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Overview

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ANDROID

First truly open, freely available Linux-based mobile phone stack built from the ground up

- Open source platform and applications
  - Linux 2.6 kernel and drivers
  - Java language framework and applications
- Complete product
  - Hardware designs
  - Full set of applications
  - Mobile operator certified

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Hardware Requirements

- **Chipset**: MSM7200A with RTR6285 and PM7540
- **Memory**: at least 128MB RAM, 256MB Flash
- **External Storage**: Mini, Micro SD
- **Primary Display**: QVGA TFT LCD or larger, 16-bit color or better
- **Navigation Keys**: 5-way navigation with 4 application keys, power and volume control
- **Camera**: 2MP CMOS
- **USB**: Standard mini-B USB interface
- **Bluetooth** 1.2 or 2.0

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Optional Hardware

- QWERTY keyboard
- WiFi
- GPS

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Project Goals

- Great phone experience
- Great Google experience
- Open application architecture

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Great Phone

- Multiple processes
  - Phone application must always be responsive
  - Wayward applications can’t crash phone
- Enable task switching
  - Can switch in and out of applications while in a call
  - Applications don’t lose state

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Google Experience

- Integrated Google applications written with public APIs
- Complete two-way sync for user data
- Open APIs for application functionality

Gmail

GTalk

YouTube

Calendar

Contacts

Picasa

Maps

Earth

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Open Architecture

- Powerful, simple application framework written in Java
  - Encourage reuse of components
- Scalable user experience
  - 12 key, QWERTY, touch screen, combinations
  - Portrait, landscape, pivoting, etc
- Rich graphics system & media experience
- Advanced, standards-based web browser

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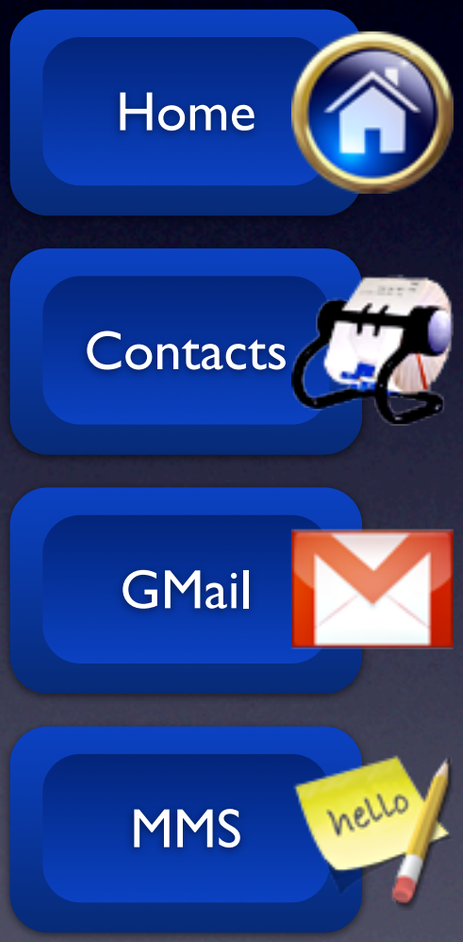
Open Architecture



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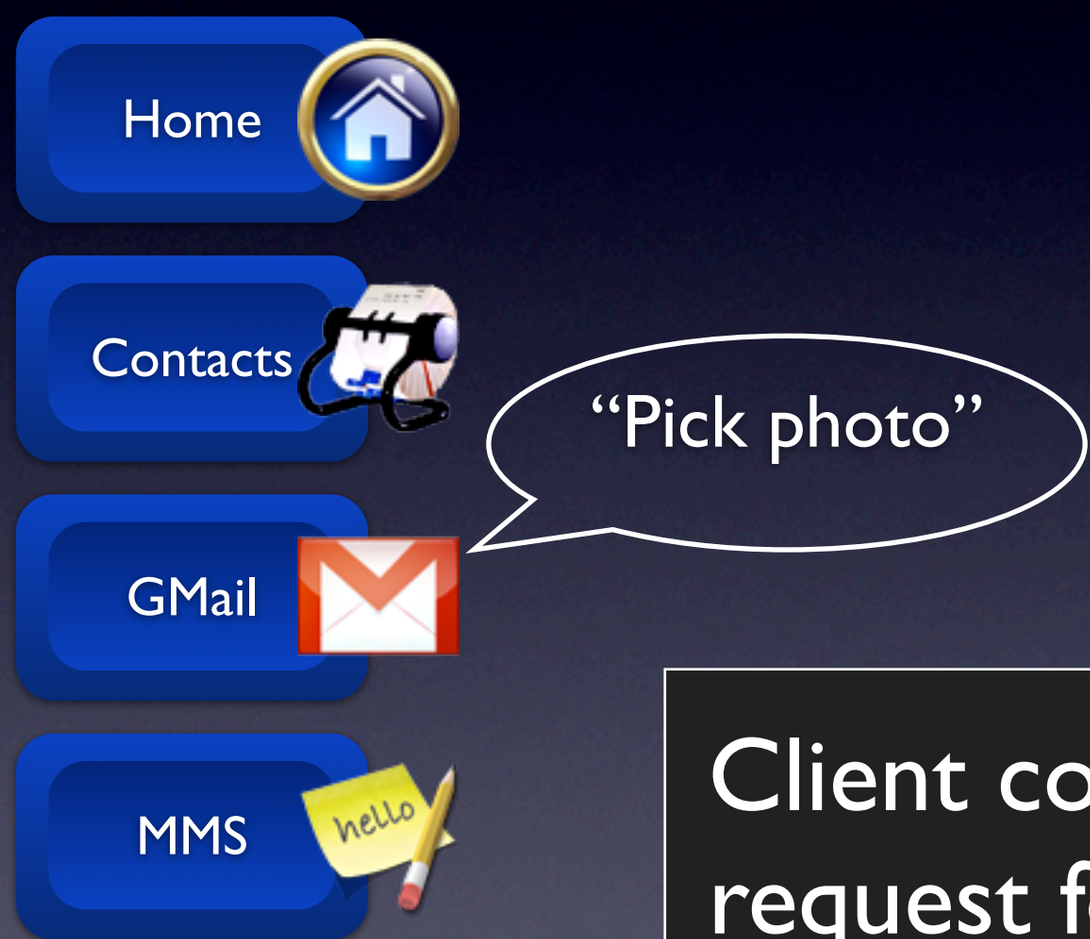
Open Architecture



Client component makes a request for a specific action

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Open Architecture

System picks best component for that action

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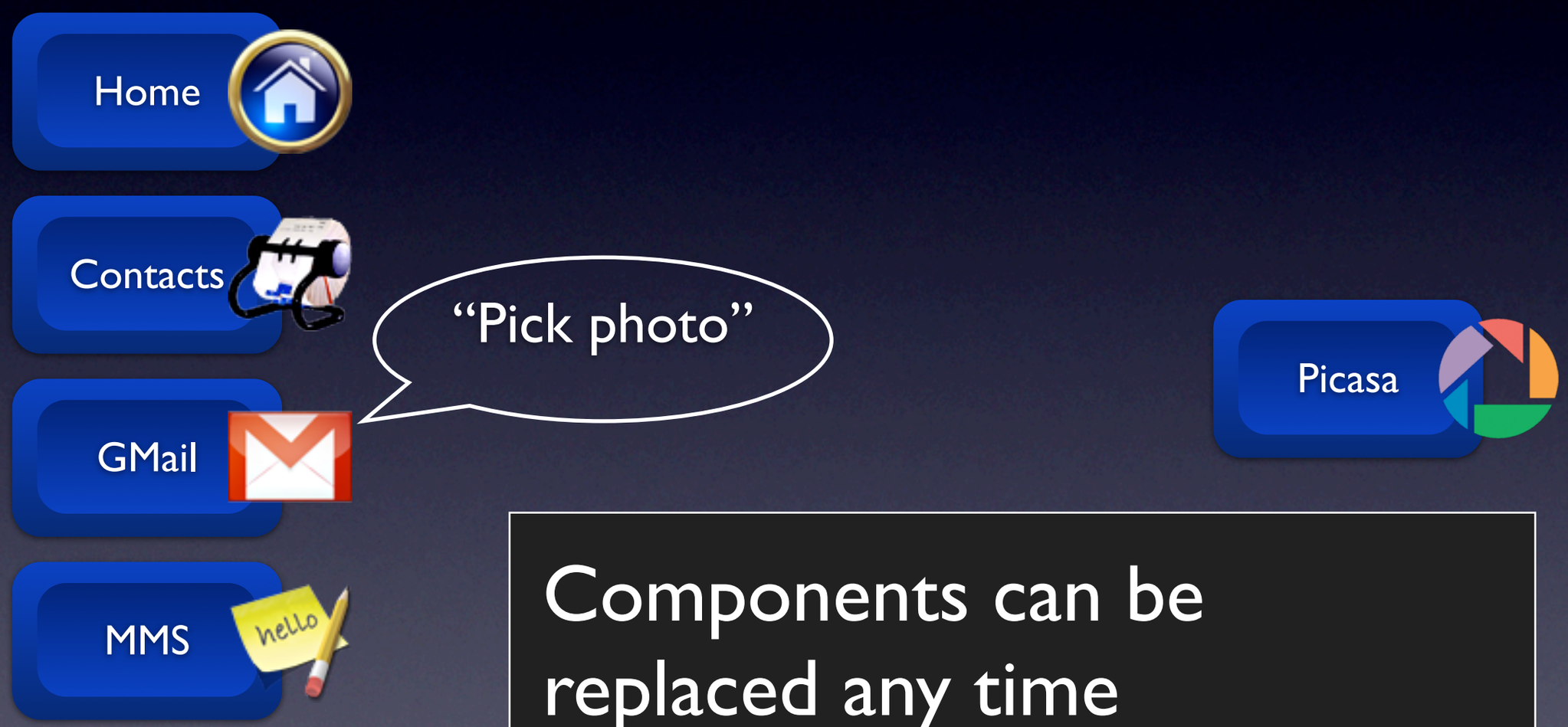
Open Architecture



Components can be replaced any time

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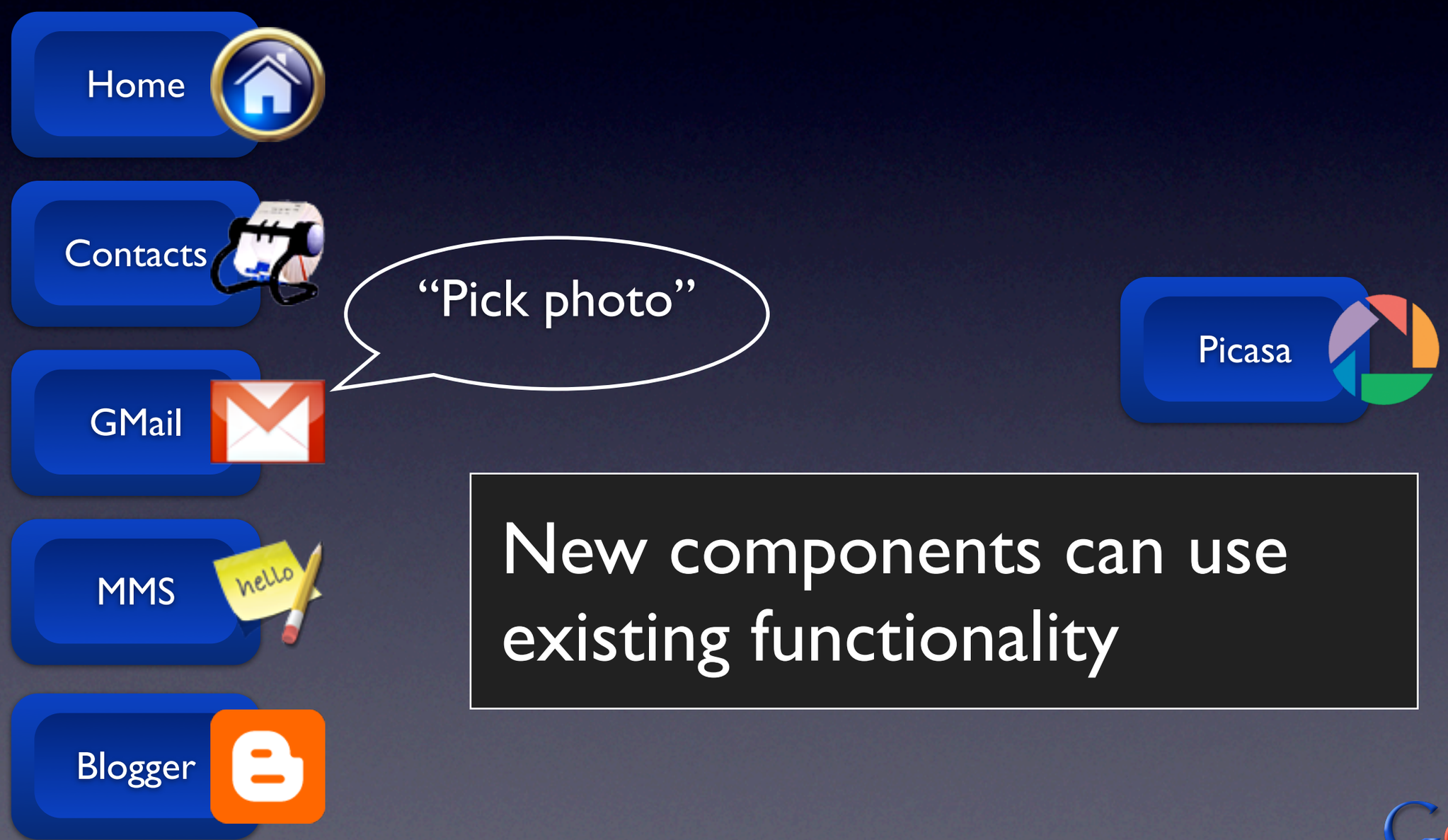
Open Architecture



New components can use existing functionality

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Software Architecture

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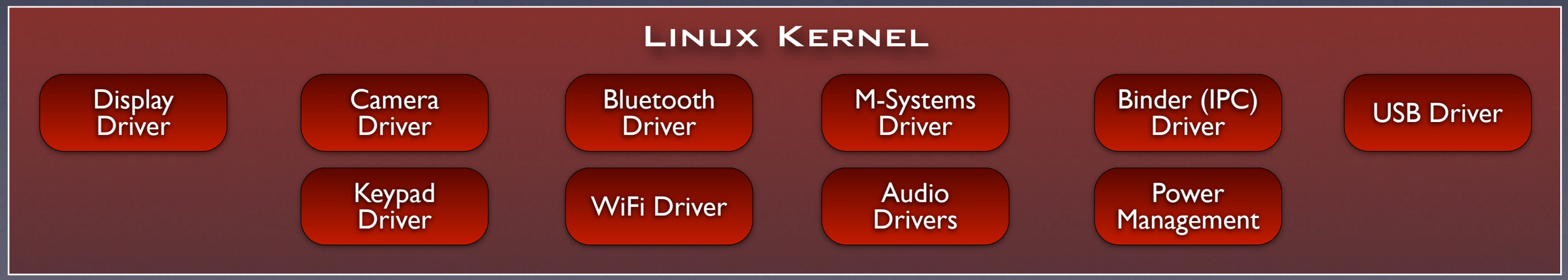
Software Architecture



