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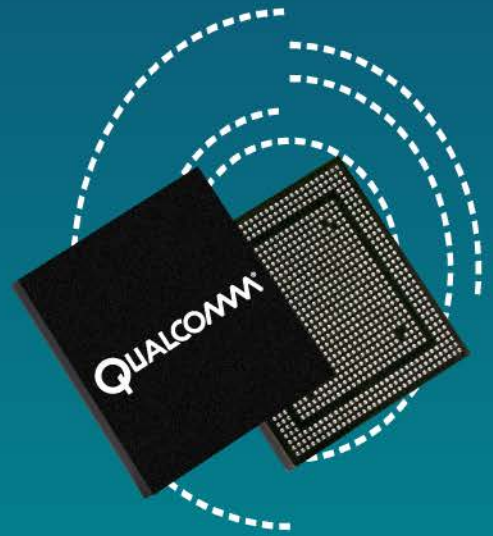

Android Memory Leak Analysis Guide

80-NJ221-1 A

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Revision History

Revision	Date	Description
A	Jul 2013	Initial release

Note: There is no Rev. I, O, Q, S, X, or Z per Mil. standards.

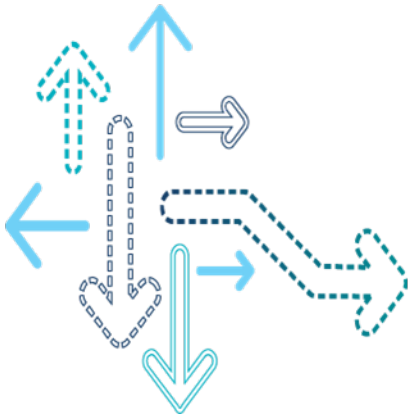
Contents

- Objectives
- What's Memory Leak?
- What's Memory Leak Dump?
- DDMS Memory Tool
- MAT(Memory Analyzer Tool)
- References
- Questions?

Objectives

- At the end of this presentation, you will understand:
  - What memory leak is.
  - What memory leak dump is and how to get it.
    - HPROF Binary Heap Dumps
    - What Garbage Collection Roots(GC roots) is
    - How to get memory leak dump for Android
  - What DDMS memory tool is and how to use it to detect memory leak.
  - What MAT is and how to use it to analyze memory leak.

What's Memory Leak



What’s Memory Leak

- In computer science, a memory leak occurs when a computer program incorrectly manages memory allocations.
- In object-oriented programming, a memory leak may happen when an object is stored in memory but cannot be accessed by the running code.

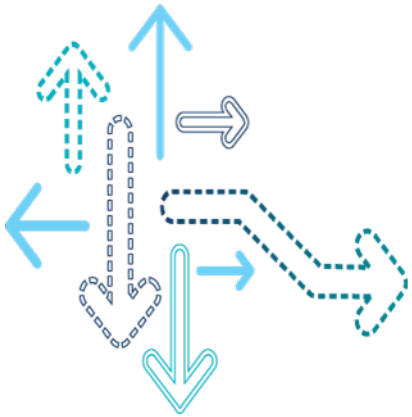
What's Memory Leak for Android

- For Android (Java), "memory leak" in your code is when you keep a reference to an object that is no longer needed. Sometimes a single reference can prevent a large set of objects from being collected as garbage.
- The memory allocated by Android application can be retrieved by the Dalvik (Android process virtual machine) after the application exits. So even the application has memory leak, after the application exits, the leaked memory also can be retrieved.

What's Memory Leak for Android

- If the Android application needs to run for a long time without exiting, or the application needs to allocate large memory, the memory leak will be a problem.
- Every Android application is running in a separate thread. And every application has the memory limitation.
- If the used memory is near the limitation, out of memory will appear, the application will be killed.
- There are two most common memory leak types.
  - The first one is a static reference to a non-static inner class, which will keep a reference to the Activity and prevent it from being GC. Upon every screen orientation change, the onCreate method will be invoked and a new MainActivity instance will be created. Due to old references, the old Activities will not be collected as garbage .
  - The second case is known as a "context leak". This case is hard to spot as the main issue lies within the application's context passed to a static class that keeps it as a field – which of course is a hard reference.

What's Memory Leak Dump



What's Memory Leak Dump

- A memory dump is a snapshot of the memory of a Java process at a certain point of time.
- There are different formats for persisting this data. Depending on the format, it may contain different pieces of information. But in general the snapshot contains information about the java objects and classes in the memory at the moment the snapshot is triggered.
- As it is just a snapshot at a given moment, a memory dump does not contain information such as when and where (in which method) an object is allocated.

HPROF Binary Heap Dumps

- Information about all loaded classes. For every class, the HPROF dump contains its name, its super-class, its class loader, the defined fields for the instances (name and type), the static fields of the class and their values.
- Information about all objects. For every object, one can find the class and the values of all fields – both references and primitive fields. The possibility to look at the names and the content of certain objects, e.g. the char[ ] within a huge StringBuilder, the size of a collection, etc. can be very helpful when performing memory analysis
- A list of GC roots.
- The call stacks of all threads.

What’s Garbage Collection Roots (GC roots)

- The Garbage Collector (GC) is responsible for removing objects that will never be accessed.
- Objects cannot be accessed if they are not reachable through any reference chain.
- The starting point of this analysis is the Garbage Collection Roots, i.e. objects that are assumed reachable by the virtual machine itself.
- Objects that are reachable from the GC roots remain in memory, objects that are not reachable are garbage collected.

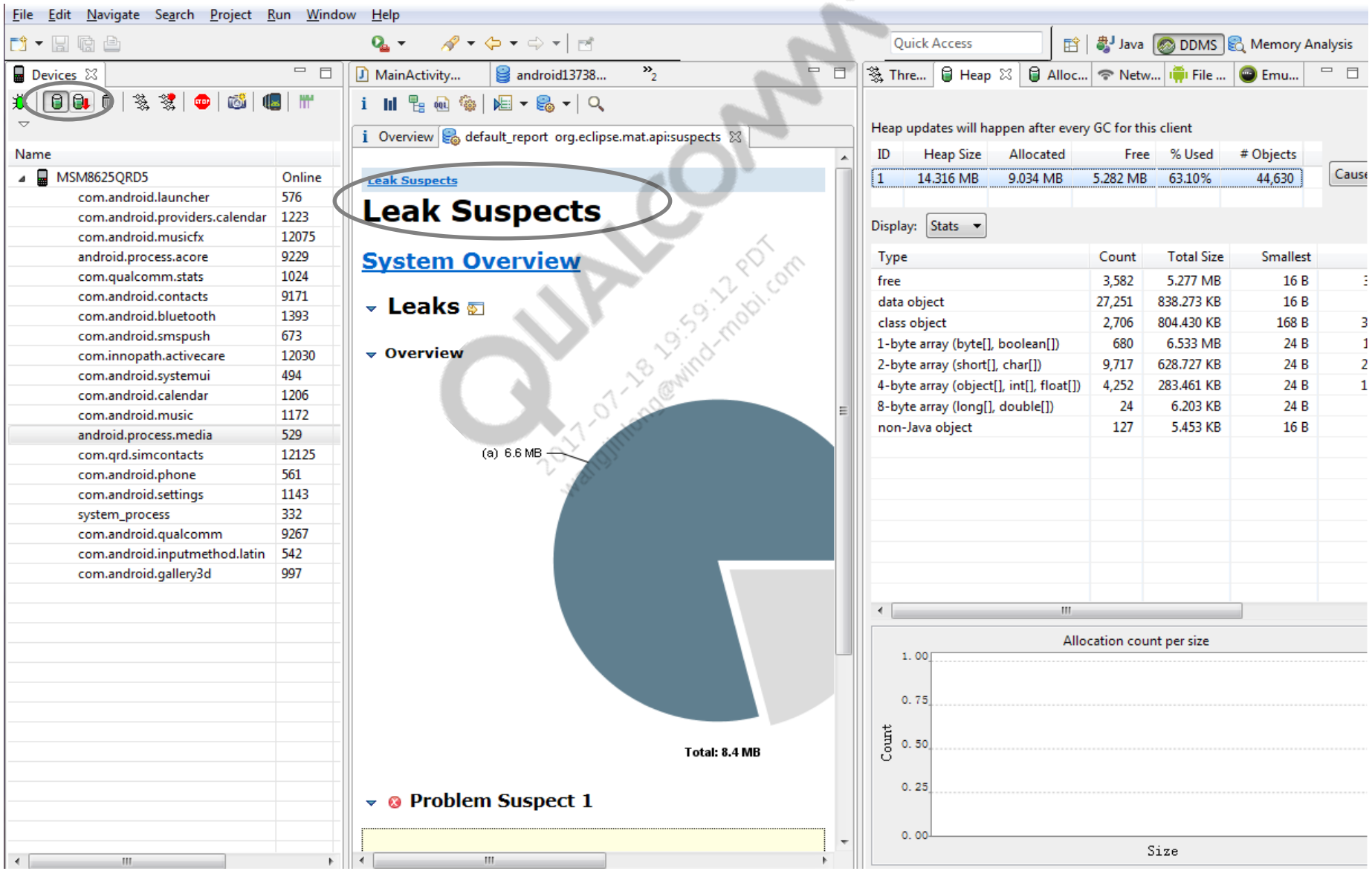
What’s Garbage Collection Roots(GC roots)

- Common GC Roots are objects on the call stack of the current thread (e.g. method parameters and local variables), the thread itself, classes loaded by the system class loader and objects kept alive due to native code.
- GC Roots are very important when determining why an object is still kept in memory: The reference chain from an arbitrary object to the GC roots (Path to GC Roots...) tells who accidentally keeps a reference.

