CHAPTER 11 Existing Wireless Systems

11.1 Introduction

A wireless system needs to take many factors into account such as call rate, call duration, distribution of MSs, traffic in an adjacent cell, the terrain, and atmospheric conditions. To get an idea of how a wireless system could behave in the real world, it is important to study various characteristics of existing cellular systems and how they support seamless mobile communication. In this chapter, we study the details of some of these existing systems.

It is important to emphasize that communication between any two devices is successful only when the receiver gets the intended information from the sender, and this is possible if both the sender and the receiver follow a set of rules called the communications protocol. To facilitate easy transfer of information, the protocol employs many steps of seven layers as described in the International Organization for Standardization (ISO)–Open Systems Interconnection (OSI) model that is widely employed for wired communication (Chapter 9). In a wireless environment, similar steps are followed, except that a few steps or layers are not used for the sake of efficiency. On the other hand, some layers may be subdivided into a number of successive operations and are given in conjunction with the specific cellular systems. From a historical point of view, we consider AMPS (Advanced Mobile Phone System) as the first representative of wireless systems.

11.2 AMPS

AMPS is the first-generation cellular system used in the United States. It transmits speech signals employing FM, and important control information is transmitted in digital form using FSK. AMPS is the first cellular phone technology created by AT&T Bell Labs with the idea of dividing the entire service area into logical divisions called cells. Each cell is allocated one specific band in the frequency spectrum.

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To explore a reuse pattern, the frequency spectrum is divided among seven cells, improving the voice quality as each user is given a larger bandwidth. Typically, AMPS uses a cell radius of 1 to 16 miles, depending on various factors such as density of users and traffic intensity. However, there is a tradeoff between the cell area and the quality of service. Larger cells tend to have more thermal noise and less interference, while smaller cells have more interference and less thermal noise. One important aspect of AMPS is that it allows both cell sectoring and splitting. It is also sufficient to have a low-power MS (about 4 watts or less) and a medium-power BS (about 100 watts). AMPS is capable of supporting about 100,000 customers per city, and the system is aimed to reduce blocking probability to about 2% during busy hours.

11.2.1 Characteristics of AMPS

AMPS uses the frequency band from 824 MHz to 849 MHz for transmissions from MSs to the BS (reverse link or uplink) and the frequency band between 869 MHz to 894 MHz from the BS to the MS (forward link or downlink). The 3 kHz analog voice signal is modulated onto 30 kHz channels. In transmitting data, the system uses **Manchester** frequency modulation at the rate of 10 kbps, while the control parameters remain the same as in voice transfer. Separate channels are used for transmitting control information and data. Since fewer control messages are exchanged between the MS and the BS as compared with voice or data messages, a smaller number of control channels are employed than voice antennas. In AMPS, there is one control transreceiver for every eight voice transreceivers.

Frequency allocation in AMPS is done by dividing the entire frequency spectrum into two bands—Band A and Band B. Frequencies are allocated to these bands, as shown in the Table 11.1 [11.1].

The non-wireline providers are given Band A, and Bell wireline providers are given Band B. A total of 666 channels (which was later increased to 832 channels)

Table 11.1: ▶
Band Allocation in AMPS

Band	MS Transmitter (MHz)	BS Transmitter (MHz)	Channel Numbers	Total Number of Channels
A	825.03–834.99	870.03–879.99	1–333	333
A'	845.01–846.48	890.01–891.48	667–716	50
A"	824.04–825.00	869.04–870.00	991–1023	33
B	835.02–844.98	880.02–889.98	334–666	333
B'	846.51–848.97	889.51–893.97	717–799	83
Not used	824.01	869.01	990	1

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is divided among these two bands, and a cluster of seven cells allows many users to employ the same frequency spectrum simultaneously. AMPS's use of directional radio propagation enables different frequencies to be transmitted in different directions, thereby reducing radio interference considerably.

11.2.2 Operation of AMPS

A general state diagram of how an AMPS system handles calls and various other responsibilities is shown in Figure 11.1. At the powerup, all MSs in the range of a BS have to go through a registration with AMPS before actual service begins. Thereafter, any incoming or outgoing call is handled according to the state of the system. Each MS also goes through the registration process when handoff to an adjacent cell occurs.

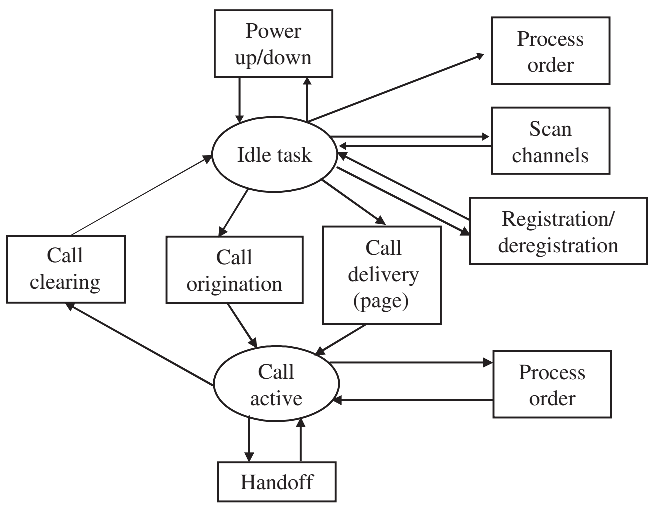

Figure 11.1 General operation of MS in AMPS.

