Putting Your App on a Memory Diet

The Problem You Are Thinking Of

```
E/AndroidRuntime(2065): FATAL EXCEPTION: main
E/AndroidRuntime(2065): java.lang.OutOfMemoryError
E/AndroidRuntime(2065):     at android.graphics.Bitmap.nativeCreate(Native Method)
E/AndroidRuntime(2065):     at android.graphics.Bitmap.createBitmap(Bitmap.java:605)
E/AndroidRuntime(2065):     at android.graphics.Bitmap.createBitmap(Bitmap.java:551)
E/AndroidRuntime(2065):     at android.graphics.Bitmap.createScaledBitmap(Bitmap.java:437)
E/AndroidRuntime(2065):     at android.graphics.BitmapFactory.finishDecode(BitmapFactory.java:618)
E/AndroidRuntime(2065):     at android.graphics.BitmapFactory.decodeStream(BitmapFactory.java:593)
E/AndroidRuntime(2065):     at
android.graphics.BitmapFactory.decodeResourceStream(BitmapFactory.java:445)
E/AndroidRuntime(2065):     at
android.graphics.BitmapFactory.decodeResource(BitmapFactory.java:468)
...
```

The Problem You Are Not Thinking Of

- System RAM
  - The bigger your app, the more likely it is to get kicked out of RAM once it moves to the background
  - Rationale: the bigger they are, the bigger the benefit for getting rid of 'em
  - Converse: the smaller your footprint, the longer you'll live, and the better your multitasking will work

Root Cause #1: Limited Heap Size

- Originally 16MB
  - (no, that's not a typo)
- Varies by Device
  - OS level
  - Screen resolution
- Not Directly Controllable by App
  - ...though we will discuss some indirect controls

The Green Mantra

- Reduce
  - Consume less of the resource in the first place
  - Example: bulk consumer packaging
- Reuse
  - Apply the resource to another problem when done with the first
  - Example: shipping eBay sale using Amazon box
- Recycle
  - Return resource to the manufacturing stream
  - Example: consumer paper, plastic recycling programs

The #A4C739 Mantra

- Reduce
- **Reorder**
  - When you allocate has impacts on what you can allocate
- Reuse
- Recycle

The #A4C739 Mantra

- **Reckon**
  - The first step on the road to recovery is to admit that you have a problem... then measure it
- Reduce
- Reorder
- Reuse
- Recycle

The #A4C739 Mantra

- Reckon
- Reduce
- Reorder
- Reuse
- Recycle
- **Cheat**

Android Memory: Reckon

Reckon: System RAM

- Why Do We Care?
  - Lower system RAM usage = somewhat less likely for Android to terminate our process
  - Improves multitasking for users

Reckon: System RAM

- What Can We Do About It?
  - GC!
    - Dalvik allocates space for our heap from system RAM on a page-by-page basis
    - Dalvik will release those pages if we allow lots of data to be garbage-collected
  - Less code (DEX, .so)
  - Stop cheatin'

Reckon: System RAM

- Process Stats
  - Available in Android 4.4
  - Gives you average, peak PSS over period
    - Proportional Set Size = how much system RAM to blame your process for
  - Also shows how much time your process ran, how much time services in that process ran

