Java Media Players

Version 1.0.3
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Java Media Framework is being developed by
Sun Microsystems, Inc., Silicon Graphics Inc., and Intel Corporation.

Contents

Preface

The Java Media Framework (JMF) is an application programming interface (API) for incorporating media data types into Java applications and applets. It is specifically designed to take advantage of Java platform features. The 1.0 version of JMF provides APIs for media players; future versions will support media capture and conferencing. This document describes the Java Media Player APIs and how they can be used to present time-based media such as audio and video.

Java Media Players

The 1.0 specification for Java Media Players addresses media display and the concerns of the application builder in that domain, with an eye towards the other application domains and other levels of developer. There are two parts to this release: a user guide entitled “Java Media Players” and the accompanying API documentation.

Future Releases

Javasoft and its partners are developing additional capabilities and features that will appear in a future release of the JMF specification. The features that we are considering for future releases include:

- *Incomplete Players* – A JMF Player is self-contained and does not provide access to its media data. Additional interfaces that provide access to media data and allow selection of rendering components are in development and intended for a future release.
- *Rendering Interfaces* – Rendering interfaces for specific audio and video formats and additional interfaces for audio and video renderers will be

developed for a future release.

- *Capture Semantics* – The JMF Player architecture does not support the media capture capabilities required for authoring or conferencing applications. Capture semantics will be addressed in a future release.
- *Data Definitions* – JMF 1.0 provides an overall structure for data manipulation and format negotiation among generic formats. Future releases will address specific interfaces for audio and video data.
- *CODEC Architecture* – A CODEC (coder-decoder) architecture will be defined in a future release to provide a common API for using CODECs to compress and decompress media data and a mechanism for installing additional CODECs into the system.

Contact Information

JavaSoft

To obtain information about the Java Media Framework, see the web site at:

HTTP://java.sun.com/products/java-media/jmf

Silicon Graphics

To obtain information about Java products for Silicon Graphics hardware, see the web site at:

HTTP://www.sgi.com/Products/DevMagic/products/java.html

Intel Corporation

To obtain information about Java Media Framework implementations for Intel hardware, see the web site at:

HTTP://developer.intel.com/ial/jmedia

Change History

Version 1.0.3

Updated contact info for SGI.

Version 1.0.2

Added attribution for `blockingRealize` example code in Section 5. Versions 1.0 and 1.0.1 of this document erroneously omitted this attribution. This example code is used with the permission of Bill Day and JavaWorld magazine. It was first published April 1997 in Bill Day's article "Java Media Framework Player API: Multimedia Comes to Java" in JavaWorld magazine, an online publication of Web Publishing Inc.

Changed references to `PlayerClosedEvent` and `Player.close` to `Controller-ClosedEvent` and `Controller.close` in Section 5.

Changed java.media to javax.media in Appendix B.

Changed example in Appendix C to use `Time` objects as parameters for `setStop-Time` and `setMediaTime`.

Version 1.0.1

Fixed inconsistencies with JMF 1.0 API.

Version 1.0

Updated document for final JMF 1.0 API release.

Java Media Players

Sun Microsystems, Inc.
Silicon Graphics Inc.
Intel Corporation

The Java Media Framework (JMF) 1.0 specification defines APIs for displaying time-based media. This document describes these APIs and how they can be used to present media such as audio and video.

Media display encompasses local and network playback of multimedia data within an application or applet. The focus of the JMF 1.0 Player APIs is to support the delivery of synchronized media data and to allow integration with the underlying platform's native environment and Java's core packages, such as `java.awt`. The Player APIs support both client *pull* protocols, such as HTTP, and server *push* protocols, such as RTP.

JMF makes it easy to incorporate media in client applications and applets, while maintaining the flexibility needed for more sophisticated applications and platform customization:

- Client programmers can create and control Java Media Players for any standard media type using a few simple method calls.
- Technology providers can extend JMF to support additional media formats or perform custom operations by creating and integrating new types of media controllers, media players, and media data sources. These extensions can be used side-by-side with existing JMF objects.

“Extending JMF” on page 32 contains information about extending JMF; however, this document is intended primarily for application and applet developers.

1.0 Overview

JMF provides a platform-neutral framework for displaying time-based media. The Java Media Player APIs are designed to support most standard media content types, including MPEG-1, MPEG-2, QuickTime, AVI, WAV, AU, and MIDI. Using JMF, you can synchronize and present time-based media from diverse sources.

Existing media players for desktop computers are heavily dependent on native code for computationally intensive tasks like decompression and rendering. The JMF API provides an abstraction that hides these implementation details from the developer. For example, a particular JMF Player implementation might choose to leverage an operating system’s capabilities by using native methods. However, by coding to the JMF API, the application or applet developer doesn’t need to know whether or not that implementation uses native methods.

The JMF Player API:

- Scales across different protocols and delivery mechanisms
- Scales across different types of media data
- Provides an event model for asynchronous communication between JMF Players and applications or applets

1.1 Data Sources

A `DataSource` encapsulates the location of media and the protocol and software used to deliver the media. A Java Media `Player` contains a `DataSource`. Once obtained, the source cannot be reused to deliver other media. A `Player’s` data source is identified by either a JMF `MediaLocator` or a `URL` (universal resource locator).

`MediaLocator` is a JMF class that describes the media that a `Player` displays. A `MediaLocator` is similar to a `URL` and can be constructed from a `URL`. In Java, a `URL` can only be constructed if the corresponding protocol handler is installed on the system. `MediaLocator` doesn’t have this restriction.

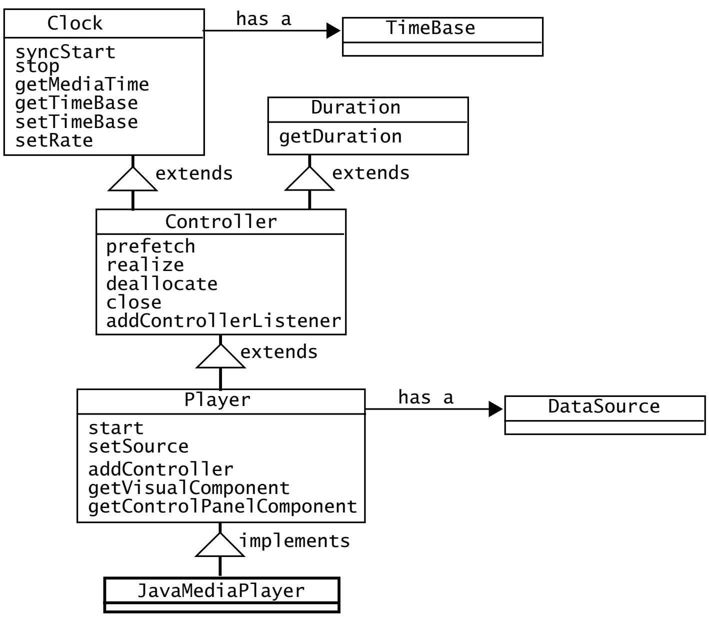
Java Media `Players` can present media data obtained from a variety of sources, such as local or network files and live broadcasts. JMF supports two different types of media sources:

- *Pull Data-Source*—the client initiates the data transfer and controls the flow of data from pull data-sources. Established protocols for this type of data include Hypertext Transfer Protocol (HTTP) and FILE.
- *Push Data-Source*—the server initiates the data transfer and controls the flow of data from a push data-source. Push data-sources include broadcast media, multicast media, and video-on-demand (VOD). For broadcast data, one protocol is the Real-time Transport Protocol (RTP), under development by the Internet Engineering Task Force (IETF). The MediaBase protocol developed by SGI is one protocol used for VOD.

The degree of control that a client program can extend to the user depends on the type of media source being presented. For example, an MPEG file can be repositioned and a client program could allow the user to replay the video clip or seek to a new position in the video. In contrast, broadcast media is under server control and cannot be repositioned. Some VOD protocols might support limited user control—for example, a client program might be able to allow the user to seek to a new position, but not fast forward or rewind.

1.2 Players

A Java Media `Player` is an object that processes a stream of data as time passes, reading data from a `DataSource` and rendering it at a precise time. A Java Media `Player` implements the `Player` interface.



- `Clock` defines the basic timing and synchronization operations that a `Player` uses to control the presentation of media data.
- `Controller` extends `Clock` to provide methods for managing system resources and preloading data and a listening mechanism that allows you to receive notification of media events.
- `Duration` provides a way to determine the duration of the media being played.
- `Player` supports standardized user control and relaxes some of the operational restrictions imposed by `Clock`.

`Players` share a common model for timekeeping and synchronization. A `Player's` *media time* represents the current position in the media stream. Each `Player` has a `TimeBase` that defines the flow of time for that `Player`. When a `Player` is started, its *media time* is mapped to its *time-base time*. To be synchronized, `Players` must use the same `TimeBase`.

A `Player's` user interface can include both a visual component and a control-panel component. You can implement a custom user-interface for a `Player` or use the `Player's` default control-panel component.

A `Player` must perform a number of operations before it is capable of presenting media. Because some of these operations can be time consuming, JMF allows you to control when they occur by defining the operational states of a `Player` and providing a control mechanism for moving the `Player` between those states.

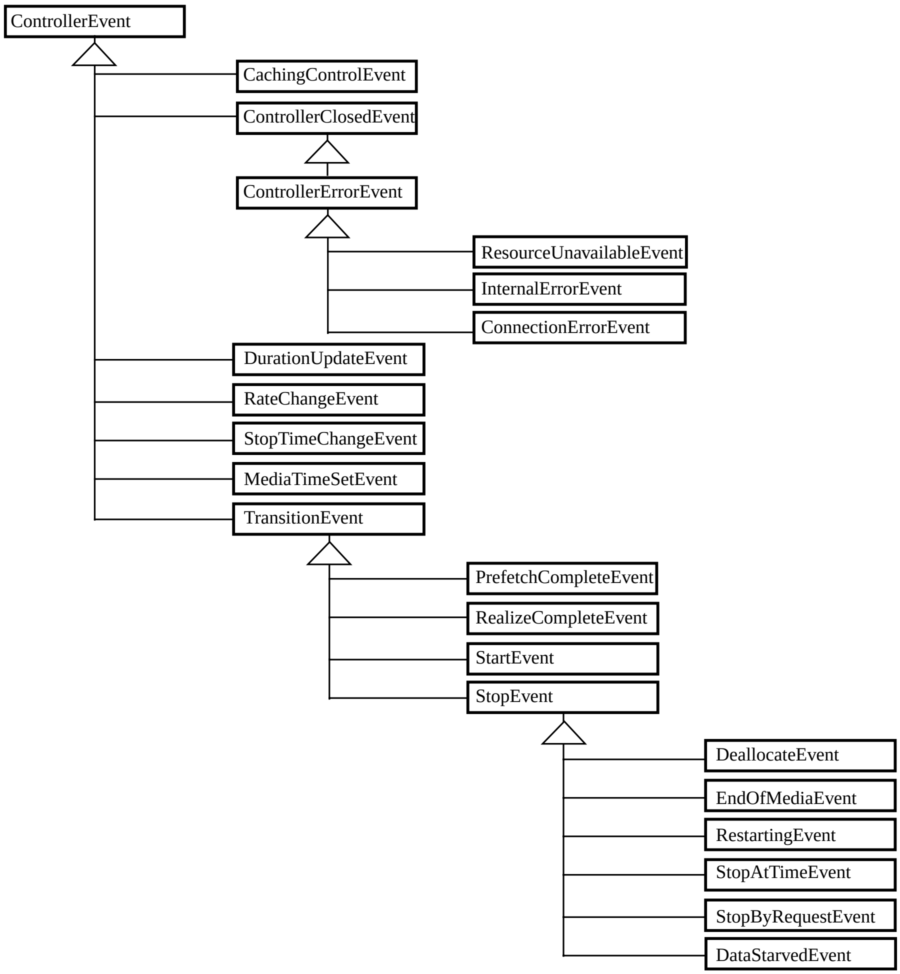
1.3 Media Events

The JMF event reporting mechanism allows your program to respond to media-driven error conditions, such as out-of-data or resource unavailable conditions. The event system also provides an essential notification protocol; when your program calls an asynchronous method on a `Player`, it can only be sure that the operation is complete by receiving the appropriate event.

