Chapter 8
Cyber-Physical Systems:
An Overview of Design Process, Applications, and Security

Lydia Ray
Columbus State University, USA

ABSTRACT

Pervasive computing has progressed significantly with a growth of embedded systems as a result of recent advances in digital electronics, wireless networking, sensors and RFID technology. These embedded systems are capable of producing enormous amount of data that cannot be handled by human brains. At the same time, there is a growing need for integrating these embedded devices into physical environment in order to achieve a far better capability, scalability, resiliency, safety, security and usability in important sectors such as healthcare, manufacturing, transportation, energy, agriculture, architecture and many more. The confluence of all these recent trends is the vision of distributed cyber-physical systems that will far exceed the performance of traditional embedded systems. Cyber-physical systems are emerging technology that require significant research in design and implementation with a few important challenges to overcome. The goal of this chapter is to present an overview of basic design and architecture of a cyber-physical system along with some specific applications and a brief description of the design process for developers. This chapter also presents a brief discussion of security and privacy issues, the most important challenge of cyber-physical systems.

1. INTRODUCTION

Advances in digital electronics throughout the last few decades have resulted in an explosive growth of embedded systems. There is a growing trend of systems with embedded wireless sensors and RFID (radio-frequency identification device) devices that can communicate with other systems such as smartphones over the Internet. These autonomous systems are capable of collecting and processing an enormous amount of data within a very short time. This characteristic is unmatched by a corresponding increase in human ability to consume information (Rajkumar et al., 2010). At the same time, there is a growing

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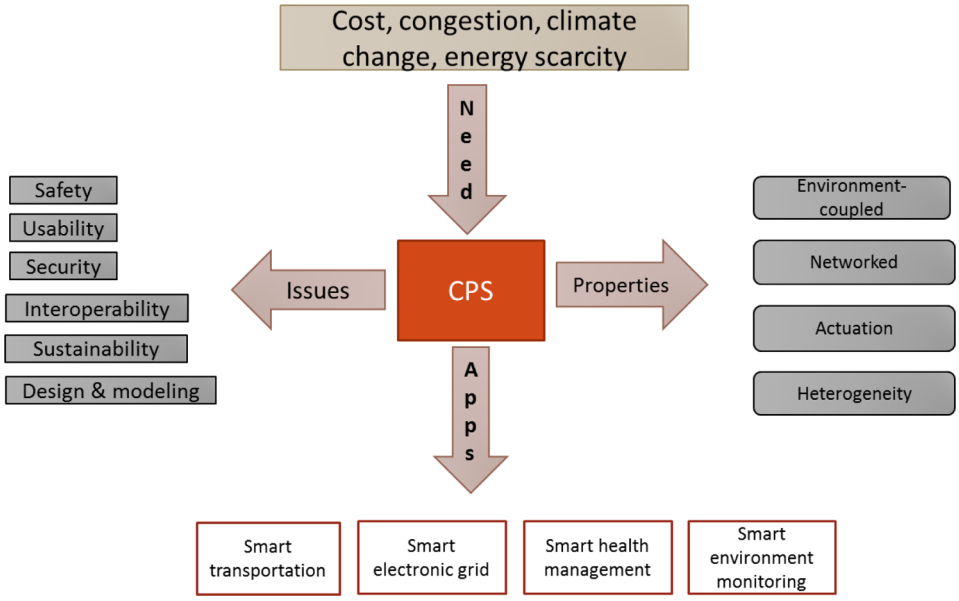
need for integrating these embedded devices into physical environment in order to achieve a far better capability, scalability, resiliency, safety, security and usability in important sectors such as healthcare, manufacturing, transportation, energy, agriculture, architecture and many more. The confluence of all these recent trends is the vision of distributed cyber-physical information distillation and control systems of embedded devices that will far exceed the performance of traditional embedded systems (Cyber Physical Systems, n.d.; Lee & Sheshia, 2011; Rajkumar et al., 2010). Figure 1 demonstrates everything about CPS in a nutshell.

Figure 1. CPS in nutshell
(Source: Venkatasubramanian, 2009)



Cyber-physical systems (CPS) are "physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core", as defined by Rajkumar et al. (2010). As the name suggests, a cyber-physical system has two components: a physical component and a cyber component. The cyber part of the system consists of sensors, computers and network devices which monitor and control activity of the physical component with feedback loops (Cyber Physical Systems, n.d.). The goal for the CPS designers is to seamlessly integrate physical processes with software applications and networking, building on the existing technology of embedded systems.

Cyber-physical systems are emerging technology, which is currently in the development phase requiring significant research work for resolving a number of key challenges. Cyber-physical systems belong to the discipline of engineering and computer science with a strong foundation of mathematical abstractions. Mathematical abstractions have been used for modeling physical processes as well as for developing algorithms and programs for cyber applications for centuries. While mathematical abstractions for modeling physical processes focus on system dynamics, mathematical abstractions for algorithms and programs focus on processing data, abstracting away a few core physical properties such as passage of