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Vikram Goyal

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In his spare time, Robert enjoys the company of his friends and his dog, Benny. Other spare-time favorites are going to concerts of soul, ska, and punk-rock bands, and playing around with old computers such as Atari 400, Commodore 8296, and MCS Alpha 1.

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Even though you see my name at the front of this book, it's the result of a collective effort on the part of several individuals. All these individuals need to be honored and acknowledged because without them, you would not be holding this book in your hands.

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My wife, Shellie, has suffered because of the hours I have spent in "the office" and deserves a reward for her patience. More than that, she supports me to be all I can and even puts up with my interference of her routine when I take away her mobile phone (to test the applications). To miss all the holidays and breaks and not complain is a feat in itself. I look forward to spending more time with her and to the upcoming addition to our family.

CHAPTER 1

Introducing Mobile Media API (MMAPI)

Embedding multimedia capabilities in a MIDlet is the next step in the evolution of MIDlets. Sun recognized early that audio and video are the future and introduced the Mobile Media API (MMAPI) via Java Specification Requests (JSR) 135 (*http://www.jcp.org/en/jsr/detail?id=135*).

The biggest requirement of the MMAPI specification was to ensure compatibility with small footprint devices while creating a specification that would be scalable for future—possibly more capable—devices. To this end, MMAPI has succeeded tremendously.

This chapter introduces you to MMAPI and explains several factors that make it a successful specification. You'll learn how this API fits in the overall scheme for MIDlet creation with the Mobile Information Device Profile (MIDP) 2.0. The chapter concludes with information on the current list of devices that support this API.

What Is Mobile Media API (MMAPI)?

MMAPI is the optional API that developers use to embed advanced multimedia capabilities in any Java-enabled device. If you've been using the audio capabilities in MIDP 2.0, you've already been using a subset of MMAPI. This subset is a forward compatible version of MMAPI created for limited-capability devices.

MMAPI allows you to create applications for Java-enabled devices that can discover and use the multimedia capabilities of the device that they are running on. You can play different formats of audio and video files from the network, a record store, or a Java Archive (JAR) file; have advanced control over the playback of these files; capture audio and video and take snapshots; play MIDI files; generate and play back tones; stream radio over the network; and do a whole lot more.

To encourage device manufactures to use this API in their Java-enabled devices, MMAPI was designed specifically to be protocol and format agnostic. In other words, this API does not come with assumptions about the supported protocol for accessing multimedia content, nor does it makes assumptions about the formats that it would be able to play. Thus, different device manufactures implement this API in their own way and make it available with the protocols and formats that their devices can support. This characteristic makes MMAPI a high-level interface and allows it to be compatible with any Java configuration.

Most devices, however, support some basic protocols and formats; for example, most allow you to access media over HTTP and play the WAV file format for audio and MP3 for video.

If a device supports a particular media format, MMAPI may mandate some control over the functionality of that format to create control uniformity across different devices. Other formats may require entirely different controls that may or may not be mandatory. Chapter 2 provides more information about mandatory controls for different formats in the "Feature Sets Implementations" section.

MMAPI Features and Requirements

MMAPI was designed for Java-enabled mobile devices, but the design is intentionally general enough that any Java-enabled device can benefit from it. This forced a set of rules on the API designers that they had to adhere to:

- **Low footprint API**: Because the main target of this API is Java-enabled mobile phones, which are severely constrained for available memory, the API must be able to support media playback in the available memory. Typically, because the Java-enabled mobile phones run on the Connected Limited Device Configuration (CLDC), the memory available ranges between 128KB and 512KB. This is the memory available for the virtual machine, the core libraries, your MIDlets, *and* MMAPI. MMAPI's place with MIDP is covered in the "How Does MMAPI Fit with MIDP 2.0?" section later in this chapter.

- **Ability to support multiple media types**: By defining the core API as a set of interfaces, MMAPI is protocol and format agnostic. Device manufactures supply their own implementation of MMAPI and implement interfaces that support the multimedia capabilities of their devices. This allows a wide range of protocols and formats to be supported based on the device, without any hard wiring of protocols and formats built-in the API itself. This makes MMAPI immensely scalable as new formats are discovered and supported by device manufacturers.

- **Support for basic controls**: Although the previous requirement states that MMAPI is protocol and format agnostic, some support for basic controls is guaranteed to be present. This creates uniform procedures for managing media, whatever format or protocol it may take. For example, all media can be played, started, or stopped.

- **Support for device capabilities discovery**: Similar to the previous requirement, all devices can be queried to discover their capabilities. This allows you to find out which protocols or formats the device supports.

- **Support for basic audio and tone generation**: Because MMAPI uses CLDC as the base minimum supported configuration, it requires some support for audio playback and tone generation. Note that the API mandates support for audio playback but doesn't restrict it to any particular format or protocol, in keeping with the ability to support multiple media types requirement. Device manufacturers are free to choose which format or playback they will support. Tone generation is important in Java-enabled mobile phones, and therefore, the API provides simple ways to play tones as well.

These requirements have led to an API interface that is truly extensible and capable of supporting a range of multimedia formats and protocols on an array of devices.

How Do I Get MMAPI?

If you have used the Java Wireless Toolkit (*http://java.sun.com/products/sjwtoolkit/download-2_3.html*) to develop your MIDlets, you already have MMAPI installed. The Toolkit comes with a reference implementation (RI) of this API installed as an optional package. Of course, MIDP 2.0 contains a subset of this API, so if you are only going to use a limited subset of MMAPI, you don't need this RI.

Most development environments (such as Netbeans and Eclipse) that support mobile application development include a version of this Toolkit, so MMAPI is included as an optional package.

Of course, the RI supplied with the Toolkit may not be your target platform (in all likelihood, it *won't* be your target platform because it contains only virtual devices). For example, you may be developing applications for the mobile devices supplied by Nokia. In which case, you need to download the implementation of MMAPI supplied by Nokia for its devices. This implementation will come bundled with the Toolkit supplied by Nokia (*http://forum.nokia.com/main/0,,034-2,00.html*). Similarly, different device manufacturers, and not just mobile device manufacturers, will supply their own implementations bundled in with their overall Java Wireless Toolkit.

In short, to start developing multimedia applications for Java-enabled devices using MMAPI, you need the Java Wireless Toolkit supplied by the device manufacturers. The last section in this chapter points you to some popular Toolkits. In this book, I will develop multimedia MIDlets using the Sun supplied Java Wireless Toolkit 2.3 and the Motorola SDK V5.2 (*http://www.motocoder.com*). In Chapters 8 and 9, I will also use the BenQ (formerly Siemens) CX 75 emulator (*http://www.benqmobile.com/developer*). The Sun Wireless Toolkit will be integrated in the Netbeans Integrated Development Environment (IDE) (*http://www.netbeans.org*), which will be the main development environment for the examples in this book. The Motorola device emulators will be used to test the MIDlets before deploying them on an actual Motorola device (the Motorola C975), and Chapters 8 and 9 will use the BenQ CX 75 emulator before testing them on the BenQ M75 device.

How Does MMAPI Fit with MIDP 2.0?

MMAPI is an optional package for the Java Micro Edition (ME) platform. MIDP 2.0 is a profile for the development of MIDlets, or applications for Java-enabled mobile devices, such as mobile phones and PDAs. MMAPI can be used with not just MIDP 2.0, but with any Java ME profile and configuration, provided an implementation is available for the device you are developing for. Refer to *Beginning J2ME: From Novice to Professional*, Third Edition, by Jonathan Knudsen and Sing Li (Apress, 2005) for a review of configurations, profiles, and development of MIDlets.

As you may already know, MMAPI is not the only optional package available for developing applications for the Java ME platform. Other prominent packages include the Web Services API (JSR 172), the Mobile 3D Graphics API (JSR 184), and the Location API (JSR 179). All of these optional packages, like the MMAPI package, are applicable to all available configurations, such as CLDC and Connected Device Configuration (CDC). On the other hand, an optional package such as the Wireless Messaging API (JSRs 120/205) is only relevant to the CLDC-based MID profile (MIDP).

MMAPI differs from the other optional packages because a scaled down version of it is present in MIDP 2.0 under the `javax.microedition.media` and `javax.microedition.media.control` packages. No other optional package makes an appearance in MIDP 2.0. So if you are developing applications that only require basic audio control, you don't need the full MMAPI installed or available. You would still be using MMAPI, just not the optional and bigger part of it. Your

application will run on all devices that support MIDP 2.0, as MIDP 1.0 does not have the scaled version.

Note Some devices support the MMAPI in MIDP 1.0 as an optional library, for example, Nokia 3650, Nokia 7650, and Sony Ericsson 610. Applications that use the features of the optional package will only run on devices that have both MIDP 2.0 and the optional MMAPI package installed. The next section includes a comprehensive list of all such devices at the time of the book going to print.

Figure 1-1 gives a bird's eye view of how MMAPI, along with the other optional packages, fits in the development of applications for Java-enabled devices. Because this book concentrates on applications developed using MIDP, which are called MIDlets, I'll use that term when talking about such applications.

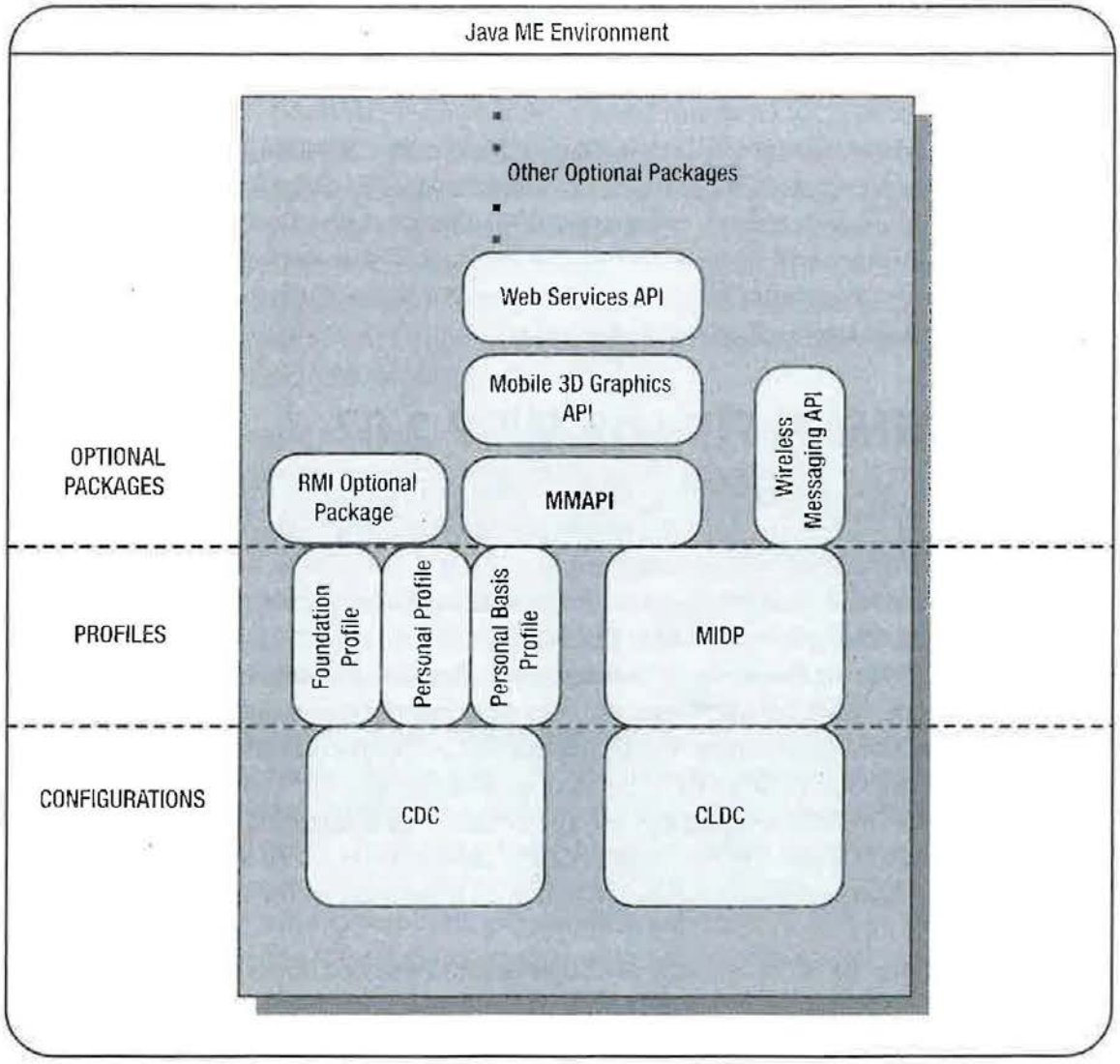


Figure 1-1. *Java ME development environment showing MMAPI as an optional package*

Who Supports MMAPI?

The specification for MMAPI was developed using the Java Community Process (JCP) (*http://www.jcp.org*) by a consortium of organizations, including device manufacturers, network operators, and multimedia companies, besides Sun Microsystems. This specification is numbered 135 and can be accessed at *http://www.jcp.org/en/jsr/detail?id=135*. The initial expert group for the development of this specification was composed of Sun, Nokia, and Beatnik.

Afterwards, several other organizations chipped in and lent their support for the development of this specification. A final release with a version number of 1.0 occurred on June 27th, 2002. A maintenance release (version 1.1) incorporating security enhancements and minor modifications was released a year later on June 26th, 2003, and is the version used for the examples in this book. Recently, JSR 234 has been released that identifies advanced supplements for this MMAPI.

As part of the development of this specification, Sun released a reference implementation of this API and a technology compatibility kit (TCK) that can be used to certify that an implementation of this API is compatible with the specification. This is par for any specification developed using the JCP. As stated earlier, this RI is bundled with the Java ME Wireless Toolkit supplied by Sun. Different device manufacturers supply their own implementations compatible with the TCK.

All devices that support MIDP 2.0 automatically support the scaled-down version of MMAPI. Many devices support the full version as an optional package. Table 1-1 gives a comprehensive list of devices that support MMAPI as an optional package.

Table 1-1. *Devices That Support MMAPI As an Optional Package*

Device Manufacturer	Supported Devices	Wireless Toolkit
Alcatel	One Touch 756	*http://www.my-onetouch.com*
BenQ	AX75 (MIDP 1.0), C70, C75, CF75/76, CL75, CX70/EMOTY, CX75, M75, S75, SL75, SXG75	*http://www.benq.com/developer*
Motorola	C975, E1000, A1000, A630, A780, A845, C380, C650, E398, E680, SLVR, T725, V180, V220, V3, V300, V303, V360, V400, V500, V525, V550, V551, V600, V620, V635, V8, V80, V980, i730	*http://www.motocoder.com*
Nokia	All Series 40, Series 60, and Series 80 based devices	*http://forum.nokia.com/main.html*
Samsung	E310, E380, E710, D400, P705, D410, 176X192 Series, E810, E310	*http://uk.samsungmobile.com/club/developers_club/cl_de_sdk_01.jsp*
Sony-Ericsson	W900, Z600, T610, T616, T618, V600, W800, K608, W550, W600, z520, D750, Z800, K600, K750, K300, K500, K700, J300, V800, Z500, S700, Z1010	*http://developer.sonyericsson.com*

Summary

This chapter introduced MMAPI, an optional package for the development of MIDlets that have embedded audio/video capabilities.

MMAPI provides these capabilities by defining a specification that is protocol and format agnostic, thereby increasing general acceptance and uptake. This has made MMAPI very popular and more and more devices support it.

With this introduction to MMAPI's features and requirements complete, the next chapter addresses the MMAPI architecture, which is key to understanding and using MMAPI.

CHAPTER 2

MMAPI Architecture

The MMAPI specification was created to cater to the widest range of multimedia options, and this is reflected in its architecture. It supports the most basic audio functions in a constrained device and at the same time provides ways to handle advanced multimedia data on more capable devices. MMAPI supports data from various sources and in various formats. MMAPI's protocol and format agnostic characteristic is achieved by a well-designed, high-level interface.

This chapter explains how the MMAPI specification achieves this aim of platform and format neutrality. You'll become familiar with the details of its architecture and the high-level objects that make it a successful specification. You'll see how the subset of MMAPI present in MIDP 2.0 differs from the overall specification. Finally, the chapter covers several small details of the MMAPI architecture, such as feature sets and security scenarios, to help you better understand and use MMAPI.

Understanding `Player`s and `DataSource`s

MIDlets can receive multimedia data from a variety of sources: located in a MIDlet's JAR file; come over the network via several different protocols (HTTP, RTP); sourced from the device's record store on which the MIDlet is running; and even come from user input via an audio or video capture device. In short, not only can this data be sourced from different locations, but also these locations can be accessed using any number of present or future protocols. At a conceptual level, MMAPI can handle all such locations and protocols without getting tied down to a specific protocol or location.

After data has been sourced, MMAPI should be able to process this data and make it available for rendering on the device. Processing multimedia data is inherently complex and requires the API to not only understand the data but decode it as well. Rendering the data and providing controls to manipulate it further complicates the process. Because MMAPI is a high-level interface, it doesn't mandate any specific data-processing functionality, besides a very low level of audio handling.

To achieve this neutrality with regard to sources of multimedia data and processing, MMAPI encapsulates these concepts into two high-level objects: `Player` and `DataSource`. Whereas `Player` is an interface that deals with processing and playing multimedia data, `DataSource` is an abstract class that encapsulates the task of data location and retrieval while maintaining protocol independence. The `Player` interface is defined in the `javax.microedition.media` package, and `DataSource` is defined in the `javax.microedition.media.protocol` package.

Player and DataSource work together to provide multimedia capability in a device. A Player instance parses data supplied to it from a DataSource instance. The Player may then render this data on the device and provide controls to manipulate it. For example, an audio Player can provide volume controls to increase or decrease the playback volume.

DataSource Basics

The DataSource class provides access to multimedia files by locating and opening a connection to them. You may not need to use this class directly, unless you are going to create a DataSource for a custom protocol or location. The MMAPI implementation provided by the device that you are targeting your MIDlet to will provide enough DataSource instances to satisfy most requirements.

Each DataSource is composed of one or more streams, known as a SourceStream (an interface in the javax.microedition.media.protocol package). A SourceStream is used to abstract a single stream of media data. Conceptually, multimedia data may be composed of several streams. For example, video files may be broken down into separate streams, one for audio and one for video. Thus, each individual stream can be acted on, independently of the other stream, thereby giving greater control than is possible otherwise. Most DataSource instances are composed of a single SourceStream.

A SourceStream also has the advantage of being randomly seekable, because it provides the seek(long where) method. This is an important consideration for multimedia data because it allows you to render this data from an arbitrary position. Of course, a particular stream may not support random seek operations, and this is reflected by the getSeekType() method. This method returns one of three integer constants, shown in Table 2-1.

Table 2-1. *Constants to Test a* SourceStream *for Seekability*

Constant	Description
NOT_SEEKABLE	The specified stream is not seekable.
SEEKABLE_TO_START	The specified stream can only be sought to its beginning.
RANDOM_ACCESSIBLE	A true seekable stream, this constant indicates that the specified stream can be randomly accessed anywhere.

A SourceStream has one more advantage. For multimedia data that supports it, a SourceStream can be used to read the logical transfer size of the data. For example, video data is normally composed of individual frames, so the logical transfer size of the data would be the size of one such frame. This allows you to create an in-memory buffer of the right size, equivalent to or greater than the size of the frame, to read data, thereby creating an efficient data read process. SourceStream instances that support this concept return a positive integer value for the method getTransferSize() and return -1 if they don't support it.

A DataSource instance is created by providing the location of the media to its constructor: DataSource(String locator). The locator parameter is specified in a Uniform Resource Identifier (URI) (*http://www.ietf.org/rfc/rfc2396.txt*) syntax—<scheme>:<scheme-specific-part>—which delineates the delivery protocol, the location of the media file, and its name. You are already familiar with HTTP for accessing files, which provides an easy example:

```
http://www.mmapibook.com/resources/media/audio/chapter2/siren.wav
```

where http refers to the protocol, http://www.mmapibook.com/resources/media/audio/chapter2 to the location, and siren.wav to the name of the file. Appendix B gives an overview of this syntax.

Player Basics

The Player interface is your handle to playing and managing your multimedia data. It provides methods to render, control, and synchronize the data with other players, and listen to player events such as starting, stopping, and pausing the data.

All media types, except for simple tones, require a Player instance for playback and control. A media type is mapped to a Player instance that can handle its playback by evaluating the extension of the file that contains the multimedia data and mapping it to a MIME type. For example, if you wanted to play an audio file with the wav extension, a Player instance that can handle the MIME type audio/x-wav is created. Similarly, a file with an mp4 extension results in the creation of a Player instance that can play video/mp4. In the next section, you'll learn about the Manager class that does this mapping between MIME types and Player instances.

Player instances are independent of the media type that they are playing and only depend on the implementation provided by the device manufacturer. This allows you to use generic methods to manipulate this data. So to start the playback of *any* multimedia data, you use the start() method, which starts playback as soon as possible. To pause, you use the stop() method, which pauses the playback. To close the data and release any resources associated with it, you use the close() method, and so on. Chapter 4 will introduce you to all the methods that you can use to control media playback.

If you are creating a multimedia MIDlet that is responsible for simultaneously playing multiple Player instances, you will run into synchronization issues, for example, making sure that video playback starts simultaneously with a separate audio track. In such cases, synchronizing different Player instances can be a problem without a timing reference. Each Player instance has a way to measure time using the TimeBase interface. This interface provides a constantly ticking source of time, and each Player instance has a default TimeBase instance built in. You can access this default instance by using the method getTimeBase(); you can override this default instance with your own implementation by using the setTimeBase(TimeBase base) method. To synchronize two Player instances so that they use the same TimeBase, you can use player2.setTimeBase(player1.getTimeBase()) code. To reset a Player instance's TimeBase, you can pass a null value to the setTimeBase(TimeBase base) method.

Player instances generate events during different stages of their working. By implementing the PlayerListener interface, you can receive notifications of these asynchronous events. This interface defines several common events, but you can create your own proprietary events as well. Chapter 4 discusses the event management of Player instances in detail.

Understanding the Manager Class

The Manager class in the javax.microedition.media package provides developers access to Player instances. These Player instances, as you already know, source their data from DataSource instances. In a nutshell, a Manager class is a bridge between a DataSource and a corresponding Player instance. Figure 2-1 shows this relationship.

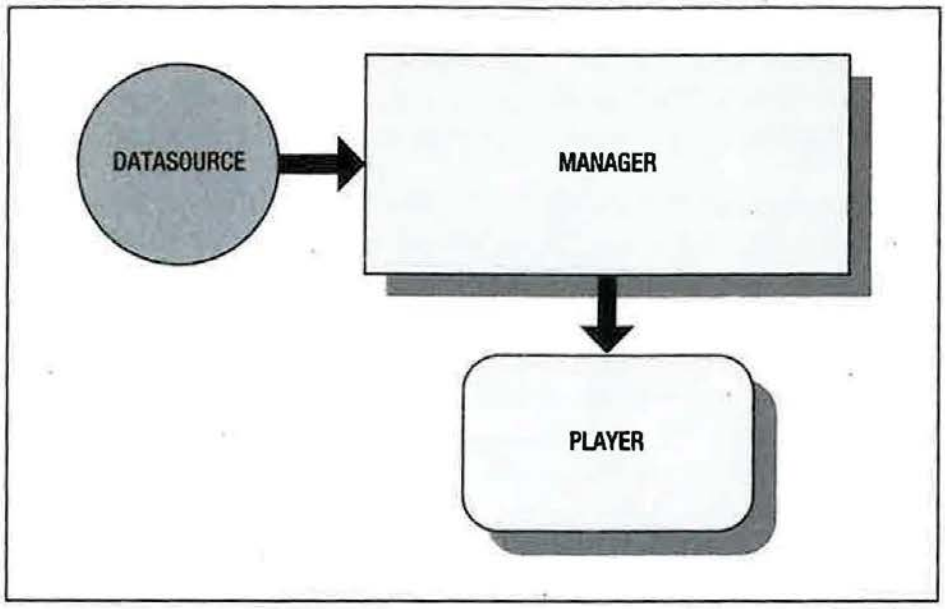


Figure 2-1. *The* `Manager` *class is the bridge between a* `DataSource` *and a* `Player`.

Creating `Player` Instances

Using methods of the `Manager` class is the only way to create `Player` instances in MMAPI. To this end, this class provides three such methods. Not surprisingly, all the methods are called `createPlayer()` and are static. The methods differ in the way the location of the multimedia data is provided to them.

As expected, `createPlayer(DataSource source)` is one of these methods. You create an instance of a `DataSource` using the `DataSource(String locator)` constructor and pass this to the `createPlayer()` method. The other two methods eventually call this method internally to create the `Player` instance.

You are more likely to use the `createPlayer(String locator)` method because it is more convenient than the previous method. Instead of having to create a `DataSource`, you only specify the location of the multimedia data using the `locator` parameter. The method internally translates it into a `DataSource` and creates a `Player` that is suitable for handling the multimedia content.

The third method, `createPlayer(InputStream is, String type)`, provides a slightly different way of creating players. It allows you to create an `InputStream` on the data and specify the content type of the data yourself, because the MIME type of the data cannot be determined with file extensions. This method has a further disadvantage because by using an `InputStream` instead of a `SourceStream`, it disallows random seek operations within the multimedia data. `Player` instances created with this method are not likely to support such operations.

Creating Player Instances for MIDI and Tone Sounds

Some Player instances do not require a physical file or location. For example, when you create a MIDlet that will play tones or Musical Instrument Digital Interface (MIDI) sounds, you need to tell the device to use its built-in MIDI synthesizer to play these sounds based on a supplied MIDI or tone sequence. The Manager class provides constants for creating Player instances based on these requirements. Table 2-2 gives details of these constants.

Table 2-2. *MIDI and Tone* Player *Constants*

Constant Name	Constant Value	Content Type	Usage
MIDI_DEVICE_LOCATOR	device://midi	audio/midi	Manager.createPlayer (Manager.MIDI_DEVICE_LOCATOR)
TONE_DEVICE_LOCATOR	device://tone	audio/x-tone-seq	Manager.createPlayer (Manager.TONE_DEVICE_LOCATOR)

You can still create MIDI and tone Player instances by specifying physical locations for them. For example, to create a MIDI Player based on a physical file, the extension of the file should be either mid or kar. Similarly, for a tone Player instance the extension of the file should be jts.

Because most simple devices support tone generation, the Manager class goes one step further by providing a static method to play single tones: playTone(int note, int duration, int volume). This provides a handy method that plays a single note for the specified duration and at the specified volume. Chapter 6 covers tone playing in detail.

Supported Protocols and Content Types

With MMAPI development for disparate devices, it becomes imperative to know beforehand what protocols are supported and what multimedia content can be rendered by the target device. The Manager class provides two methods that can help you understand the capabilities of a target MMAPI implementation.

The static getSupportedContentTypes(String protocol) method provides a list of all supported content types for a particular protocol. If you pass a null parameter to this method, it will give you a list of all content types supported by this device's MMAPI implementation. The static getSupportedProtocols(String contentType) method does the opposite; given a content type, it tells you all the protocols over which it can be accessed. If you pass a null parameter to this method, it will give you a list of all protocols supported by the device's MMAPI implementation.

Table 2-3 lists the output of running these methods on three different environments.

Table 2-3. *Supported Protocols and Content Types on Different MMAPI Implementations*

Method	Sun Java Wireless Toolkit 2.3	Motorola C975 Emulator	Motorola C975 Actual Device
getSupported ContentTypes (null)	audio/x-tone-seq, audio/x-wav, audio/midi, audio/sp-midi, image/gif, video/mpeg,← video/vnd.sun.rgb565	audio/x-wav audio/x-tone-seq audio/midi video/mng video/x-rgb	audio/amr, audio/x-amr, audio/amr-wb audio/x-amr-wb, audio/mp4, audio/x-mp4, audio/3gp, audio/mp3, audio/x-mp3, audio/mpeg3, audio/x-mpeg3, audio/mpeg, audio/x-mpeg, audio/mpg, audio/x-mpg, audio/wav, audio/x-wav, audio/au, audio/x-au, audio/basic, audio/asf, audio/x-ms-wma, audio/x-pn-realaudio, audio/midi, audio/x-midi, audio/mid, audio/x-mid, audio/sp-midi, audio/mobile-xmf, audio/imelody, audio/ x-imelody, audio/imy, audio/x-imy, text/ x-imelody, audio/ x-tone-seq, video/mp4, video/x-mp4, video/3gp, video/asf, video/x-ms-asf, video/x-ms-wmv, video/x-pn-realvideo, video/vnd.rn-realvideo, application/x-pn-realmedia, application/ vnd.rn-realmedia, image/gif, audio, video, camera
getSupported Protocols(null)	device, http, file, capture	http, https, device, capture	file, rtsp, http, https, device, capture
getSupported ContentTypes ("capture")	audio/x-wav video/vnd.sun.rgb565	audio/x-wav video/x-rgb	audio, video, camera
getSupported Protocols ("audio/x-wav")	http, file, capture	http, https, capture	file, rtsp, http, https

As you can see from Table 2-3, the supported protocols and content types vary greatly depending on the target device or emulator. Even though the emulator for Motorola C975 should support the same protocols and content types as the actual device, the difference is huge, especially for the supported content types. Actual device configurations vary greatly from their supposed emulators, and this is a typical result. Your MIDlets should always be tested on actual devices before bringing them into a production environment.

Understanding Controls

MMAPI defines `Control` objects that provide fine-grained control over the functionality of a `Player`. For example, if you have created a `Player` object to play an audio file, you will want to control its volume. Rather than provide volume control as a method in the `Player` interface, the interface `VolumeControl` is used. Volume is a type of control that is applicable to audio files, indeed to almost all multimedia files, but there may be several such individual controls that are exposed by individual media types. For example, `FramePositioningControl` is a control that is exposed by video players to control precise positioning of individual frames. The `Control` interface in `javax.microedition.media` package is used to abstract this concept.

MMAPI defines some standard controls in the `javax.microedition.media.control` package, but you are free to create your own controls by implementing the `Control` interface. The controls in the `javax.microedition.media.control` package are all defined as interfaces, and it is left for actual MMAPI implementations to provide concrete classes for them. Table 2-4 lists these controls and provides a brief explanation of each control.

Table 2-4. *Standard MMAPI Controls*

Control Interface	Description
`FramePositioningControl`	A control for video data that allows access to individual frames.
`GUIControl`	A control for data that requires a display, such as video.
`MetaDataControl`	Used to determine the metadata information stored within a media stream, such as title, copyright, author, and so on.
`MIDIControl`	A fully functional control that enables access to a device's MIDI player.
`PitchControl`	Used to control the pitch (frequency) of audio data.
`RateControl`	Used to control the playback rate of a `Player`.
`RecordControl`	Allows you to control the recording of data from a capture device, such as video from a camera or audio from a sound recorder.
`StopTimeControl`	A control that allows you to set a preset time when you want the `Player` to stop playing.
`TempoControl`	Similar to `RateControl`, this control allows you to change the tempo (speed) of playback for an audio `Player`, typically, a MIDI `Player`.
`ToneControl`	A fully functional control that allows you to play monotonic tone sequences.
`VideoControl`	Extends `GUIControl` and controls the display of video.
`VolumeControl`	The simplest control that allows you to control the volume of audio in a `Player`.