Two types of JMF objects post events: `GainControl` objects and `Controller` objects. `Controller` and `GainControl` follow the established Java Beans patterns for events.

A `GainControl` object posts only one type of event, `GainChangeEvent`. To respond to gain changes, you implement the `GainChangeListener` interface.

A `Controller` can post a variety of events that are derived from `Controller-Event`. To receive events from a `Controller` such as a `Player`, you implement the `ControllerListener` interface. The following figure shows the events that can be posted by a `Controller`.



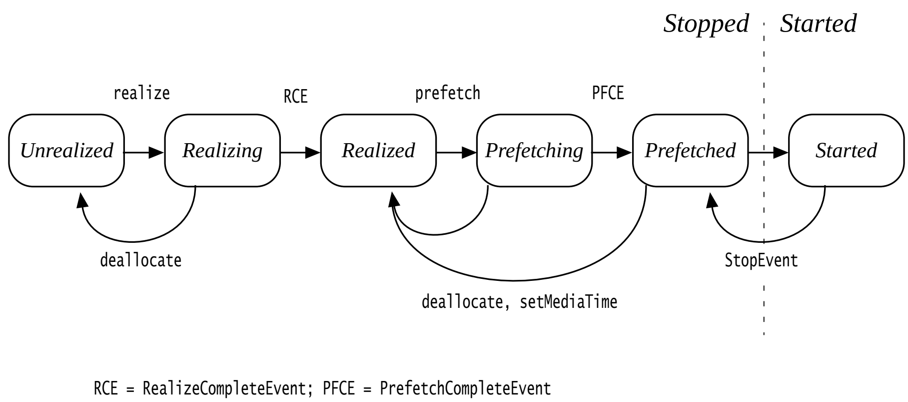
`ControllerEvents` fall into three categories: change notifications, closed events, and transition events:

- Change notification events such as `RateChangeEvent` and `DurationUpdateEvent` indicate that some attribute of the `Player` has changed, often in response to a method call. For example, the `Player` posts a `RateChangeEvent` when its rate is changed by a call to `setRate`.

- TransitionEvents allow your program to respond to changes in a Player's state. A Player posts transition events whenever it moves from one state to another. (See Section 1.4 for more information about Player states.)
- ControllerClosedEvents are posted by a Player when the Player shuts down. When a Player posts a ControllerClosedEvent, it is no longer usable. A ControllerErrorEvent is a special case of ControllerClosedEvent. You can listen for ControllerErrorEvents so that your program can respond to Player malfunctions, minimizing the impact on the user.

1.4 Player States

A Java Media Player can be in one of six states. The Clock interface defines the two primary states: *Stopped* and *Started*. To facilitate resource management, Controller breaks the *Stopped* state down into five standby states: *Unrealized*, *Realizing*, *Realized*, *Prefetching*, and *Prefetched*.



In normal operation, a Player steps through each state until it reaches the *Started* state:

- A Player in the *Unrealized* state has been instantiated, but does not yet know anything about its media. When a media Player is first created, it is *Unrealized*.
- When realize is called, a Player moves from the *Unrealized* state into the *Realizing* state. A *Realizing* Player is in the process of determining its resource requirements. During realization, a Player acquires the resources that it only needs to acquire once. These might include rendering resources

other than exclusive-use resources. (Exclusive-use resources are limited resources such as particular hardware devices that can only be used by one `Player` at a time; such resources are acquired during *Prefetching*.) A *Realizing* `Player` often downloads assets over the net.

- When a `Player` finishes *Realizing*, it moves into the *Realized* state. A *Realized* `Player` knows what resources it needs and information about the type of media it is to present. Because a *Realized* `Player` knows how to render its data, it can provide visual components and controls. Its connections to other objects in the system are in place, but it does not own any resources that would prevent another `Player` from starting.
- When `prefetch` is called, a `Player` moves from the *Realized* state into the *Prefetching* state. A *Prefetching* `Player` is preparing to present its media. During this phase, the `Player` preloads its media data, obtains exclusive-use resources, and anything else it needs to do to prepare itself to play. *Prefetching* might have to recur if a `Player's` media presentation is repositioned, or if a change in the `Player's` rate requires that additional buffers be acquired or alternate processing take place.
- When a `Player` finishes *Prefetching*, it moves into the *Prefetched* state. A *Prefetched* `Player` is ready to be started; it is as ready to play as it can be without actually being *Started*.
- Calling `start` puts a `Player` into the *Started* state. A *Started* `Player's` time-base time and media time are mapped and its clock is running, though the `Player` might be waiting for a particular time to begin presenting its media data.

A `Player` posts `TransitionEvents` as it moves from one state to another. The `ControllerListener` interface provides a way for your program to determine what state a `Player` is in and to respond appropriately.

Using this event reporting mechanism, you can manage `Player` latency by controlling when a `Player` begins *Realizing* and *Prefetching*. It also enables you to ensure that the `Player` is in an appropriate state before calling methods on the `Player`.

1.4.1 Methods Available in Each Player State

To prevent race conditions, not all methods can be called on a `Player` in every state. Table 1, "Restrictions on Player Methods" identifies the restrictions imposed by JMF. If you call a method that is illegal in a `Player's` current state, the `Player` throws an error or exception.

Table 1: Restrictions on Player Methods

Method	Unrealized Player	Realized Player	Prefetched Player	Started Player
getStartLatency	NotRealizedError	legal	legal	legal
getTimeBase	NotRealizedError	legal	legal	legal
setMediaTime	NotRealizedError	legal	legal	legal
setRate	NotRealizedError	legal	legal	legal
getVisualComponent	NotRealizedError	legal	legal	legal
getControlPanelComponent	NotRealizedError	legal	legal	legal
getGainControl	NotRealizedError	legal	legal	legal
setStopTime	NotRealizedError	legal	legal	StopTimeSetError if previously set
syncStart	NotPrefetchedError	NotPrefetchedError	legal	ClockStartedError
setTimeBase	NotRealizedError	legal	legal	ClockStartedError
deallocate	legal	legal	legal	ClockStartedError
addController	NotRealizedError	legal	legal	ClockStartedError
removeController	NotRealizedError	legal	legal	ClockStartedError
mapToTimeBase	ClockStoppedException	ClockStoppedException	ClockStoppedException	legal

1.5 Calling JMF Methods

JMF uses the following convention for errors and exceptions:

- Java Media Errors are thrown when a program calls a method that is illegal in the object's current state. Errors are thrown in situations where you have control over the state and the requested operation could result in a race condition. For example, it is an error to call certain methods on a *Started* `Player`. It is your responsibility to ensure that a `Player` is stopped before using these methods. Applications should not catch JMF errors; well-written applications will never encounter these errors.
- Java Media Exceptions are thrown when a program calls a method that cannot be completed or is not applicable in the object's current state. Exceptions are thrown in situations where you do not necessarily have control over the state. For example, an exception is thrown if you attempt to synchronize two `Players` with incompatible time bases. This is not an error because you could

not determine ahead of time that the time bases were incompatible. Similarly, if you call a method that is only applicable for a *Started* `Player` and the `Player` is *Stopped*, an exception is thrown. Even if you just started the `Player`, it might have already stopped in response to other conditions, such as end of media.

Some JMF methods return values that indicate the results of the method call. In some instances, these results might not be what you anticipated when you called the method; by checking the return value, you can determine what actually happened. For example, the return value might indicate:

- The value that was actually set. For example, not all `Players` can present media data at five times the normal rate. If you call `setRate(5.0)`, the `Player` will set its rate as close as it can to 5.0 and return the rate it actually set. That rate might be 5.0, or it might be 1.0; you need to check the return value to find out.
- That the information you requested is not currently available. For example, a `Player` might not know its duration until it has played its media stream once. If you call `getDuration` on such a `Player` before it has played, `getDuration` returns `DURATION_UNKNOWN`. If you call `getDuration` again after the `Player` has played, it might be able to return the actual duration of the media stream.

2.0 Example: Creating an Applet to Play a Media File

The sample program `PlayerApplet` demonstrates how to create a Java Media `Player` and present an MPEG movie from within a Java applet. This is a general example that could easily be adapted to present other types of media streams.

The `Player's` visual presentation and its controls are displayed within the applet's presentation space in the browser window. If you create a `Player` in a Java application, you are responsible for creating the window to display the `Player's` components.

Note: While `PlayerApplet` illustrates the basic usage of a Java Media `Player`, it does not perform the error handling necessary in a real applet or application. For a more complete sample suitable for use as a template, see "Appendix A: Java Media Applet" on page 37.

2.1 Overview of PlayerApplet

The APPLET tag is used to invoke `PlayerApplet` in an HTML file. The WIDTH and HEIGHT fields of the HTML APPLET tag determine the dimensions of the applet's presentation space in the browser window. The PARAM tag identifies the media file to be played. For example, `PlayerApplet` could be invoked with:

```
<APPLET CODE=ExampleMedia.PlayerApplet
WIDTH=320 HEIGHT=300>
<PARAM NAME=FILE VALUE="Astrnmy.mpg">
</APPLET>
```

When a user opens a web page containing `PlayerApplet`, the applet loads automatically and runs in the specified presentation space, which contains the `Player's` visual component and default controls. The `Player` starts and plays the MPEG movie once. The user can use the default `Player` controls to stop, restart, or replay the movie. If the page containing the applet is closed while the `Player` is playing the movie, the `Player` automatically stops and frees the resources it was using.

To accomplish this, `PlayerApplet` extends `Applet` and implements the `ControllerListener` interface. `PlayerApplet` defines five methods:

- `init`—creates a `Player` for the file that was passed in through the PARAM tag and registers `PlayerApplet` as a controller listener so that it can observe media events posted by the `Player`. (This causes `PlayerApplet's` `controllerUpdate` method to be called whenever the `Player` posts an event.)
- `start`—starts the `Player` when `PlayerApplet` is started.
- `stop`—stops and deallocates the `Player` when `PlayerApplet` is stopped.
- `destroy`—closes the `Player` when `PlayerApplet` is removed.
- `controllerUpdate`—responds to `Player` events to display the `Player's` components.