How to Get Memory Dump?

- We can get the *.hprof (memory dump file) with one of the ways below:
  - In DDMS, select ‘Update Heap’ and ‘Dump HPROF file’ can get the *.hprof file.
  - Call the function ‘adroid.os.Debug.dumpHprofData("/data/temp/myapp.hprof");’ can save the *.hprof file to a folder in the device.
  - Dalvik VM will dump hprof file within /data/misc folder if SIGUSR1 and/or SIGQUIT signal is received. Manually send SIGUSR1 to process: kill -10 pid. (Before Android 2.3)
  - The Android provides monkey tool (random testing tool), with --hprof option will generate hprof file within /data/misc folder.
  - The folder /data/misc shall have 777 permissions.

How to Get Memory Dump?



How to Get Memory Dump?

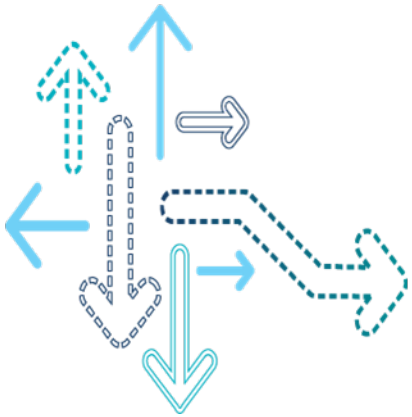
- If the *.hprof can’t be recognize by the MAT(Memory Analyzer Tool), we need to convert it as below:

  sdk\tools\hprof-conv a.hprof b.hprof

  Now the ‘b.hprof’ can be used in the MAT.

  ‘hprof-conv’ is a tool including in Android SDK.

DDMS Memory Tool



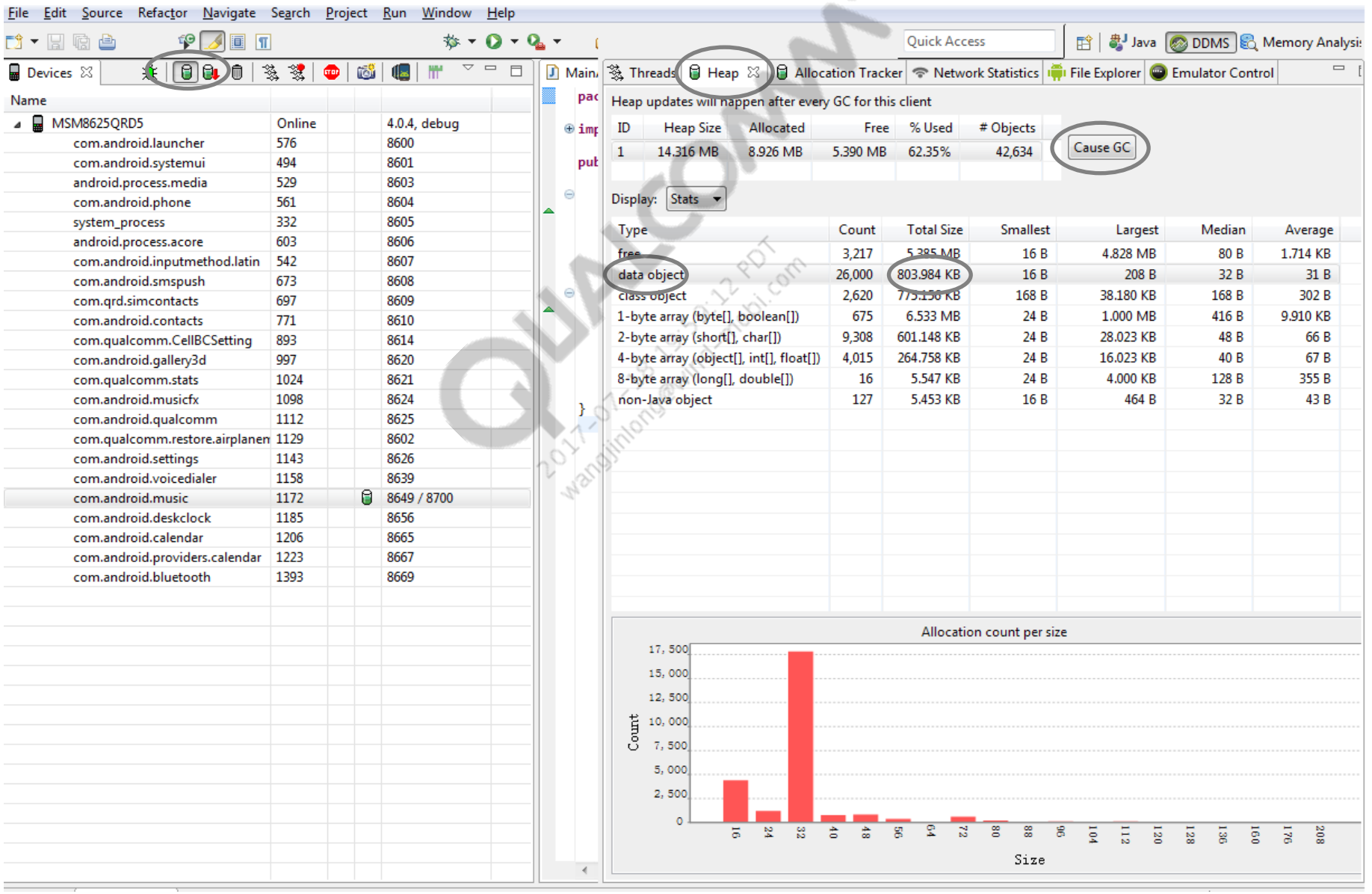
DDMS Memory Tool

- Android ships with a debugging tool called the Dalvik Debug Monitor Server (DDMS), which provides port-forwarding services, screen capture on the device, thread and heap information on the device, logcat, process, and radio state information, incoming call and SMS spoofing, location data spoofing, and more.

Viewing Heap Usage for a Process

- DDMS allows you to view how much heap memory a process is using. This information is useful in tracking heap usage at a certain point of time during the execution of your application.
- To view heap usage for a process:
  1) In the Devices tab, select the process that you want to see the heap information for.
  2) Click the **Update Heap** button to enable heap information for the process.
  3) In the Heap tab, click **Cause GC** to invoke garbage collection, which enables the collection of heap data. When the operation completes, you will see a group of object types and the memory that has been allocated for each type. You can click **Cause GC** again to refresh the data.
  4) Click on an object type in the list to see a bar graph that shows the number of objects allocated for a particular memory size in bytes.

Viewing Heap Usage for a Process



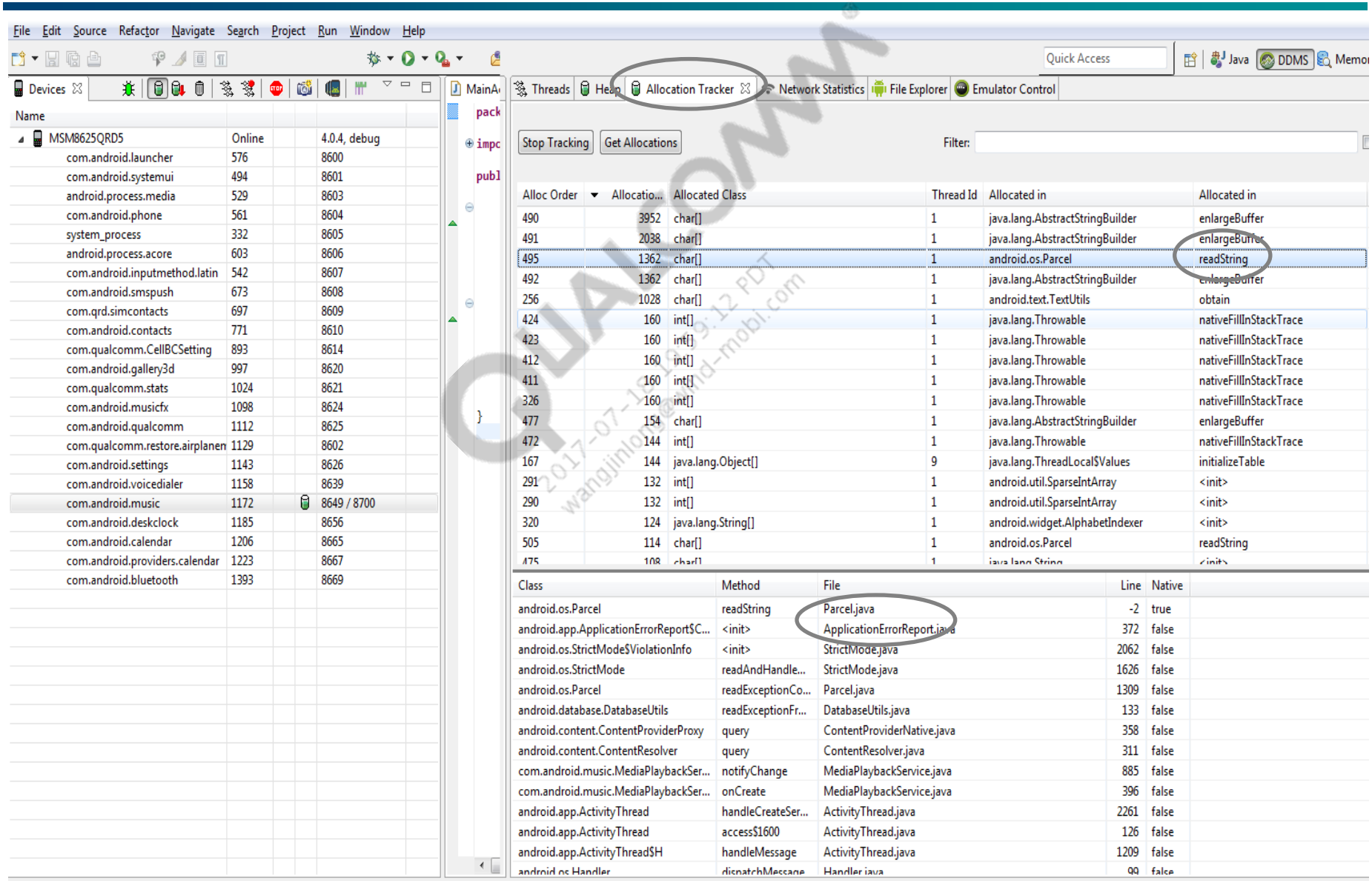
Viewing Heap Usage for a Process

- In this heap view, there is a type called ‘data object’, we should pay attention to the ‘Total Size’ of this type.
- We can make different operations in our application and check the size.
  - If there is no memory leak, the size will keep in a range.
  - If the size increases continuously, there should be memory leak.

