CYBER PHYSICAL SYSTEMS, ARCHITECTURE AND FUTURE DEVELOPMENTS

RESEARCH PROPOSAL

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DATE OF SUBMISSION: 12/06/2017
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ABSTRACT

Cyber-Physical Systems (CPS) are integrations of computation and physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa. The economic and societal potential of such systems is vastly greater than what has been realized, and major investments are being made worldwide to develop the technology. There are considerable challenges in physical side, network security side, etc. For instance, because the physical components of such systems introduce safety and reliability requirements, which are different from those in general purpose computing. Moreover, physical components are qualitatively different from object-oriented software components. Standard abstractions based on method calls and threads do not work. This proposal examines the challenges and potential architectures in designing such systems, and in particular raises the question of whether today’s computing and networking technologies provide an adequate foundation for CPS.
INTRODUCTION

Cyber-Physical Systems (CPS) are integrations of computation with physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa. In the physical world, the passage of time is inexorable and concurrency is intrinsic. Neither of these properties is present in today’s computing and networking abstractions.

Applications of CPS arguably have the potential to dwarf the 20-th century IT revolution. They include high confidence medical devices and systems, assisted living, traffic control and safety, advanced automotive systems, process control, energy conservation, environmental control, avionics, instrumentation, critical infrastructure control (electric power, water resources, and communications systems for example), distributed robotics (telepresence, telemedicine), defense systems, manufacturing, and smart structures. It is easy to envision new capabilities, such as distributed micro power generation coupled into the power grid, where timing precision and security issues loom large. Transportation systems could benefit considerably from better embedded intelligence in automobiles, which could improve safety and efficiency. Networked autonomous vehicles could dramatically enhance the effectiveness of our military and could offer substantially more effective disaster recovery techniques. Networked building control systems (such as HVAC and lighting) could significantly improve energy efficiency and demand variability, reducing our dependence on fossil fuels and our greenhouse gas emissions. In communications, cognitive radio could benefit enormously from distributed consensus about available bandwidth and from distributed control technologies. Financial networks could be dramatically changed by precision timing. Large scale services systems leveraging RFID and other technologies for tracking of goods and services could acquire the nature of distributed real-time control systems. Distributed real-time games that integrate sensors and actuators could change the (relatively passive) nature of on-line social interactions.

The positive economic impact of any one of these applications areas would be enormous. Today’s computing and networking technologies, however, may have properties that unnecessarily impede progress towards these applications. For example, the lack of temporal semantics and adequate concurrency models in computing, and today’s “best effort” networking technologies make predictable and reliable real-time performance difficult, at best. Software component technologies, including object-oriented design and service-oriented architectures, are built on abstractions that match software much better than physical systems. Many of these applications may not be achievable without substantial changes in the core abstractions.
PROBLEM DESCRIPTION

Advances in CPS research can be accelerated by identifying needs, challenges, and opportunities in several industrial sectors and by encouraging multidisciplinary collaborative research between academia and industry. The objective is to develop new systems science and engineering methods for building high-confidence systems in which cyber and physical designs are compatible, synergistic, and integrated at all scales. Current and past industry investments in CPS technology research have been significant but focused on shorter-term, quicker-payoff proprietary technologies. Recently, governments and some industry sectors are investing in longer-term, precompetitive technologies and innovative testbeds. For example, the European Union has initiated a major joint technology initiative with public-private funding by European nations and industry called Advanced Research and Technology for Embedded Intelligence Systems (ARTEMIS). Similarly, based on recommendations in the August 2007 report of the U.S. President’s Council of Advisors on Science and Technology (PCAST), the U.S. National Science Foundation has been funding fundamental CPS research and education. Related initiatives are being pursued in other countries, including Japan, China, South Korea, and Germany. CPS grand challenges are being articulated in many industry sectors. The U.S. National Academy of Engineering has listed 14 grand challenges that relate environmental, health, and societal issues; these issues will clearly benefit from advances achieved in cyber-physical systems. One of the key components of CPS is selecting proper architecture which fits the system. In the following I will review some examples and propose the key elements of a CPS along with importance and role of them.
SURVEY ON THE RELATED WORK

In this proposal the architecture of CPS systems for different applications are reviewed. These applications are in manufacturing, healthcare, military and etc.