2.2 PlayerApplet Code Listing

```
PlayerApplet.java:
package ExampleMedia;

import java.applet.*;
import java.awt.*;
import java.net.*;
import javax.media.*;

public class PlayerApplet extends Applet implements ControllerListener {
   Player player = null;
   public void init() {
      setLayout(new BorderLayout());
      String mediaFile = getParameter(“FILE”);
      try {
         URL mediaURL = new URL(getDocumentBase(), mediaFile);
         player = Manager.createPlayer(mediaURL);
         player.addControllerListener(this);
      }
      catch (Exception e) {
         System.err.println("Got exception "+e);
      }
   }
   public void start() {
      player.start();
   }
   public void stop() {
      player.stop();
      player.deallocate();
   }
   public void destroy() {
      player.close();
   }
   public synchronized void controllerUpdate(ControllerEvent event) {
      if (event instanceof RealizeCompleteEvent) {
         Component comp;
         if ((comp = player.getVisualComponent()) != null)
            add ("Center", comp);
         if ((comp = player.getControlPanelComponent()) != null)
            add ("South", comp);
         validate();
      }
   }
}
```

2.3 Initializing the Applet

When a Java applet starts, its `init` method is invoked automatically. You override `init` to prepare your applet to be started. `PlayerApplet` performs four tasks in `init`:

1. Retrieves the applet's FILE parameter.
2. Uses the FILE parameter to locate the media file and build a `URL` object that describes that media file.
3. Creates a `Player` for the media file by calling `Manager.createPlayer`.
4. Registers the applet as a controller listener with the new `Player` by calling `addControllerListener`. Registering as a listener causes `PlayerApplet's` `controllerUpdate` method to be called automatically whenever the `Player` posts a media event. The `Player` posts media events whenever its state changes. This mechanism allows you to control the `Player's` transitions between states and ensure that the `Player` is in a state in which it can process your requests. (For more information, see "Player States" on page 6.)

```
public void init() {
   setLayout(new BorderLayout());
   // 1. Get the FILE parameter.
   String mediaFile = getParameter("FILE");
   try {
      // 2. Create a URL from the FILE parameter. The URL
      // class is defined in java.net.
      URL mediaURL = new URL(getDocumentBase(), mediaFile);
      // 3. Create a player with the URL object.
      player = Manager.createPlayer(mediaURL);
      // 4. Add PlayerApplet as a listener on the new player.
      player.addControllerListener(this);
   }
   catch (Exception e) {
      System.err.println("Got exception "+e);
   }
}
```

2.4 Controlling the Player

The `Applet` class defines `start` and `stop` methods that are called automatically when the page containing the applet is opened and closed. You override these methods to define what happens each time your applet starts and stops.

`PlayerApplet` implements `start` to start the `Player` whenever the applet is started:

```
public void start() {
   player.start();
}
```

Similarly, `PlayerApplet` overrides `stop` to stop and deallocate the `Player`:

```
public void stop() {
   player.stop();
   player.deallocate();
}
```

Deallocating the `Player` releases any resources that would prevent another `Player` from being started. For example, if the `Player` uses a hardware device to present its media, `deallocate` frees that device so that other `Players` can use it.

When an applet exits, `destroy` is called to dispose of any resources created by the applet. `PlayerApplet` overrides `destroy` to close the `Player`. Closing a `Player` releases all of the resources that it's using and shuts it down permanently.

```
public void destroy() {
  player.close();
}
```

2.5 Responding to Media Events

`PlayerApplet` registers itself as a `ControllerListener` in its `init` method so that it receives media events from the `Player`. To respond to these events, `PlayerApplet` implements the `controllerUpdate` method, which is called automatically when the `Player` posts an event.

`PlayerApplet` responds to one type of event, `RealizeCompleteEvent`. When the `Player` posts a `RealizeCompleteEvent`, `PlayerApplet` displays the `Player’s` components:

```
public synchronized void controllerUpdate(ControllerEvent event)
{
    if (event instanceof RealizeCompleteEvent) {
        Component comp;
        if ((comp = player.getVisualComponent()) != null)
            add ("Center", comp);
        if ((comp = player.getControlPanelComponent()) != null)
            add ("South", comp);
        validate();
    }
```

A `Player’s` user-interface components cannot be displayed until the `Player` is *Realized*; an *Unrealized* `Player` doesn’t know enough about its media stream to provide access to its user-interface components. `PlayerApplet` waits for the `Player` to post a `RealizeCompleteEvent` and then displays the `Player’s` visual component and default control panel by adding them to the applet container. Calling `validate` triggers the layout manager to update the display to include the new components.

3.0 Creating and Displaying a Player

You create a `Player` indirectly through the media `Manager`. To display the `Player`, you get the `Player’s` components and add them to the applet’s presentation space or application window.

3.1 Creating a Player

When you need a new `Player`, you request it from the `Manager` by calling `createPlayer`. The `Manager` uses the media `URL` or `MediaLocator` that you specify to create an appropriate `Player`.

A `URL` can only be successfully constructed if the appropriate corresponding `URL-StreamHandler` is installed. `MediaLocator` doesn’t have this restriction.

This level of indirection allows new `Players` to be integrated seamlessly. From the client perspective, a new `Player` is always created the same way, even though the `Player` might actually be constructed from interchangeable parts or dynamically loaded at runtime.

3.2 Displaying a Player and Player Controls

JMF specifies the timing and rendering model for displaying a media stream, but a `Player's` interface components are actually displayed using `java.awt`, Java's core package for screen display. A `Player` can have two types of AWT components, its visual component and its control components.

3.2.1 Displaying a Player's Visual Component

The component in which a `Player` displays its media data is called its visual component. Even an audio `Player` might have a visual component, such as a waveform display or animated character.

To display a `Player's` visual component, you:

1. Get the component by calling `getVisualComponent`.
2. Add it to the applet's presentation space or application window.

You can access the `Player's` display properties, such as its *x* and *y* coordinates, through its visual component. The layout of the `Player` components is controlled through the AWT layout manager.

3.2.2 Displaying a Player's Controls

A `Player` often has a control panel that allows the user to control the media presentation. For example, a `Player` might be associated with a set of buttons to start, stop, and pause the media stream, and with a slider control to adjust the volume.

Every Java Media `Player` provides a default control panel. To display a `Player's` default control panel, you get it by calling `getControlPanelComponent` and add it to the applet's presentation space or application window. If you prefer to define a custom user-interface, you have access to the interfaces through which the standard control panel is implemented.

A `Player's` control-panel component often interacts with both the `Player` and the `Player's` controls. For example, to start and stop the `Player` or set its media time, the control panel calls the `Player` directly. But many `Players` have other properties that can be managed by the user. For example, a video `Player` might allow the user to adjust brightness and contrast, which are not managed through the `Player` interface.To handle these types of controls, JMF defines the `Control` interface.

A media `Player` can have any number of `Control` objects that define control behaviors and have corresponding user interface components. You can get these controls by calling `getControls` on the `Player`. For example, to determine if a `Player` supports the `CachingControl` interface and get the `CachingControl` if it does, you can call `getControls`:

```
Control[] controls = player.getControls();
   for (int i = 0; i < controls.length; i++) {
      if (controls[i] instanceof CachingControl) {
         cachingControl = (CachingControl) controls[i];
      }
   }
```

What controls are supported by a particular `Player` depends on the `Player` implementation.

3.2.3 Displaying a Gain Control Component

`GainControl` extends the `Control` interface to provide a standard API for adjusting audio gain. To get this control, you must call `getGainControl`; `getControls` does not return a `Player's GainControl`. `GainControl` provides methods for adjusting the audio volume, such as `setLevel` and `setMute`. Like other controls, the `GainControl` is associated with a GUI component that can be added to an applet's presentation space or an application window.

3.2.4 Displaying a Player's Download Progress

Downloading media data can be a time consuming process. In cases where the user must wait while data is downloaded, a progress bar is often displayed to reassure the user that the download is proceeding and to give some indication of how long the process will take. The `CachingControl` interface is a special type of `Control` supported by `Players` that can report their download progress. You can use this interface to display a download progress bar to the user.

You can call getControls to determine whether or not a Player supports the CachingControl interface. If it does, the Player will post a CachingControlEvent whenever the progress bar needs to be updated. If you implement your own progress bar component, you can listen for this event and update the download progress whenever CachingControlEvent is posted.

A CachingControl also provides a default progress bar component that is automatically updated as the download progresses. To use the default progress bar in an applet:

1. Implement the ControllerListener interface and listen for CachingControlEvents in controllerUpdate.
2. The first time you receive a CachingControlEvent:

   a. Call getCachingControl on the event to get the caching control.

   b. Call getProgressBar on the CachingControl to get the default progress bar component.

   c. Add the progress bar component to the applet's presentation space.
3. Each time you receive a CachingControlEvent, check to see if the download is complete. When getContentProgress returns the same value as getContentLength, remove the progress bar.

4.0 Controlling Media Players

The Clock and Player interfaces define the methods for starting and stopping a Player.

4.1 Starting a Player

You typically start a Player by calling start. The start method tells the Player to begin presenting media data as soon as possible. If necessary, start prepares the Player to start by performing the realize and prefetch operations. If start is called on a *Started* Player, the only effect is that a StartEvent is posted in acknowledgment of the method call.

Clock defines a syncStart method that can be used for synchronization. See "Synchronizing Players" on page 27 for more information.

To start a `Player` at a specific point in a media stream:

1. Specify the point in the media stream at which you want to start by calling `setMediaTime`.
2. Call `start` on the `Player`.

4.2 Stopping a Player

There are four situations in which a `Player` will stop:

- When the `stop` method is called on the `Player`.
- When the `Player` has reached the specified stop time.
- When the `Player` has run out of media data.
- When the `Player` is receiving data too slowly to allow acceptable playback.

When a non-broadcast `Player` is stopped, its *media time* is frozen. If the *Stopped* `Player` is subsequently restarted, media time resumes from the stop time. When you stop a broadcast `Player`, only the receipt of the media data is stopped; the data continues to be broadcast. When you restart a broadcast `Player`, the playback will resume wherever the broadcast is at that point in time.

You use the `stop` method to stop a `Player` immediately. If you call `stop` on a *Stopped* `Player`, the only effect is that a `StopByRequestEvent` is posted in acknowledgment of the method call.

4.2.1 Stopping a Player at a Specified Time

You can call `setStopTime` to indicate when a `Player` should stop. The `Player` stops when its *media time* passes the specified stop time. If the `Player's` rate is positive, the `Player` stops when the media time becomes greater than or equal to the stop time. If the `Player's` rate is negative, the `Player` stops when the media time becomes less than or equal to the stop time. The `Player` stops immediately if its current media time is already beyond the specified stop time.

For example, assume that a `Player's` media time is 5.0 and `setStopTime` is called to set the stop time to 6.0. If the `Player's` rate is positive, media time is increasing and the `Player` will stop when the media time becomes greater than or equal to 6.0. However, if the `Player's` rate is negative, it is playing in reverse and the `Player` will stop immediately because the media time is already beyond the stop time. (For more information about `Player` rates, see “Setting a Player’s Rate” on page 26.)

You can always call `setStopTime` on a stopped `Player`. However, you can only set the stop time on a *Started* `Player` if the stop time is not currently set. If the `Player` already has a stop time, `setStopTime` throws an error.

You can call `getStopTime` to get the currently scheduled stop time. If the clock has no scheduled stop time, `getStopTime` returns `Clock.UNSET`. To remove the stop time so that the `Player` continues until it reaches end-of-media, call `setStopTime(UNSET)`.

5.0 Managing Player States

The transitions between states are controlled with five methods:

- `realize`
- `prefetch`
- `start`
- `deallocate`
- `stop`
- `close`

By controlling when these methods are called, you can manage the state of a `Player`. For example, you might want to minimize start-latency by preparing the `Player` to start before you actually start it.

You can implement the `ControllerListener` interface to manage these control methods in response to changes in the `Player’s` state. Listening for a `Player’s` state transitions is also important in other cases. For example, you cannot get a `Player’s` components until the `Player` has been *Realized*. By listening for a `RealizeCompleteEvent` you can get the components as soon as the `Player` is *Realized*.

5.1 Preparing a Player to Start

Most media `Players` cannot be started instantly. Before the `Player` can start, certain hardware and software conditions must be met. For example, if the `Player` has never been started, it might be necessary to allocate buffers in memory to store the media data. Or, if the media data resides on a network device, the `Player` might have to establish a network connection before it can download the data.

Even if the `Player` has been started before, the buffers might contain data that is not valid for the current media position.

5.1.1 Realizing and Prefetching the Player

JMF breaks the process of preparing a `Player` to start into two phases, *Realizing* and *Prefetching*. *Realizing* and *Prefetching* a `Player` before you start it minimizes the time it takes the `Player` to begin presenting media when `start` is called and helps create a highly-responsive interactive experience for the user. Implementing the `ControllerListener` interface allows you to control when these operations occur.