To get a list of controls that a `Player` instance exposes, use the method `getControls()` on the `Player` instance. To get to an actual control, use the method `getControl(String controlType)` and pass to it the name of the control interface. For example, to access the `VolumeControl` on a `Player`, you can use the method `getControl("VolumeControl")`. These methods are not defined in the `Player` interface, but the `Controllable` interface that the `Player` interface implements. As a point of interest, both `SourceStream` interface and the `DataSource` abstract class implement the `Controllable` interface, which gives you access to type-specific controls, if available.

As you may expect, some Player instances may expose multiple controls. For example, a Player created to handle video data will expose both a VideoControl and a VolumeControl at the very least. An audio player may expose a VolumeControl, a RateControl, a PitchControl, and a ToneControl. Some Player instances may support no controls, in which case, getControls() returns a zero length array (and not a null value).

After you have access to a control, you have access to the behavior of that control (and control of the underlying multimedia data). Each control is different in terms of its behavior and exposes methods that manipulate this behavior. For example, FramePositioningControl has a method called seek(int frameNumber) that when invoked on a video Player, renders the specified frame in the video on to the display. The method skip(int framesToSkip) skips the given number of frames from the current video position. Similarly, other controls define their own methods that best allow you to manipulate the underlying multimedia data. Detailed descriptions of the controls listed in Table 2-4 are scattered throughout this book.

The MIDP 2.0 Subset

MMAPI is an optional package, which means that device manufacturers may choose not to include an implementation for it in their devices. However, if the profile on a device is MIDP 2.0, then the device includes a subset of MMAPI. This subset was created to provide a base common MMAPI implementation for the MID 2.0 profile.

This subset was created to solve two problems: (1) resource constrained devices do not have enough processing power to display video-based multimedia data, and (2) even if these devices were powerful enough, they would be constrained in terms of the size of a MMAPI implementation. To support extensive processing and multiple multimedia data formats, the size of a MMAPI implementation can be large.

To solve these problems, the MIDP 2.0 subset of MMAPI ignores some of the requirements of the complete set. Although still a forward compatible version of MMAPI, it ignores some of the controls and provides a scaled-down version of the Manager class. Table 2-5 lists how the MIDP 2.0 subset differs from the complete MMAPI implementation

Table 2-5. *MIDP 2.0 MMAPI Subset Features*

Feature	Description
Audio only	The subset only supports audio-based data. Thus, no video-based controls, such as VideoControl, GUIControl, or FramePositioningControl, are present, and any content type that is video-based is ignored.
No MIDI support	Even in audio, only simple tones and sampled audio is supported, ignoring MIDI. Thus MIDIControl is absent and only ToneControl and VolumeControl is provided.
No support for synchronization	The subset is missing the TimeBase interface, and the Player interface is without the setTimeBase() and getTimeBase() methods. Thus, multiple Player instances cannot be synchronized to play back simultaneously.
No support for recording	Even for audio data, recording and capturing are not enabled, and thus RecordControl is absent.
No support for controlling the rate of audio playback	TempoControl and RateControl are absent.

Feature	Description
Controlling audio frequency is not supported	`PitchControl` is absent.
Other missing controls	`StopTimeControl` and `MetaDataControl` are also not supported.
No support for custom protocols	The `javax.microedition.media.protocol` package is excluded. The `Manager` class, therefore, does not include the `createPlayer(DataSource source)` method.

These features make the subset a lightweight implementation that meets the design goals of MIDP 2.0, including support for low footprint audio playback functionality in MIDlets, support for tone generation, and consistent media playback options. At the same time, the subset maintains upward compatibility with the MMAPI specification and is a true subset.

Feature Set Implementations

With intrinsic support for such a diverse range of features, protocols, and file formats, MMAPI is a truly flexible specification. It doesn't mandate support for any formats but allows device manufacturers to build in support for formats that they deem fit. However, with this flexibility, application development becomes a bit more difficult. You can query for a device implementation to give you a list of supported protocols and formats, but are you guaranteed that it will behave how you expect it to?

To alleviate this concern and to bring about some uniformity in the way multimedia data is controlled, MMAPI specification defines feature sets. A *feature set* is a grouping of multimedia data that has some common features. The API defines required and expected behavior for each feature set if the feature set is implemented by a device manufacturer's implementation. This way, if you are developing applications that target a particular feature set, you are guaranteed that it will behave by exposing controls that are similar across different manufacturers.

The simplest feature set is called *sampled audio*. As far as MMAPI is concerned, sampled audio refers to any audio data that is digital in its format, ignoring its origin. If a device supports sampled audio, it *should* implement the `VolumeControl` and `StopTimeControl` interfaces. Note the emphasis on should, which implies that this is a recommended practice, which barring any adverse circumstance, must be implemented. The MIDP 2.0 MMAPI subset is good example. Because it supports sampled audio, it should implement both `VolumeControl` and `StopTimeControl`; however, it only implements `VolumeControl` and ignores `StopTimeControl`.

MIDI is the next feature set. If a device's MMAPI implementation declares that it supports the MIDI feature set, which means that it allows you to play external audio files with extensions of `mid` or `kar`, it *should* implement `VolumeControl`, `MIDIControl`, `TempoControl`, `PitchControl`, and `StopTimeControl`. Again, notice the emphasis on should. Although there's no guarantee that the device will support all these controls, there's a good chance that it will.

The *Tone Sequence* feature set is the first set that mandates a "must" requirement. If a device allows you to play tone sequences, it *must* implement the `ToneControl` interface. If the device doesn't implement this interface, then it does not conform to the MMAPI specification. The Tone Sequence feature set is applicable to `Player` instances that are created using the `Manager.createPlayer(Manager.TONE_DEVICE_LOCATOR)` method.

Similar to the Tone Sequence set, the *Interactive MIDI* feature set is applicable to `Player` instances that are created using the `Manager.createPlayer(Manager.MIDI_DEVICE_LOCATOR)`

method, which allows you to create MIDlets that directly manipulate the device's MIDI player. This feature set *must* implement the `MIDIControl` interface.

Finally, the *video* feature set applies to all video data. If video is supported by a device's MMAPI implementation, it *must* allow you to control the video with the `VideoControl` interface. The implementation *should* also support `FramePositioningControl`, the `StopTimeControl`, and the `VolumeControl`, but it doesn't have to. If it doesn't support the last three controls, but supports `VideoControl`, it is still an MMAPI-compliant implementation.

Security Architecture

As you now know, MMAPI does not work in isolation; it is an add-on or optional package that works on top of a profile. In this book, we are concerned with exploring MMAPI for the profile for small devices, MIDP 2.0; however, as explained in Chapter 1, MMAPI can be run on any compatible profile and configuration.

The capability to acquire and render multimedia data on any profile or configuration, even with an optional package such as MMAPI, creates a few problems with the security architecture of the device in question. The device must be able to control certain aspects of the multimedia process, such as recording using a camera and microphone for devices that have them. Similarly, the network and device's file system should be accessed only by a permission-based model.

Keeping these issues in mind, MMAPI allows control over the methods that are security sensitive. However, the specification does not dictate a particular architecture, and leaves it to specific implementations to work out the exact details, much like the interfaces that it describes for `Player` and `Control` objects.

Methods that are security conscious throw a `SecurityException` if permission to run that method has not been granted. Table 2-6 lists all these methods, the classes/interfaces they reside in, and the permissions required to make them run.

Table 2-6. *Security Conscious Methods*

Method Name	Method Class/ Interface	Permission Required
`setRecordLocation(String locator)`	`RecordControl`	`javax.microedition.media.control.RecordControl`
`setRecordStream (OutputStream stream)`	`RecordControl`	`javax.microedition.media.control.RecordControl`
`getSnapshot(String type)`	`VideoControl`	`javax.microedition.media.control.VideoControl.getSnapshot`
`createPlayer(String locator)`	`Manager`	
`createPlayer(InputStream is, String type)`	`Manager`	
`createPlayer(DataSource source)`	`Manager`	
`realize()`	`Player`	
`prefetch()`	`Player`	
`start()`	`Player`	
`start()`	`DataSource`	
`connect()`	`DataSource`	

Permissions are granted by the profile that MMAPI is running in. This is, in turn, either inherently built in the profile—for example, if recording is not supported at all then permissions will be false irrespective of any other conditions—or requested from the user running an application on the device to explicitly enable them.

As you may expect, the first three methods in Table 2-6 relate to privacy issues. An application must not start recording, even if the underlying device can record, without an explicit permission from the user of the application. The rest of the methods are related with general security issues of network access for data retrieval and depend on the protection domain that the MIDlet is running in. If data has to be retrieved over HTTP, then the user must be asked if transmission over the network is permitted, as it may result in charges billed to the user.

For HTTP/HTTPS access, the required permissions are `javax.microedition.io.Connector.http` and `javax.microedition.io.Connector.https`, respectively. Permissions are specified in the descriptor file (the Java Application Descriptor or JAD file) for the MIDlet and can be granted to a signed MIDlet. Refer to *Beginning J2ME* by Knudsen and Li (Apress, 2005) for an understanding of the process required for enabling permissions in Java ME. Chapter 5 also contains a detailed example of this process.

Summary

The MMAPI architecture was purposefully built to be extensible and not cater to a particular format or protocol. `DataSources`, `Players`, and `Controls` make the MMAPI a very flexible API that gives freedom to its implementers to support any media types, and at the same time, be true to the contract specified between the MMAPI interfaces.

This chapter explained this contract by specifying the MMAPI architecture. You saw the way the interfaces interact with each other and how device manufacturers can implement them. Using three different MMAPI implementations, you saw the different contents and protocols that they supported and how they still provided support for the basic MMAPI/MIDP 2.0 subset. Finally, you understood the security issues involved in using the libraries and classes of MMAPI.

The next chapter will leave the theory of MMAPI behind for a moment to introduce your very first media player using MMAPI.

CHAPTER 3

Getting Started with MMAPI

By now, you know that MMAPI is an optional API for building multimedia-enabled MIDlets. You also know that creating a MMAPI application requires knowledge of not just the MMAPI architecture, but also the MIDlet architecture, which you should be well conversant with. MMAPI MIDlets don't require any modifications to the way MIDlets are created, and basic architectural knowledge of the API is enough to get you started creating the simplest of multimedia MIDlets. You have already learned about the architecture in Chapter 2, and in this chapter, you'll use this knowledge to create two simple MMAPI MIDlets.

The first MIDlet is an example of the simplest MMAPI MIDlet that can be created. It plays an audio file and shows basic interaction between the `Manager` class and the `Player` interface. The second MIDlet is much more advanced and shows the interplay between the `Manager` class and the `Player` and the `Control` interfaces.

Both MIDlets will give you grounding in MMAPI MIDlet creation. Consider them as the Hello World MIDlets of the MMAPI world.

A Simple Multimedia Player

The simplest MMAPI MIDlet that can be built allows you to easily play a multimedia file from within your MIDlet without worrying about controls, feature sets, or security architecture. If all you're doing is adding some sampled audio (or any other media) in a game, MMAPI allows you to do so in two lines of code. Listing 3-1 shows this code within a complete MIDlet.

Listing 3-1. *A Simple MMAPI MIDlet*

```
package com.apress.chapter3;

import javax.microedition.midlet.MIDlet;

import javax.microedition.media.Manager;
import javax.microedition.media.Player;

public class SimplePlayer extends MIDlet {

  public void startApp() {
```

```
    try {

      Player player =
        Manager.createPlayer(
          getClass().getResourceAsStream("/media/audio/chapter3/baby.wav"),
          "audio/x-wav");

      player.start();

    } catch(Exception e) {
      e.printStackTrace();
    }
  }

  public void pauseApp() {
  }

  public void destroyApp(boolean unconditional) {
  }
}
```

To keep things simple at this stage, the media file is played by creating an `InputStream` on a wav file, which is embedded in the MIDlet's JAR. This media file is kept in the folder `media/audio/chapter3` and is called `baby.wav` (which is the sound of a baby crying).

Of course, you don't need to play an audio file only. You can substitute the wav file with a video file, provided the emulator supports the format of the video file. The video will not show anywhere, because this listing doesn't provide a mechanism to show the video. You can substitute the wav file for a midi, tone, or any other supported audio format. The point is that playing multimedia files using the MMAPI is as simple as creating a `Player` instance using the `Manager` class and calling method `start()` on it.

Let's analyze the two lines that make up the core of this MIDlet.

```
Player player = Manager.createPlayer(
 getClass().getResourceAsStream("/media/audio/chapter3/baby.wav"),   "audio/x-wav");
```

A `Player` instance is created here using the `Manager` class's `createPlayer(InputStream is, String contentType)` method. Simpler still would have been to use the `createPlayer(String locator)` method, which would let the `Manager` class figure out the content type of the audio file. However, using this method would have required specifying a protocol to access the file. Because the file is stored in the MIDlet's JAR file, there is no protocol to access it directly. If the multimedia file had been stored on the Internet or the emulator/device's local file system, you could have used either `http://<url-to-file>` or `file:///<file-location>` (if the optional `FileConnection` API [JSR 75] is supported by the device), respectively. However, to access files over these protocols would require explicit permission from the user or a signed MIDlet requesting these permissions, and therefore, this example would not remain simple anymore.

Note Some devices support the `resource` protocol for accessing files stored in a JAR file. In such devices, you can use `resource://media/audio/chapter3/baby.wav` or similar to create a locator for a media file. However, because this support is not universal, use it only if you are confident that the target device(s) will understand it.

The second line of code,

```
player.start();
```

is where the `Player` instance gets to start playing the media file. A lot of things happen behind the scenes when you call this method, but effectively, the media file will play back as soon as possible when this method is called. The method returns as soon as the media has started playing. The `start()` method is also used to resume playback of a media file that was previously paused (or had stopped because it had reached its end), with playback starting at the point where the media was paused.

Both the lines of code described previously throw several exceptions. Although Listing 3-1 ignores the individual exceptions, you can catch them and deal with them individually. Table 3-1 shows a list of these exceptions and information on which method throws what exception.

Table 3-1. *Exceptions Thrown Playing a Media File Using MMAPI*

Exception	Thrown By	Description
`IllegalArgumentException`	`createPlayer(String InputStream, String type)` `createPlayer(String locator)` `createPlayer(DataSource source)`	Thrown if the `InputStream`, locator, or `DataSource` is null.
`MediaException`	`createPlayer()`—all three variants	Thrown if a `Player` instance cannot be created for the given stream and type, `DataSource`, or locator, possibly because the protocol and/or the format is not supported.
`IOException`	`createPlayer()`—all three variants	Thrown if connection to the source of the media file encounters a problem, such as network congestion, corrupt file, and so on.
`SecurityException`	`createPlayer()`—all three variants	Thrown if permission to create a `Player` instance has not been granted to the calling MIDlet.
`IllegalStateException`	`start()`	Thrown if the `Player` instance cannot be started because it has been closed. More about `Player` states appears in Chapter 4.

Continued

Table 3-1. *Continued*

Exception	Thrown By	Description
`MediaException`	`start()`	A catchall exception that is thrown if the `Player` instance can't be started because of any number of reasons.
`SecurityException`	`start()`	The calling MIDlet may have permission to create the `Player` instance but not to start it, in which case, it throws this exception.

After a `Player` instance has been started, it can be paused, closed, restarted, played repeatedly, and controlled by instances of the `Control` interface. A `Player` also fires information about various events that can be listened to and appropriate activities performed based on these events. Chapter 4 will cover handling `Player` events and the lifecycle of a `Player` instance. For now, let's create a slightly advanced `Player` instance that can be paused, restarted, played in a loop, and closed.

Creating a Functional Player

Listing 3-1 created a very basic `Player` instance. In this section, you'll learn to create a slightly more advanced and functional `Player` that allows you to select a media file to play from a list and gives you control over the volume.

Before we get into the actual code, let's look at Figure 3-1, which shows the finished MIDlet, called `AudioPlayer`, in operation using the Sun Java Wireless Toolkit 2.3 DefaultColorPhone emulator, the Motorola C975 emulator, and the Motorola C975 actual device.

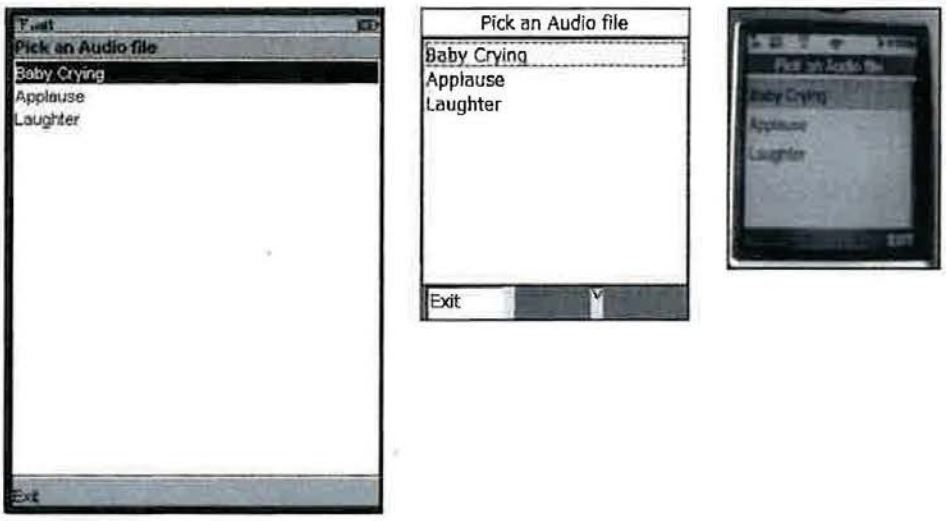


Figure 3-1. *AudioMIDlet shows list of audio files on Sun's DefaultColorPhone emulator, Motorola C975 emulator, and Motorola C975 device.*

The MIDlet shows a list of three audio files that the user can select and play. Figure 3-2 shows the resulting screens when the user selects one of these files.

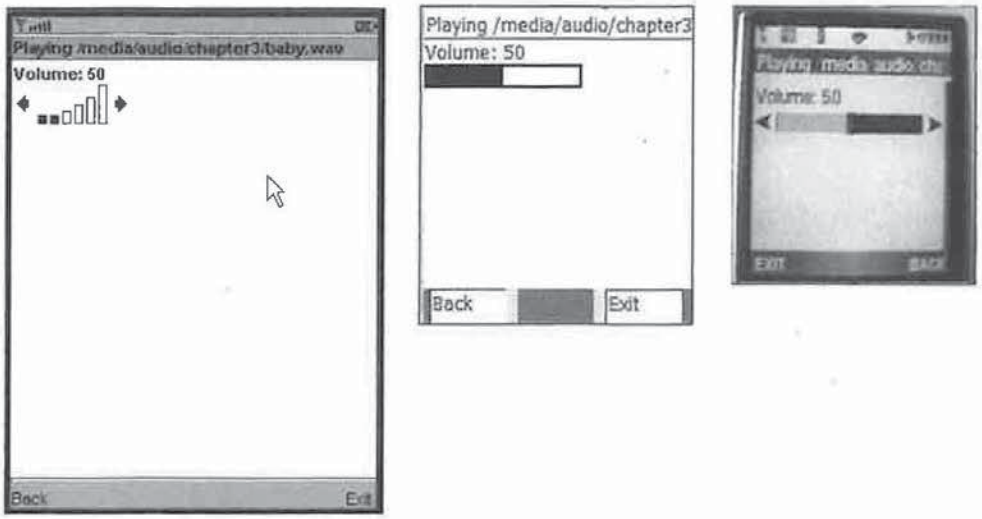


Figure 3-2. *Playing* `baby.wav` *in Sun's DefaultColorPhone emulator,* `applause.wav` *in Motorola C975 emulator, and* `laughter.wav` *in Motorola C975 device*

When a file is selected from the list, a new screen shows the actual file name and location, plays this file, and allows the user to control the volume of the playback. This volume control is rendered on the screen using a `Gauge` item. The user can use this gauge to increase or decrease the volume, and the actual volume level is reflected on the screen. The user can also choose to go back to the audio list or exit from the MIDlet. The audio file is played twice unless the user exits or goes back to the list before that.

Writing the Code

The code for this MIDlet is divided into two files: `AudioPlayer` and `AudioPlayerCanvas`. `AudioPlayerCanvas` is responsible for the canvas that the user sees when an audio file is being played and allows the user to increase or decrease the volume. More importantly, it manages the playing of the audio files and their lifecycle when they are paused or stopped. `AudioPlayerCanvas` is shown in Listing 3-2.

Listing 3-2. `AudioPlayerCanvas`*—an Interface for Playing Audio Files*

```
package com.apress.chapter3;

import javax.microedition.lcdui.*;
import javax.microedition.media.*;
import javax.microedition.media.control.*;

public class AudioPlayerCanvas implements ItemStateListener {

  // the parent MIDlet
  private AudioPlayer parent;
```

```
// form that contains canvas elements
private Form form;

// gauge to allow user to manipulate volume
private Gauge gauge;

// the volume control
private VolumeControl volume;

// the player used to play media
private Player player;

// is the player paused?
private boolean paused = false;

public AudioPlayerCanvas(AudioPlayer parent) {

  this.parent = parent;

  // create form and add elements and listeners
  form = new Form("");
  gauge = new Gauge("Volume: 50", true, 100, 50);
  form.append(gauge);
  form.addCommand(parent.exitCommand);
  form.addCommand(parent.backCommand);
  form.setCommandListener(parent);

  // a change in volume gauge will be handled by this class
  form.setItemStateListener(this);
}

public void playMedia(String locator) {

  try {

    // create the player for the specified string locator
    player = Manager.createPlayer(
      getClass().getResourceAsStream(locator), "audio/x-wav");

    // realize it
    player.realize();

    // get the volume control
    volume = (VolumeControl)player.getControl("VolumeControl");

    // initialize it to 50
    volume.setLevel(50);
```

```
        // initialize the gauge
        gauge.setValue(volume.getLevel());
        gauge.setLabel("Volume: " + volume.getLevel());

        // play it twice
        player.setLoopCount(2);

        // start the player
        player.start();

        // set the title of the form
        form.setTitle("Playing " + locator);

      } catch(Exception e) {
        e.printStackTrace();
      }

    }

    public void pauseMedia() {

      // if the player needs to be paused, either due to an incoming call,
      // or due to user actions
      if(player != null) {
        try {
          player.stop();
          paused = true;
        } catch(Exception e) {}
      }
    }

    public void restartMedia() {

      // restarting after player was paused
      if(player != null) {
        try {
          player.start();
          paused = false;
        } catch(Exception e) {}
      }
    }

    public boolean isPlayerPaused() {
      return paused;
    }

    public Form getForm() {
      return this.form;
```

```
    }

    public void itemStateChanged(Item item) {

      // there is only one item on the form, the gauge, and any change in its
      // value means the user wants to increase or decrease the playback volume
      volume.setLevel(gauge.getValue());
      gauge.setLabel("Volume: " + volume.getLevel());
    }

    public void cleanUp() {

      // clean up, either due to user action or AMS call
      if(player != null) {
        player.close();
        player = null;
      }
    }
}
```

AudioPlayerCanvas creates a Form that displays the volume control and allows the user to interact with it. It attaches a Gauge to this Form for the volume control and adds the back and exit commands to the Form. These commands are created in the parent, which is the main MIDlet class AudioPlayer, shown in Listing 3-3. However, the canvas takes care of any changes to the Gauge (and consequently to the volume of a Player instance) by implementing the itemStateChanged(Item item) method.

A Player instance is created when the parent MIDlet calls the playMedia(String locator) method on this canvas. This method attempts to create a Player instance by using the createPlayer(InputStream is, String contentType) method, guessing the content to be of type audio/x-wav. The next step after a successful player creation is the realization of the player, which is done by calling player.realize(). You'll learn more about realization in Chapter 4, but suffice to say at this point that after a Player instance has been realized, it can expose any controls that may be associated with it. Thus, you couldn't have accessed the VolumeControl associated with the player without actually realizing the player. This VolumeControl is used to initialize the Gauge besides allowing the user to control the volume in the itemStateChanged (Item item) method.

By calling player.setLoopCount(2), the player plays the audio file twice. By default, this value is set to 1, and if you wanted to play the file indefinitely, you could set this value to -1. Setting this value to 0 will result in an IllegalArgumentException. The loop count must be set before the start() method is called or rather when the Player instance is in a paused state; otherwise, an IllegalStateException will be thrown.

The Player instance is paused in the pauseMedia() method, which calls the stop() method to pause the media at the current media time. The next time the player is started, or rather, restarted, it will resume from the same media time. This occurs when the restartMedia() method is called, where the audio file's playback is restarted by a call to the start() method on the Player instance. Although this example does not allow the user to pause or restart the playback explicitly by way of commands, this behavior can be easily simulated by an incoming phone call when this MIDlet is being run.

The final noteworthy method is the `cleanUp()` method that closes each `Player` instance after it is no longer required. This method is called any time the user issues the `exit` or `back` commands. Calling `close()` on a `Player` instance releases any resources held by the player (including the audio file and the audio device, such as a speaker). After a `Player` instance has been closed, it can no longer be used.

In a nutshell, the `Player` instance is created when the `playMedia()` method is called with the location of the media file. This instance, if successfully created, is then realized, which allows it to expose the `VolumeControl`. This control is initialized and shown on a canvas to the user to interact with. Finally, the `Player` instance is started by calling the `start()` method. The `Player` instance is paused and restarted in the `pauseMedia()` and `restartMedia()` methods, respectively. The `cleanUp()` method closes the `Player` instance.

The actual MIDlet code is written in the `AudioPlayer` class. Listing 3-3 shows the code for this class.

Listing 3-3. `AudioPlayer` MIDlet *Creates* `AudioPlayerCanvas`

```
package com.apress.chapter3;

import javax.microedition.midlet.*;
import javax.microedition.lcdui.*;

public class AudioPlayer extends MIDlet implements CommandListener {

  // the list of media names
  private String[] audioDisplayList =
    {"Baby Crying", "Applause", "Laughter"};

  // the list of media locations
  private String[] audioList        =
    {"/media/audio/chapter3/baby.wav",
     "/media/audio/chapter3/applause.wav",
     "/media/audio/chapter3/laughter.wav"};

  protected Display display;
  private AudioPlayerCanvas canvas;
  private List list;

  protected Command exitCommand;
  protected Command backCommand;

  public AudioPlayer() {

    // initialize the list and add the exit command
    list = new List(
      "Pick an Audio file", List.IMPLICIT, audioDisplayList, null);
    exitCommand = new Command("Exit", Command.EXIT, 1);
    list.addCommand(exitCommand);
    list.setCommandListener(this);
```

```
    // the back command
    backCommand = new Command("Back", Command.BACK, 1);

    // create the canvas
    canvas = new AudioPlayerCanvas(this);

    // and initialize the display
    display = Display.getDisplay(this);
  }

  public void startApp() {

    // if startApp() is called after MIDlet has been paused
    if(canvas.isPlayerPaused()) {

      // restart the player
      canvas.restartMedia();
      display.setCurrent(canvas.getForm());
    } else {

      // else display the audio list
      display.setCurrent(list);
    }
  }

  public void pauseApp() {
    // pauses the playing of the player, if any
    canvas.pauseMedia();
  }

  public void destroyApp(boolean unconditional) {
    // cleans up and closes player, if any
    canvas.cleanUp();
  }

  public void commandAction(Command command, Displayable disp) {

    // exiting the MIDlet
    if(command == exitCommand) {
      canvas.cleanUp(); // clean up, if any
      notifyDestroyed(); // let AMS know clean up is done
      return;
    } else if(command == backCommand) { // back to the list
      canvas.cleanUp();
      display.setCurrent(list);
      return;
    }
```

```
        // the implicit list handling
        if(disp == list) {

          // play the current selected file
          canvas.playMedia(audioList[list.getSelectedIndex()]);

          // display the canvas's form
          display.setCurrent(canvas.getForm());
        }
      }
    }
```

The AudioPlayer constructor creates a List of audio files, adds the exitCommand to it, and initializes the current display for the MIDlet. It also creates the player canvas of Listing 3-2 (earlier in this chapter). When the MIDlet is started using the startApp() method, the method checks whether the player canvas was playing any media. If the player canvas was startApp() the method restarts the media. If nothing was being played, and presumably this would be the case the first time the MIDlet is run, the list of audio files is displayed for the user to select from.

After the user selects a file from the list, the implicit list handling takes over and selects the location of the actual audio file from the String array audioList. It then proceeds to call the playMedia() method on this location and sets the Form instance created by the canvas as the main display.

If the user issues either the back or exit commands, the canvas is told to clean up by calling the cleanUp() method before acting appropriately. The same is true when the Application Management Software (AMS) calls the destroyApp() method; cleanup is done before quitting by calling the cleanUp() method. When the MIDlet needs to be paused by the AMS by invoking the pauseApp() method, the pauseMedia() method is called.

Improving AudioPlayerCanvas: Caching Player Instances

One problem is obvious with the AudioPlayerCanvas class: It creates new instances of the Player interface each time a request to play an audio file is received, even if the audio file has been played before. This happens in the playMedia() method. Creating objects is an expensive task, especially multimedia objects such as Player instances. Performance can be improved by caching Player instances that do not need to change. For examples like this, where the media file and its location do not change and especially media stored in the MIDlet's JAR file, caching Player instances is an obvious choice.

However, caching Player instances is not an easy task. In Chapter 4, you'll learn about the various states of a Player instance. If an instance is cached, it must be cached so that the next time it is played, it starts in the right state. Also, when an instance is started, it acquires resources on the device. For example, audio files acquire access to the audio device (speakers, in-memory buffers, and so on) on a multimedia device. These resources must be released before the instance is cached so that other instances can acquire exclusive access.

Let's modify the commandAction() method from the AudioPlayer MIDlet in Listing 3-3 to find out the time taken to play one of the audio files (baby.wav). The following snippet shows the changes in bold.

```
long t1 = System.currentTimeMillis();

// play the current selected file
canvas.playMedia(audioList[list.getSelectedIndex()]);

long t2 = System.currentTimeMillis();

canvas.getForm().setTitle("Time taken: " + (t2-t1) + " ms");
```

The title of the canvas's form is changed to reflect the time taken to start playing a listing in milliseconds. Table 3-2 now shows the time taken to play the file `baby.wav` three times over the different devices: Sun's DefaultColorPhone emulator, Motorola C975 emulator, and the actual Motorola C975 device.