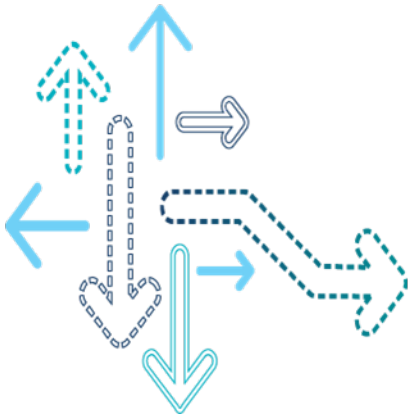
Tracking Memory Allocation of Objects

- DDMS provides a feature to track objects that are being allocated to memory and to see which classes and threads are allocating the objects. This allows you to track, in real time, where objects are being allocated when you perform certain actions in your application. This information is valuable for assessing memory usage that can affect application performance.
- To track memory allocation of objects:
  1) In the Devices tab, select the process that you want to enable allocation tracking for.
  2) In the Allocation Tracker tab, click the **Start Tracking** button to begin allocation tracking. At this point, anything you do in your application will be tracked.
  3) Click **Get Allocations** to see a list of objects that have been allocated since you clicked on the **Start Tracking** button. You can click on **Get Allocations** again to append to the list new objects that that have been allocated.
  4) To stop tracking or to clear the data and start over, click the **Stop Tracking button**.
  5) Click on a specific row in the list to see more detailed information such as the method and line number of the code that allocated the object.

Tracking Memory Allocation of Objects



MAT (Memory Analyzer Tool)



MAT (Memory Analyzer Tool)

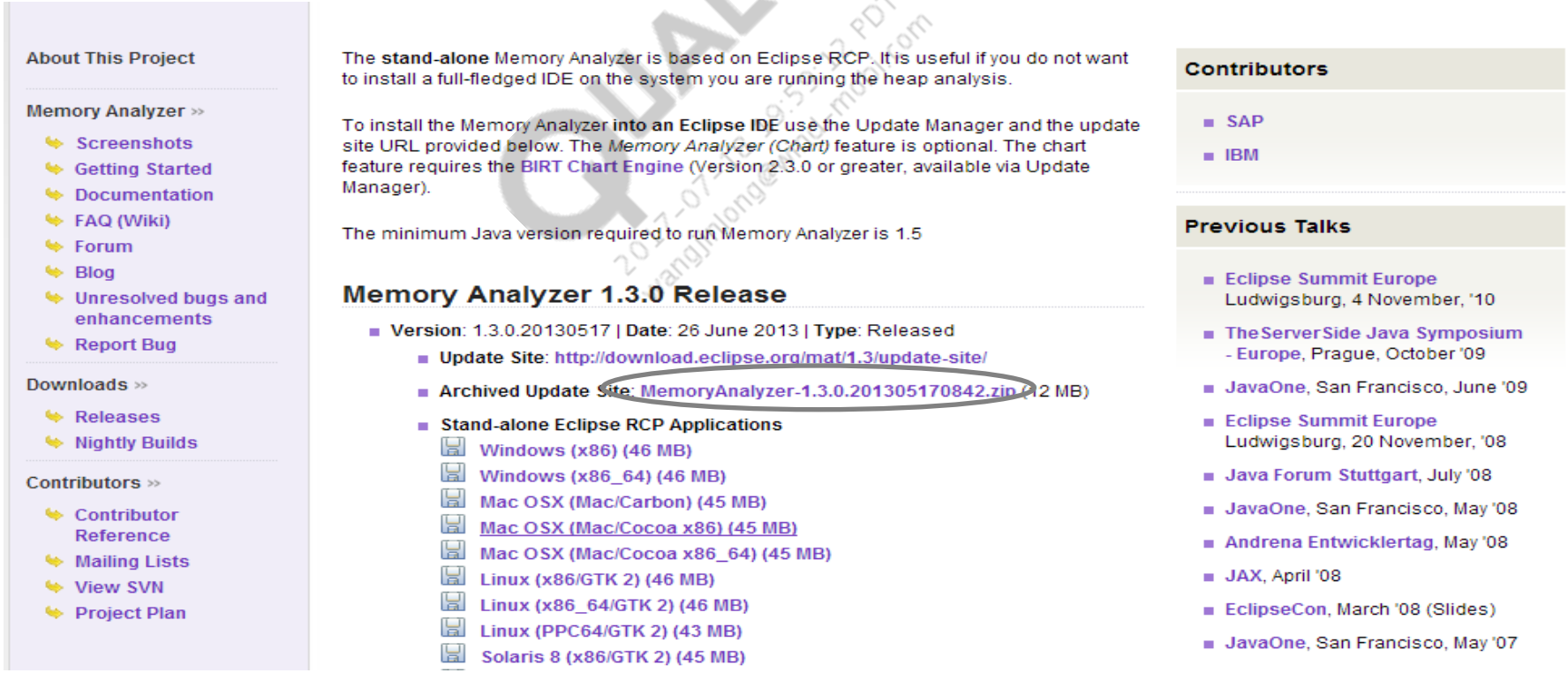
- The Eclipse Memory Analyzer Tool is a fast and feature-rich Java heap analyzer that helps you find memory leaks and reduce memory consumption.
- Use the Memory Analyzer Tool to analyze productive heap dumps with hundreds of millions of objects, quickly calculate the retained sizes of objects, see who is preventing the Garbage Collector from collecting objects, run a report to automatically extract leak suspects.
- The Dalvik virtual machine can produce a complete dump of the contents of the virtual heap. This is very useful for debugging memory usage and looking for memory leaks.

Install MAT

- We can get the MAT from below URL:

  http://www.eclipse.org/mat/

  Get the correct version and install it from eclipse.



About This Project

Memory Analyzer »
- Screenshots
- Getting Started
- Documentation
- FAQ (Wiki)
- Forum
- Blog
- Unresolved bugs and enhancements
- Report Bug

Downloads »
- Releases
- Nightly Builds

Contributors »
- Contributor Reference
- Mailing Lists
- View SVN
- Project Plan

The **stand-alone** Memory Analyzer is based on Eclipse RCP. It is useful if you do not want to install a full-fledged IDE on the system you are running the heap analysis.

To install the Memory Analyzer **into an Eclipse IDE** use the Update Manager and the update site URL provided below. The *Memory Analyzer (Chart)* feature is optional. The chart feature requires the BIRT Chart Engine (Version 2.3.0 or greater, available via Update Manager).