You call `realize` to move the `Player` into the *Realizing* state and begin the realization process. You call `prefetch` to move the `Player` into the *Prefetching* state and initiate the prefetching process. The `realize` and `prefetch` methods are asynchronous and return immediately. When the `Player` completes the requested operation, it posts a `RealizeCompleteEvent` or `PrefetchCompleteEvent`. “Player States” on page 6 describes the operations that a `Player` performs in each of these states.

A `Player` in the *Prefetched* state is prepared to start and its start-up latency cannot be further reduced. However, setting the media time through `setMediaTime` might return the `Player` to the *Realized* state, increasing its start-up latency.

Keep in mind that a *Prefetched* `Player` ties up system resources. Because some resources, such as sound cards, might only be usable by one program at a time, this might prevent other `Players` from starting.

5.1.2 Blocking until a Player is Realized

Many of the methods that can be called on a `Player` require that the `Player` be in the *Realized* state. One way to guarantee that a `Player` is *Realized* when you call these methods is to implement a method that calls `realize` and blocks until the `Player` posts a `RealizeCompleteEvent`.

Note: Be aware that blocking on `realize` can produce unsatisfactory results. For example, if an applet blocks while a `Player` is realizing, `Applet.start` and `Applet.stop` will not be able to interrupt the process.

To block until a `Player` is *Realized*, you could implement a method called `blockingRealize` that calls `realize` on your `Player` and returns when the `Player` posts a `RealizeCompleteEvent` and your `controllerUpdate` method is called. This requires that you implement the `ControllerListener` interface and register as a listener with the `Player`. If you register as a listener with multiple `Players`, your `controllerUpdate` method needs to determine which `Player` posted the `RealizeCompleteEvent`.[1]

```
boolean realized = false;
public synchronized void blockingRealize()
{
   myPlayer.realize();
   while (!realized) {
      try {
         wait();
      }
      catch (java.lang.InterruptedException e) {
         status.setText("Interrupted while waiting on
                         realize...exiting.");
         System.exit(1);
      }
   }
}
public synchronized void controllerUpdate (ControllerEvent
event)
{
   if (event instanceof RealizeCompleteEvent) {
      realized = true;
      notify();
   }
   else if (event instanceof EndOfMediaEvent) {
      eomReached = true;
   }
}
```

5.1.3 Determining a Player's Start-up Latency

To determine how much time is required to start a `Player`, you can call `getStartLatency`. For `Players` that have a variable start latency, the return value of `getStartLatency` represents the maximum possible start latency. For some media types, `getStartLatency` might return `LATENCY_UNKNOWN`.

1. This example code is used with the permission of Bill Day and JavaWorld magazine. The blockingRealize example code was first published by Bill Day in "Java Media Framework Player API: Multimedia Comes to Java" in JavaWorld magazine, an online publication of Web Publishing Inc., April 1997. Please see http://www.javaworld.com/javaworld/jw-04-1997/jw-04-jmf.html for the complete article, example code listing, and demonstration applets.

The start-up latency reported by getStartLatency might differ depending on the Player's current state. For example, after a prefetch operation, the value returned by getStartLatency is typically smaller. A Controller that can be added to a Player will return a useful value once it is *Prefetched*. (For more information about added Controllers, see "Using a Player to Manage and Synchronize other Controllers" on page 29.)

5.2 Starting and Stopping a Player

Calling start moves a Player into the *Started* state. As soon as start is called, methods that are only legal for stopped Players cannot be called until the Player has been stopped.

If start is called and the Player has not been prefetched, start performs the realize and prefetch operations as needed to move the Player into the *Prefetched* state. The Player posts transition events as it moves through each state.

When stop is called on a Player, the Player is considered to be stopped immediately; stop is synchronous. However, a Player can also stop asynchronously when:

- The end of the media stream is reached.
- The stop time previously set with setStopTime is reached.
- The Player is data starved.

When a Player stops, it posts a StopEvent. To determine why the Player stopped, you must listen for the specific stop events: DeallocateEvent, EndOfMediaEvent, RestartingEvent, StopAtTimeEvent, StopByRequestEvent, and DataStarvedEvent.

5.3 Releasing Player Resources

The deallocate method tells a Player to release any exclusive resources and minimize its use of non-exclusive resources. Although buffering and memory management requirements for Players are not specified, most Java Media Players allocate buffers that are large by the standards of Java objects. A well-implemented Player releases as much internal memory as possible when deallocate is called.

The deallocate method can only be called on a *Stopped* Player. To avoid ClockStartedErrors, you should call stop before you call deallocate. Calling deallocate on a Player in the *Prefetching* or *Prefetched* state returns it to the

Realized state. If `deallocate` is called while the `Player` is realizing, the `Player` posts a `DeallocateEvent` and returns to the *Unrealized* state. (Once a `Player` has been realized, it can never return to the *Unrealized* state.)

You generally call `deallocate` when the `Player` is not being used. For example, an applet should call `deallocate` as part of its `stop` method. By calling `deallocate`, the program can maintain references to the `Player`, while freeing other resources for use by the system as a whole. (JMF does not prevent a *Realized* `Player` that has formerly been *Prefetched* or *Started* from maintaining information that would allow it to be started up more quickly in the future.)

When you are finished with a `Player` (or other `Controller`) and are not going to use it anymore, you should call `close`. The `close` method indicates that the `Controller` will no longer be used and can shut itself down. Calling `close` releases all of the resources that the `Controller` was using and causes the it to cease all activity. When a `Controller` is closed, it posts a `ControllerClosedEvent`. A closed `Controller` cannot be reopened and invoking methods on a closed `Controller` might generate errors.

5.4 Implementing the ControllerListener Interface

`ControllerListener` is an asynchronous interface for handling events generated by `Controller` objects. Using the `ControllerListener` interface enables you to manage the timing of potentially time-consuming `Player` operations such as prefetching.

To implement the `ControllerListener` interface, you need to:

1. Implement the `ControllerListener` interface in a class.
2. Register that class as a listener by calling `addControllerListener` on the `Controller` that you want to receive events from.

When a `Controller` posts an event, it calls `controllerUpdate` on each registered listener. Typically, `controllerUpdate` is implemented as a series of if-else statements of the form:

```
if(event instanceof EventType){
...
} else if(event instanceof OtherEventType){
...
}
```

This filters out the events that you are not interested in. If you have registered as a listener with multiple `Controllers`, you also need to determine which `Controller` posted the event. `ControllerEvents` come "stamped" with a reference to their source that you can access by calling `getSource`.

"Appendix D: ControllerAdapter" on page 67 provides the source for an implementation of `ControllerListener` that can be easily extended to respond to particular `Events`.

When you receive events from a `Controller`, you might need to do some additional processing to ensure that the `Controller` is in the proper state before calling a control method. For example, before calling any of the methods that are restricted to *Stopped* `Players`, you should check the `Player's` target state by calling `getTargetState`. If `start` has been called, the `Player` is considered to be in the *Started* state, though it might be posting transition events as it prepares the `Player` to present media.

Some types of `ControllerEvents` are stamped with additional state information. For example, the `StartEvent` and `StopEvent` classes each define a method that allows you to retrieve the media time at which the event occurred.

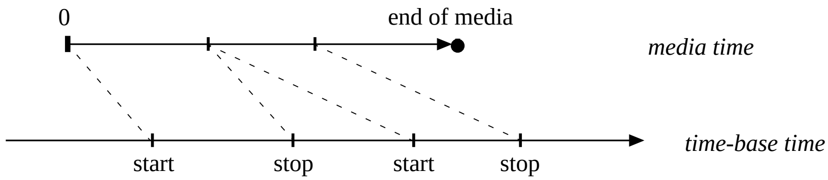
6.0 Managing Timing

In many cases, instead of playing a single media stream from beginning to end, you want to play a portion of the stream or synchronize the playback of multiple streams. The JMF `TimeBase` and `Clock` interfaces define the mechanism for managing the timing and synchronization of media playback.

A `TimeBase` represents the flow of time. A *time-base time* cannot be transformed or reset. A Java Media `Player` uses its `TimeBase` to keep time in the same way that a quartz watch uses a crystal that vibrates at a known frequency to keep time. The system maintains a master `TimeBase` that measures time in nanoseconds from a specified base time, such as January 1, 1970. The system `TimeBase` is driven by the system clock and is accessible through the `Manager.getSystemTimeBase` method.

A `Player's` *media time* represents a point in time within the stream that the `Player` is presenting. The *media time* can be started, stopped, and reset much like a stopwatch.

A `Clock` defines the mapping between a `TimeBase` and the *media time*.



A Java Media `Player` can answer several timing queries about the media source it is presenting. Of course, timing information is subject to the physical characteristics and limitations of both the media source and of the network device on which it is stored.

A `Time` object represents a quantity of some time unit, such as nanoseconds. You use `Time` objects when you query or set a `Player's` timing information.

6.1 Setting the Media Time

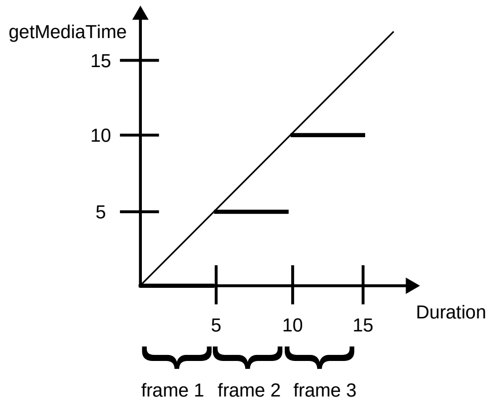
Setting a `Player's` *media time* is equivalent to setting a read position within a media stream. For a media data source such as a file, the *media time* is bounded; the maximum *media time* is defined by the end of the media stream.

To set the *media time* you call `setMediaTime` and pass in a `Time` object that represents the time you want to set.

6.2 Getting the Current Time

Calling `getMediaTime` returns a `Time` object that represents the `Player's` current *media time*. If the `Player` is not presenting media data, this is the point from which media presentation will commence. There is not a one-to-one correspondence between a *media time* and a particular frame. Each frame is presented for a certain period of time, and the *media time* continues to advance during that period.

For example, imagine you have a slide show `Player` that displays each slide for 5 seconds—the `Player` essentially has a frame rate of 0.2 frames per second.



If you start the `Player` at time 0.0, while the first *frame* is displayed, the media time advances from 0.0 to 5.0. If you start at time 2.0, the first frame is displayed for 3 seconds, until time 5.0 is reached.

You can get a `Player's` current *time-base time* by getting the `Player's` `TimeBase` and calling `getRefTime`:

```
myCurrentTBTime = player1.getTimeBase().getRefTime();
```

When a `Player` is running, you can get the *time-base time* that corresponds to a particular *media time* by calling `mapToTimeBase`.

6.3 Setting a Player's Rate

The `Player's` rate determines how *media time* changes with respect to time-base time; it defines how many units a `Player's` *media time* advances for every unit of *time-base time*. The `Player's` rate can be thought of as a temporal scale factor. For example, a rate of 2.0 indicates that *media time* passes twice as fast as the *time-base time* when the `Player` is started.

In theory, a `Player's` rate could be set to any real number, with negative rates interpreted as playing the media in reverse. However, some media formats have dependencies between frames that make it impossible or impractical to play them in reverse or at non-standard rates.

When `setRate` is called on a `Player`, the method returns the rate that is actually set, even if it has not changed. `Players` are only guaranteed to support a rate of 1.0.

6.4 Getting a Player's Duration

Since your program might need to determine how long a given media stream will run, all `Controllers` implement the `Duration` interface. This interface comprises a single method, `getDuration`. Duration represents the length of time that a media object would run, if played at the default rate of 1.0. A media stream's duration is accessible only through the `Player`.

If the duration can't be determined when `getDuration` is called, `DURATION_UNKNOWN` is returned. This can happen if the `Player` has not yet reached a state where the duration of the media source is available. At a later time, the duration might be available and a call to `getDuration` would return the duration value. If the media source does not have a defined duration, as in the case of a live broadcast, `getDuration` returns `DURATION_UNBOUNDED`.

