ISSN: 0975-766X
CODEN: IJPTFI
Available Online through
Research Article
www.ijptonline.com

CYBER PHYSICAL SYSTEM AS INTERNET OF THINGS IN CRITICAL APPLICATIONS

H. Parveen Sultana[1], P. Venkata Krishna[2]
[1]School of Computing Science and Engineering, VIT University, Vellore, Tamil Nadu, India.
[2] Sri Padmavati MahilaVisvavidyalayam, Government State Level University, Tirupati, Andhra Pradesh, India.
Email: h.p.sultana@gmail.com

Received on: 18.10.2016 *Accepted on: 11.11.2016*

Abstract

This paper discusses about the Cyber Physical System based Scenarios that are act as Internet of Things (IoT). This is possible when the CPS based application is connected with the Internet server to perform suitable tasks at appropriate time. This paper considers three scenarios such as smart hospital, smart highway lane and smart parking area as CPS based applications. Since whole world is revolving around sensor based actuator devices, it has been shown that how CPS applications manages the precarious and emergency situations that arise in the automated wireless structure. We have considered few application areas in which CPS performs a key role in avoiding collisions and preserve energy when any task is inactive.

Key words: CPS, IoT, Collisions, Smart systems, Case study, health care, sensors, Actuators.

Introduction

Internet of Things (IoT) (Coetzee and Eksteen, 2011) is a wireless capability which shows that how machine can interact with other device to perform certain task. This device to device (Wan et al., 2013) communication is possible only through Internet. In IoT human to device (Wan et al., 2013) is possible at unusual cases. Nowadays everywhere all sensor devices are considered as smart devices with the help of Internet of things (IoT) (Sun et al., 2010; Xia et al., 2012; Gubbi et al., 2013). These devices are capable enough to collect and disseminate the information to the servers that are connected wired or wirelessly with the Internet. This paper discusses various application regions as case study that can be carried through Cyber Physical Systems (CPSs) (Lee, 2008; Wan et al., 2013) to avoid collisions in the specified scenarios. Already in the healthcare applications Cyber Physical System performs its major role to handle the critical scenario with the help of CPS (Haque et al., 2014). The following section discusses three types of case studies that show

how cyber physical system involves in the critical applications. The critical scenarios in which sensor cum actuator built devices can be used are smart highway lane, Smart Parking area and Smart hospital.

This paper also deals with the scenarios that are connected with the automated wireless structure. The paper comprises six sections. Section 2 briefs about the survey related to Internet of Things (IoT) (Nunes et al., 2015). Section 3 explicates the case study on highway with the help of critical scenario. Section 4 deals with the problems that arise in the hospitals with respect power consumption. Section 5 elucidates how emergency situations can be handled in a parking area. Section 6 concludes about the scenarios dealt with the help of CPS.

Literature Review

Authors of (Chen et al., 2011) had described about the IoT architecture. IoT architecture consists of three levels such as sensing level, communication level and processing level. In the first level the data is gathered through physical entities that are involved in the wireless personal system. The communication level (referred as network level) transfers the data to the controllers for further process. In the application level according to the instructions, data gets processed and the relevant services are provided to the corresponding devices attached to the wireless network area.

In (Kortuem et al., 2010; Xia et al., 2012) authors discussed that how Internet has changed the lives of human in present day. The authors have specified that Internet of Things (IoT) (Atzori et al., 2010) had made the way easier for the hardware devices to combine with computational devices to perform certain activities like gathering the information, scheduling the events, estimating the arrival and departure time of automobile vehicles. Moreover this new technological approach assists the people in remote or inaccessible locations by providing necessary instructions. These instructions help them to get medical care at free of cost. The authors of (Wan et al., 2013) have explained that how devices connect with other devices to enable reliable communication while transferring useful information. This is practically possible only if these devices are connected through integrated databases. These databases fetch the information from the sensor coordinators that are located in different regions but are connected with the Internet. Internet enriched applications become a part of CPS to manage the overall maintenance of the wide area wireless system in which human intervention is very less. In (Dillon et al., 2011) presented that how CPS can be combined with the IoT to perform computational and physical activities together. This integrated framework locates the sensors, extracts the data and regulates the functionalities to be executed. The sensor devices used in this combined structure not only gather the data but also

disseminate the calculated data to the actuators. Though this framework enables the devices to communicate and perform some action, there are certain limitations that can be solved by human intervention.