The term Cyber-physical systems (CPS) has been defined as the systems in which natural and human made systems (physical space) are tightly integrated with computation, communication and control systems (cyber space). Cyber physical systems has been called as national research priority of the United States and European research council (Horizon 2020 program) in various sectors such as automotive, aerospace, civil, railways, medical and manufacturing (1) (2). Applications of CPS arguably have the potential to dwarf the 20-th century IT revolution. They include high confidence medical devices and systems, assisted living, traffic control and safety, advanced automotive systems, process control, energy conservation, environmental control, avionics, instrumentation, critical infrastructure control (electric power, water resources, and communications systems for example), distributed robotics (telepresence, telemedicine), defense systems, manufacturing, and smart structures. It is easy to envision new capabilities, such as distributed micro power generation coupled into the power grid, where timing precision and security issues loom large. Transportation systems could benefit considerably from better embedded intelligence in automobiles, which could improve safety and efficiency. Networked autonomous vehicles could dramatically enhance the effectiveness of our military and could offer substantially more effective disaster recovery techniques. Networked building control systems (such as HVAC and lighting) could significantly improve energy efficiency and demand variability, reducing our dependence on fossil fuels and our greenhouse gas emissions. In communications, cognitive radio could benefit enormously from distributed consensus about available bandwidth and from distributed control technologies.

Considering recent developments and broad implementation of sensors, data acquisition systems, computer networks and cloud computing have prepared the infrastructure for designing and implementing cyber-physical systems in the aforementioned industry sectors. On the other hand, the vast usage of sensors and control systems in the industry results in generating huge amount of data. Managing such high volume of data, which is called Big Data, requires specific consideration (3). Therefore, in the big data environment, it is important to have a systematic approach for acquiring, managing and analyzing the data in order to acquire relevant knowledge from it. Cyber-physical systems can be used to address these issues in today’s industry by bringing autonomous control, self-awareness and self-management capabilities to industrial machines.

1. CPS architecture in industry 4.0 (5)
In manufacturing area, the presence of a systematic approach to bring intelligence into the shop floor is required to provide factories with continuous production and near-zero downtime. Therefore, integration of CPS in production, logistics and services would provide factories with self-aware and self-adapt machines and comprehensive information to intelligently adjust production pattern. These features would transform today’s factories into an Industry 4.0 factory with significant economic potential. Lee et al (3) tabulated the major difference between today’s manufacturing factories and an industry 4.0 factory in three levels of components, machines and production systems (4). The industry 4.0 is a term introduced by Siemens and refers to the integration of interconnected systems into the
industry and is known as the fourth industrial revolution. Lee et al (5) introduced a stepwise approach for designing CPS for manufacturing, an adaptive clustering method for self-aware machines and discussed the implementation challenges with a case study on band-saw machines.

![5C Architecture](image)

**Figure 1. 5C architecture for cyber-physical systems in manufacturing**

The 5-level CPS architecture (Figure 1), named 5C, consists of methodologies and guidelines to step-by-step design, and deploy CPS for manufacturing from data acquisition stage to analysis and final value creation.

Effectiveness of the proposed CPS structure very much relies on the performance of the data analysis functions deployed in the cyber level. Served as a bridge connecting the lower level data acquisition and upper level cognition functions, the cyber level is required to autonomously summarize, learn and accumulate system knowledge based on data collected from a group of machines. Algorithm wise, unsupervised learning algorithms such as Self-Organizing Map (SOM) and Gaussian Mixture Model (GMM) can be used for autonomously creating clusters for different working regime and machine conditions.

Considering a production line with several types of machines such as machine tools, band-saw machines and etc. Data from each machine will be acquired and transformed into meaningful information. For instance, a cyber-twin of each machine and their components will be created to keep track of the changes in the similar machines and components. The cyber-twins use the proposed adaptive algorithm to observe and learn the patterns of various working regimes each type of machines undergoes. This means a band-saw cyber-twin primarily analyzes its assigned machine to generate health status and identify working regimes. At the same time, it communicates with other band-saw cyber-twins to synchronize the acquired knowledge across the network. Each cyber-twin keeps individual machine patterns from their assigned machines and share knowledge acquired from the machine with others.
over machines to provide the fleet with self-comparison capability. Further, aggregated knowledge from components and machine level information provides self-configurability and self-maintainability to the factory. This level of knowledge not only guarantees a worry free and near zero downtime production, but also provides optimized production planning and inventory management plans for factory management (Figure 2).

