sources, have become simpler to implement thanks to Sensing Devices. This is despite the fact that sensor networks aren't considered as independent units, but instead as elements of bigger systems, such as detection systems and fire suppression system.

In the development of the concept of Ubiquitous Computing, CPS has had a major influence. Furthermore, it was claimed that computer systems may be rendered "invisible" to end users by being incorporated into everyday human activities. There are a number of specialists who believe that the Internet of Things (IoT), pervasive computing, and ambient intelligence belong under the umbrella of ubiquitous computing. As stated by Verdejo Espinosa et al. in [2], one of the primary goals of IoT is to provide end users with a means to push the limits of their everyday gadgets and to create individualized services by connecting widely dispersed devices. Embedded systems are being replaced by ubiquitous computing and the Internet of Things (IoT), which need more flexibility and adaptability. CPS and IoT were created as a consequence of the advancement of computer systems.

An important step away from the traditional division between operational and information technology has been made possible by prototypes that combine the two in a seamless fashion. Internet of Things (IoT) has been defined as an infrastructure that incorporates communication technologies, standard protocols, and other features that offers services provided by "things" to different high-level applications, despite the absence of a unified definition. Many people believe the term "Internet of Things" refers to scenarios in which the capabilities of smart devices/objects are upgraded and allow for global communication through the internet and similar technologies. Some publications [3,4, 5] support this view. The Internet of Things (IoT) may be seen in a variety of ways, and CPS is one of them. For devices and systems to communicate, CPS is a first-row system that can also be distributed and have global connection, but it can also be self-sufficient as an individual unit. Several CPS support technologies are shown in **Fig. 1**.

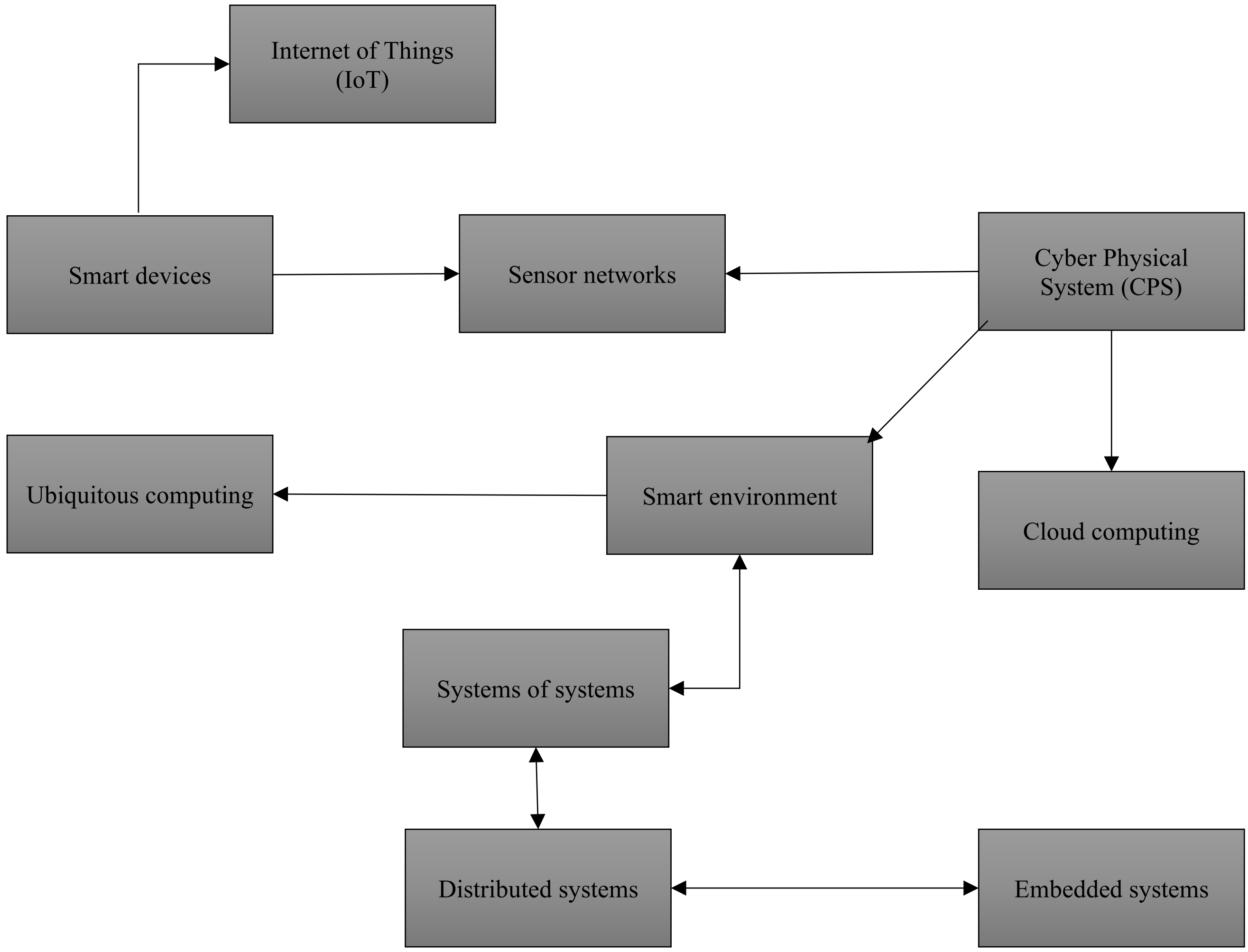

Fig 1. Data flow between CPS support technologies

Sensors collect a wide range of data from the actual environment. All this information is then sent to the internet to be studied and evaluated. It is the goal of the CPS to bring common items and services together to perform vital activities. Several IT-based social service models rely heavily on the notion of CPS. It may be used in a variety of fields, including social services and healthcare. Across the world, several nations are suffering from severe shortages of healthcare workers, which has resulted in a decrease in medical care quality and a significant rise in healthcare expenses. Skills in the area of integrating new medical devices into existing health monitoring systems have improved significantly. Due to the proliferation of low-cost detectors and several modes of transmission, the current platforms are unable to handle the massive amounts of real-time data. Therefore, infrastructures and a conceptual paradigm are required in order to progress this field. From this, Medical Cyber-Physical Systems (MCPS) with big data processing systems connect cyber and real-world aspects with dynamic, entirely adjustable decision making, as well as other healthcare technologies [6].