7.0 Synchronizing Players

To synchronize the playback of multiple media streams, you can synchronize the `Players` by associating them with the same `TimeBase`. To do this, you use the `getTimeBase` and `setTimeBase` methods defined by the `Clock` interface. For example, you could synchronize `player1` with `player2` by setting `player1` to use `player2's` time base:

```
player1.setTimeBase(player2.getTimeBase());
```

When you synchronize `Players` by associating them with the same`TimeBase`, you must still manage the control of each `Player` individually. Because managing synchronized `Players` in this way can be complicated, JMF provides a mechanism that allows a `Player` to assume control over any `Controller`. The `Player` manages the states of the controllers automatically, allowing you to interact with the entire group through a single point of control. For more information, see “Using a Player to Manage and Synchronize other Controllers” on page 29.

In a few situations, you might want to manage the synchronization of multiple `Players` yourself so that you can control the rates or media times independently. If you do this, you must:

- Register as a listener for each synchronized `Player`.
- Determine which `Player's` time base is going to be used to drive the other `Players` and set the time base for the synchronized `Players`. Not all `Players` can assume a new time base. For example, if one of the `Players` you want to synchronize has a push data-source, that `Player's` time base must be used to

drive the other Players.

- Set the rate for all of the Players. If a Player cannot support the rate you specify, it returns the rate that was used. (There is no mechanism for querying the rates that a Player supports.)
- Synchronize the Players' states. (For example, stop all of the Players.)
- Synchronize the operation of the Players:
  - Set the media time for each Player.
  - Prefetch all of the Players.
  - Determine the maximum start latency among the synchronized Players.
  - Start the Players by calling syncStart with a time that takes into account the maximum latency.

You must listen for transition events for all of the Players and keep track of which ones have posted events. For example, when you prefetch the Players, you need to keep track of which ones have posted PrefetchComplete events so that you can be sure all of the Players are *Prefetched* before calling syncStart. Similarly, when you request that the synchronized Players stop at a particular time, you need to listen for the stop event posted by each Player to determine when all of the Players have actually stopped.

In some situations, you need to be careful about responding to events posted by the synchronized Players. To be sure of the Players' states, you might need to wait at certain stages for all of the synchronized Players to reach the same state before continuing.

For example, assume that you are using one Player to drive a group of synchronized Players. A user interacting with that Player sets the media time to 10, starts the Player, and then changes the media time to 20. You then:

- Pass along the first setMediaTime call to all of the synchronized Players.
- Call prefetch on the Players to prepare them to start.
- Call stop on the Players when the second set media time request is received.
- Call setMediaTime on the Players with the new time.
- Restart the prefetching operation.
- When all of the Players have been prefetched, start them by calling syncStart, taking into account their start latencies.

In this case, simply listening for PrefetchComplete events from all of the Players before calling syncStart isn't sufficient. You can't tell whether those events were posted in response to the first or second prefetch operation. To avoid this problem, you can block when you call stop and wait for all of the Players to post stop events before continuing. This guarantees that the next PrefetchComplete events you receive are the ones that you are really interested in.

8.0 Using a Player to Manage and Synchronize other Controllers

Synchronizing Players manually using syncStart requires that you carefully manage the states of all of the synchronized Players. You must control each one individually, listening for events and calling control methods on them as appropriate. Even with only a few Players, this quickly becomes a difficult task. Through the Player interface, JMF provides a simpler solution: a Player can be used to manage the operation of any Controller.

When you interact with a managing Player, your instructions are automatically passed along to the managed Controllers as appropriate. The managing Player takes care of the state management and synchronization for all of the other Controllers.

This mechanism is implemented through the addController and removeController methods. When you call addController on a Player, the Controller you specify is added to the list of Controllers managed by the Player. Conversely, when you call removeController, the specified Controller is removed from the list of managed Controllers.

Typically, when you need to synchronize Players or other Controllers, you should use this addController mechanism. It is simpler, faster, and less error-prone than attempting to manage synchronized Players individually.

When a Player assumes control of a Controller:

- The Controller assumes the Player's time-base.
- The Player's duration becomes the longer of the Controller's duration and its own. If multiple Controllers are placed under a Player's control, the Player's duration is the longest of all of their durations.
- The Player's start latency becomes the longer of the Controller's start latency and its own. If multiple Controllers are placed under a Player's control, the Player's start latency is the longest of all of their latencies.

A managing Player only posts completion events for asynchronous methods after every added Controller has posted the event. The managing Player reposts other events generated by the managed Controllers as appropriate.

8.1 Adding a Controller

You use the addController method to add a Controller to the list of Controllers managed by a particular Player. To be added, a Controller must be in the *Realized* state; otherwise, a NotRealizedError is thrown. Two Players cannot be placed under control of each other. For example, if player1 is placed under the control of player2, player2 cannot be placed under the control of player1 without first removing player1 from player2's control.

Once a Controller has been added to a Player, do not call methods directly on the added Controller. To control an added Controller, you interact with the managing Player.

To have player2 assume control of player1, call:

```
player2.addController(player1);
```

8.2 Managing the Operation of Added Controllers

To control the operation of a group of Controllers managed by a particular Player, you interact directly with the managing Player. Do not call control methods on the managed Controllers directly.

For example, to prepare all of the managed Controllers to start, call prefetch on the managing Player. Similarly, when you want to start them, call start on the managing Player. The managing Player makes sure that all of the Controllers are *Prefetched*, determines the maximum start latency among the Controllers, and calls syncStart to start them, specifying a time that takes the maximum start latency into account.

When you call a Controller method on the managing Player, the Player propagates the method call to the managed Controllers as appropriate. Before calling a Controller method on a managed Controller, the Player ensures that the Controller is in the proper state. The following table describes what happens to the managed Controllers when you call control methods on the managing Player.

Function	Stopped Player	Started Player
setMediaTime	Invokes setMediaTime on all managed Controllers.	Stops all managed Controllers, invokes setMediaTime, and restarts Controllers.
setRate	Invokes setRate on all managed Controllers. Returns the actual rate that was supported by all Controllers and set.	Stops all managed Controllers, invokes setRate, and restarts Controllers. Returns the actual rate that was supported by all Controllers and set.
start	Ensures all managed Controllers are *Prefetched* and invokes syncStart on each of them, taking into account their start latencies.	Depends on the Player implementation. Player might immediately post a StartEvent.
realize	The managing Player immediately posts a RealizeCompleteEvent. To be added, a Controller must already be realized.	The managing Player immediately posts a RealizeCompleteEvent. To be added, a Controller must already be realized.
prefetch	Invokes prefetch on all managed Controllers.	The managing Player immediately posts a PrefetchCompleteEvent, indicating that all managed Controllers are *Prefetched*.
stop	No effect.	Invokes stop on all managed Controllers.
deallocate	Invokes deallocate on all managed Controllers.	It is illegal to call deallocate on a *Started* Player.
setStopTime	Invokes setStopTime on all managed Controllers. (Player must be *Realized*.)	Invokes setStopTime on all managed Controllers. (Can only be set once on a *Started* Player.)
syncStart	Invokes syncStart on all managed Controllers.	It is illegal to call syncStart on a *Started* Player.
close	Invokes close on all managed Controllers.	It is illegal to call close on a *Started* Player.

8.3 Removing a Controller

You use the removeController method to remove a Controller from the list of controllers managed by a particular Player.

To have `player2` release control of `player1`, call:

```
player2.removeController(player1);
```

9.0 Extending JMF

The JMF architecture allows advanced developers to create and integrate new types of controllers and data sources. For example, you might implement a new `Player` that supports a special media format.

This section introduces the JMF Player architecture and describes how new `Players` and `DataSources` can be integrated into JMF.

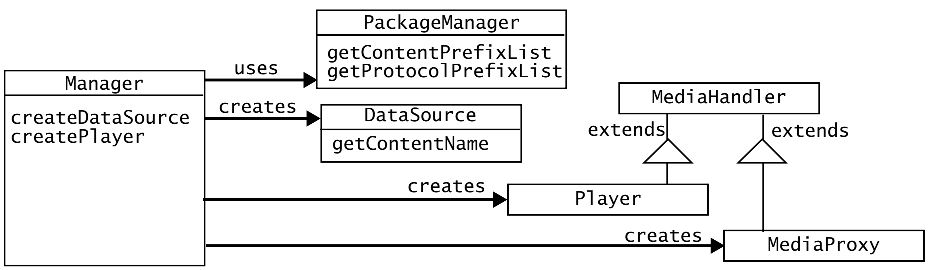
9.1 Understanding the Player Architecture

As described in "Creating a Player" on page 14, a client programmer calls `Manager.createPlayer` to get a new `Player` for a particular media source. When `createPlayer` is called, an appropriate `Player` is created and returned to the caller.

`Manager` constructs `Players` for particular media sources. A `DataSource` is first constructed from a `URL` or `MediaLocator` and then used to create a `Player`. (A `DataSource` is a protocol-specific source of media data. `Players` usually use `DataSources` to manage the transfer of media-content.)

When creating a `Player`, `Manager`:

- Obtains the connected `DataSource` for the specified protocol
- Obtains the `Player` for the content-type specified by the `DataSource`
- Attaches the `DataSource` to the `Player`



9.1.1 Locating a DataSource

The `createDataSource` method locates and instantiates an appropriate `DataSource` for a specified `MediaLocator`. To do this, it first creates a search list of `DataSource` class names and then steps through each class in the list until a usable data source is found. To construct the search list of `DataSource` class names, `createDataSource`:

1. Obtains a vector of protocol package-prefixes from `PackageManager`.
2. Adds a class name of the form:

   ```
   <package-prefix>.media.protocol.<protocol>.DataSource
   ```

   for each `<package-prefix>` in the protocol package-prefix-vector.

`Manager` steps through each class in the list until it finds a `DataSource` that it can instantiate and to which it can attach the `MediaLocator`.

9.1.2 Locating a Player

The `createPlayer` method uses a similar mechanism to locate and instantiate an appropriate `Player` for a particular `DataSource`. A `Player` is a type of `MediaHandler`, an object that reads data from a `DataSource`. `MediaHandlers` are identified by the content type that they support. `Manager` uses the content type name obtained from a `DataSource` to find `MediaHandler` objects. JMF supports two types of `MediaHandlers`, `Player` and `MediaProxy`.

A `MediaProxy` processes content from one `DataSource` to create another. Typically, a `MediaProxy` reads a text configuration file that contains all of the information needed to make a connection to a server and obtain media data.

When `createPlayer` is called, `Manager` first creates a search list of class names using the content name from the `DataSource` and the list of installed packages returned by the `PackageManager`. It then steps through each class in the list until it finds a `MediaHandler` that can be constructed and to which it can attach the `DataSource`.

If the `MediaHandler` is a `Player`, the process is finished and `Manager` returns the new `Player`. If the `MediaHandler` is a `MediaProxy`, `Manager` obtains a new `DataSource` from the `MediaProxy`, creates a new list for the content type that the `DataSource` supports and repeats the search process.

If an appropriate `Player` cannot be found, the procedure is repeated, substituting "unknown" for the content type name. The "unknown" content type is supported by generic `Players` that are capable of handling a large variety of media types, often in a platform dependent way.

To construct the search list of `MediaHandler` class names, `createPlayer`:

1. Obtains a vector of content package-prefixes from `PackageManager`.
2. Adds a class name of the form:

   ```
   <package-prefix>.media.content.<content-type>.Handler
   ```

   for each `<package-prefix>` in the content package-prefix-vector.