Reckon: System RAM

- procstats
  - Same backing data as Process Stats, but with command-line goodness
- meminfo
  - Available on older versions of Android
  - PSS per process, grouped by importance

```
mmurphy@xps-1502x:/tmp$ adb shell dumpsys procstats --hours 3
AGGREGATED OVER LAST 3 HOURS:
  * com.android.nfc / 1027:
           TOTAL: 100% (7.9MB-8.0MB-8.1MB/7.3MB-7.4MB-7.4MB over 6)
      Persistent: 100% (7.9MB-8.0MB-8.1MB/7.3MB-7.4MB-7.4MB over 6)
  * com.google.process.location / u0a23:
           TOTAL: 100% (14MB-14MB-14MB/12MB-12MB-12MB over 7)
         Imp Fg: 100% (14MB-14MB-14MB/12MB-12MB-12MB over 7)
  * system / 1000:
           TOTAL: 100% (58MB-66MB-74MB/54MB-62MB-69MB over 6)
      Persistent: 100% (58MB-66MB-74MB/54MB-62MB-69MB over 6)
  * com.android.vending / u0a50:
           TOTAL: 100% (16MB-41MB-56MB/15MB-39MB-53MB over 7)
             Top: 2.1% (56MB-56MB-56MB/53MB-53MB-53MB over 1)
          Imp Bg: 0.16%
         Service: 98% (16MB-38MB-50MB/15MB-36MB-47MB over 6)
  * tunein.player.pro / u0a97:
           TOTAL: 100% (8.4MB-8.4MB-8.4MB/7.6MB-7.6MB-7.6MB over 6)
         Service: 100% (8.4MB-8.4MB-8.4MB/7.6MB-7.6MB-7.6MB over 6)
  * com.espn.radio:com.urbanairship.process / u0a142:
           TOTAL: 100% (6.3MB-6.3MB-6.3MB/5.5MB-5.6MB-5.6MB over 6)
         Service: 100% (6.3MB-6.3MB-6.3MB/5.5MB-5.6MB-5.6MB over 6)
  * com.amblingbooks.bookplayerpro / u0a84:
           TOTAL: 100% (12MB-12MB-12MB/11MB-11MB-11MB over 7)
          Imp Fg: 100% (12MB-12MB-12MB/11MB-11MB-11MB over 7)
  * com.fsck.k9 / u0a128:
           TOTAL: 100% (49MB-53MB-69MB/45MB-49MB-64MB over 5)
             Top: 2.0% (69MB-69MB-69MB/64MB-64MB-64MB over 1)
         Service: 98% (49MB-50MB-51MB/45MB-45MB-46MB over 4)
  * com.evernote / u0a86:
           TOTAL: 100% (16MB-16MB-16MB/15MB-15MB-15MB over 5)
          Imp Bg: 0.15%
         Service: 100% (16MB-16MB-16MB/15MB-15MB-15MB over 5)
  * com.google.android.inputmethod.latin / u0a34:
           TOTAL: 100% (35MB-35MB-35MB/33MB-33MB-33MB over 7)
          Imp Fg: 100% (35MB-35MB-35MB/33MB-33MB-33MB over 7)
  * com.google.process.gapps / u0a23:
           TOTAL: 100% (15MB-15MB-15MB/13MB-13MB-14MB over 7)
          Imp Fg: 100% (15MB-15MB-15MB/13MB-13MB-14MB over 7)
  * com.android.bluetooth / 1002:
           TOTAL: 100% (7.1MB-7.1MB-7.1MB/6.5MB-6.5MB-6.5MB over 7)
          Imp Fg: 100% (7.1MB-7.1MB-7.1MB/6.5MB-6.5MB-6.5MB over 7)
  * com.google.android.gms.drive / u0a23:
           TOTAL: 100% (6.3MB-6.4MB-6.4MB/4.9MB-4.9MB-4.9MB over 6)
         Service: 100% (6.3MB-6.4MB-6.4MB/4.9MB-4.9MB-4.9MB over 6)
```

```
  * com.guywmustang.silentwidget / u0a78:
          TOTAL: 0.01%
       Service: 0.01%
      Receiver: 0.00%
      (Cached): 79% (2.1MB-2.2MB-2.4MB/1.5MB-1.5MB-1.7MB over 5)
  * com.megagram.widget.myip / u0a134:
          TOTAL: 0.01%
      Receiver: 0.01%
      (Cached): 54% (2.6MB-3.0MB-3.4MB/2.0MB-2.4MB-2.9MB over 4)
  * com.stackexchange.marvin / u0a154:
          TOTAL: 0.00%
       Service: 0.00%
      Receiver: 0.00%
      (Cached): 73% (7.1MB-7.4MB-7.5MB/6.0MB-6.5MB-6.8MB over 3)
  * us.wmwm.njrail / u0a217:
          TOTAL: 0.00%
      Receiver: 0.00%
      (Cached): 100% (56MB-56MB-56MB/51MB-51MB-51MB over 6)
  * nz.co.softwarex.hundredpushupsfree / u0a168:
          TOTAL: 0.00%
      Receiver: 0.00%
      (Cached): 100% (27MB-27MB-27MB/23MB-23MB-23MB over 6)
  * com.google.android.partnersetup / u0a27:
          TOTAL: 0.00%
       Service: 0.00%
      Receiver: 0.00%
      (Cached): 68% (2.4MB-2.4MB-2.4MB/1.8MB-1.8MB-1.8MB over 3)
  * com.android.chrome / u0a10:
          TOTAL: 0.00%
      Receiver: 0.00%
      (Cached): 59% (4.6MB-4.9MB-5.0MB/3.7MB-4.1MB-4.3MB over 3)
  * com.google.android.setupwizard / u0a53:
          TOTAL: 0.00%
      Receiver: 0.00%
      (Cached): 32% (3.7MB-3.7MB-3.7MB/3.1MB-3.1MB-3.1MB over 2)

Run time Stats:
  SOff/Norm: +21m33s116ms
  SOn /Norm: +17m21s272ms
      TOTAL: +38m54s388ms

         Start time: 2014-08-04 10:15:01
  Total elapsed time: +4h29m6s903ms (partial) libdvm.so chromeview
```