Innovations in communication and computers are taking place now. Especially in the medical field, the Internet has opened up a slew of new networks in a variety of fields. Both the CPS and MCPS systems have far-reaching social and economic implications that are much better. Several investments have been made across the globe on this technology. There are a number of physical hurdles that must be overcome in order for biomedical data to be interchanged vita and social and wireless networking systems, including dependability, security, and safety standards. In contrast to typical computer applications, these problems provide a unique set of obstacles. Object-oriented software has many similarities, but its physical components do not. A wide variety of resources with great sensing capacity will be employed in the upcoming generations to incorporate multimodal data from intellectual, physiological, and social networking sites. As a result of this standard update, Net-Centric Societies (NCS) [7] or Cyber-Physical Social Systems (CPSS) [8] will be built using interdependent social networking sites (networks of people), handheld computers, technological devices, and telecommunication technologies. It is essential to establish if the networking and computing technologies are capable of supporting the MCPS. Automated widespread health monitoring technologies are regarded a crucial function in improving infrastructures for relieving healthcare difficulties. In the event of a medical emergency, these technologies inform the appropriate healthcare workers to provide the best possible treatment with little administration.

Gadgets with advanced sensing and networking capabilities, such as wearable sensors, smart meters, and other devices, are on the rise. These gadgets, referred to as the Internet of Things (IoTs), shall be constantly interpreting, perceiving, and monitoring the ecosystem for the unforeseeable future. Social networks and IoT have a significant impact on new computing and communications infrastructure. In most cases, the IoT is restricted to the monitoring and management of tiny devices, with no need for the devices to be connected to a shared network. As a result of this, the CPSs are increasingly concerned with the manner in which physical systems are effectively monitored and managed in the cyber system. Because they may be linked to the internet, CPSs are considered instances of the Internet of Things (IoT). When it comes to transferring data, the Internet of Things is essentially a network of Cyber-Physical devices. To put it another way, the initial level of vertical systems integration is CPS, followed by IoT.

The Internet of Things (IoT) is a term that refers to systems that are interconnected. Monitoring and feedback control services may be provided in real-time by embedding sensing, processing, and communication platforms within physical procedures as segment of larger systems/processes. MCPS are the schemes in the medical field that include both a physical and a computational component in order to enhance healthcare via the understanding of ubiquitous monitoring frameworks. It makes it easier to employ wireless devices in distributed computing. It has revealed that WBANs are the main technology for delivering universal medical care and real-time health screening in the context of smart health. These medical cyber-physical systems, for example, are capable of working in impermeable settings like hospitals and so may cause high interactive communication disruption in many medical applications. Therefore, one must demonstrate that one's behaviors are in accordance with one's convictions.

The primary goal of this study is to provide a critical understanding of the MCPS technologies illustrating their function in healthcare. The WSN-based CPS systems are presented as a significant milestone in the development of ant MCPS systems, and its architecture and platform are described. Physical infrastructure, general needs, and security challenges relating to CPS were all addressed in this study. There is also an introduction to CPS and MCPS, which will be used in the social settings. Healthcare systems with interconnected medical equipment and IT-based social services are also taken into account. At long last, the most recent MCPS research goals and issues for future medical devices are addressed. Section II presents a review of the MCPS structure and CPS. Section III concentrates on MCPS, which Section IV evaluates the future research directions and reviews the issues in MCPS for future clinical devices. Lastly, a conclusion to the research is arrived at in Section V.

II. MEDICAL CPS STRUCTURE AND CYBER-PHYSICAL SYSTEMS

When a CPS fails and affects the operation of the associated systems, tremendous economic harm occurs. The CPS necessitates the use of both physical and network concepts. The CPS is expanding in scope, diversification, customization, and dependability. Real-world applications include robots, smart grids, and healthcare for these systems. A new type of system that is fundamentally distinct from the basic embedded systems in terms of adaptability and scalability, as well as its resilience, security and safety, is expected to be created through improvements in CPSs. For example, i) must meet actual-time performance requirement; ii) should have response and input from physical domains with no consideration to the protocol of communications; iii) incorporate decentralized control and management; iv) have multi-scale features; and v) geographic distributions for elements in locations, which are affected by low component supply.

Telemedicine, for example, connects patients and doctors over the internet. A high-security internet connectivity s needed for the transmission of patient data and reports. Controlling the flow of unauthorized information while taking into consideration both the physical and cyber consequences is essential. Additional consideration must be given to the application's communication and data requirements. **Fig. 2** depicts the data flow and interaction patterns for CPS applications. MCPS, medical sensors, and other devices' reactions to human operators, as well as the physical communication routes used by sensors and external processes, are all critical.

When it comes to CPS and MCPS security and privacy, high-confidence CPS and MCPS take infrastructure challenges into consideration. When it comes to predicting system behavior, traditional analytic methodologies fall short due to the system's complexity. Medical equipment and sensors connected to the Internet of Things (IoT) interact with humans and the physical environment, escalating the MCPS security, dependability, privacy, and safety requirements. As a consequence, it is vital to have access to the relevant technology in order to generate and verify hypotheses concerning complicated engineering systems. Large and geographically dispersed CPSs need new architectural approaches since traditional real-time performance is inadequate. Since the input and the feedback are protected from the physical world, the CPS and MCPS seldom consider the availability of communication routes that need security. The CPS has this as a key feature.