Table 3-2. *Time Taken to Start Playback of* `baby.wav` *Across Three Devices*

Device	1st Attempt	2nd Attempt	3rd Attempt
Sun's DefaultColorPhone	180ms	40ms	40ms
Motorola C975 emulator	100ms	10ms	10ms
Motorola C975 device	236ms	218ms	207ms

The values shown are reflective only and will be different on different machines and environments.

The fact that the emulators take a long time for the first attempt and much less time for the next two suggests that the emulators are performing some sort of caching themselves. The actual device doesn't seem to be doing any caching, and the times are pretty consistent for the device. However, the emulators aren't really performing any caching of `Player` instances, and the long startup delay suggests latency in acquiring audio device on the emulator's computer platform.

Let's now modify `AudioPlayerCanvas` to `CachedAudioPlayerCanvas` so that it caches `Player` instances and plays the cached instances when called upon (and creates them when called for the first time). Similarly, `AudioPlayer` will be modified to `CachingAudioPlayer` to use this new canvas class. Listing 3-4 shows `CachedAudioPlayerCanvas`.

Listing 3-4. `CachedAudioPlayerCanvas` *Caches* `Player` *Instances*

```
package com.apress.chapter3;

import java.util.*;
import javax.microedition.lcdui.*;
import javax.microedition.media.*;
import javax.microedition.media.control.*;

public class CachedAudioPlayerCanvas implements ItemStateListener {

  // the parent MIDlet
  private CachingAudioPlayer parent;
```

```
// form that contains canvas elements
private Form form;

// gauge to allow user to manipulate volume
private Gauge gauge;

// the volume control
private VolumeControl volume;

// the player used to play media
private Player player;

// is the player paused?
private boolean paused = false;

private Hashtable players;

public CachedAudioPlayerCanvas (CachingAudioPlayer parent) {

  this.parent = parent;

  // create form and add elements and listeners
  form = new Form("");
  gauge = new Gauge("Volume: 50", true, 100, 50);
  form.append(gauge);
  form.addCommand(parent.exitCommand);
  form.addCommand(parent.backCommand);
  form.setCommandListener(parent);

  // a change in volume gauge will be handled by this class
  form.setItemStateListener(this);

  players = new Hashtable();
}

public void playMedia(String locator) {

  try {

    // first look for an existing instance
    player = (Player)players.get(locator);

    if(player == null) {

      // create the player for the specified string locator
      player = Manager.createPlayer(
        getClass().getResourceAsStream(locator), "audio/x-wav");
```

```
        // fetch it
        player.prefetch();

        // put this instance in the Hashtable
        players.put(locator, player);
      }

      // get the volume control
      volume = (VolumeControl)player.getControl("VolumeControl");

      // initialize it to 50
      volume.setLevel(50);

      // initialize the gauge
      gauge.setValue(volume.getLevel());
      gauge.setLabel("Volume: " + volume.getLevel());

      // play it twice
      player.setLoopCount(2);

      // start the player
      player.start();

      // set the title of the form
      form.setTitle("Playing " + locator);

    } catch(Exception e) {
      e.printStackTrace();
    }
  }

  public void pauseMedia() {

    // if the player needs to be paused, either due to an incoming call,
    // or due to user actions
    if(player != null) {
      try {
        player.stop();
        paused = true;
      } catch(Exception e) {}
    }
  }

  public void restartMedia() {

    // restarting after player was paused
```

```
    if(player != null) {
      try {
        player.start();
        paused = false;
      } catch(Exception e) {}
    }
  }

  public boolean isPlayerPaused() {
    return paused;
  }

  public Form getForm() {
    return this.form;
  }

  public void itemStateChanged(Item item) {

    // there is only one item on the form, the gauge, and any change in its
    // value means the user wants to increase or decrease the playback volume
    volume.setLevel(gauge.getValue());
    gauge.setLabel("Volume: " + volume.getLevel());
  }

  public void cleanUp() {

    // clean up, either due to user action or AMS call
    if(player != null) {

      try {
        player.setMediaTime(0);
      } catch(Exception e) {}

      player.deallocate();
      player = null;
    }
  }

  public void closeAll() {
    // iterate through the player instances and close all
    for(Enumeration e = players.elements(); e.hasMoreElements();) {
      Player p = (Player)e.nextElement();
      p.close();
    }
  }
}
```

The major changes between AudioPlayerCanvas and CachedAudioPlayerCanvas are shown in bold. A Hashtable is used to cache Player instances, and the locator String is used as the key. When a request to play a particular audio file is made, the Hashtable is searched and an instance is used if found. Note that a VolumeControl is still constructed fresh for each instance.

Instead of using the realize() method, prefetch() is used when creating a Player instance for the first time. The purpose of these methods and the distinction between them will be explained in Chapter 4. Note that using prefetch() instead of realize() allows quicker startup time for media playback.

Similarly, the cleanUp() method is modified to use deallocate() rather than close(). Further, the media time is set to 0 to allow the media to be played back from the starting point of the file each time it is started. This is done by using the method setMediaTime(), which is like a fast-forward and rewind method for moving through the media. Player instances that don't support seek operations like this will throw a MediaException. In this case, calling this method is really only necessary for the Sun emulator, which does not reset the media time on deallocation.

Finally, a new method called closeAll() is added to allow the CachingAudioPlayer MIDlet to shut down all the Player instances before it is itself shut down.

Listing 3-5 shows the modified CachingAudioPlayer. Once again, the changes from Listing 3-3 are highlighted in bold.

Listing 3-5. CachingAudioPlayer *Uses the New* CachedAudioPlayerCanvas

```
package com.apress.chapter3;

import javax.microedition.midlet.*;
import javax.microedition.lcdui.*;

public class CachingAudioPlayer extends MIDlet implements CommandListener {

  // the list of media names
  private String[] audioDisplayList =
    {"Baby Crying", "Applause", "Laughter"};

  // the list of media locations
  private String[] audioList        =
    {"/media/audio/chapter3/baby.wav",
     "/media/audio/chapter3/applause.wav",
     "/media/audio/chapter3/laughter.wav"};

  protected Display display;
  private CachedAudioPlayerCanvas canvas;
  private List list;

  protected Command exitCommand;
  protected Command backCommand;

  public CachingAudioPlayer() {
```

```
    // initialize the list and add the exit command
    list = new List(
      "Pick an Audio file", List.IMPLICIT, audioDisplayList, null);
    exitCommand = new Command("Exit", Command.EXIT, 1);
    list.addCommand(exitCommand);
    list.setCommandListener(this);

    // the back command
    backCommand = new Command("Back", Command.BACK, 1);

    // create the canvas
    canvas = new CachedAudioPlayerCanvas(this);

    // and initialize the display
    display = Display.getDisplay(this);
  }

  public void startApp() {

    // if startApp() is called after MIDlet has been paused
    if(canvas.isPlayerPaused()) {

      // restart the player
      canvas.restartMedia();
      display.setCurrent(canvas.getForm());
    } else {

      // else display the audio list
      display.setCurrent(list);
    }
  }

  public void pauseApp() {
    // pauses the playing of the player, if any
    canvas.pauseMedia();
  }

  public void destroyApp(boolean unconditional) {
    // closes all players before shutdown
    canvas.closeAll();
  }

  public void commandAction(Command command, Displayable disp) {
```

```
        // exiting the MIDlet
        if(command == exitCommand) {
          canvas.closeAll(); // close all players
          notifyDestroyed(); // let AMS know clean up is done
          return;
        } else if(command == backCommand) { // back to the list
          canvas.cleanUp();
          display.setCurrent(list);
          return;
        }

        // the implicit list handling
        if(disp == list) {

          long t1 = System.currentTimeMillis();

          // play the current selected file
          canvas.playMedia(audioList[list.getSelectedIndex()]);

          long t2 = System.currentTimeMillis();

          canvas.getForm().setTitle("Time taken: " + (t2-t1) + " ms");

          // display the canvas's form
          display.setCurrent(canvas.getForm());
        }
      }
    }
```

Using the new version of these files, Table 3-3 shows the times taken to play baby.wav over the three different emulators/devices.

Table 3-3. *Time Taken to Play Back* baby.wav *with Caching of* Player *Instances*

Device	1st Attempt	2nd Attempt	3rd Attempt
Sun's DefaultColorPhone	180ms	30ms	30ms
Motorola C975 emulator	100ms	0ms	0ms
Motorola C975 device	202ms	14ms	14ms

Comparing Table 3-3 with Table 3-2 should show the obvious performance improvement that caching has brought about. The real gain is on the actual device, which is where it matters the most. The time to playback has been reduced to a consistent 14ms after an initial startup time of 202ms. The performance on the emulators is encouraging as well with reduction in playback time by about 10ms each over the noncached version.

Summary

Creating MMAPI-based multimedia MIDlets requires knowledge of not just MMAPI, but an understanding of the MIDlet creation process as well. The understanding required is nominal, as MMAPI MIDlets are no different from other MIDlets in terms of their architecture and process.

This chapter gave you a hands-on introduction to MMAPI by creating a simple media player. You enhanced the media player MIDlet by caching, and saw how the enhancement improved the performance of the original player.

The next chapter, on media player lifecycle and events, will explain what happens behind the scenes when the media player is used to play media files. You'll also see the various events that occur during a media player's lifecycle and how to respond and take advantage of this knowledge.

CHAPTER 4

Media Player Lifecycle and Events

As a MIDlet transitions between different states during its lifecycle, so does a `Player` instance that has a lifecycle of its own. A `Player` instance has many more states that it transitions between. These states are well defined, and transitions between them raise events that interested parties can listen to and respond accordingly.

In this chapter, you'll learn about these different states, the lifecycle of a `Player` instance, and how a `Player` instance transitions between these states. Finally, you'll learn how events generated during these transitions can be captured by interested listeners and acted upon.

Overview

A `Player` instance goes through five different states during its lifetime. The capability for an instance to go through these many states gives developers greater control over the working of an instance. These states are UNREALIZED, REALIZED, PREFETCHED, STARTED, and CLOSED.

A `Player` instance is guaranteed to go through all these states if started; that is, the instance is not just created but playback (or recording as the case may be) is initiated. Moving between states is not necessarily linear and can happen either due to programmatic control or some external or internal events. Movement from the CLOSED state to any other state is not possible.

Movement between different states results in events being fired for any listeners to act on. These events are delivered asynchronously and in the order that they are generated. The whole event delivery mechanism is extensible, which allows you to define application-specific events. Several system-level events are already defined that will satisfy most cases.

Exploring the Different `Player` States

MMAPI allows you to programmatically move between different states (except moving away from the CLOSED state). This gives you greater control over the way you manage the lifecycle of a `Player` instance, increases responsiveness, and allows manageability of these instances. This section explores these different states and the methods that allow you to gain this control.

In a nutshell, a `Player` instance starts life in the UNREALIZED state. It moves from this state to the REALIZED state when the user calls the `realize()` method. The REALIZED state

gives way to the PREFETCHED state when the `prefetch()` method is called. Calling `start()` moves the instance to the STARTED state, and calling `close()` leads to the CLOSED state. This simple transition path is displayed in Figure 4-1.

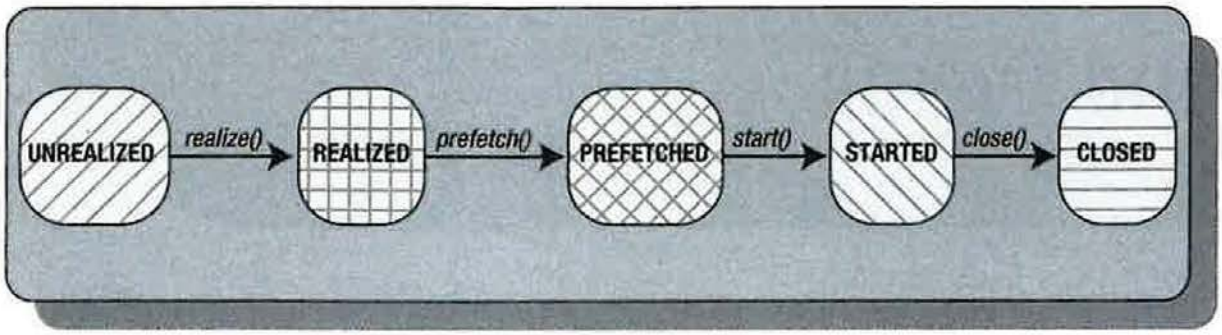


Figure 4-1. *A simple linear transition path for a* `Player` *instance*

Figure 4-1 shows the most *likely* transition path for a `Player` instance. Except for the CLOSED state, transitions can occur between the other states by calling special methods. These methods are covered shortly when the individual states are discussed.

Calling any of these methods to make a transition between different states is synchronous in nature. The methods don't return till the transition is complete. However, if any of these methods cannot make the transition, a `MediaException` is thrown to indicate so.

You can determine the current state of a `Player` instance by using the method `getState()`. This returns one of five constants defined in the `Player` interface corresponding to the five states shown in Figure 4-1. These constants are `UNREALIZED`, `REALIZED`, `PREFETCHED`, `STARTED`, and `CLOSED`.

Let's examine each of these states individually to see what they mean and how movement between them is not always so linear.

■ **Note** Most of these state transition methods are implemented in Java, as opposed to the code for parsing and decoding multimedia data, which is implemented in the native language of the device on which the MIDlet is running. Parsing and decoding are memory-intensive operations and implementing them in Java would sacrifice performance. Media transition methods, on the other hand, are not CPU-intensive and can be safely implemented in Java, as most of them are. Some parts of these methods may be implemented in native language to take advantage of device-specific performance features.

UNREALIZED

A `Player` instance starts life in an UNREALIZED state. When you use the `Manager` class to create a `Player` instance using any of the three `createPlayer()` methods, it creates a barely usable instance in the UNREALIZED state. An UNREALIZED `Player` is of no use because it doesn't have enough information to start functioning. It needs to acquire resources, such as audio and recording hardware on the device; set up in memory buffers for acquiring the media content; and communicate with the location of the media data. All these processes are performed in other states.

A Player instance moves away from the UNREALIZED state when the realize() method is called, which if successful, moves it to the REALIZED state. If unsuccessful, a MediaException is thrown, and the instance remains in the UNREALIZED state. If the realize() method blocks for a long time because it is a synchronous method, you can attempt to call the deallocate() method on the Player instance, which tries to keep the method in the UNREALIZED state. You'll learn more about this in the upcoming "REALIZED" section.

Not many actions can be performed on an UNREALIZED Player instance. For example, you cannot retrieve any controls from this instance using the getControl() or the getControls() methods, because the instance doesn't have enough information to generate the controls. You cannot change the playback time of the media, provided that it allows you to change the media time in the first place, with the setMediaTime() method. You cannot even retrieve or change the instance's TimeBase for synchronization using the getTimeBase() or setTimeBase() methods. A call to any of these methods in the UNREALIZED state results in an IllegalStateException.

The only useful operation that you can do with an UNREALIZED instance, besides realizing or closing it, is to set the number of times the instance should loop using the setLoopCount() method. You can also retrieve the likely duration of the media, which almost always returns –1, indicating an unknown time (TIME_UKNOWN constant in the Player interface).

The Player interface has a static integer constant to represent this state, UNREALIZED.

Figure 4-2 summarizes the UNREALIZED state and its transitions.

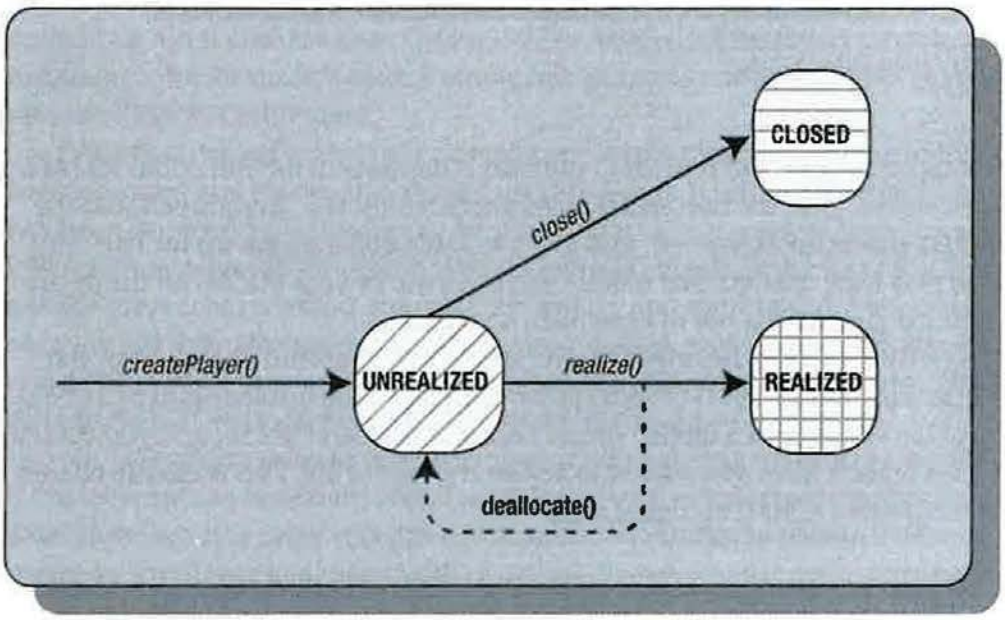


Figure 4-2. *UNREALIZED state transitions*

REALIZED

A Player instance moves from the UNREALIZED to the REALIZED state when the realize() method is called. The realize() method can be time consuming because it actually retrieves the media data. If the UNREALIZED state represents that the instance has connected to its media location, in a REALIZED state, it has in all probability retrieved this data (except for data that is streaming in nature).

After it has been REALIZED, a `Player` instance cannot go back to the UNREALIZED state. As you learned in the last section, a `realize()` method that is taking too long to return can be preempted by calling the `deallocate()` method, which keeps the instance in the UNREALIZED state. But from a REALIZED state itself, an instance can only go to the PREFETCHED or the CLOSED states. Figure 4-3 shows the REALIZED state transitions.

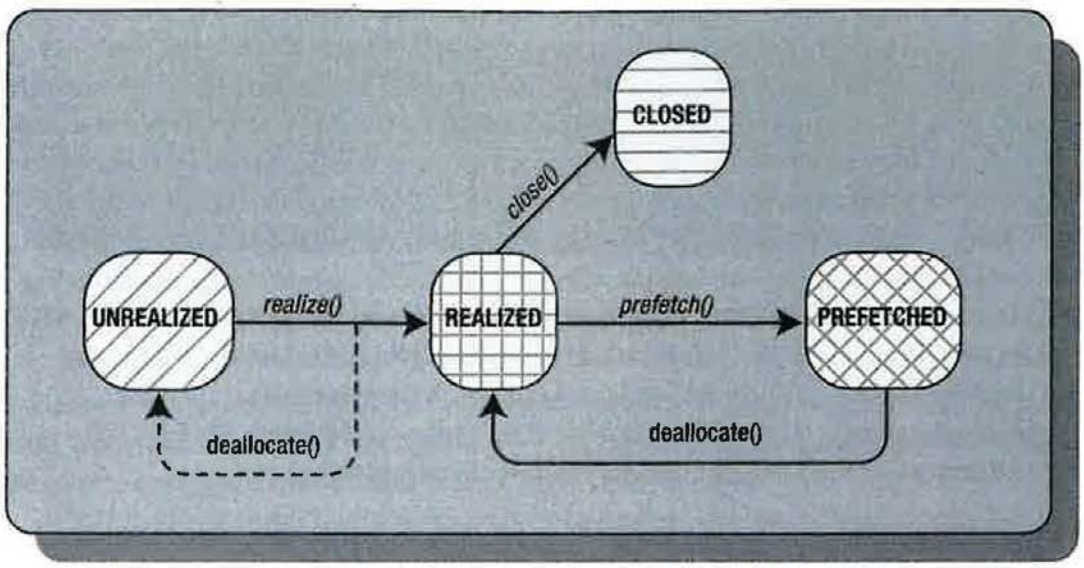


Figure 4-3. *REALIZED state transitions*

What actually happens within the `realize()` method is dependent on individual MMAPI implementations. However, after the method returns successfully, it is guaranteed that the underlying media data has been examined, and any available controls are up for use. Any resources required to play back the data that require exclusive use by your MIDlet on the device that it is running are also guaranteed *not* to have been acquired.

The `realize()` method throws, besides `IllegalStateException` and `MediaException`, a `SecurityException` as well. The `IllegalStateException` is thrown if the instance is in a CLOSED state; the `MediaException` is thrown if a media-specific error occurs; and the `SecurityException` is thrown if the MIDlet doesn't have permission to access the media file. This is closely related to Digital Rights Management (DRM) of digital data.

■ **Note** DRM is an industry term that refers to a service or technology to control access to digital data.

Because MMAPI is used to access some of the most popular digital data, such as music and video, it allows implementations to plug in a DRM technology to control this access. This allows very simple control over the media data. For example, `SecurityException` is thrown by

the realize() method if the DRM indicates that the right of the user to use the media data has expired (because it could only be used within a specific timeframe, it could only be played once, or for any other DRM-based reason). The realize() method implementation calls the DRM technology built in to the device to make this call.

Ideally, a call like this happens when the Player instance is created. DRM kicks in when createPlayer() is called on a Manager class, and you'll receive a SecurityException for trying to create an instance on an expired or inaccessible content. (You'll also receive a SecurityException for protocol-specific restrictions built in to the user's device, such as accessing the network when no permission to access the network has been given.) However, you might want to replay content without needing to create another Player instance on the same media data (as you saw in Chapter 3 when you cached Player instances). In those cases, realize() checks to make sure that DRM rules haven't been breached; if they have been, realize() throws a SecurityException.

The Player interface has a static integer constant that represents this state, REALIZED.

PREFETCHED

In the PREFETCHED state, a Player instance is in the best possible state to get started with the playback (or recording in case of a player for capturing data) of media. The instance has decoded the data and acquired access to any exclusive resources required for playback (or recording). A Player instance that hasn't been prefetched cannot be started.

Player instances move into the PREFETCHED state when the user calls the prefetch() method on a REALIZED instance. Calling deallocate() does the reverse, that is, moves a PREFETCHED instance to the REALIZED state, thereby releasing any exclusive resources acquired to move into the PREFETCHED state.

Note that calling prefetch() doesn't necessarily mean that all the media data would have been decoded and ready for playback (or recording). It just means that most of the processing has been done and the media can be played back (or recorded) with the minimum possible latency. To accentuate this point, if an instance is already in the PREFETCHED state, and you use the prefetch() method, the instance will try and minimize the latency even further. However, the reduction in startup times is not guaranteed, and different implementations of MMAPI will differ in what they exactly do if prefetch() is called twice. If you do call prefetch() on an already PREFETCHED instance, it is guaranteed not to throw any errors.

An IllegalStateException is thrown if you call this method on a CLOSED instance. A MediaException is also thrown if an error occurs when processing or decoding the media data. However, this same exception is thrown if an exclusive resource cannot be acquired. For example, if a Player instance requires exclusive access to the audio hardware on a device, and this is not available because it is being used by some other instance, a MediaException will be thrown to indicate this. Although there's no way to differentiate between the two reasons for MediaException, in the case of the latter reason, you can call prefetch() again and if exclusive access is now possible, the instance will move to the PREFETCHED state.

Similar to the realize() method, calling the prefetch() method may throw a SecurityException if the Player instance has insufficient permissions to either decode media data or acquire exclusive resources.

Figure 4-4 shows the possible state transitions in the PREFETCHED state.

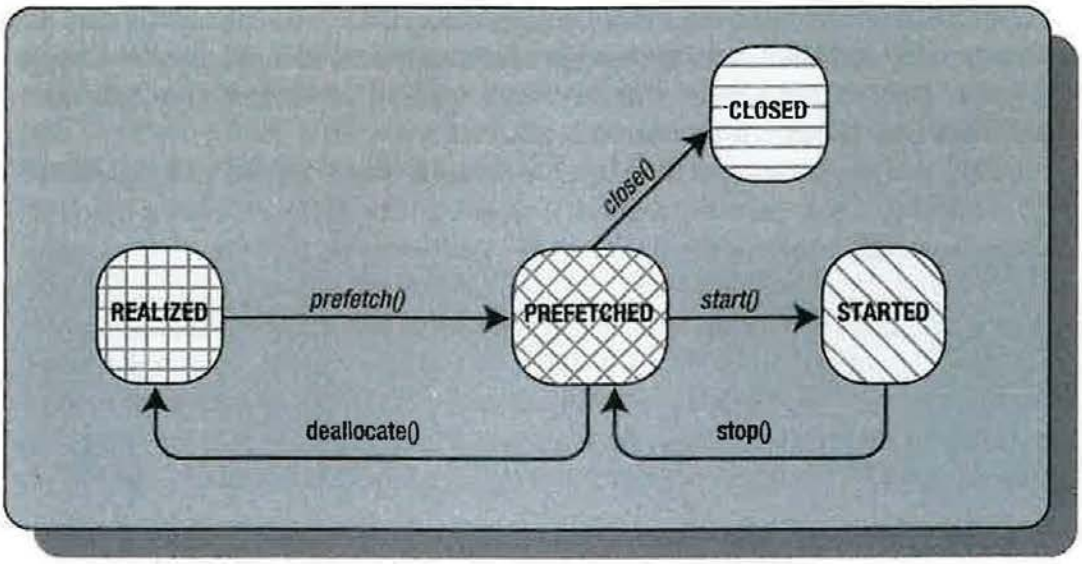


Figure 4-4. *PREFETCHED state transitions*

As you can see, there is no direct transition path for an `UNREALIZED` instance to go to the PREFETCHED state. This is why, if you call `prefetch()` on an `UNREALIZED` instance, it implies a call to the `realize()` method first. However, a transition from the PREFETCHED state to the REALIZED state can occur by using the `deallocate()` method. By doing so, you allow your instance to give up the exclusive resources acquired by your instance for other instances (or other MIDlets, applications, or AMS) to use.

An instance can arrive in the PREFETCHED state from the STARTED state as well. This transition can occur in several ways as explained in detail in the next section.

The `Player` interface has a static integer constant that represents this state, `PREFETCHED`.

STARTED

A `Player` instance in the STARTED state is playing back (or recording, streaming, and so on) actual media. This is the most useful state that an instance can be in. This state is achieved by calling the `start()` method on a `PREFETCHED` instance. However, note that calling the `start()` method doesn't guarantee that the instance will actually move immediately into the STARTED state. By calling the `start()` method, you are telling the instance to move into the STARTED state as soon as possible. Only when the `start()` method returns successfully is the instance considered to be in this state.

Of course, the instance may not be able to successfully move into the STARTED state when this method is called. Besides a `SecurityException`, thrown if there is not enough permission to start the media, a `MediaException` may be thrown if an error occurs when processing the media for playback (or recording). When any of these exceptions is thrown, the instance remains in the PREFETCHED state. As expected, an `IllegalStateException` is thrown if you try calling `start()` on an instance that is in the CLOSED state.

STARTED is the only state that has an automatic transition based on the state of the media playback (or recording). If you call `start()` on a `Player` instance, it automatically moves to the PREFETCHED state if the end of media playback is reached; that is, there is nothing left to play. STARTED also automatically moves to the PREFETCHED state if a preset stop time is reached. Preset stop times are set using the `StopTimeControl`.

Media that has a very short playback time moves to the PREFETCHED state almost immediately. For example, consider that you are trying to play an audio file and want to initiate some action when its `Player` instance is in the STARTED state. When you call the `start()` method, the instance temporarily moves to this state, but before you can react to the STARTED event, the playback would be over for a very short audio file, and the instance would have moved back to the PREFETCHED state. Thus, there are no guarantees for successfully acting on a STARTED instance because of this automatic transition.

Besides these automatic transitions, a `Player` instance also moves back to the PREFETCHED state when the `stop()` method is called in the STARTED state and the method returns successfully. The effect of the `stop()` method is to pause the instance at the current media time. (Note that there is *no* corresponding STOPPED state for the STARTED state. When stopped, an instance is in the PREFETCHED state.) Similar to the `start()` method, the `stop()` method also throws the `IllegalStateException` and `MediaException`. The first exception is thrown if this method is called on a `CLOSED` instance, whereas the second is thrown if the instance cannot be stopped.

If you call the `start()` method again, after you have stopped a previously started instance, it resumes at the media time that it was stopped at, effectively restarting paused media. This can, of course, be overridden by using the method `setMediaTime()`, which allows you to restart the playback from whenever you want it to. As expected, this will not work for media that is being recorded, and may or may not be supported for streaming data. In cases where this is not supported, calling `setMediaTime()` will throw a `MediaException`.

After a `Player` instance is in the STARTED state, calling either `setTimeBase()` or `setLoopCount()`throws an `IllegalStateException`. This makes sense. A `Player`'s `TimeBase` allows it to synchronize itself with other instances via the internal clock. After the instance has already started, this clock will be out of sync if changed midstream. Similarly, changing the number of times the instance must play back in the STARTED state will cause confusion over this count.

If you call the `start()` method on an `UNREALIZED` instance, it implies a call to the `realize()` and `prefetch()` methods, in that order. If you call it on a `REALIZED` instance, it implies a call to the `prefetch()` method first. In short, no direct transition occurs between the UNREALIZED state and the STARTED state on the one hand, and the REALIZED and STARTED state on the other, with the `start()` method taking care of these transitions for you. This is why listings in Chapter 3 were able to get away with calling the `start()` method only. However, calling the `start()` method on a `PREFETCHED` instance is always better than calling on `UNREALIZED` or `REALIZED`, because it reduces the overall startup time. You should only call the `start()` method after you've brought the instance to the PREFETCHED state, rather than letting the `start()` method bring it to that state.

Figure 4-5 shows the state transitions for the STARTED state.

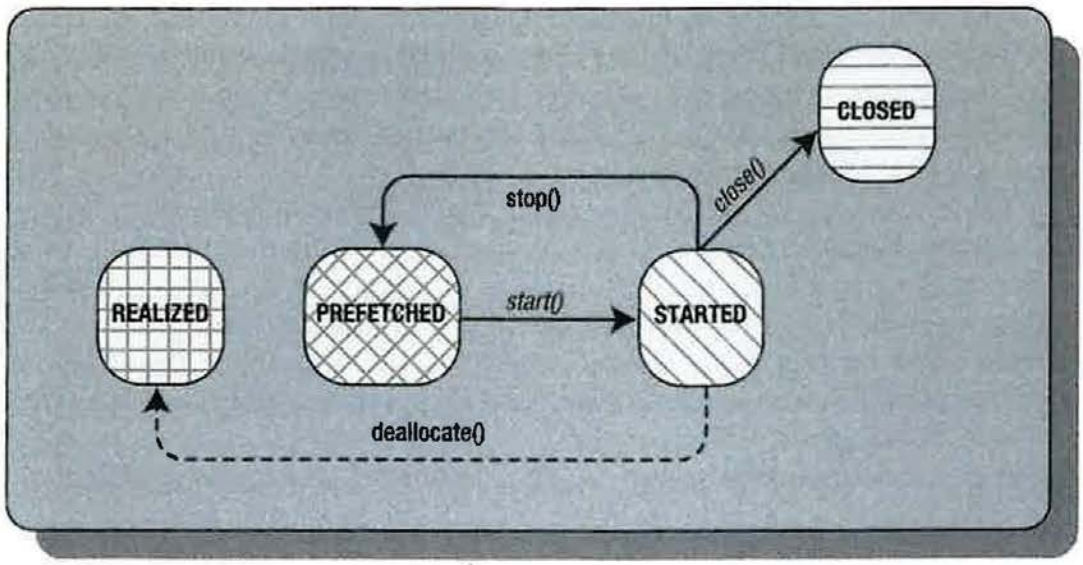


Figure 4-5. *STARTED state transitions*

You can call the `deallocate()` method on a `STARTED` instance, which internally implies a call to the `stop()` method first, and thus, the state of the instance transitions from STARTED to PREFETCHED to REALIZED, if both methods return successfully.