Case Study On Smart Highway

Let us consider a case study of smart freeway lane. Assume this freeway lane has three lanes such as fast way lane, medium way lane and a slow lane. Each of these lanes is designed such that the respective vehicles travel at different speeds according to them. The slow lanes mostly constitutes of heavy duty vehicles which have to travel slow in accordance with the load they carry. The medium and fast lanes both have a sensor fitted along the dividing markers. The sensors work on the principle of allowing vehicles to move forward in the lanes. The sensor also has priorities in which it should allow the incoming vehicles according to its speed. This scenario is depicted in the figure 1. The following section explains how Cyber Physical System based application is used to avoid accidents (collisions) in a emergency situations according to priority.

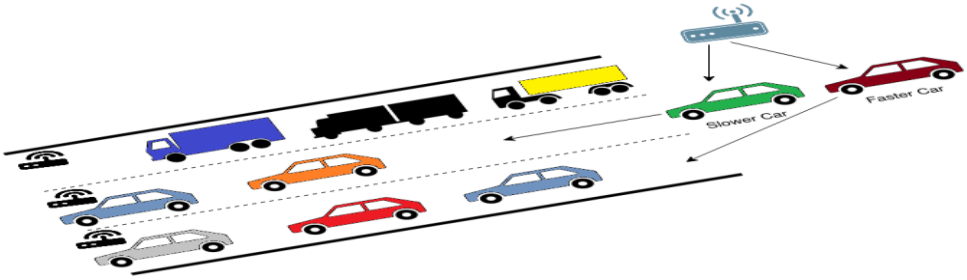

Figure 1: Smart Highway Scenario I.

In the above figure 1 the top most lane is considered for heavy loaded vehicles, moderate speed vehicals traverse through second lane referred as medium lane and high speed vehicles travel through below lane which is referred as fast lane. According to speed of a vehicle it is allowed to travel through the corresponding lane with the help of sensors situated on the road ways.

3.1 Cyber Physical System Based Smart Freeway Lane

The freeway lanes of a highway are a perfect example of how sensor cum actuator built devices could be used to manage the traffic and avoid any accident. There are basically three types of lanes on highway such as slow, medium, and fast lanes as shown in figure 2. Slow lane is majorly occupied by heavy duty vehicles which weigh more than 4.5 tons. Medium lane is used by regular traffic vehicles whereas the fast lane is used by vehicles such an ambulance to help in an emergency situation. In the below figure 2 the slow, medium and the fast lanes have sensors fitted along the dividing

markers. These sensors serve two operations, measuring the speed of the incoming vehicle and measuring lateral clearances maintained by vehicles from road elements (like road edge, dividers). The operations are semi-automotive with little human intervention. The sensors also help vehicles to move forward in a lane based on the priority.

Let us consider a situation in which the incoming vehicle on a medium lane is of type ambulance. In case of an emergency situation, the ambulance is given top priority to move forward in the lane. If other vehicle, for example, a car is unable to slow down to make way for the ambulance then an electromagnetic pulse discharged by the sensor which disables the car's engine temporarily allowing it to slow down. This process slows down the car and thus allows the ambulance to move forward in the lane.

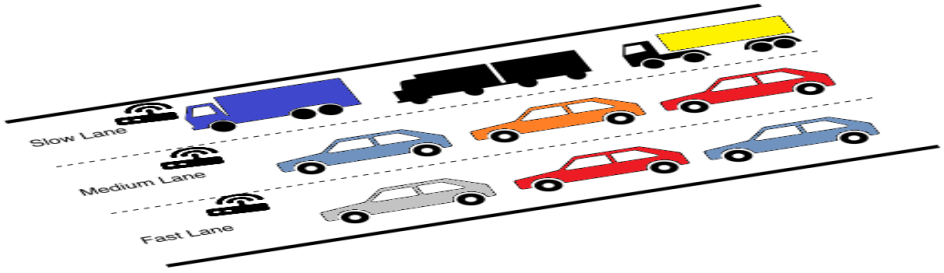

Figure 2: Smart Highway Scenario II.