The MCPS and CPS systems are vulnerable to security attacks in case the data flow, control, accessibility requirements, and application flaws are incorrectly specified. For the best network construction, security specifications must be taken into account. The CPS and MCPS systems cannot function properly without the protection of their sensors. For the cyber-physical system to avoid being compromised, the sensors' tamper detection and input validation procedures are critical. Consequently, the security is seen as a component of the application design and system architecture. Security considerations must be taken into account when putting up data storage, monitoring, and control systems. At long last, we have MCPS designs and tools for system enhancement. Virtualized distributed systems may be isolated for security reasons, including performance isolation, data isolation and control isolation.

In comparison to general-purpose computation, embedded systems have greater standards of predictability and dependability. Embedded systems, in particular, have benefited greatly from the convergence of computational and physical processes. Examples include aviation control models, healthcare models, and military models, communication models, and motor electronics. The embedded systems, also, may be seen as sealed compartments that do not interpret the computer's computational power. The fundamental shift necessitated by connecting the embedded devices has a number of practical issues to work through. Embedded systems, which are both feature-rich and networked are needed for many tasks. Before embedded computing, real-time dominating vision had already been firmly entrenched. CPS and MCPS may not be compatible with today's operating systems, programming languages, or computers in general.

The most widely used networking techniques exhibit randomness and time unpredictability. Networking technologies are currently used in embedded systems. The integration of computing with cyber-physical systems needs the simultaneous composition of the computer approaches with the physical ones, which are synchronized with nature. Real-time sensor inputs and actuator control must be handled concurrently by embedded systems. As a result, computer languages fail to express the interfere idea, which arises when actuator hardware and sensors are interconnected. CPS often demands greater predictability and dependability in healthcare, automobile safety, and traffic management applications. Due to the non-predictability of physical systems, CPSs must be able to adapt to subsystem failures and withstand unexpected situations.

The social spaces in CPS and MCPS may be regarded to have a common architecture. People will increasingly interact with cyber-physical systems, e.g., the smart grid and crisis response systems, which are designated to be utilized by human beings. Artificial intelligence, advanced complexity, and adaptive structure/structure are some of the primary characteristics of CPSs, which contribute to humans' enormous effect on the ecosystem. CPS permits users to be both out and, in the loop, when the two systems are compatible. A foundation for future computing environments is laid by the IoT's adoption of the idea, which things exchange data and interact effectively.

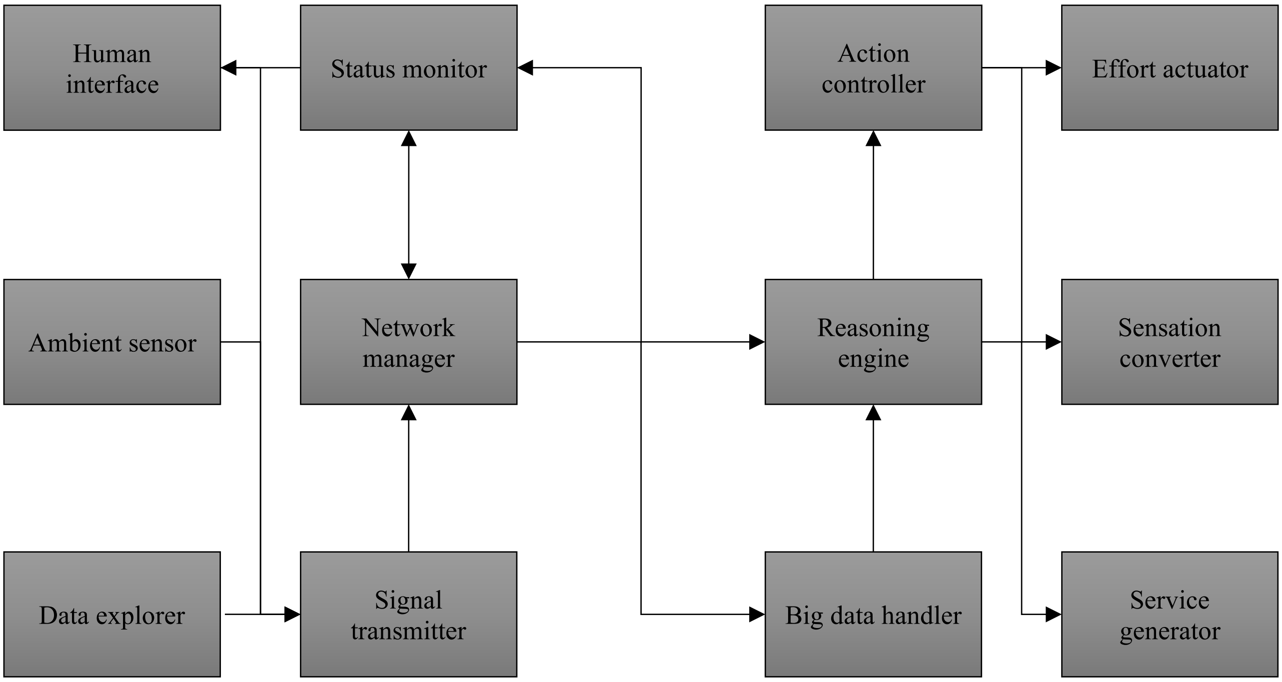

Fig 2. The CPS standard infrastructure

At this early stage of development, a wide range of interpretations and applications are being considered for the CPS paradigm. Physical, engineered systems may be characterized as CPSs and MCPSs when they are under the direction and supervision of a central computer and communication system at any level or size. Cyber-physical systems may be broken down into two subsystems: one is a discrete event-oriented and logic-based system responsible for communications and computing, while the other is an integrated physical system that is governed by the laws of physics. This kind of system's openness to the physical and cyber worlds, as well as its intelligence and context-awareness, allow it to further infiltrate the social and human worlds in support of healthcare, which is a hallmark of MCPSs.

Our social-technology civilization increasingly sees CPSs as more than merely a technological construct. They produce two unique socialization axes by incorporating the interaction between the embedded environment and the human realm.