Reckon: Heap Usage

- Runtime Information
  - ActivityManager#getMemoryClass()
    - Returns number of MB for max heap size
    - Exception: large heap (but that's cheatin')
  - android.os.Debug methods
    - `getNativeHeapSize()`
    - `getNativeHeapAllocatedSize()`
    - `getNativeHeapFreeSize()`
    - Not as useful as you might think...

Reckon: Heap Usage

- Memory Analysis Tool (MAT)
  - Used to examine heap dumps
    - From DDMS
    - From Debug#dumpHprofData()
  - Available as standalone GUI or as Eclipse plugin
  - Uses
    - Understanding what's using up your heap
    - Finding memory leaks

Android Memory: Reduce

Reduce: Scale All Your Caches

- Use getMemoryClass()
  - Plus algorithm for capping your caches to certain portion of possible heap
  - On top of using weak or soft references
- Beware Multiple Caches
  - Library A has a cache, Library B has a cache, etc.
  - Sum of all caches must be reasonable, beyond any individual cache

Reduce: Load What You Need, Not What You Have

- Avoid massive scrolling lists
  - User can't find anything anyway
  - Steer user towards searching large data sets
- Load bitmaps as needed
  - Example: avatars for a list
  - And pay attention to row recycling and such
- Easy on the POJOs
  - ...or at least close your cursors after copying

Reduce: Ponder Bitmap Sizes

- Load the Size You Need
- Example: ListView rows
  - Load thumbnails, using inSampleSize on BitmapFactory.Options
  - Only load full-size image for the ones the user clicks upon and brings up some sort of details fragment/activity/whatever

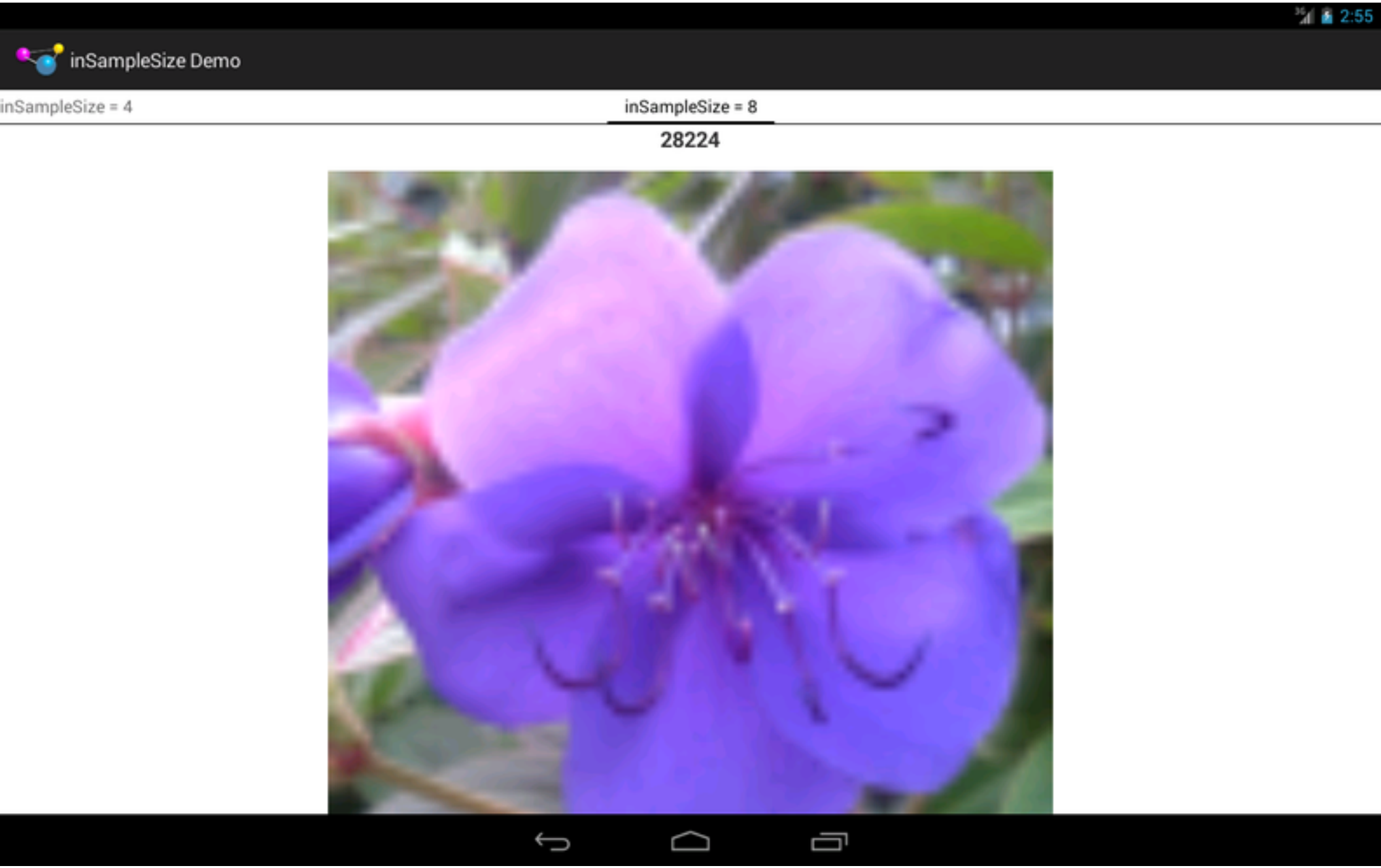
```
private Bitmap load(String path, int inSampleSize) throws IOException {
  BitmapFactory.Options opts=new BitmapFactory.Options();

  opts.inSampleSize=inSampleSize;

  return(BitmapFactory.decodeStream(assets().open(path), null, opts));
}
```