Three identification numbers are included in the AMPS system to perform various functions [11.1]:

1. **Electronic serial number (ESN)**: A 32-bit binary number uniquely identifies a cellular unit or a MS and is established by the manufacturer at the factory. Since it is unique, any MS can be precisely identified by this number. For security reasons, this number should not be alterable and should be present in all MSs.
2. **System identification number (SID)**: A unique 15-bit binary number assigned to a cellular system. The Federal Communications Commission (FCC) assigns one SID to every cellular system, which is used by all MSs registered in the service region. A MS should first transmit this number before any call can be handled. The SID serves as a check and can be used in determining if a particular MS is registered in the same system or if it is just roaming.
3. **Mobile identification number (MIN)**: A digital representation of the MS's 10-digit directory telephone number.

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The location of a particular MS is not predictable. Then the question is, how does a MS know when it receives a call? The answer lies in the messages passed on the control channels. Whenever the MS is not in service, it tunes to the strongest channel to find out useful control information. The same happens at the BS as well. There are two important control channels: forward control channel (FOCC) from the BS to the MS, and reverse control channel (RECC) from MS to BS, both operating at 10 kbps, as shown in Figure 11.2. Various channels used by the AMPS are as follows:

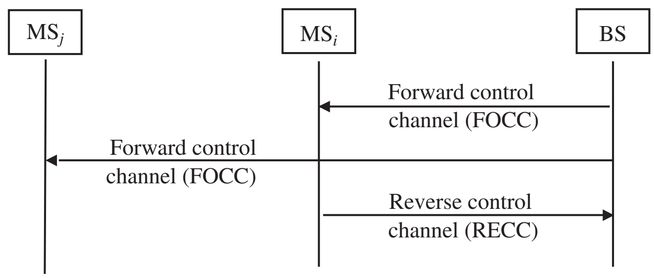

Figure 11.2
Forward and reverse channels.

- **Forward control channel (FOCC)**: FOCC is used primarily by the BS to page and locate the MSs using the control information in three-way time division multiplexing mode (Figure 11.3). The busy/idle status shows if the RECC is busy, and stream A and stream B allow all the MSs to listen to the BS. Stream A is for MSs having least significant bit (LSB) of MIN as zero, while stream B is for those MSs with LSB of MIN as one. As a part of control information, BS also allocates voice channels to MSs. Each data frame consists of several components, starting with a dotting sequence (alternating 1s and 0s), continues with a word-sync pattern, and is followed by five repeats of word-A and word-B data. The BS forms each word by encoding 28 content bits into a (40, 28) BCH code. Figure 11.3 shows the detailed FOCC frame format. The first busy/idle bits are inserted at the beginning of the dotting sequence. The second is inserted at the beginning of the word sync, and the third is inserted at the end of the word sync. After the third busy/idle bit, a busy/idle bit is inserted every 10 bits through the five repeats of word-A and word-B data. The busy/idle bits indicate the control channel availability with the BS. An idle-to-busy transition coordinates messages sent on the control channel.

Bits	10	11	40	40	…	40	40	10	
	Dotting	Word sync	Repeat 1 of word A	Repeat 1 of word B	…	Repeat 5 of word A	Repeat 5 of word B	Dotting	…

Dotting = 1010…101
Word sync = 11100010010

Figure 11.3
Format of FOCC.

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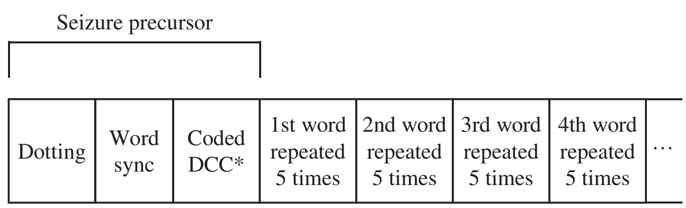
- **Reverse control channel (RECC)**: Control for the reverse direction is little involved as this information comes from one or more MSs using the RECC channel. This could also be in response to the page sent by the BS. There could be several MSs responding to queries. A simple mechanism to indicate whether RECC is busy or idle is to model it after the slotted ALOHA packet radio channel. Figure 11.4 shows a typical format of the RECC message, which begins with the RECC seizure precursor of 30 bits of dotting, 11 bits of word sync, and the 7-bit coded digital color code (DCC). DCC is primarily used to detect if any co-channel interference is occurring in the specified region. For a single-word transmission following the seizure precursor, a single RECC message word repeats itself five times. The seizure precursor fields are used for synchronization and identification. For a multiple-word transmission following the seizure precursor, the first RECC message word repeats itself five times; then the second RECC message word is repeated five times.



Dotting = 1010…101

Word sync = 11100010010

* DCC = Digital color code

Figure 11.4
Format of RECC.

- **Forward voice channel (FVC)**: FVC is used for one-to-one communication from the BS to each individual MS. A limited number of messages can be sent on this channel. A 101-bit dotting pattern represents the beginning of the frame. The forward channel supports two different tones—continuous supervisory audio, in which the BS transmits beacon signals to check for the live MSs in the service area, and discontinuous data stream, which is used by the BS to send orders or new voice channel assignments to the MS.
- **Reverse voice channel (RVC)**: Reverse voice channel is used for one-to-one communication from the MS to the BS during calls in progress and is assigned by the BS to a MS for its exclusive use.

11.2.3 General Working of AMPS Phone System

When a BS powers up, it has to know its surroundings before providing any service to the MSs. Thus, it scans all the control channels and tunes itself to the strongest channel. Then it sends its system parameters to all the MSs present in its service area. Each MS updates its SID and establishes its paging channels only if its SID matches the one transmitted by the BS. Then the MS goes into the idle state, responding only to the beacon and page signals.

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