These systems are complicated social-technical systems because of their intertwined human and technology components. In order for Socio-Cyber-Physical Systems (SCPS) to function, people's expectations and social/community norms must be taken into account. Synchronizing performance, accessing user information, recognizing social networks/associations between users, deducing social context from network topology, and giving an output that is contextually appropriate are some of the core social skills necessary for these systems A person's beliefs, culture, attitudes, and interpersonal relationships must all be taken into account by the SCPS in order for it to be effective. Additionally, i) SCPS systems will be able to adapt themselves towards optimal collaboration; ii) they will have the highest possible level of dependability, security, accountability and maintainability; iii) they will have the ability to achieve a balance between the resources required to produce an output and the costs of producing that output; If data sources aren't dependable in this setting, then CPS systems may struggle.

Advanced CPS applications have begun to operate in social settings where people play an important role in the inclusive system. From now on, future CPS and MCPS applications will take into account the presence of people in the loop. Survivors of catastrophic disasters may gather damage data from survivors, and drivers can provide data on traffic jams at different places by using medical sensors to collect information for patient records. The MCPS may be utilized in the wide-range of medical applications, including CPS in the social sphere.

III. MEDICAL CYBER-PHYSICAL SYSTEM

Biocompatible and implantable devices, electro-anatomic intervention and mapping, as well as robotic prosthetics all fall under the umbrella term "Medical Cyber Physical System," which describes a group of cutting-edge healthcare technologies, which utilize sophisticated embedded systems and networking communications to potentially control and track the physical dynamics of patients' bodies. Patients' physical dynamics may be monitored and controlled with the help of these technologies. Inappropriate use of these instruments may have a significant impact on a patient's health. It's critical to ensure that all interactions are safe and correct, yet this may be difficult due to the complexity of the interactions themselves. a Medical CPS, and testing and development of custom treatment programs, will benefit greatly from body Modeling and efficient simulation. A basic desktop computer equipped with GPU technology may reach real-time simulation speeds (for complicated spatial patterns, which might be interlinked to cardiac arrhythmias). Medical facilities will soon be capable to undertake organ simulation in real-time. Without supercomputers, it might still be possible to apply model-centric treatment planning and clinical diagnosis.

Importance of Medicalcyber Physical Systems (MCPS) and Cyber Physical Systems (CPS)

Embedded systems and IT executives need it as a key enabler disruptive technology to maintain their economic and social dominance. There are a wide range of social issues that these systems might help to address in the present and the future. It's the next generation of system architectures, and it's attracting a lot of interest. The relevance of CPS is highlighted by the fact that CPS is a point of confluence for a wide range of disciplines, emerging technologies, and the need to create large-scale systems to meet societal requirements. Virtual and real worlds are intertwined through CPS, which stands for computer-based systems.

Importance of MCPS

Since the previous decade, the medical world has seen an increase in the creation and production of CPS. Embedded system analytics and medical devices are rapidly progressing as a result of their successful integration. Modern Medical Cyber Physical System research and design disciplines include pacemakers, medical ventilators, infusion pumps, etc. (MCPS). In order to share, analyze, sense and generate 'big' clinical data for processing, many systems integrate a massive number of physical devices, such as sensors and gyros. Many problems and hurdles must be overcome in order to develop the frame or chassis of such gadgets and equipment. Large-scale communication and computing, as well as scalability, are included in this list of features. The breadth and relevance of MCPS and CPS in general are discussed in this section. Now, in the next part, we'll go through a number of prominent attacks against MCPS and CPS.

In general, the term "social media" or "social spaces" alludes to the web-centric equipment and tools, which enable people to communicate quickly, easily, and widely. Patients, doctors, and healthcare workers may swiftly and easily communicate with one another using this technology, which has a significant influence in the medical and healthcare fields. It makes it easy to transmit patients' files and information. Thereby, the social media role in healthcare applications may be evaluated. Therefore, SCPS becomes an unstoppable force in the medical business, particularly in light of the advancements in medical device software and networking connections that have been made possible by SCPS. By using distributed systems that simultaneously regulate and examine several physiological parameters of a patient, it has become possible to replace individual device designs that treat patients in isolation.

Trends in the Application of MCPS

When embedded devices, networking capabilities and complicated physical dynamics were combined to create medical CPS (MCPS) systems, the medical system was changed into current medical device systems. Trends in MCPS usage may be divided into numerous categories as shown in **Table 1**.

Table 1: Trends in MCPS usage

Improvement networking abilities:	**As of now, the networking capabilities of medical devices are utilized to monitor patients via local connections of many clinical equipment to integrate distant monitoring and/or patient monitoring, and to communicate with e-health for storage.**
New software-empowered embedded systems:	It is now possible to design new features for medical devices because to the advancements in embedded systems software, which has led to an increase in functionality.
The requirement for automated monitoring for patients' conditions:	Continuous monitoring of the patient's condition may be achieved using an automatic controller, which can handle regular circumstances.
Novel intentions in the medical industry:	The introduction of cloud computing as well as, by extensions, social CPS frameworks has been hastened by advancements in medical equipment such as biosensors.
Advancement of wireless communication and computer technology:	Accessibility to Internet services through mobile devices is made possible by advances in information technology, communications, and wide-spread deployments of wireless broadband networks. As a result, mobile health is becoming more popular via CPS systems.