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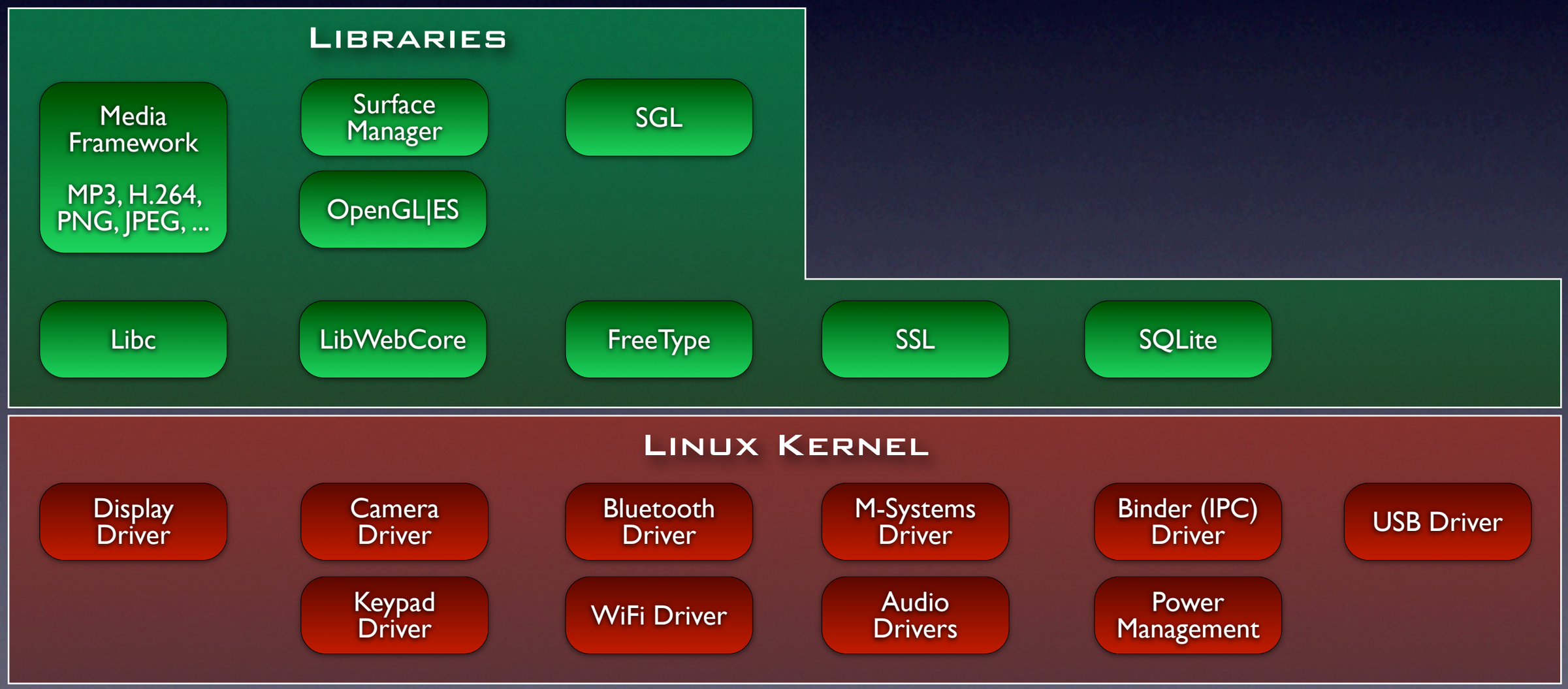
Software Architecture



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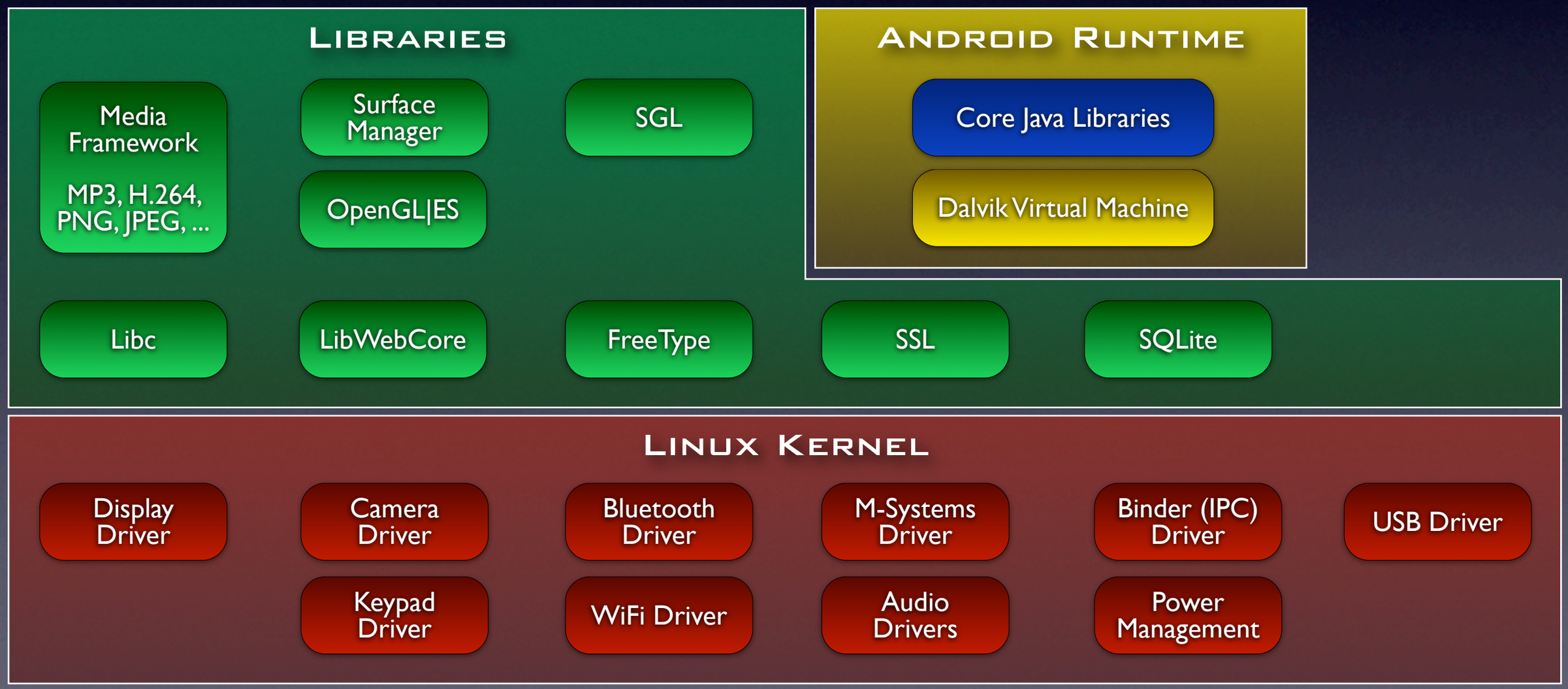
Software Architecture



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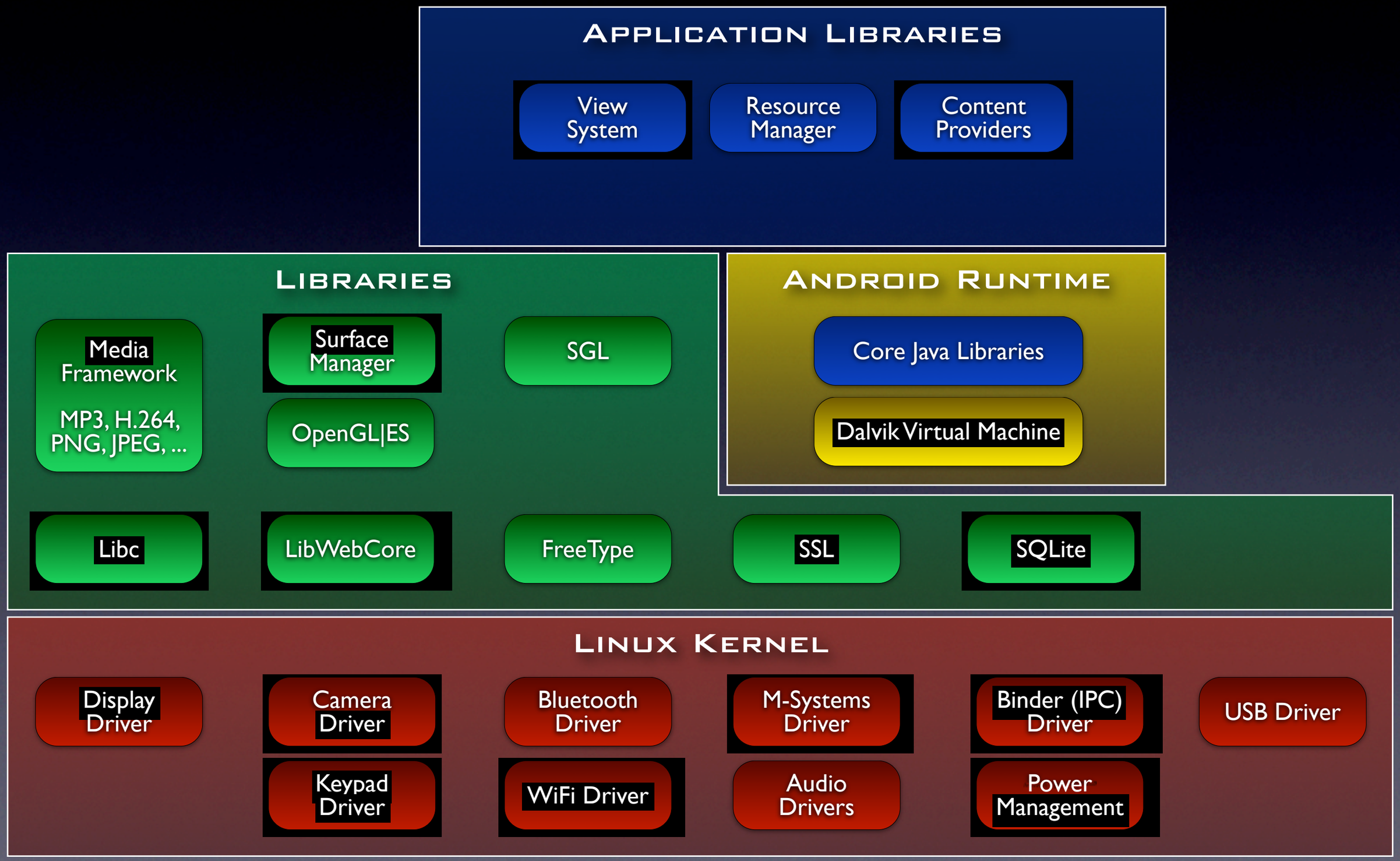
Software Architecture



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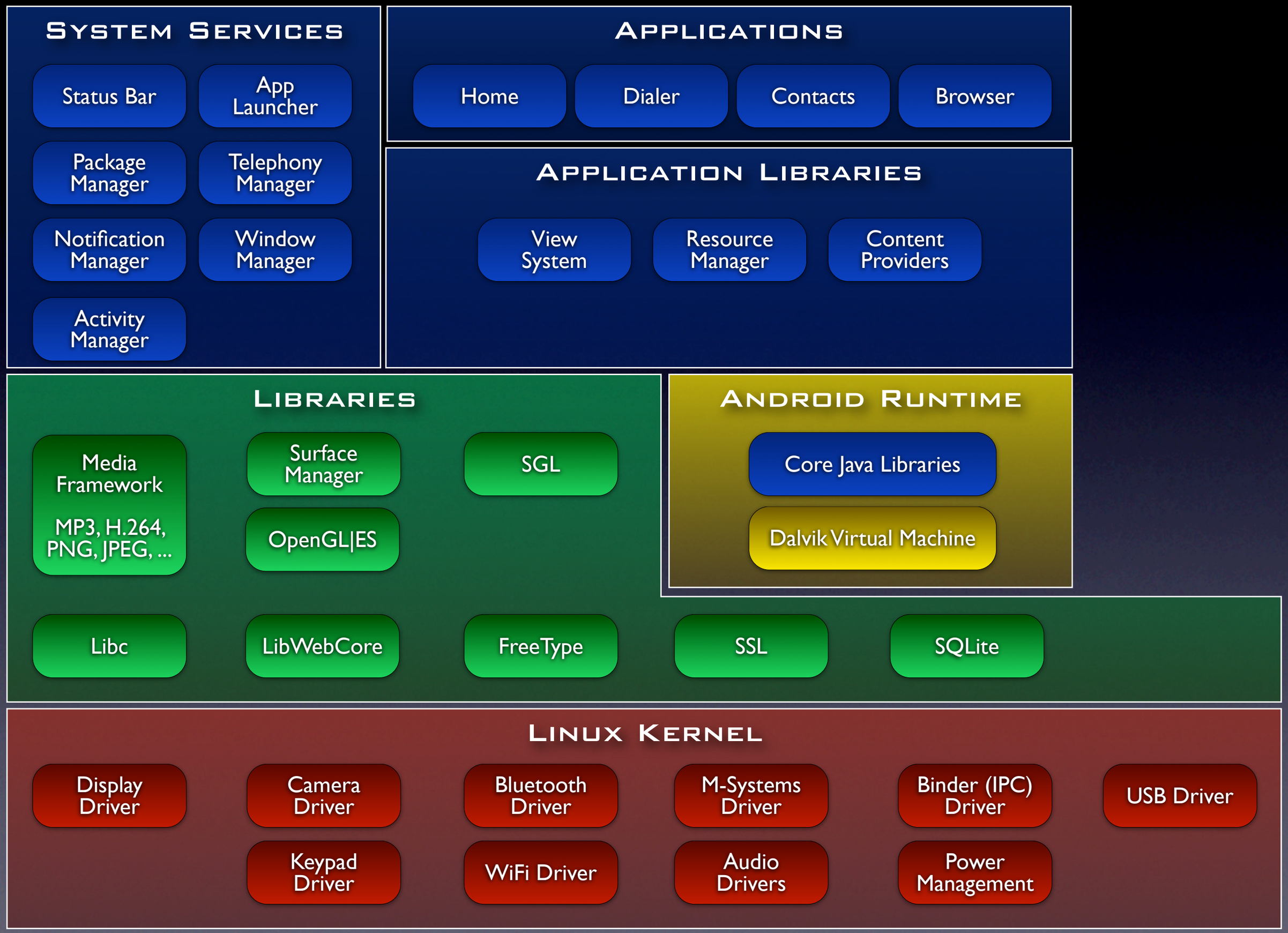

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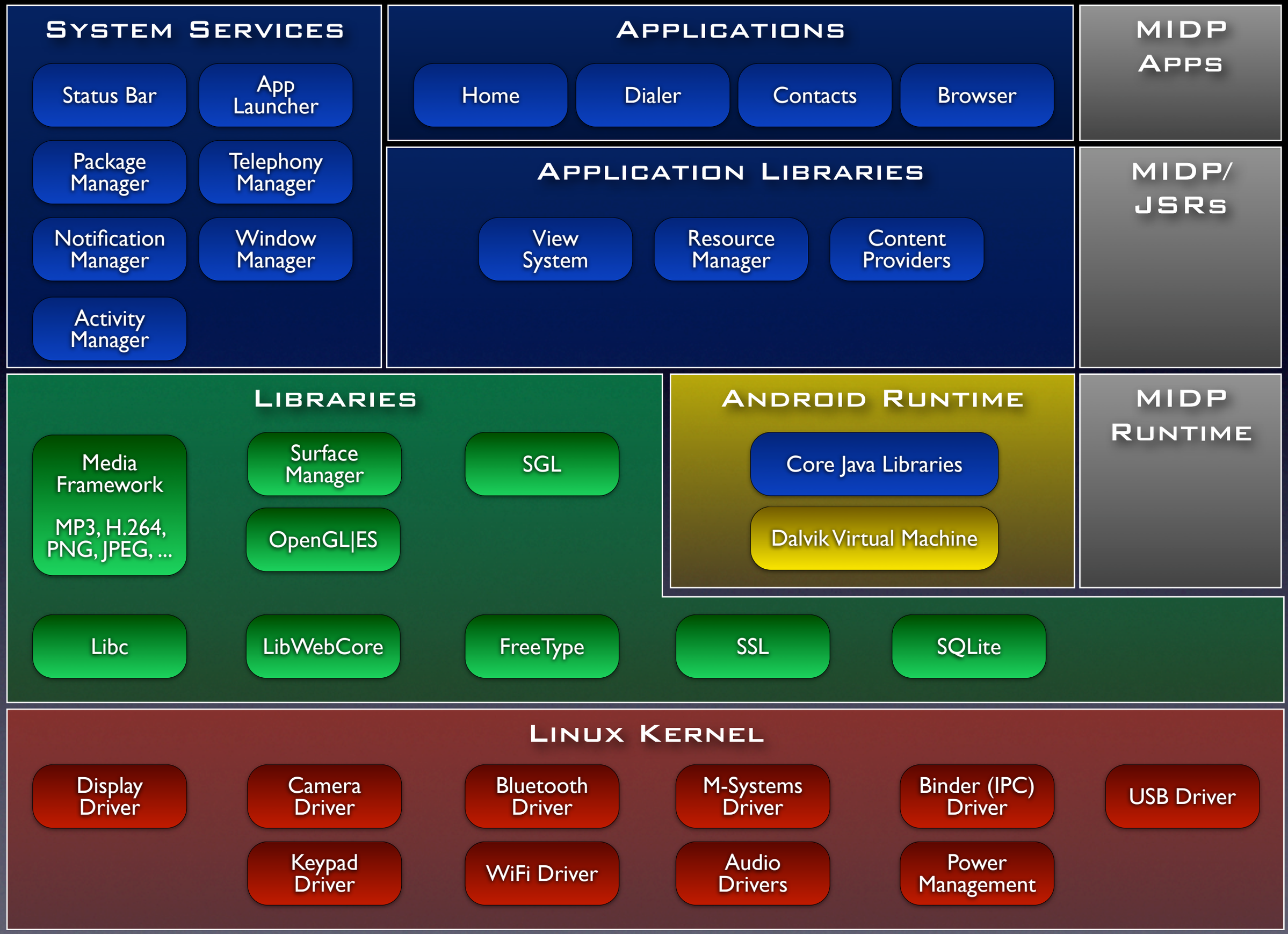