Consider a scenario in which two different vehicles travelling with different speeds on the same lane. Then the sensors can measure their speeds and redirect them to different lanes depending upon the speed. Two ultra-sonic sensors are placed along the side of the road at known distance. As a vehicle passes in front of sensor 1, the Sensor 1 gets activated and start receiving the reflected waves from the vehicle. Based on the travel time of emitted wave and reflected wave, lateral clearance of the vehicle from the sensor is calculated. Similar process is repeated at sensor 2. As sensors are places apart with known distance, travel time of the vehicle for the distance is determined from the time difference of actuation of both the sensors. Based on the measured travel time, speed of the vehicle is calculated and therefore redirection takes place which is depicted in figure 3.

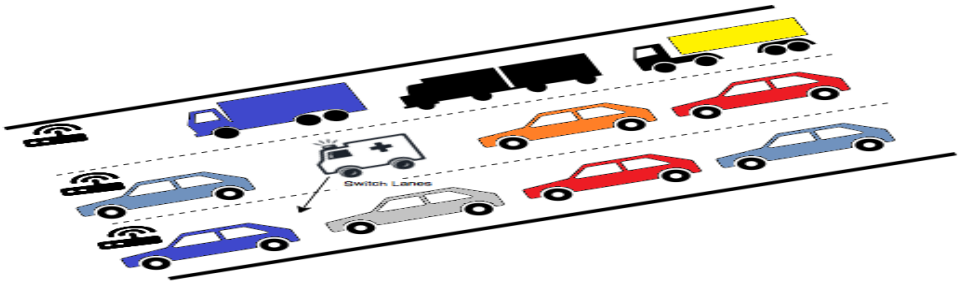

Figure 3: Smart Highway Scenario III.

Finally, the sensors help in switching of the lanes that is shown in figure 4. If a vehicle decides to speed up from either the slow or medium lane, it has to change lanes in order to match up with other vehicles. If it takes place without warning, then the whole freeway is sure to be held up by an accident that will be triggered. In order to avoid that, when a change is to occur between lanes, the sensor signals from incoming vehicle should react to the commands received from the sensors. So that the vehicle may slow down according to the change occurs . Or else, it may remotely control its speed to make way for the change that would happen.

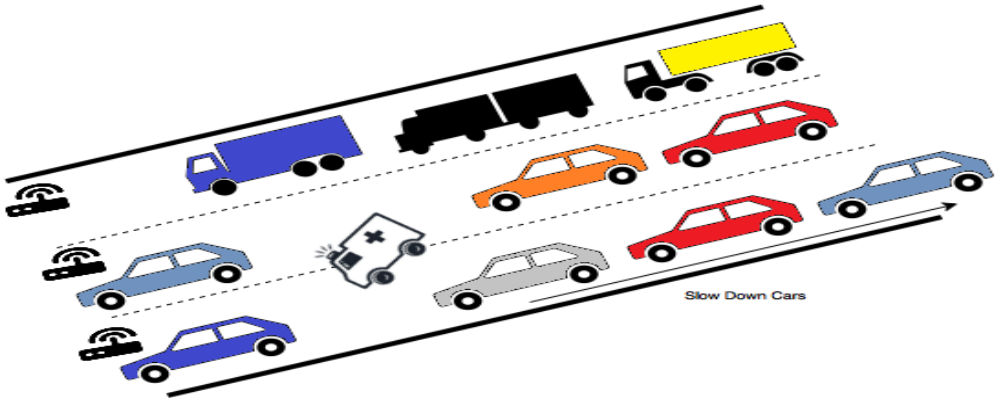

Figure 4: Smart Highway Scenario IV.

This smart highway scenario deals with different case of two vehicles approaching at different speeds. The sensors deployed at dividers makes way for these vehicles to go on to separate lanes according to their speeds. And also these sensor cum actuator built devices helps in changing of lanes. This assures that these sensor cum actuator built devices provide smooth way travelling by preventing collisions (accidents) with the help of cyber physical system approach.