The minimum Java version required to run Memory Analyzer is 1.5

Memory Analyzer 1.3.0 Release

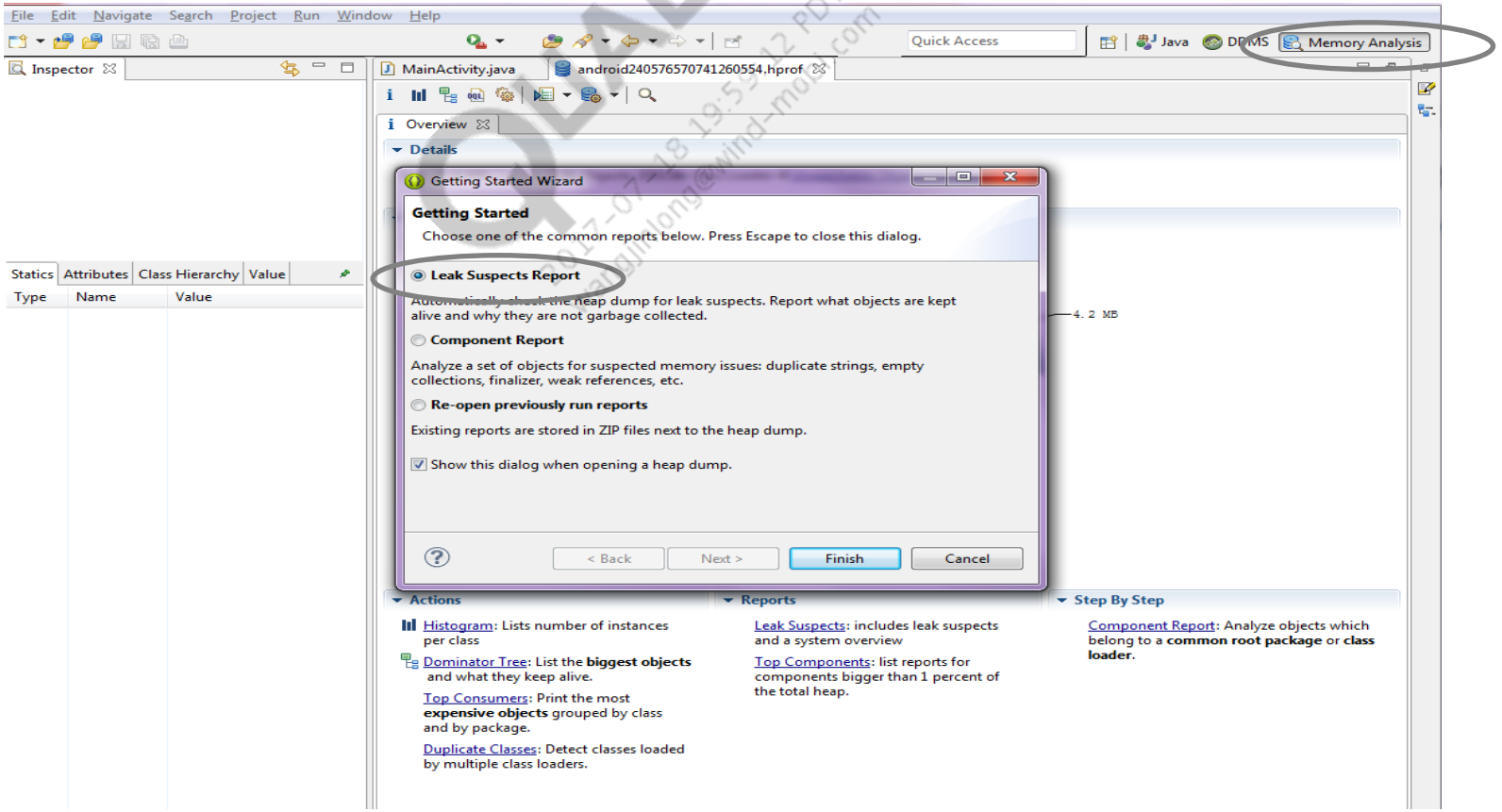
- **Version**: 1.3.0.20130517 | **Date**: 26 June 2013 | **Type**: Released
  - **Update Site**: http://download.eclipse.org/mat/1.3/update-site/
  - **Archived Update Site**: MemoryAnalyzer-1.3.0.201305170842.zip (12 MB)
  - **Stand-alone Eclipse RCP Applications**
    - Windows (x86) (46 MB)
    - Windows (x86_64) (46 MB)
    - Mac OSX (Mac/Carbon) (45 MB)
    - Mac OSX (Mac/Cocoa x86) (45 MB)
    - Mac OSX (Mac/Cocoa x86_64) (45 MB)
    - Linux (x86/GTK 2) (46 MB)
    - Linux (x86_64/GTK 2) (46 MB)
    - Linux (PPC64/GTK 2) (43 MB)
    - Solaris 8 (x86/GTK 2) (45 MB)

Contributors
- SAP
- IBM

Previous Talks
- Eclipse Summit Europe Ludwigsburg, 4 November, '10
- TheServerSide Java Symposium - Europe, Prague, October '09
- JavaOne, San Francisco, June '09
- Eclipse Summit Europe Ludwigsburg, 20 November, '08
- Java Forum Stuttgart, July '08
- JavaOne, San Francisco, May '08
- Andrena Entwicklertag, May '08
- JAX, April '08
- EclipseCon, March '08 (Slides)
- JavaOne, San Francisco, May '07

Load Dump File

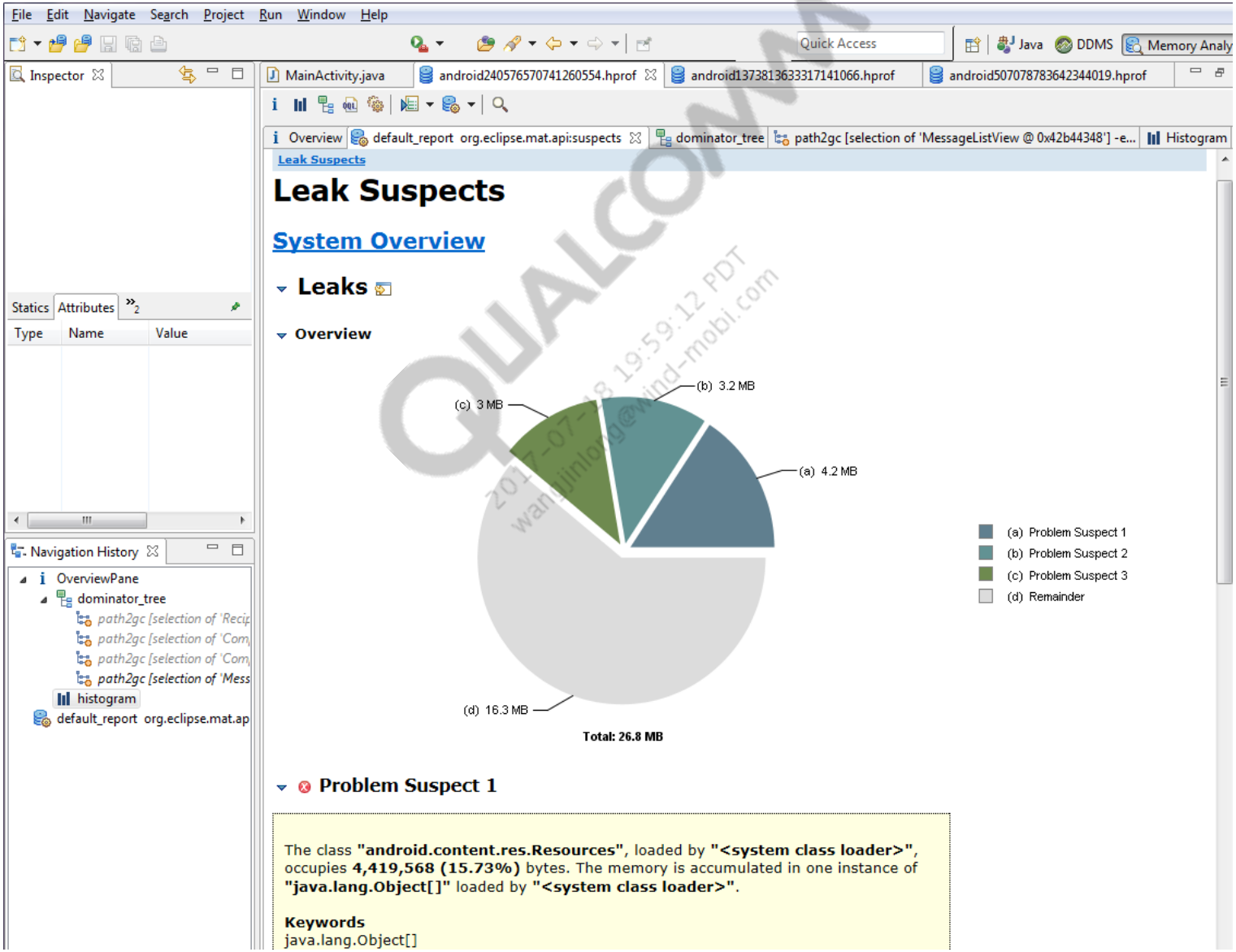
- In eclipse, select ‘Memory Analysis’ tool, select the dump file by click the menu ‘File > Open Heap Dump’, select the ‘Leak Suspects Report’ in the ‘Wizard’ dialog as below and click ‘Finish’, after a delay, the Leak Suspects report will appear.



The Leak Suspects Report

- The report will generate a graph indicating things it thinks may be memory leaks.
- Leak Suspects include leak suspects and a system overview.
- Not everything it thinks may be a leak actually is.
- What you really need to suspect is things that have multiple instances allocated or things which are using huge amounts of memory.