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Processes

- Applications and System services run in separate processes
- Activity Manager runs each application in a separate process and manages application life cycle
- Boot process responsible for system startup
- System process hosts persistent core system services
  - *Window Manager, Surface Manager, Activity Manager, etc*
- Application processes can also be persistent
  - *Dialer application*

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Processes

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Application Framework

- **Window Manager**
  - Allows multiple apps with multiple windows to share screen
- **Package Manager**
  - Maintains information for all installed applications
- **Activity Manager**
  - Manages lifecycle of application UI components
  - Maintains cross-application history

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Application Framework

- **Notification Manager**
  - Allows all applications access to status bar and onscreen notifications
- **Resource Manager**
  - Provide access to graphics, localized strings, XML layout descriptions, etc
- **View System**
  - Rich set of built-in controls (buttons, text, lists, etc)
  - Supports diverse screen sizes

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Dalvik

- Android's custom Java-compatible virtual machine
- Runs optimized file format (.dex)
- Also runs unmodified Java .class / .jar files
- Designed for embedded environment
  - Uses runtime memory very efficiently
  - Highly CPU-optimized bytecode interpreter
  - Supports multiple virtual machine processes per device

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Dalvik

- Custom file format (.dex) designed for runtime efficiency
  - Shared constant pool reduces memory
  - Read-only structures improves cross-process sharing
  - Concise, fixed-width structures reduces parse time
  - Installed apps are translated to .dex at build time
- Bytecodes designed for speedy interpretation
  - Register-based rather than stack-based instructions reduce memory I/O and dispatch overhead
  - Only fixed-width instructions simplifies parsing
  - 16 bit code units minimizes reads

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Telephony Manager

- Application level Java interface to telephony sub-system
- Event notifications
  - *Phone state, network state, SIM status, voicemail, etc.*
- Access to state information
  - *Network info, SIM info, voicemail presence, etc.*
- Initiate calls
- Query and control call state

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Browser

- Based on open source KHTML "WebKit" browser
- Active collaboration with Apple and industry partners
- Renders pages in full, desktop-like manner with navigation
- Allows single column, small screen rendering as well
- HTML views can be embedded in other applications

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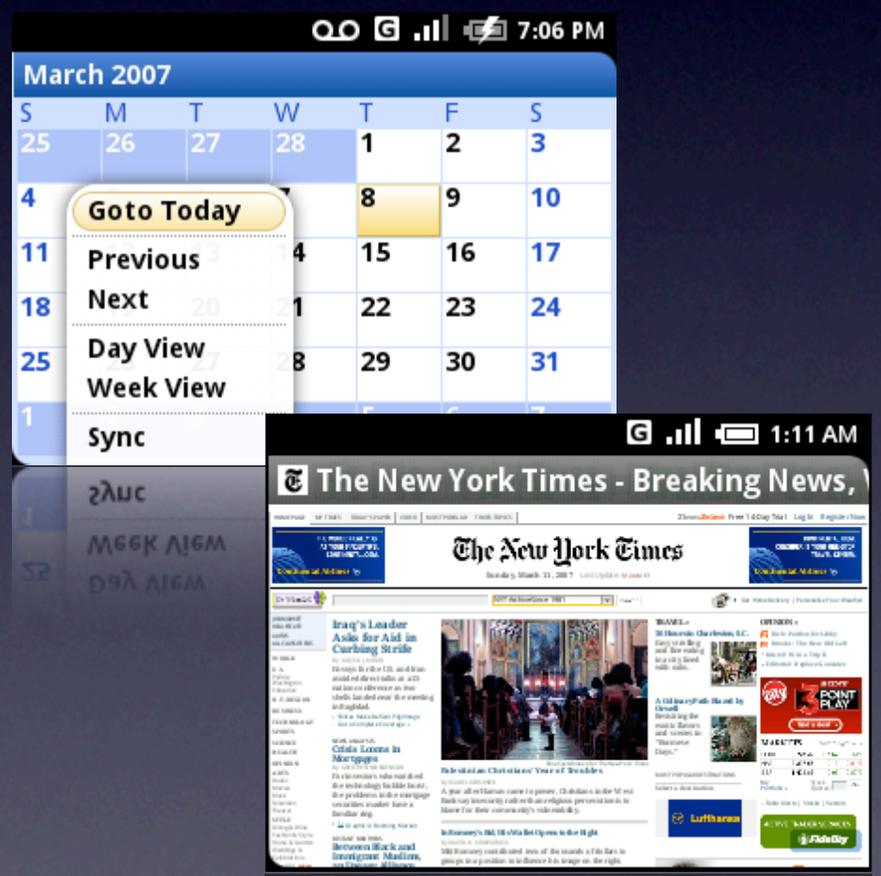
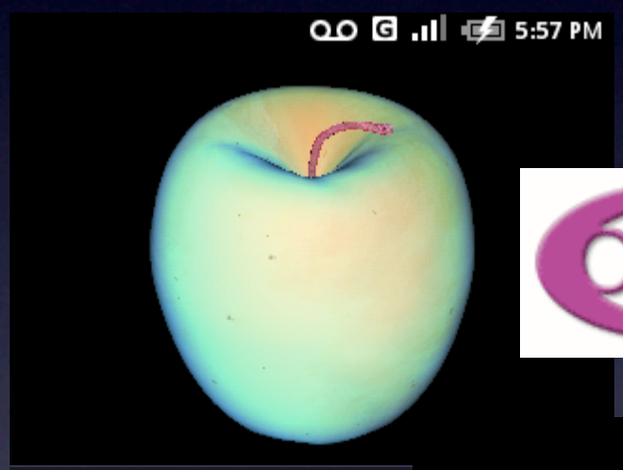
Graphics

- SGL Library for 2D application drawing
- OpenGL|ES for gaming, 3D





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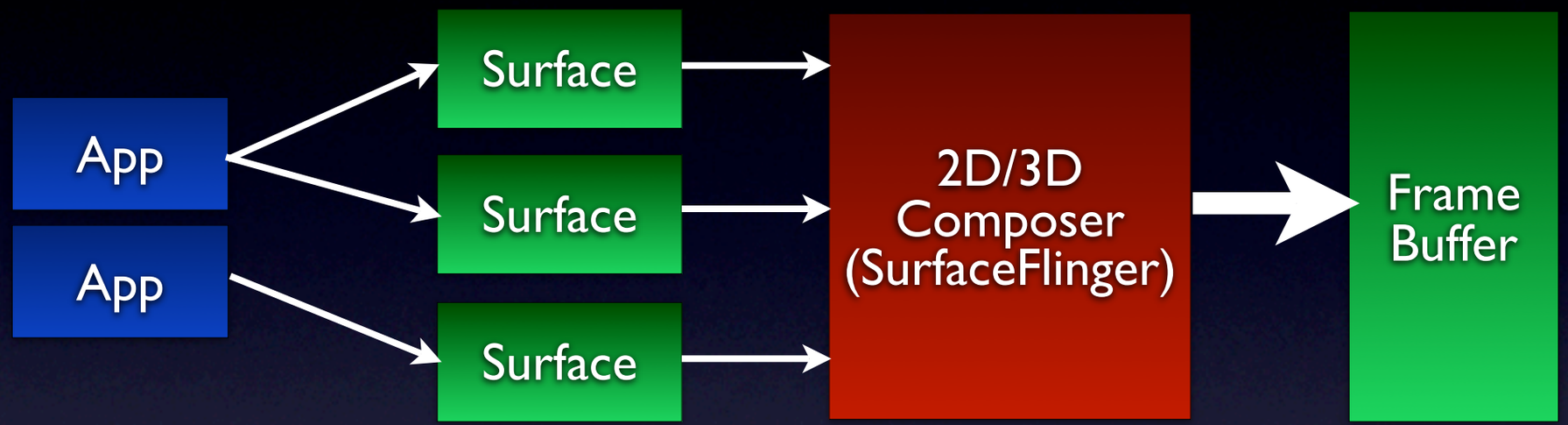
Graphics



- SurfaceFlinger is system-wide “composer”
- Manages Surfaces and the Frame-buffer
- Handles window transitions
- Uses OpenGL|ES and 2D hardware accelerator for its compositions

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Media Framework

- Based on PacketVideo source code license
- Supports standard video, audio, still-frame formats
  - MPEG4, H.264, MP3, AAC, AMR, JPEG
- Advanced framework with simple Java API layer

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Bluetooth

- Based on BlueZ (3.8)
- Supports 2.0
- Profile support
  - Headset and Hands-Free
  - Dial-Up Networking and PAN
  - Audio Streaming (A2DP/AVRCP)
- Java bindings for scanning, pairing/unpairing, service queries, etc.

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Android Tools

- Compatible with standard IDEs
  - Eclipse, IntelliJ
- Android-specific tools to increase visibility into what is happening on device
  - Full support for on-device debugging
  - Performance & memory profiling

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Application Architecture

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Design Goals

- Open platform
  - Anything we can do they can do
  - Encourage reuse of components
  - Encourage sharing data
- Work well on an embedded device
  - Constrained memory, battery, CPU, network, screen

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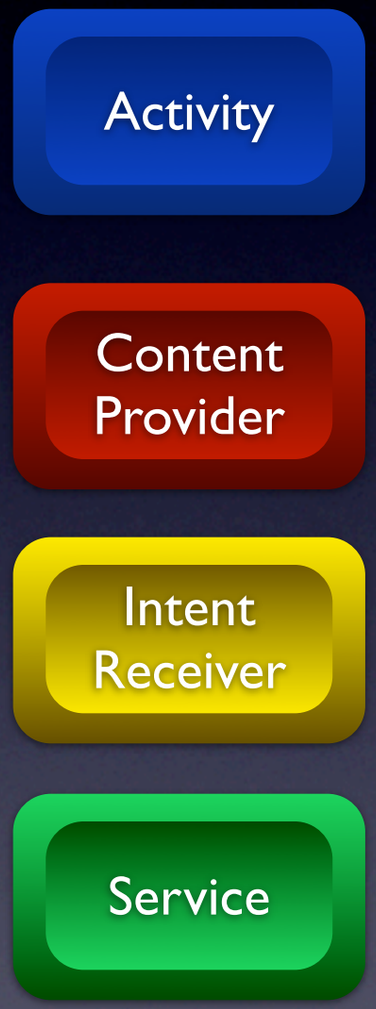
Android Applications

- Built out of 4 main building blocks:
  - Activity
  - ContentProvider
  - IntentReceiver
  - Service



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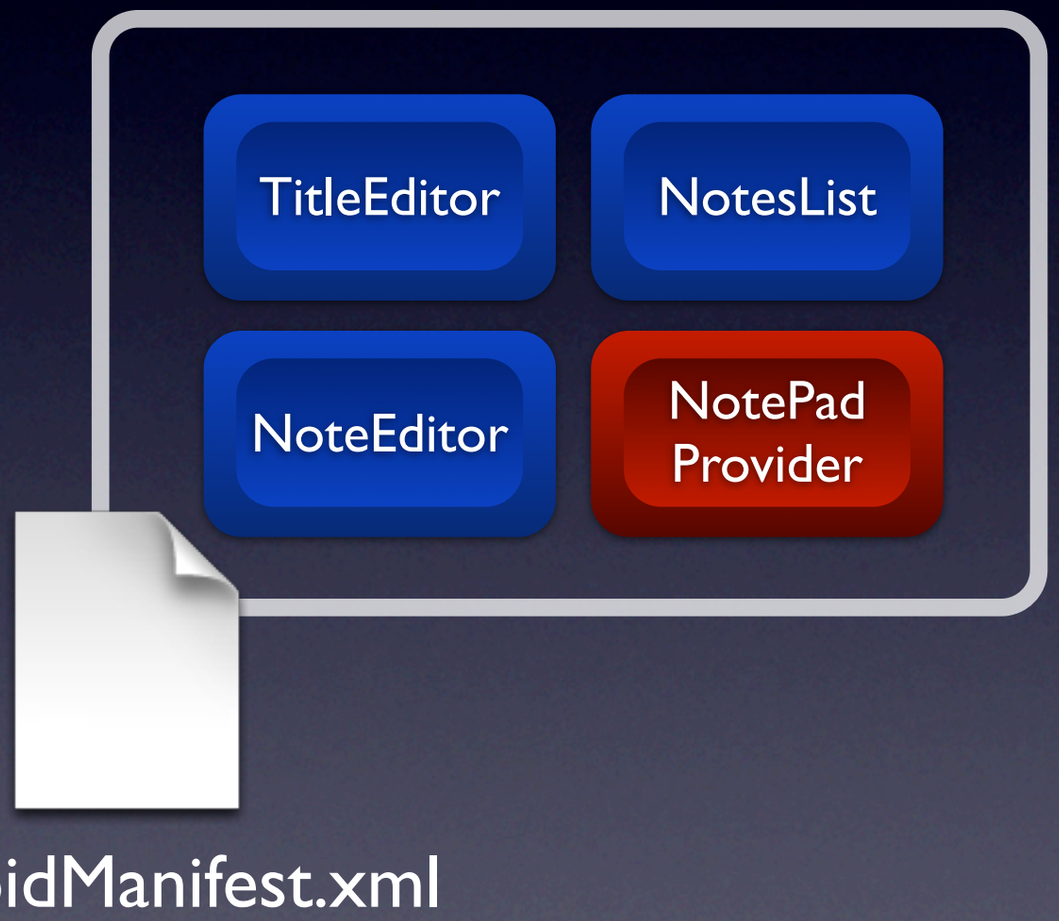
AndroidManifest.xml

- Lists all of the components of your application
- Describes capabilities and behaviors of each component



samples/Notes/AndroidManifest.xml

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Application Lifecycle

- Applications run in their own processes
  - Many Activities, Services, etc can run in the same process
- Processes are started and stopped as needed to run an application's components
- Processes may be killed to reclaim resources

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Application Lifecycle

- Each application is assigned its own process (whose name is the application's package name)
- Individual parts of an application can be assigned another process name
- Activities and content providers can instead run in the process of the code that is invoking them

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Application Lifecycle

- Activities, IntentReceivers, Services run in main thread
  - Can spawn other threads if needed
  - Be careful about thread safety of platform classes
- ContentProviders are always multi-threaded