Case Study On Smart Hospital

Consider a scenario of smart hospital in which several distributions in the treatments available that range from minor diagnosis to major surgeries. The two aspects that need more attention at a time are the Intensive Care Unit (ICU) and the Surgical theatre where most important surgeries take place. In case of a power loss, a sensor works to divide power between the ICU and the surgerical unit. The following section discussess how power can be consumed and dispersed to the relevant units with the help of sensors. Again these sensors are of actuator based devices which helps the power unit to save power when there is a less need of it.

4.1. Cyber Physical System Based Smart Hospital Unit

Sensors are of great use in a hospital where power distribution among various units is necessary. Since some units, like the Intensive Care Unit need power all the time to serve the patients when an emergency comes. However other units

like the surgical theatre or pathology lab do not require power for 24 hours on all days. In a hospital there are many services used by people ranging from minor diagnosis to a major surgery of the heart. While minor diagnosis would not be interrupted much if the power goes off. At the same time it can be very critical if a surgery is carried out by a team of doctors and hospital staff. Imagine the risk to a person's life when suddenly there is no power for few seconds during a surgery (minor or major). Same is the case when any person is brought in the critical care unit. The patient needs immediate attention of doctors who tries to save the patient's life with best efforts. Thus, these two units are of utmost importance in a hospital for power management.

In case of power loss, sensor divides the power between the two units as shown in figure 5. From the figure 5 it is depicted that power distribution is done based on actuator based sensor devices that disseminate the information to the server connected to it. If a surgery is going on, 75% power is distributed to the surgical unit and the rest 25% power is allotted to the intensive unit of critical patients. The reason for unequal distribution is that even though the surgery is more important than the ICU, the ICU cannot be neglected. This is because it is a main unit where a patient requiring emergency care to be attended. Though the critical unit gets less power with the help of actuator based sensor devices it require more attention to the emergency patients than the patients who are undergoing some surgeries. A person brought in an ICU has precarious needs to be served because the patient life is at stake. The immediate action taken care by the hospital team can either save patient's life or the patient's life would be regretful.

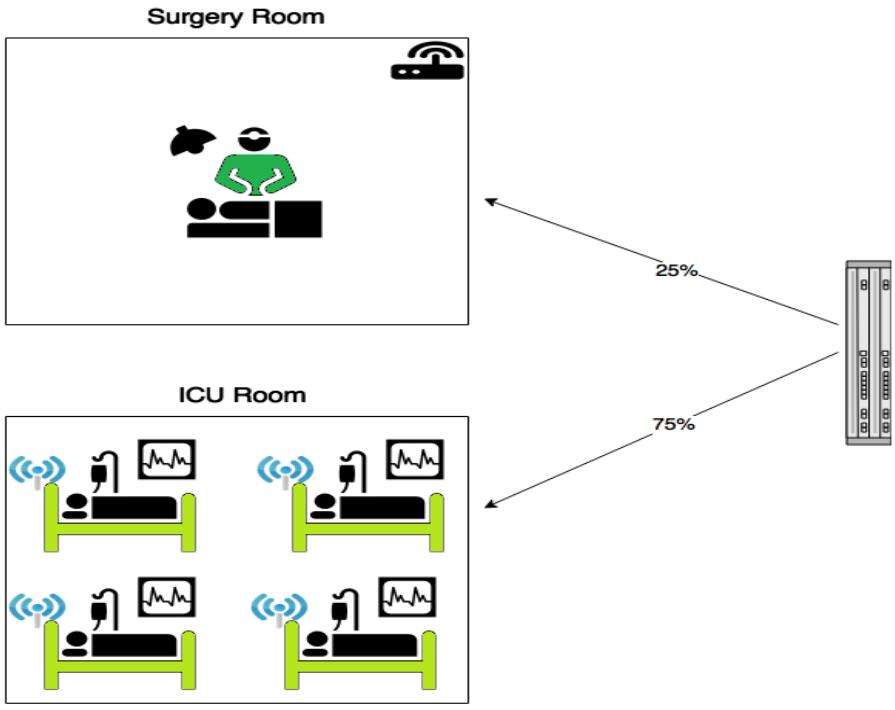

Figure 5: Smart Hospital Scenario I.