The `Player` interface has a static integer constant that represents this state, `STARTED`.

CLOSED

A `Player` instance in the CLOSED state is no longer usable. No methods can be called on it in this state with the exception of the `getState()` method. All other states transition to this state when the `close()` method is called, but there are no automatic transitions. If you call `close()` in the CLOSED state, no exception is thrown and the call is ignored. In fact, this method does not throw any exceptions; if any errors occur, the method returns silently and moves the instance to the CLOSED state anyway. All resources held by the instance are released, including any connections, exclusive device resources, and internal buffers.

■ **Note** Although the MMAPI specification does not say so, calling `close()` during different states causes different actions to be performed. Because the specification is silent on this issue, different implementations implement the actions in their own way. However, most implementations try to call the `deallocate()` method before performing any closeup actions. Recall that the `deallocate()` method can be called in all states (except, of course, the CLOSED state, whereas in the REALIZED state, the `deallocate()` call is ignored). Calling the `deallocate()` method in the STARTED state causes the `stop()` method to be called first. Thus, in all probability, if you call `close()` on a `STARTED Player` instance, it will go through the following cleanup methods: `close()` ➤ `stop()` ➤ `deallocate()`.

The `Player` interface has a static integer constant that represents this state, `CLOSED`.

Responding to Player Events

Each state transition and many other events generate a regular stream of notifications for any listener objects interested in a Player instance. This event delivery mechanism is implemented using an asynchronous model that is similar to most Java event delivery mechanisms.

The key class in this mechanism is the PlayerListener interface. Any class may implement this interface, register this implementation with the target Player instance, and start receiving notifications as the instance goes through its lifecycle. Several events are defined within this interface that cover a comprehensive list of Player events. You can create your own events as well and listen and react to them.

The PlayerListener interface defines only one method that implementations must implement. This method—playerUpdate(Player player, String event, Object eventData)—is invoked when an event takes place. To register an implementation with a Player instance, you use the method addPlayerListener(PlayerListener listener); to remove the instance, you use removePlayerListener(PlayerListener listener). Multiple listeners can be attached to a single instance, and multiple instances can send their events to the same listener. Because the playerUpdate() method receives the instance as an argument, it knows how to differentiate between the different instances.

As a simple example, let's modify Listing 3-1 from Chapter 3 to receive notifications from the simple Player instance that was created in that listing. The new code will display the events on the device screen as they are received. Listing 4-1 shows this modified code in the MIDlet called EchoEventsMIDlet.

Listing 4-1. EchoEventsMIDlet *Echoes Player Events Onscreen*

```
package com.apress.chapter4;

import javax.microedition.media.*;
import javax.microedition.lcdui.*;
import javax.microedition.midlet.*;

public class EchoEventsMIDlet extends MIDlet implements PlayerListener {

  private StringItem stringItem;

  public void startApp() {

    try {

      Form form = new Form("Player State");
      stringItem = new StringItem("", null)
      form.append(stringItem);
      Display.getDisplay(this).setCurrent(form);

      Player player = Manager.createPlayer(
        getClass().getResourceAsStream(
        "/media/audio/chapter4/baby.wav"), "audio/x-wav");
      player.addPlayerListener(this);
```

```
            player.start();

        } catch(Exception e) {
            e.printStackTrace();
        }
    }

    public void pauseApp() {
    }

    public void destroyApp(boolean unconditional) {
    }

    public void playerUpdate(Player player, String event, Object eventData) {
        stringItem.setText(event);
        System.err.println(event);
    }
}
```

The EchoEventsMIDlet acts as the listener for the Player instance that it creates by implementing PlayerListener and adding the playerUpdate() method. When created, the Player instance registers this MIDlet by using the method addPlayerListener(this). Any event that is now generated by the corresponding event is delivered to the playerUpdate() method.

The other change in this MIDlet from Listing 3-1 is to create a Form object with a single StringItem on it to promptly display onscreen and print the current event received by the playerUpdate() method to the error output stream.

Running this MIDlet returns mostly consistent results because the Sun Java Wireless Toolkit's DefaultColorPhone emulator fires an extra volumeChanged event.

Note You may not notice the volumeChanged event on the DefaultColorPhone emulator because it may happen too fast depending on the time it takes for the media file to enter the STARTED state. Check the error output stream. The volumeChanged event is fired when the Player instance enters the PREFETCHED state (on the Sun MMAPI implementation).

The Motorola emulator and actual C975 device do not fire this volumeChanged event. The events that are fired and received by all three environments are the started and the endofmedia events. As you may guess, the started event represents when an instance has entered the STARTED state. The endofmedia event is delivered when no more media is left to play (or record/stream). This event is delivered each time an instance that is set to loop reaches the end of the media for each loop.

Of course, many more events than the two (or three if you consider the DefaultColorPhone) are fired by this simple example. Table 4-1 lists all the events defined in the MMAPI specification in the `PlayerListener` interface defined as constants.

Table 4-1. *A Complete List of* `Player` *Events Defined in the* `PlayerListener` *Interface*

Player Event Constant	Constant Value	When Fired
`BUFFERING_STARTED`	`bufferingStarted`	When an instance has started buffering media data for processing or playback.
`BUFFERING_STOPPED`	`bufferingStopped`	When an instance has exited the buffering stage.
`CLOSED`	`closed`	When an instance is closed.
`DEVICE_AVAILABLE`	`deviceAvailable`	When a system resource required by a `Player` instance becomes available for use.
`DEVICE_UNAVAILABLE`	`deviceUnavailable`	When a system resource required by a `Player` instance becomes unavailable. This event must precede the previous event.
`DURATION_UPDATED`	`durationUpdated`	When the duration of previously unknown media data becomes available.
`END_OF_MEDIA`	`endOfMedia`	When an instance has reached the end of the media during the current loop.
`ERROR`	`error`	When an error, which is usually fatal, occurs.
`RECORD_ERROR`	`recordError`	When an error occurs during recording (audio or video).
`RECORD_STARTED`	`recordStarted`	When recording of media data has started.
`RECORD_STOPPED`	`recordStopped`	When recording of media data has stopped.
`SIZE_CHANGED`	`sizeChanged`	When the size of a video display has changed for whatever reason.
`STARTED`	`started`	When the instance has entered the STARTED state.
`STOPPED`	`stopped`	When the instance has paused due to the `stop()` method being called.
`STOPPED_AT_TIME`	`stoppedAtTime`	When the instance has paused due to the `StopTimeControl`'s `setStopTime()` method.
`VOLUME_CHANGED`	`volumeChanged`	When the volume of an audio device is changed.

If you look at the signature of the `playerUpdate()` method, you'll see that it takes three parameters. The first is the `Player` instance that has thrown the event, the second is the actual event, and the third is the `eventData` as an `Object`. The `eventData` is interesting because it contains specific information about each event that can help you do something when the particular event is fired. For example, when the `stopped` event is received by this method, the `eventData`

is a Long object identifying the media time when the corresponding Player instance is stopped. Similarly, the started event's eventData contains the media time when the media is started. Almost each event carries some useful information in the corresponding eventData; Table 4-2 shows the complete list.

Table 4-2. *Events and Corresponding Event Data*

Event	Event Data
BUFFERING_STARTED	A Long object designating the time when buffering has started.
BUFFERING_STOPPED	A Long object designating the time when buffering has stopped.
CLOSED	Event data is null when this event is fired.
DEVICE_AVAILABLE	A String object that is the name of the device that is now available.
DEVICE_UNAVAILABLE	A String object that is the name of the device that is not available.
DURATION_UPDATED	A Long object designating the new duration of the media.
END_OF_MEDIA	A Long object that contains the media time when the Player instance reached the end of media and stopped.
ERROR	A String that contains the error message.
RECORD_ERROR	A String that contains the error message.
RECORD_STARTED	A Long object that designates the media time when recording has started.
RECORD_STOPPED	A Long object that designates the media time when recording has stopped.
SIZE_CHANGED	A VideoControl control object that contains information about the new size.
STARTED	A Long object designating the media time when the Player instance is started.
STOPPED	A Long object designating the media time when the Player instance is stopped (paused).
STOPPED_AT_TIME	Similar to STOPPED, the eventData contains the media time when the Player instance is stopped in the form of a Long object.
VOLUME_CHANGED	A VolumeControl control object that contains information about the new volume.

Note that in MMAPI all times are measured in microseconds, not milliseconds.

Understanding the Event Delivery Mechanism

The event delivery mechanism in MMAPI is based on an asynchronous model that allows you to create multimedia applications that do not block the main application thread. This means that events are fired using an event delivery thread separate from the main application thread. This thread may or may not be in existence till an actual event is to be delivered. For example, in the Sun's MMAPI reference implementation, this thread is only created when the first event is fired. Even then, this thread remains active only for another five seconds, after which, if no more events are delivered, the thread exits. A new thread is created the next time an event needs to be delivered. Most actual commercial implementations follow a similar model that only differs in the time that they stay alive for; however, they are guaranteed to all follow this asynchronous nature of event delivery.

The MMAPI also guarantees that events will be delivered to their respective listeners in the order they are generated. This way, events that occur very fast after one another are guaranteed to be received by the registered listeners in order, without getting overwhelmed by newer events. For example, suppose you start playing a media file, which would fire a `STARTED` event. However, if the media file is short, it will end very quickly and generate an `END_OF_MEDIA` event almost immediately after it sends the `STARTED` event. The listener is guaranteed to receive the `STARTED` event before the `END_OF_MEDIA` event even if it occurs nearly simultaneously.

Of course, if an error occurs at any stage during a `Player` instance creation or usage so that the instance cannot continue working, the event delivery mechanism sends an `ERROR` event. The receipt of this event implies that the instance is unusable and is in a CLOSED state.

Creating an Event Handling Class

In Chapter 3, you created a MIDlet that allowed you to select a media audio file from a list to play and control its volume. In this section, you'll create an event handling class and attach it to the functional `Player` instances created in that MIDlet. This event handling class is basic, but it gives you an idea of how to listen for events, handle them accordingly, and use the event and `eventData` parameters. Listing 4-2 shows this event handling class, called `EventHandler`.

Listing 4-2. `EventHandler` *Is the Listener for Functional* `Player` *Instances Created in the Previous Chapter*

```
package com.apress.chapter4;

import javax.microedition.media.*;
import javax.microedition.media.control.*;
import javax.microedition.lcdui.StringItem;

public class EventHandler implements PlayerListener {

  private StringItem item;

  public EventHandler(StringItem item) {
    this.item = item;
  }

  public void playerUpdate(Player player, String event, Object eventData) {

    if(event.equals(PlayerListener.VOLUME_CHANGED)) {

      // a player's volume has been changed
      VolumeControl vc = (VolumeControl)eventData;
      updateDisplay("Volume Changed to: " + vc.getLevel());

      if(vc.getLevel() > 60)  {
        updateDisplay("Volume higher than 60 is too loud");
        vc.setLevel(60);
      }
    } else if(event.equals(PlayerListener.STOPPED)) {
```

```
            // player instance paused
            updateDisplay("Player paused at: " + (Long)eventData);
        } else if(event.equals(PlayerListener.STARTED)) {

            // player instance started (or restarted)
            updateDisplay("Player started at: " + (Long)eventData);
        } else if(event.equals(PlayerListener.END_OF_MEDIA)) {

            // player instace reached end of loop
            updateDisplay("Player reached end of loop.");
        } else if(event.equals(PlayerListener.CLOSED)) {

            // player instance closed
            updateDisplay("Player closed.");
        } else if(event.equals(PlayerListener.ERROR)) {

            // if an error occurs, eventData contains the error message
            updateDisplay("Error Message: " + (String)eventData);
        }
    }

    public void updateDisplay(String text) {

        // update the item on the screen
        item.setText(text);

        // and write to error stream as well
        System.err.println(text);
    }

}
```

The `EventHandler` constructor accepts a `StringItem` screen item to which it can write updates as it receives events. The `playerUpdate()` method is where the updates are written to the screen based on the event that has occurred.

If you change the volume of a `Player` instance, the associated `VolumeControl` is retrieved from the `eventData` after casting it appropriately. You can then query the new volume level from this control.

Note You can, of course, retrieve the same `VolumeControl` by querying the associated `Player` instance with the `getControl(" VolumeControl ")` method call that returns a reference to the same instance as referenced by the `eventData` parameter. The direct referencing `eventData` omits a method call, whereas `getControl()` method omits the use of a cast.

Here, the handler informs the user that volume over 60 is too loud and resets the volume back to 60. Note that resetting the volume in turn generates another VOLUME_CHANGED event!

The rest of the events are handled accordingly, and you can use the associated event data with appropriate casts. The updateDisplay() method updates the screen as well as writes message to the error output stream because some of the messages on the screen will happen too quickly.

The event generating Player instances now need to be told to send the instances to this handling class. This is done in the CachingAudioPlayerCanvas class where these instances are first created. This class is now modified to add a StringItem to display the messages from the event handler, create the EventHandler class, and set each Player instance up with this class as the listener. These changes are shown in bold in Listing 4-3.

Listing 4-3. *Enabling Event Handling in the* CachingAudioPlayerCanvas *Class*

```
package com.apress.chapter4;

import java.util.*;
import javax.microedition.lcdui.*;
import javax.microedition.media.*;
import javax.microedition.media.control.*;

public class CachedAudioPlayerCanvas implements ItemStateListener {

  // the parent MIDlet
  private CachingAudioPlayer parent;

  // form that contains canvas elements
  private Form form;

  // gauge to allow user to manipulate volume
  private Gauge gauge;

  // the volume control
  private VolumeControl volume;

  // the player used to play media
  private Player player;

  // is the player paused?
  private boolean paused = false;

  // to display event info
  private StringItem eventInfo;

  // the event handler
  private EventHandler handler;

  private Hashtable players;
```

```
public CachedAudioPlayerCanvas(CachingAudioPlayer parent) {

  this.parent = parent;

  // create form and add elements and listeners
  form = new Form("");
  gauge = new Gauge("Volume: 50", true, 100, 50);
  eventInfo = new StringItem("", null);
  form.append(gauge);

  // add the event info string item
  form.append(eventInfo);

  // create the EventHandler
  handler = new EventHandler(eventInfo);

  form.addCommand(parent.exitCommand);
  form.addCommand(parent.backCommand);
  form.setCommandListener(parent);

  // a change in volume gauge will be handled by this class
  form.setItemStateListener(this);

  players = new Hashtable();
}

public void playMedia(String locator) {

  try {

    // first look for an existing instance
    player = (Player)players.get(locator);

    if(player == null) {

      // create the player for the specified string locator
      player = Manager.createPlayer(
        getClass().getResourceAsStream(locator), "audio/x-wav");

      // add the EventHandler as a listener
      player.addPlayerListener(handler);

      // fetch it
      player.prefetch();

      // put this instance in the Hashtable
      players.put(locator, player);
```

```
        }

        // get the volume control
        volume = (VolumeControl)player.getControl("VolumeControl");

        // initialize it to 50
        volume.setLevel(50);

        // initialize the gauge
        gauge.setValue(volume.getLevel());
        gauge.setLabel("Volume: " + volume.getLevel());

        // play it twice
        player.setLoopCount(2);

        // start the player
        player.start();

        // set the title of the form
        form.setTitle("Playing " + locator);

      } catch(Exception e) {
        e.printStackTrace();
      }
    }

... rest of the code omitted as it doesn't change from Listing 3-4 ...
```

A single `EventHandler` instance is used for all three `Player` instances that are created. Because `playerUpdate()` receives the instance that generated the event, it's easy to distinguish between these instances, if necessary.

Handling a Custom Event

As you may realize by now, there is no special event class in the MMAPI. That is, events are distinguished as `String` constants in the `PlayerListener` interface. To create, rather to handle, a custom event, you do not need to extend any other class.

Custom event creation is primarily designed for MMAPI implementations. This means that the MMAPI specification, having designed its own mandatory events, makes it open for MMAPI implementations to create and broadcast their own events. The description of these events would be made clear in the documentation for each implementation, and the events are likely to be named in the reverse domain name convention. For example, the MMAPI reference implementation from Sun defines a custom event called `com.sun.midi.lyrics`, which is a Sun-specific event for karaoke lyrics.

Although the `PlayerListener` interface provides for events that are most common, in some special cases, you may want to define your own. For example, let's say you wanted to do something special that requires an event to be raised whenever an audio file has been played

halfway through. None of the predefined events will satisfy this requirement, so you'll need to raise and handle your own custom event. But how do you actually create and raise an event?

The short answer is that you can't. Unless you are ready to implement your own version of a `Player` instance that handles the type of media that you are after. This is not an easy task and requires you to handle all the steps required in realizing, prefetching, and decoding, not to mention interfacing with the controls that it exposes. Further, you have to use your own version over the version supplied with the MMAPI implementation that you are working with. After you have accomplished these difficult tasks, you may be able to plug in and raise your own event.

Handling custom events is, as you may expect, much easier. You only need to know the name of the event and the type of `eventData` that it exposes to be able to use it in the `playerUpdate()` method. Thus, the following code fragment will catch the `com.sun.midi.lyrics` event, and the event data exposed will be a `byte` array:

```
if(event.equals("com.sun.midi.lyrics")) {
  byte[] data = (byte[])eventData;
}
```

Note that the MMAPI specification states that to catch standard events in the `playerUpdate()` method, you should use the reference equality check, and for custom events, you should use the object equality check. Thus, `(event == PlayerListener.CLOSED)` should be preferred over `event.equals(PlayerListener.CLOSED)`, and `event.equals("com.sun.midi.lyrics")` must be used for custom events. Standard events are automatically interned because they are constants; therefore, using the reference check will be faster than the object equality check. However, the same cannot be guaranteed for custom events, so you must always use the object equality test. The `EventHandler` in Listing 4-2 used the object equality test and is now converted to use the reference check in Listing 4-4 to make it more responsive.

Listing 4-4. *Converting* `EventHandler` *to Use Reference Checking Instead of Object Equality*

```
package com.apress.chapter4;

import javax.microedition.media.*;
import javax.microedition.media.control.*;
import javax.microedition.lcdui.StringItem;

public class EventHandler implements PlayerListener {

  private StringItem item;

  public EventHandler(StringItem item) {
    this.item = item;
  }

  public void playerUpdate(Player player, String event, Object eventData) {
```

```
    if(event == (PlayerListener.VOLUME_CHANGED)) {

      // a player's volume has been changed
      VolumeControl vc = (VolumeControl)eventData;
      updateDisplay("Volume Changed to: " + vc.getLevel());

      if(vc.getLevel() > 60)  {
        updateDisplay("Volume higher than 60 is too loud");
        vc.setLevel(60);
      }
    } else if(event == (PlayerListener.STOPPED)) {

      // player instance paused
      updateDisplay("Player paused at: " + (Long)eventData);
    } else if(event == (PlayerListener.STARTED)) {

      // player instance started (or restarted)
      updateDisplay("Player started at: " + (Long)eventData);
    } else if(event == (PlayerListener.END_OF_MEDIA)) {

      // player instance reached end of loop
      updateDisplay("Player reached end of loop.");
    } else if(event == (PlayerListener.CLOSED)) {

      // player instance closed
      updateDisplay("Player closed.");
    } else if(event == (PlayerListener.ERROR)) {

      // if an error occurs, eventData contains the error message
      updateDisplay("Error Message: " + (String)eventData);
    }
  }

  public void updateDisplay(String text) {

    // update the item on the screen
    item.setText(text);

    // and write to error stream as well
    System.err.println(text);
  }
```

```
}
```

Due to device fragmentation, not all MMAPI implementations support reference check for events. Instead, you have to use `equals()` for comparison from Listing 4-2, instead of the improved code from Listing 4-4. The trick is to test your target device(s) for what is supported and optimize accordingly.

Summary

The several different states that a `Player` instance goes through in processing and playing media data allows developers to gain control over these states, provide feedback, and process events at these stages. These states are UNREALIZED, REALIZED, PREFETCHED, STARTED, and CLOSED, and the transitions between them are well defined and accessible.

In this chapter, you learned the background behind these states, the how and why of the transitions that take place between them, and how to respond to the various events generated during these transitions. You learned to create an event handling class and also how to listen to custom events.

The next chapter will introduce you to accessing media data over the network using MMAPI, a task that must be handled efficiently and cleanly for responsive multimedia MIDlets.

CHAPTER 5

Accessing Media Over the Network

The greatest advantage of applications built on mobile devices is that they can be run anywhere any time. These applications are truly mobile lifestyle choices because they allow us to extend our lifestyles by bringing these applications wherever we go, whether for fun or business. Applications that keep all data on mobile phones have the added advantage of being complete without requiring network access to function or update. However, truly mobile applications take advantage of available networks to provide an enhanced user experience.

Take the case of accessing multimedia files over a network. Although games and other fun applications can work with small embedded sound and other audio files, for an even, all-encompassing experience, the user requires network connectivity for his application to stream media over the network. A good reason for streaming over storing media files locally is the size of these files, video especially. Also streaming over stored media is used to provide updated files and to maintain digital rights over the provided content.

Whatever the reasons, accessing multimedia data over a network reliably is an important aspect of learning to use MMAPI. Although the issues involved are not unique to accessing multimedia data per se, they do need to be taken care of.

In this chapter, you'll learn about these common issues and how they affect multimedia data access over the network using MMAPI. You'll learn how to overcome these issues to create MIDlets that can access the network reliably and consistently. Finally, you'll see examples of these issues and the solutions to them.

Understanding Threads in Java ME

The threading environment in Java ME is slightly different from the normal environment in Java SE. The JVM in Java ME does not create a separate application thread for your MIDlet, which is contrary to what happens in an application being run on Java SE, where an application gets its own application thread separate from the system thread. All processing in a MIDlet takes place inside the main system thread. Thus, methods that take a long time to complete hog this single thread and create a bottleneck for a functional MIDlet.

Any threads that you create yourself within your MIDlet are, of course, separate from the system thread and therefore not restrictive. These threads can do their own thing independent of the main system thread. Of course, you have to strike a fine balance between the number of

threads required versus the number of threads that the limited resources operating system can handle. Thread creation and management is a processor- and memory-hungry task and should be carefully used, especially in the Java ME environment, which runs on constrained devices.

To understand this better, take a look at Listing 5.1. When started, the MIDlet in this listing displays the name of the current system thread, which is the main MIDlet thread. When the user clicks the command for a new thread, the MIDlet creates a new thread, which displays an alert momentarily with its own name. It then simulates a long activity by sleeping for 4 seconds.

Listing 5-1. *Understanding Threads in MIDlets*

```
package com.apress.chapter5;

import javax.microedition.midlet.*;
import javax.microedition.lcdui.*;

public class ThreadTest extends MIDlet implements CommandListener {

  private Form form;
  private StringItem text;
  private Display display;

  public ThreadTest() {
    form = new Form("Thread Test");

    // displays the name of the current system thread
    text = new StringItem(
      "Current Thread:",
      Thread.currentThread().getName());

    form.append(text);

    // commands to exit and create new threads
    Command exit = new Command("Exit", Command.EXIT, 1);
    Command newThread = new Command("New Thread", Command.SCREEN, 1);

    form.addCommand(exit);
    form.addCommand(newThread);

    form.setCommandListener(this);

    display = Display.getDisplay(this);
  }

  public void startApp() {
    display.setCurrent(form);
  }
```

```
  public void pauseApp() {
  }

  public void destroyApp(boolean unconditional) {
  }

  public void commandAction(Command cmd, Displayable disp) {
    if(cmd.getLabel().equals("Exit")) {
      notifyDestroyed();
    } else {
      System.err.print("Starting new thread ... ");

      // create a new thread
      Thread runner = new Thread(new ThreadRunner(display));

      // and start it
      runner.start();

      System.err.println("Done");
    }
  }
}

class ThreadRunner implements Runnable {

  // the parent MIDlet's display
  Display display;

  ThreadRunner(Display display) {
    this.display = display;
  }

  public void run() {

    System.err.print(
      "New thread ( " + Thread.currentThread().getName() + " ) running .. ");

    display.setCurrent(
      new Alert(Thread.currentThread().getName()));

    try {
      Thread. sleep(3000);
    } catch(Exception e) {}

    System.err.println("Done");
  }
}
```

Caution The `getName()` used in this listing for the `Thread` class is a CLDC 1.1 method. This listing will not work in CLDC 1.0 devices.

Figure 5-1 shows the MIDlet running in the Motorola emulator across a few actions, along with the output.

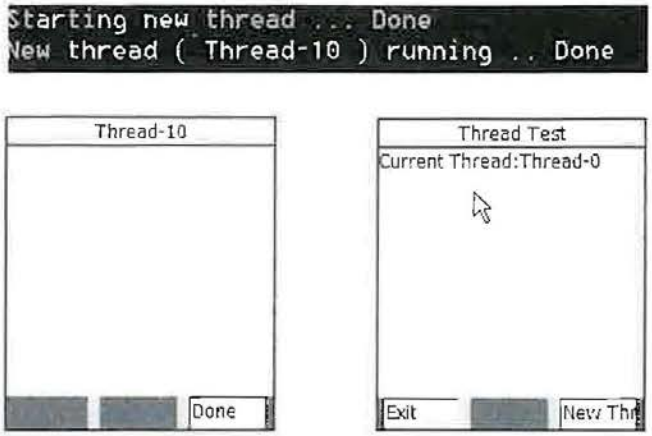


Figure 5-1. *Screen and console output for the* `ThreadTest` *MIDlet on Motorola emulator*

The MIDlet identifies the way threads work in the Java ME environment. The simulation of a long activity inside a new thread doesn't lock up the main MIDlet thread waiting for this activity to finish. The main MIDlet thread continues its processing after creating and starting the new thread. This concept is further established in Figure 5-2, which shows the main system thread and a new thread's activity and actions.

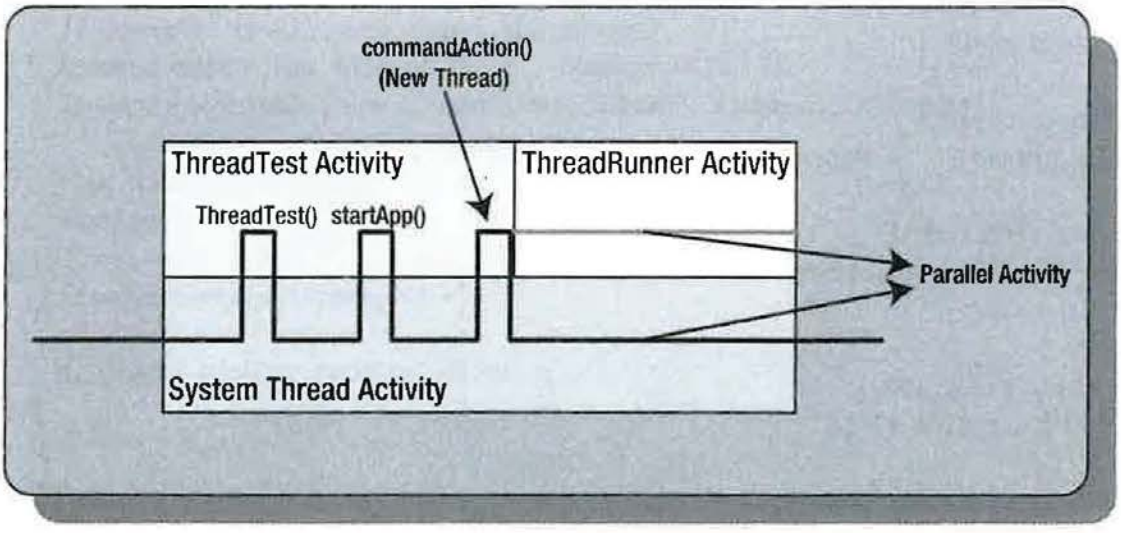


Figure 5-2. *System and new thread activity*

At this stage, you may be wondering if an understanding of thread activity in MIDlets has anything to do with using the MMAPI over a network. It does because network access of multimedia files (and all network activity) should only be done in a separate thread, distinct from the system thread. This is to make sure that network access of these files doesn't leave the main application unresponsive to the user. This is discussed further later in this chapter.

Understanding Permissions for Network Access

Whereas creating responsive MMAPI MIDlets with separate threads is one aspect of accessing network based media, another issue relates to permissions for media access over the network. MIDlets don't automatically have permissions to grab files over the network, so this must be explicitly or implicitly configured.

MIDlets run in a protection domain, which provides access to individual permissions based on whether or not the user grants (or denies) these permissions for the current MIDlet session or for the life of the MIDlet. Individual permissions must be requested explicitly, but not from within the MIDlet code. The permissions that are interesting for MMAPI development are `javax.microedition.io.Connector.http` and `javax.microedition.io.Connector.https`. This section focuses on these permissions, which allow retrieval of media files over the Web.

When any attempt is made to retrieve media files over the network, for example, by specifying an HTTP locator for the `createPlayer()` method, the MIDlet's protection domain kicks in. Because `javax.microedition.io.Connector.http` is a restricted permission, the user of the MIDlet must decide whether to grant access to the network.

As an example, consider the MIDlet in Listing 5-2, which wants to make a connection to a remote server to retrieve and play an audio file.

Listing 5-2. *Playing an Audio File Over the Network*

```
package com.apress.chapter5;

import javax.microedition.midlet.*;
import javax.microedition.lcdui.*;
import javax.microedition.media.*;

public class NetworkTest extends MIDlet implements CommandListener {

  private List list;
  private StringItem text;
  private Display display;

  public NetworkTest() {

    list = new List("Press Play", List.IMPLICIT);
```

```
    // commands to exit and play
    Command exit = new Command("Exit", Command.EXIT, 1);
    Command play = new Command("Play", Command.SCREEN, 1);

    list.addCommand(exit);
    list.addCommand(play);

    list.setCommandListener(this);
    display = Display.getDisplay(this);
  }

  public void startApp() {
    display.setCurrent(list);
  }

  public void pauseApp() {
  }

  public void destroyApp(boolean unconditional) {
  }

  public void commandAction(Command cmd, Displayable disp) {
    if(cmd.getLabel().equals("Exit")) {
      notifyDestroyed();
    } else {
      try {
        Player player =
          Manager.createPlayer(
        "http://www.mmapibook.com/resources/media/audio/chapter5/siren.wav");
        player.start();
      } catch(Exception e) { System.err.println(e); }
    }
  }
}
```

The bold code is where a `Player` instance is created by making a network connection for file retrieval. When you run this listing, the MIDlet needs to be granted permission by the user. Figure 5-3 shows how this permission is granted in the three different environments (Sun Java ME emulator, Motorola C975 emulator, and the Motorola C975 device, respectively).