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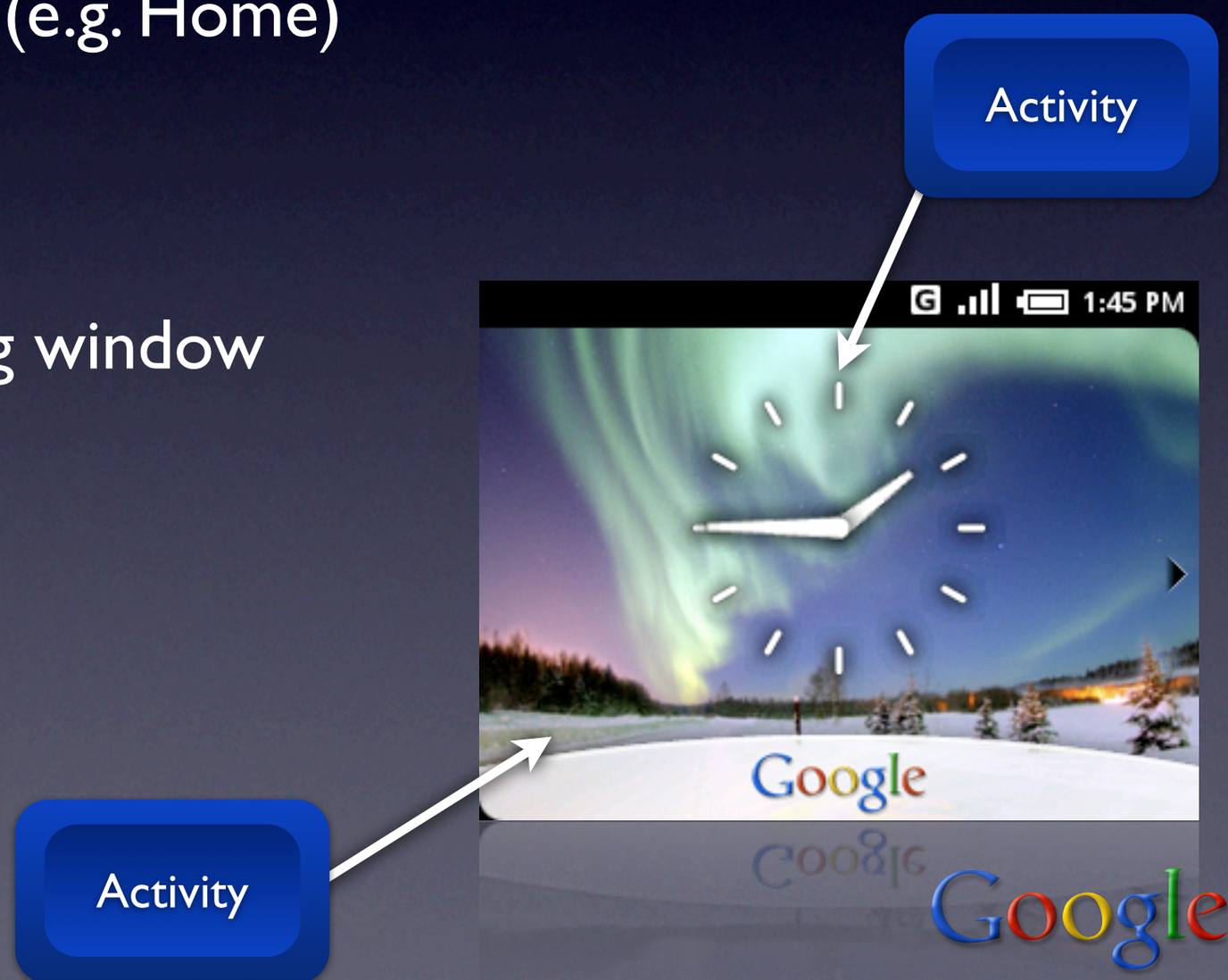
Activities

- Typically corresponds to one screen in the UI
  - Can be embedded (e.g. Home)
  - Can be faceless
  - Can be in a floating window
  - Can return a value



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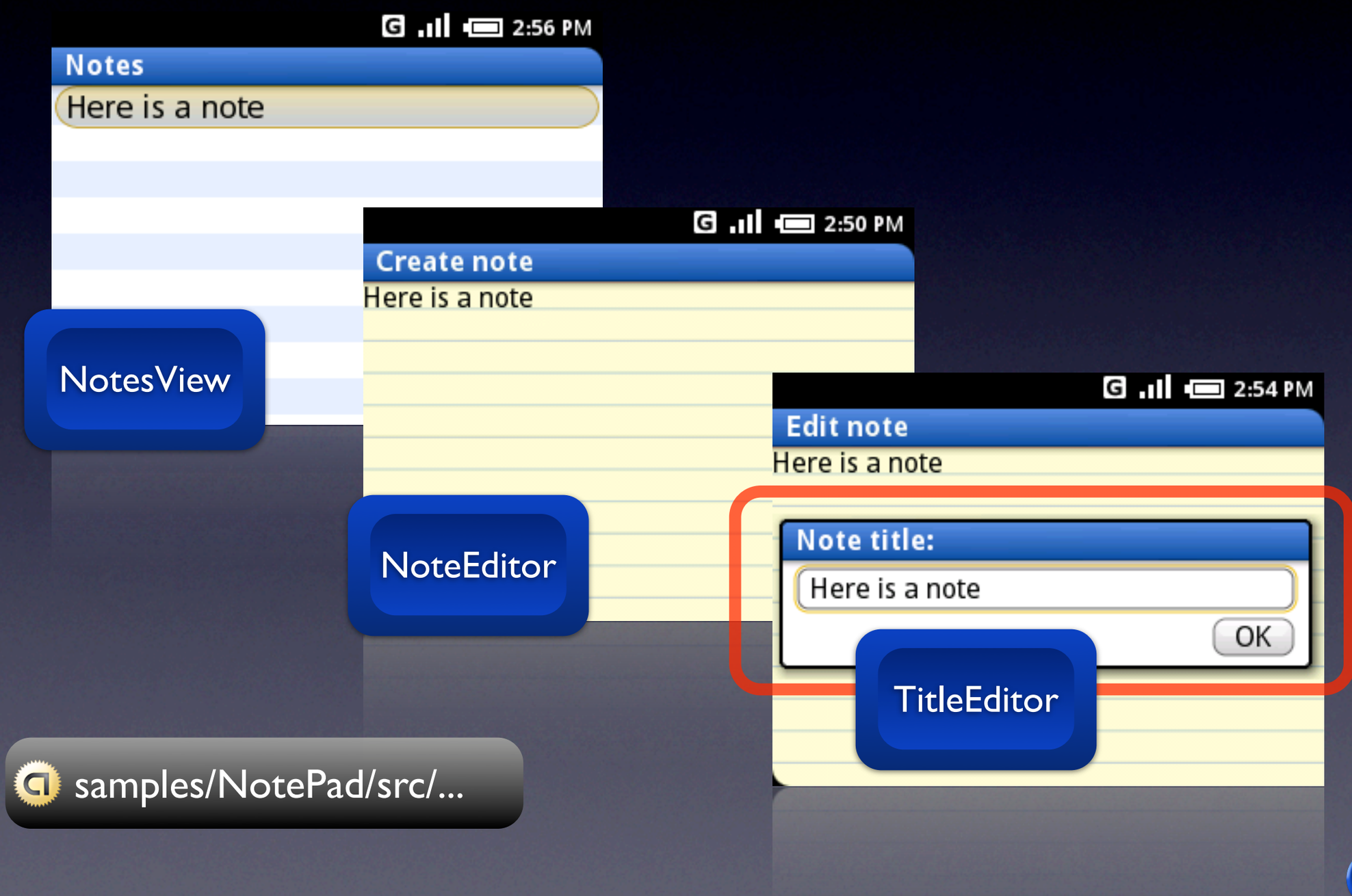
Sample Activities



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Activities

- Designed to be reused and replaced
  - Your application can invoke Activities from another application
  - Another application can invoke your Activities
- Existing Activities can be replaced with a new Activity that fulfills the same contract

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Activity Lifecycle

- Moving between activities pauses the current one then starts/resumes the next
- Navigation facilitated by a common backstack:
  - Application and process boundaries are invisible to users
  - Activities can be frozen and thawed to conserve system resources

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Intents & IntentFilters

- Intents: description of what you want done
- IntentFilter: what a piece of code (Activity or IntentReceiver) can do
- Activities publish their IntentFilters in AndroidManifest.xml

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Intents & IntentFilters

- Forward navigation is accomplished by resolving Intents
  - Caller calls startActivity(myIntent)
  - System picks Activity whose IntentFilter best matches myIntent
  - New Activity is informed of the Intent which caused it to be launched

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Intent Details

- Action: what to do
  - *MAIN*, *PICK*, *EDIT*, ...
- Data: data to act upon (expressed as URI)
  - Action + Data defines contract between caller and callee
- Category: additional detail about the action
- Extras: name/value pairs
- ClassName: force a specific Activity class to be used

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ContentProviders

- Provide uniform APIs to:
  - query data (returns a Cursor)
  - delete, update, and insert rows
- Work across processes
- Customers of ContentProviders don't use them directly. ContentResolver acts as clearinghouse.

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ContentProviders

- All content is represented by URIs
  - Convenience methods mean clients don't need to know syntax
- ContentProviders own URIs based on authority, e.g. content://contacts/...
- ContentProviders are responsible for mapping URIs they own to a MIME type

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ContentProviders

- Example: *content://note_pad/notes*
  - Represents list of all notes
  - Owned by NotePadProvider
  - MIME type: vnd.android-dir/note

NotePad Provider

samples/NotePad/src/com/google/android/notepad/NotepadProvider.java

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ContentProviders

- Example: *content://note_pad/notes/6*
  - Represents one particular note whose id is 6
  - Owned by NotePadProvider
  - MIME type: vnd.android/note

NotePad Provider

samples/NotePad/src/com/google/android/notepad/NotepadProvider.java

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ContentProviders

- Example: *content://contacts/people/6/phones*
  - Represents the list of all phones for a particular person
  - Owned by ContactsProvider
  - MIME type: vnd.android-dir/phone

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Cursor

- Provides random read/write access to a result set returned from a database query
  - count(), move(), moveTo(), next(), prev()
- Can get and set columns
  - getString(), getInt(), getLong()
  - updateString(), updateInt(), updateLong()

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Cursor

- Can be bound to ListView, GridView, Gallery, Spinner, etc for display
- Client provides an Adapter which knows how to make a View for each row in Cursor
- Changes are visible across processes

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IntentReceivers

- Code to run when an Intent is broadcast
- Will wake up process if it is not already running
- Can register in AndroidManifest.xml
- Can also register from code: Context.registerReceiver()

Intent Receiver

samples/SampleCode/src/com/google/android/samples/app/Alarm*.java

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IntentReceivers

- Useful for responding to alarms and notifications of status change
- Can start Services for lengthy tasks (e.g. downloading new data)

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Services

- Faceless classes that run in the background, for example:
  - Music player
  - Network download
- Can run in your application's process or their own process

Service

samples/SampleCode/src/com/google/android/samples/app/*Service*.java

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Services

- System will try to keep processes with running services alive for as long as possible
- Can connect to Services in your process or another process
  - bindService(String className, ServiceConnection conn)

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RSS Example

Rss Activity	Displays RSS data to user
Rss Provider	Stores downloaded data
RssIntent Receiver	Wakes up periodically to fetch new data using RssService
Rss Service	Runs in background to download RSS data

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Application APIs

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Application APIs

- Resources
  - Drawables
- Views
  - Layouts & LayoutParams
  - AdapterViews
  - Animation
- Graphics
  - SGL
  - OpenGL|ES
- ContentResolver
- Storage
  - Raw Files
  - Preferences
  - Databases
- Alarm Manager
- Notification Manager
  - Transient Notifications
  - PersistnetNotifications

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Resources

- Each application can access it's own resource directory as well as system resources
  - Strings, graphics, layouts, animations, etc.
  - Resource manager will pick correct version from alternatives based on language, aspect ratio, etc.

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Resources

- Resource set is detected at build time by scanning source director
- Each resource is assigned a unique ID
- Tool generates java constants for you:
  - Local resource: R.layout.foo
  - System resource: android.R.layout.bar

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Resource Examples

Java constant	XML attribute	Resource
R.layout. title_editor	@layout/ title_editor	layout XML file
R.drawable. lander_plain	@drawable/ lander_plain	
R.string. menu_edit	@string/ menu_edit	“Edit note”
R.drawable. earthrise	@drawable/ earthrise	

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Drawables

- Base class for something which can fill a rectangle on screen
- Usually loaded from resources
  - Bitmaps: res/drawable/*.png, *.jpg
  - Stretchable Bitmaps: res/drawable/*.9.png
  - Colors: defined in res/values/colors.xml

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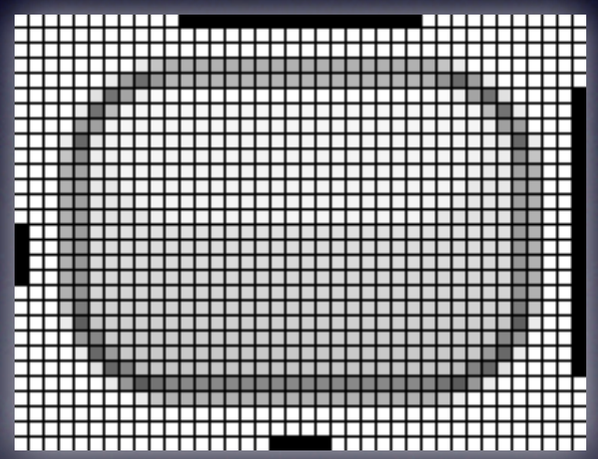
Stretchable Bitmaps

Horizontal stretch

Vertical stretch



Vertical padding

Horizontal padding

Button background can stretch to accommodate any content

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Views

- Basic user interface building block:
  - TextView, EditText, Button, ImageView, Checkbox, etc
- Each activity has a tree of views
  - Views can be inflated from XML
  - Views can be instantiated from code
- Views responsible for handling events, drawing, measuring

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Views

- Basic cycle:
  - Event is dispatched
  - View state is updated
  - Framework updates Views layout (if necessary)
  - Framework draws invalid region (if any)
- Let the framework position and draw Views for you

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Views

- View tree is single-threaded
- Use Handler.post to invoke a Runnable on the event thread

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Views

- Views with children are called ViewGroups
- ViewGroups are responsible for laying out their children
- ViewGroups route events to child that has focus
- Drawing is an in-order traveral:
  - Parents before children; siblings in order

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Layouts

- FrameLayout: Each child is a layer
- LinearLayout: Arranges children in a single row or column
- RelativeLayout: Size and position are described relative to parent and other views
- AbsoluteLayout: Views given specific <x, y>

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LayoutParams

- All Views have properties that are intrinsic to their type
  - TextViews have textSize, textColor, etc.
- All Views also have a LayoutParams object which describe how they should be sized & positioned
  - A TextView inside a LinearLayout will have a LinearLayout.LayoutParams object