The sensor cum actuator built devices do not reduce the power to the critical unit imbalanced way. The sensor deployed in these critical units performs proper actuations according to the power necessities of various equipments available (to be used) in the surgical theatre like the anaesthesia machine, ECG machine, oxygen pumping etc. So that it can calculate the power consumption required for surgical unit and the intensive care unit gets the rest of the power that is depicted in figure 6.

This kind of computation is very important and makes power management easier with the help of sensor cum actuator built devices. This CPS based smart hospital scenario shows that how energy utilization can be done effectively with the help of information (instructions) received from sensors. It is noted that the requirement of power calculation in surgical unit can be pre-determined whereas in critical units this cannot be done due to the emergency situations might occur in a hospital.

Case Study On Smart Parking Area

Day by day space management is a major concern in a parking area when the automobile vehicles are increasing in size and number. Due to this allotting specific area for any vehicle is restricted in various parking zones. Efficient management of space is necessary in some locations such as an office building or a shopping mart where vehicles are parked for long interval of time. These building's parking zone is always occupied with vehicles. Hence a situation arises when there is no place for parking emergency vehicles such as an ambulance or a fire truck.

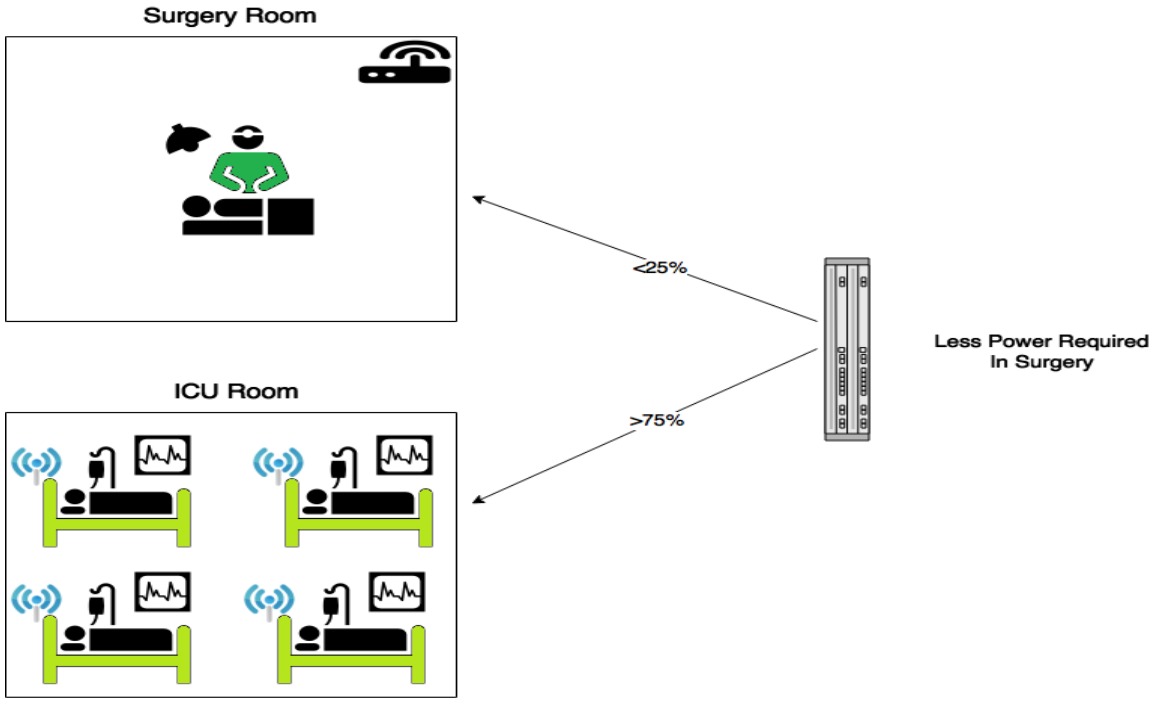

Figure 6: Smart Hospital Scenario II.

But it is necessary to provide space for emergency vehicles. So to overcome this issue it has been explained in the following section that how a sensor cum actuator built devices are used to provide space for the emergency vehicles.

