



Research Directions in

Cyber Physical Systems


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Introduction to CyberPhysicalSystem

Definition

- A Cyber Physical System(CPS) is a collection of computing elements connected and interact with each other.
- Each computing element consist of a low weight computational system equipped with sensors.
- The sensors are meant to detect and capture the presence of any physical events like temperature, pressure, clinical parameters of human body, presence of objects etc.

Introduction to CyberPhysicalSystem (cont'd)

- The computing element captures the physical event and transmit to a central node (ICT equipment) which receives the data. The data received are transmitted to the world wide web through standard internet protocols.
- Data stored in the world wide web can be analyzed to predict and detect the occurrence of events

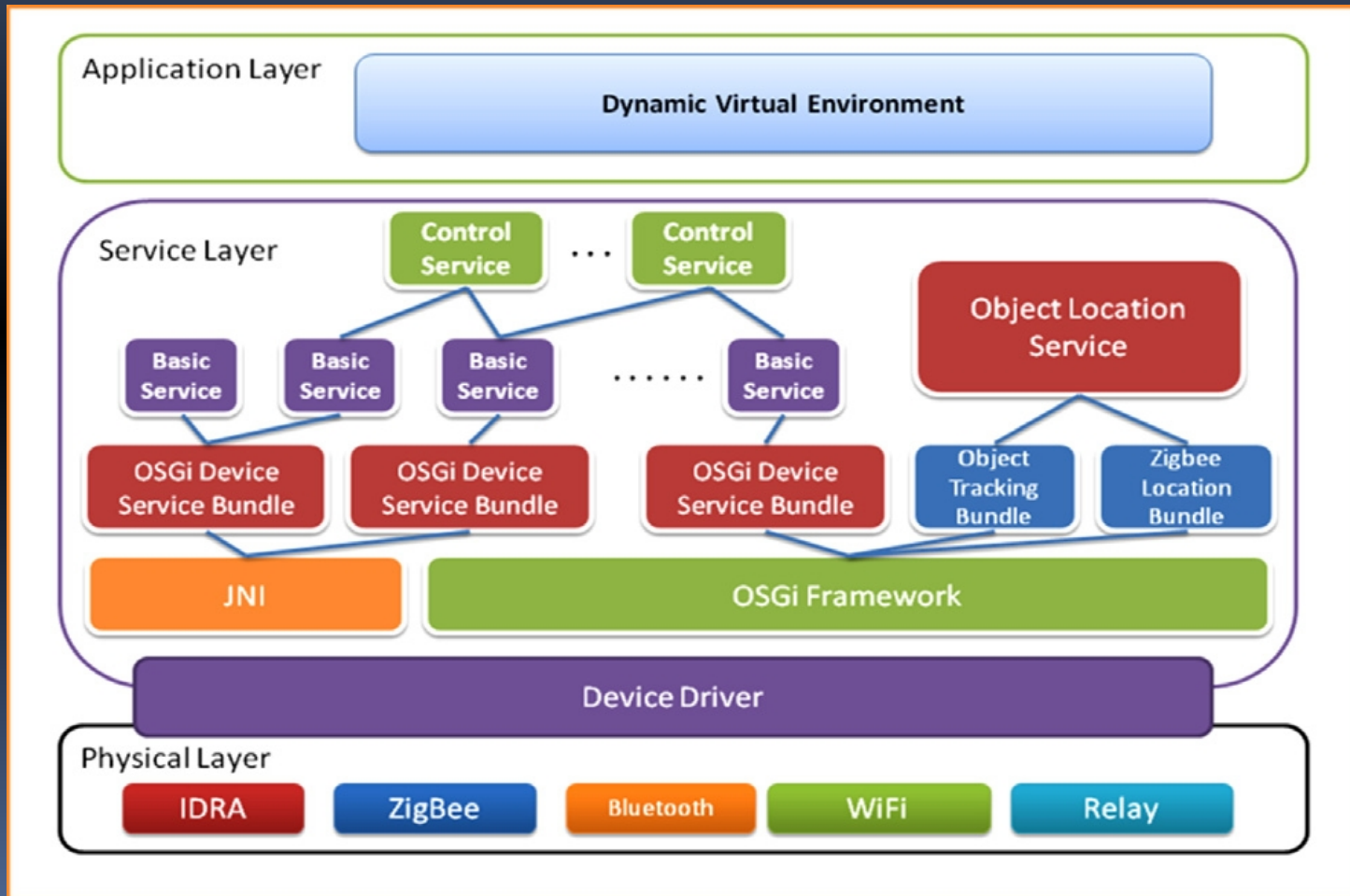
Introduction to CyberPhysicalSystem (cont'd)