9.2 Integrating a New Player Implementation

You can create custom implementations of `Player` that can work seamlessly with the rest of JMF. To integrate a `Player` with JMF, you need to:

- Implement `Player.setSource` to check the `DataSource` and determine whether or not the `Player` can handle that type of source. When the client programmer calls `createPlayer`, `setSource` is called as the `Manager` searches for an appropriate `Player`.
- Install the package containing the new `Player` class.
- Add the package prefix to the content package-prefix list controlled by the `PackageManager`. The `Manager` queries the `PackageManager` for the list of content package-prefixes it uses to search for a `Player`.

For example, to integrate a new `Player` for the content type mpeg.sys, you would create and install a package called:

```
<package-prefix>.media.content.mpeg.sys
```

that contains the new `Player` class. The package prefix is an identifier for your code, such as `COM.yourbiz`. Your installation program also needs to add your package prefix to the content package-prefix list managed by the `PackageManager`.

```
Vector  packagePrefix = PackageManager.getContentPrefixList();
string myPackagePrefix = new String("COM.yourbiz");
// Add new package prefix to end of the package prefix list.
packagePrefix.addElement(myPackagePrefix);
PackageManager.setContentPrefixList();
// Save the changes to the package prefix list.
PackageManager.commitContentPrefixList();
```

9.3 Implementing a New Data Source

A `DataSource` is an abstraction of a media protocol-handler. You can implement new types of `DataSources` to support additional protocols by extending `PullDataSource` or `PushDataSource`. If your `DataSource` supports changing the media position within the stream to a specified time, it should implement the `Positionable` interface. If the `DataSource` supports seeking to a particular point in the stream, the corresponding `SourceStream` should implement the `Seekable` interface.

A `DataSource` manages a collection of `SourceStreams`. A `PullDataSource` only supports pull data-streams; it manages a collection of `PullSourceStreams`. A `PushDataSource` only supports push data-streams; it manages a collection of `PushSourceStreams`. When you implement a new `DataSource`, you also need to implement the corresponding source stream, `PullSourceStream` or `PushSourceStream`.

See "Appendix B: Sample Data Source Implementation" on page 43 for an example illustrating how a new `PullDataSource`, `FTPDataSource`, could be implemented.

9.4 Integrating a New Data Source Implementation

The mechanism for integrating a custom `DataSource` implementation with JMF is similar to the one used for integrating a `Player`. You need to:

- Install the package containing the new `DataSource` class.
- Add the package prefix to the protocol package-prefix list controlled by the `PackageManager`. The `Manager` queries the `PackageManager` for the list of protocol package prefixes it uses to search for a `DataSource`.

Appendix A: Java Media Applet

This Java Applet demonstrates proper error checking in a Java Media program. Like `PlayerApplet`, it creates a simple media player with a media event listener.

When this applet is started, it immediately begins to play the media clip. When the end of media is reached, the clip replays from the beginning.

```
import java.applet.Applet;
import java.awt.*;
import java.lang.String;
import java.net.URL;
import java.net.MalformedURLException;
import java.io.IOException;
import javax.media.*;

/**
 * This is a Java Applet that demonstrates how to create a simple
 * media player with a media event listener.  It will play the
 * media clip right away and continuously loop.
 *
 * <!-- Sample HTML
 * <applet code=TypicalPlayerApplet width=320 height=300>
 * <param name=file value="Astrnmy.avi">
 * </applet>
 * -->
 */

public class TypicalPlayerApplet extends Applet implements
ControllerListener
{
   // media player
   Player player = null;
```

```
// component in which video is playing
Component visualComponent  = null;
// controls gain, position, start, stop
Component controlComponent = null;
// displays progress during download
Component progressBar      = null;

/**
 * Read the applet file parameter and create the media
 * player.
 */

public void init()
{
   setLayout(new BorderLayout());
   // input file name from html param
   String mediaFile = null;
   // URL for our media file
   URL url = null;
   // URL for doc containing applet
   URL codeBase = getDocumentBase();

   // Get the media filename info.
   // The applet tag should contain the path to the
   // source media file, relative to the html page.

   if ((mediaFile = getParameter("FILE")) == null)
      Fatal("Invalid media file parameter");

   try
   {
      // Create an url from the file name and the url to the
      // document containing this applet.

      if ((url = new URL(codeBase, mediaFile)) == null)
         Fatal("Can't build URL for " + mediaFile);

      // Create an instance of a player for this media
      if ((player = Manager.createPlayer(url)) == null)
         Fatal("Could not create player for "+url);

      // Add ourselves as a listener for player's events
         player.addControllerListener(this);
   }
   catch (MalformedURLException u)
   {
      Fatal("Invalid media file URL!");
   }
   catch(IOException i)
   {
```

```
            Fatal("IO exception creating player for "+url);
        }

        // This applet assumes that its start() calls
        // player.start().This causes the player to become
        // Realized. Once Realized, the Applet will get
        //  the visual and control panel components and add
        // them to the Applet.  These components are not added
        // during init() because they are long operations that
        // would make us appear unresposive to the user.
    }

    /**
     * Start media file playback.  This function is called the
     * first time that the Applet runs and every
     * time the user re-enters the page.
     */

    public void start()
    {
        // Call start() to prefetch and start the player.

        if (player != null) player.start();
    }

    /**
     * Stop media file playback and release resources before
     * leaving the page.
     */

    public void stop()
    {
        if (player != null)
        {
            player.stop();
            player.deallocate();
        }
    }

    /**
     * This controllerUpdate function must be defined in order
     * to implement a ControllerListener interface.  This
     * function will be called whenever there is a media event.
     */

    public synchronized void controllerUpdate(ControllerEvent event)
    {
        // If we're getting messages from a dead player,
        // just leave
```

```
if (player == null) return;

// When the player is Realized, get the visual
// and control components and add them to the Applet

if (event instanceof RealizeCompleteEvent)
{
   if ((visualComponent = player.getVisualComponent()) != null)
      add("Center", visualComponent);
  if ((controlComponent = player.getControlPanelComponent()) != null)
      add("South",controlComponent);
      // force the applet to draw the components
      validate();
}
else if (event instanceof CachingControlEvent)
{

   // Put a progress bar up when downloading starts,
   // take it down when downloading ends.

   CachingControlEvent  e = (CachingControlEvent) event;
   CachingControl      cc = e.getCachingControl();
   long cc_progress       = e.getContentProgress();
   long cc_length         = cc.getContentLength();

   // Add the bar if not already there ...

   if (progressBar == null)
      if ((progressBar = cc.getProgressBarComponent()) != null)
      {
         add("North", progressBar);
         validate();
      }

   // Remove bar when finished ownloading
   if (progressBar != null)
      if (cc_progress == cc_length)
      {
         remove (progressBar);
         progressBar = null;
         validate();
      }
}
else if (event instanceof EndOfMediaEvent)
{
   // We've reached the end of the media; rewind and
   // start over

   player.setMediaTime(new Time(0));
   player.start();
```

```
        }
        else if (event instanceof ControllerErrorEvent)
        {
            // Tell TypicalPlayerApplet.start() to call it a day

            player = null;
            Fatal (((ControllerErrorEvent)event).getMessage());
        }
    }

    void Fatal (String s)
    {
        // Applications will make various choices about what
        // to do here.  We print a message and then exit

        System.err.println("FATAL ERROR: " + s);
        throw new Error(s);  // Invoke the uncaught exception
                             // handler System.exit() is another
                             // choice
    }
}
```

Appendix B: Sample Data Source Implementation

This sample demonstrates how to implement a new `DataSource` to support an additional protocol, the FTP protocol. There are two classes:

- `DataSource` extends `PullDataSource` and implements `intel.media.protocol.PullProtocolHandler`.
- `FTPSourceStream` implements `PullSourceStream`.

FTP Data Source

```
package COM.intel.media.protocol.ftp;

import javax.media.protocol.PullDataSource;
import javax.media.protocol.SourceStream;
import javax.media.protocol.PullSourceStream;
import javax.media.Time;
import javax.media.Duration;
import java.io.*;
import java.net.*;
import java.util.Vector;

public class DataSource extends PullDataSource
{
   public static final int FTP_PORT = 21;
   public static final int FTP_SUCCESS = 1;
   public static final int FTP_TRY_AGAIN = 2;
```

```
public static final int FTP_ERROR = 3;

// used to send commands to server
protected Socket controlSocket;

// used to receive file
protected Socket dataSocket;

// wraps controlSocket's output stream
protected PrintStream controlOut;

// wraps controlSocket's input stream
protected InputStream controlIn;

// hold (possibly multi-line) server response
protected Vector response = new Vector(1);

// reply code from previous command
protected int previousReplyCode;

// are we waiting for command reply?
protected boolean replyPending;

// user login name
 protected String user = "anonymous";

// user login password
protected String password = "anonymous";

// FTP server name
protected String hostString;

// file to retrieve
protected String fileString;

public void connect() throws IOException
{
   initCheck();  // make sure the locator is set
   if (controlSocket != null)
   {
      disconnect();
   }
  // extract FTP server name and target filename from locator
   parseLocator();
   controlSocket = new Socket(hostString, FTP_PORT);
   controlOut = new PrintStream(new BufferedOutputStream(
```

```
            controlSocket.getOutputStream()), true);
         controlIn = new
            BufferedInputStream(controlSocket.getInputStream());

        if (readReply() == FTP_ERROR)
         {
             throw new IOException("connection failed");
         }

         if (issueCommand("USER " + user) == FTP_ERROR)
         {
            controlSocket.close();
            throw new IOException("USER command failed");
         }

         if (issueCommand("PASS " + password) == FTP_ERROR)
         {
            controlSocket.close();
            throw new IOException("PASS command failed");
         }
      }

      public void disconnect()
      {
         if (controlSocket == null)
         {
            return;
         }

         try
         {
            issueCommand("QUIT");
            controlSocket.close();
         }

         catch (IOException e)
         {
            // do nothing, we just want to shutdown
         }

         controlSocket = null;
         controlIn = null;
         controlOut = null;
      }

       public void start() throws IOException
```

```
 {
      ServerSocket serverSocket;
      InetAddress myAddress = InetAddress.getLocalHost();
      byte[] address = myAddress.getAddress();

      String portCommand = "PORT ";
      serverSocket = new ServerSocket(0, 1);

      // append each byte of our address (comma-separated)

      for (int i = 0; i < address.length; i++)
      {
       portCommand = portCommand + (address[i] & 0xFF) + ",";
      }

    // append our server socket's port as two comma-separated
   // hex bytes
      portCommand = portCommand +
         ((serverSocket.getLocalPort() >>> 8)
       & 0xFF) + "," + (serverSocket.getLocalPort() & 0xFF);

      // issue PORT command
      if (issueCommand(portCommand) == FTP_ERROR)
      {
         serverSocket.close();
         throw new IOException("PORT");
      }

      // issue RETRieve command
      if (issueCommand("RETR " + fileString) == FTP_ERROR)
      {
         serverSocket.close();
         throw new IOException("RETR");
      }

      dataSocket = serverSocket.accept();
      serverSocket.close();
}

public void stop()
{
   try
   {
   // issue ABORt command
   issueCommand("ABOR");
   dataSocket.close();
```

```
        }
        catch(IOException e) {}
    }

    public String getContentType()
    {
     // We don't get MIME info from FTP server.  This
     // implementation makes an attempt guess the type using
     // the File name and returns "unknown" in the default case.
     // A more robust mechanisms should
     // be supported for real-world applications.

        String locatorString = getLocator().toExternalForm();
        int dotPos = locatorString.lastIndexOf(".");
        String extension = locatorString.substring(dotPos + 1);
        String typeString = "unknown";

        if (extension.equals("avi"))
           typeString = "video.x-msvideo";
        else if (extension.equals("mpg") ||
           extension.equals("mpeg"))
           typeString = "video.mpeg";
        else if (extension.equals("mov"))
           typeString = "video.quicktime";
        else if (extension.equals("wav"))
           typeString = "audio.x-wav";
        else if (extension.equals("au"))
           typeString = "audio.basic";
        return typeString;
    }

    public PullSourceStream[] getStreams()
    {
        PullSourceStream[] streams = new PullSourceStream[1];
        try
        {
           streams[0] = new
FTPSourceStream(dataSocket.getInputStream());
        }

        catch(IOException e)
        {
           System.out.println("error getting streams");
        }
        return streams;
    }
```

```
public Time getDuration()
{
   return Duration.DURATION_UNKNOWN;
}

public void setUser(String user)

{
   this.user = user;
}

public String getUser()
{
   return user;
}

public void setPassword(String password)
{
   this.password = password;
}

public String getPassword()
{
   return password;
}

private int readReply() throws IOException
{
   previousReplyCode = readResponse();
   System.out.println(previousReplyCode);
   switch (previousReplyCode / 100)
   {
      case 1:
         replyPending = true;
         // fall through
      case 2:
      case 3:
         return FTP_SUCCESS;
      case 5:
         if (previousReplyCode == 530)
         {
            if (user == null)
            {
```

```
                throw new IOException("Not logged in");
             }
             return FTP_ERROR;
          }
          if (previousReplyCode == 550)
          {
             throw new FileNotFoundException();
          }
    }
    return FTP_ERROR;
 }

/**
* Pulls the response from the server and returns the code as a
 * number. Returns -1 on failure.
 */

private int readResponse() throws IOException
{
   StringBuffer buff = new StringBuffer(32);
   String responseStr;
   int   c;
   int   continuingCode = -1;
   int   code = 0;

   response.setSize(0);

   while (true)
   {
      while ((c = controlIn.read()) != -1)
      {
         if (c == '\r')
         {
            if ((c = controlIn.read()) != '\n')
            {
               buff.append('\r');
            }
         }
         buff.append((char)c);

         if (c == '\n')
         {
             break;
         }
      }
      responseStr = buff.toString();
```

```
        buff.setLength(0);
        try
        {
         code = Integer.parseInt(responseStr.substring(0, 3));
        }
        catch (NumberFormatException e)
        {
           code = -1;
        }
        catch (StringIndexOutOfBoundsException e)
        {
           /* this line doesn't contain a response code, so
            * we just completely ignore it
            */
            continue;
        }
        response.addElement(responseStr);
        if (continuingCode != -1)
        {
           /* we've seen a XXX- sequence */
           if (code != continuingCode ||
              (responseStr.length() >= 4 &&
              responseStr.charAt(3) == '-'))
           {
               continue;
           }
           else
           {
              /* seen the end of code sequence */
              continuingCode = -1;
              break;
           }
        }
        else if (responseStr.length() >= 4 &&
           responseStr.charAt(3) == '-')
        {
           continuingCode = code;
           continue;
        }
        else
        {
           break;
        }
     }
     previousReplyCode = code;
     return code;
```

```
    }

    private int issueCommand(String cmd) throws IOException
    {
       int reply;
       if (replyPending)
       {
          if (readReply() == FTP_ERROR)
          {
             System.out.print("Error reading pending reply\n");
          }
       }
       replyPending = false;
       do
       {
          System.out.println(cmd);
          controlOut.print(cmd + "\r\n");
          reply = readReply();
       } while (reply == FTP_TRY_AGAIN);
       return reply;
    }

    /**
     * Parses the mediaLocator field into host and file strings
     */

    protected void parseLocator()
    {
       initCheck();
       String rest = getLocator().getRemainder();
       System.out.println("Begin parsing of: " + rest);
       int p1, p2 = 0;
       p1 = rest.indexOf("//");
       p2 = rest.indexOf("/", p1+2);
       hostString = rest.substring(p1 + 2, p2);
       fileString = rest.substring(p2);
       System.out.println("host: " + hostString + "   file: "
          + fileString);
    }
 }
```