5.1. Cyber Physical System Based Smart Parking Zone

Consider a scenario in which importance is given to emergency vehicles that are most required in locations when there is a possibility of any accidents to occur. The possible accidents might occur due to mishap or fire. This is due to negligence of any electrical wiring or it might be due to power failures. To handle the situation in a smooth way it is imposed that special parking lane to be allocated for emergency vehicles. The allocation process is done through sensor cum actuator built devices which are installed in the parking zone for identifying these emergency vehicles as shown in figure 6.

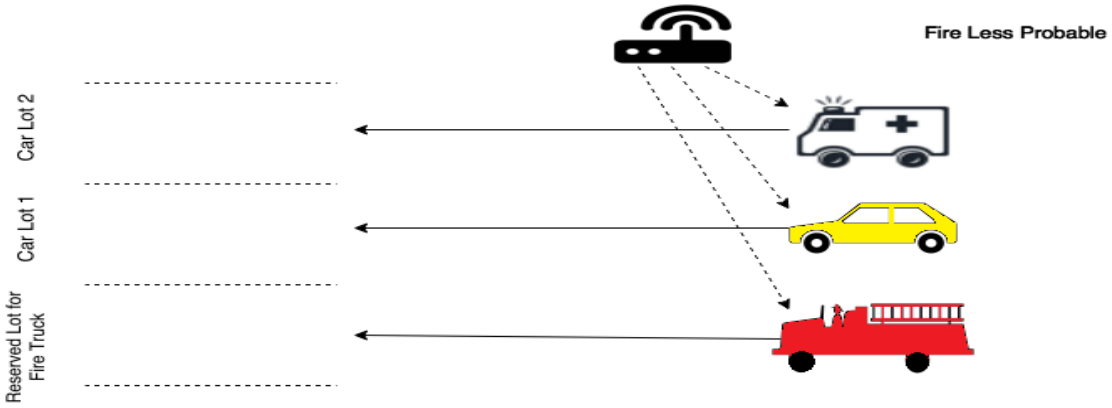

Figure 7: Smart Parking Zone Scenario I.

In the above figure 7 the sensors identify the emergency vehicles with the help of code emitted from these vehicles. Since these vehicles are embedded with the automatic sensor devices it emits the code whenever it gets into the region of other wireless network region. These codes are treated as priorities to situate these vehicles in its appropriate lane. The priority of fire truck is less than (sometimes equal) the ambulance because of its requirement at any time. The space reserved for an ambulance or a fire truck depends on the probability occurrence of motorway accident or a fire accident. If the probability of motorway accidents is more, then the space is reserved for the fire truck. As the ambulance will stay out for a longer time compared to fire truck. This kind of situation might arise in the buildings near residential or office areas. These areas have more number of people in the locality; hence the possibility of an accident occurrence is more.

On the other hand, if the probability of fire accident is more, then the space is reserved by the ambulance because it is more likely that the fire truck will stay out. Such situations might arise in under construction buildings or refineries

where probability of fire occurrence is more than a normal accident. In both of the above cases, depending on the probability of occurrence only one space is reserved. A situation arises when there is a possibility of fire accident and that of a motorway accident is same. In such cases like shown in figure 7, there are two parking lots are reserved rather than allocating a single space.

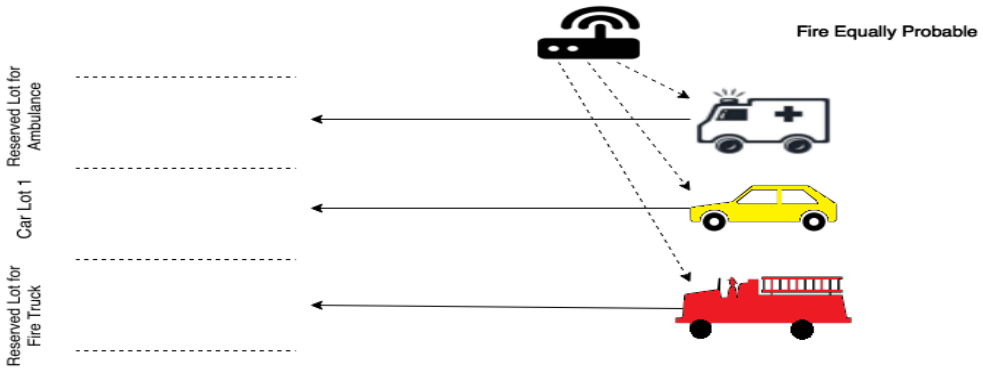

Figure 8: Smart Parking Zone Scenario II.

