# Mobile Embedded System Architecture

CONTENTS



Mobile device is the indispensable part of a mobile sys- tem, and all the chips used in a mobile device are embedded systems. These embedded systems with various functions are controlled by the mobile operating system and collaborate with each other to complete every task mobile apps request.

In this chapter, we introduce the mobile embedded system architecture, including:

Overview of embedded systems Applications of embedded system.

The processor technology in embedded systems

Basic concepts in processor technology in embedded systems

The scheduling algorithms in processor technology in embedded systems

Memory technology in embedded systems Embedded systems in mobile devices Embedded systems in Android

## 5.1 EMBEDDED SYSTEMS

### 5.1.1 Embedded Systems Overview

Embedded systems are anything that uses a microprocessor but is not a general-purpose computer. An embedded system is a computer system with a dedicated function, which is embedded as a part of a complete device, including hardware and mechanical parts. These tiny systems can be found everywhere, ranging from commercial electronics, such as cell phones, cameras, portable health monitoring systems, auto- mobile controllers, robots, and smart security devices, to critical infras- tructure, such as telecommunication networks, electrical power grids, financial institutions, and nuclear plants. The increasingly complicated embedded systems require extensive design automation and optimization tools.

Modern embedded systems are often based on microcontrollers, such as Central Processing Units (CPU) with integrated memory or peripheral interfaces, but ordinary microprocessors, which use external chips for memory, and peripheral interface circuits are still common. Embedded systems are commonly used in telecommunication systems, consumer electronics, transportation systems, and medical equipment.

#### Telecommunication Systems

Telecommunication systems employ numerous embedded systems, from telephone switches to cell phones.

#### Consumer Electronics

Consumer electronics include personal digital assistants (PDAs), such as audio players, mobile phones, videogame consoles, digital cameras, video players, and printers. Embedded systems are used to provide flexibility, efficiency, and features.

### Home Automation

Embedded devices are used for sensing and controlling in-home automation using wired and wireless networks. Embedded devices can be used to control lights, climate, security, audio/visual, and surveillance.

### Transportation Systems

Embedded systems are increasingly used from flight to automo- biles in transportation systems. New airplanes contain advanced avionics, such as Inertial Guidance Systems (IGS) and Global Positioning System (GPS) receivers that also have considerable safety requirements. Various electric motors use electric motor controllers. Automobiles, electric vehicles, and hybrid vehicles increasingly use embedded systems to maximize efficiency and reduce pollution.

### Medical Equipment

Medical equipment uses embedded systems for vital signs moni- toring, electronic stethoscopes for amplifying sounds, and various medical imaging for non invasive internal inspections. Embedded systems within medical equipment are often powered by indus- trial computers.

Besides the usages mentioned above, embedded systems are also widely used in a new kind of technology, which is *wireless sensor networking* (WSN). The WSN consists of spatially distributed au- tonomous sensors to monitor physical or environmental conditions. Commonly monitored parameters are temperature, humidity, pressure, wind direction and speed, illumination intensity, vibration intensity, sound intensity, power-line voltage, chemical concentrations, pollutant levels, and vital body functions. WSN enables people and companies to measure myriad things in the physical world and acts on this information under the help of embedded Wi-Fi systems. Furthermore, the network wireless sensors, using optimization technologies of em- bedded systems, are completely self-contained and will typically run off a battery source for years before the batteries need to be changed or charged.

Embedded systems also can be defined as computers purchased as part of some other piece of equipment. They always have a dedicated software in them, and the software may be customizable to users. There are often no “keyboard” and limited display or no general purpose display in an embedded system.

Embedded systems are important for three kinds of reasons:

Engineering reasons. Any device that needs to be controlled can be controlled by a microprocessor. In many situations, it is impossible or unnecessary for the devices to being a complete computer. McDon- ald’s POS (Point of Sale) terminal is only in charge of recording pur- chases, calculating and showing price, collecting money, giving change, and printing receipts. This kind of functions is simple, so the POS ter- minals have little calculating resources. It is unnecessary for the POS terminal to be complete as a general computer, because it is really a waste.