Source Stream

```
 package intel.media.protocol.ftp;

 import java.io.*;
import javax.media.protocol.ContentDescriptor;
import javax.media.protocol.PullSourceStream;
import javax.media.protocol.SourceStream;

public class FTPSourceStream implements PullSourceStream
{
   protected InputStream dataIn;
   protected boolean eofMarker;
   protected ContentDescriptor cd;

   public FTPSourceStream(InputStream in)
   {
      this.dataIn = in;
      eofMarker = false;
      cd = new ContentDescriptor("unknown");
   }

   // SourceSteam methods

   public ContentDescriptor getContentDescriptor()
   {
      return cd;
   }

   public void close() throws IOException
   {
      dataIn.close();
   }

   public boolean endOfStream()
   {
      return eofMarker;
   }

   // PullSourceStream methods

   public int available() throws IOException
   {
      return dataIn.available();
   }
```

```
    public int read(byte[] buffer, int offset, int length) throws
IOException
    {
        int n = dataIn.read(buffer, offset, length);
        if (n == -1)
        {
            eofMarker = true;
        }
        return n;
    }

    public boolean willReadBlock() throws IOException
    {
        if(eofMarker)
        {
            return true;
        }
        else
        {
            return dataIn.available() == 0;
        }
    }

    public long getContentLength()
    {
        return SourceStream.LENGTH_UNKNOWN;
    }
}
```

Appendix C: Sample Controller Implementation

This sample illustrates how a simple time-line `Controller` can be implemented in JMF. This example includes three classes:

- `TimeLineController.java`

  The `Controller`. You give it an array of time values (representing a time line) and it keeps track of which segment in the time line you are in.

- `TimeLineEvent.java`

  An event posted by the `TimeLineController` when the segment in the time line changes.

- `EventPostingBase.java`

  A base class used by `TimeLineController` that handles the `Controller` methods `addControllerListener` and `removeControllerListener`. It also provides a `postEvent` method that can be used by the subclass to post events.

This implementation also uses two additional classes whose implementations are not shown here.

- `EventPoster`

  A class that spins a thread to post events to a `ControllerListener`.

- `BasicClock`

  A simple `Clock` implementation that implements all of the `Clock` methods.

TimeLineEvent

```
TimeLineEvent.java

import javax.media.*;

// TimeLineEvent -- posted by TimeLineController when we have
// switched segments in the time line.
public class TimeLineEvent extends ControllerEvent
{
    protected int segment;

    public TimeLineEvent (Controller source, int currentSegment)
    {
      super (source);
      segment = currentSegment;
    }
    public final int getSegment ()
    {
      return segment;
    }
}
```

EventPostingBase

```
EventPostingBase.java

import javax.media.*;
import COM.yourbiz.media.EventPoster;

// EventPoster supports two methods:
//   public EventPoster ();
//   public void postEvent (ControllerListener who,
//   ControllerEvent what);

// A list of controller listeners that we are supposed to send
// events to.
class ListenerList
{
    ControllerListener observer;
    ListenerList next;
}

public class EventPostingBase
{
    protected ListenerList olist;
```

```
    protected Object olistLock;
    protected EventPoster eventPoster;

    // We sync around a new object so that we don't mess with
    // the super class synchronization.
    EventPostingBase ()
    {
        olistLock = new Object ();
    }

    public void addControllerListener (ControllerListener observer)
    {
        synchronized (olistLock)
        {
            if (eventPoster == null)
            {
                eventPoster = new EventPoster ();
            }

            ListenerList iter;
            for (iter = olist; iter != null; iter = iter.next)
            {
                if (iter.observer == observer) return;
            }
            iter = new ListenerList ();
            iter.next = olist;
            iter.observer = observer;
            olist = iter;
        }
    }

    public void removeControllerListener (ControllerListener  observer)
    {
        synchronized (olistLock)
        {
            if (olist == null)
            {
                return;
            }
            else if (olist.observer == observer)
            {
                olist = olist.next;
            }
            else
            {
                ListenerList iter;
               for (iter = olist; iter.next != null; iter = iter.next)
                {
                    if (iter.next.observer == observer)
                    {
```

```
                        iter.next = iter.next.next;
                        return;
                    }
                }
            }
        }
    }

    protected void postEvent (ControllerEvent event)
    {
        synchronized (olistLock)
        {
            ListenerList iter;
            for (iter = olist; iter != null; iter = iter.next)
            {
                eventPoster.postEvent (iter.observer, event);
            }
        }
    }
}
```