- A CPS program was initiated at the National Science Foundation (NSF) with a funding level around 30 Million US dollars per Year with an intention to address the following issues
- Electricity generation and distribution with out electricity blackout
- Safe and rapid evacuation in response to disasters
- Helping aid for busy ,older and disabled people

Introduction to CyberPhysicalSystem (cont'd)

- Helping aid for busy ,older and disabled people
- High yield agriculture
- location independent access to world class health care service
- Reducing the traffic fatalities to Zero and reduced traffic congestion
- Reducing the testing and integration time for complex CPS systems as in Avionics

A Service Architecture for Cyber Physical Home Control System



CyberPhysical Home Control System Architecture (cont'd)

Uses three layers

- Physical Layer – Defines protocols to control home appliances
- Service Layer-provides conversion and management of physical layer signals and application layer services through device drivers
- Application layer- OSGI service model for users

CyberPhysical Home Control System Architecture (cont'd)

- Control Service-use basic API of device driver which use OSGI Service bundle-uses JNI (java native interfaces) or OSGI frame work
- Object location Service uses
 - a) Zigbee location bundle which determines planar co-ordinates to judge the approximate values of x and y
 - b) Object Tracing bundle to capture object location and judge height and approximate regional co-ordinates through captured images

Application domains of Cyber Physical System

- Health care
 - a) Real time image guided surgery
 - b) Patient controlled analgesia infusion pump
 - c) Improving the connectivity of medical devices using wireless technologies
 - d) Robotic Surgery
- Automotive
 - a) Collision avoidance that **minimize** drivers interaction by use of sensors to minimize accidents
 - b) Reducing traffic congestion
 - c) By using a set of CPS techniques that can control autonomous vehicles providing the best possible routes ,reducing accidents ,death caused by human being

Application domains of Cyber Physical System (cont'd)

- Smart Power Grid

Electricity power generation , transmission , distribution and control networks are called electrical grids

a)Monitoring partial discharge detection in a number of transformers in an electrical substation

b)used to balance the power flow in smart grid systems

c)Protect the energy infrastructure from failure and outside attacks

Application domains of Cyber Physical System (cont'd)

- Avionics
 - Air traffic management
- Coastal observing System that allow dense and 4D spatio-temporal sensing
- Structural health monitoring technologies for monitoring the condition of various civil structures
- Factory Automation
- Home Energy Management System
- Intelligent Highways

Application domains of Cyber Physical System (cont'd)

- Symbiotic Cyber physical networks are used to observe the usage of natural resource which intend to protect our environment against mega-catasrophes
- Net Zero energy buildings
- Home Control Systems
- Deep sea exploration

Research Directions in CyberPhysicalSystem

- A research on real time computing and communication mechanisms are required in order to provide better levels of performance such as safety , security ,robustness and reliability
- Interaction with the physical environment causes uncertainty due to randomness in the environment, errors in the physical devices, security attacks, a research on methods to reduce this uncertainty

Research Challenges in CyberPhysical System

Network control

- Methods for Reduction of time delays
- Methods for reducing transmission failures
- Methods to improve quality of service over wireless network
- Methods to minimize packet loss

Research Directions in CyberPhysicalSystem

Sensor Actuator Networks


Usage of wireless sensor actuator networks on CPS and its impact on the overall performance on the system need to be carefully studied