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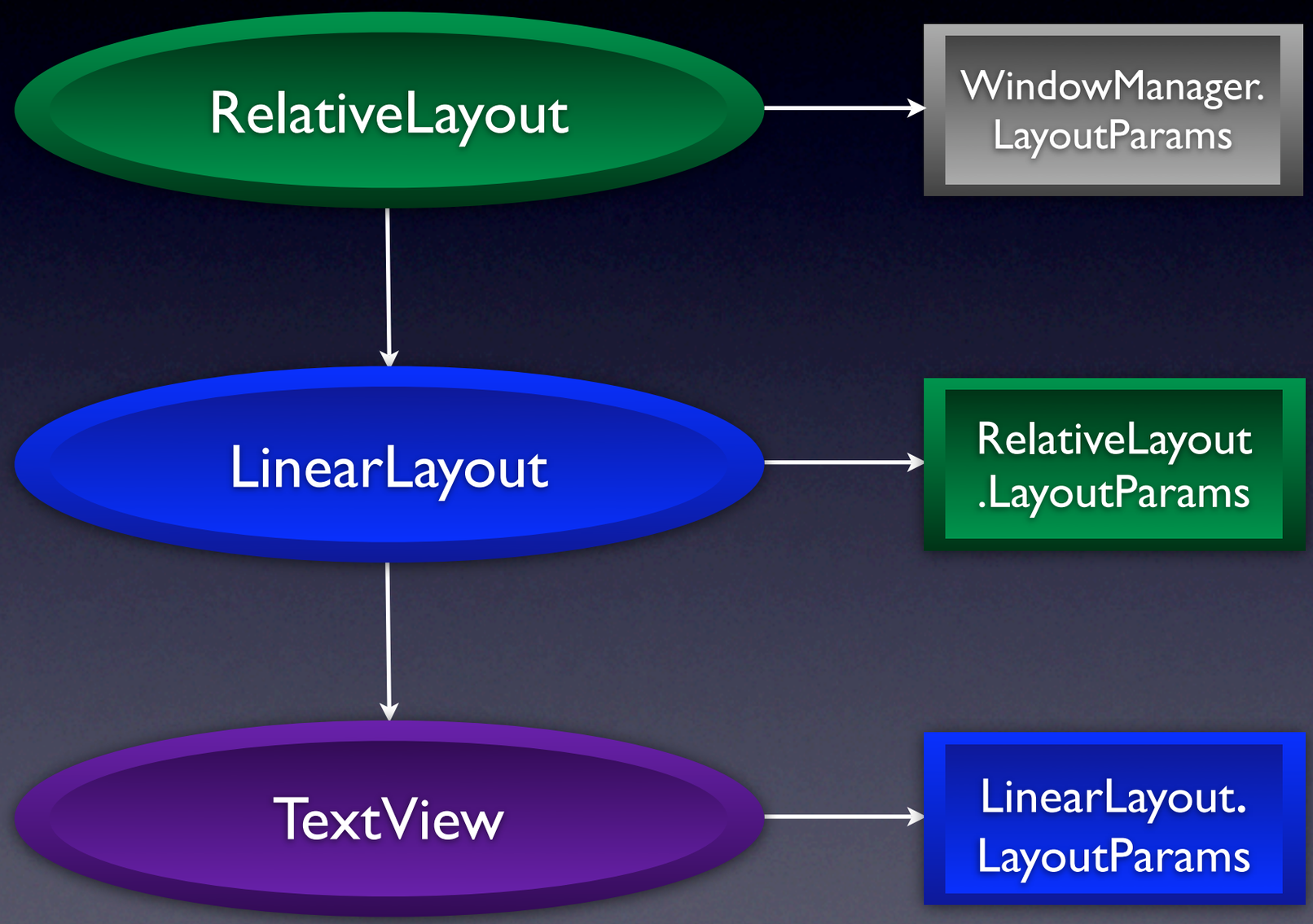
LayoutParams



Sample view tree

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Views in XML

```
<TextView
  android:layout_width="fill_parent"
  android:layout_height="wrap_content"
  android:layout_weight="1"
  android:background="@android:drawable/box"
  android:text="This is the middle view." />
```

Red attributes go into the LayoutParams object and are interpreted by the parent.
Green attributes go into the TextView

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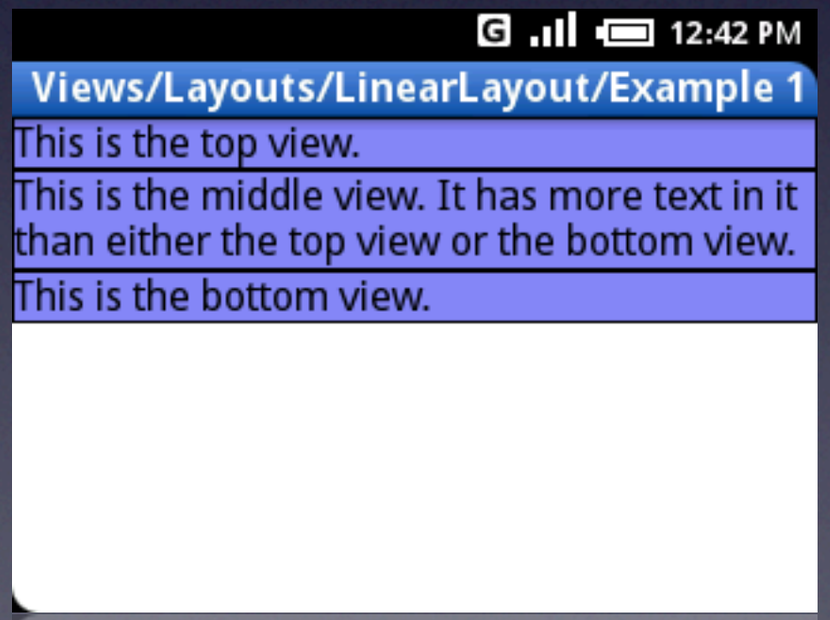
LinearLayout Example

LinearLayout's width: fill_parent
LinearLayout's height: wrap_content

TextViews' width: fill_parent
TextViews' height: wrap_content



samples/SampleCode/res/layout/linear_layout*.xml

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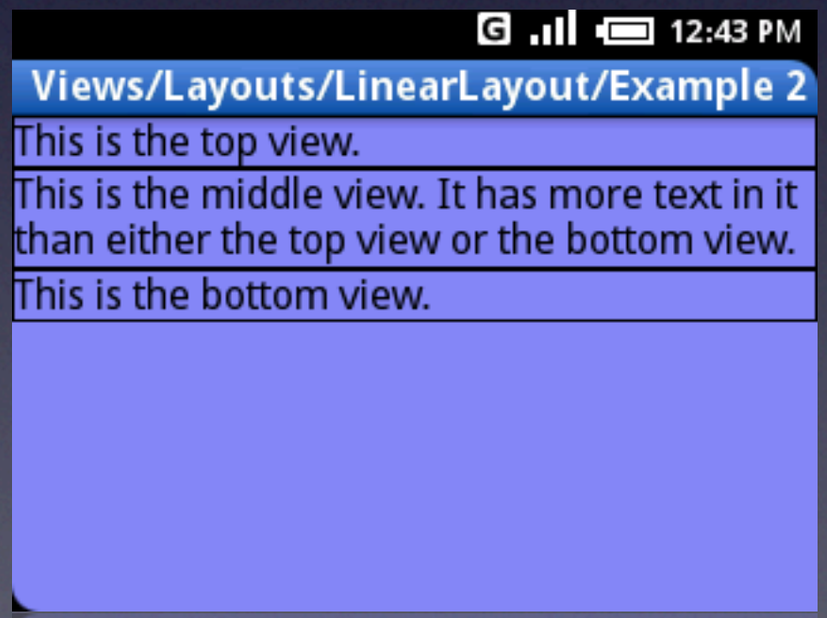
LinearLayout Example

LinearLayout's width: fill_parent
LinearLayout's height: fill_parent

TextViews' width: fill_parent
TextViews' height: wrap_content



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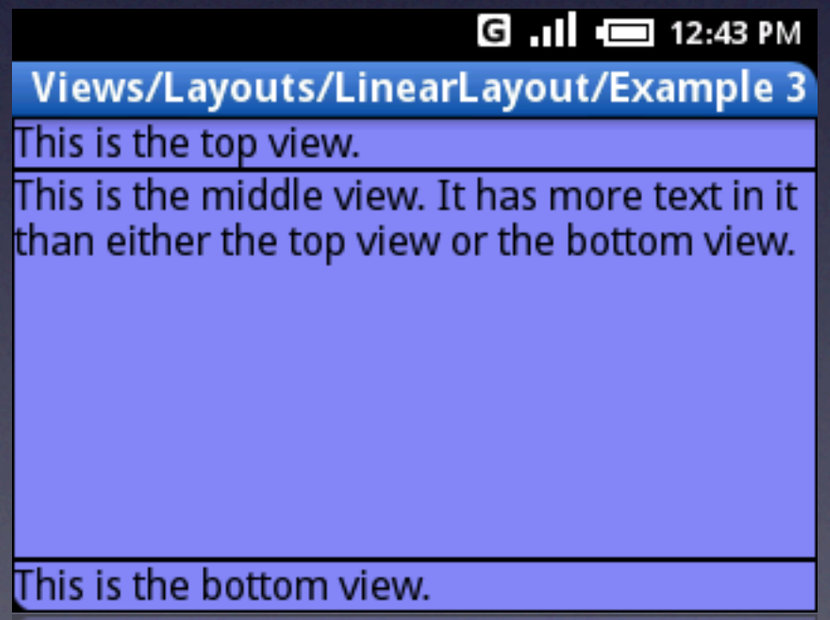
LinearLayout Example

LinearLayout's width: fill_parent
LinearLayout's height: fill_parent

TextView 1's width: fill_parent
TextView 1's height: wrap_content

TextView 2's width: fill_parent
TextView 2's height: wrap_content
TextView 2's weight: 1

TextView 3's width: fill_parent
TextView 3's height: wrap_content



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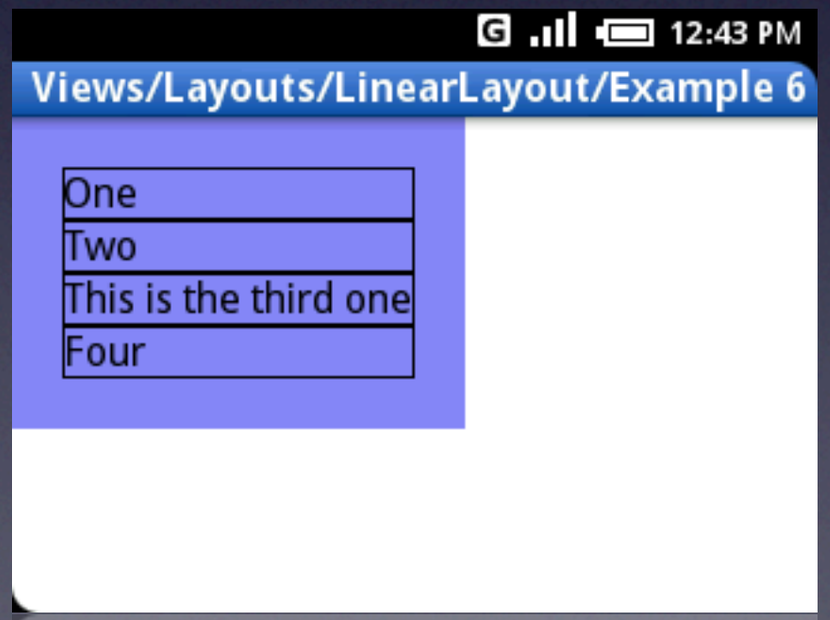
LinearLayout Example

LinearLayout's width: wrap_content
LinearLayout's height: wrap_content
LinearLayout's padding: 20

TextViews' width: fill_parent
TextViews' height: wrap_content



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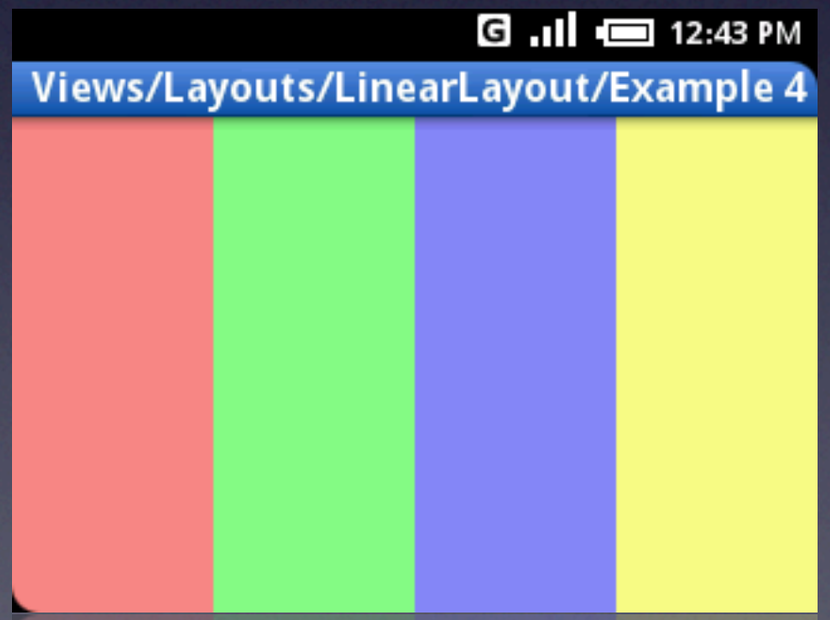
LinearLayout Example

LinearLayout's width: fill_parent
LinearLayout's height: fill_parent
LinearLayout's orientation: horizontal

TextViews' width: 0
TextViews' weight: 1
TextViews' height: fill_parent



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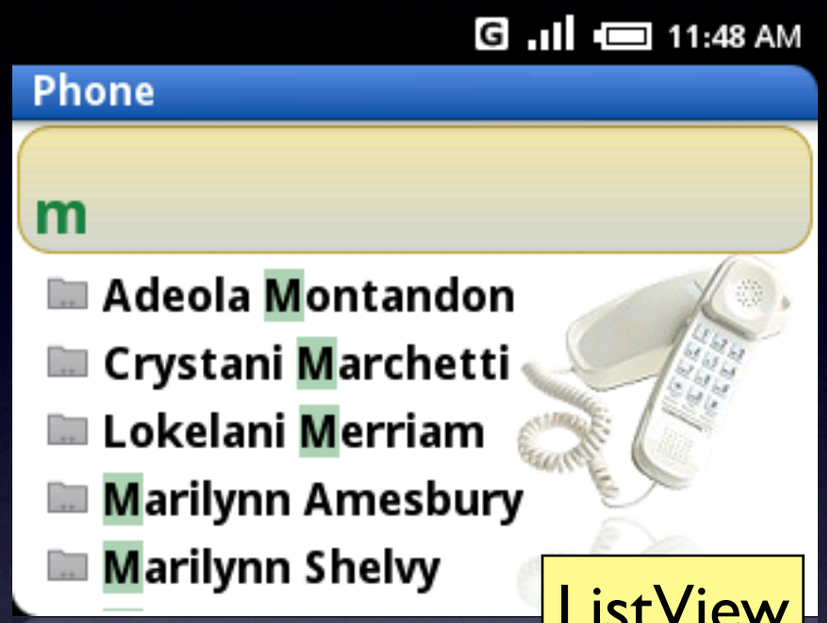
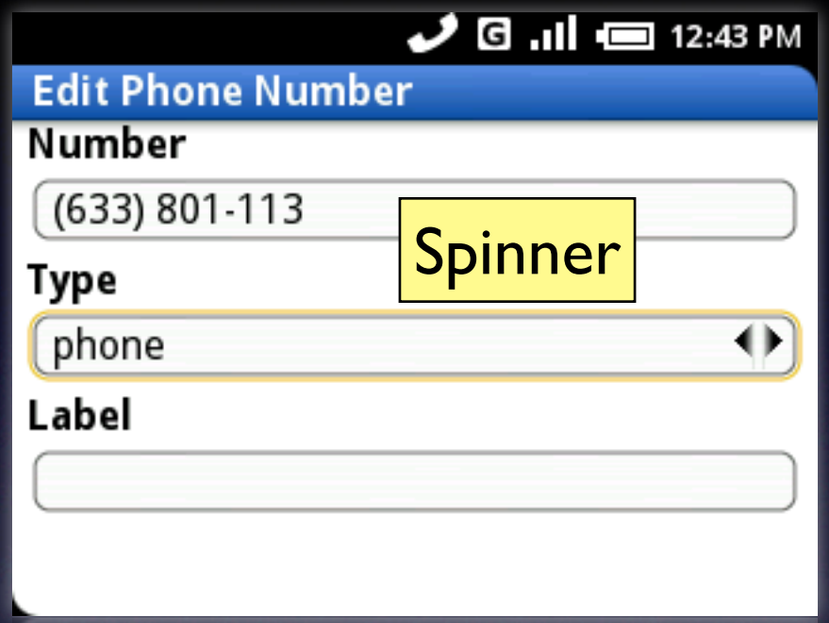
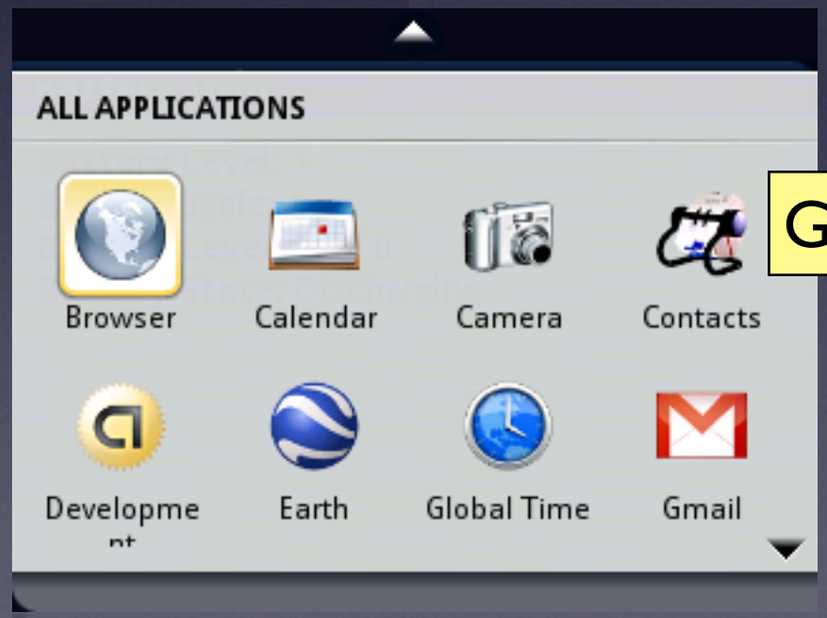
AdapterView Examples