Figure 2. The flow of data and information in a CPS enabled factory

To deal with interconnected systems and huge volume of data in the Big Data environment resulted in emergence of new research areas such as cyber-physical systems in manufacturing and a systematic framework is required to leverage the advantages offered by the cyber-physical systems. Lee et al (5), discussed about a 5 level architecture for utilizing CPS in manufacturing process. This architecture covers the process from acquiring data until generating meaningful information and decision-making process for the end user. The 5C architecture utilizes recent computing and communication technologies such as cloud computing to provide connectivity between machines. To fulfill the requirements of this architecture with more advanced analytical methods, an adaptive clustering method has briefly introduced that is capable of identifying new working regimes autonomously.

2. Real-time network solution of the Cyber-physical System and limitations (6)

With the fast development of computer network, electronic technology and control technology and the increased requirement for the modern industry, the needs to become more compatible with information and internet on physical devices are quickly emerging. However, traditional embedded system was designed as a closed system, which means no operational interface was left, thus it cannot meet new demands which requires physical devices to be controllable, reliable, and extendable. In line with this issue, the CPS, which integrated the functions of compute, communication and control, have been gaining momentum as a new direction for the development of physical device system. CPS is
recognized as a network-connected collection of loosely coupled distributed cyber systems and physical systems monitored/controlled by user defined semantic laws [7]. The network links the cyber system and the physical system, forming a large-scale heterogeneous distributed real-time system. Figure 3 depicts the system model of CPS.

![Figure 3. CPS structure](image)

As a critical part of the CPS, CPS network participates in the closed-circle process of sensing, deciding, and executing, and all the operations can be performed in different planes. In the future, CPS network would require connection to every physical device that contains a networking module, with features like real-time processing, asynchronous operation and reducing the information lag to its minimum. In order to make this target tangible, the timeliness of CPS naturally becomes an absolutely key factor. In the following paragraphs, the CPS basic structure will serve as a base, upon which the two features including “Task scheduling mechanism” and the “Real-time network analysis” will be discussed in-depth, with the ultimate aim of boosting the timeliness of CPS.

![Figure 4. the architecture of scheduling scheme](image)
As Figure 4 depicts, the Admission control in the first layer assess the newly issued command and classify them into one of the three different types, namely hard real-time task, soft real-time task and the non-real-time task. This process ensures the controllability of the system load.

The second layer consists of 4 different types of schedulers, each with a unique function: 1. Hard real-time scheduler which uses the EDF computing method (8) 2. Soft real-time scheduler that uses the EDF computing method (9) 3. Best effort scheduler that is designed for non-real-time tasks; 4. RPDS (10)(11) which can simultaneously dispatch soft real-time tasks and non-real-time tasks. For tasks that requires real-time processing, the Hard-time scheduler which adopts a EDF computing method will be utilized in order to make sure high priority tasks are always been dealt with in a timely manner, and increase the response rate of the system loop control. For soft real-time and non-real-time tasks, system can postpone the commencement of the processing for those tasks whenever appropriate, and give other tasks a better chance to be process earlier. Therefore, by utilizing RPDS and through dispatching server to cut the system processing timeline into multiple time slices with relatively equal length instead of large pieces of continuous timeline, it is possible to allocate non real-time tasks such as best-effort tasks into appropriate time slices. The advantage of performing the above operation is that: when a real-time task has been processed and it is not enough to process another hard-time task, the remaining resource in this time slice can then be used to process this best-effort task, instead of waiting for the next time slice to start. This method can effectively enhance the scheduling of non-real-time tasks while ensuring all the hard-time tasks are being processed with priority.

The development of CPS is still on the preliminary stage, most of the research results are confined within certain specific areas, but hardly any studies on the systematic level. As the investigation gets more intense, it is estimated that CPS research will be more focused on the enhancement of timeliness of Heterogeneous networks convergence, networking architecture, diversification of system modeling, construction of complete networking experiment platform and the realization of holistic CPS.