2:54
inSampleSize Demo
inSampleSize = 1
inSampleSize = 2
1806336


2:55
inSampleSize Demo
inSampleSize = 1
inSampleSize = 2
CommonsWare
CommonsWare


2:55
inSampleSize Demo
inSampleSize = 4
inSampleSize = 8
28224


2:55
inSampleSize Demo
inSampleSize = 4
inSampleSize = 8
CommonsWare
CommonsWare

Reduce: Ponder Bitmap Pixels

- Default: ARGB_8888
  - 4 bytes per pixel
- Alternative: RBG_565
  - 2 bytes per pixel = half the memory for same resolution
  - No transparency
- Example: ListView rows
  - Thumbnails perhaps can get away with less color depth

Reduce: Simpler UI/Progressive Enhancement

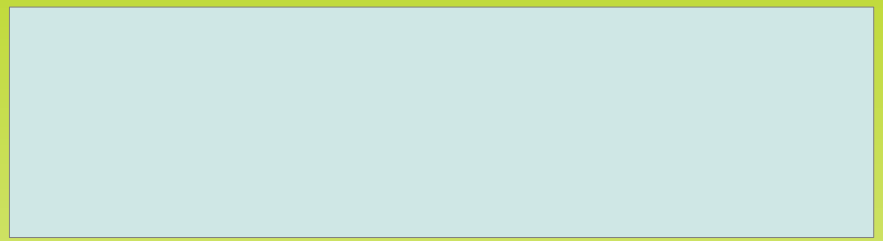
- Think Web apps
  - Opt into different page rendering depending on browser capabilities
  - Usually same broad-brush features for the user, but missing “sizzle” or optional features
- Treat low-memory devices differently
  - Steer the user away from things that may blow out your available heap
  - Problem: how best to package this
    - “Hey! Get a real phone!” unlikely to prove popular