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Adapters

- Adapters are where AdapterViews get their data from.
  - getCount()
  - getItem(int position)
- Also responsible for providing a View to display data at a particular position
  - getView(int position, ...)
- Adapters notify their host when their data changes

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Adapters

- You can write your own, or...
  - CursorListAdapter: data comes from a Cursor
  - SimpleCursorListAdapter: all views come from the same XML file; maps column names to views.
  - ArrayListAdapter: data lives in an array

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Other Useful Views

- ScrollView: Add as parent of another View (typically LinearLayout) to make that View scroll
- TabHost/TabWidget: Can switch between embedded Activities (or Views)
- ViewFlipper: Shows child Views one at a time
- ViewSwitcher: Double-buffers Views to enable transition effects

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Animation

- Views have built-in support for animations
- Animations can be calculated from code or loaded from resources
- Primitive animations (scale, translate, rotate, alpha) can be composed for more complex effects
- Can apply different Interpolators to vary tweening calculations (EaseIn, EaseOut, etc)

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Animation Resources

```
Animation shake =
    AnimationUtils.loadAnimation(this,
                                 R.anim.shake);
v.startAnimation(shake);
```

```
<translate
  android:fromX="0"
  android:toX="10"
  android:duration="1000"
  android:interpolator="@anim/cycle_7" />
```

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Graphics: SGL

- Postscript-like 2D API
  - SVG capable
  - Object Oriented
  - Complex polygons
  - Powerful paints
  - 2D and 3D Transformations
- High quality
  - Floating-point coordinates
  - Everything can be anti-aliased
  - Dithered gradients

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Graphics: SGL

- **Canvas**
  - Destination of rendering operations (a Surface or a Bitmap)
  - Contains current clipping and transform
  - Rasterization operations (fill, bitmap, text, paths)
- **Paint**
  - Defines all parameters used to fill a shape
  - Color, Gradient, Pen Size, Stippling, Anti-aliasing, etc...
- **Path**
  - Used to define the shapes to render
  - Comprised of Lines segments, Bezier curves and Arcs
  - Paths can be stroked and used as baseline for text
  - Can be concave and self-intersecting

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Graphics: OpenGL|ES

- Embedded version of the industry-standard OpenGL API
- Available to applications through JSR 239
- Software implementation
  - Fast, uses dynamic code generation
  - Version 1.0 with extensions
- Hardware implementation where available

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Graphics: OpenGL|ES

- Syncronize drawing (e.g. in View.draw)
  - OpenGLContext.waitNative()
  - OpenGLContext.waitGL()

```
OpenGLContext glc = new OpenGLContext(0);
GL10 gl = (GL10)( glc.getGL() );

glc.waitNative( canvas, ... );

// use JSR239 here
gl.glViewPort( ... )

glc.waitGL();
```

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ContentResolver

- Perform operations on URIs
- Find ContentProvider responsible for URI's authority and call corresponding API on it
- Loads/starts ContentProvider if needed
- Uses information in AndroidManifest.xml to match authority to ContentProvider

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ContentResolver

- Cursor query(ContentURI uri, ...)
  Perform a SQL-like query on the provider
- String getType(ContentURI uri)
  Retrieve MIME type of a provider's URI
- ContentURI insert(ContentURI uri, ...)
  Add a new row of data to the provider
- int delete(ContentURI uri, ...)
  Remove one or more rows of data
- int update(ContentURI uri, ...)
  Modify the data in a row

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Persistent Storage

- Every application is given a directory (on internal flash) in which to store its data
- Sub-directories hold different kinds of data
  - Raw files the application can manage
  - Structured files for “preferences”
  - SQLite Databases / Content Providers
- Use Context to access your data

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Storage: Raw Files

- Context APIs to read/write/delete/list files:
  - FileInputStream openFileInput(String name)
  - FileOutputStream openFileOutput(String name)
  - boolean deleteFile(String name)
  - String[] fileList()
- Other applications can not access these files
- Example: used by maps to cache tiles

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Storage: Preferences

- Context APIs to read/write data in a Map
  - void writePreferences(String name, Map prefs)
  - Map readPreferences(String name)
- Activity also has APIs for per-Activity prefs
  - writePreferences(Map prefs)
  - Map readPreferences()
  - Simply calls the former with Activity's class name
- Preferences currently stored as XML

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Storage: Databases

- Context APIs to create/open databases:
  - SQLiteDatabase createDatabase()
  - SQLiteDatabase openDatabase()
- Provides raw SQLite access, plus helper functions: query(), insert(), delete(), update()
- High-level Cursor interface that can be used across processes

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Alarm Manager

- Alarms will cause your app to be started
  - Can wake up device
  - Can be based on real or elapsed time
- set(int type, long triggerAtTime, Intent intent);
- setRepeating(int type, long triggerAtTime,
  long interval, Intent intent);
- cancel(Intent intent);

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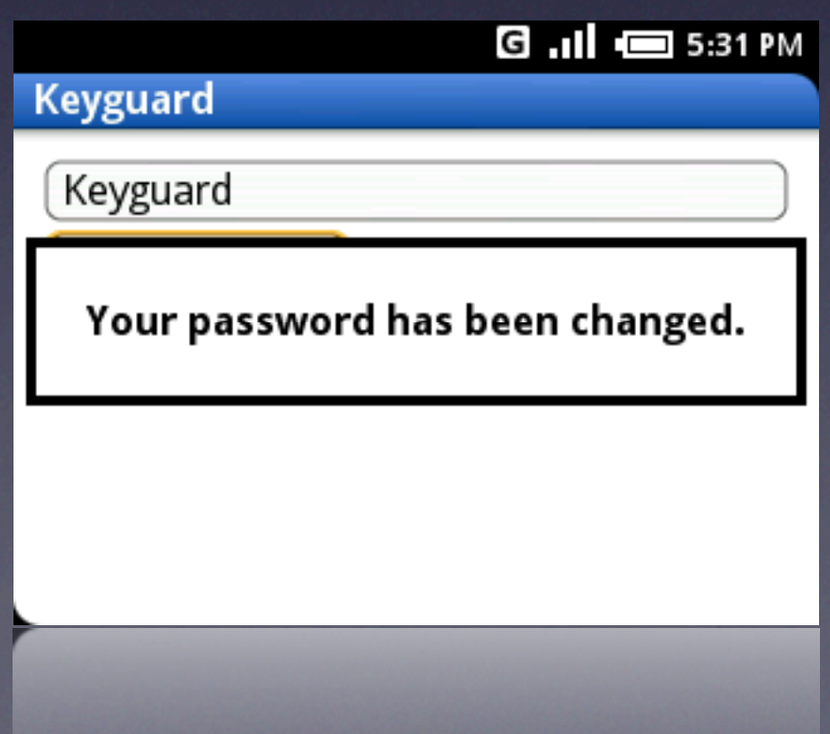
Transient Notifications

```
notify(int id,
  CharSequence transientMessage,
  int transientDuration);

notifyView(int id,
  View transientView,
  int transientDuration);
```



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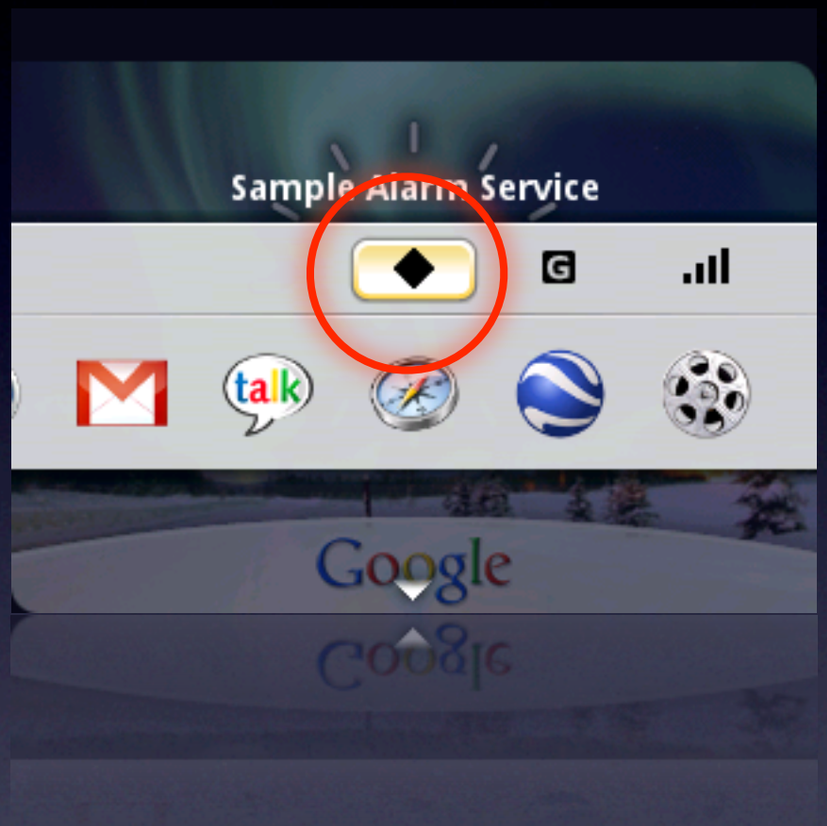
Persistent Notifications

- Apps can add notifications to status bar and app launcher
- Notifications can have an associated action (Intent)



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Persistent Notifications

```
void notify(int id,
    CharSequence transientMessage,
    int transientDuration,
    int persistentIcon,
    CharSequence persistentLabel,
    Intent peristentIntent,
    int persistentHow);
```

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Context

- Activity is a Context
- Access to system APIs
  - Resources
  - ContentResolver
  - Find system Services:
    - *Window Manger*
    - *Alarm Manager*
    - *NotificationManager*
    - *View Inflation*
- Start/Stop/Bind Services
- Register/Broadcast Intents
  - Preferences
  - Storage

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Development

Tools

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Android Tools

- Compatible with standard IDEs
  - Eclipse, IntelliJ
- Android-specific tools to increase visibility into what is happening on device
  - Full support for on-device debugging
  - Performance & memory profiling

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Eclipse Device Debugging

Debug – View.java – Eclipse SDK – /Users/mcleron/Documents/workspace-x

Debug

TelephonyEditor [Remote Java Application]
DalvikVM[localhost:8700]
Thread [<3> Main] (Suspended)
PhoneWindow$DecorView(View).draw(Canvas, Transformation
PhoneWindow$DecorView.draw(Canvas, Transformation, long
PhoneWindow$DecorView(View).drawTraversal(Canvas, Transf
PhoneWindow$DecorView(FrameLayout).drawTraversal(Canva
PhoneWindow$DecorView.drawTraversal(Canvas, Transformat
ViewRoot.draw(boolean) line: 373
ViewRoot.performTraversals() line: 288
ViewRoot.handleMessage(Message) line: 421
ViewRoot(Handler).dispatchMessage(Message) line: 40

Call stack

Variables | Breakpoints

Name	Value
this	PhoneWindow$DecorView (id=830011
canvas	Canvas (id=830011571256)
mBitmap	null
mNativeCanvas	1249144
mSurfaceFormat	4
currentTransformation	null
drawTime	1179363240090

Examine variables

View.java

```
1823     * @param drawTime The time at which the current draw pass started
1824     */
1825    protected void draw(Canvas canvas, Transformation currentTransformation, long drawTime) {
1826        Drawable bg = mBGDrawable;
1827        if (bg == null) {
1828            mBackgroundSizeChanged = false;
1829            return;
1832        if (mBackgroundSizeChanged) {
1833            bg.setBounds(0, 0,  mRight - mLeft, mBottom - mTop);
1834        }
```

Breakpoints, single stepping

Console | Tasks | Display | Search

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Dalvik Debug Monitor Server

- Makes Java Debugging Easier
  - Shows process names and remote-debug port numbers
  - Provides debugger network pass-through to Java apps
  - Shortcut to debug current app: select it, connect to port 8700
  - Apps that are told to wait for debugger are highlighted in DDMS UI; Allows debugging startup problems

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Dalvik Debug Monitor Server

- Finds all Java apps running on the device
- Automatically detects device when attached to USB
- Displays statistics on thread and memory usage.
- Commands to gather for bug reports
  - *screen shots, radio logs, system state*

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Dalvik Debug Monitor Server

Dalvik Debug Monitor

ADB proxy (device) | Update Threads | Update Heap | Halt | GC

Examine thread & heap state

Java processes

	Client Name
00	system_process
adb 8001	com.google.android.phone
adb 8002	com.google.android.home
adb 8004	com.google.android.gtalk
adb 8005	<pre-initialized>

Info | Threads | Java Heap | Native Heap

ID	Tid	Status	utime	stime	Name
3	279	wait	1353	104	Main
*5	284	vmwait	8	0	HeapWorker
*7	285	vmwait	0	0	Signal Catcher
*9	286	running	45	102	JDWP
11	292	native	20	1	Binder Thread #1
				0	Binder Thread #2
				0	Binder Thread #3

Remote Command

Executing 'logcat '*:d jdwp:w"'

View logs

```
D/dalvikvm(  433): Sending app name
I/dalvikvm(  433): JDWP has attached
I/dalvikvm(  433): Broadcasting DDM connect
I/ddm-hello(  433): Connected!
D/ddm-hello(  433): Server version is 1
D/ActivityManager(  248): Broadcast: Intent { action=android.intent.action.TIME_TICK }
I/AlarmManager(  248): Intent: Intent { action=android.intent.action.TIME_TICK }
D/ActivityManager(  248): Broadcast: Intent { action=android.intent.action.TIME_TICK }
I/AlarmManager(  248): Intent: Intent { action=android.intent.action.TIME_TICK }
D/ActivityManager(  248): Broadcast sticky: Intent { action=android.intent.action.BATTERY_CHANGED
extras={scale=9, icon-large=16973963, level-raw=69, draw-level=6666, icon-small=16973940,
state=Normal, level=6} }
D/ActivityManager(  248): Broadcast: Intent { action=android.intent.action.TIME_TICK }
I/AlarmManager(  248): Intent: Intent { action=android.intent.action.TIME_TICK }
D/ActivityManager(  248): Broadcast: Intent
{ action=android.intent.action.SIGNAL_STRENGTH_CHANGED extras={asu=27, phoneName=GSM} }
D/ActivityManager(  248): Broadcast: Intent { action=android.intent.action.TIME_TICK }
I/AlarmManager(  248): Intent: Intent { action=android.intent.action.TIME_TICK }
D/ActivityManager(  248): Broadcast: Intent { action=android.intent.action.TIME_TICK }
I/AlarmManager(  248): Intent: Intent { action=android.intent.action.TIME_TICK }
D/ActivityManager(  248): Broadcast sticky: Intent { action=android.intent.action.BATTERY_CHANGED
extras={scale=9, icon-large=16973963, level-raw=70, draw-level=6666, icon-small=16973940,
state=Normal, level=6} }
D/ActivityManager(  248): Broadcast: Intent { action=android.intent.action.TIME_TICK }
I/AlarmManager(  248): Intent: Intent { action=android.intent.action.TIME_TICK }
```