Verification and validation

- Development of models ,algorithms and tools that incorporate verification and validation of software's are required for agile development of CPS applications



Research Directions in CyberPhysicalSystem

- Designing new network protocols that is suitable to work for large scale CPS
 - Developing programming abstractions that capture real time power constraints ,security characteristics to speed up CPS software development
 - In medical CPS Patient modeling and simulation to study the performance of CPS under various physical constraints
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Research Directions in CyberPhysicalSystem


- Wireless connectivity between medical devices to reduce the deployment cost and time, improves reliability and safety
- Development of matrices that can assess the safety , security and reliability of automotive CPS
- Improve energy efficiency by introducing advanced technologies in the energy infrastructure

Research Directions in CyberPhysicalSystem

- To explore the possibility to optimize the electrical energy production , distribution and use
- Development of frame work for smart grids in order to support penetration of renewable distributed energy resources
- Development of an efficient and comprehensive Co-Simulation platform for CPS applications



Research Directions in Cyber Physical System

- Development of secure and dependable data sharing scheme for Cyber physical system in order to maintain the confidentiality of the data exchanged between various nodes
 - Development of efficient sensors that can easily program in bulk, resistant to malicious attack, failures and false data feeds
 - Development of new bandwidth allocation protocols , new queuing strategies, new routing schemes that can reduce and accommodate network delays
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Research Directions in CyberPhysicalSystem

- Knowledge discovery from the vast amount of raw data collected from various sensor nodes
- Development of a model based development platform for CPS
- Development of a service architecture to provide better service

Some recent research works

Byeong-Gi Kim , Yong-Jin Park, Won-Tae Kim, Soo-Hyung Lee and Kim Jae Hyuk on “Opportunistic Multicast Routing for Cyber Physical Systems” proposes a reliable and scalable real time multicast routing protocol based on the opportunistic routing and location information of nodes called opportunistic multicast routing (OMR) for CPS

Some recent research works

- Irfan Al-Anbagi , Melike Erol- Kantarci and Hussein. T. Mouftah on “A reliable IEEE 802.15.4 Model for Cyber Physical Power Grid Monitoring Systems “.The study proposes a Markov based model for cluster WSN topologies that enhances the stability of WSNs.The cluster tree deployments are particularly of interest to Cyber Physical power grid monitoring Systems since they are suitable for large scale deployments.

Some recent research works

Feng Xia, Alexy Vinel, Ruxia Gao, Linqiang Wang and Tie Qiu on “Evaluating IEEE 802.15.4 for Cyber physical systems “ makes a comprehensive evaluation of IEEE 802.15.4 standard in two different modes in the context of CPS. The study examines several network QoS metrics including the effective data rate, packet loss rate and end to end delay. This has been analysed with respect to some important and variable protocol parameters..

Some recent research works

Cheng- Yi Liu, Yin-Jun Chen, Chi-Hsuan Wang, Chih-Wei Hsu, Sheng-Tzong Cheng , Chih-Hsiung Tseng on “Coding Based Contention Forwarding Protocol for Cyber Physical Systems” is a study that propose three mechanisms to exploit the characteristics of network coding .Applying of intra-node contention, inter node contention and coding based contention forwarding protocol provides packet with more coding opportunities from the source to the destination.

Some recent research works

MinYoung Kim, Mark-Oliver Stehr, and Jinwoom Kim, Soonhoi on “An application framework for loosely coupled networked Cyber Physical Systems”. The study presents an application framework based on the partially ordered knowledge sharing model and an API for Cyber Physical Devices that enables interaction with physical world. The key feature of the framework is that it enables the same application code to be used in various environments including simulation models and real world deployments

Conclusions

- CPS forms a strong area for research in the next generation of wireless communication
- CPS forms an ideal combination of technologies like embedded systems, distributed systems, wireless sensor networks, real time systems etc
- CPS plays a significant role in the design and development future engineering systems