Market reasons. The general-purpose computer market worths billions of dollars; meanwhile the embedded systems market is also worths billions of dollars. Although the price of an embedded sys- tem may be much lower than that of a general-purpose computer, the amount of embedded systems are much larger than that of general- purpose computers. In 2009, about 200 embedded systems were used in every new car. There are more than 80 million personal computers were sold every year. While over 3 billion embedded CPUs were sold annually. Furthermore, the personal computer market is mostly saturated, but the embedded market is still growing.

Pedagogical reasons. Embedded system designers often need to know hardware, software, and some combination of networking, con- trol theory, and signal processing. This makes the teaching methods of designing embedded systems different from that for designing general- purpose systems.

In this section, we introduce the overview of embedded systems, an- alyze their usages, explain their importance, list some real applications of embedded systems, and give a high-level of the design of embedded system. We introduce deeper knowledge after introducing the design of embedded system. The first and the most important thing is schedul- ing.

## 5.2 SCHEDULING ALGORITHMS

### 5.2.1 Basic Concepts

First of all, some basic concepts must be introduced and explained. Scheduling is central to operating system design. The success of CPU scheduling depends on two executions. The first one is the process execution consisting of a cycle of CPU execution and Input/ Output (I/O) wait. The second one is the process execution, which begins with a CPU processing, followed by I/O processing, then followed by another CPU processing, then another I/O processing, and so on. The CPU I/O Processing Cycle is the basic concept of processor technology. The processing time is the actual time that is required to complete some job.

The CPU scheduler selects from among the processes in memory that are ready to execute, and allocates the CPU to one of them. CPU scheduling decisions take place when a process is switching from run- ning to waiting state; switching from running to ready state; switching from waiting to ready and terminating.

Beside the CPU scheduler, dispatcher is also a basic and important concept in processor technology. The dispatcher module gives control of the CPU to the process selected by the short-term scheduler, and this involves: switching context, switching to user mode, and jumping to the proper location in the user program to restart that program. Most dispatchers have dispatch latency, which is the time they take for the dispatcher to stop one process and start another running.

Then we discuss some criteria of scheduling.

CPU Utilization. The CPU utilization refers to a computer's usage of processing resources, or the amount of work handled by a CPU, and it is used to gauge system performance. Actual CPU utilization varies depending on the amount and type of managed computing tasks. The first aim of processor technology is increasing the CPU utilization by keeping the CPU as busy as possible.

**Throughput**. The throughput means the amount of processes that complete their execution per time unit.

**Turnaround Time.** The turnaround time means the amount of time to execute a particular process, and it can be calculated as the sum of the time waiting to get into memory, waiting in the ready queue, and executing on the CPU and the I/O.

**Waiting Time**. The waiting time means the amount of time a process has been waiting in the ready queue.

**Response Time**. The response time means the amount of time it takes from when a request was submitted until the first response is produced.

**Completion Time**. The completion time of one job means the amount of time needed to complete it, if it is never preempted, inter- rupted, or terminated.

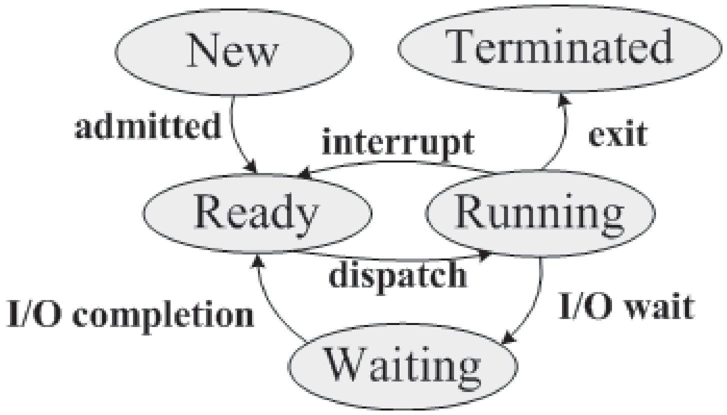


Figure 5.1 The diagram of the process states.

As shown in Fig. 5.1, processes have five types of states. At the *new* state, the process is in the stage of being created. At the *ready* state, the process has all the resources available that it needs to run, but the CPU is not currently working on this process's instructions. At the *running* state, the CPU is working on this process's instructions. At the *waiting* state, the process cannot run at the moment, because it is waiting for some resource to become available or for some event to occur. At the *terminate* state, the process was completed.