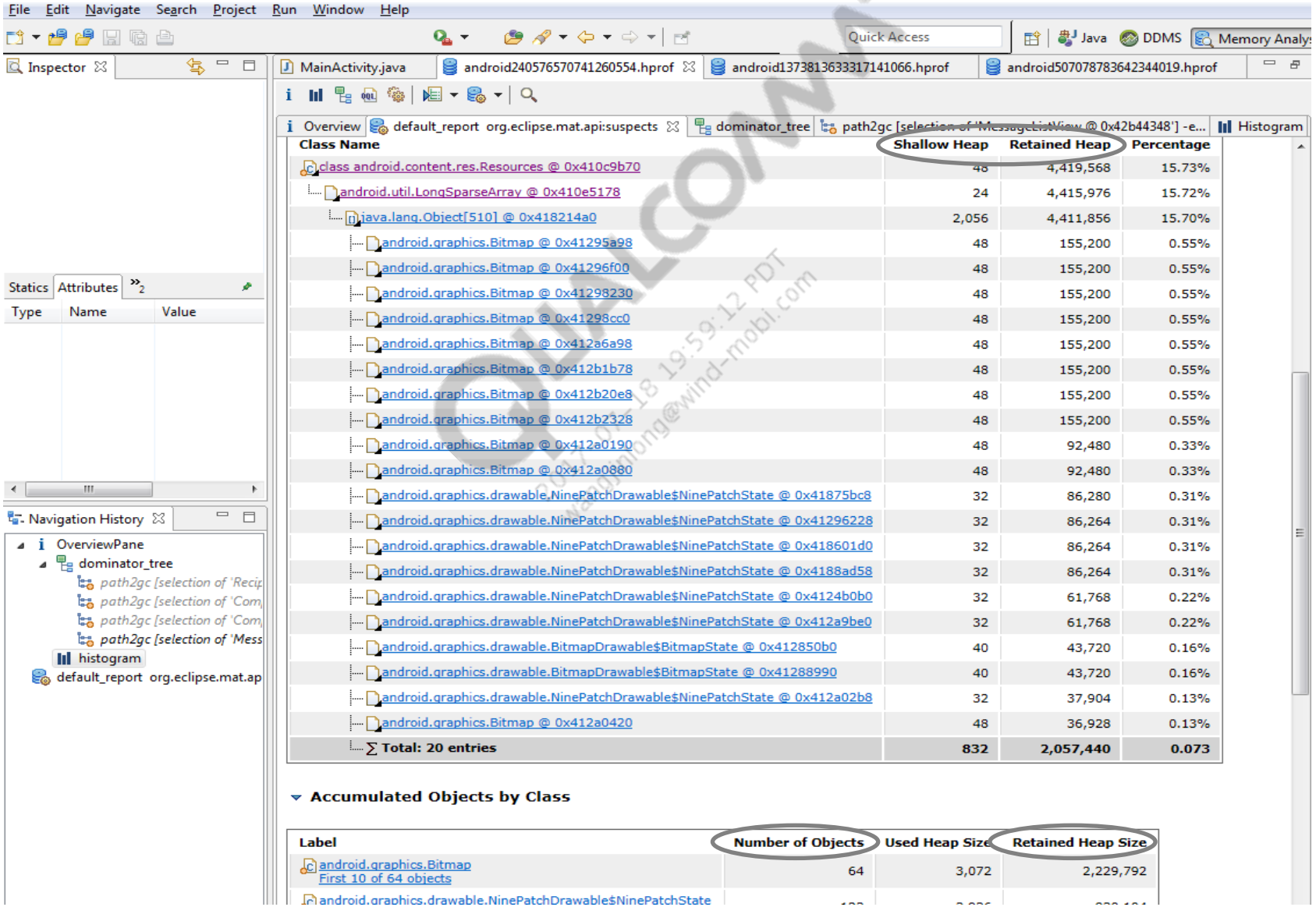
The Leak Suspects Report



The Leak Suspects Report

- Clicked on the Details link. This causes three more reports to appear: '*Shortest Paths To the Accumulation Point'*, '*Accumulated Objects'*, '*Accumulated Objects by Class'.*
- Shallow size of an object is the amount of memory allocated to store the object itself, not taking into account the referenced objects. Shallow size of a regular (non-array) object depends on the number and types of its fields. Shallow size of an array depends on the array length and the type of its elements (objects, primitive types). Shallow size of a set of objects represents the sum of shallow sizes of all objects in the set.
- Retained size of an object is its shallow size plus the shallow sizes of the objects that are accessible, directly or indirectly, only from this object. In other words, the retained size represents the amount of memory that will be freed by the garbage collector when this object is collected.

The Leak Suspects Report



Class Name	Shallow Heap	Retained Heap	Percentage
class android.content.res.Resources @ 0x410c9b70	48	4,419,568	15.73%
android.util.LongSparseArray @ 0x410e5178	24	4,415,976	15.72%
java.lang.Object[510] @ 0x418214a0	2,056	4,411,856	15.70%
android.graphics.Bitmap @ 0x41295a98	48	155,200	0.55%
android.graphics.Bitmap @ 0x41296f00	48	155,200	0.55%
android.graphics.Bitmap @ 0x41298230	48	155,200	0.55%
android.graphics.Bitmap @ 0x41298cc0	48	155,200	0.55%
android.graphics.Bitmap @ 0x412a6a98	48	155,200	0.55%
android.graphics.Bitmap @ 0x412b1b78	48	155,200	0.55%
android.graphics.Bitmap @ 0x412b20e8	48	155,200	0.55%
android.graphics.Bitmap @ 0x412b2328	48	155,200	0.55%
android.graphics.Bitmap @ 0x412a0190	48	92,480	0.33%
android.graphics.Bitmap @ 0x412a0880	48	92,480	0.33%
android.graphics.drawable.NinePatchDrawable$NinePatchState @ 0x41875bc8	32	86,280	0.31%
android.graphics.drawable.NinePatchDrawable$NinePatchState @ 0x41296228	32	86,264	0.31%
android.graphics.drawable.NinePatchDrawable$NinePatchState @ 0x418601d0	32	86,264	0.31%
android.graphics.drawable.NinePatchDrawable$NinePatchState @ 0x4188ad58	32	86,264	0.31%
android.graphics.drawable.NinePatchDrawable$NinePatchState @ 0x4124b0b0	32	61,768	0.22%
android.graphics.drawable.NinePatchDrawable$NinePatchState @ 0x412a9be0	32	61,768	0.22%
android.graphics.drawable.BitmapDrawable$BitmapState @ 0x412850b0	40	43,720	0.16%
android.graphics.drawable.BitmapDrawable$BitmapState @ 0x41288990	40	43,720	0.16%
android.graphics.drawable.NinePatchDrawable$NinePatchState @ 0x412a02b8	32	37,904	0.13%
android.graphics.Bitmap @ 0x412a0420	48	36,928	0.13%
Σ Total: 20 entries	832	2,057,440	0.073

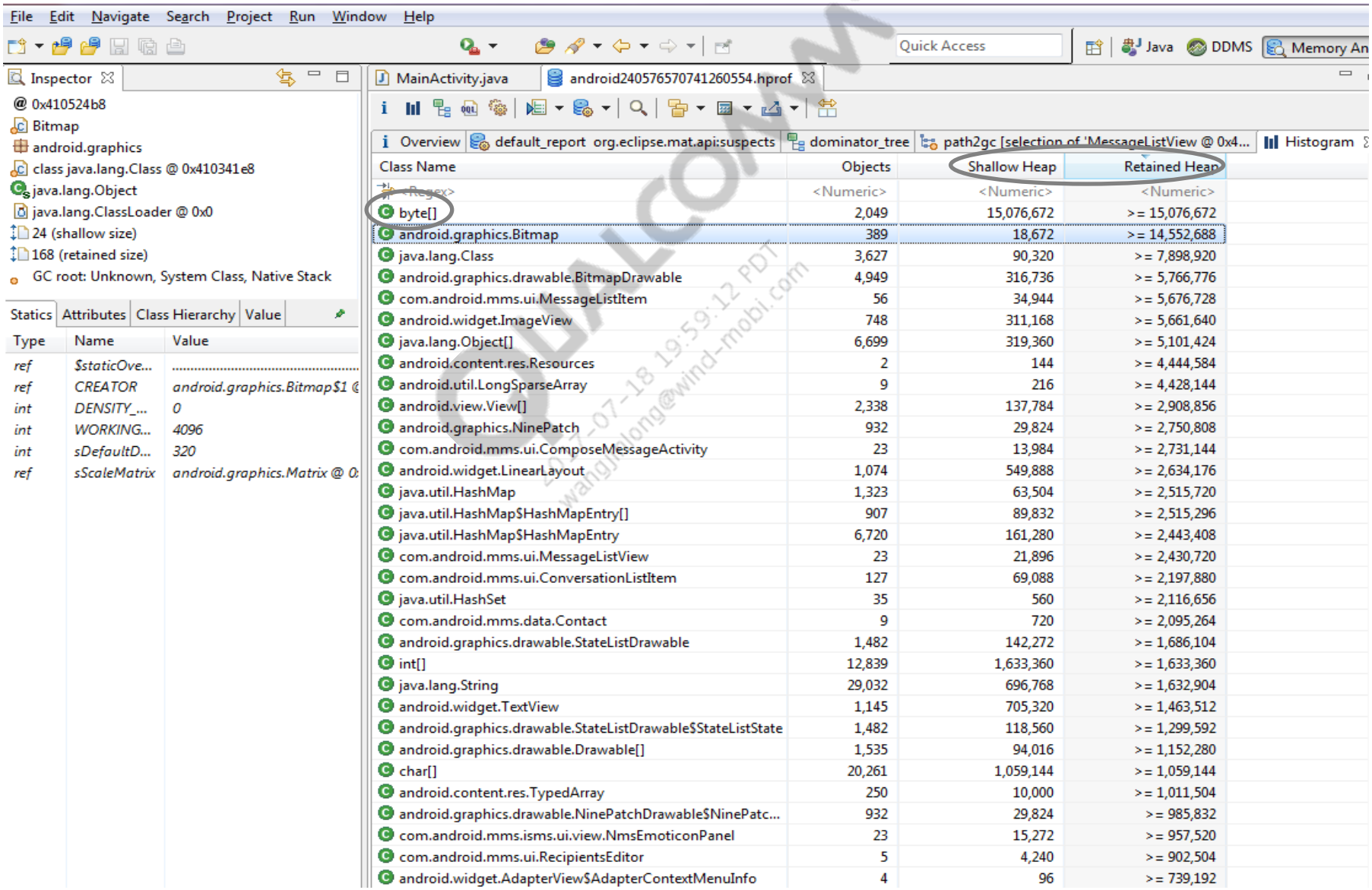
Accumulated Objects by Class

Label	Number of Objects	Used Heap Size	Retained Heap Size
android.graphics.Bitmap First 10 of 64 objects	64	3,072	2,229,792
android.graphics.drawable.NinePatchDrawable$NinePatchState			