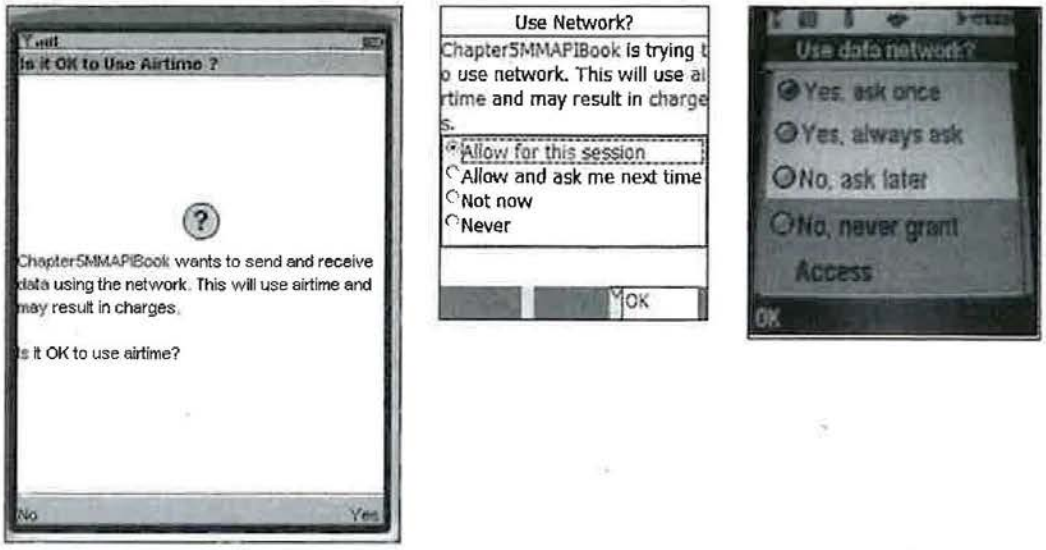


Figure 5-3. *Granting network access permission*

Most users who trust your MIDlet will want to select the Yes, Ask Once choice (or similar), so they won't be bothered the next time they run your MIDlet. By default, all MIDlets are run in an untrusted protection domain, where the user is always consulted for granting network access permission rights. You'll need to establish a level of trust for the device to run your network accessing MIDlet without requiring interaction from the user.

Trust is established by signing your MIDlet and putting it in a trusted domain. The complete details of how you do that is beyond the scope of this book, but this section outlines the steps required to get the `NetworkTest` MIDlet working without needing to request permission to access the network from the user.

To start with, you'll need to modify the JAD manifest file for this MIDlet and add an entry to request permission for HTTP access, as shown here:

```
MIDlet-Permissions: javax.microedition.io.Connector.http
```

If the connection to access the file will be over a secure connection, you need to request HTTPS access. If you're not sure, you can request both permissions.

```
MIDlet-Permissions:
  javax.microedition.io.Connector.http, javax.microedition.io.Connector.https
```

Note The preceding code lines should not be broken into two lines during coding; they are broken here due to space concerns.

Now when this MIDlet is being installed on a device, the AMS will fail the installation if it's unable to provide these permissions to the MIDlet. This means that if AMS is unable to put this MIDlet in a trusted domain, it halts the installation.

Of course, simply requesting permissions in the JAD file is only half the story. Any rogue MIDlet could request the permission this way and cause trouble. You still need to establish some sort of trust principle between the MIDlet and the AMS; the AMS will then trust your MIDlet enough to let it be installed in a trusted domain. This is done by signing the MIDlet with a certificate that can be validated up to a root certificate installed on the device.

To complete this test, at least on the Sun Java ME emulator, sign the `NetworkTest` MIDlet with the `trustedkey` key installed with the emulator. You access it by selecting Project ➤ Sign in the emulator as shown in Figure 5-4. This `trustedkey` is shown in Figure 5-5.

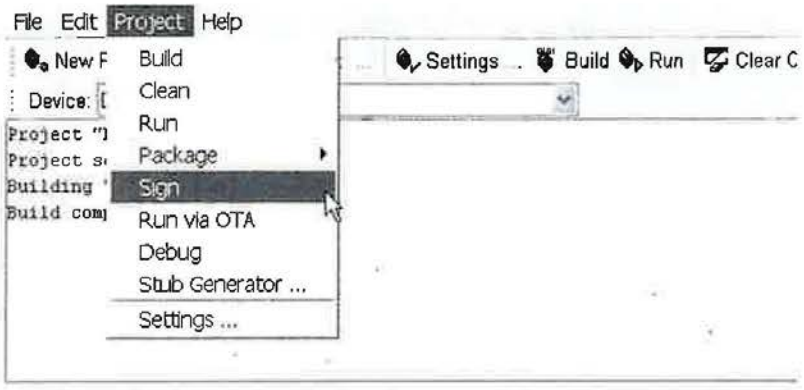


Figure 5-4. *Signing the* `NetworkTest` *MIDlet in the Sun Java ME emulator*

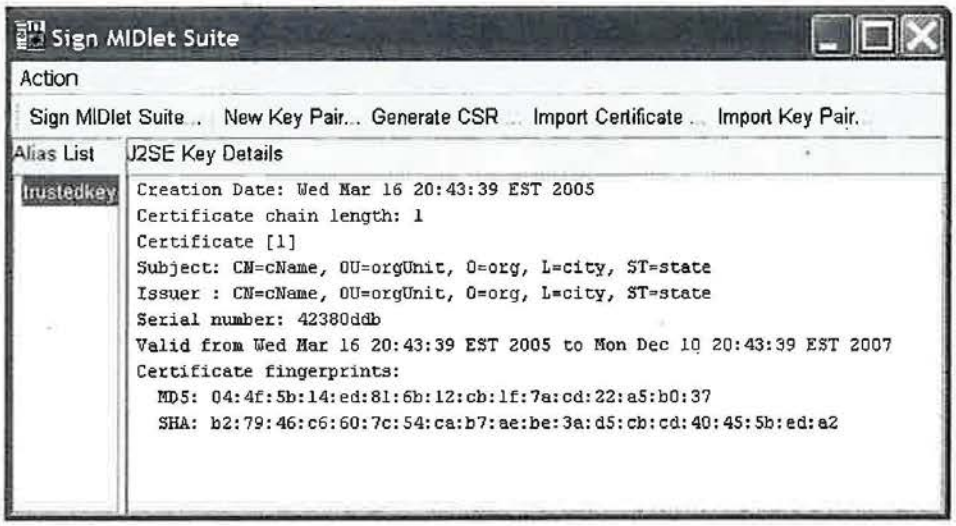


Figure 5-5. *The* `trustedkey` *used to sign the* `NetworkTest` *MIDlet*

After the MIDlet is signed, you can test it by using the Run via OTA menu option shown in Figure 5-6. You don't use the Run menu option like you have been doing so far because when you run the MIDlet locally (by selecting the Run menu option), it does not get installed into a protection domain. Only when installed via the Run via OTA option does your MIDlet gets a chance to be installed into a requested domain, which is the domain that you request by specifying permission for it in the JAD file.

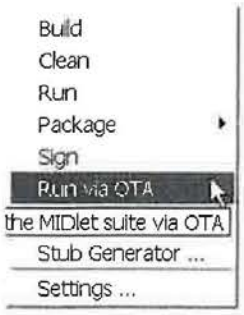


Figure 5-6. *Running* `NetworkTest` *MIDlet via Over the Air provisioning*

Of course, so far, you've only tested in the Sun Java ME emulator platform. Testing on the Motorola C975 emulator and device is only possible if you have a certificate containing a key-pair that can be trusted to a root certificate installed on the emulator and device, respectively. Even then, the actual device may only keep your MIDlet in a third-party trust domain that will never be fully trusted. To get it to a higher trust level, you need to sign it with a certificate supplied by either a manufacturer (Motorola) or an operator (for example, Vodafone). An alternate mechanism is to use the Java Verified Program, which certifies your application for deployment on devices that support this program. See more details of this program at *http://www.javaverified.com*.

To summarize, using MMAPI across a network requires looking at two issues:

- Network operations can be time consuming and should be done in a separate thread from the main application thread.
- Network access requires permission from the user. To gain this permission and then acquire a level of trust, your MIDlet must request this permission implicitly and be signed with a certificate that can be traced to a root certificate. Alternatively, explicit permission from the user is required when network access is attempted, which the user may not give.

You just learned about the second item in the preceding list; the next section covers the first issue in the list in more detail, expanding on what you've learned so far.

Putting It Together

The MIDlets created in the previous chapters have accessed their media files through the JAR file in which they are bundled. In this section, you'll create a `Player` instance that will access a media file over the network via HTTP. You'll create a separate thread from the main MIDlet thread to handle the task of creating and realizing the `Player` instance.

Listing 5-3 shows the code for the `ThreadedMIDlet` that initiates the playback. When requested by the user, it creates a new thread using the `NetworkPlayerManager` class, shown in Listing 5-4.

Listing 5-3. `ThreadedMIDlet` *Creates a New Thread to Play Back a Media File*

```
package com.apress.chapter5;

import javax.microedition.midlet.*;
```

```
import javax.microedition.lcdui.*;
import javax.microedition.media.*;

public class ThreadedMIDlet extends MIDlet implements CommandListener {

  private List list;
  private StringItem text;
  private Display display;

  private NetworkPlayerManager mgr;
  private Command cancel = new Command("Cancel", Command.CANCEL, 1);

  public ThreadedMIDlet() {

    list = new List("Press Play", List.IMPLICIT);

    // commands to exit and play
    Command exit = new Command("Exit", Command.EXIT, 1);
    Command play = new Command("Play", Command.SCREEN, 1);

    list.addCommand(exit);
    list.addCommand(play);

    list.setCommandListener(this);
    display = Display.getDisplay(this);
  }

  public void startApp() {
    display.setCurrent(list);
  }

  public void pauseApp() {
  }

  public void destroyApp(boolean unconditional) {
  }

  public void commandAction(Command cmd, Displayable disp) {
    if(cmd.getLabel().equals("Exit")) {
      notifyDestroyed();
    } else if(cmd.getLabel().equals("Cancel")) {
      mgr.cancel();
      display.setCurrent(list);
    } else {
      try {
        mgr = new NetworkPlayerManager(display, cancel, this);
        Thread runner = new Thread(mgr);
        runner.start();
```

```
      } catch(Exception e) { System.err.println(e); }
    }
  }
}
```

As you can see, Listing 5-3 is built on top of Listing 5-2. The changes are marked in bold. A new command is added to allow users to cancel a request to play the media file, in case it takes too long or the user changes his mind. The code to handle this command is added in the `commandAction()` method. More importantly, the default handling of the play command is now changed. A new class, `NetworkPlayerManager`, is created, and because it implements the `Runnable` interface, it can be started as a thread. Before going forward, let's take a look at this class in Listing 5-4.

Listing 5-4. `NetworkPlayerManager` *Class Implements the* `Runnable` *Interface and Makes Network Connections for Media Playback*

```
package com.apress.chapter5;

import javax.microedition.lcdui.*;
import javax.microedition.media.*;

public class NetworkPlayerManager implements Runnable {

  private Display display;
  private Form form;
  private StringItem msg;

  private boolean cancel = false;

  private Player player = null;

  public NetworkPlayerManager(
    Display display, Command cancelCmd, ThreadedMIDlet parent) {

    this.display = display;

    form = new Form("Network Player Manager");
    msg = new StringItem("Please Wait ... ", null);
    form.append(msg);
    form.addCommand(cancelCmd);

    form.setCommandListener(parent);
  }

  public void run() {

    display.setCurrent(form);
    boolean connected = false;
```

```
      try {
        player =
          Manager.createPlayer(
            "http://www.mmapibook.com/resources/media/audio/chapter5/siren.wav");

        player.realize();

        connected = true;
      } catch (Exception e) {
        msg.setText("Failed: " + e.getMessage());
        System.err.println(e);
        return;
      }

      if(connected && !cancel)
        msg.setText("Connected. Starting playback...");
      else {
        msg.setText("Unable to connect.");
        return;
      }

      try {
        player.start();
      } catch(Exception pe) {
        msg.setText(pe.getMessage());
        System.err.println(pe);
      }
    }

    public void cancel() {
      cancel = true;
      if(player!= null) player.deallocate();
    }
}
```

When a new instance of the `NetworkPlayerManager` class is created, it creates a `Form` instance and appends a `StringItem` for displaying messages. The cancel command is attached to this form, but the command listener for this command is still the calling MIDlet.

When the thread is started, the `run()` method takes over. It makes the `form` instance as the current display and tries to realize the `Player` instance for playback of the media file. If connection can be established, the message on the screen is updated and the playback is initiated. If, for some reason, the connection cannot be established, an error message is displayed and the display returns to the calling MIDlet.

Connection may not be established for a variety of reasons. The device may not allow your MIDlet access to the network if it isn't signed and in a correct domain, as you learned in the previous section. A path to the remote server may not be available.

While the MIDlet is trying to connect to the remote server, the user must be given a chance to cancel the request. The user can do this by issuing the cancel command. When this happens, the `cancel()` method is called, which deallocates the `Player` instance. Recall from Chapter 4 that calling `deallocate()` on an instance that is blocked at the realize call results in the instance being returned to the UNREALIZED state. Thus, if the network is intermittent or taking too long, the user can cancel the request. If the `Player` instance has already reached the REALIZED state, calling cancel will not affect anything.

If you sign this MIDlet and put it in the correct domain, you will not be asked permission to access the network when you run it. Figure 5-7 shows running a MIDlet over the Sun Java ME and the Motorola C975 emulators.

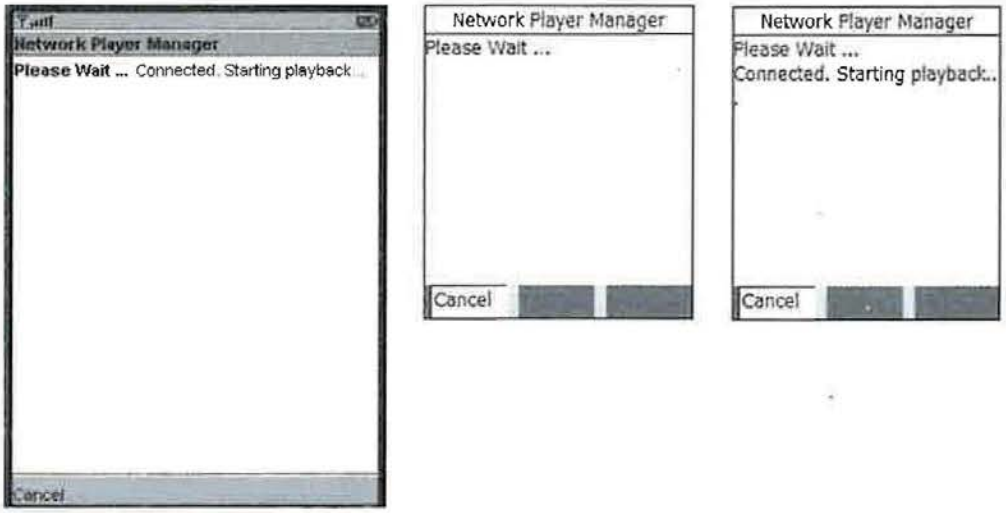


Figure 5-7. *Network access of a media file using a separate thread over Sun's DefaultColorPhone and Motorola C975 emulators*

Summary

Accessing media data over the network requires careful consideration because it involves two issues. First, network access should be done in a separate thread from the main thread, because accessing the network may block the main thread for a long time, leading to an unresponsive MIDlet. Second, network access requires permission from the user of the MIDlet as it may lead to charges from the network operator.

This chapter showed you how to overcome these two issues by explaining threads in Java ME and how they affect network access. The chapter also explained the concept of protection domains and how to overcome them for requesting permissions for network access. The chapter finished with an all-encompassing example that solved those two issues together.

The next chapter covers generating and playing tones using MMAPI with the help of the `ToneControl` control.

CHAPTER 6

Creating and Playing Tones Using ToneControl

The MMAPI is unique in providing a genuine capability to play synthetic tones on mobile devices. We all recognize the sometimes annoying, but practical, ring tones on most mobile phones. With MMAPI, you can program your own tones to build a ring tone that plays when an event occurs, to embed in a game as a musical accompaniment to the main action, or just for plain fun.

In this chapter, you'll learn how to use the built-in tone generator mechanism in MMAPI to generate and distribute synthetic tones. You'll start with the single note generator provided by the `Manager` class. You'll then learn about the `ToneControl` class, which provides mechanisms to generate complex tones based on user-defined sequences. Finally, you'll learn how to distribute these tone sequences using the JTS file structure.

First, however, you need to understand the basics of synthetic tones. Let's start with some background on this topic.

Understanding Synthetic Tones

Synthetic tones, as the name suggests, are tones generated synthetically, or more specifically, by a computer system. A ring tone is a dominant example of synthetic tones, but computer systems have been capable of generating these tones for quite some time. The ring tone industry has popularized the enormous push for this technology to enhance capabilities of mobile phones, resulting in first, monophonic, and now, polyphonic ring tones.

A synthetic tone is a musical note that has a defined duration. Monophonic ring tones only play one note of music at a time. Before the start of the next note, the previous note is cut off. Older synthesizers and almost all mobile phones and devices can play monophonic tones.

Note In music, a *note* is the unit of fixed pitch that has been given a name, or the graphic representation of that pitch in a notation system. In English, notes are given seven names: A, B, C, D, E, F, and G (in order of rising pitch).

Comparatively, polyphonic ring tones can play multiple tones at the same time, thereby providing the effect of multiple instruments playing together. Not only does it resemble a more convincing musical background, but also it's pleasing to the ears. Most modern mobile devices are capable of playing polyphonic tones.

As far as MMAPI is concerned, a single tone is specified using the note, duration, and volume. These three must be specified for the underlying engine to be able to play the tone. MMAPI provides the capability to play either a single tone using the static method `Manager.playTone(int note, int duration, int volume)` or more complex tone sequences (ring tones are nothing but sequences of tones) using the `ToneControl` interface. You'll see examples of both of these shortly.

Understanding Note, Pitch, and Frequency

To better understand how MMAPI plays tones, you must differentiate between different notes of music by understanding how notes relate to pitches and how their representation is used in MMAPI.

As stated earlier, in English seven notes are represented by the symbols A, B, C, D, E, F, and G. Each of these represents an increasing frequency of music. However, frequency is a physical term, as far as human understanding of music is concerned, and therefore, it is replaced with the more generic term of pitch. Thus, musically, pitch is the perception of the frequency of a note, and the symbols A to G represent notes in order of rising pitch. Symbol A represents a lower pitched musical note than symbol B, which is lower than symbol C, and so on.

Mathematically, each symbol is related to a frequency value, because each symbol represents a pitch. Table 6-1 shows the frequency value of each symbol.

Table 6-1. *Frequency Values for the Basic Notes*

Note Symbol	Frequency (in Hertz (Hz))
A	440
B	493.92
C	523.28
D	587.36
E	659.28
F	698.48
G	784

Of course, things are not this simple. There are a large number of variations on the basic symbols, so let's clarify some of the more important ones.

Even though notes are represented using only these seven symbols, the symbols are repetitive for frequencies that are an octave above or below them. This is better explained with an example.

Note An *octave* is the interval between one musical note and another with half or double the frequency.

Consider the symbol A. Although it represents the frequency 440, it also represents the frequencies 220 (= 440 / 2) and 880 (= 440 * 2). Further, it represents the frequencies 110 (= 220 / 2), 55 (= 110 / 2), and 27.5 (= 55 / 2) as well. All these frequencies are an octave interval apart because they are double or half of the frequency before or after them, respectively. Thus, A is a musical note that represents the frequencies 27.5, 55, 110, 220, 440, and 880. To distinguish between the different octaves, a number is placed after the symbol. A4 represents the fourth octave for the musical note A, which is 440 Hz. Table 6-2 summarizes some of these symbols.

Table 6-2. *The Different Octaves for the Musical Note A*

Symbol	Frequency (Hz)
A0	27.5
A1	55
A2	110
A3	220
A4	440
A5	880

The other seven symbols are similarly modified to arrive at different corresponding octaves. As an example, Table 6-3 shows some of the different octaves for the musical note C.

Table 6-3. *The Different Octaves for the Musical Note C*

Symbol	Frequency (Hz)
C0	16.35
C1	32.70
C2	65.41
C3	130.82
C4	261.64
C5	523.28

When no number is placed after a musical symbol, it usually means the fourth octave. Thus, A implies the frequency at 440 Hz (A4), and C implies the frequency at 261.64 (C4).

Besides octaves, the notes can differ by a semitone. If an octave difference in frequency is double or half of each frequency, a semitone is a musical interval that is one-twelfth of an octave. Alternatively, an octave contains 12 semitones.

Note A *semitone* is one-twelfth of an octave and is also known as half step. It is the smallest musical interval.

Thus, if a musical note differs from another by a semitone, it is modified into either a *sharp* or a *flat*. A sharp raises the pitch of a note by a semitone interval, whereas a flat lowers the pitch

by a semitone interval. Using musical notation, a sharp is denoted by # while b is used to denote a flat. Thus, C# (pronounced C-sharp) denotes the musical note that is a semitone above C_4 and equals 277.183 Hz. This symbol may also be written as $C_4^{\#}$, but C# is more common.

The figure of 277.183 for a pitch that is a semitone above C4 (261.64 Hz) comes from the fact that a semitone is one-twelfth of an octave, and an octave above a frequency means doubling over the previous frequency. This implies that a semitone above (or sharp as it is called) a frequency means multiplying it by the twelfth root of 2. The twelfth root of 2 equals 1.059463. Therefore, 261.64 * 1.059463 = 277.183.

Similarly, a flat pitch implies dividing the frequency by the twelfth root of 2. Therefore, C_4^{b} equals 261.64 / 1.059463 = 246.95.

Given any note, you can thus arrive at the note higher or lower than that by multiplying or dividing it by the constant 1.059463.

Using a MMAPI Formula to Calculate Note Values

With this brief interlude into musical mathematics complete, let's return to the tone support in MMAPI. To play a single tone, you can use the `Manager` class static method `playTone(int note, int duration, int volume)`. The second and third parameters are self explanatory, but the first one needs an explanation. With the background in mind from the previous section, the first parameter cannot be the frequency of a note because it is only an `int` value, whereas frequencies can have a decimal part.

The Javadoc for this method defines that the `note` parameter can be a value between `0` and `127`, both inclusive. It also provides a formula to arrive at these values as well, based on the frequency of the desired note to be played as a tone by this method. This method is shown here:

```
note = ln(freq/8.176)*(17.31234049066755)
```

The value `17.31234049066755` is called the `SEMITONE_CONST` and is arrived at with the formula:

```
SEMITONE_CONST = 1/(ln(2^(1/12)))
```

Note that `ln` in both these formulas means log to the base 'e,' also called the natural logarithm of a number (as opposed to the common logarithm, which is log to the base 10).

Using this formula, let's calculate the corresponding `int note` parameter value for the note represented by C#. As you learned in the last section, the frequency of C# is equal to 277.183.

```
note (C#) = ln(277.183/8.176) * (17.31234049066755) = 61 (after rounding)
```

To play C# using MMAPI, you use the value `61`. Listing 6-1 shows a MIDlet that will play this value when run.

Listing 6-1. *Playing C# for 5 Seconds at Max Volume*

```
package com.apress.chapter6;

import javax.microedition.midlet.MIDlet;
import javax.microedition.media.Manager;
import javax.microedition.media.MediaException;

public class CSharpMIDlet extends MIDlet {
  public CSharpMIDlet() {
  }
```

```
  public void startApp() {
    try {
      // plays C# (frequency of 277.183 for 5 seconds at max volume)
      Manager.playTone(61, 5000, 100);
    } catch(MediaException me) { System.err.println(me); }
  }

  public void pauseApp() {
  }

  public void destroyApp(boolean unconditional) {
  }

}
```

The outcome on all three of our test environments will be the same sound being played for a maximum of 5 seconds at the loudest permissible volume. Not terribly exciting, but it demonstrates the basic way of using this method to play tones.

You don't have to manually calculate the integer value of a note given its frequency. Listing 6-2 shows a simple Java class that does this for you using the formula provided earlier. The class also contains a method for doing the reverse; that is, given the integer value of a note, it will tell you the corresponding frequency of the note/tone. Finally, this Java class contains a method that will print all the 128 notes along with their corresponding frequencies.

■ **Caution** Listing 6-2 cannot be run in a Java ME environment because Java ME doesn't contain the methods `ln(double val)` and `exp(double val)` in the `Math` class. Therefore, this method must be run in a Java SE environment.

Listing 6-2. *A Simple Java Class to Calculate Note Frequencies and* `int` *Values*

```
package com.apress.chapter6;

public class NoteCalculator {

  public static final double SEMITONE_CONST = 17.31234049066755;
  public static final double ARBIT_CONST = 8.176;

  public static int getNoteAsInt(double freq) {
    return (int)Math.round((Math.log(freq/ARBIT_CONST) * SEMITONE_CONST));
  }

  public static double getNoteFreq(int note) {
    return (ARBIT_CONST * Math.exp(note/SEMITONE_CONST));
  }
```

```
  public static void printAllNoteFreq() {
    for(int i = 0; i < 128; i++) {
      System.err.println(i + " : " + getNoteFreq(i));
    }
  }

  public static void main(String[] args) {

    try {
      if(args.length == 2) {
        if(args[0].equals("1")) {
          double freq = new Double(args[1]).doubleValue();
          System.err.println(args[1] + " Hz : " + getNoteAsInt(freq));
        } else {
          int note = new Integer(args[1]).intValue();
          System.err.println(args[1] + ": " + getNoteFreq(note));
        }
      } else {
        System.err.println("Usage: NoteCalculator convType convVal \r\n" +
          " where convType: 1 for freq in Hz and 2 for note value in int \r\n" +
          " and convVal is the actual value");
      }
    } catch(Exception e) {
      System.err.println(e);
    }

    // print all notes from 0 to 127
    printAllNoteFreq();
  }
}
```

Using the methods of this class, Table 6-4 lists the integer note values for the basic notes defined in Table 6-1.

Table 6-4. *Integer Note Values for the Basic Notes*

Basic Note	Integer Note Value
A	69
B	71
C	72
D	74
E	76
F	77
G	79

Using the playTone() Method

playTone() is a nonblocking method, which means that after it is called, it returns immediately. Your MIDlet continues to play the tone for the time you specify with the duration parameter. Listing 6-3 shows an example MIDlet that will play all the notes from 0 to 127 sequentially.

Listing 6-3. *Playing All Notes Sequentially*

```
package com.apress.chapter6;

import javax.microedition.midlet.MIDlet;
import javax.microedition.media.*;
import javax.microedition.lcdui.*;

public class AllTonesPlayer extends MIDlet implements CommandListener {

  Form displayForm = new Form("Playing all tones");
  StringItem info = new StringItem("", "");
  Command exit = new Command("Exit", Command.EXIT, 1);
  Thread runner;
  boolean stop = false;

  public void startApp() {

    displayForm.append(info);
    Display.getDisplay(this).setCurrent(displayForm);
    displayForm.addCommand(exit);
    displayForm.setCommandListener(this);

    // create and start a new thread to play all the notes
    runner = new Thread(new TonePlayer(info));
    runner.start();
  }

  public void pauseApp() {
  }

  public void destroyApp(boolean unconditional) {
    if(runner != null) stop = true;

  }
```

```
  public void commandAction(Command cmd, Displayable disp) {
    // only exit command defined in this MIDlet
    destroyApp(true);
    notifyDestroyed();
  }

}

// Plays all notes sequentially
class TonePlayer implements Runnable {

  StringItem info;
  AllTonesPlayer midlet;

  public TonePlayer(StringItem info, AllTonesPlayer midlet) {
    this.info = info;
    this.midlet = midlet;
  }

  public void run() {
    try {
      for(int i = 0; i < 128; i++) {
        // wait a second before playing the next note
        Thread.sleep(1000);
        info.setText("Playing: " + i);
        Manager.playTone(i, 500, 100); // play for 500 milliseconds at max vol
        if(midlet.stop) break;
      }

    } catch(Exception me) { System.err.println(me); }
  }
}
```

The MIDlet starts playing the tones as soon as it's started. The `playTone()` method is called sequentially after every 1 second to play the note for 500 milliseconds. The note generation part is separated from the main MIDlet system thread into its own thread using the `TonePlayer` class to allow easy termination of this thread, and consequently, the tone generation sequence from the main system thread. Figure 6-1 shows the output on the Sun Java ME DefaultColorPhone emulator.

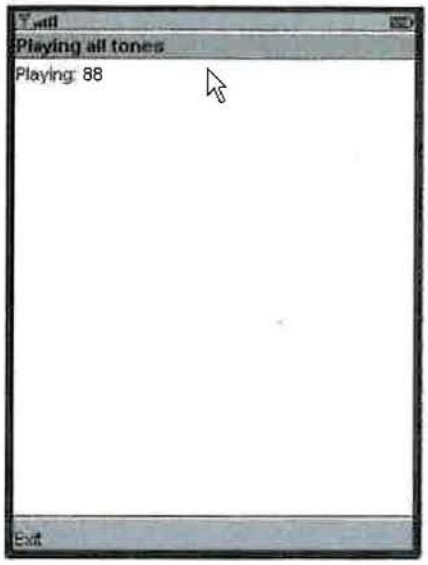


Figure 6-1. *Playing all tones in the Sun Java ME DefaultColorPhone emulator*

The `playTone()` method can throw a `MediaException` if the note can't be played due to a hardware problem with the underlying mobile device. This usually occurs if the device doesn't support the playback of tones or if the device is using the built-in tone generator (by ringing to indicate an incoming call, for example). The method also throws the runtime `IllegalArgumentException` if the `duration` parameter is set to a negative value. Setting the `volume` parameter to a negative value results in the volume being set to 0 and 100 for any value over 100.

Using Tone Sequences with `ToneControl`

Of course, playing single tones isn't very useful in itself, except in games and applications where you may want to emphasize a critical point by playing a note of high pitch to draw the user's attention. Of more interest to most developers is the ability to play tones in a sequence that resembles popular songs so they can integrate them as ring tones on mobile devices or as background tones in games.

In the last section, you saw an example of playing tones in a sequence using the `playTone()` method. The underlying hardware was told to play single tones after a predefined interval, which is hardly suitable for realistic and continuous music.