3. Heterogeneity in Cyber-Physical Systems Architectures (12)

Cyber-physical systems (CPS) are heterogeneous, because they tightly couple computation, communication, and control along with physical dynamics, which are traditionally considered separately. Without a comprehensive modeling formalism, model based development of CPS involves using a multitude of models in a variety of formalisms that capture various aspects of the system design, such as software design, networking design, physical models, and protocol design. Without a rigorous unifying framework, system integration and integration of the analysis results for various models remains ad hoc. In this paper, we propose a multi-view architecture framework that treats models as views of the underlying system structure and uses structural and semantic mappings to ensure consistency and enable system-level verification in a hierarchical and compositional manner.

The challenge in defining an architectural style for the physical domain of CPS is to strike a balance between specificity and generality. Architectural models should not have all the details required for a full simulation of the physical dynamics as they are often unnecessary at the architectural level. At the same time, the architectural components and connectors should correspond to intuitive notions of physical dynamics in the same way cyber components and connectors correspond to elements of computational systems. To achieve this balance, Rajhans et al (12) introduced components and connectors based on a behavioral view of open and interconnected physical systems, as defined by Willems (13). This provides a domain-independent perspective, including the ability to represent
interactions between different physical domains and the possibility to specify system properties such as power flow and energy conservation laws. In the behavioral approach, laws that govern physical phenomena impose relations on a component’s variables, while interconnection means that variables are shared between the connected components, i.e., component behaviors are coupled via their common variables.

Figure 5. Cooperative intersection collision avoidance system for stop-sign assist (CICAS-SSA) and a collection of models for it. (a) Illustration of CICAS-SSA.

Rajhans et al (12) investigated the theoretical concepts by illustrating two examples: a quadrotor and an automotive intersection collision avoidance system. The first example is the Stanford Testbed of Autonomous Rotorcraft for Multi-Agent Control (STARMAC) (14), which is a quadrotor platform developed to test algorithms that enable autonomous operation of aerial vehicles. The other example is a cooperative intersection collision avoidance system for stop-sign assist (CICAS-SSA), illustrated in Figure 5, which aims to augment human judgment about safe gaps in oncoming traffic at stop-sign-controlled intersections (15).

Figure 6. (a) Base Architecture of STARMAC in AcmeStudio. (b) Base architecture of CICAS-SSA
The base architecture (BA) of a cyber-physical system is an instance of the CPS architectural style and provides the reference structure for all the models used for design and verification. It contains the set of system elements that are related to the analyses carried out in each model, as well as the elements that are common between the models. The BA should contain enough detail to describe the nature of the information exchanged and the physical quantities flowing between components, as well as component connectivity and coupling between physical variables represented by connectors. Figure 6 illustrates the use of the CPS style to model the BA of the quadrotor in our custom architecture design environment called AcmeStudio (16). On the cyber side, each controller (attitude, position, and ground station) is mapped to a separate computation component that implements the control algorithm.

Rajhans et al (12) presented an architecture-based framework with structural and semantic mappings to manage multi-model heterogeneous development of cyber-physical systems. They extended software architecture principles by adding architectural modeling vocabulary to include physical and cyber-physical interface elements and using architectural views to capture structure of various models and structural mappings to ensure consistency. Semantic mappings using behavior relations and abstraction functions enable the use of hierarchical and compositional heterogeneous verification. Finally, they combined the architectural views with behavior relations within a unified analytical framework to utilize the advantages of both during model-based development of CPS. For control system development, their framework creates a formal connection between the concerns addressed by control engineering models and tools, and the concerns addressed by the many other models and tools used to design and implement the complete system.


Kit et. al. (17) present DEECo (Dependable Emergent Ensembles of Components) (18) – a model and framework for developing complex smart CPS. In its model, DEECo provides the holistic view that combines the goals of a system, the system’s operational model (including real-time constraints), and realistic communication model (including limited communication and latencies). With its framework, DEECo allows large-scale simulations of complex CPS. Combined with the real-time perspective of DEECo and the network-accurate simulation of communication, DEECo offers accurate insight into the effects of adaptation strategies in complex smart CPS.