TimeLineController

```
TimeLineController.java

import javax.media.*;
import COM.yourbiz.media.BasicClock;

// This Controller uses two custom classes:
//    The base class is EventPostingBase.  It has three methods:
//      public void addControllerListener (ControllerListener
//         observer);
//      public void removeControllerListener (ControllerListener
//         observer);
//      protected void postEvent (ControllerEvent event);
//
//   This Controller posts TimeLineEvents.  TimeLineEvent has
//   two methods:
//      public TimeLineEvent (Controller who, int
//         segmentEntered);
//      public final int getSegment ();

public class TimeLineController extends EventPostingBase
    implements Controller, Runnable
{
    Clock ourClock;
```

```
// This simple controller really only has two states:
// Prefetched and Started.
int ourState;

long timeLine[];
int currentSegment = -1;
long duration;
Thread myThread;

// Create a TimeLineController giving it a sorted time line.
// The TimeLineController will post events indicating when
// it has passed to different parts of the time line.

public TimeLineController (long timeLine[])
{
    this.timeLine = timeLine;
    ourClock = new BasicClock ();
    duration = timeLine[timeLine.length-1];
    myThread = null;

    // We always start off ready to go!
    ourState = Controller.Prefetched;
}

// Binary search for which segment we are now in.  Segment
// 0 is considered to start at 0 and end at timeLine[0].
// Segment timeLine.length is considered to start at
// timeLine[timeLine.length-1] and end at infinity.  At the
// points of 0 and timeLine[timeLine.length-1] the
// Controller will stop (and post an EndOfMedia event).

int computeSegment (long time)
{
    int max = timeLine.length;
    int min = 0;
    for (;;)
    {
        if (min == max) return min;
        int current = min + ((max - min) >> 1);
        if (time < timeLine[current])
        {
            max = current;
        }
        else
        {
            min = current + 1;
        }
    }
}
```

```
// These are all simple...
public float setRate (float factor)
{
    // We don't support a rate of 0.0.  Not worth the extra math
    // to handle something the user should do with the stop()
    // method!
    if (factor == 0.0f)
    {
        factor = 1.0f;
    }
    float newRate = ourClock.setRate (factor);
    postEvent (new RateChangeEvent (this, newRate));
    return newRate;
}

public void setTimeBase (TimeBase master)
    throws IncompatibleTimeBaseException
{
    ourClock.setTimeBase (master);
}

public long getStopTime ()
{
    return ourClock.getStopTime ();
}

public long getSyncTime ()
{
    return ourClock.getSyncTime ();
}

public long mapToTimeBase (long t) throws ClockStoppedException
{
    return ourClock.mapToTimeBase (t);
}

public long getMediaTime ()
{
    return ourClock.getMediaTime ();
}

public TimeBase getTimeBase ()
{
    return ourClock.getTimeBase ();
}

public float getRate ()
{
    return ourClock.getRate ();
}
```

```
// From Controller
public int getState ()
{
    return ourState;
}
public int getTargetState ()
{
    return ourState;
}
public void realize ()
{
    postEvent (new RealizeCompleteEvent (this, ourState,
        ourState, ourState));
}
public void prefetch ()
{
  postEvent (new PrefetchCompleteEvent (this, ourState,
        ourState, ourState));
}
public void deallocate () {
  postEvent (new DeallocateEvent (this, ourState,
        ourState, ourState, ourClock.getMediaTime ()));
}
public long getStartLatency ()
{
    // We can start immediately, of course!
    return 0;
}
public Control[] getControls ()
{
    return new Control[0];
}
public long getDuration ()
{
    return duration;
}

// This one takes a little work as we need to compute if we
// changed segments.
public void setMediaTime (Time now)
{
    ourClock.setMediaTime (now);
    postEvent (new MediaTimeSetEvent (this, now));
    checkSegmentChange (now);
}

// We now need to spin a thread to compute/observe the
// passage of time.
public synchronized void syncStart (long tbTime)
{
```

```
long startTime = ourClock.getMediaTime ();
// We may actually have to stop immediately with an
// EndOfMediaEvent. We compute that now.  If we are already
// past end of media, then we
// first post the StartEvent then we post a EndOfMediaEvent
boolean endOfMedia;
float rate = ourClock.getRate ();
if ((startTime > duration && rate >= 0.0f) ||
    (startTime < 0 && rate <= 0.0f))
{
    endOfMedia = true;
} else
{
    endOfMedia = false;
}

// We face the same possible problem with being past the stop
// time.  If so, we stop immediately.
boolean pastStopTime;
long stopTime = ourClock.getStopTime ();
if ((stopTime != Long.MAX_VALUE) &&
    ((startTime >= stopTime && rate >= 0.0f) ||
    (startTime <= stopTime && rate <= 0.0f)))
{
    pastStopTime = true;
}
else
{
    pastStopTime = false;
}
if (!endOfMedia && !pastStopTime)
{
    ourClock.syncStart (tbTime);
    ourState = Controller.Started;
}
postEvent (new StartEvent (this, Controller.Prefetched,
    Controller.Started, Controller.Started,
    startTime, tbTime));
if (endOfMedia)
{
    postEvent (new EndOfMediaEvent (this,
        Controller.Started,
        Controller.Prefetched, Controller.Prefetched,
        startTime));
}
else if (pastStopTime)
{
    postEvent (new StopAtTimeEvent (this, Controller.Started,
        Controller.Prefetched, Controller.Prefetched,
        startTime));
```

```
        }
        else
        {
            myThread = new Thread (this, "TimeLineController");
            // Set thread to appopriate priority...
            myThread.start ();
        }
    }

    // Nothing really special here except that we need to notify
    // the thread that we may have.
    public synchronized void setStopTime (Time stopTime)
    {
        ourClock.setStopTime (stopTime);
        postEvent (new StopTimeChangeEvent (this, stopTime));
        notifyAll ();
    }

    // This one is also pretty easy.  We stop and tell the running
    // thread to exit.
    public synchronized void stop ()
    {
        int previousState = ourState;
        ourClock.stop ();
        ourState = Controller.Prefetched;
        postEvent (new StopByRequestEvent (this, previousState,
            Controller.Prefetched, Controller.Prefetched,
            ourClock.getMediaTime ()));
        notifyAll ();

        // Wait for thread to shut down.
        while (myThread != null)
        {
            try
            {
                wait ();
            }
            catch (InterruptedException e)
            {
                // NOT REACHED
            }
        }
    }

    protected void checkSegmentChange (long timeNow)
    {
        int segment = computeSegment (timeNow);
        if (segment != currentSegment)
        {
            currentSegment = segment;
```

```
            postEvent (new TimeLineEvent (this, currentSegment));
        }
    }

    // Most of the real work goes here.  We have to decide when
    // to post events like EndOfMediaEvent and StopAtTimeEvent
    // and TimeLineEvent.
    public synchronized void run ()
    {
        for (;;)
        {
            // First, have we changed segments?  If so, post an event!
            long timeNow = ourClock.getMediaTime ();
            checkSegmentChange (timeNow);

            // Second, have we already been stopped?  If so, stop
            // the thread.
            if (ourState == Controller.Prefetched)
            {
                myThread = null;
              // If someone is waiting for the thread to die, let them
                // know.
                notifyAll ();
                break;
            }

            // Current rate.  Our setRate() method prevents the value
            // 0 so we don't check for that here.
            float ourRate = ourClock.getRate ();

            // How long in clock time do we need to wait before doing
            // something?
            long mediaTimeToWait;
            long endOfMediaTime;
            // Next, are we past end of media?
            if (ourRate > 0.0f)
            {
                mediaTimeToWait = duration - timeNow;
                endOfMediaTime = duration;
            }
            else
            {
                mediaTimeToWait = timeNow;
                endOfMediaTime = 0;
            }
            // If we are at (or past) time to stop due to EndOfMedia,
            // we do that now!
            if (mediaTimeToWait <= 0)
            {
                ourClock.stop ();
```

```
        ourClock.setMediaTime (endOfMediaTime);
        ourState = Controller.Prefetched;
      postEvent (new EndOfMediaEvent (this, Controller.Started,
            Controller.Prefetched, Controller.Prefetched,
            endOfMediaTime));
        continue;
    }

    // How long until we hit our stop time?
    long stopTime = ourClock.getStopTime ();
    if (stopTime != Long.MAX_VALUE)
    {
        long timeToStop;
        if (ourRate > 0.0f)
        {
            timeToStop = stopTime - timeNow;
        }
        else
        {
            timeToStop = timeNow - stopTime;
        }

       // If we are at (or past) time to stop due to the stop
        // time, we stop now!
        if (timeToStop <= 0)
        {
            ourClock.stop ();
            ourClock.setMediaTime (stopTime);
            ourState = Controller.Prefetched;
            postEvent (new StopAtTimeEvent (this,
                Controller.Prefetched, Controller.Prefetched,
                stopTime));
            continue;
        }
        else if (timeToStop < mediaTimeToWait)
        {
            mediaTimeToWait = timeToStop;
        }
    }

    // How long until we pass into the next time line segment?
    long timeToNextSegment;
    if (ourRate > 0.0f)
    {
       timeToNextSegment = timeLine[currentSegment] - timeNow;
    }
    else
    {
    if (currentSegment == 0)
    {
```

```
                timeToNextSegment = timeNow;
            }
            else
            {
              timeToNextSegment = timeNow - timeLine[currentSegment-1];
            }
        }
        if (timeToNextSegment < mediaTimeToWait)
        {
            mediaTimeToWait = timeToNextSegment;
        }

        // Do the ugly math to compute what value to pass to
        // wait():
        long waitTime;
        if (ourRate > 0)
        {
            waitTime = (long) ((float) mediaTimeToWait / ourRate)  /
                 1000000;
        }
        else
        {
            waitTime = (long) ((float) mediaTimeToWait / -ourRate) /
                1000000;
        }
        // Add one because we just rounded down and we don't
        // really want to waste CPU being woken up early.
        waitTime++;
        if (waitTime > 0)
        {
            // Bug in some systems deals poorly with really large
            // numbers. We will cap our wait() to 1000 seconds
            // which point we will probably decide to wait again.
            if (waitTime > 1000000) waitTime = 1000000;
            try
            {
                wait (waitTime);
            }
            catch (InterruptedException e)
            {
            // NOT REACHED
        }
    }
}
```

Appendix D: ControllerAdapter

This appendix describes an implementation of ControllerListener, ControllerAdapter, that can be easily extended to respond to particular events.

Implementing ControllerAdapter

ControllerAdapter is an event adapter that recieves ControllerEvents and dispatches them to an appropriate stub-method. Classes use this adapter by extending it and replacing only the message handlers that they are interested in.

```
import javax.media.*;
public void cachingControl(CachingControlEvent e) {}
    public void controllerClosed(ControllerClosedEvent e) {}
    public void controllerError(ControllerErrorEvent e) {}
    public void connectionError(ConnectionErrorEvent e) {}
    public void internalError(InternalErrorEvent e) {}
    public void resourceUnavailable(ResourceUnavailableEvent
                e) {}
    public void durationUpdate(DurationUpdateEvent e) {}
    public void mediaTimeSet(MediaTimeSetEvent e) {}
    public void rateChange(RateChangeEvent e) {}
    public void stopTimeChange(StopTimeChangeEvent e) {}
    public void transition(TransitionEvent e) {}
    public void prefetchComplete(PrefetchCompleteEvent e) {}
    public void realizeComplete(RealizeCompleteEvent e) {}
    public void start(StartEvent e) {}
    public void stop(StopEvent e) {}
    public void dataStarved(DataStarvedEvent e) {}
    public void deallocate(DeallocateEvent e) {}
    public void endOfMedia(EndOfMediaEvent e) {}
```

```
public void restarting(RestartingEvent e) {}
public void stopAtTime(StopAtTimeEvent e) {}
public void stopByRequest(StopByRequestEvent e) {}

/**
 * Main dispatching function.  Subclasses should not need to
  * override this method, but instead subclass only
  * the individual event methods listed above that they need
  */
public void controllerUpdate(ControllerEvent e) {

if (e instanceof CachingControlEvent) {
    cachingControl((CachingControlEvent)e);

} else if ( e instanceof ControllerClosedEvent) {
    controllerClosed((ControllerClosedEvent)e);

    if (e instanceof ControllerErrorEvent) {

    controllerError((ControllerErrorEvent)e);

    if (e instanceof DataLostErrorEvent) {
        connectionError((ConnectionErrorEvent)e);

    } else if (e instanceof InternalErrorEvent) {
        internalError((InternalErrorEvent)e);

    } else if (e instanceof ResourceUnavailableEvent) {
        resourceUnavailable((ResourceUnavailableEvent)e);
    }
    }

} else if (e instanceof DurationUpdateEvent) {
    durationUpdate((DurationUpdateEvent)e);

} else if (e instanceof MediaTimeSetEvent) {
    mediaTimeSet((MediaTimeSetEvent)e);

} else if (e instanceof RateChangeEvent) {
    rateChange((RateChangeEvent)e);

} else if (e instanceof StopTimeChangeEvent) {
    stopTimeChange((StopTimeChangeEvent)e);

} else if (e instanceof TransitionEvent) {
    transition((TransitionEvent)e);
```

```
            if (e instanceof PrefetchCompleteEvent) {
            prefetchComplete((PrefetchCompleteEvent)e);

            } else if (e instanceof RealizeCompleteEvent) {
            realizeComplete((RealizeCompleteEvent)e);

            } else if (e instanceof StartEvent) {
            start((StartEvent)e);

            } else if (e instanceof StopEvent) {
            stop((StopEvent)e);

            if(e instanceof DataStarvedEvent) {
                dataStarved((DataStarvedEvent)e);

            } else if (e instanceof DeallocateEvent) {
                deallocate((DeallocateEvent)e);

            } else if (e instanceof EndOfMediaEvent) {
                endOfMedia((EndOfMediaEvent)e);

            } else if (e instanceof RestartingEvent) {
                restarting((RestartingEvent)e);

            } else if (e instanceof StopAtTimeEvent) {
                stopAtTime((StopAtTimeEvent)e);

            } else if (e instanceof StopByRequestEvent) {
                stopByRequest((StopByRequestEvent)e);
            }
            }
        }
        }
    }
```

Using ControllerAdapter

To implement the `ControllerListener` interface using a `ControllerAdapter`, you need to:

1. Subclass `ControllerAdapter` and override the event methods for the events that you're interested in.

2. Register your `ControllerAdapter` class as a listener for a particular

`Controller` by calling `addControllerListener`.

When a `Controller` posts an event, it calls `controllerUpdate` on each registered listener. `ControllerAdapter` automatically dispatches the event to the appropriate event method, filtering out the events that you're not interested in.

For example, the following code extends a `ControllerAdapter` with a JDK 1.1 anonymous inner-class to create a self-contained `Player` that is automatically reset to the beginning of the media and deallocated when the `Player` reaches the end of the media:

```
player.addControllerListener(new ControllerAdapter() {
   public void endOfMedia(EndOfMediaEvent e) {
      Controller controller = e.getSource();
      controller.stop();
      controller.setMediaTime(0);
      controller.deallocate();
   }
}
```

If you register a single `ControllerAdapter` as a listener for multiple `Players`, in your event method implementations you need to determine which `Player` generated the event. `Controller` events come "stamped" with a reference to their source that you can access by calling `getSource`.

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