Histogram View

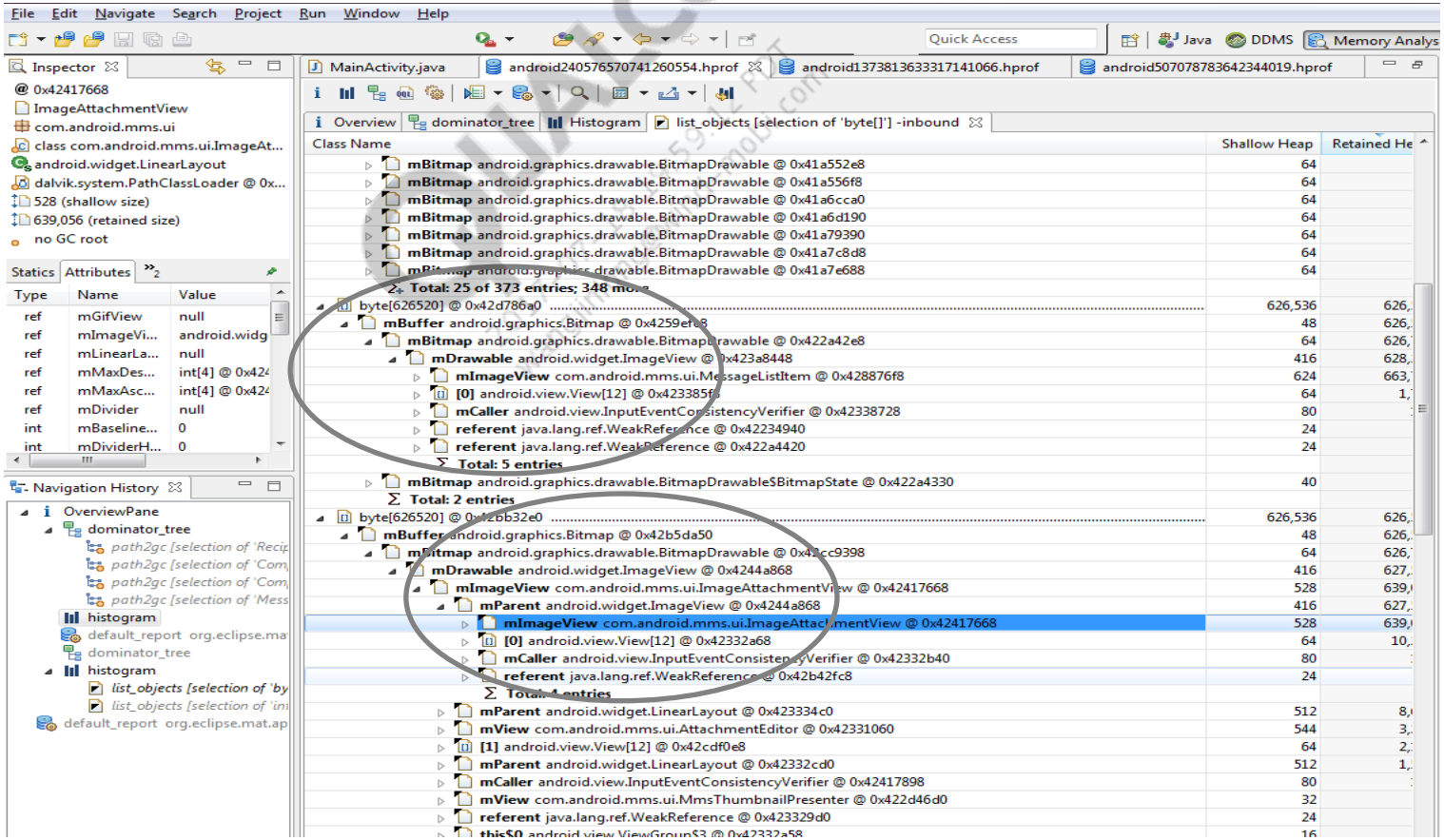
- Analyze the results using the Histogram view.
- Histogram lists number of instances per class.
  - Identifies types of objects allocated.
  - Doesn't know whether they will eventually be freed.
  - We must compare two HPROF snapshots to identify which objects are responsible for a leak.

Histogram View



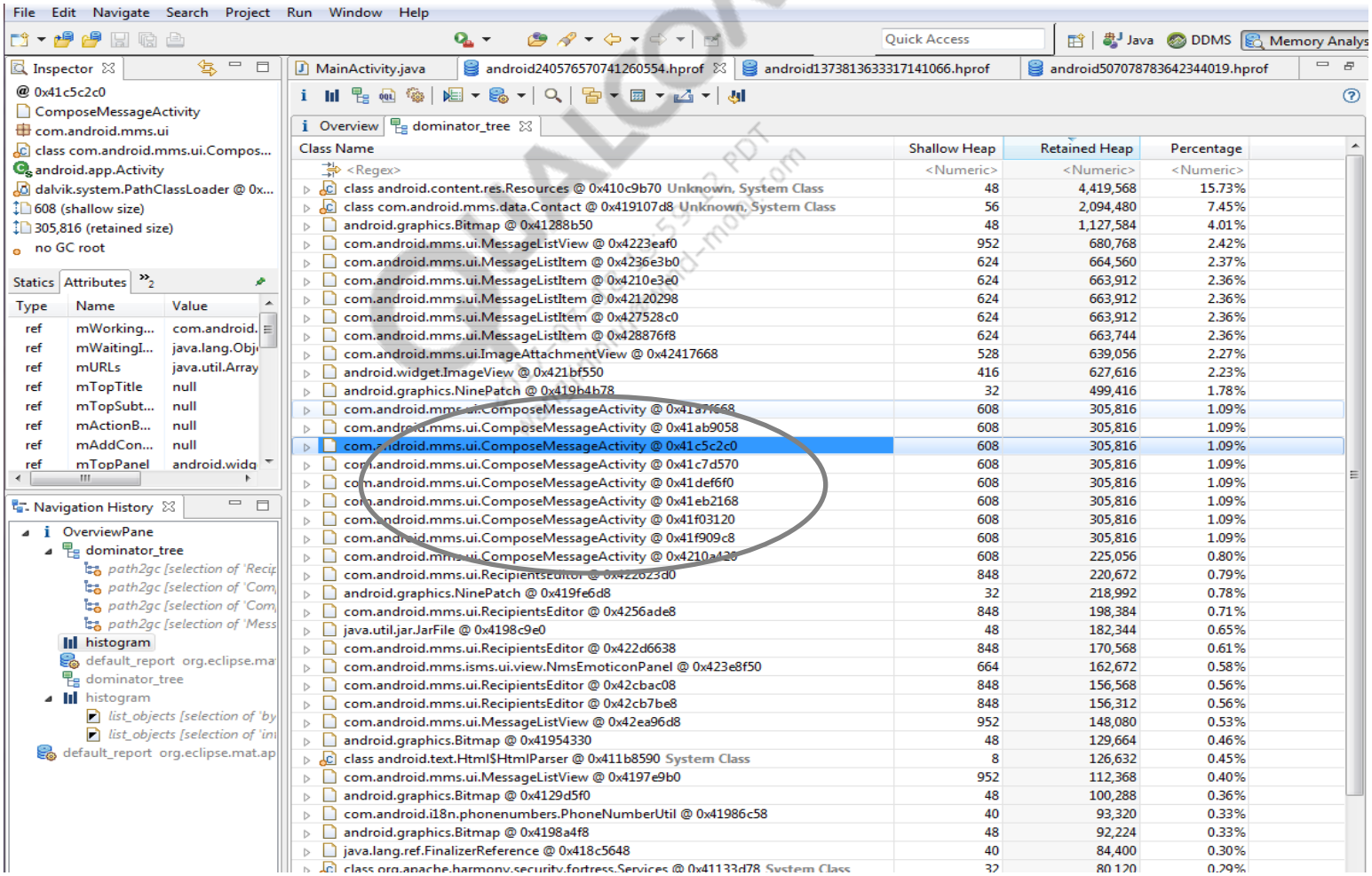
Histogram View

- The ‘byte[ ]’ costs most of the heap, so right click on it and select ‘List Objects > with incoming references’, from this, we can find which object the data belong to.



Dominator Tree

- Dominator Tree will list the biggest objects and what they keep alive.