For this reason, the MCPS systems incorporate embedded devices, communication routes and controlling software for effective interaction. The prompt development in clinical technology has amounted to a novel generation of medical providers and advanced treatment options. Implantable/biocompatible equipment, electro-anatomic imaging, robotic prosthesis, and complex embedding devices are among the newly deployed technologies. The stand-alone system is transformed into a remote monitoring system using MPCS. A variety of MCPS applications prevail, incorporating analgesic implantable equipment, implanted sensor and patient monitoring systems. For real-time calculation, the computerization of many medications and medical equipment enhances their dependability on a computer system. These devices may be connected to a computer network so that the monitoring procedure can be carried out regardless of location. These medical gadgets are made up of sensors that collect data from various sections of the body, which is then sent to computers for further processing and decision-making. Several medical systems, such as in patient safety, may benefit from the CPS because of the latest advancements in medical devices, WSN, and cloud computing. Using these bio-sensors, doctors may gather critical patient data, including medical records. The acquired data are then sent to a gateway through wireless connection. Clinicians will be able to view and save the sensor-collected data. The privacy of patient information necessitates that security be a top priority. Therefore, healthcare applications need unique considerations while creating the CPS architecture to ensure data security.

Furthermore, in order to make informed decisions based on patient data, healthcare apps need computational resources. In order to increase the model's scalability and allows real-time data evaluation, prevailing research MCPS-oriented in turning in cloud computing as a foundation. CPS research in the healthcare industry is still in its infancy. Making decisions based on the patient's feedback in CPS. Input data covers both active and passive data, e.g., smart feedback and digital recording systems, including bioelectronics and smart devices in the clinical settings. Medical applications may benefit from this configuration of data acquisition and decision-making systems. It is possible to apply novel management ideologies for clinical physical systems centred on computation and control in relation of body area networks, minimized implanted smart devices, programmable material, and innovative manufacturing processes to take advantage of CPS in the healthcare industry.

Although several CPS designs have been developed, the proposed CPS structures for smart healthcare are quite restricted. An infrastructure for CPS model in medical provided by Mun [9] has been proposed by these researchers. It was decided to use a WSN-cloud integrated model. CPS-MAS was established by Park [10] to model and analyze MCPS. Despite this, the security and privacy issues went unaddressed. Safety verification was mentioned as a potential focus of the CPS-MAS framework by one of the authors. Medical devices interact with humans in complicated ways, and modeling these interactions may be difficult due to factors such as transit delays, nonlinearity features, and the nontrivial aggregation of interactions that occurs when devices are networked. An example of a chemotherapy and pain treatment medication delivery approach was discussed. According to Zang [11], a SOA-based MCPS idea has been proposed, however the whole architectural context was left out. Controlled- and assisted-applications of CPS in healthcare are often divided into two categories: The former (aided apps) provide health monitoring but do not regulate the patient's daily routines. Biosensors are used to gather real-time physiological data, which is then utilized to provide medical recommendations. It is possible to use aided apps to help elderly persons stay at home.

Controlled uses, on the other hand, are available in hospitals and critical care units for medical assistance. In a controlled setting, the degree of observation and monitoring is quite high. In hospitals, for example, biosensors, bedside monitors, and clinicians' observations are combined to help guide treatment decisions. The development of medical processes is possible via the use of these networked, closed-loop systems, which include people. Patients may also get remote care through new technology, which can reveal the impact of various everyday activities on heath. The healthcare system becomes a sophisticated, vast, and safety-critical cyber-physical system with multiple benefits and difficulties when aided and controlled features are combined.

To meet the unique demands of each patient, healthcare increasingly relies on interconnected medical systems and technologies. For example, image-guided psychosocial interventions; smart operating units, biological test fluid flow control, and neural/physical prosthesis development are all possibilities arising from CPS research. Oxygen and ventilator equipment, infusion machines for sedation, and detectors to check patient status are common in operating rooms. When these devices are put together in a novel system configuration, they meet the exact procedural and patient demands. Controlling techniques and improving systems for running and developing these systems is a major problem in MCPSs of this kind. Because of this, scientists are motivated to develop advanced and networked medical equipment technologies centred on IT-oriented social services in medical systems.

Networked Clinical Device Models and IT-oriented Socio-Service in Clinical Models

As novel manufacturing materials, digital networking, wired/wireless, microprocessors, and electronic circuits become more available, they will definitely replace analogue electro-mechanical systems and devices as a means of patient monitoring, diagnosis, and treatment. A wide range of systems may be built, from tiny, localized electronic records systems to ultra-large, distributed networks for various medical devices. IT-enabled medical equipment will allow operators to control passive devices through computer systems in the future. Consequently, sensors and actuators actively control patients psychological processes and activities. There is a rise in the development of systems that include both physical and cyber components. With a CPS system, you may get a wide range of features, as well as flexibility and efficiency.

Modern health care systems, such as medical sensors, may enhance the health of patients by making use of new health care facilities, such as practical health services. Control of the integrated device Doctors and medical professionals utilize Smart Medical Device (SMD) to communicate progressively with the human body or the patients. A connection of physical computations and processes are controlled and monitored by embedded systems. From health care to transportation and robotics, Computer-Based Systems (CPS) may be found everywhere.

Control and distributed sensing may be accomplished by using many levels of medical device networking. Network applications for medical devices are reviewed on an ad hoc basis while decentralized medical-device schemes offer acceptable Quality of Service (QoS). Because of this, networks using PDAs, such as those using IR and Bluetooth, memory sticks, barcodes, and other social service technologies, may send data in a very unsafe manner. It's apparent that medical device CPS designs need to be realistically developed with great certainty. The development of clinical networked embedded-control frameworks is needed to provide high QoS. Patients' privacy and safety, as well as security and robustness, should be taken into account as a result.

Development of Medical Devices

The clinical devices' design integrates both wireless and wired interface, which permits for networked connections and transmissions of clinical report of patients' data. Unplanned consequences might arise when many devices in an ad hoc network are aggregating data from each other. Distributed communication and sophisticated networking play a major role in healthcare systems, integrating telemedicine, digital medical analysis, home medical services, by transferring clinical information effectively across the network. It is necessary to develop and manufacture sophisticated clinical device models and software, e.g., modalities, implants, bio/nano devices and invasive surgical tools, with high trust levels for networked clinical device models. High-trust medical device cyber-physical architectures may be realistically ensured by the design of medical equipment.