Android Memory: Reorder

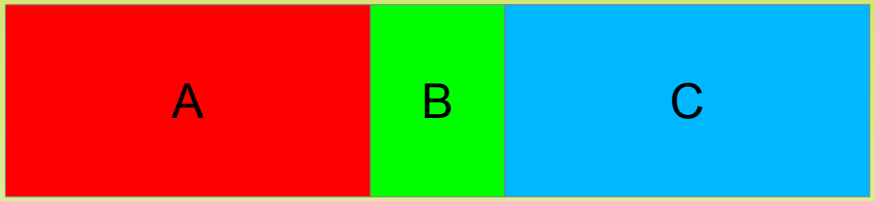
Root Cause #2: Non-Compacting GC

- Only combines adjacent free blocks into larger free block
  - Does not move objects in memory to try to coalesce free blocks
- Net: heap fragmentation
  - OutOfMemoryError = no block big enough to satisfy request
  - Think defragmenting hard drives

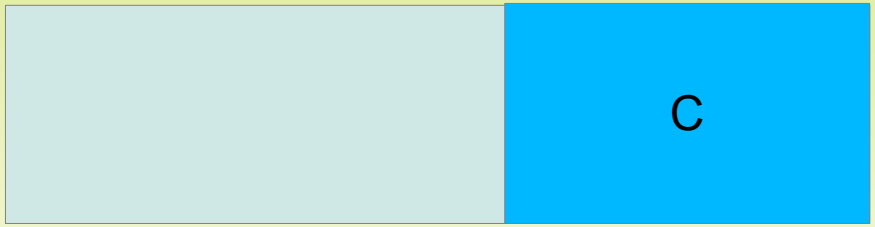
Root Cause #2: Non-Compacting GC



In the beginning, there was heap, and it was good...

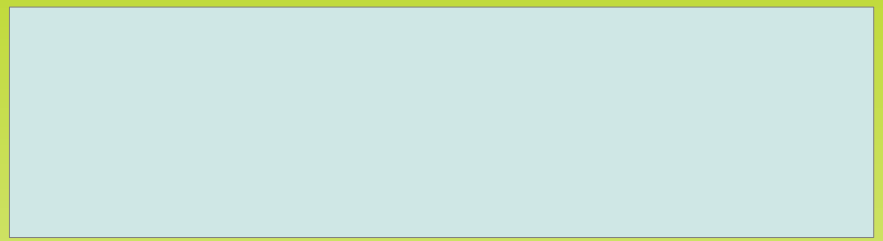


The story of “The Three Little Blocks and the Big Bad OutOfMemoryError”

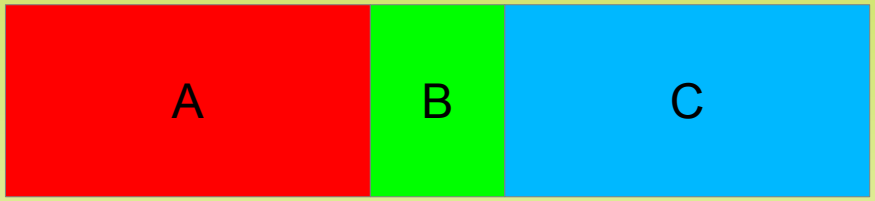


Trash compactor

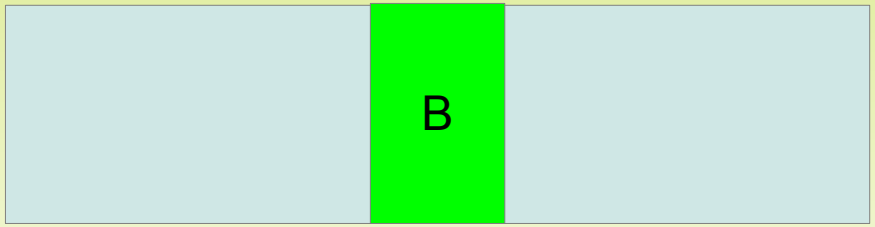
Root Cause #2: Non-Compacting GC



In the beginning, there was heap, and it was good...



The story of “The Three Little Blocks and the Big Bad OutOfMemoryError”



Where, o where has my heap space gone? O where, o where can it be?