Dominator Tree

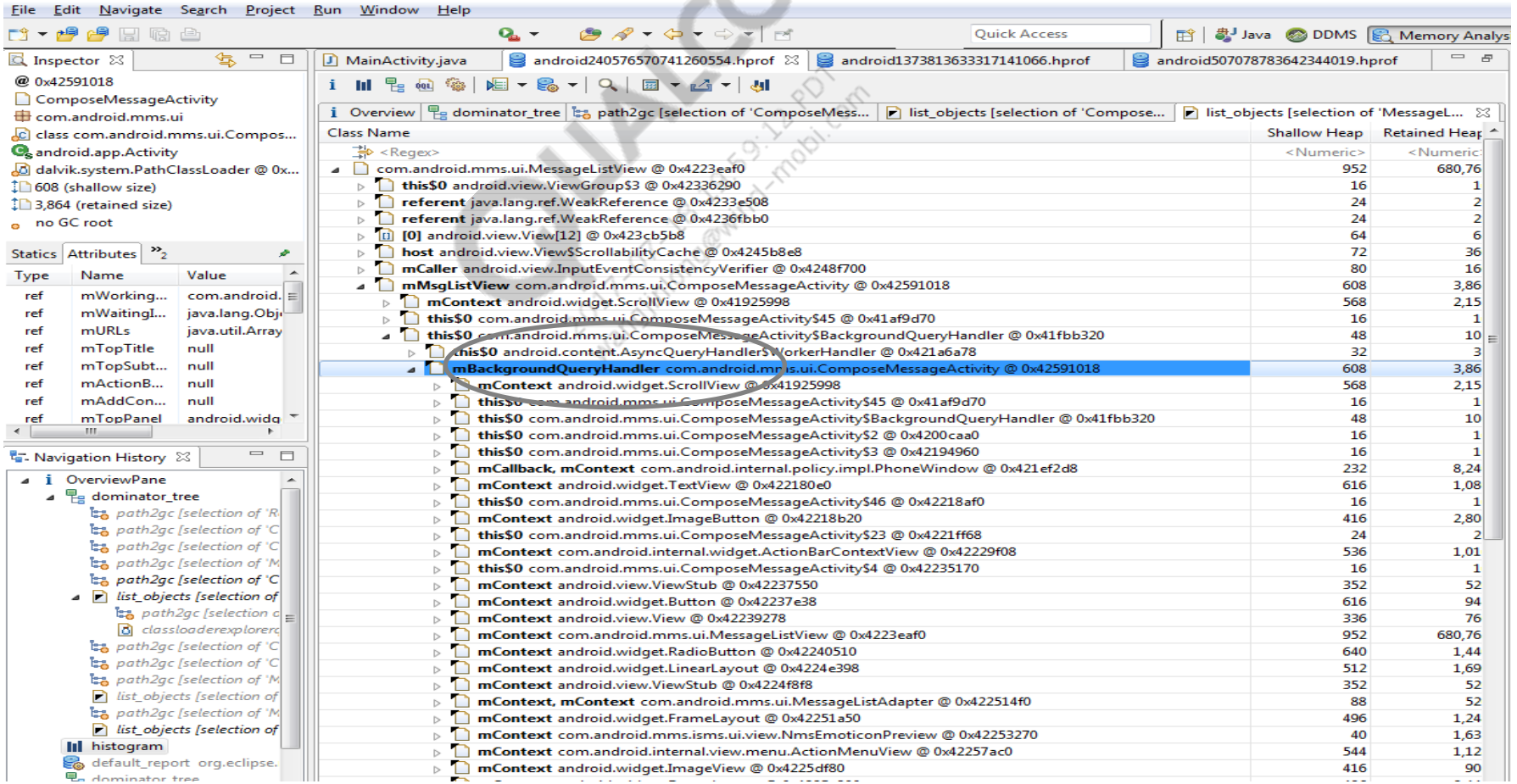
- From this list we can find potential leaked object, so many instances of ‘ComposeMessageActivity’ for this case, it’s abnormal.
- Right click on it and select:
  - List Objects > with incoming references: Shows objects that have an incoming reference to the selected object. If there is a class that has many unwanted instances it is good practice to find incoming references that are keeping it from being GC.
  - Path To GC Roots > exclude weak/soft references: Shows the reference path from the object to GC roots excluding weak/soft references
  - Merge Shortest Paths to GC Roots – Finds the common paths from garbage collection roots to an object or a set of objects.

Dominator Tree

- Right click on it and select:
  - Show Retained Set - Calculates the retained set of an arbitrary set of objects.
  - Java Basics > Class Loader Explorer: Show the defined classes and the number of live instances. If one and the same component is loaded multiple times, the number of live instances can indicate which class loaders is more alive and which one should be garbage collected

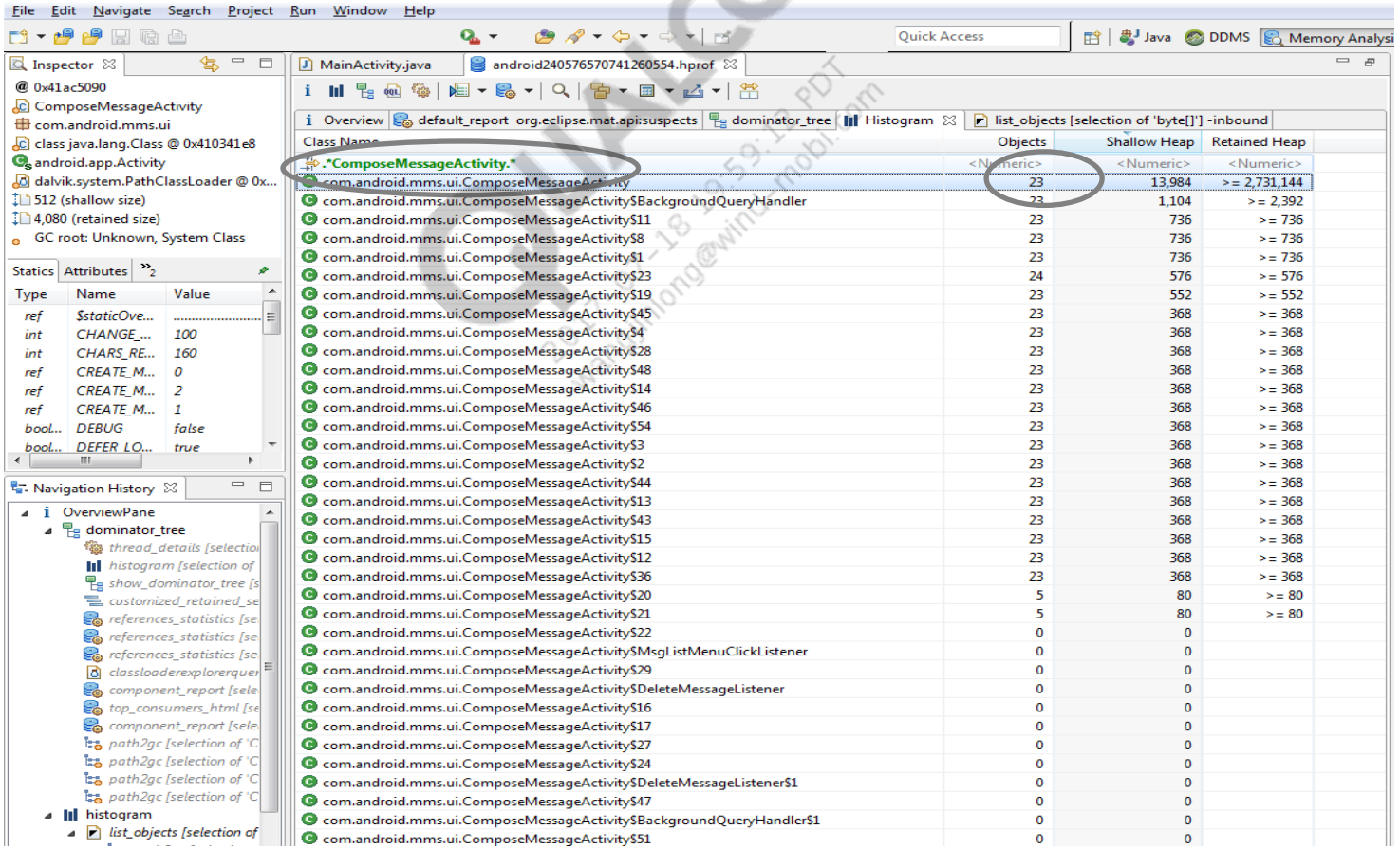
What to Do?

- Perhaps it's because the 'mBackgroundQueryHandler' hasn't be released before this activity is finished which cause this activity can't be released.



What to Do?

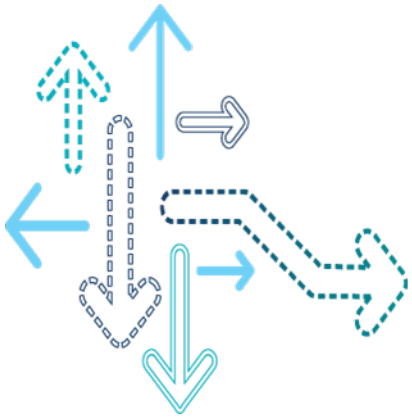
- Use the Regex filter to find ‘ComposeMessageActivity’ objects inside the Histogram view. There are 23 instances of ‘ComposeMessageActivity’.



What to Do?