The MMAPI defines the `ToneControl` interface to play tones in a sequence. You specify the notes that you want played in any sequence that you want, including repetitive blocks, along with tempo, volume, and duration using a `byte` array. A `Player` instance for playing tones can then be used like a normal `Player` instance, including using all control and lifecycle methods that you have learned about so far.

Before you learn how to create a `Player` instance for tone playback, you need to learn how to create tone sequences using the proprietary format defined by MMAPI.

Defining Tone Sequences

Tone sequences are defined using a slightly complicated format. Basically, a tone sequences is a collection of notes and durations values as you have learned in the previous sections. Note values range from 0 to 127 representing the various frequencies, but the value of the duration for each note is defined differently than before.

For tone sequences, the duration of each note is specified using *resolution*, as opposed to measuring it in milliseconds, which you've seen so far. To understand resolution, you need to know about another standard measurement of music using the beats present in musical notes.

Understanding Time Signature

A beat, as you may know, is the pulse of music. A *time signature* is used to define how many beats are in each *bar* (segment of time) of music along with how many note values constitute one beat. Just remember that time signature is a way to quantify musical work using the beats and the notes duration that constitute one beat.

Time signature is written as a fraction. The numerator indicates the number of beats in a bar and the denominator specifies the notes/beat (that is, the fraction of note duration that makes up one beat). The most common time signature is 4/4 (called *common time*), which means that there are 4 beats in a bar and 1/4 of a note makes up a beat.

Caution Make sure it is 1/4 of a note, not 4 notes.

In other words, common time written as 4/4 implies that there will be 4 beats per measure (musical measure or bar), with each beat composed of a quarter note.

Calculating Duration Using Resolution and Tempo

Let's say you want to play a tone for 1 second. To completely specify the duration, you also need to specify the tempo of the tone of the note because tempo, which represents the beats per minute of a note, varies the way the tone is heard. Let's say the tone that you want to play for 1 second should correspond to the common time you read about in the last section. That is, there should be 4 beats (one whole note) in the tone. Then, the resolution (which is a measure of duration) is specified using the following formula:

```
duration (milliseconds) * default resolution * default tempo / 240000 = resolution
```

Now, the default resolution equals 64, and the default tempo is equal to 120 beats per minute (bpm). Thus, playing a note for 1 second using the default resolution of 64 and the default tempo of 120 bpm by using the preceding formula equals the duration of

```
1000 * 64 * 120 / 240000 = 32
```

You are, of course, allowed to change the values of the default resolution and tempo. Thus, let's say the default tempo is changed to a faster beat, with 240 bpm as the value. The same tone will have the duration of

```
1000 * 64 * 240 / 240000 = 64
```

and for a slower beat of say 60 bpm:

```
1000 * 64 * 60 / 240000 = 16
```

Similarly, changing the default resolution to say 32 will result in a duration of

```
1000 * 32 * 120 / 240000 = 16
```

If all this seems too complicated for simple tone generation, then just remember to use the duration of a note in multiples of 8, with 8 being the lowest interval for which you want the tone to play and 120 being the longest. (You can use values that are not multiples of 8 as well, but they don't produce accurate results. No duration value can be greater than 127, as the duration is represented as a byte.)

Creating Sequences

Now that you know how to specify the note and calculate the duration for the note, you can now actually create a tone sequence to play using the `ToneControl` interface. The simplest tone sequence contains the `ToneControl` version number, which is always `1`, followed by note-duration pairs. Thus, the following is a single note tone sequence:

```
ToneControl.VERSION, 1
69, 32
```

The first two values in the sequence must always be `ToneControl.VERSION` and `1`. This identifies the version of this `ToneControl` (version of the `ToneControl`, not the sequence that you are describing), and by default is equal to 1 and unlikely to change. Next, you will have a note followed by its duration as described in the previous sections. Thus, the preceding sequence consists of a single note 69 that must be played for duration of 32 resolution.

There is no specific value to end a sequence. The last note-duration pair ends the sequence. Therefore, the preceding sequence is complete and valid. In code, it looks like the following:

```
byte[] sequence = new byte[] {
  ToneControl.VERSION, 1,
  69, 32,
};
```

`VERSION` is a constant in the `ToneControl` interface and is assigned a value of `-2`.

Let's now add more notes to this sequence. Actually, let's try to create the sequence for a popular tune, "Happy Birthday to You."

The tone sequence for the first stanza for this tune is shown here in note-duration pairs:

```
72, 4, 72, 2, 74, 8, 72, 8, 77, 8, 76, 16
```

In code, it looks like this:

```
byte[] sequence = new byte[] {
  ToneControl.VERSION, 1,
  72, 4, // Hap-
  ToneControl.SILENCE, 2,
  72, 2, // -py
  ToneControl.SILENCE, 2,
  74, 8, // Birth-
```

```
  ToneControl.SILENCE, 2,
  72, 8, // -day
  ToneControl.SILENCE, 2,
  77, 8, // to
ToneControl.SILENCE, 2,
76, 16 // you
};
```

To arrive at the note values and their durations for this sequence the trick is to use tone values that are available freely on the Internet for various other formats. However, these formats are different from the MMAPI format described so far, so you need to be able to convert between these formats and the MMAPI format.

The most popular format is the Ringing Tone Text Transfer Language (RTTTL) format, published by Nokia. Various Web sites on the Internet will provide you with the RTTTL format for a song or tune (just search for the name of the song or tune along with the text "RTTTL"). For example, the RTTTL format for the complete "Happy Birthday to You" tune is

```
Happy Birthday Song:d=4,o=5,b=125:16c, 32p, 32c, 32p, 8d, 32p, 8c, 32p, 8f, 32p, e,
 16p, 16c, 32p, 32c, 32p, 8d, 32p, 8c, 32p, 8g, 32p, f, 8p, 16c, 32p, 32c, 32p,
 8c6, 32p, 8a, 32p, 8f, 32p, 8e, 32p, 8d, 32p, 16a#, 32p, 32a#, 32p, 8a, 32p, 8f,
 32p, 8g, 32p, f
```

After you get the format for your particular song/tune, you need to convert it to the MMAPI format. You could try to understand the RTTTL format before you start to convert it to the MMAPI format, or you could just use the `RingToneConverter` class provided by Sun to do this for you.

Converting RTTTL to MMAPI Format Using `RingToneConverter`

The `RingToneConverter` class is provided with the examples in the Wireless Toolkit. This class is present in the MMADemo application as a standalone Java ME class. It converts the RTTTL format to the MMAPI format and is very handy. Listing 6-4 shows a MIDlet called `ConverterMIDlet` that uses this class to load and parse the RTTTL format of the "Happy Birthday to You" tune from a file. At this stage, it simply prints the equivalent MMAPI format.

Listing 6-4. *Using the* `RingToneConverter` *Class to Parse RTTTL Formats to MMAPI Format*

```
package com.apress.chapter6;

import javax.microedition.midlet.*;

import javax.microedition.media.*;
import javax.microedition.media.control.*;


public class ConverterMIDlet extends MIDlet {
```

```
public void startApp() {
  try {

    // Load the RTTTL format of the file as an InputStream
    RingToneConverter rtc =
      new RingToneConverter(
        getClass().getResourceAsStream(
          "/media/misc/happybday.rtttl"), "Happy Birthday");

    // get the equivalent sequence
    byte[] seq = rtc.getSequence();

    // print it
    printSequence(seq);

  } catch (Exception e) {
    System.err.println(e);
  }
}

private void printSequence(byte[] seq) {

  // print the sequence in a user friendly format
  byte bite = 0;
  for(int i = 0; i < seq.length; i++) {
    // the first control structure or the note value
    bite = seq[i];
    if(i % 2 == 0) {
      if(bite == ToneControl.VERSION)
        System.err.print("ToneControl.VERSION, ");
      else if(bite == ToneControl.TEMPO)
        System.err.print("ToneControl.TEMPO, ");
      else if(bite == ToneControl.SILENCE)
        System.err.print("ToneControl.SILENCE, ");
      else if(bite == ToneControl.RESOLUTION)
        System.err.print("ToneControl.RESOLUTION, ");
      else if(bite == ToneControl.SET_VOLUME)
        System.err.print("ToneControl.SET_VOLUME, ");
      else
        System.err.print(bite + ", ");
    }
    else {
      // the value of a control structure or the note duration
      if(i != (seq.length - 1))
        System.err.println(bite + ", ");
```

```
        else
          System.err.println(bite);
      }
    }

  }

  public void pauseApp() {
  }

  public void destroyApp(boolean unconditional) {
  }
}
```

Several constructors for the `RingToneConverter` class allow you to load the RTTTL format from a variety of sources. In this case, the RTTTL format for the "Happy Birthday to You" tune is stored in a text file called `happybday.rtttl`, and the `RingToneConverter(InputStream is, String tuneName)` constructor is used to load it. You can also use the `RingToneConverter(String url, String name)` constructor to load the file from a URL, or if you have the RTTTL format for a tune in a byte[] array, you can use the `RingToneConverter(byte[] data, String tuneName)` constructor directly. All constructors ultimately use the last constructor to parse the data.

Because the constructor also does the parsing of the RTTTL format, after it returns successfully, the corresponding MMAPI sequence is easily available by calling the `getSequence()` method. This method returns the MMAPI format in a byte array sequence, perfect for use with the `ToneControl`. You can print this sequence out using the `printSequence()` method in a format that makes it easy to copy and paste the resulting MMAPI sequence format in code.

Note the other constants from the `ToneControl` class that we've used besides the `ToneControl.VERSION` constant as listed in Table 6-5.

Table 6-5. `ToneControl` *Constants*

`ToneControl` Constant	`ToneControl` Value	`ToneControl` Description
`ToneControl.VERSION`	`-2`	The first control in a sequence and denotes the `ToneControl` version. Always equal to `1`.
`ToneControl.TEMPO`	`-3`	The second control in a sequence and used to set the tempo of the following sequence. Default value is `30`.
`ToneControl.RESOLUTION`	`-4`	The third control in a sequence and used to set the resolution of a sequence, as defined earlier. Default equals `64`.
`ToneControl.SET_VOLUME`	`-8`	Can be used at any stage in a sequence to set the volume of the notes following it.
`ToneControl.SILENCE`	`-1`	Can be used at any stage in a sequence to indicate a silent note value. It must, of course, be followed by a duration value.

Other constants will be discussed in the coming sections.

Creating, Defining, and Playing Blocks of Sequences

Ring tones that have repetitive stanzas don't need to define these stanzas separately each time they are required to be played. The MMAPI format allows you to define a repetitive block once and then refer to it whenever and wherever you want it played.

Sticking with the "Happy Birthday to You" tune, let's say you wanted the first stanza played a couple of times before moving on to the rest of the tune. This first stanza is the "Happy Birthday to You" part and is reproduced here:

```
72, 4, ToneControl.SILENCE, 2, 72, 2, ToneControl.SILENCE, 2, 74, 8,
ToneControl.SILENCE, 2, 72, 8, ToneControl.SILENCE, 2, 77, 8,
ToneControl.SILENCE, 2, 76, 16
```

To mark this as a block, start by putting the `ToneControl` control constant `BLOCK_START` with a number to identify this block and end with `BLOCK_END` using the same number:

```
ToneControl.BLOCK_START, 0,
72, 4, ToneControl.SILENCE, 2, 72, 2,
ToneControl.SILENCE, 2, 74, 8, ToneControl.SILENCE, 2, 72, 8,
ToneControl.SILENCE, 2, 77, 8, ToneControl.SILENCE, 2,  76, 16,
ToneControl.BLOCK_END, 0
```

The sequence has been marked as block `0`. This block can now be played anywhere in the sequence by using the `ToneControl` control constant `PLAY_BLOCK` followed by the number identifying the block. Thus, the following placed anywhere in a sequence after the block definition will play the block just defined:

```
ToneControl.PLAY_BLOCK, 0
```

Of course, you can't play a block that hasn't been defined. Therefore, all block definitions must come before an attempt to play them is made. There is no limit to the number of blocks that you can define.

The following byte array shows the sequence of playing the first two stanzas of "Happy Birthday to You," with the first stanza repeated once.

```
byte[] sequence = new byte[] {
  ToneControl.VERSION, 1,
  ToneControl.BLOCK_START, 0,
  72, 4, ToneControl.SILENCE, 2, 72, 2, ToneControl.SILENCE, 2, 74, 8,
  ToneControl.SILENCE,  2, 72, 8, ToneControl.SILENCE, 2, 77, 8,
  ToneControl.SILENCE, 2, 76, 16,
  ToneControl.BLOCK_END, 0,
  ToneControl.PLAY_BLOCK, 0, // plays block 0
  ToneControl.SILENCE, 4,  72, 4, ToneControl.SILENCE, 2, 72, 2,
  ToneControl.SILENCE, 2, 74, 8, ToneControl.SILENCE, 2, 72, 8,
  ToneControl.SILENCE, 2, 79, 8,
  ToneControl.SILENCE, 2, 77, 16, // plays the second stanza
  ToneControl.PLAY_BLOCK, 0 // plays block 0 again
}
```

`BLOCK_START`, `BLOCK_END`, and `PLAY_BLOCK` constants have a value of `-5`, `-6`, and `-7`, respectively.

Playing Sequences Using ToneControl and Player

Defining sequences is great, but it's of no use if you can't play them using MMAPI. So let's see how you can play the sequences you have learned to create in the previous sections using a combination of the ToneControl and Player interfaces.

Listing 6-4 showed how to parse a tone file in RTTTL format to the MMAPI format. Let's now add a method (see Listing 6-5) to the ConverterMIDlet defined in this listing that will play this converted tone.

Listing 6-5. *Playing Tone Sequences*

```
private void playSequence(byte[] seq) throws Exception {

  // create a Tone Player
  Player player = Manager.createPlayer(Manager.TONE_DEVICE_LOCATOR);

  // must realize it before getting ToneControl
  player.realize();

  // now get the ToneControl
  ToneControl toneControl = (ToneControl)player.getControl("ToneControl");

  // set the sequence
  toneControl.setSequence(seq);

  // and start the player - this will play the sequence
  player.start();
}
```

After creating or generating a sequence, playing it using MMAPI is relatively simple. You need a Player instance that can play tones. The Manager class provides a constant for creating a tone-based Player instance, which is supplied by the mobile device's hardware. This constant is the TONE_DEVICE_LOCATOR, and its value is equal to device://tone. So a tone-based Player instance is created by supplying this constant as the locator to the createPlayer() method.

This tone-based Player instance will now behave like any other instance. You can start it, stop it, realize it, prefetch it, and so on. To play tones, you need to access the ToneControl control provided by this instance. However, recall from Chapter 4 that an unrealized instance cannot provide any controls. Therefore, in Listing 6-5, the Player instance is realized before the ToneControl control is fetched using the getControl() method.

Finally, ToneControl is supplied the tone sequence by using the setSequence() method. This sequence is the final MMAPI formatted sequence, either created manually or by parsing the RTTTL format.

The Player instance is now ready and can be started when required. In Listing 6-5, the instance is started immediately by using the normal start() method. This instance will behave like any other Player instance; for example, you can pause it using the stop() method, make it repeat using the setLoopCount() method, or listen to events by attaching a PlayerListener.

Distributing Tone Sequences

The tone sequences that you create using the special MMAPI tone sequence format can be distributed using the same file format in a binary mode. This means that the sequence of a tone is dumped into a binary file with the extension of `jts` (Java Tone Sequence). This file can then be downloaded or loaded into any MMAPI-compliant device, and the device will be able to play the tone. To help with the recognition of these files by Web servers and Web browsers, the JTS files have the MIME type of audio/x-tone-seq associated with them.

Creating JTS Files

To create these binary files, you'll need to dump your tone sequence into a file. However, you can't do this within the MIDlet environment because there is no provision to write to a file easily.

The `RingToneConverter` comes to the rescue again by providing a method called `dumpSequence()`, which provides the hexadecimal representation of the tone sequence for you to take and create a binary file out of. To get this representation, simply use `rtc.dumpSequence()` to print the sequence on the standard out. The hex dump sequence for the "Happy Birthday to You" tone is shown here:

```
FE 01 FD 1F 48 04 FF 02
48 02 FF 02 4A 08 FF 02
48 08 FF 02 4D 08 FF 02
4C 10 FF 04 48 04 FF 02
48 02 FF 02 4A 08 FF 02
48 08 FF 02 4F 08 FF 02
4D 10 FF 08 48 04 FF 02
48 02 FF 02 54 08 FF 02
51 08 FF 02 4D 08 FF 02
4C 08 FF 02 4A 08 FF 02
52 04 FF 02 52 02 FF 02
51 08 FF 02 4D 08 FF 02
4F 08 FF 02 4D 10
```

Now, to convert this hexadecimal representation into a binary file, you need to create a Java class that will read this representation from a file, convert it back into a byte array, and write the byte array out to a binary file with the extension of `jts`. Listing 6-6 shows such a class called `CreateJTSFileFromHexString`. Store the hexadecimal representation just shown in a file called `happybday_hex.txt` and compile and run `CreateJTSFileFromHexString` with this file as a parameter.

Listing 6-6. *A Class to Create a Binary JTS File from a Hex Representation*

```
package com.apress.chapter6;

import java.io.*;

public class CreateJTSFileFromHexString {

  public static void main(String[] args) {
```

```
if(args[0] == null) System.err.println("Usage: java <filename>");

// initialize streams that we will need
FileReader fr = null;
BufferedReader br = null;
ByteArrayOutputStream bos = null;
FileOutputStream fos = null;

try {
  // the argument must be the file containing tone format in hex string
  File hexStringFile = new File(args[0]);

  // create text-based readers on it
  fr = new FileReader(hexStringFile);
  br = new BufferedReader(fr);

  String lineRead;
  String hexString = "";

  // read the file, a line at a time into the hexString variable
  while((lineRead = br.readLine()) != null) {
     hexString += lineRead;
  }

  // remove the spaces within this hexString
  StringBuffer buf = new StringBuffer();
  for(int i = 0; i < hexString.length(); i++) {
    if(!Character.isWhitespace(hexString.charAt(i)))
      buf.append(hexString.charAt(i));
  }

  // the final hexString with spaces removed
  hexString = buf.toString();

  // now write the hexString out to a file as a byte array making it a
  // binary file
  byte[] txtInByte = new byte[hexString.length()/2];
  int j = 0;
  for (int i = 0; i < hexString.length(); i += 2)
  {
    txtInByte[j++] =
      (byte)Integer.parseInt(hexString.substring(i, i + 2), 16);
  }

  // the byte array created, write it to a ByteArrayOutputStream
```

```
            bos = new ByteArrayOutputStream();
            bos.write(txtInByte, 0, txtInByte.length);

            // and create a physical file with the extension jts containing this data
            fos = new FileOutputStream(
              new File(args[0].substring(0, args[0].indexOf(".")) + ".jts"));
            bos.writeTo(fos);

        } catch (Exception e) {
            System.err.println(e);
        } finally {
            try {
                if(fos != null) fos.close();
                if(bos != null) bos.close();
                if(br != null) br.close();
                if(fr != null) fr.close();
            } catch(Exception e) {
                System.err.println(e);
            }
        }
    }

}
```

Remember that this is a normal Java file and not a Java ME class. So this will need to be run in its own Java SE environment, as was the case with Listing 6-2, `NoteCalculator`.

The output will be a file named `happybday_hex.jts`. This is a binary file that cannot be viewed in a text editor. However, this file contains the tone sequence for "Happy Birthday to You" in the MMAPI format and can now be distributed and played.

Playing Tone Sequences Stored in Files

Because MMAPI recognizes the `jts` extension files, you can now create `Player` instances that can load these files using locator strings. So now it's possible to create a `Player` instance that loads a tone sequence as a `jts` extension file from a Web site, using the `createPlayer(String locator)` method. First, let's load a JTS file stored in a JAR file. Listing 6-7 shows the code for the `DistributedToneMIDlet` that will load and play the `happybday_hex.jts` file, created in the previous section, from its JAR file.

Listing 6-7. *Loading and Playing JTS File from JAR File*

```
package com.apress.chapter6;

import javax.microedition.midlet.*;
import javax.microedition.lcdui.*;
import javax.microedition.media.*;
import javax.microedition.media.control.*;

public class DistributedToneMIDlet extends MIDlet {
```

```
  private Player tonePlayer;

  public DistributedToneMIDlet() {
    try {
      tonePlayer = Manager.createPlayer(getClass().getResourceAsStream(
          "/media/misc/happybday_hex.jts"), "audio/x-tone-seq");
    } catch(Exception e) {
      System.err.println(e);
    }
  }

  public void startApp() {
    try {
      if(tonePlayer != null)
        tonePlayer.start();
    } catch(Exception e) {
      System.err.println(e);
    }
  }

  public void pauseApp() {
  }

  public void destroyApp(boolean unconditional) {
  }
}
```

As you can see, this code is not very special. In fact, it's almost identical to the code in Listing 3-1 in Chapter 3, where you learned to play a simple wav file, with changes made for the different content types. Notice that you didn't even need to get the `ToneControl` and set the sequence on it. By creating a tone-playing instance like this, most of the other things that you learned about earlier are abstracted nicely.

To play the same sequence on a Web site, all you need to do is replace it with the corresponding `createPlayer(String locator)` method that takes the location of the Web site as a parameter. An example is shown here:

```
tonePlayer = Manager.createPlayer(
  "http://www.mmapibook.com/resources/media/tones/chapter6/happybday_hex.jts");
```

The extension of the file will let MMAPI's `Manager` class know that it needs to create a `TonePlayer` and set its sequence to the sequence specified in the JTS file. If there are any errors in the JTS file, you will get an error similar to "bad jts file. Error no <no>." Most of these errors occur if the JTS file hasn't been created correctly, so if you've followed the steps so far, these errors will not occur.

Summary

MMAPI identifies the fact that even the simplest of devices offer the developer and the user some capability of tone generation. MMAPI provides the ability to generate simple tones in its most simple form using the `Manager` class. Of course, if the device supports the full set of the MMAPI implementation, it provides an even richer set of tone-generation, modification, and playback capabilities.

This chapter showed you how to take advantage of this capability in MMAPI. You also learned how to play simple, single tones and to create and distribute more complex tones and tone sequences. You also learned a simple lesson in music theory, which was essential to understanding some of the concepts behind tone generation.

The next chapter covers the basics of MIDI and how MMAPI is capable of handling it.

CHAPTER 7

Managing MIDI Using MIDIControl, TempoControl, and PitchControl

Contrary to popular belief, Musical Instrument Digital Interface (MIDI) is not a representation of music. Rather, it's a communication protocol, designed to transmit information about music digitally across disparate musical systems. Instead of describing audio data directly, MIDI represents it by using events that take place when a sound from an electronic synthesizer is made. This event information is what constitutes a MIDI data/file.

In this chapter, you'll learn about the support MMAPI provides for playing and controlling MIDI. You'll also learn about the different MIDI specifications that are supported and how the different aspects of the specification map to the actual implementation. Extensive examples with `MIDIControl` allow you to use `MIDIControl` effectively. You'll also learn how to play and manipulate MIDI files, without using `MIDIControl`, by using just `TempoControl` and `PitchControl`. You'll understand soundbanks, programs, and other MIDI-related terminology and how to use them.

But first, you need to get a working understanding of MIDI.

Understanding MIDI

Even though you may not realize it, these days MIDI is all around you. Seen a movie at a cinema? The orchestra in the movie was most probably synthesized in MIDI using an electronic keyboard. Been to a concert or a nightclub? The themed lights are in all probability controlled using MIDI messages, synchronized with the music. Love a series on TV? The title music is done using a MIDI synthesizer. How about your cell phone? Your polyphonic ring tone is generated using MIDI!

With such widespread use, it's no wonder that there is a strong industry momentum behind this technology. An audio engineer named Dave Smith proposed the original MIDI standard, and the first specification was published in 1982. Although there have been several updates on this original specification, the current specification is still called MIDI 1.0 with a smaller version number of 96.1 Second Edition (released in November 2001).

Polyphonic ring tones that you have on your mobile phone are based on a variation of the original MIDI specification, called Scalable Polyphony MIDI (SP-MIDI). This specification allows a varying number of notes to define the same MIDI data and, therefore, caters to both high-end and low-end phones with varying polyphonic capabilities.

The official and definitive Web site for keeping up to date with the various facets of the MIDI specification is *http://www.midi.org*. Although it doesn't contain a free copy of the MIDI specification, it still contains a wealth of information. The MIDI specification is available for purchase as a book, although it's available on the Internet in snippets. You can also find useful MIDI-related information at *http://en.wikipedia.org/wiki/MIDI*.

Understanding the MIDI Specification

The MIDI specification has two parts. One deals with the physical hardware interface standard for transmitting MIDI; the other is a software protocol dealing with the communication, transmission, and format of MIDI messages. The physical specification is elaborate and specifies the serial transfer rate of messages (31.25 Kbaud), besides defining characteristics of ports and connector cables for MIDI IN, MIDI OUT, and MIDI THRU. The physical side of the MIDI specification doesn't help much with applying it to MMAPI, so it isn't covered further in this book.

The software specification specifies the MIDI message format, which is used for transmission of messages. Considering that the MIDI specification is a communication protocol, it helps to think of a transmitter and a receiver. A transmitter can be any instrument that is capable of producing synthesized music, such as a computer system or an electronic synthesizer. A receiver can also be another computer system and/or an electronic synthesizer, as long as it contains a MIDI IN port. A transmitter, as expected, should contain a MIDI OUT port. This simple configuration is depicted in Figure 7-1.

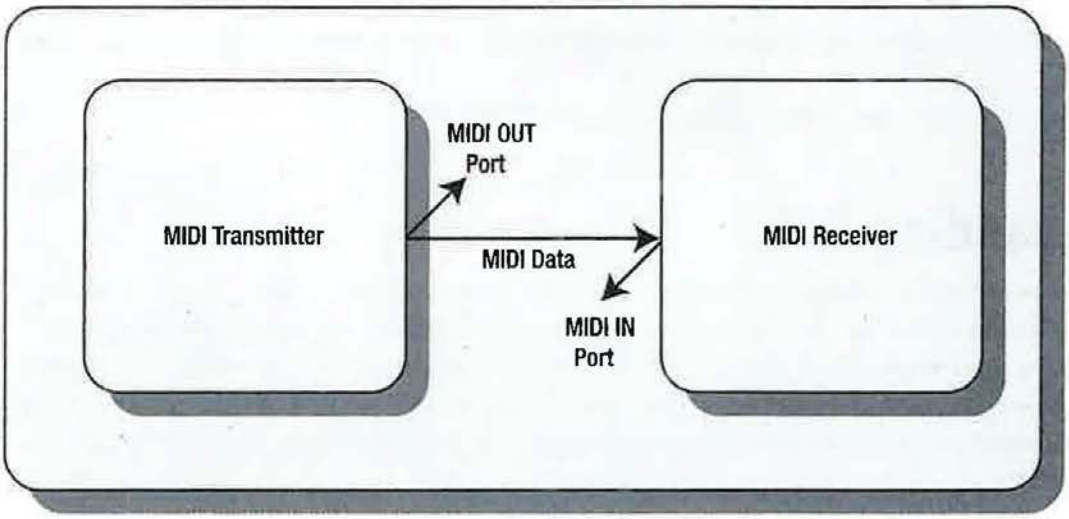


Figure 7-1. *MIDI communication*

As expected, a MIDI transmitter can act as a receiver and vice versa.

The MIDI data in Figure 7-1 is organized into messages. Each message can be thought of as a multi-byte packet that contains information about a particular channel. Think of a channel in MIDI as an exclusive transmission network for the transfer of note information for a particular musical instrument. Transmitters and receivers are primed to send and receive information about 16 possible channels. If any of the channel information is missing, for example, if there is no information about drums being played, then both parties ignore that channel.

The MIDI message format allows the depiction of all notes that can be played by a musical instrument. The MIDI specification assigns notes to particular messages, and any electronic instrument that follows this specification can interpret these messages.

MIDI Message Format

When a musician plays a note on, let's say, a musical keyboard, three events take place:

- Musician presses the key to play the note with a particular volume.
- Musician keeps pressing the key, increasing or decreasing the force with which the note is being played.
- Musician stops playing the note by taking his finger off the particular key.

All three events are transmitted via the MIDI OUT port serially, through a series of three messages, one for each event. Each of these messages is a MIDI message and consists of a multi-byte packet. The first byte in each message is a Status byte, and is followed by 0, 1, or 2 Data bytes. Status bytes have their most significant bit set to 1, and Data bytes have their most significant bit set to 0. This is the standard MIDI message format (see Figure 7-2).

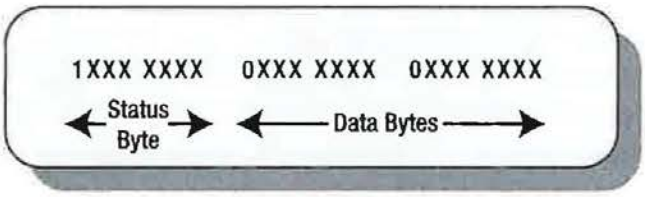


Figure 7-2. *Standard MIDI message format*

These MIDI messages are then divided into two types, depending on whether they are carrying information for a particular channel or whether they are system-wide messages that are intended for all devices that may be interconnected in a MIDI network. These two types of messages are called Channel messages and System messages. These types are further subclassified, with the Channel messages divided into either the Voice or Mode Channel message type, and the System messages divided into Common, Real-Time, or Exclusive System message type. Figure 7-3 shows these classifications.

