

Exhibit 19

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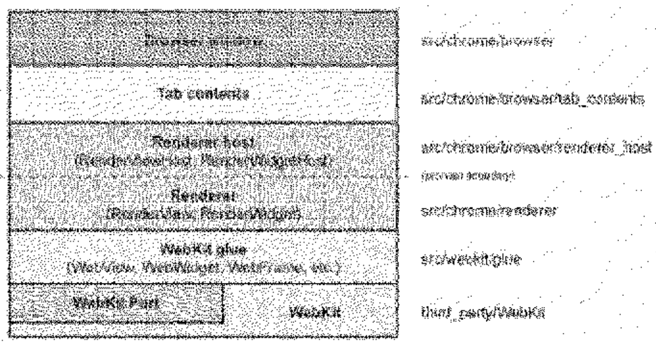
How Chromium Displays Web Pages

This document describes how web pages are displayed in Chromium from the bottom up. Be sure you have read the multi-process architecture design document. You will especially want to understand the block diagram of major components. You may also be interested in multi-process resource loading for how pages are fetched from the network.

Conceptual application layers



Each box represents a conceptual application layer. It should generally be possible to build a different browser by picking any layer and replacing the layers above it. Therefore, no layer should have knowledge of or dependencies on any higher-level layers.

- **WebKit:** Rendering engine shared between Safari, Chromium, and all other WebKit-based browsers. The **Port** is a part of WebKit that integrates with platform dependent system services such as resource loading and graphics.
- **Glue:** Converts WebKit types to Chromium types. This is our "WebKit embedding layer." It is the basis of two browsers, Chromium, and test_shell (which allows us to test WebKit).
- **Renderer / Render host:** This is Chromium's "multi-process embedding layer." It proxies notifications and commands across the process boundary. You could imagine other multi-process browsers using this layer, and it should have dependencies on other browser services.
- **Tab contents:** Chrome-specific layer that represents the contents of a tab. It binds with application services such as the history system and the password manager. It should not, however, assume it's embedded inside a Chromium browser window (it's used by some other Chromium components like HTML dialogs).
- **Browser:** Represents the browser window, it embeds multiple TabContentses.

WebKit

We use the WebKit open-source project to lay out web pages. This code is pulled from Apple and stored in the `/third_party/WebKit` directory. WebKit consists primarily of "WebCore" which represents the core layout functionality, and "JavaScriptCore" which runs JavaScript. We only run JavaScriptCore for testing purposes, normally we replace it with our high performance V8 JavaScript engine. We do not actually use the layer that Apple calls "WebKit," which is the embedding API between WebCore and OS X applications such as Safari. We normally refer to the code from Apple generically as "WebKit" for convenience.

The WebKit port

At the lowest level we have our WebKit "port." This is our implementation of required platform-specific functionality that interfaces with the platform-independent WebCore code. These files are located in the WebKit tree, typically in `chromium` directories or as Chromium-suffixed files. Much of our port is not actually OS-specific: you could think of it as the "Chromium port" of WebCore. Some parts, like font rendering, must be handled differently for each platform.

- Network traffic is handled by our multi-process resource loading system rather than being handed off to the OS directly from the render process.
- Graphics uses the Skia graphics library developed for Android. This is a cross-platform graphics library and handles all images and graphics primitives except

for text. Skia is located in /third_party/skia. The main entrypoint for graphics operations is /webkit/port/platform/graphics/GraphicsContextSkia.cpp. It uses many other files in the same directory as well as from /base/gfx.

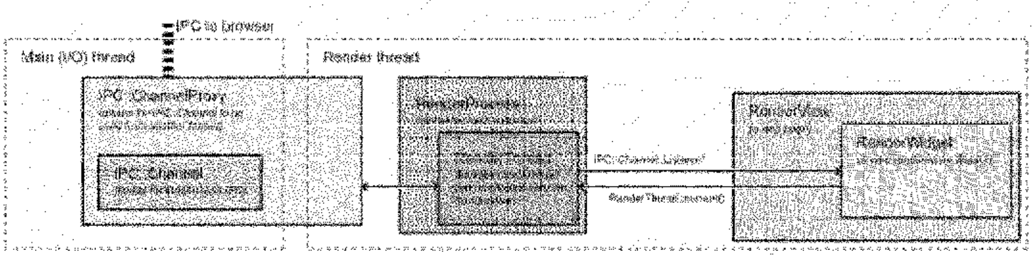
The WebKit glue

The Chromium application uses different types, coding styles, and code layout than the third-party WebKit code. The WebKit "glue" provides a more convenient embedding API for WebKit using Google coding conventions and types (for example, we use std::string instead of WebCore::String and GURL instead of KURL). The glue code is located in /webkit/glue. The glue objects are typically named similar to the WebKit objects, but with "Web" at the beginning. For example, WebCore::Frame becomes WebFrame.

The WebKit "glue" layer insulates the rest of the Chromium code base from WebCore data types to help minimize the impact of WebCore changes on the Chromium code base. As such, WebCore data types are never used directly by Chromium. APIs are added to the WebKit "glue" for the benefit of Chromium when it needs to poke at some WebCore object.