Save | Cancel

Idle

Device Screen Capture

Captured image:

Screen capture

Refresh | Save | Done

Emulator

- ARM emulator runs same code as device
- Uses same tool set
- Allows profiling of native code

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Performance Tools

- Custom-built tools offers accurate, detailed performance analysis of code running on device
- Linked views to help navigate large data sets
- Powerful visualizations to identify performance bottlenecks

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Performance: Traceview

Traceview: /Users/mcleron/Desktop/jtrace/com.google.android.pressmwarminst.PressMWarmInstrumentationProfiled.jtrace

msec: 452.295 max msec: 526.464

24 android/view/View.drawTraversal (Landroid/graphics/Canvas;Landroid/view/animation/Transformation;)V

0 50 100 150 200 250 300 350 400 450 500

mInstrumentationProfiled

[3] Main

[17] Binder Thread #3

Timeline view

Name	Incl %	Inclusive	Excl %	Exclusive	Calls+Recur Calls/Total
8 android/view/ViewRoot.performTraversals ()V	32.2%	169.472	0.1%	0.545	2+0
Parents					
7 android/view/ViewRoot.handleMessage (Landroid/os/Message;)V	100.0%	169.472			2/2
Children					
self	0.3%	0.545			
37 android/view/View.setFrameTraversal (IIIIII)V	38.0%	64.377			1/17
41 android/view/ViewRoot.draw (Z)V	37.2%	63.036			2/2
62 android/policy/PhoneWindow$DecorView.measure (II)V	20.1%	34.085			1/1
198 android/view/IWindowSession$Stub$Proxy.relayout (Landroid/view/IWindo	3.4%	5.688			2/2
388 android/view/IWindowSession$Stub$Proxy.finishDrawing (Landroid/view/IV	0.8%	1.430			1/1
775 android/view/ViewRoot.getRootMeasureSpec (II)I	0.1%	0.152			2/2
774 android/graphics/Rect.width ()I	0.0%	0.058			4/11
782 android/graphics/Rect.height ()I	0.0%	0.050			4/11
420 android/view/View.getVisibility ()I	0.0%	0.028			2/86
574 android/view/View.getLayoutParams ()Landroid/view/ViewGroup$LayoutP	0.0%	0.023			2/43
9 com/google/android/phone/Dialer.initializeCursor ()V	28.1%	147.994	0.0%	0.107	1+0
10 android/widget/DialerFilter.onKeyDown (ILandroid/os/KeyEvent;)Z	28.0%	147.414	0.0%	0.107	1+0
11 android/text/SpannableStringBuilder.replace (IILjava/lang/CharSequence;II)I	24.0%	126.522	0.0%	0.231	3+0
12 android/text/SpannableStringBuilder.change (IILjava/lang/CharSequence;II)I	23.8%	125.414	0.0%	0.093	3+0
13 android/text/SpannableStringBuilder.change (ZIILjava/lang/CharSequence;II)I	23.8%	125.321	0.2%	1.175	3+0
14 android/text/SpannableStringBuilder.send	22.9%	120.885	0.1%	0.388	3+0
15 android/widget/TextView.onKeyDown (ILar	18.7%	98.727	0.0%	0.041	1+0
16 android/text/method/MultiTapInputMethod	18.7%	98.686	0.0%	0.070	1+0
17 android/text/method/QwertyInputMethod.	18.7%	98.616	0.1%	0.455	1+0
18 android/text/SpannableStringBuilder.repla	18.2%	95.813	0.0%	0.042	1+0
19 android/pim/ContactPickerActivity$ContactPickerTextWatcher.onTextChanged (Ljava	17.1%	90.067	0.0%	0.045	1+0
20 android/pim/ContactPickerActivity.search (Ljava/lang/String;)V	17.0%	89.593	0.0%	0.102	1+0
21 android/policy/PhoneWindow$DecorView.drawTraversal (Landroid/graphics/Canvas	16.4%	86.270	0.0%	0.098	2+0
22 android/widget/DialerFilter.setMode (I)V	16.3%	85.880	0.0%	0.205	2+0

Profile view

Find:

Per-thread Call Tree	Cpu time	% of Total
183 android/os/MessageQueue.next ()Landroid/os/Message;	0.128	0.0%
1 android/os/Handler.dispatchMessage (Landroid/os/Message;)V	1.991	0.4%
308 android/os/Message.recycle ()V	0.067	0.0%
183 android/os/MessageQueue.next ()Landroid/os/Message;	4.51	0.9%
1 android/os/Handler.dispatchMessage (Landroid/os/Message;)V	2.934	0.6%
308 android/os/Message.recycle ()V	0.066	0.0%
183 android/os/MessageQueue.next ()Landroid/os/Message;	0.136	0.0%
1 android/os/Handler.dispatchMessage (Landroid/os/Message;)V	35.407	6.7%
2 android/app/ActivityThread$H.handleMessage (Landroid/os/Messa	35.377	6.7%
59 android/app/ActivityThread.access$1000 (Landroid/app/Act	35.335	6.7%
60 android/app/ActivityThread.handleStopActivity (Landroid/	35.248	6.7%
241 java/util/HashMap.get (Ljava/lang/Object;)Ljava/lar	0.218	0.0%
894 android/app/ActivityThread$StopInfo.<init> (Landr	0.058	0.0%
69 android/app/ActivityThread.performStopActivityInner	30.939	5.9%
86 android/app/ActivityThread.createThumbnailBitn	26.248	5.0%
596 android/graphics/Bitmap.createBitmap (IIZ)	0.438	0.1%
797 android/graphics/Bitmap.eraseColor (I)V	0.133	0.0%
711 android/graphics/Canvas.<init> (Landroid/	0.233	0.0%
88 android/app/Activity.onCreateThumbnail (Lar	25.318	4.8%
1033 android/app/Activity.onCreateDescription ()Lja	0.012	0.0%
220 android/app/Activity.performStop ()V	4.612	0.9%
296 android/view/View.setVisibility (I)V	1.1	0.2%
883 android/app/ActivityManagerNative.getDefault ()Lan	0.016	0.0%
282 android/app/ActivityManagerProxy.activityStopped (	2.751	0.5%
308 android/os/Message.recycle ()V	0.064	0.0%
183 android/os/MessageQueue.next ()Landroid/os/Message;	0.134	0.0%
1 android/os/Handler.dispatchMessage (Landroid/os/Message;)V	0.074	0.0%
308 android/os/Message.recycle ()V	0.054	0.0%
183 android/os/MessageQueue.next ()Landroid/os/Message;	0.195	0.0%
1 android/os/Handler.dispatchMessage (Landroid/os/Message;)V	3.277	0.6%
308 android/os/Message.recycle ()V	0.063	0.0%
183 android/os/MessageQueue.next ()Landroid/os/Message;	0.41	0.1%
[17] Binder Thread #3	3.696	0.7%

Callstack view

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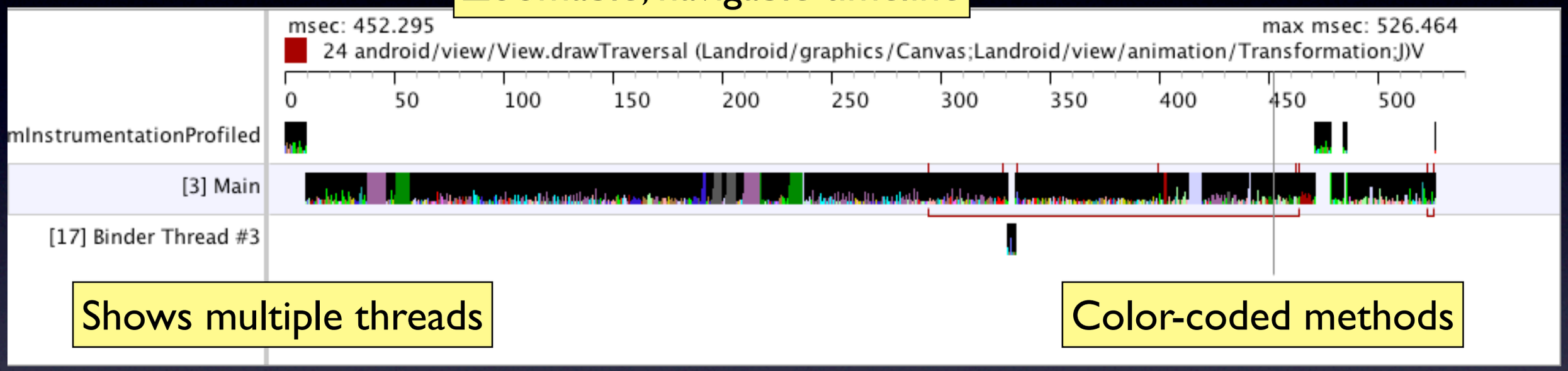
Timeline View

Zoomable, navigable timeline



Shows multiple threads

Color-coded methods

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Profile View

Summarizes cost of each method

Inclusive & exclusive method times

Name	Incl %	Inclusive	Excl %	Exclusive	Calls+Recur Calls/Total
8 android/view/ViewRoot.performTraversals ()V	32.2%	169.472	0.1%	0.545	2+0
Parents					
7 android/view/ViewRoot.handleMessage (Landroid	00.0%	169.472			2/2
Children					
self	0.3%	0.545			
37 android/view/View.setFrameTraversal (IIIIII)V	38.0%	64.377			1/17
41 android/view/ViewRoot.draw (Z)V	37.2%	63.036			2/2
62 android/policy/PhoneWindow$DecorView.measure (II)V	20.1%	34.085			1/1
198 android/view/IWindowSession$Stub$Proxy.relayout (Landroid/view/IWindo	3.4%	5.688			2/2
388 android/view/IWindowSession$Stub$Proxy.finishDrawing (Landroid/view/IV	0.8%	1.430			1/1
775 android/view/ViewRoot.getRootMeasureSpec (II)I	0.1%	0.152			2/2
774 android/graphics/Rect.width ()I	0.0%	0.058			4/11
782 android/graphics/Rect.height ()I	0%	0.050			4/11
420 android/view/View.getVisibility ()I	0%	0.028			2/86
574 android/view/View.getLayoutParams ()Landrol	0%	0.023			2/43
9 com/google/android/phone/Dialer.initializeCursor ()V	28.1%	147.994	0.0%	0.107	1+0
10 android/widget/DialerFilter.onKeyDown (ILandroid/os/KeyEvent;)Z	28.0%	147.414	0.0%	0.107	1+0
11 android/text/SpannableStringBuilder.replace (IILjava/lang/CharSequence;II)I	24.0%	126.522	0.0%	0.231	3+0
12 android/text/SpannableStringBuilder.change (IILjava/lang/CharSequence;II)I	23.8%	125.414	0.0%	0.093	3+0
13 android/text/SpannableStringBuilder.change (ZIILjava/lang/CharSequence;II)I	23.8%	125.321	0.2%	1.175	3+0
14 android/text/SpannableStringBuilder.sendTextChange ([Ljava/lang/Object;III)V	22.9%	120.885	0.1%	0.388	3+0
15 android/widget/TextView.onKeyDown (ILandroid/os/KeyEvent;)Z	18.7%	98.727	0.0%	0.041	1+0
16 android/text/method/MultiTapInputMethod.onKeyDown (Landroid/text/Editable;ILa	18.7%	98.686	0.0%	0.070	1+0
17 android/text/method/QwertyInputMethod.qwerty (Landroid/text/Editable;ILandroid,	18.7%	98.616	0.1%	0.455	1+0
18 android/text/SpannableStringBuilder.replace (IILjava/lang/CharSequence;)I	18.2%	95.813	0.0%	0.042	1+0
19 android/pim/ContactPickerActivity$ContactPickerTextWatcher.onTextChanged (Ljava	17.1%	90.067	0.0%	0.045	1+0
20 android/pim/ContactPickerActivity.search (Ljava/lang/String;)V	17.0%	89.593	0.0%	0.102	1+0
21 android/policy/PhoneWindow$DecorView.drawTraversal (Landroid/graphics/Canvas	16.4%	86.270	0.0%	0.098	2+0
22 android/widget/DialerFilter.setMode (I)V	16.3%	85.880	0.0%	0.205	2+0

Calls to method

Calls from method

Find:

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Callstack View

Per-thread Call Tree	Cpu time	% of Total
183 android/os/MessageQueue.next ()Landroid/os/Message;	0.128	0.0%
1 android/os/Handler.dispatchMessage (Landroid/os/Message;)V	1.991	0.4%
308 android/os/Message.recycle ()V	0.067	0.0%
183 android/os/MessageQueue.next ()Landroid/os/Message;	4.51	0.9%
1 android/os/Handler.dispatchMessage (Landroid/os/Message;)V	2.934	0.6%
308 android	0.066	0.0%
183 android	0.136	0.0%
1 android/os/Handler.dispatchMessage (Landroid/os/Message;)V	35.407	6.7%
2 android/app/ActivityThread$H.handleMessage (Landroid/os/Mess	35.377	6.7%
59 android/app/ActivityThread.access$1000 (Landroid/app/Act	35.335	6.7%
60 android/app/ActivityThread.handleStopActivity (Landroid,	35.248	6.7%
241 java/util/HashMap.get (Ljava/lang/Object;)Ljava/lar	0.218	0.0%
894 android/app/ActivityThread$StopInfo.<init> (Landr	0.058	0.0%
69 android/app/ActivityThread.performStopActivityInner	30.939	5.9%
86 android/app/ActivityThread.createThumbnailBitn	26.248	5.0%
596 android/graphics/Bitmap.createBitmap (IIZ)	0.438	0.1%
797 android/graphics/Bitmap.eraseColor (I)V	0.133	0.0%
711 android/graphics/Canvas.<init> (Landroid/	0.233	0.0%
88 android/app/Activity.onCreateThumbnail (La	25.318	4.8%
1033 android/app/Activity.onCreateDescription ()Lja	0.012	0.0%
220 android/app/Activity.performStop ()V	4.612	0.9%
296 android/view/View.setVisibility (I)V	1.1	0.2%
883 android/app/ActivityManagerNative.getDefault ()Lan	0.016	0.0%
282 android/app/ActivityManagerProxy.activityStopped (	2.751	0.5%
308 android/os/Message.recycle ()V	0.064	0.0%
183 android/os/MessageQueue		0.0%
1 android/os/Handler.dispatch		0.0%
308 android/os/Message.recycle ()V	0.054	0.0%
183 android/os/MessageQueue.next ()Landroid/os/Message;	0.195	0.0%
1 android/os/Handler.dispatchMessage (Landroid/os/Message;)V	3.277	0.6%
308 android/os/Message.recycle ()V	0.063	0.0%
183 android/os/MessageQueue.next ()Landroid/os/Message;	0.41	0.1%
[17] Binder Thread #3	3.696	0.7%