Figure 7. Vehicles sharing data about parking space capacity.
To illustrate the DEECo models and significant features, we rely on a smart parking scenario. In the frame of this scenario, vehicles are equipped with vehicle-to-vehicle (V2V) communication and smart sensors to detect available parking spaces along the streets and exchange their knowledge about the available parking capacity (Figure 7).

Figure 8. IRM tree for the smart parking scenario.

To correctly design complex self-adaptive smart CPS is a hard task stemming from the fact that a correct design of such systems has to apply a holistic view that takes into account multiple aspects, many times even conflicting ones. In this paper, we have briefly introduced DEECo framework, which is intended for development and simulations of such complex self-adaptive smart CPS. In contrast to other frameworks, DEECo (i) is open and easily extensible, (ii) offers a dynamic component model based on ensembles, (iii) has two implementations for experimenting with smart CPS and self-adaptability, (iv) provides a goal-based design method taking into account self-adaptation, and (v) allows for simulations of real-life deployment by evaluating the system behavior under different network configurations and settings (taking into account also network latency and limited connectivity).
5. Cyber-Physical Energy System Architecture for Electric Vehicles Charging Application

(19)

With the requirement of low-carbon economy and energy crisis, many new information technologies have been applied to Cyber-Physical Energy Systems (CPES) for saving energy and protecting environment, such as smart grid, electric vehicles and home automation. In these systems, issues about energy efficiency and system reliable control are becoming more important. The CPES is extended from Cyber-Physical Systems (CPS) applied in the energy area (20). It demands that system design implants some non-functional properties, such as heterogeneous, autonomy, real-time, etc. CPES is composed of energy resources, networks, applications, and consumers to satisfy future energy and environmental needs. There are a lot of researches on CPS architecture design and analysis, however, research on CPES architecture is few. Gabor Karsai and Janos Sztipanovits (21) gave the layers of CPS design and models of real world in CPS. Ying Tan, Steve Goddard and Lance C. Perez (22) gave prototype architecture for CPS and the architecture leads to identification of many research challenges. Kim J.E. and Mosse D. (23) gave general framework for design, modeling and simulation of CPS. These papers are short for energy system applications in energy area. Ge et al (19) presented CPES architecture for electric vehicles charging application. They proposed CPES architecture to apply in intelligent charging system for electric vehicles experiment.

![CPES Features Diagram](image)

**Figure 9. CPES Features**

Compared to the existing energy system based on real-time embedded systems and network control system, CPES pays more attention to energy resources utilization. It aims to achieve real-time sensing and dynamic monitoring of largescale load system and WAN environment, and provides the network services more flexible, intelligent and efficient (24). For this purpose, it is needed to figure out the CPES features first for understanding the concept of CPES, then we can do deeply research on CPES. CPES has features of deeply embedded, autonomy, heterogeneous, real-time, reliability, and recomposition, etc. Considering the CPES concept and requirement, the main CPES features are proposed as shown in Figure 9.
Only to establish a scientific and rational CPES architecture, it is able to satisfy the demands of energy systems. The CPES layered architecture is distribution architecture combined with the embedded system. The layered architecture should include an information-centric protocol stack to support data fusion for making the data into the network and converting to high-level information for applications. In this article, a layered architecture is given for CPES shown in Figure 10. The architecture is divided into three layers: physical layer, network layer and application layer. Data is perceived by physical layer, and transmitted by network layer, and then formed control information through application layer, finally, the control information gives feedback to the physical layer forming a closed-loop of information processing.

The CPES architecture embodies the requirements and features of CPES. The computation nodes (such as sensors, actuators) are deeply embedded into the physical environment, and perceive the environment change in real-time. The respond to the specific circumstances reflects the computation processed deeply embedded into physical processes; a large number of different energy resources and network resources reflect the heterogeneity; the closed-loop reflects the CPES autonomy; the combination of networks and computing reflect the real-time; the entire system design rationality and security reflects the reliability; when certain energy resources or network resources run failure, the CPES can recompose by itself.
Ge et al (19) proposed an origin and concept of Cyber Physical Energy System, and summarizes the CPES features, such as heterogeneous, autonomy, real-time, reliability, safety and recomposition. The CPES architecture is designed into three layers include physical, network and application, and which integrates control process, communication process, computational process and physical process deeply. CPES need focus on confidence features to construct a Cyber Physical System for energy application. In addition, an intelligent charging system for electric vehicles base on CPES architecture is taken as an experiment, which can guide future research and development of the CPES.