The "test shell" application is a bare-bones web browser for testing our WebKit port and glue code. It uses the same glue interface for communicating with WebKit as Chromium does. It provides a simpler way for developers to test new code without having many complicated browser features, threads, and processes. This application is also used to run the automated WebKit tests.

The render process



Chromium's render process embeds our WebKit port using the glue interface. It does not contain very much code: its job is primarily to be the renderer side of the IPC channel to the browser..

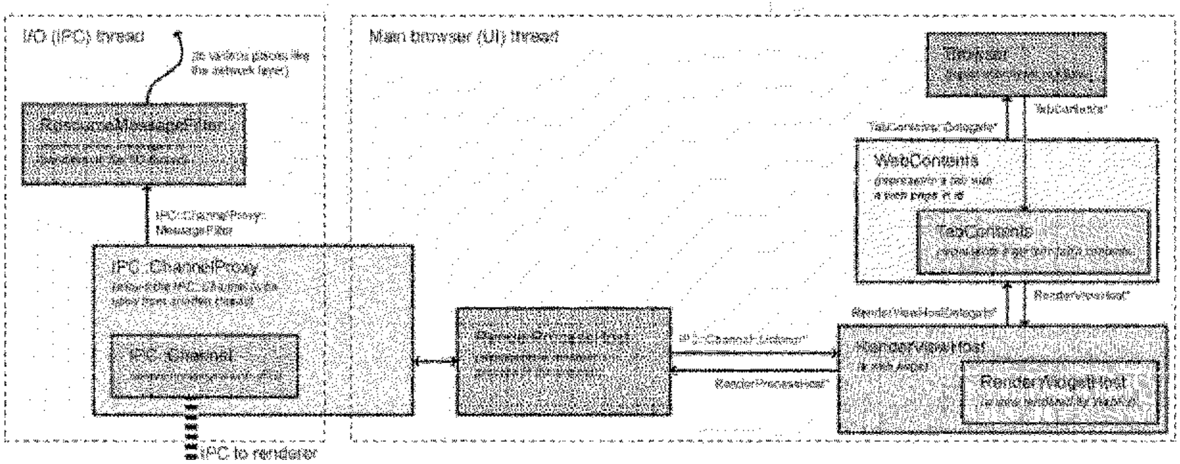
The most important class in the renderer is the RenderView, located in /chrome/renderer/render_view.cc. This object represents a web page. It handles all navigation-related commands to and from the browser process. It derives from RenderWidget which provides painting and input event handling. The RenderView communicates with the browser process via the global (per render process) RenderProcess object.

FAQ: What's the difference between RenderWidget and RenderView?
RenderWidget maps to one WebCore::Widget object by implementing the abstract interface in the glue layer called WebWidgetDelegate.. This is basically a Window on the screen that receives input events and that we paint into. A RenderView inherits from RenderWidget and is the contents of a tab or popup Window. It handles navigational commands in addition to the painting and input events of the widget. There is only one case where a RenderWidget exists without a RenderView, and that's for select boxes on the web page. These are the boxes with the down arrows that pop up a list of options. The select boxes must be rendered using a native window so that they can appear above everything else, and pop out of the frame if necessary. These windows need to paint and receive input, but there isn't a separate "web page" (RenderView) for them.

Threads in the renderer

Each renderer has two threads (see the multi-process architecture page for a diagram, or threading in Chromium for how to program with them). The render thread is where the main objects such as the RenderView and all WebKit code run. When it communicates to the browser, messages are first sent to the main thread, which in turn dispatches the message to the browser process. Among other things, this allows us to send messages synchronously from the renderer to the browser. This happens for a small set of operations where a result from the browser is required to continue. An example is getting the cookies for a page when requested by JavaScript. The renderer thread will block, and the main thread will queue all messages that are received until the correct response is found. Any messages received in the meantime are subsequently posted to the renderer thread for normal processing.

The browser process



Low-level browser process objects

All IPC communication with the render processes is done on the I/O thread of the browser. This thread also handles all network communication which keeps it from interfering with the user interface.

When a `RenderProcessHost` is initialized on the main thread (where the user interface runs), it creates the new renderer process and a `ChannelProxy` IPC object with a named pipe to the renderer. This object runs on the I/O thread of the browser, listening to the named pipe to the renderer, and automatically forwards all messages back to the `RenderProcess` on the UI thread. A `ResourceMessageFilter` will be installed in this channel which will filter out certain messages that can be handled directly on the I/O thread such as network requests. This filtering happens in `ResourceMessageFilter::OnMessageReceived`.

The `RenderProcessHost` on the UI thread is responsible for dispatching all view-specific messages to the appropriate `RenderViewHost` (it handles a limited number of non-view-specific messages itself). This dispatching happens in `RenderProcessHost::OnMessageReceived`.

High-level browser process objects

View-specific messages come into `RenderViewHost::OnMessageReceived`. Most of the messages are handled here, and the rest get forwarded to the `RenderWidgetHost` base class. These two objects map to the `RenderView` and the `RenderWidget` in the renderer (see "The Render Process" above for what these mean). On Microsoft Windows, we have a `RenderWidgetHostHWND` associated with each `RenderWidgetHost` that specifically manages events and drawing into a native HWND. Other systems will have a similar class for native input and painting.