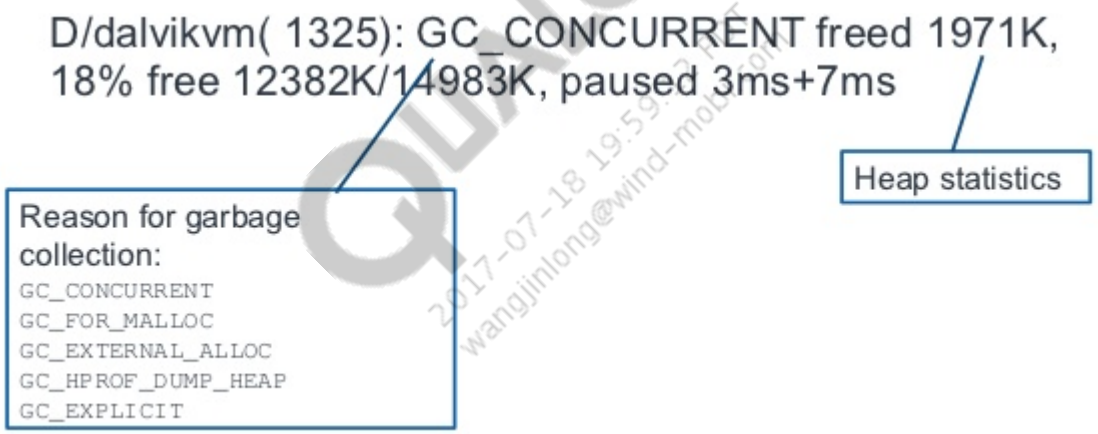
- What we can do now is just check the related code to see if there are any bugs.
- Refer to [R5] for Android Memory Leaks and the solutions.
- To avoid context-related memory leaks, remember the followings:
  - Do not keep long-lived references to a context-activity (a reference to an activity should have the same life cycle as the activity itself)
  - Try using the context-application instead of a context-activity
  - Avoid non-static inner classes in an activity if you don't control their life cycle, use a static inner class and make a weak reference to the activity inside.
  - A garbage collector is not an insurance against memory leaks.

Detecting a Memory Leak



Check the logcat Output Message

- Your application crashes with an ‘Out of memory’ error after running for a long time.
- You can see frequent GC_ lines in logcat before the crash.



Check the logcat Output Message

- Out of memory message from the logcat output:

I/dalvikvm-heap(3088): Clamp target GC heap from 103.616MB to 96.000MB

D/dalvikvm(3088): GC_CONCURRENT freed 165K, 1% free 97769K/98148K, paused 7ms+80ms, total 483ms

D/dalvikvm(3088): WAIT_FOR_CONCURRENT_GC blocked 147ms

I/dalvikvm-heap(3088): Forcing collection of SoftReferences for 376296-byte allocation

I/dalvikvm-heap(3088): Clamp target GC heap from 103.600MB to 96.000MB

D/dalvikvm(3088): GC_BEFORE_OOM freed 16K, 1% free 97753K/98148K, paused 392ms, total 392ms

E/dalvikvm-heap(3088): Out of memory on a 376296-byte allocation

Check the logcat Output Message

D/dalvikvm(3088): GC_CONCURRENT freed 165K, 1% free 97769K/98148K, paused 7ms+80ms, total 483ms

The first part of message indicates the type of GC (reason of GC). There are four different types:

GC_CONCURRENT	Invoked when the heap gets too large to prevent overflow.
GC_FOR_MALLOC	Invoked when GC_CONCURENT was not run on time and the application had to allocate more memory.
GC_EXTERNAL_ALLOC	Used before Honeycomb for freeing external allocated memory. In Honeycomb and higher there is no external allocation.
GC_EXPLICIT	Invoked when System.gc is called.

Check the logcat Output Message

D/dalvikvm(3088): GC_CONCURRENT freed 165K, 1% free 97769K/98148K, paused 7ms+80ms, total 483ms

- "freed 165K" – indicates how much memory is freed.
- "1% free 97769K/98148K" – indicates the percentage of free memory left, the size of live objects and the total heap size.
- "paused 7ms+80ms" – indicates how much time it takes the GC to finish collection.

With this information, it is possible to tell after a few collections if the GC successfully frees the memory. If the allocated memory does not go down after some period of time (and keeps growing), it is clear that there is a memory leak.

Check the logcat Output Message

E/dalvikvm-heap(3088): Out of memory on a 376296-byte allocation

When the available resources are exhausted, an OutOfMemoryError exception is thrown. It may indicate that there is a memory leak. This method is not the best way to know if there is a leak as the exception may occur when the developer tries to allocate a large amount of memory (ex. bitmap) and the total heap size will exceed the platform limit. It surely indicates that the developer should rethink his memory management method.

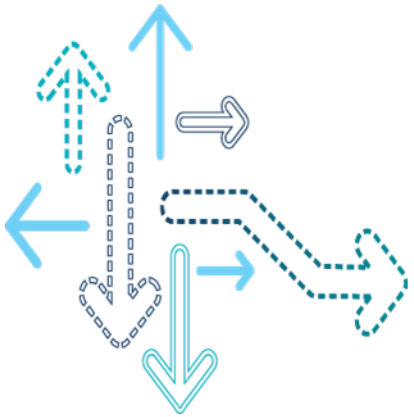
Comparing Heap Dumps with MAT

- When debugging memory leaks, sometimes it's useful to compare the heap state at two different points in time. To do this, you'll need to:
  - Create two separate HPROF files (don't forget to convert them using hprof-conv).
  - Open the first HPROF file (using File > Open Heap Dump).
  - Open the Histogram view.
  - In the Navigation History view (use Window > Navigation History if it's not visible), right click on histogram and select Add to Compare Basket.
  - Open the second HPROF file and repeat steps 2 and 3.
  - Switch to the Compare Basket view, and click Compare the Results (the red "!" icon in the top right corner of the view).

Comparing Heap Dumps with MAT

- Compare the number of instances and sizes of each type of object between the two snapshots.
- An unexplained increase in the number of objects may indicate a leak!

Useful Information



ServiceConnection Leak

- Usually ServiceConnection leak is caused by client try to bind to service but the service still not ready. For example, the service hasn't been started or the service can't be started successfully.

```
06-13 10:23:15.672 W/ActivityManager(  654): Unable to start service Intent { act=com.zte.zgesture.IGestureService }: not found
06-13 10:23:15.762 E/ActivityThread( 1009): Activity com.android.phone.InCallScreen has leaked ServiceConnection android.view.ViewRootGestureDispatcher$1@41e2e730
that was originally bound here
06-13 10:23:15.762 E/ActivityThread( 1009): android.app.ServiceConnectionLeaked: Activity com.android.phone.InCallScreen has leaked ServiceConnection
android.view.ViewRootGestureDispatcher$1@41e2e730 that was originally bound here
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.app.LoadedApk$ServiceDispatcher.<init>(LoadedApk.java:969)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.app.LoadedApk.getServiceDispatcher(LoadedApk.java:863
)06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.app.ContextImpl.bindService(ContextImpl.java:1263)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.app.ContextImpl.bindService(ContextImpl.java:1255)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.content.ContextWrapper.bindService(ContextWrapper.java:394)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.view.ViewRootGestureDispatcher.<init>(ViewRootGestureDispatcher.java:32)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.view.ViewRootImpl.<init>(ViewRootImpl.java:415)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.view.WindowManagerImpl.addView(WindowManagerImpl.java:300)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.view.WindowManagerImpl.addView(WindowManagerImpl.java:232)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.view.WindowManagerImpl$CompatModeWrapper.addView(WindowManagerImpl.java:149)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.view.Window$LocalWindowManager.addView(Window.java:547)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.app.ActivityThread.handleResumeActivity(ActivityThread.java:2641)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.app.ActivityThread.handleLaunchActivity(ActivityThread.java:2092)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.app.ActivityThread.access$600(ActivityThread.java:133)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.app.ActivityThread$H.handleMessage(ActivityThread.java:1198)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.os.Handler.dispatchMessage(Handler.java:99)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.os.Looper.loop(Looper.java:137)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at android.app.ActivityThread.main(ActivityThread.java:4777)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at java.lang.reflect.Method.invokeNative(Native Method)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at java.lang.reflect.Method.invoke(Method.java:511)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at com.android.internal.os.ZygoteInit$MethodAndArgsCaller.run(ZygoteInit.java:789)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at com.android.internal.os.ZygoteInit.main(ZygoteInit.java:556)
06-13 10:23:15.762 E/ActivityThread( 1009):                 at dalvik.system.NativeStart.main(Native Method)
06-13 10:23:15.762 W/ActivityManager(  654): Unbind failed: could not find connection for android.os.BinderProxy@42127e18
```

StrictMode

- Enable ‘StrictMode’ also can find some object leak.
- Please refer to [R10] for more information about ‘StrictMode’

References

Ref.	Document	
Qualcomm Technologies		
Q1	*Application Note: Software Glossary for Customers*	CL93-V3077-1
Resources		
R1	http://memoryanalyzer.blogspot.com/	Memory Analyzer Blog
R2	http://developer.android.com/tools/debugging/ddms.html	Using DDMS
R3	http://www.eclipse.org/mat/	Memory Analyzer Tool (MAT)
R4	http://milk.com/kodebase/dalvik-docs-mirror/docs/heap-profiling.html	Dalvik Heap Profiling
R5	http://blog.evendanan.net/2013/02/Android-Memory-Leaks-OR-Different-Ways-to-Leak	Android Memory Leak
R6	http://www.youtube.com/watch?v=_CruQY55HOk	Google I/O 2011: Memory management for Android Apps
R7	http://www.yourkit.com/docs/90/help/sizes.jsp	Shallow and retained sizes
R8	http://kohlerm.blogspot.com/2009/07/eclipse-memory-analyzer-10-useful.html	Eclipse Memory Analyzer, 10 useful tips/articles
R9	http://developer.samsung.com/android/technical-docs/Memory-Profiler-Identifying-Potential-Problems	Memory Profiler - Identifying Potential Problems
R10	http://developer.android.com/reference/android/os/StrictMode.html	Strict Mode

References

Ref.	Document	
Resources		
R11	http://help.eclipse.org/indigo/index.jsp?topic=%2Forg.eclipse.mat.ui.help%2Fconcepts%2Fheapdump.html	Memory Analyzer Online Help

Questions?

https://support.cdmatech.com