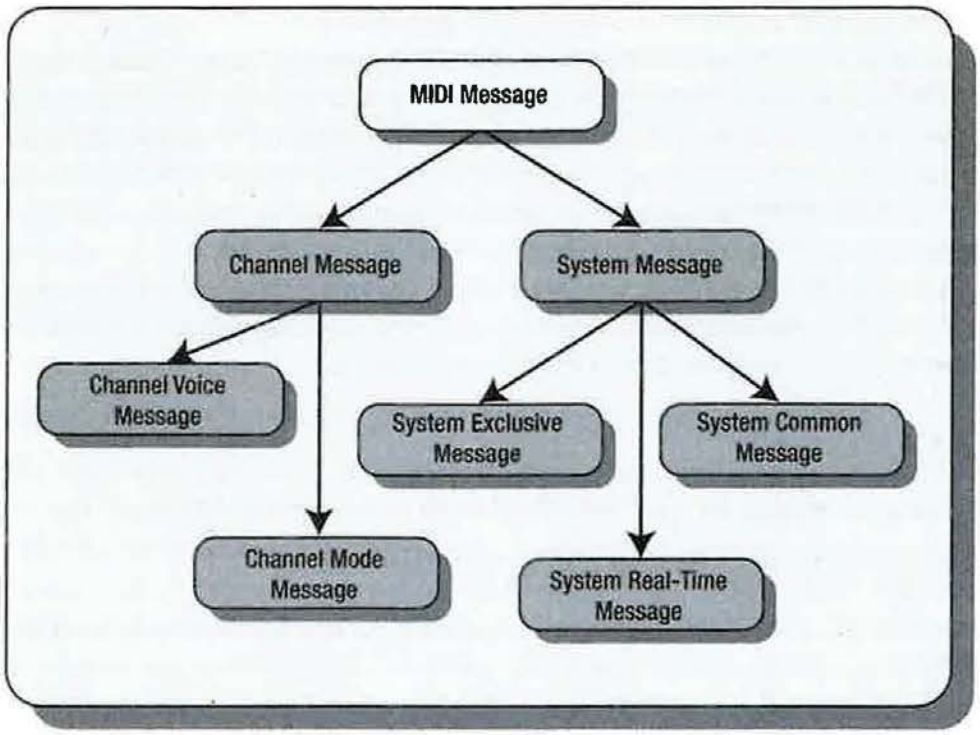


Figure 7-3. *MIDI message classifications*

System messages are differentiated from Channel messages by the presence of 1 in the first 4 bits of the Status byte. That is, if the Status byte is of the format `1111 XXXX`, then the message is a System message; otherwise, it is a Channel message, in which case, the last 4 bits in the Status byte identify one of 16 channels that the message is intended for. For example, `1000 1111` as Status byte in a message indicates that it is intended for Channel 16, `1000 0000` indicates the message is for Channel 1, `1000 0001` is a message for Channel 2, and so on.

Further, a Channel message is classified as a Voice or a Mode Channel message by a specific set of bits in the first 4 bits of the Status byte. If the Status byte is of the format `1011 XXXX` and has a special character in the Data byte that follows it, it is a Mode Channel message; otherwise, it is a Voice Channel message. A Voice Channel message controls a particular channel by starting or stopping the playing of a note, among other things. The Data bytes following this Status byte contain information about the note. The Mode Channel message is a response to the Voice Channel message.

Table 7-1 shows how to spot the different messages discussed so far.

Table 7-1. *Differentiating Between Different MIDI Messages*

First 4 Bits of Status Byte	Last 4 Bits of Status Byte	Message Type	Comment
1111	XXXX	System	
1011	XXXX	Mode Channel message	Only if the Data bytes following this Status byte contain a value between 121 and 127

First 4 Bits of Status Byte	Last 4 Bits of Status Byte	Message Type	Comment
1000			
1001			
1010			
1011			
1100			
1101			
1110	XXXX	Voice Channel message	Only if the Data bytes following this Status byte contain a value between 0 and 120

Continuing on to the three different System message types, their formats are shown in Table 7-2 along with a brief description.

Table 7-2. *The Three Different Types of System Messages in MIDI*

Message Type	Format	Comment
System Real Time	1111 1XXX	XXX is a value between 0 and 7 (000 = 0, 111 = 7). These messages are used to synchronize the whole MIDI system in real time and do not contain any Data bytes.
System Common	1111 0XXX	XXX is a value between 1 and 7. These messages may contain 0 to 2 Data bytes and are intended for an interconnected MIDI network.
System Exclusive	1111 0000	This tracing or debugging message may contain several Data bytes following it with system information.

More About the Voice Channel Messages

The majority of the messages in a MIDI transmission are the Voice Channel messages. These messages contain specific information about notes; how long to play them, what channel to play them on, whether to turn them on or off, how much key pressure is to be applied, and so on. As you have learned so far, these messages consist of a Status byte followed by one or two Data bytes. Let's examine the composition of these Data bytes now.

One of the primary functions of the Voice Channel message is to turn a particular note on or off on a specific channel. This message must also include information about the velocity (roughly equivalent to volume) at which the note was turned on or off. To turn a note on, the message is of the format 1001 XXXX 0YYY YYYY 0ZZZ ZZZZ. As you can see, the first byte is a Status byte followed by two Data bytes, which is indicated by the presence of 0 in the most significant bit. To turn the note off, the format is 1000 XXXX 0YYY YYYY 0ZZZ ZZZZ. The value of the note to turn on or off is indicated by the first Data byte (0YYY YYYY) and can be any value between 0 and 127. The velocity with which to turn the note on or off is indicated by the last Data byte (0ZZZ ZZZZ), and it can be a value between 0 and 127.

Note See the "Using MMAPI Formula to Calculate Note Values" section in Chapter 6 for an explanation of note values.

As an example, suppose you wanted to compose a MIDI message that would tell a MIDI receiver to turn on the note Middle C (equal to 60) on MIDI Channel 12 at a high velocity (remember velocity roughly means volume) of 100. Start with the Status byte:

```
1001 1011
```

The first 4 bits (from the left) are the Note ON command, and the last four bits represent Channel 12 (Channel 1 is 0000 *not* 0001). Next, write the first Data byte representing the note Middle C (equal to 60):

```
0011 1100
```

Finally, write the second Data byte, indicating the velocity as equal to 100:

```
0110 0100
```

Putting it all together,

```
1001 1011 0011 1100 0110 0100
```

will start playing the note Middle C at a velocity of 100 on the MIDI Channel indicated by the number 12. This will not stop playing until a corresponding Note OFF message is received:

```
1000 1011 0011 1100 0110 0100
```

Of course, the velocity with which to turn the note off could be made different than the original one in this Note OFF message, but in this example it has been left as is.

Turning notes on and off is not the only Voice Channel message, and Table 7-3 lists all the possibilities along with a brief description.

Table 7-3. *All Possible Voice Channel Messages*

Status Byte	First Data Byte	Second Data Byte	Message	Comment
1000 XXXX	0YYY YYYY	0ZZZ ZZZZ	Note OFF	Turn a note off on a channel with a given velocity.
1001 XXXX	0YYY YYYY	0ZZZ ZZZZ	Note ON	Turn a note on with a given velocity on a particular channel.
1010 XXXX	0YYY YYYY	0AAA AAAA	After-Touch	Key pressure for polyphony; second Data byte indicates the pressure value (0-127).
1011 XXXX	0BBB BBBB	0CCC CCCC	Control Change	First Data byte indicates which control to change (0-121); second Data byte indicates control value (0-127).

Status Byte	First Data Byte	Second Data Byte	Message	Comment
1100 XXXX	0DDD DDDD	No second Data byte	Program Change	Used to change the instrument of a channel to another instrument, so that more than 16 instruments can be used at one time.
1101 XXXX	0EEE EEEE	No second Data byte	Channel Pressure	Changes the pressure of a whole instrument, not just a single note (which is done with After-Touch).
1110 XXXX	0GGG GGGG	0FFF FFFF	Pitch Bend	A shift in a note's pitch in a very small increment or decrement.

The key Voice Channel messages are the first two for turning notes on or off on a channel, and you'll use these more often than the others. The fourth message (Control Change) is also used extensively to effect changes to various controls within the MIDI environment, including main volume (7), modulation wheel (1), and pan controller (10) controls, among others. Finally, you'll use the Program Change message to change instruments before sending the note to be played on a particular channel.

Storing and Distributing MIDI Messages

The format of MIDI messages presented in the previous section is true for live streaming of these messages, which essentially means that messages are played back as they are received in real time. However, MIDI messages can be stored in a file, and distributed for playback later as well. When these messages are stored in a file, they require timing information to be stored with them as well to allow for synchronization of these messages.

The most common format for storing these files is in Standard MIDI file (SMF) format, denoted by the extension `.smf`. These files are created (and read) using sequencer software on computers/electronic instruments and contain a sequence of tracks. Each track contains information about a particular channel and the note sequence to perform, including other meta-level information.

SMF files are generally distributed on the Internet with the extension of `.mid`. Most files with `.mid` (short for MIDI) extensions are compatible with `.smf` files, and you can interchange the use of these files. The distinction lies in the fact that `.mid` extension files correspond to a narrow interpretation of the MIDI file format specification, called the General MIDI specification.

General MIDI Specification

The General MIDI (GM) specification is a tighter, more focused interpretation of the overall MIDI specification that is intended for greater interoperability between MIDI devices. It specifies a general set of features that the GM devices must conform to. The core features of this specification are

- Support for polyphony (GM devices must allow playback of simultaneous, multiple notes on a single channel)
- Definite support for all 16 channels
- Defined and standard program numbers for various instruments

The standard program numbers for various instruments was one of the main driving forces for the adoption of the GM spec. These devices and their corresponding numbers are listed here: *http://en.wikipedia.org/wiki/General_MIDI*.

Note that only 128 instruments can be supported, as per this specification. To support more instruments, the concept of a *bank* was introduced. A soundbank, or bank, is a collection of the 128 instruments that are supported by a particular MIDI device. Soundbanks can be added or removed, and custom soundbanks can be created to support the existing ones in a device.

Using MIDI in MMAPI

Support for MIDI in MMAPI is provided in the form of the `MIDIControl` control and is aided by the use of `PitchControl` and `TempoControl` controls. However, note that `MIDIControl` is an optional control, and MMAPI implementations are not required to support it. Most instances, however, do support this popular control in one form or another. On one hand, at the minimum, if `MIDIControl` is implemented, you are guaranteed support for sending MIDI events to the control, thereby creating your own set of sequences and messages, as you learned in the previous section. If a full `MIDIControl` is implemented, you are allowed to query the installed soundbanks and manipulate them extensively. You'll learn shortly how to find out whether the MMAPI implementation that you are working on supports a minimum or full `MIDIControl` control.

The MMAPI specification states that for basic usage, you don't even need to access the `MIDIControl` control. This is true, as long as you have a basic MIDI file that you want to play as is, without any modifications. Let's try and play such a basic MIDI file.

Playing MIDI Without `MIDIControl`

Even though you may not directly need to access the `MIDIControl` control to play MIDI files, it doesn't mean that `MIDIControl` is not implemented. Behind the scenes, `MIDIControl` is used to access the synthesizer on the device that you are working on, but you won't need to use it directly. Instead, for simple changes, such as pitch and tempo, you can use the `PitchControl` and `TempoControl` controls. For volume changes, simply use the `VolumeControl` control.

Playing a MIDI File

As you may realize by now, playing, controlling, and using MIDI files is similar to playing other file types that you've learned about in previous chapters, thanks to a similar interface. Therefore, playing MIDI files should not require extra effort on your part. Listing 7-1 shows you a simple code listing that plays a local MIDI file.

Listing 7-1. *Playing a Local MIDI File*

```
package com.apress.chapter7;

import javax.microedition.midlet.*;
import javax.microedition.media.*;

public class PlayMIDIMIDlet extends MIDlet {
```

```
  Player midiPlayer = null;

  public PlayMIDIMIDlet() {
    try {
      midiPlayer = Manager.createPlayer(
        getClass().getResourceAsStream(
          "/media/midi/chapter7/cabeza.mid"), "audio/midi");
    } catch(Exception e) {
      System.err.println(e);
    }
  }

  public void startApp() {
    try {
      if(midiPlayer != null) {
        midiPlayer.start();
      }
    } catch(Exception e) {
      System.err.println(e);
    }
  }

  public void pauseApp() {
  }

  public void destroyApp(boolean unconditional) {
  }
}
```

To play the MIDI file, you just need to create a `Player` instance, passing the location of the file to the `Manager` class's `createPlayer()` method, as you learned to do before. The MIME type for the MIDI files is audio/midi or audio/x-midi, as the case may be. For network-based MIDI files, you can simply point to these files by using the `createPlayer(String locator)` method; the MIME type will be specified by the server that is retrieving the file. For example, if the same file was placed at

`http://www.mmapibook.com/resources/media/midi/chapter7/cabeza.mid`

you would use the `Manager.createPlayer("http://www.mmapibook.com/resources/media/midi/chapter7/cabeza.mid")` method to retrieve and play this MIDI file, taking care to make sure that the access is done in a separate thread, as you learned in Chapter 5.

Note The MIDI file (downloaded from the Internet) used here is `cabeza.mid`, which is a MIDI representation of the "Tango Por una cabeza" (the famous Tango, also used in the movie *True Lies*).

Controlling the Pitch, Tempo, and Volume of MIDI Files

Let's now add a few controls to control the pitch, tempo, and volume of a MIDI file. Figure 7-4 shows a MIDlet that allows you to do so (shown in Sun's DefaultColorPhone and Motorola C975 emulators, respectively).

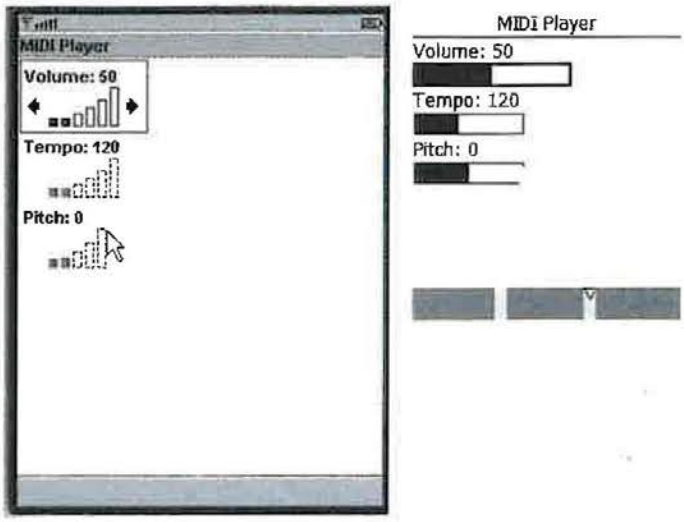


Figure 7-4. *Running* `ControllableMIDIMIDlet` *to control pitch, tempo, and volume in Sun's DefaultColorPhone and Motorola C975 emulators, respectively*

Listing 7-2 shows the code for this MIDlet. An explanation of the code follows this listing.

Listing 7-2. *Controlling MIDI with Pitch, Tempo, and Volume Controls*

```
package com.apress.chapter7;

import javax.microedition.lcdui.*;
import javax.microedition.midlet.*;
import javax.microedition.media.*;
import javax.microedition.media.control.*;

public class ControllableMIDIMIDlet extends MIDlet implements ItemStateListener {

  // the midi player
  Player midiPlayer = null;

  // the controls
  VolumeControl volControl = null;
  PitchControl pitchControl = null;
  TempoControl tempoControl = null;

  // the visual elements
  Form form = null;
```

```
Gauge volGauge = null;
Gauge pitchGauge = null;
Gauge tempoGauge = null;

public ControllableMIDIMIDlet() {
  try {

    // load the midi file
    midiPlayer = Manager.createPlayer(
      getClass().getResourceAsStream(
        "/media/midi/chapter7/cabeza.mid"), "audio/midi");

    // you must prefetch it to get the controls
    midiPlayer.prefetch();

    // extract the controls
    volControl = (VolumeControl) midiPlayer.getControl(
      "javax.microedition.media.control.VolumeControl");
    pitchControl = (PitchControl) midiPlayer.getControl(
      "javax.microedition.media.control.PitchControl");
    tempoControl = (TempoControl) midiPlayer.getControl(
      "javax.microedition.media.control.TempoControl");

    // create the visual elements
    form = new Form("MIDI Player", null);

    // volume is set at a max of 100 with initial value of 50
    volGauge = new Gauge("Volume: 50", true, 100, 50);

    // tempo is set at a max of 30 with 12 (default) as initial value
    tempoGauge = new Gauge("Tempo: 120", true, 30, 12);

    // pitch is set at a max of 5 with initial value of 0, and a min of -5
    // note that because pitch can be negative and positive, the starting value
    // is at 5 (which is pitch 0), with +5 being 10 and -5 being 0.
    pitchGauge = new Gauge("Pitch: 0", true, 10, 5);

    // add the gauges to the form
    form.append(volGauge);
    form.append(tempoGauge);
    form.append(pitchGauge);

    // add the listener to listen to gauge changes
    form.setItemStateListener(this);

    // and set this form as the current display
    Display.getDisplay(this).setCurrent(form);
```

```
    } catch(Exception e) {
      System.err.println(e);
    }
  }

  /**
   * Listens to changes in control gauges and applies them to actual controls
   */
  public void itemStateChanged(Item item) {

    // we are only interested in item state changes of gauges
    if(!(item instanceof Gauge)) return;

    // get the new value of this gauge
    Gauge gauge = (Gauge)item;
    int val = gauge.getValue();

    // and change the control and label accordingly

    // changing volume?
    if(item == volGauge) {
      volControl.setLevel(val);
      volGauge.setLabel("Volume: " + val);
    }

    // changing tempo? make sure that tempoControl is available
    if(item == tempoGauge && tempoControl != null) {
      tempoControl.setTempo((val) * 10 * 1000);
      tempoGauge.setLabel("Tempo: " + (val * 10));
    }

    // changing pitch? make sure that pitchControl is available
    // remember, actual pitch is (val - 5)
    if(item == pitchGauge && pitchControl != null) {
      pitchControl.setPitch((val - 5) * 12 * 1000);
      pitchGauge.setLabel("Pitch: " + (val - 5));
    }
  }

  public void startApp() {
    try {
      // start the MIDI player if it was created
      if(midiPlayer != null) {
        midiPlayer.start();
      }
    } catch(Exception e) {
      System.err.println(e);
    }
  }
```

```
    // standard pause and destroy methods
    public void pauseApp() {
      try {
        if(midiPlayer != null) {
          midiPlayer.stop();
        }
      } catch(Exception e) {
        System.err.println(e);
      }
    }

    public void destroyApp(boolean unconditional) {
      try {
        if(midiPlayer != null) {
          midiPlayer.close();
        }
      } catch(Exception e) {
        System.err.println(e);
      }
    }
}
```

After the `Player` instance is prefetched, `TempoControl`, `PitchControl`, and `VolumeControl` are extracted using the `getControl()` method, casting them appropriately. A form is created that contains three gauges, which allow you to control each of the controls individually. The default values of each gauge are set as well. For volume, the default is set at 50 with a maximum value of 100.

For tempo, the default is set at 12, with 30 as the maximum value. These values seem arbitrary, but they are used to show how the `TempoControl` control works.

How `TempoControl` Works

`TempoControl` allows you to vary the tempo of the MIDI file that you are working with. Tempo, which is measured in beats per minute (bpm), is a measure of how fast or slow a piece of music is being played. Using `TempoControl`, you can vary this speed of playback of a MIDI sequence by using the method `setTempo(int milliTempo)` and also retrieve the current speed of a sequence by using the `getTempo()` method. However, setting the tempo doesn't always mean that the desired value will be kept, because a MIDI sequence may contain its own information on the desired tempo. The tempo value in the sequence overrides any value for the tempo that you set using the `setTempo()` method, if such a value is found in a sequence.

The default tempo of any musical piece (not just MIDI) is usually 120 bpm. With any implementation of `TempoControl`, you are guaranteed to be able to set the tempo ranging between 10 bpm and 300 bpm. Actual implementations may support more values, specifically over the higher range, but no implementation will support 0 or negative values for the tempo. Instead, most revert to the lowest possible value for the tempo, which in most cases is 10 bpm, but could be as low as 1 bpm.

You can set the tempo using the `setTempo(int milliTempo)` method. Notice that it accepts the value in `milliTempo`. This means, to set the value at 200 bpm, you need to use the method `setTempo(200 * 1000)`. This method returns the actual tempo that was set, expressed as milli-beats per minute.

Returning to Listing 7-2, you can now see that the default value of `12` for the `TempoControl` gauge makes sense. The maximum value is set at `30`. When a change in value of this gauge is detected, the changed value is multiplied by 10 to get the effective value, and then by 1,000 to arrive at the final milli-beats per minute value. This is done in the `itemStateChanged(Item item)` method.

How `PitchControl` Works

As you learned in Chapter 6, pitch is the perception of the frequency of a musical note. The `PitchControl` control allows you to vary the pitch of not only a MIDI sequence, but a normal audio file as well.

Pitch changes are always relative to the original value and can never be set to an absolute value. The changes are specified in semitones; a semitone is one-twelfth of an octave (refer to Chapter 6). Thus, to raise the pitch of a sequence by an octave, you need to raise it by 12 semitones.

The `PitchControl`'s `setPitch(int milliSemitones)` method is used to set the actual value. As you can see, the value is set in milli-semitones. Thus, to raise the pitch by an octave, you need to use the method as `setPitch(12 * 1000)`. To *lower* the pitch by an octave, you use a negative value: `setPitch(-12 * 1000)`.

Of course, you don't have to raise or lower the pitch by an octave. You can change the pitch by any value, down to a single semitone. Just remember that the changes are relative to the original value. To raise by a single semitone, use `setPitch(1000)`; to lower it by a semitone, use `setPitch(-1000)`.

The current *raised* pitch value of a sequence can be queried by using the `getPitch()` method, which returns the value in milli-semitones.

Again, returning to code Listing 7-2, you can see now see why the maximum value of the `PitchControl` gauge is set at `10`, with a default (initial) value of `5`. Due to limitations in the `Gauge` item, negative values can't be set. Thus, the initial, default value of `5` represents `0`, whereas a value of `10` is 5 times the original value, and a value of `0` is –5 times. When you change the value from the default value `5` to, let's say `6`, the code in `itemStateChanged()` method interprets it as raising the pitch by a single octave. The corresponding code is shown here:

```
pitchControl.setPitch((val - 5) * 12 * 1000);
```

Raising the pitch any higher leads to higher octaves, whereas lowering the value below `5` means lowering the pitch by corresponding octaves, so the minimum pitch you can get is five times lower than the original one.

Lowering or raising the pitch up to five octave times the original one is only an arbitrary example that illustrates how to use this control. You can raise or lower the pitch to any values that you desire, which is only limited by the maximum or minimum values that are supported

by the particular Player instance. You can get these values by using the methods getMaxPitch() and getMinPitch() methods, respectively.

Differentiating Between TempoControl and RateControl

Figure 7-4 shows how Listing 7-2 plays out in two emulators: Sun's DefaultColorPhone and Motorola C975 emulator. Most MIDlets' working has been shown in a Motorola C975 device as well. However, because the TempoControl control doesn't work on the actual device, it isn't shown here. If you run this listing in an actual C975 device, you won't be able to control the tempo of the MIDI playback.

Tip You would think that the Motorola C975 emulator would exactly mimic the actual device, in terms of functionality and MIDlet support; however, in MIDlet development, what is promised is not always delivered. You should always confirm the working of your MIDlet on the actual device.

In the absence of TempoControl, to control the tempo on the actual device or on devices that don't support TempoControl, you use the superclass of TempoControl, called RateControl.

RateControl is analogous to the PitchControl control in terms of functionality. Like PitchControl, you can use the RateControl as *relative to original* change medium. Thus, RateControl changes the speed of playback relative to the original speed. Rates are specified in milli-percentages and can be negative as well, thereby allowing you to reduce the playback speed, compared to the original playback speed. This is something that you can't do with TempoControl (you can reduce the tempo from the default tempo, however).

It helps to think of TempoControl as a change medium for tempo, where you want an *absolute* value for the speed of playback of your musical piece. Think of RateControl as a *relative* change medium, where you change the speed of playback relative to the original value. Therefore, when using TempoControl, you use the setTempo() method where an absolute value of the desired tempo is required. When using RateControl, you can use the setRate() method where a relative value in percentages is specified.

Using the setTempo() method may not actually result in the desired tempo being set, as the musical sequence may override the tempo value. Using setRate() is guaranteed to succeed as the playback is relative to the original value, which is set against the Player instance's TimeBase and results in media time of the playback passing faster or slower than the original rate.

Besides the setRate() method, the RateControl control provides the getRate() method, which returns the current playback rate of a musical piece. You can also query for the minimum rate by using getMinRate(), and you can query for the maximum rate by using getMaxRate(). All these methods return the actual rate in milli-percentages.

Listing 7-3 (a modified version of Listing 7-2) uses RateControl instead of TempoControl, so that the new listing can be run on the Motorola C975 device, and you can modify the actual speed of playback. A quirk concerning the RateControl implementation in this device is described after the listing.

Listing 7-3. RateControllableMIDIMIDlet *Controls Playback Rate*

```
package com.apress.chapter7;

import javax.microedition.lcdui.*;
import javax.microedition.midlet.*;
import javax.microedition.media.*;
import javax.microedition.media.control.*;

public class RateControllableMIDIMIDlet extends MIDlet
  implements ItemStateListener {

  // the midi player
  Player midiPlayer = null;

  // the controls
  VolumeControl volControl = null;
  PitchControl pitchControl = null;
  RateControl rateControl = null;

  // the visual elements
  Form form = null;
  Gauge volGauge = null;
  Gauge pitchGauge = null;
  Gauge rateGauge = null;

  public RateControllableMIDIMIDlet() {
    try {

      // load the midi file
      midiPlayer = Manager.createPlayer(
        getClass().getResourceAsStream(
          "/media/midi/chapter7/cabeza.mid"), "audio/midi");

      // you must prefetch it to get the controls
      midiPlayer.prefetch();

      // extract the controls
      volControl = (VolumeControl) midiPlayer.getControl(
        "javax.microedition.media.control.VolumeControl");
      pitchControl = (PitchControl) midiPlayer.getControl(
        "javax.microedition.media.control.PitchControl");
      rateControl = (RateControl) midiPlayer.getControl(
        "javax.microedition.media.control.RateControl");

      // create the visual elements
      form = new Form("MIDI Player", null);
```

```
        // volume is set at a max of 100 with initial value of 50
        volGauge = new Gauge("Volume: 50", true, 100, 50);

        // rate is set at a max of 10 with 5 (default) as initial value
        rateGauge = new Gauge("Rate: 100%", true, 10, 5);

        // pitch is set at a max of 5 with initial value of 0, and a min of -5
        // note that because pitch can be negative and positive, the starting value
        // is at 5 (which is pitch 0), with +5 being 10 and -5 being 0.
        pitchGauge = new Gauge("Pitch: 0", true, 10, 5);

        // add the gauges to the form
        form.append(volGauge);
        form.append(rateGauge);
        form.append(pitchGauge);

        // add the listener to listen to gauge changes
        form.setItemStateListener(this);

        // and set this form as the current display
        Display.getDisplay(this).setCurrent(form);

      } catch(Exception e) {
        System.err.println(e);
      }
    }

    /**
     * Listens to changes in control gauges and applies them to actual controls
     */
    public void itemStateChanged(Item item) {

      // we are only interested in item state changes of gauges
      if(!(item instanceof Gauge)) return;

      // get the new value of this gauge
      Gauge gauge = (Gauge)item;
      int val = gauge.getValue();

      // and change the control and label accordingly

      // changing volume?
      if(item == volGauge) {
        volControl.setLevel(val);
        volGauge.setLabel("Volume: " + val);
      }
```

```
    // changing rate? Is rateControl available?
    if(item == rateGauge && rateControl != null) {
      val = (val == 5 ? 6 : val);
      rateControl.setRate((val - 5) * 100 * 1000);
      rateGauge.setLabel("Rate: " + ((val - 5) * 100) + "%");
    }

    // changing pitch? make sure that pitchControl is available
    // remember, actual pitch is (val - 5)
    if(item == pitchGauge && pitchControl != null) {
      pitchControl.setPitch((val - 5) * 12 * 1000);
      pitchGauge.setLabel("Pitch: " + (val - 5));
    }
  }

  // the rest of the methods are unchanged from Listing 7-2 and are omitted from
  // the book version for brevity
}
```

The changes from Listing 7-2 are highlighted in bold. For `rateGauge` values `5` and `6`, the rate is set at 100%; that is, the rate of playback is not changed. For values higher than that, the rate is increased; for values lower, the playback rate is decreased.

If you run this MIDlet on the actual device, you can increase the rate, but decreasing the rate even by a single value completely stops playing it. This is where the Motorola C975 emulator differs from the actual device. You can confirm this by using the method `getMinRate()`, which returns 100% on the actual device and 500% on the emulator (or negative 500%). A value of 100% on the actual device confirms that the minimum rate will not be lower than the original rate of play.

This quirkiness reemphasizes the need to test your MIDlets on actual devices before distributing them.

Figure 7-5 shows this MIDlet running on the device.



Figure 7-5. `RateControllableMIDIMIDlet` *running on a Motorola C975 device*

Tip `RateControl`, unlike `TempoControl`, can be used to control the rate of all media types, not just MIDI.

Playing MIDI with MIDIControl

MIDIControl allows advanced handling of a MIDI file. In fact, using MIDIControl doesn't even require a MIDI file, although you can use one if required. This control allows you to create your own sequences from scratch. However, doing so requires expert knowledge of the MIDI specification and knowing exactly what commands to call.

Creating a Standalone MIDI Player Instance

Recall from Chapter 6 that to play tones, the Manager class provides a constant that can be used for creating Player instances that fetch a ToneControl, without requiring an actual tone file. Similarly, the Manager class provides a MIDI locator constant that can be used to create a standalone MIDI Player instance, from which you can retrieve a MIDIControl and create your own sequences. This constant is called MIDI_DEVICE_LOCATOR and has a value of device://midi. Using it is pretty straightforward and an example is shown here:

```
Player p = Manager.createPlayer(Manager.MIDI_DEVICE_LOCATOR);
p.prefetch();
MIDIControl mControl =
  (MIDIControl)p.getControl("javax.microedition.media.control.MIDIControl");
```

Of course, because this Player instance doesn't correspond to an actual file, it doesn't have any associated data. If you call the method getDuration() on this instance, it will return a value of 0.

Caution You can also retrieve the MIDIControl with the getControl("MIDIControl"); method. However, this is not guaranteed to work on all implementations, even though the Javadoc for the getControl(String controlName) method seems to suggest otherwise.

Querying for MIDIControl Capabilities

The "Using MIDI in MMAPI" section earlier in this chapter stated that MMAPI implementations that provide support for MIDIControl may do so in a minimum or full form. At the minimum, if MIDIControl is provided, you are guaranteed support for sending MIDI events to the underlying device. On the other hand, if a full MIDIControl is implemented, you are allowed to query the installed soundbanks and manipulate them as well. Next you'll see how to query the installed MIDIControl for its capabilities.

Listing 7-4 shows a MIDlet that informs whether a full MIDIControl is installed.

Listing 7-4. MIDICapabilitiesMIDlet *Provides Information About* MIDIControl*'s Capability*

```
package com.apress.chapter7;

import javax.microedition.midlet.*;
import javax.microedition.lcdui.*;
import javax.microedition.media.*;
import javax.microedition.media.control.MIDIControl;
```

```
public class MIDICapabilitiesMIDlet extends MIDlet {

  public void startApp() {
    try {

      // create Player using MIDI Device locator
      Player p = Manager.createPlayer(Manager.MIDI_DEVICE_LOCATOR);

      // must prefetch before extracting controls
      p.prefetch();

      // get the MIDIControl
      MIDIControl mControl =
        (MIDIControl)p.getControl(
          "javax.microedition.media.control.MIDIControl");

      // create a message based on whether advanced capabilities are supported
      String msg =
        mControl.isBankQuerySupported() ?
          "MIDIControl is fully supported" : "Minimum MIDIControl is provided";

      // and display message as alert
      Display.getDisplay(this).setCurrent(
        new Alert("Message", msg, null, AlertType.INFO));

    } catch(Exception e) {
      System.err.println(e);
    }
  }

  public void pauseApp() {
  }

  public void destroyApp(boolean unconditional) {
  }
}
```

As you can see, querying for advanced capabilities of a `MIDIControl` boils down to using the method `isBankQuerySupported()`, which returns true if these advanced queries are indeed supported and false otherwise. If this method returns true, then you can do the following with your `MIDIControl`:

- Get a list of all the installed soundbanks on your device. This is done by using the method `getBankList(boolean custom)`, which returns an array of integers, where each `int` corresponds to an installed soundbank. If the `custom` parameter is true, only custom soundbanks that you may have installed are returned, otherwise all soundbanks, preinstalled or custom, are returned.