In the figure 8 it is noticed that when two vehicles services are often required according its criticality parking areas are allotted separately. So that when emergency situation arise, it can be handled effectively without any mishap. This is done with the help of sensors that had been situated in an entrance of any parking zone as well as in the parking lanes of these areas.

Conclusion

This paper discusses collision avoidance approaches that can be carried out in cyber physical system based applications such as smart hospital, smart free lane and smart parking zone. These sensor cum actuator built devices helps the users to solve the issues that arise in emergency situations. To avoid accidents in a smart highway lane sensors helps the motor vehicles to choose the lane according to its speed. Sameway in smart hospitals it has shown that power would be utilized efficiently with the help of sensor cum actuator built devices installed in critical unit and surgical unit. Further in smart parking zones these sensor based devices helps the server to allocate space for the emergency vehicles that are often in access. The sensors used in these CPS based applications are connected with centre server to communicate and perform action with the help of Internet.

References

1. Atzori, L. , A. Iera and G. Morabito (2010). The Internet of Things: A survey. Computer networks, Vol. 54, No. 15, pp. 2787-2805.

2. Baheti, R. and H. Gill (2011). Cyber-Physical Systems. The Impact of Control Technology, IEEE Computer Society, Vol. 12, pp. 161-166.
3. Broy, M., M.V. Cengarle and E. Geisberger, (2012). Cyber-physical systems: imminent challenges. Large-Scale Complex IT Systems, Development, Operation and Management, Springer Berlin Heidelberg, pp. 1-28.
4. Cardenas, A.A. , S. Amin and S. Sastry (2008). Secure Control: Towards Survivable Cyber-Physical Systems. The 28th International Conference on Distributed Computing Systems Workshops, IEEE, Beijing, pp. 495-500.
5. Chen, H. , X. Jia and H. Li (2011). A brief introduction to IoT gateway, In IET International Conference on Communication Technology and Application, Beijing, China, pp. 610-613.
6. Coetzee, L. and J. Eksteen (2011). The Internet of Things - promise for the future? An introduction, IST-Africa Conference Proceedings, IEEE, Gaborone, pp. 1-9.
7. Conti, M., S.K. Das, C. Bisdikian, M. Kumar, L.M. Ni, A. Passarella, A., George Roussos, G. Tröster, G. Tsudik, and F. Zambonelli (2012). Looking Ahead in Pervasive Computing : Challenges and Opportunities in the era of Cyber–Physical Convergence, Pervasive and Mobile Computing, Vol. 8, No. 1, pp. 2-21.
8. Dillon, T. S. , H. Zhuge, C. Wu, J. Singh and E. Chang (2011). Web-of-things Framework for Cyber–Physical Systems. Concurrency and Computation: Practice and Experience, Vol. 23, No. 9, pp. 905-923.
9. Gubbi, J. , R. Buyya, S. Marusic and M. Palaniswami (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. Future Generation Computer Systems, Vol. 29, No. 7, pp. 1645-1660.
10. Gunes, V. , S. Peter, T. Givargis and F. Vahid (2014). A Survey on Concepts, Applications and Challenges in Cyber-Physical Systems, KSII Transactions on Internet and Information Systems, Vol. 8, No. 12, pp. 4242-4268.
11. Haque, S. A. , S.M. Aziz and M. Rahman (2014). Review of Cyber-Physical System in Healthcare. International Journal of Distributed Sensor Networks, Vol. 2014, Article ID. 217415.
12. Kortuem, G., F. Kawsar, D. Fitton and V. Sundramoorthy (2010). Smart Objects as Building blocks for the Internet of Things. Internet Computing, IEEE, Vol. 14, No.1, pp. 44-51.
13. Lee, E. A. (2006). Cyber-physical Systems-Are Computing Foundations Adequate. In Position Paper for NSF Workshop on Cyber-Physical Systems: Research Motivation, Techniques and Roadmap, Austin, TX, Vol. 2, pp. 1-9.
14. Rajkumar, R. (2012). A Cyber–Physical Future, Proceedings of IEEE, vol. 100, pp. 1309-1312.

