TDMA platform. Simultaneously, international wireless carrier Nextel announced its decision to upgrade its iDen air interface standard to support up to five times the number of current users based on a data compression methodology using Internet protocol (IP) packet data. Most other carriers throughout the world had already committed to adopting a 3G standard based on either GSM or CDMA prior to 2001. Decisions like these have set the stage for the inevitability of two universal and competing third generation (3G) cellular mobile radio technologies, one based on the philosophy and backward compatibility of GSM, and the other based on the philosophy and backward compatibility of CDMA.

2.1.1 Evolution to 2.5G Mobile Radio Networks

Since the mid 1990s, the 2G digital standards have been widely deployed by wireless carriers for cellular and PCS, even though these standards were designed before the widespread use of the Internet. Consequently, 2G technologies use circuit-switched data modems that limit data users to a single circuit-switched voice channel. Data transmissions in 2G are thus generally limited to the data throughput rate of an individual user, and this rate is of the same order of magnitude of the data rate of the designated speech coders given in Table 2.1. (As discussed in Chapter 11, each of the 2G standards specify different coding schemes and error protection algorithms for data transmissions versus voice transmissions, but the data throughput rate for computer data is approximately the same as the throughput rate for speech coded voice data in all 2G standards.) From inspection of Table 2.1, it can be seen that all 2G networks, as originally developed, only support single user data rates on the order of 10 kilobits per second, which is too slow for rapid email and Internet browsing applications. Chapter 11 presents the technical specifications of the original GSM, CDMA, and IS-136 standards which originally supported 9.6 kilobits per second transmission rates for data messages.

Even with relatively small user data rates, 2G standards are able to support limited Internet browsing and sophisticated short messaging capabilities using a circuit switched approach. *Short messaging service (SMS)* is a popular feature of GSM, and allows subscribers to send short, real-time messages to other subscribers in the same network by simply dialing a recipient's cell phone number. SMS first became popular in Europe through the dominant network of GSM service providers, and then became popular in Japan through the NTT DoCoMo PDC network. As of late 2001, SMS had not yet become widespread in the USA, since the wireless markets there are fragmented between many different types of technologies and network owners, and SMS presently only works between users of the same network.

In an effort to retrofit the 2G standards for compatibility with increased throughput data rates that are required to support modern Internet applications, new data-centric standards have been developed that can be overlaid upon existing 2G technologies. These new standards represent *2.5G* technology and allow existing 2G equipment to be modified and supplemented with new base station add-ons and subscriber unit software upgrades to support higher data rate transmissions for web browsing, e-mail traffic, mobile commerce (*m-commerce*), and location-based mobile services. The 2.5G technologies also support a popular new web browsing format language, called *Wireless*

Applications Protocol (WAP), that allows standard web pages to be viewed in a compressed format specifically designed for small, portable hand held wireless devices. Numerous other competing web page compression protocols have also been developed recently [Ald00].

It is interesting to note that Japan, one of the world's first countries to adopt commercial cellular telephony in the late 1970s, was the first country to enjoy a successful widespread mobile data service and web browser capability that preceded the introduction of WAP. NTT DoCoMo introduced its own proprietary wireless data service and Internet microbrowser technology, called *I-mode*, on its PDC network in 1998, and is currently distributing its I-mode technology to other wireless carriers throughout the world. I-mode supports games, color graphics, and interactive web page browsing using the modest 2G PDC data transmission rate of 9.6 kilobits per second. As of late 2001, DoCoMo's I-mode was supporting wireless web access for over 25 million Japanese subscribers.

The appropriate 2.5G upgrade path for a particular wireless carrier must match the original 2G technology choice made earlier by the same carrier. For example, a 2.5G upgrade solution designed for GSM must dovetail with the original GSM air interface standard [Gar99], since it would otherwise be incompatible and require wholesale equipment changes at each base station. For this reason, a wide range of 2.5G standards have been developed to allow each of the major 2G technologies (GSM, CDMA, and IS-136) to be upgraded incrementally for faster Internet data rates. Figure 2.3 illustrates the various 2.5G and 3G upgrade paths for the major 2G technologies [Tel01]. Table 2.2 describes the required changes to the network infrastructure (e.g., the base station and the switch) and the subscriber terminals (e.g., the handset) for the various upgrade options for 2.5G and 3G. The technical features of each 2.5G upgrade path are described below.

2.1.2 Evolution for 2.5G TDMA Standards

Three different upgrade paths have been developed for GSM carriers, and two of these solutions also support IS-136. The three TDMA upgrade options include: (a) High Speed Circuit Switched Data (HSCSD); (b) General Packet Radio Service (GPRS); and (c) Enhanced Data Rates for GSM Evolution (EDGE). These options provide significant improvements in Internet access speed over today's GSM and IS-136 technology and support the creation of new Internet-ready cell phones.

2.1.2.1 HSCSD for 2.5G GSM

As the name implies, High Speed Circuit Switched Data is a circuit switched technique that allows a single mobile subscriber to use consecutive user time slots in the GSM standard. That is, instead of limiting each user to only one specific time slot in the GSM TDMA standard, HSCSD allows individual data users to commandeer consecutive time slots in order to obtain higher speed data access on the GSM network. HSCSD relaxes the error control coding algorithms originally specified in the GSM standard for data transmissions and increases the available application data rate to 14,400 bps, as compared to the original 9,600 bps in the GSM specification. By using up to four consecutive time slots, HSCSD is able to provide a raw transmission rate of up to 57.6 kbps to