Strategies for developing improved, end-to-end engineering-oriented process equipment for medical device manufacturers are critical to their success. It is critical that business, academia, and government work together to develop the essential standards/networking, and IT frameworks, to enable the development of future MCPS systems. The embedded systems (ES) in medical devices have control capabilities and may connect with the engineering systems as well as with patients. This makes them very important. Electronic Systems (ESs) may be thought of as computer systems built to perform certain tasks inside mechanical devices. The MD system's device design is extremely exclusive and relies on experts to provide input and evaluate results. It is possible to extract knowledge from data that is streamed into medical records through networks. This information may then be used to power a wide range of activities, including computer-based treatments.

IT-oriented Social Services within the Clinical Context

With CPS-based social networking, users are able to communicate with one other in a more meaningful way than with traditional Web-based social networks. Examples include audio, position, motion, and acceleration data that may be shared through mobile phones. It is now possible to share information about a user's position, activities, and movement patterns with others in the virtual world because of this. Significant shifts in healthcare policy and delivery have pushed social service integration to the fore. IT's future depends on the emergence of new terms like "pervasive computing" and "ambient intelligence". The term "ambient intelligence" signifies to the communications technology's importance in smart buildings and future healthcare homes. To help healthcare systems and medical approaches, the SMDS is used. A huge amount of progress in healthcare has been made possible because to embedded systems and clinical decision support systems. It is possible to write embedded software in such a manner that it is not visible to the user. Microprocessors integrated inside small devices, known as "embedded systems," are used to boost the automatic device's intelligence in wide-range of applications.

Emerging Clinical Device Systems

The future design of clinical devices integrates wireless and wired interfaces to permit networked device communications and recording patient data. Patients must be linked to many medical devices at the same time in order for these gadgets to operate. For example, such devices may be used to control respiration, distribute medications, or provide physiological status information. The collected health data from various clinical sensors and devices must be analyzed and consolidated through IT-based socioeconomic services in a coordinated manner. Misunderstandings, information overload, and exhaustion are just a few of the issues that might arise. The combination of these factors might lead to a negative patient outcome. There is several equipment in the operating room that may perform life-support duties depending on information given by various monitoring devices. In recent years, the majority of medical devices have included IT to collect and aggregate device data for later transmission to medical practitioners for action or to initiate independent actions by the devices if required. Whenever it becomes essential to provide medical services in a home-care context, or via telemedicine by transferring clinical practices over the networks, or by undertaking online medical laboratory assessments, it emphasizes the dominant objective of clinical data in networking and distributed communications. Control mechanisms and computation must be included into the networking of critical medical information in order to allow the construction of highly reliable cyber-physical medical systems. For optimal patient care with a high degree of trust, many CPS devices must work together.

WSNs towards CPSs

A wireless network of computer wearable devices refers to the BAN (Body Area Network) that is also referred to the BSN (Body Sensor Network) or WBAN (Wireless Body Area Network) [12]. Implantable, miniaturized, and wearable sensors are all part of wireless health management systems/networks, which include a variety of sensors. Physiological parameters including skin and body temperatures, respiratory rates, heart rates and blood pressure, as well as an electrocardiogram may all be measured by these biosensors. An interface, such as a Personal Digital Assistant (PDA) or microcontroller board, receives the data and displays it on the user's interface or transmits it to a medical center. The data is either cable or wirelessly linked. Both WSNs and MANETs, which use wireless sensor networks, are now the subject of study. **Fig. 3** depicts the standard CPS design.

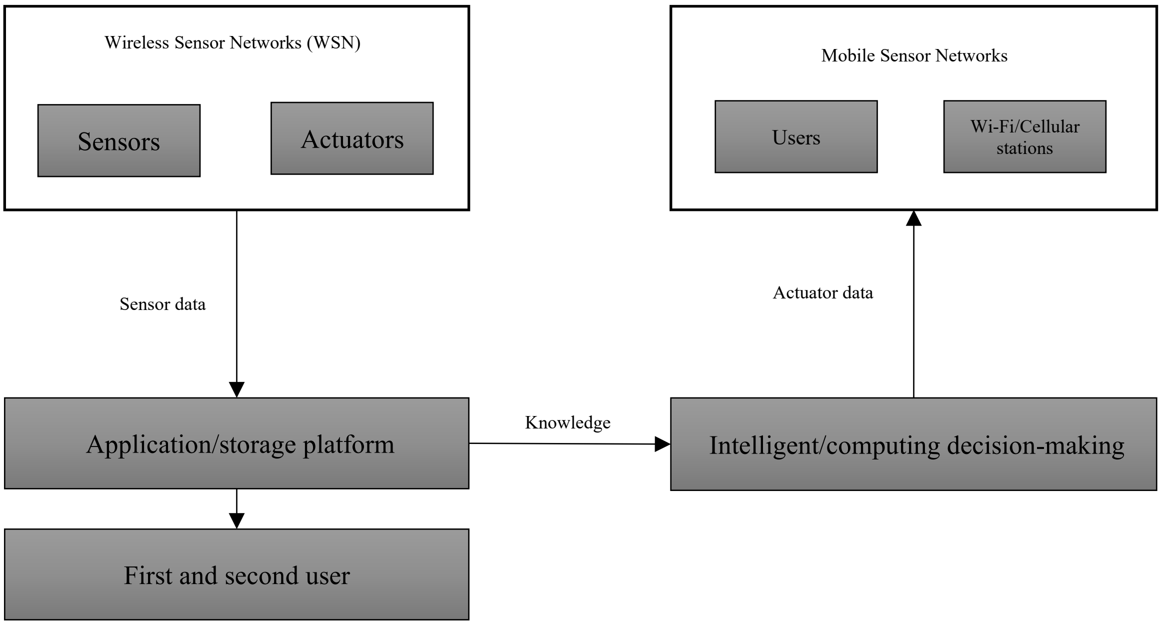

Fig 3. A typical CPS architecture framework

In contrast, the CPS technologies are defined by heterogeneity data flows, smart linear actuators, and cross-domain detector coordination. It is therefore possible to use a CPS system for many different purposes. In addition, one of the MCPS systems' fascinating facets is the interaction between humans and machines. Medical equipment and systems may interact with people in two ways: as clients or controllers, i.e., users. Empowering adaptable and patient-specific therapeutics requires patient-specific modeling and simulation. There are several techniques to designing interfaces that allow for: a) collective human and digitalized awareness of multi-model setting (including regular and failure); b) noting the activities; and c) sharing of power between people and healthcare devices.