- Get a list of all instruments installed or associated with a given soundbank. Instruments on a soundbank are also called programs. Thus, you can get all the program numbers by using the method `getProgramList(int bank)`, and you can get the name of the instrument/program by using `getProgramName(int bank, int prog)`.
- Get the current instrument/program assigned to a given channel using the method `getProgram(int channel)`. This returns an integer array with two values in it; the first integer represents the soundbank and the second represents the program number on that soundbank.
- Get the name of a key, given the soundbank, program, and key identifications. Thus, using the method `getKeyName(int bank, int program, int key)`, you can get the device-assigned name of this key.

With all the methods, the valid value for the soundbank parameter is `0-16383`, and the value is `0-127` for the program and key parameters.

With the target devices/emulators that you have been using so far, the result of running the MIDlet in Listing 7-4 is shown here:

- *Sun's DefaultColorPhone emulator*: Minimum `MIDIControl` is provided.
- *Motorola C975 emulator*: `MIDIControl` is fully supported.
- *Motorola C975 device*: Minimum `MIDIControl` is provided.

As you can see, the functionality on the emulator differs from the actual device. You'll use the C975 emulator to perform some of the functions provided by a full `MIDIControl`.

All implemented `MIDIControl` controls, minimum or full, can do the functions described in the following sections.

Send a Short MIDI Event to the Device

This means that you can send any MIDI message (refer to Figure 7-3), except System Exclusive to the device, and the device will interpret and react to it accordingly. To send a short MIDI event message, use the method `shortMidiEvent(int type, int data1, int data2)` where the type of the message is specified using the first parameter and the actual data, if any, using the last two parameters.

Refer to Tables 7-1, 7-2, and 7-3 for a list of the possible messages and their formats.

Send a Long MIDI Event to the Device

You can do this to send System Exclusive messages to the device using the `longMidiEvent (byte[] data, int offset, int length)` method.

Change Program and Volume of a Channel

You can set the program/instrument to use on a particular channel and set the volume for the channel as well.

The first is accomplished by the method `setProgram(int channel, int bank, int program)` and the second by `setChannelVolume(int channel, int volume)`. You can do the same using the `shortMidiEvent()` method, as these are really high-level convenience methods that are translated internally to use it. For a minimum `MIDIControl`, the `setProgram()` method uses a value of `-1` for the soundbank, which translates to the default soundbank on the device.

Sending Simple MIDI Messages

By using the `shortMidiEvent()` method, and to a lesser degree, the `longMidiEvent()` method, you can send all types of messages (as described at the beginning of this chapter) to the MIDI player on your device. In effect, you can create sequences of MIDI or create your own user-editable MIDI player.

Single MIDI Message

Let's start with how to send a single MIDI message by expanding on the "More About the Voice Channel Messages" section, where you learned to describe a MIDI message and created the message to turn on the note Middle C on MIDI Channel 12 at the velocity of 100. This complete Note ON command is repeated here:

```
1001 1011 0011 1100 0110 0100
```

The first byte from the left is the Status byte with the first 4 bits representing the Note ON command and the last four bits representing Channel 12 (again, Channel 1 is `0000`, *not* `0001`). The next Data byte represents Middle C (equal to 60) and the last Data byte is the velocity, equal to 100.

The `shortMidiEvent()` method takes three parameters; first, an integer that is the type of the message, and the next two are any data bytes associated with it. The type of the message is essentially information about the status and the channel that it is intended for, both of which are shown with the first byte. Thus, for the given message, `1001 1011` equals 155, `0011 1100` equals 60, and `0110 0100` equals 100. These are the three parameter values, and `shortMidiEvent(155, 60, 100)` will send the Note ON command for the note Middle C on MIDI Channel 12 at a velocity of 100.

Of course, you don't need to calculate the binary values first to arrive back at the decimal values, but this process illustrates the concept. Also, because it's so frequently used, `MIDIControl` provides a constant for the Note ON command, which you can use to create your Status bytes. For example, if you know your channel, note value, and velocity, you can use the following to send the command:

```
shortMidiEvent(MIDIControl.NOTE_ON | channel, note, velocity);
```

For the current case, this equates to:

```
shortMidiEvent(MIDIControl.NOTE_ON | 11, 60, 100); // 11 means Channel 12 not 11
```

The constant `NOTE_ON` has a value of `144`, as you would expect for the binary upper nibble value of `1001`.

You can send other MIDI messages in a similar way. For example, to send a corresponding Note OFF command, you can either use the actual value of 128 OR'ed with the channel number or send a Note ON command with a velocity of 0. Both examples are shown here:

```
shortMidiEvent(128 | 11, 60, 100);
shortMidiEvent(MidiControl.NOTE_ON | 11, 60, 0);
```

Both examples are equivalent and will achieve the same result.

Note Using the `shortMidiEvent()` method means that you don't have to physically start the associated `Player` instance for the event to be played. Sending the event acts on the MIDI device and not on any associated MIDI files.

Control Change Messages

`MIDIControl` provides another constant, `CONTROL_CHANGE`, which can be used to send Control Change messages. From Table 7-3, Control Change messages are used to change a particular control on a particular channel. For example, volume is a control that can be set individually for each channel. The format of Control Change messages is

```
1011 XXXX 0BBB BBBB 0CCC CCCC
```

The Status byte combines a static value with the channel information, while the first Data byte indicates the control that needs to be changed. The last Data byte provides the new value for this control. Thus, to change the volume of Channel 12 to 50, you can use the following command:

```
shortMidiEvent(MIDIControl.CONTROL_CHANGE | 11, 7, 50);
```

The actual value for the control is taken from the table provided by the MIDI organization at *http://www.midi.org/about-midi/table3.shtml*. Table 7-4 shows some of the more useful control numbers taken from this online table. As you can see, the Channel Volume control is given a value of 7.

Table 7-4. *Control Change Messages and Their Values*

Control Function	Control Number
Bank Select	0
Modulation Wheel or Lever	1
Foot Controller	4
Channel Volume	7
Balance	8
Pan	10

Instead of using the `shortMidiEvent()` method to change the volume of a channel, you can use the convenience method `setChannelVolume(int channel, int volume)`, which does the same thing internally.

Program Change Message

If you want to change the current instrument/program that is assigned to a particular channel, you can send one of the Program Change messages. This requires knowledge of the program numbers that can be assigned to each channel, which you can look up at *http://en.wikipedia.org/wiki/General_MIDI*.

The format of the Program Change message as per Table 7-3 is

```
1100 XXXX 0DDD DDDD No second Data byte
```

The new program number is identified by the only Data byte, and the Status byte is a combination of a static upper nibble and the channel number. Thus, as an example, to change the program on Channel 12 to a Xylophone (value 14), you can use:

```
shortMidiEvent(192 | 11, 14, 0);
```

As a convenience, `MIDIControl` provides another method that does the same thing, `setProgram(int channel, int bank, int program)`.

Giving Events Time to Process

One practical issue with using the `shortMidiEvent()` method arises because the method returns almost immediately. Now, this would be okay if the `MIDIControl` implementation was to form a queue of all the event messages arising out of the use of this method. However, there are no guarantees of this occurring. This doesn't mean it won't happen, but you'll rarely find two implementations that work the same way and queue the messages, thus ensuring that a message is received and processed in the order it was sent.

To overcome this issue, you need to give the device's MIDI receiver time to process the event, before sending it another one. Hence, a simple `Thread.sleep(100)` after every event will ensure that the events are received in order and processed in order as well.

Listing 7-5 combines the information from the previous three sections (and this section as well) to create a MIDlet that first sends a Note ON event, followed by a Note OFF event. A Program Change message is then sent to change the program to Xylophone. Finally, a Control Change message to change the volume is followed by a Note ON (and OFF) Message to see the effect of the changes.

Listing 7-5. *The* `shortMidiEvent()` *Method in Action*

```
package com.apress.chapter7;

import javax.microedition.midlet.*;
import javax.microedition.media.*;
import javax.microedition.lcdui.*;
import javax.microedition.media.control.MIDIControl;

public class MIDIEventsMIDlet extends MIDlet {

  Display display = null;
  Alert alert = null;

  public MIDIEventsMIDlet() {
    display = Display.getDisplay(this);
    alert = new Alert("Message");
    alert.setString("Working...");
    alert.setTimeout(Alert.FOREVER);
  }
```

```
public void startApp() {

  // show the alert at startup
  display.setCurrent(alert);

  try {

    // create a MIDI player
    Player p = Manager.createPlayer(Manager.MIDI_DEVICE_LOCATOR);

    // prefetch
    p.prefetch();

    // extract MIDI Control
    MIDIControl mControl =
      (MIDIControl)p.getControl(
        "javax.microedition.media.control.MIDIControl");

    if(mControl == null) throw new Exception("MIDIControl not available");

    // send Note ON for Channel 12 for note MIDDLE C at 100 velocity
    mControl.shortMidiEvent(MIDIControl.NOTE_ON | 11, 60, 100);

    Thread.sleep(100);

    // send Note OFF
    mControl.shortMidiEvent(MIDIControl.NOTE_ON | 11, 60, 0);

    Thread.sleep(100);

    // send program change to Xylophone (14)
    // alternatively, use setProgram(11, -1, 14);
    mControl.shortMidiEvent(192 | 11, 14, 0);
    // mControl.setProgram(11, -1, 14);

    Thread.sleep(100);

    // set volume change to 50
    // alternatively, use setChannelVolume(11, 50);
    mControl.shortMidiEvent(MIDIControl.CONTROL_CHANGE | 11, 7, 50);

    Thread.sleep(100);

    // send Note ON for Channel 12 for note MIDDLE C at 100 velocity
    mControl.shortMidiEvent(MIDIControl.NOTE_ON | 11, 60, 100);

    Thread.sleep(100);
```

```
            // send Note OFF
            mControl.shortMidiEvent(MIDIControl.NOTE_ON | 11, 60, 0);

            Thread.sleep(100);

        } catch(Exception e) {
            alert.setString(e.getMessage());
            System.err.println(e);
        }
    }

    public void pauseApp() {
    }

    public void destroyApp(boolean unconditional) {
    }
}
```

In this code, the main MIDlet thread sleeps for 100 milliseconds each time an event is sent, but you can use a lesser value (and send the events in a separate thread) for better performance and responsiveness. When you run this MIDlet, you will hear a single beep followed by a lesser audible beep made by the Xylophone.

Caution On the Motorola C975 device, the Program Change message using `shortMidiEvent(192 | 11, 14, 0);` doesn't work, so you'll have to use the alternate method `setProgram(11, -1, 14);`.

Working with Soundbanks

A soundbank, as you learned earlier, is a collection of 128 programs (or instruments) that are supported by a particular MIDI device, to overcome the limitation of only 128 programs. You also learned that not all MIDI devices support the concept of soundbanks, and the subsequent support for soundbank operations is limited, leading to either a full `MIDIControl` or minimum `MIDIControl` implementation.

The method `isBankQuerySupported()` is used to find out whether a full or minimum `MIDIControl` is available. Of the devices/emulators that you have used so far in this book, only the Motorola C975 emulator supports a full `MIDIControl`. Let's exercise this full `MIDIControl` to query the installed soundbank(s).

Figure 7-6 shows a MIDlet running on the C975 emulator, taking advantage of its support for a full `MIDIControl`. The MIDlet first queries the installed soundbanks and then lists the available programs, along with their names. When the user selects a program from the list, a note is played using that particular program.

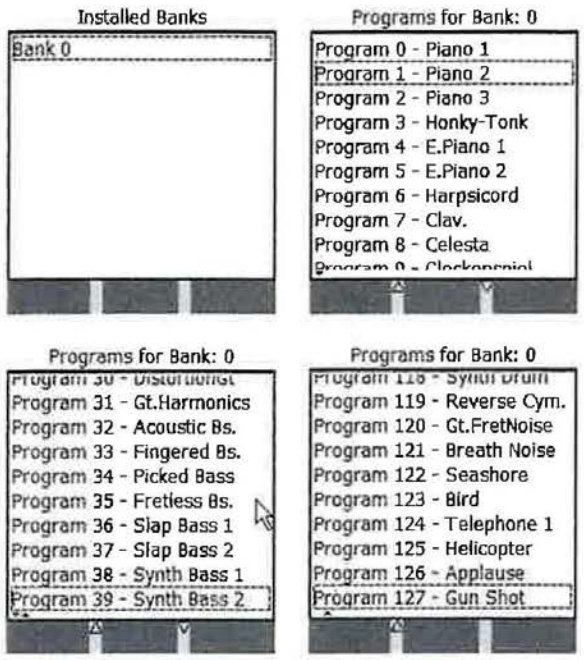


Figure 7-6. *Installed banks and programs on the C975 emulator*

As you can see, only one soundbank is installed, and it has 128 programs installed on it. This list of programs and their names mimics the one mentioned earlier, which is found at *http://en.wikipedia.org/wiki/General_MIDI*.

Note The fact that you can't query Sun's DefaultColorPhone emulator or the actual Motorola C975 device doesn't mean that no soundbank is installed. There is a default soundbank installed, but querying it is not permitted.

The full code for this MIDlet is shown in Listing 7-6. A brief explanation follows this listing, which should be read along with the comments in the code.

Listing 7-6. `ProgramNamesMIDlet` *Queries Installed Soundbanks/Programs and Plays Notes in Different Programs*

```
package com.apress.chapter7;

import javax.microedition.midlet.*;
import javax.microedition.lcdui.*;
import javax.microedition.media.*;
import javax.microedition.media.control.MIDIControl;

public class ProgramNamesMIDlet extends MIDlet implements CommandListener {
```

```
// MIDlet's display
private Display display = null;

// the bank and program lists
private List bankList = null;
private List programList = null;

// the actual banks and programs (instruments)
private int[] banks = null;
private int[] programs = null;

// the player and MIDIControl
private Player player = null;
private MIDIControl mControl = null;

public ProgramNamesMIDlet() {

  display = Display.getDisplay(this);

  try {
    // create a MIDI player
    player = Manager.createPlayer(Manager.MIDI_DEVICE_LOCATOR);

    // prefetch
    player.prefetch();

    // extract MIDI Control
    mControl = (MIDIControl)player.getControl(
      "javax.microedition.media.control.MIDIControl");

  } catch (Exception e) {
    error(e);
  }
}

public void startApp() {

  try {

    // check if we can query the banks
    if(mControl.isBankQuerySupported()) {

      // get the list of banks
      banks = mControl.getBankList(false);

      // create a list to display the banks
      bankList = new List("Installed Banks", Choice.IMPLICIT);
```

```
        // and populate the list
        for(int i = 0; i < banks.length; i++) {
          bankList.append("Bank " + banks[i], null);
        }

        // add this MIDlet as the CommandListener
        bankList.setCommandListener(this);

        // and show the list
        display.setCurrent(bankList);

      } else { // Bank Query not supported
        display.setCurrent(new Alert("Bank Query not supported"));
      }

    } catch(Exception e) {
      error(e);
    }
  }

  public void commandAction(Command cmd, Displayable disp) {

    // only bankList and programList commands are being listened for
    if(disp != bankList && disp != programList) return;

    try {

      // for bankList
      if(disp == bankList) {

        // the selected bank
        int selectedBank = banks[bankList.getSelectedIndex()];

        // get the programs for this selected bank
        programs = mControl.getProgramList(selectedBank);

        // and create a programList
        programList =
          new List("Programs for Bank: " + selectedBank, Choice.IMPLICIT);

        // populate this list
        for(int i = 0; i < programs.length; i++) {
          programList.append("Program " + programs[i] + " - " +
            mControl.getProgramName(selectedBank, programs[i]), null);
        }

        // add this MIDlet as the CommandListener
        programList.setCommandListener(this);
```

```
            // and show this list
            display.setCurrent(programList);

          } else { // can be programList only

            // send command to change program
            mControl.setProgram(
              11, // on channel 11
              banks[bankList.getSelectedIndex()], // the selected bank
              programs[programList.getSelectedIndex()]); // the selected program

            // sleep
            Thread.sleep(100);

            // send a Note ON command
            mControl.shortMidiEvent(MIDIControl.NOTE_ON | 11, 60, 100);

            // sleep
            Thread.sleep(100);

            // send a Note OFF command
            mControl.shortMidiEvent(MIDIControl.NOTE_ON | 11, 60, 0);

            // shorter sleep
            Thread.sleep(20);
          }

        } catch(Exception e) {
          error(e);
        }
      }

      // general purpose error method, displays on screen as well to output
      private void error(Exception e) {
        display.setCurrent(new Alert(e.getMessage()));
        e.printStackTrace();
      }

      public void pauseApp() {
      }

      public void destroyApp(boolean unconditional) {
      }
    }
```

The MIDlet starts by finding out whether querying the soundbanks is permitted. If not, a brief message is displayed. Otherwise, the `getBankList(false)` method is used to get a list of all soundbanks. This list is then displayed, and the user can make a soundbank selection

(in the case of the C975 emulator, there is only one soundbank). The programs installed on this soundbank are then displayed, along with their names, using the methods `getProgramList(selectedBank)` and `getProgramName(selectedBank, programs[i]), null)`. Finally, when the user selects any program from the list, a Note ON command with Middle C note and velocity 100 is sent after changing the program by using the `setProgram(int channel, int bank, int program)` method.

Mapping key presses on a device to a program in a soundbank should now be fairly easy. This can be used to create a user-controlled MIDI player if you want to do so.

Summary

MIDI is an extensive and diverse communication protocol for transmission of audio messages. It is a widely used protocol for digital music, and MMAPI does well to support MIDI by providing `MIDIControl` as a separate control.

Of course, the exact level of support varies between MMAPI implementations, with the most basic support being the capability to play MIDI files. This chapter introduced you to the concepts of MIDI, including a guide on how MIDI works and an overview of its message structure.

MMAPI allows you to control MIDI files without actually needing to use a `MIDIControl` control, and this chapter showed you how, using `VolumeControl`, `PitchControl`, and `TempoControl` only.

Of course, greater control is provided by using `MIDIControl`, which was shown with the help of various examples, including working with soundbanks, program and control change messages, and the like.

The next chapter will show you how to work with audio and video in MMAPI, one of the most exciting parts of this specification.

CHAPTER 8

Working with Audio and Video

Being able to embed audio and video in your MIDlets provides the biggest advantage that MMAPI brings. The entertainment value provided by multimedia-based options like these is a sure way to get your MIDlets noticed. These MIDlets provide a richer user experience than those without any such visual stimuli.

By being an open-ended API, MMAPI provides a single, simple yet powerful medium to embed audio and video in your MIDlets. Device manufacturers decide which part of the API they want to and can support and consequently provide implementations that take full advantage of the device's features. For example, if the device contains a camera, the MMAPI implementation on it may provide means to capture snapshots or full videos. The point is that the device manufacture is in full control of the capabilities that it wants enabled and can do so with a single API interface.

Whether audio capture or live radio streaming, video capture to video playback, synchronized audio and video, or simple snapshots, MMAPI provides the means using your device. The trick is to find a device that supports all these options so you can create your magical MIDlet. This chapter shows you all the capabilities provided by the MMAPI to support these features.

Querying the Capabilities of Your Device

Before you decide to make an audio/video-enabled MIDlet, you should find out the capabilities of your target device(s). MMAPI provides a simple way of finding out these capabilities, by using the `System.getProperty(String key)` method, which, technically, is a CLDC method.

MMAPI defines several unique properties that you can query for using this method. Table 8-1 gives a list of these properties, along with what they indicate. Almost all these properties relate to the support of audio and video in a particular MMAPI implementation, which is why they are introduced in this later chapter.

Table 8-1. *MMAPI System Properties*

Property Key	Description
`microedition.media.version`	Returns the version of MMAPI that the implementation implements. Currently it returns either 1.1 or 1.0, depending on the implementation that you try it on.
`supports.recording`	Returns true or false, depending on whether either audio and/or video capture is supported by the implementation. Thus, if neither audio nor video can be captured, it returns false; otherwise, true is returned in all other cases.
`streamable.contents`	Returns a list of supported media types, only if the MMAPI implementation supports streaming of media data. In most cases, this returns null, meaning that streaming content is not supported.
`supports.mixing`	Returns true if audio media data can be "mixed" or returns false otherwise. If true, you can have more than one `Player` instance playing audio and/or tones at the same time.
`supports.audio.capture`	Returns true if audio can be captured; returns false otherwise. If true, the following property must not return a null or empty value.
`audio.encodings`	Returns the supported formats for recording audio; returns null if audio capture is not supported.
`supports.video.capture`	Similar to audio, returns true if video capture is supported; returns false otherwise. If true, the following property must not return a null or empty value.
`video.encodings`	Returns the supported formats for recording video content; returns null if video capture is not supported.
`video.snapshot.encodings`	Returns the list of supported formats for taking snapshots with the device camera; returns null if this is not supported.

Listing 8-1 shows a MIDlet that you can use to find out the value of these properties and hence the capabilities of your MMAPI implementation.

Listing 8-1. `CapabilitiesMIDlet` *Lists the Capabilities of a MMAPI Implementation*

```
package com.apress.chapter8;

import javax.microedition.midlet.*;
import javax.microedition.lcdui.*;

public class CapabilitiesMIDlet extends MIDlet {
```

```
  // all the possible capabilities
  private String[] capabilitiesIdx = {
    "microedition.media.version",
    "supports.mixing",
    "supports.audio.capture",
    "supports.video.capture",
    "supports.recording",
    "audio.encodings",
    "video.encodings",
    "video.snapshot.encodings",
    "streamable.contents"
  };

  public void startApp() {

    // create a list
    List list = new List("Audio/Video Capabilities", Choice.IMPLICIT);

    // and query the device for each of the properties
    for(int i = 0; i < capabilitiesIdx.length; ++i) {
      list.append(
        System.getProperty(capabilitiesIdx[i]) + " - " +
        capabilitiesIdx[i], null);
    }

    // show this list
    Display.getDisplay(this).setCurrent(list);
  }

  public void pauseApp() {
  }

  public void destroyApp(boolean unconditional) {
  }
}
```

Finally, Figure 8-1 gives you the result of running this MIDlet in the three development environments used so far in this book: Sun's DefaultColorPhone, Motorola C975 emulator, and Motorola C975 device.

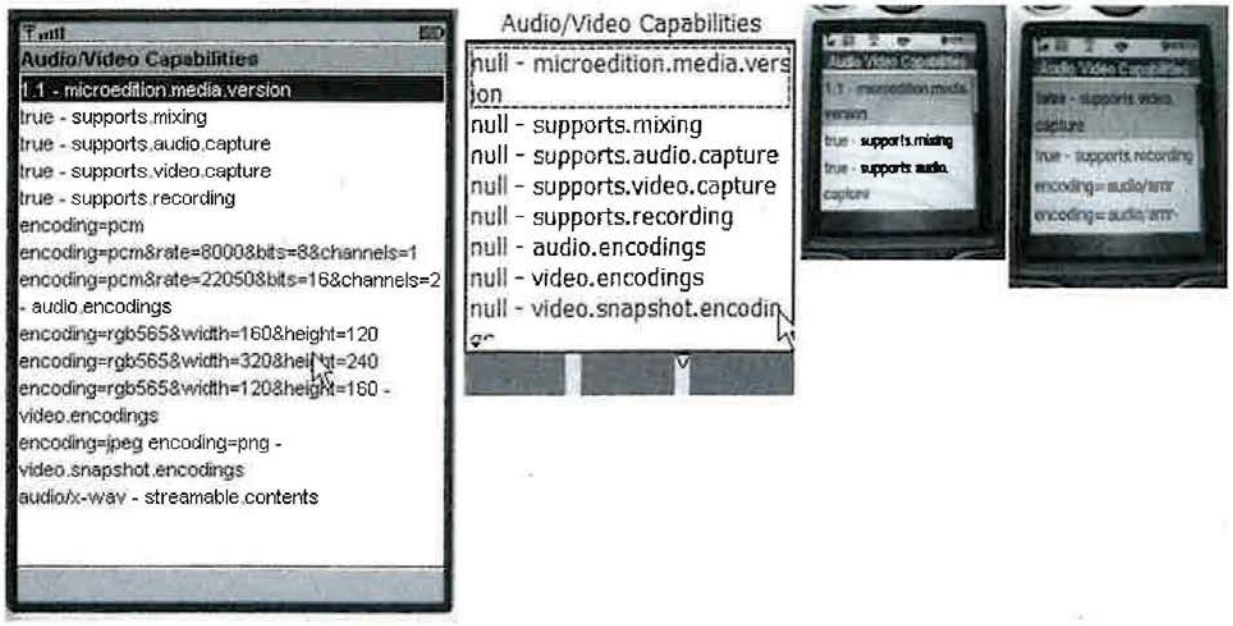


Figure 8-1. *MMAPI capabilities in Sun's DefaultColorPhone emulator, Motorola C975 emulator, and Motorola C975 device (last two figures)*

As you can see, the result of running this MIDlet in various environments is less than encouraging. The Motorola C975 emulator gives a twisted result, returning null for every property, whereas the actual device returns null for `supports.video.capture`, a disappointing result for the continued use of this device for testing in this chapter on audio/video.

Note A variance in the output between the Motorola C975 emulator and the actual device must come as no surprise at this stage. Emulator and actual device implementations vary considerably and no MIDlet should be released without testing on target devices.

You may also wonder why the actual device does not support capturing of video, especially if you glance at Table 2-3 from Chapter 2, which shows the result of running `getSupportedContentTypes("capture")`. This table suggests that the Motorola C975 device should support capture of audio, video, and camera (meaning snapshots), yet Figure 8-1 shows that `supports.video.capture` for the actual device is false.

This is the bane of Java ME development. It's one thing to worry about matching the behavior of devices to their emulators, but even devices themselves don't support the MMAPI implementation consistently. Worse, the implementations sometimes give contradictory results, as in this case, which can confuse the developer to no end. All device manufacturers are guilty of this lapse in consistency, lest you believe that it is a Motorola-specific problem.

One reason for this contradiction is that `System.getProperty(String key)` is a CLDC implementation method, whereas `getSupportedContentTypes(String protocol)` is a MMAPI implementation method. Each API may be implemented by different teams, which may result in the said inconsistency. A feeble excuse, but an excuse nonetheless.

Because the Motorola C975 device can't be used to develop video capture MIDlets, the BenQ (formerly Siemens) M75 (*http://www.benqmobile.com/cds/frontdoor/0,2241,hq_en_0_89745_rArNrNrNrN,00.html*) is used in this chapter. The emulator for this device can be downloaded from the BenQ developer site at *http://developer.benqmobile.com/*. This device and the associated emulator are used interchangeably between the Motorola C975 emulator and device for the rest of the MIDlets in this chapter and the next.

Running the MIDlet from Listing 8-1 again in this new emulator and actual device gives the results shown in Figure 8-2.



Figure 8-2. *BenQ M75 emulator and device MMAPI capabilities*

Because it may not be very easy to make out the properties completely in Figure 8-2, they are tabulated in Table 8-2. Thankfully, both the emulator and the device support the same set of properties.

Table 8-2. *MMAPI Capabilities on BenQ M75 Emulator and Device*

Property Name	Value
microedition.media.version	1.1
supports.mixing	false
supports.audio.capture	true
supports.video.capture	true
supports.recording	true
audio.encodings	encoding=audio/AMR
video.encodings	encoding=video/3gpp
video.snapshot.encodings	encoding=jpeg encoding=image/jpeg
streamable.contents	null

With the support for audio and video capture, the device/emulator must specify the supported format(s) of the captured media. This is done with the help of `audio.encodings`, `video.encodings`, and `video.snapshot.encodings` properties.

Understanding Media Encodings

Media encoding strings are used for specifying the format of media supported, or desired, for a particular operation. It is explained with the help of a string that has the supported or desired formats separated by a single space. The MMAPI specification states that there are four types of intermixable strings, but in reality, not all are supported, and almost certainly, intermixing of these strings is rare (but possible).

These four types of encoding strings are used to define the format of audio, video, intermixed, and custom media data. The general format for each type is

```
encoding=contentType&encodingParams
```

which resembles the HTTP URL query format. As you saw in Table 8-2 and Figures 8-1 and 8-2, the supported formats vary greatly with the specific device MMAPI implementation.

Audio encodings specify, or request, the correct audio formats. From Figure 8-1, you can see that the Sun's DefaultColorPhone emulator specifies the following encoding formats for the property `audio.encodings`:

```
encoding=pcm encoding=pcm&rate=8000&bits=8&channels=1
encoding=pcm&rate=22050&bits=16&channels=2
```

Using this format, the emulator is informing you that it supports three encoding formats for audio capture:

- PCM (Pulse Code Manipulation), which is a ubiquitous form of storing audio data
- PCM at a frequency rate of 8,000 and 8 bits per sample and a single channel (mono)
- PCM at a frequency rate of 22,050, 16 bits per sample, and dual channels (stereo)

All three formats are separated by a single space, and each starts with the text `encoding=`. This is followed by the content type of the encoding and then the parameters (if any) of the content type that qualifies it. Each parameter and its value are separated by the ampersand sign (&), which also separates the content type from its parameters.

The first encoding is assumed to be the default encoding. That is, as you'll see later, if you don't request a particular encoding, and there are multiple encodings that the device may support for a particular operation, the first returned encoding is the format of the resulting media.

Similarly, the video encodings specify the correct video formats, given by the `video.encodings` property. Again, taking the example from Figure 8-1, Sun's DefaultColorPhone emulator supports the following formats for video capture:

```
encoding=rgb565&width=160&height=120 encoding=rgb565&width=320&height=240
encoding=rgb565&width=120&height=160
```

The content type is the same for all the encodings, and the formats only differ in the size of the capture that is supported. This is only a theoretical possibility with this emulator, as it only simulates video capture and doesn't actually implement it.

Mixed encodings allow you to specify audio and video encodings together in one single string for operations that require specific encodings for mixed formats. Each encoding is separately specified, as if they were being specified for single encodings, and then combined using the ampersand (&) operator. The following is an example of mixed encoding, where the first part is the audio encoding, and the latter (in bold) part is the video encoding:

```
encoding=pcm&rate=8000&bits=8&channels=1&encoding=rgb565&width=320&height=240
```