Reorder: Allocate Long-Lived Stuff Earlier

- CIY (Compact It Yourself)
  - Allocate bitmap or other object pools early
  - Objective: minimize long-lived objects fragmenting the heap
  - Only really useful for memory buffers that can be reused, rather than recycled

Reorder: Let Your Process Go Poof

- Nuke Your Entire Heap From Orbit
  - It's the only way to be sure that you're going to get a nice clean heap again
- Avoid the “Must Keep Process Running” Syndrome
  - Or use a second process for focused heap for long-running stuff (but that's cheatin')

And Now, a Word from ART

- Compacting ("Moving") Garbage Collector
  - Solves the heap fragmentation issue, but...
  - Will only run while app is in background
  - Net: will not help games, other foreground-only apps
- Segmented Heaps
  - Separate area in heap for large buffers (e.g., bitmaps)

Android Memory: Reuse

Reuse: Object Pools

- Pools
  - Collection of some common resource (objects, threads, etc.)
  - Access patterns to acquire and release
    - Use the resource in between
  - Pre-allocated minimum pool contents
  - Cap on maximum pool size
    - Grow as need to limit, release resources to shrink
    - Acquire blocks if needed for other thread to release

Reuse: Object Pools

- Rationale
  - Avoid heap fragmentation!
  - Slight heap compacting effect via pre-allocation
  - Reduce GC processing time
  - Minimize constructor CPU time
- Counter-Arguments
  - Shades of `malloc()` and `free()`

Reuse: Object Pools

- Framework-Enforced
  - SensorEvent, etc.
- Framework-Encouraged
  - TypedArray, etc.
- Custom
  - Stormpot
  - Commons-Pool
  - A zillion blog posts

Reuse: inBitmap

- BitmapFactory.Options field
- Specifies Bitmap to reuse
  - API Level 19+: must be same size or larger than bitmap to be loaded
  - API Level 18 and lower: must match exactly
- Great for thumbnails, other scenarios with constant bitmap sizes
  - Usually integrated into bitmap libraries

Android Memory: Recycle

Recycle: MAT and Leaks

- Look for Leak Candidates
  - Instances of your classes that should not be around
  - Bitmaps and byte arrays
- Trace Your GC Roots
  - “GC Roots” = “what the @#$%&! is holding onto this &%&$ thing?!?”

Recycle: Choose the Right Context

- Beware of a Custom Application Class
  - Singleton, so anything it holds onto cannot be GC'd
- Use Application in the Right Places
  - If you are holding onto things in static data members that might be associated with a Context, use Application, as it is “pre-leaked”
  - Failure to do so: leak activities, etc.

Recycle: onTrimMemory()

- Called On Your Components
  - Activity, Service, ContentProvider, Application, etc.
- Objective: Release Some Heap Space
  - In hopes that Dalvik can release some of that heap back to the OS

Recycle: onTrimMemory()

- You Are Safe (But Please Be Kind to Others)
  - TRIM_MEMORY_RUNNING_MODERATE
  - TRIM_MEMORY_RUNNING_LOW
  - TRIM_MEMORY_RUNNING_CRITICAL
- You Are Invisible
  - TRIM_MEMORY_UI_HIDDEN

Recycle: onTrimMemory()

- Your Time is Running Out
  - TRIM_MEMORY_BACKGROUND
  - TRIM_MEMORY_MODERATE
  - TRIM_MEMORY_COMPLETE
    - Also available as onLowMemory() for sub-API Level 14 devices

Recycle: Watch Your Threads

- Threads = GC Roots
  - Anything reachable by a thread cannot be GC'd
- Tips
  - Leaking threads = leaking heap
  - Ensure threads in pools `null` out data members
  - Beware the everlasting service!
    - Its threads, and anything else, cannot be GC'd
    - Also screws up multitasking, etc.

Android Memory: Cheat

Cheat: Request Large Heap

- `android:largeHeap` in `<application>`
- **Probably** gives you a larger heap on API Level 11+
  - Depends a bit on device capabilities
- Use `getLargeMemoryClass()` to determine how large your heap is

Cheat: Multiple Processes

- Reason #1: More Heap
  - Use second process for specific memory-intensive operations
  - Workaround for pre-Honeycomb devices
- Reason #2: Focused Heap
  - Use second process for long-running background services
  - May be able to accomplish same basic end with `onTrimMemory()`

Cheat: NDK

- Native allocations do not count against Dalvik heap
- Use native code for memory-intensive operations
  - Particularly where you could gain some performance from native code
  - Example: image processing

The Costs of Cheating

- Larger system RAM consumption
  - More likely to get blamed by OS, users
  - More likely to have background process terminated
- Multiple processes = IPC
  - CPU and battery consumption
  - Keep your protocol relatively coarse-grained

Summary

- Reckon: measure twice, cut if needed
- Reduce: what you don't use can't hurt you
- Reorder: avoid fragmentation (the heap kind)
- Reuse: object pools FTW!
- Recycle: this is why we used managed code
- Cheat: try not to, #kthxbye