M2M Architecture toward CPS

Wi-Fi sensor networks, WBANs, and M2M communications have made significant advances in a variety of fields in the last few years. Communication between integrated systems and portable devices, as well as smart sensor networks, may be referred to as M2M. As a result of this, the interconnected machine is highly valued than the secluded one, and this is because several machines may link efficiently in smart applications. As a result, the M2M telecommunications developer creates various new chances for medical care, smart home technology, smart metering, manufacturing technologies and data industry. M2M systems can gather data from a variety of sensors due to WSNs integration into their architectures, M2M networks with autonomous decision-making and control might be developed to MCPS. The CPSs have developed as a potential approach to boost human-to-object, humans-to-humans, and objects-to-objects communications in both the real and virtual worlds.

To be more accurate, MCPSs might acknowledge and foster M2M as well as WSNs, which demand more sensors and a more robust network connection. The architecture and design philosophy of WSNs, M2Ms, and CPSs are the most significant distinctions; even in many networking capabilities, they are relatively comparable. Wireless sensor networks provide sensor-related data; M2M supports communication without/with limited human interventions; as well as MCPS integrate multiple sensing data metrics and cross the multiple sensor networks/internet in order to highlight control functions and build intelligence across multiple domains. As improved network methods, real-time/distributed control, as well as cloud computing progress, the M2M MCPS systems are created. Networked at high- and multi-scales, integrated, have complex multiple temporal and spatial scales, are constantly reconfigured/reorganized and have high dimensions of automations as well as closed-loop controls, and have verified and reliable operations.

Medical Cyber Physical Systems, Big Data Platforms, and Social Network

There are several types of big data that need novel processing methods in order to enable better discovery of new insights and decision-making and process optimization. It alludes to the gathering of unstructured and/or structured data provided by embedded physical, chemical and biological detectors, radiofrequency identification readers, aerial (remote) sensors, wireless sensors, mobile sensor devices application detectors, application logs, or any other data group architectures of MCPS and CPS systems. All of this is combined with publicly available data from a variety of socially constructed open sources. Images, video, text, and audio are all part of big data. Big data may combine information from many different sources, allowing for vast volumes of information to be distilled down into manageable chunks. To support CPS, big data design typically requires new approaches to design the 4V elements, conventional database systems, spatial constrictions and the time limits as well as the dynamic consistent physical realm performance.

Big data management and exploitation are two of the most pressing issues in this area. Extracting information from raw data requires both qualitative and quantitative processing. Many CPS search engines use computer learning algorithms to accomplish this goal. There should be a clear understanding of the MCPS active component's generated large data, the needed target data, and the learning operations themselves. Information that has been synthesized or extracted may either stay internal to the system or be made available to users as external data. MCPS modules must be able to exchange the extracted data. Big data management in the future will need sophisticated, cost-effective data processing approaches for better decision-making and insight.

The ability to adapt necessitates the use of a novel group of medical monitoring sensors. Medical monitoring has become more dependent on low-cost sensors and a variety of communication methods, resulting in a major problem for the current platforms. For example, Medical Cyber Physical Systems (MCPS) include both physical and cyberspace elements in a single system. In order to work, the systems use a collection of embedded devices and command and control instructions to control these devices from cyberspace. There is a direct correlation between the physical and virtual worlds. MCPS are often used in healthcare-related applications. In the remote medical monitoring system, small embedded devices may be connected to the human body to monitor different bodily states. Only pertinent information is transmitted back to the internet or through mobile once the data has been analyzed locally in real time.

Big data and healthcare applications both rely heavily on CPSs for their analyses. Medical facilities may have to deal with increased prices and a significant lack of medical professionals. Pervasive Health Monitoring System (PHMS) could keep track of the health of the patients in real time to assist relieve this issue. BANs are the wireless network of the ambient sensors/devices and clinical devices, which are employed in monitoring health. Medical data gathered by PHMS is protected from unwanted accessibility by the patients' privacy. CPS systems are the computer systems, which are incorporated and networked in precise physical operations to potentially control and monitor a variety of different functions.

IV. FUTURE MCPS RESEARCH AND ISSUES FOR FUTURE CLINICAL EQUIPMENT

Clinical device technologies are the best implementations of CPS because of their intricate and tight interaction with the physical parts of the system and, most importantly, the patient. When it comes to the CPS medical device, it is critical to guarantee and develop the medical device's security, safety and dependability. Researchers are increasingly interested in social media and big data analysis and applications. Cyber-physical systems, an intriguing new technology, are supporting medical applications.

Considering the proliferation of ubiquitous computing technologies, radio frequency identification (RFID), WSNs, M2M, networking communications systems, and an evolving control model, the CPSs might be regarded a new pattern of the Internet of Things. It is possible to benefit from the massive cellular networks, and smart devices, which could tolerate the CPS programs to potentially supply smart amenities centred on data from all encompassing physical setting. The provisions of high-performance CPS models as a high IoT stage are thus one of the issues to be encountered in this phase. For the upcoming iteration of CPS models, simultaneous frameworks of computing, which are far more intelligible, and predictable, and foreseeable will not be integrated.