The research on CPS in healthcare is still in the early stages. In CPS, the combination of active user input such as smart feedback system, digital records of patient data, and passive user input such as biosensors and/or smart devices in healthcare environments can support the data acquisition for efficient decision making. This combination of data acquisition and decision making system is yet to be rigorously explored in healthcare applications and, therefore, such combination is a matter of high research interest. Opportunities of utilizing CPS in healthcare include the introduction of coordinated interoperation of autonomous and adaptive devices, as well as new concepts for managing and operating medical physical systems using computation and control, miniaturized implantable smart devices, body area networks, programmable materials, and new fabrication approaches. It is desirable to have a set of taxonomies that characterizes and classifies approaches of CPS in healthcare. From a survey of the literature available to date, we summarize in Figure 2 such a taxonomy for CPS in healthcare. It consists of the following elements: (1) application, (2) architecture, (3) sensing, (4) data management, (5) computation, (6) communication, (7) security, and (8) control/actuation. In this section, the classifications within each of these elements are discussed in detail.
Figure 11. Taxonomy of CPS for healthcare.
ARCHITECTURE OF PROPOSED SYSTEM

CPS can be used in a wide range of application fields, including intelligent transportation, precision agriculture, Health CPS, water and mine monitoring, aerospace and so on. The general architecture of CPS should be modified to suit the requirements of each system. Some of the application examples are in the following:

A. **Vehicular CPS**: With the increasing number of personal cars, many problems such as the traffic congestion, air pollution and safety issues are taking more attentions to be addressed. Advanced computing and sensing capabilities will be widely used in next-generation transportation systems, such as air traffic, railway, and car control, in order to improve safety and throughput. Vehicular Cyber Physical System (VCPS) is not a new concept.

B. **Agricultural CPS**: Accuracy in agriculture was expected in the early 1980s from traditional agriculture, which is supported by information technology, to implement a full range of modern systems of agricultural management strategies and technologies. Design of precision agriculture includes data management of production experiments, fundamental geographic information of farmland, micro-climate information and other data.

C. **Health CPS**: Health CPS (HCPS) will replace traditional Health devices working individually which we will face in the future. With sensors and networks, various Health devices work together to detect the patients’ physical condition in real time, especially for critical patients, such as the patients with heart disease. The portable terminal devices carried by the patient can detect the patient’s condition at any time and send timely warning or prediction in advance. In addition, the collaboration between Health equipment and real-time data delivery would be much more convenient for patients. Some of the requirements for applications supporting CPS are summarized in Table 1.

<table>
<thead>
<tr>
<th>Applications</th>
<th>CPS Requirements</th>
</tr>
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<tbody>
<tr>
<td>Vehicular CPS</td>
<td>CPSs for the automotive industry require high computing power, due to complex traffic control algorithms that calculate for example the best route according to traffic situation.</td>
</tr>
<tr>
<td>Environmental CPS</td>
<td>CPSs for environment monitoring, distributed in a wide and varied geographical area (forests, rivers, mountains) must operate without human intervention for long time periods with minimal energy consumption. In such an environment, the accurate and in-time data collection provided by the ad-hoc network with low power consumption, represent a real research challenge.</td>
</tr>
<tr>
<td>Air CPS</td>
<td>CPSs for aviation and defense require a precise control and high security and not least high power computing. In this scope, the development of the security protocols is a main research challenge.</td>
</tr>
<tr>
<td>Critical Infrastructure</td>
<td>management, etc. require a precise and reliable control, leading to application software methodologies to ensure the quality of the software.</td>
</tr>
<tr>
<td>Health CPS</td>
<td>CPSs for healthcare and Health equipment require a new generation of analysis, synthesis and integration technologies, leading to the development and the application of the interoperability algorithms.</td>
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</tbody>
</table>
I propose a six-part architecture for CPS whose parts are mentioned below:

A. Sensing Module: For data collection from physical world through sensors, the main function of this module works for environment awareness which is achieved by preliminary data preprocessing. The data is provided to the Data Management Module (DMM). The Sensing module supports multiple networks. It depends on nature of networks that is deployed.