Above the `RenderViewWidget` is the `WebContents` object, and most of the messages actually end up as function calls on that object. A `WebContents` represents the contents of a tab that shows web data. It derives from the generic `TabContents` class (there are a number of other specializations of `TabContents` for history and downloads, for example). It is the central switching point for most navigation and toplevel browser UI updating.

FAQ: Why are WebContents and RenderViewHost separate? These two objects provide different layers of functionality. You could think of `RenderViewHost` as Chromium's "multi-process embedding layer." `RenderViewHost` objects could be (but are not currently) used in other parts of the application to render content. For example, you could imagine a dialog box with a web view in it. This could use `RenderViewHost` to manage drawing and communication with the render process, but it would not have a "tab" or the normal navigation commands. The `RenderViewHost` forwards many messages to the `WebContents` via its `RenderViewHostDelegate` abstract interface. The `WebContents` handles the navigational state and anything related to the UI of the web browser. Our hypothetical dialog box wouldn't need any of this functionality and would only implement the parts of the `RenderViewHostDelegate` interface that it cares about.

Illustrative examples

Additional examples covering navigation and startup are in Getting Around the

Chromium Source Code.

Life of a "set cursor" message

Setting the cursor is an example of a typical message that is sent from the renderer to the browser. In the renderer, here is what happens.

- Set cursor messages are generated by WebKit internally, typically in response to an input event. The set cursor message will start out in `RenderWidget::SetCursor` in `chrome/renderer/render_widget.cc`.
- It will call `RenderWidget::Send` to dispatch the message. This method is also used by `RenderView` to send messages to the browser. It will call `RenderThread::Send`.
- This will call the `IPC::SyncChannel` which will internally proxy the message to the main thread of the renderer and post it to the named pipe for sending to the browser.

Then the browser takes control:

- The `IPC::ChannelProxy` in the `RenderProcessHost` receives all message on the I/O thread of the browser. It first sends them through the `ResourceMessageFilter` that dispatches network requests and related messages directly on the I/O thread. Since our message is not filtered out, it continues on to the UI thread of the browser (the `IPC::ChannelProxy` does this internally).
- `RenderProcessHost::OnMessageReceived` in `chrome/browser/render_process_host.cc` gets the messages for all views in the corresponding render process. It handles several types of messages directly, and for the rest forwards to the appropriate `RenderViewHost` corresponding to the source `RenderView` that sent the message.
- The message arrives at `RenderViewHost::OnMessageReceived` in `chrome/browser/render_view_host.cc`. Many messages are handled here, but ours is not because it's a message sent from the `RenderWidget` and handled by the `RenderWidgetHost`.
- All unhandled messages in `RenderViewHost` are automatically forwarded to the `RenderWidgetHost`, including our set cursor message.
- The message map in `chrome/browser/render_widget_host.cc` finally receives the message in `RenderWidgetHost::OnMsgSetCursor` and calls the appropriate UI function to set the mouse cursor.

Life of a "mouse click" message

Sending a mouse click is a typical example of a message going from the browser to the renderer.

- The Windows message is received on the UI thread of the browser by `RenderWidgetHostHWND::OnMouseEvent` which then calls `ForwardMouseEventToRenderer` in the same class.
- The forwarder function packages the input event into a cross-platform `WebMouseEvent` and ends up send it to the `RenderWidgetHost` it is associated with.
- `RenderWidgetHost::ForwardInputEvent` creates an IPC message `ViewMsg_HandleInputEvent`, serializes the `WebInputEvent` to it, and calls `RenderWigetHost::Send`.
- This just forwards to the owning `RenderProcessHost::Send` function, which in turn gives the message to the `IPC::ChannelProxy`.
- Internally, the `IPC::ChannelProxy` will proxy the message to the I/O thread of the browser and write it to the named pipe to the corresponding renderer.

Note that many other types of messages are created in the `WebContents`, especially navigational ones. These follow a similar path from the `WebContents` to the `RenderViewHost`.

Then the renderer takes control:

- `IPC::Channel` on the main thread of the renderer reads the message sent by the browser, and `IPC::ChannelProxy` proxies to the renderer thread.
- `RenderView::OnMessageReceived` gets the message. Many types messages are handled here directly. Since the click message is not, it falls through (with all other unhandled messages) to `RenderWidget::OnMessageReceived` which in turn forwards it to `RenderWidget::OnHandleInputEvent`.
- The input event is given to `WebWidgetImpl::HandleInputEvent` where it is converted to a WebKit `PlatformMouseEvent` class and given to the `WebCore::Widget` class inside WebKit.

Attachments (3)

Rendering in the browser.ai - on Jul 21, 2008 9:27 PM by Brett Wilson (version 1)
534k Download

Rendering in the renderer.ai - on Jul 21, 2008 9:27 PM by Brett Wilson (version 1)
530k Download

layers.ai - on Mar 22, 2009 2:22 PM by Brett Wilson (version 1)
327k Download