15. Lee, E. A. (2007). Computing Foundations and Practice for Cyber-Physical Systems: a Preliminary Report. Technical Report, University of California, Berkeley, UCB/EECS-2007-72.
16. Lee, E. A. (2008). Cyber physical systems: Design challenges. 11th IEEE International Symposium on Object Oriented Real-Time Distributed Computing, Orlando, FL, pp. 363-369.
17. Li, J. Z., H. Gao and B. Yu (2009). Concepts, Features, Challenges and Research Progresses of CPSs. Development Report of China Computer Science, pp. 1-17.
18. Nunes, D. , P. Zhang and J. Silva (2015). A Survey on human-in-the-loop Applications towards an Internet of all. IEEE Communications Surveys and Tutorials, Vol. 17, No. 12, pp. 944-965.
19. Rajkumar, R.R. , I. Lee, L. Sha and J. Stankovic (2010). Cyber-Physical Systems: The Next Computing Revolution, In Proceedings of the 47th Design Automation Conference, ACM, New York, USA, pp. 731-736.
20. Savvides, A. , I. Paschalidis, and M. Caramanis (2011). Cyber-physical systems for next generation intelligent buildings, In Proceedings of the 2nd International Conference on Cyber Physical Systems, Vol. 8, No. 2, pp. 35-38.
21. Schirner, G. , D. Erdogmus, K. Chowdhury and T. Padir (2013). The Future of human-in-the-loop Cyber-Physical Systems, Computer, Vol.1, pp. 36-45.
22. Sha, L., S. Gopalakrishnan, X. Liu and Q. Wang (2009). Cyber-physical systems: A new frontier. In Machine Learning in Cyber Trust, Springer US , pp. 3-13.
23. Shafi, Q. (2012). Cyber Physical Systems Security: A brief Survey. 12th International Conference on Computational Science and its Applications, IEEE, Salvador, Bahia, Brazil, pp. 146-150.
24. Shi, J.H. , J. F. Wan, H. H Yan, and H. Suo (2011). A Survey of Cyber-physical Systems. Proceedings of the International Conference on Wireless Communications and Signal Processing, IEEE, Nanjing, China, pp. 1-6.
25. Sun, Q.B. , J. Liu, S. Li, C. X. FAN and J. J. SUN (2010). Internet of Things: Summarize on Concepts, Architecture and Key Technology Problem. Journal of Beijing University of Posts and Telecommunications, Vol. 3, No. 3, pp. 1-9.
26. Sztipanovits, J., X. Koutsoukos, G. Karsai, N. Kottenstette, P. Antsaklis, V. Gupta, B. Goodwine, J. Baras and S. Wang (2012). Toward a Science of Cyber–Physical System Integration. Proceedings of the IEEE, Vol. 100, No. 1, pp. 29-44.

27. Wan, J. , H. Yan, H. Suo, and F. Li. (2011). Advances in Cyber-Physical Systems research, KSII Transactions on Internet and Information Systems, Vol. 5, No. 11, pp. 1891-1908.

28. Wan, J. , M. Chen, F. Xia, L. Di and K. Zhou (2013). From machine-to-machine Communications towards Cyber-Physical Systems, Computer Science and Information Systems, Vol. 10, No. 3, pp. 1105-1128.

29. Wan, J. , H. Yan, Q. Liu, K. Zhou, R. Lu and D. Li (2013). Enabling Cyber–Physical Systems with machine–to–machine technologies, International Journal of Ad Hoc and Ubiquitous Computing, Vol. 13, No. 4, pp. 187-196.

30. Xia, F. , L. T. Yang, L. Wang and A. Vinel (2012). Internet of Things, International Journal of Communication Systems, Vol. 25, No. 9, pp. 1101-1102.