B. Data Management Module (DMM): DMM consists of the computational devices and storage media. This provides the heterogeneous data processing such as normalization, noise reduction, data storage and other similar functions. DMM is considered as the bridge between dynamic environment and services as it is collecting the sensed data from sensors and forwards the data to service aware modules using Next Generation Internet.

C. Next Generation Internet: A common feature of emerging Next Generation Internet is the ability for applications to select the path, or paths that their packets take between the source and destination. This dynamic nature of internet service is required for designing Cyber Physical System. Unlike the current Internet architecture where routing protocols find a single (the best) path between a source and destination, future Internet routing protocols will need to present applications with a choice of paths.

D. Service Aware Modules: Service Aware Module (SAM) provides the typical functions of the whole system, including the decision-making, task analysis, task schedule and so on. After receiving sensed data, this module recognizes and sends data to the services available.

E. Application Module: In Application Module, a number of services are deployed and interact with NGI. Simultaneously, information is getting saved on secured database for QoS support. Database is maintained at local storage and on cloud platforms at the same time in order to keep data safe. Once data is saved on cloud, this saved data over can be accessed from anywhere followed by authenticated access.

F. Sensors and Actuators: Actuators and the Sensing Modules are two different electronic devices which interact with the physical environment [5]; the actuator may be a physical device, a car, a lamp or watering pump. It receives the commands from the Application Module, and executes. The security assurance part is inherently important in a whole system, from the access security, data security to device security. CPS security is divided into different requirements in different scenarios. For example, as for military applications, the confidentiality feature is more important, but in the smart home system or HCPS, the real-time requirements are more emphasized. Security of CPS can be divided into the following three phases: awareness security, which is to ensure the security and accuracy of the information collected from physical environment; transport security, which is to prevent the data from being destroyed during the transmission processes; physical security, such as safety procedures in servers or workstations. Feedback Awareness is one of the advanced level services to minimize the data processing by communication between sensor and actuator for executing required actions directly.
EXTENDED FUTURE PLAN

CPS researchers are focusing on following areas: the definition of a standard architecture, the classification of the CPSs design principles in their application domains, the modeling of the CPSs, the ensuring of the CPSs dependability, and the CPSs implementation (for critical infrastructure control and beyond). The software architecture provides a good starting point but the concept should be extended to CPS by using a new vocabulary for physical and cyber-physical elements necessary to analyze the system behavior. In the past, significant efforts were made to ensure end-to-end QoS support using algorithms and different mechanisms at varying network protocol layers. Distinguishing characteristics of CPS however enlightened further challenges in order to provide QoS support. In this section, some open research topics of interest are identified.

QoS-Aware Communication Protocols: Efficiency is always considered as back-bone of any network topology. In CPS, due to heterogeneity between sensing modules and the need of applications to ensure real time data control, real time QoS aware MAC, routing and transport protocols are required to be developed. It was formerly indicated that CPS bridges the cyber world to the physical world through lots of sensors and actuators for varied applications, which have different QoS support requirements. Network protocols for CPS should be capable of identifying application requirement of each type of traffic so that QoS can be guaranteed at certain level.

Resource Management: In CPS, we are not lacking in resources but data from such applications is also expected to generate streaming data with a very large volume, storing, processing, and interpreting these data in a real-time manner is essential. While dealing with more dynamic environmental changes, more complex computing, communication resources are inherently restricted. To overcome these limitations, auto-management techniques are required to ensure that a system will address resource management issues in an autonomous mode. Some feedback scheduling techniques seem promising for WSN proposed in the last decade. We can use these technologies but they need to be more flexible to provide guaranteed QoS support. However, how to map resource management to control problems is still a subject of future research.

QoS-Aware Power Management: Energy consumption is a vital challenge from a very beginning of WSN, WMN, and UWSN, etc. Network lifetime and performance is always dependent on the residual energy of sensor nodes and actuators in most applications. In CPS, dynamic computing with real time control demands much CPU energy consumption, which should be minimized by exploiting dynamic voltage technology.
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