Shows complete call tree

Color codes critical path

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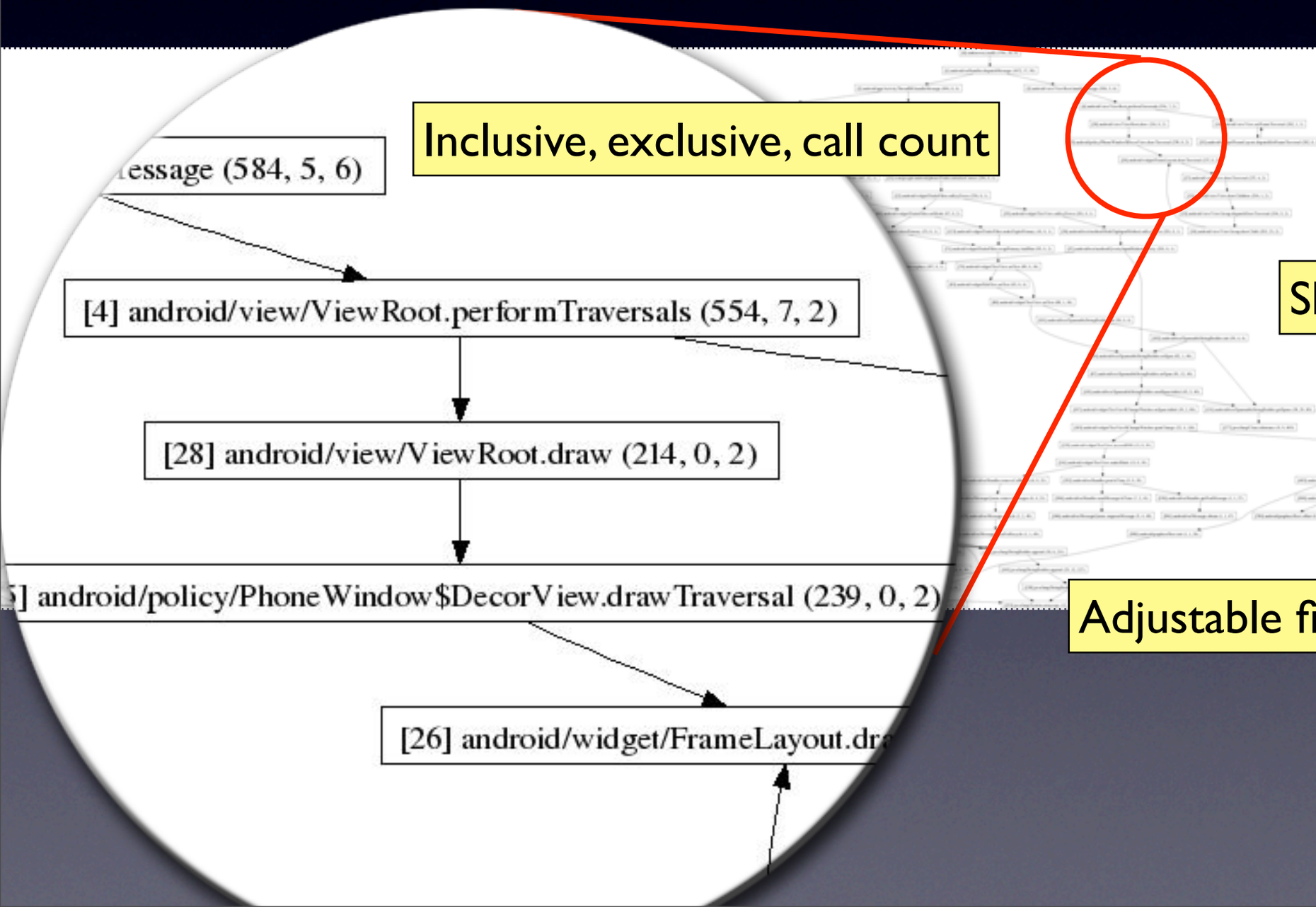
JTracedump



Inclusive, exclusive, call count

Shows filtered call graph

Adjustable filter threshold

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Memory Tools

- Leak checker instruments malloc
- Records stack for every allocation
- Information can be retrieved from device and viewed in DDMS

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DDMS: Leak checker

Dalvik Debug Monitor

ADB proxy (device) | Update Threads | Update Heap | Halt | GC

D	Port	Client Name
	adb 8000	system_process
	adb 8001	com.google.android.phone
	adb 8002	com.google.android.home
	adb 8003	<pre-initialized>
	adb 8004	com.google.android.gtalk

Info | Threads | Java Heap | Native Heap

Press 'Request Update' to retrieve latest data

Request Update

Can get heap snapshots on demand

< 1 / 154 > Total Memory: 2,252,410

List of allocation sites

Total	Count	Size	Library	Method	File
66,560	1	66,560	/android/lib/libjava_runtime.so	??	??
62,652	1	62,652	/android/lib/libdvm.so	dvmDexFileParse	dal
57,344	7	8,192	/android/lib/libdvm.so	allocThread	dal

Stack for each allocation

Address	Library	Method	File
5303bde4	/android/lib/libc.so	calloc	system/bionic/bionic
660384dc	/android/lib/libdvm.so	dvmDexFileParse	dalvik/vm/DexFile.c
660387d8	/android/lib/libdvm.so	dvmDexFileOpenFromF	dalvik/vm/DexFile.c
4a338	/android/lib/libdvm.so	dvmJarFileOpen	dalvik/vm/JarFile.c
646b0	/android/lib/libdvm.so	prepareCpe	dalvik/vm/oo/Class.
66064968	/android/lib/libdvm.so	dvmClassStartup	dalvik/vm/oo/Class.
6603ebd4	/android/lib/libdvm.so	dvmStartup	dalvik/vm/Init.c
66048090	/android/lib/libdvm.so	D_JNI_CreateJavaVM	dalvik/vm/Jni.c
5801e0f4	/android/lib/libjava_runtime.so	Autolock	include/utils/threads

Idle

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Heap Analysis Tool

- Provides a browsable snapshot of the entire VM heap
  - Object types
  - Object relationships
  - Memory usage
  - Differences over time

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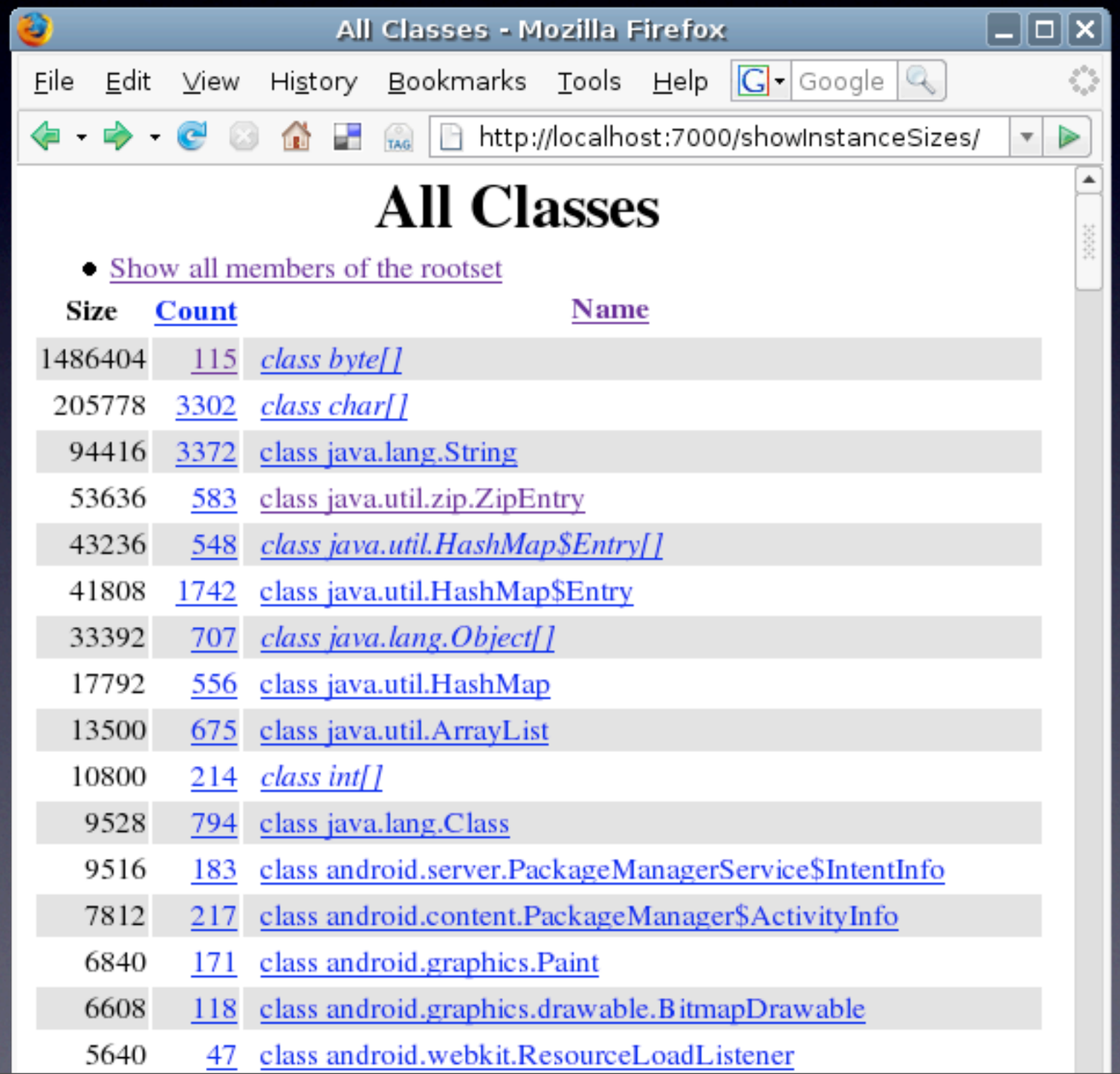
Heap Analysis Tool

- Integrated with the Dalvik VM
- Uses standard, open-source Sun formats and tools



Size	Count	Name
1486404	115	*class byte[]*
205778	3302	*class char[]*
94416	3372	class java.lang.String
53636	583	class java.util.zip.ZipEntry
43236	548	*class java.util.HashMap$Entry[]*
41808	1742	class java.util.HashMap$Entry
33392	707	*class java.lang.Object[]*
17792	556	class java.util.HashMap
13500	675	class java.util.ArrayList
10800	214	*class int[]*
9528	794	class java.lang.Class
9516	183	class android.server.PackageManagerService$IntentInfo
7812	217	class android.content.PackageManager$ActivityInfo
6840	171	class android.graphics.Paint
6608	118	class android.graphics.drawable.BitmapDrawable
5640	47	class android.webkit.ResourceLoadListener

DDMS Heap Viewer

- Provides runtime inspection of VM memory usage on a device
- Lets developers visually inspect memory layout, providing insight into memory usage and fragmentation
- Memory is presented as a Hilbert curve (a type of fractal) for a more useful visual representation than typical methods

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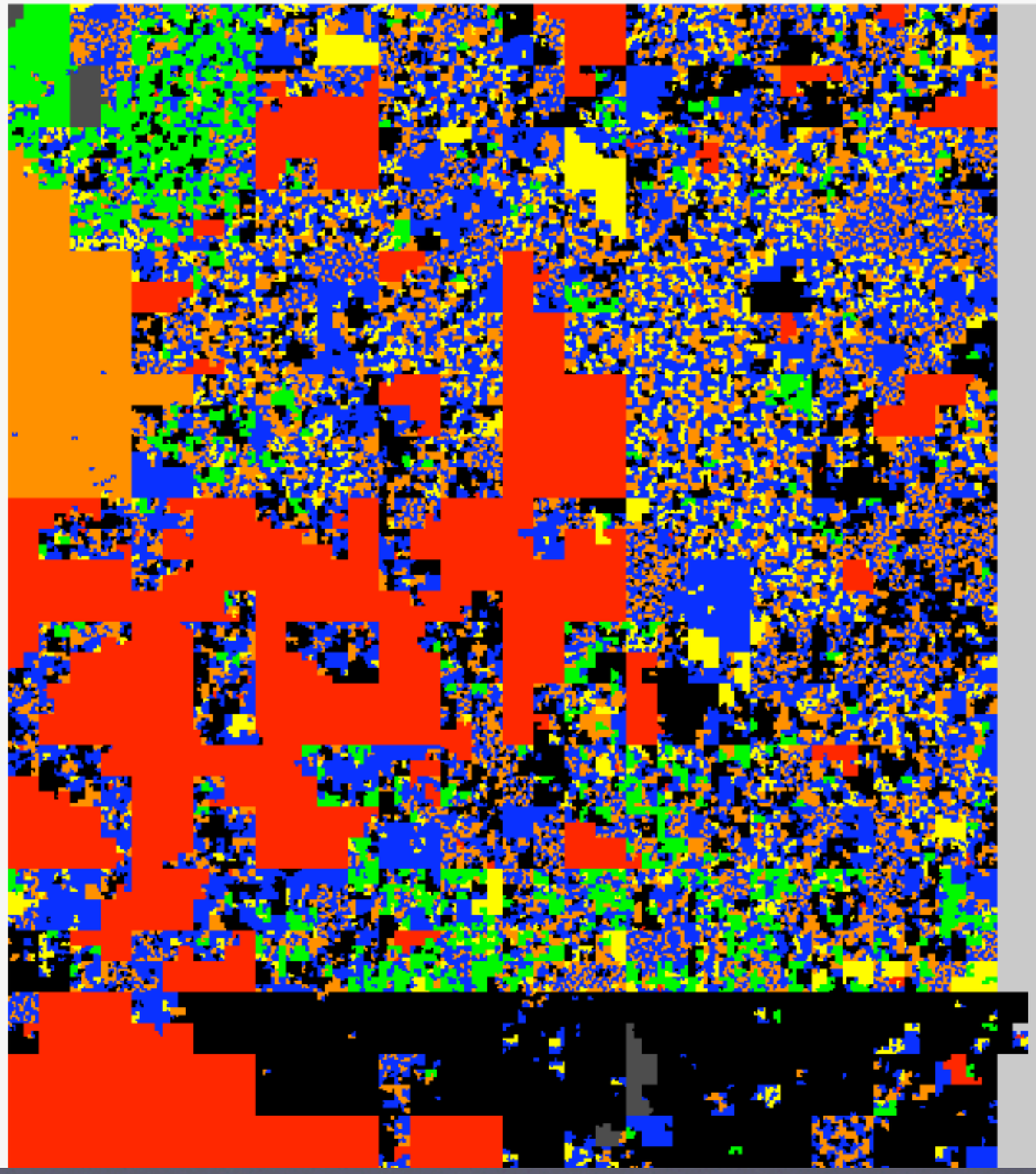
ID	Heap Size	Allocated	Free	% Used	# Objects
1	4.066MB	2.890MB	1.176MB	71.08%	25,791



Key (1 pixel = 8 bytes):

- (heap expansion area)
- free
- data object
- class object
- 1-byte array (byte[], boolean[])
- 2-byte array (short[], char[])
- 4-byte array (object[], int[], float[])
- 8-byte array (long[], double[])
- unknown object
- non-Java object

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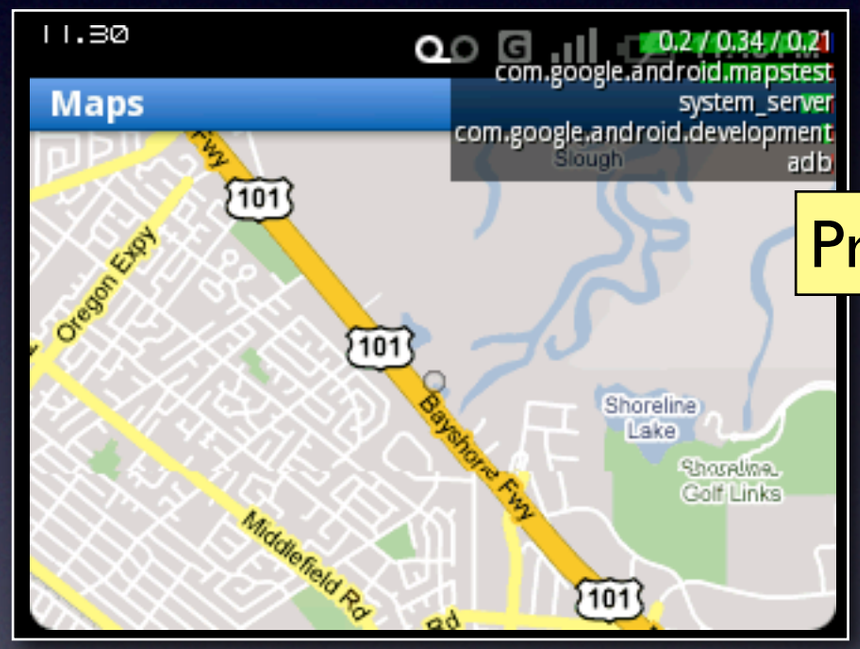
Device Debug Display

Rendering frames per second



Process summary

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Instrumentation

- Framework for driving application code with test code
  - Test code can invoke application code, simulate events, monitor results, catch exceptions, etc.
  - Test code can be downloaded
- Enables sophisticated automated testing, repeatable performance and memory analysis

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