Numerous issues that motivate academics include the advancement of secure authentication, simulation and virtualization, certification approaches, software engineering procedures, software components, and design patterns. The fundamental computing abstractions must be rethought incrementally in order to fully comprehend the impact of CPS. Semantic models, on the other hand, are necessary for both software interoperation and physical processes. A few of the research issues could potentially be mitigated through:

- Application platforms and technologies to potentially support developments as well as the development and designs that are based on science;
- Novel approaches for progress of end-to-end, principled, and developmental tools.

Additional considerations for MCPS healthcare schemes and equipment include:

- Medical data synthesis, where the healthcare systems evolve into CPS. Since a result, gathering medical data presents significant complications, as various doctors may recommend different treatment plans for the same patient.;
- Medical systems based on CPS need novel services, such as schedulers, to deal with the responsive and concurrent system.

CPS-supported health services have the chance of becoming the most cost-effective medical/laboratory technology in the future. Due to patient-specific medical considerations, device structural similarities will be very dynamic. Elastic configurations of embedded devices with control capabilities and networking are essential to this future's development. The data technology must concurrently handle optimal therapy administration, a wide range of device requirements, and quick changes in the user's needs. Medical technology is moving closer to cellular and molecular sizes, which is creating new potential for integrated control and sensing. To construct the future generation of clinical CPS devices, more research should be focused on Integrated cyber-physical systems in healthcare. However, CPS is seen as a progression of M2M since it introduces more interactive activities and intelligence within the IoT framework. M2M, WSN, CPS, and the Internet of Things (IoT) are still open research areas.

V. CONCLUSION

The Information Technology (IT) as well as Internet revolution have paved way for a wide-range of novel control possibilities, which could influence human life differently, including medical care, transportation, energy management, and new services. Cyber-physical systems (CPSs), which integrates human relations as a key element, are complex systems that integrate interconnected, hybrid, and networked interconnected subsystems. Modeling, computational intelligence, control space testing and management are all affected by this consideration. Because of this, the human element should be critically modelled and studied. CPSs in the medical and healthcare field were applied in the current research. CPSs unearth another threat, whereby the physical system elements could be attacked via cyberspace that in turn might be affected via physical machines. As a result, personal and financial well-being rely on the protection of one's privacy and security. Medical Cyber-Physical System (MCPS) alters the design rules for dependable systems in the context of faults. Multiple, simultaneous failures are considered unlikely in physical models since it is presumed that failures are released. Cyber-attacks can be massive, causing failures to occur instantly or in a coordinated manner. It is essential to go a long way toward theoretically true MCPSs and Socio-Cyber-Physical Systems (SCPS) framework. Long-term orientation and self-adaptation in MCPSs are difficult to manage, and no consolidated design methodology exists to address these issues effectively. Non-linear, high-end, CPSs that are completely available, customizable, and compatible require a large amount of engineering and design technology knowledge. Multidisciplinary interventional knowledge synthesis is critical to the advancement of the current state of the art, and this introduces the connection between Machine-to-Machine (M2M), Wireless Sensor Network (WSN), MCPS, and IoT. Finally, various obstacles were overcome in practically all areas associated to the healthcare CPS.

Data Availability

No data were used to support this study.

Conflicts of Interest

The author(s) declare(s) that they have no conflicts of interest

References

[1]. M. Panda, A. Abraham and M. Patra, "Hybrid intelligent systems for detecting network intrusions", Security and Communication Networks, vol. 8, no. 16, pp. 2741-2749, 2012. Doi: 10.1002/sec.592.

[2]. Á. Verdejo Espinosa, J. Lopez Ruiz, F. Mata Mata and M. Estevez, "Application of IoT in Healthcare: Keys to Implementation of the Sustainable Development Goals", Sensors, vol. 21, no. 7, p. 2330, 2021. Doi: 10.3390/s21072330.

[3]. S. Jiao and R. Liu, "A survey on physical authentication methods for smart objects in IoT ecosystem", Internet of Things, vol. 6, p. 100043, 2019. Doi: 10.1016/j.iot.2019.02.003.
[4].]M. Romeo, "Intrusion Detection System (IDS) in Internet of Things (IoT) Devices for Smart Home", International Journal of Psychosocial Rehabilitation, vol. 23, no. 4, pp. 1217-1227, 2019. Doi: 10.37200/ijpr/v23i4/pr190448.
[5]. M. Berges and C. Samaras, "A Path Forward for Smart Cities and IoT Devices", IEEE Internet of Things Magazine, vol. 2, no. 2, pp. 2-4, 2019. Doi: 10.1109/miot.2019.8892758.
[6]. M. Kanjee and H. Liu, "Authentication and key relay in medical cyber-physical systems", Security and Communication Networks, vol. 9, no. 9, pp. 874-885, 2014. Doi: 10.1002/sec.1009.
[7]. M. Hamilton, "Java and the shift to net-centric computing", Computer, vol. 29, no. 8, pp. 31-39, 1996. Doi: 10.1109/2.532043.
[8]. V. Kant, "Cyber-physical systems as sociotechnical systems: a view towards human–technology interaction", Cyber-Physical Systems, vol. 2, no. 1-4, pp. 75-109, 2016. Doi: 10.1080/23335777.2017.1289983.
[9]. Y. Mun, "Development and Application of CPS Model into the Instruction of Geography for Creativity Enhancement", Journal of the Association of Korean Geographers, vol. 2, no. 2, pp. 123-136, 2013. Doi: 10.25202/jakg.2.2.1.
[10]. J. Park, "Smart Factory and Cyber-Physical Systems: Analysis of CPS Case Study", Regional Industry Review, vol. 44, no. 1, pp. 161-181, 2021. Doi: 10.33932/rir.44.1.7.
[11]. S. Zhang, "Community Medical Management System Based on SOA", Applied Mechanics and Materials, vol. 539, pp. 349-354, 2014. Doi: 10.4028/www.scientific.net/amm.539.349.
[12]. "Implementation of Body Temperature and Pulseoximeter Sensors for Wireless Body Area Network", Sensors and Materials, p. 1, 2015. Doi: 10.18494/sam.2015.1108.