Delivering Highly Optimized Android* Runtime (ART) and Web Runtime on Intel® Architecture

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STTS004

Agenda

- Delivering Highly Optimized Android* Runtime (ART) on Intel® Architecture based devices
  - Intel ART Contributions and Extensions
  - Case Study on Compiler Optimization
  - Case Study on Garbage Collection Optimization
- Delivering Highly Optimized Android Web Runtime on Intel Architecture based devices
  - What's New in latest Android Web Runtime
  - Case Study on Performance Optimization
  - Case Study on Power Optimization
  - Case Study on Memory Optimization

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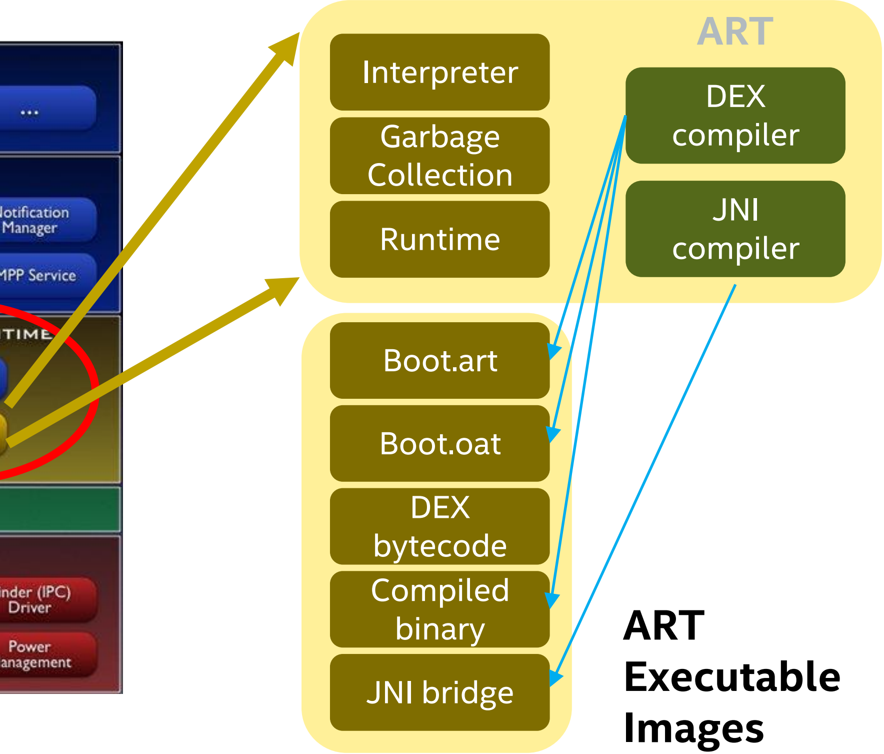
Android* and ART (Android Runtime)

Pre-Lollipop Release:

Lollipop Release:



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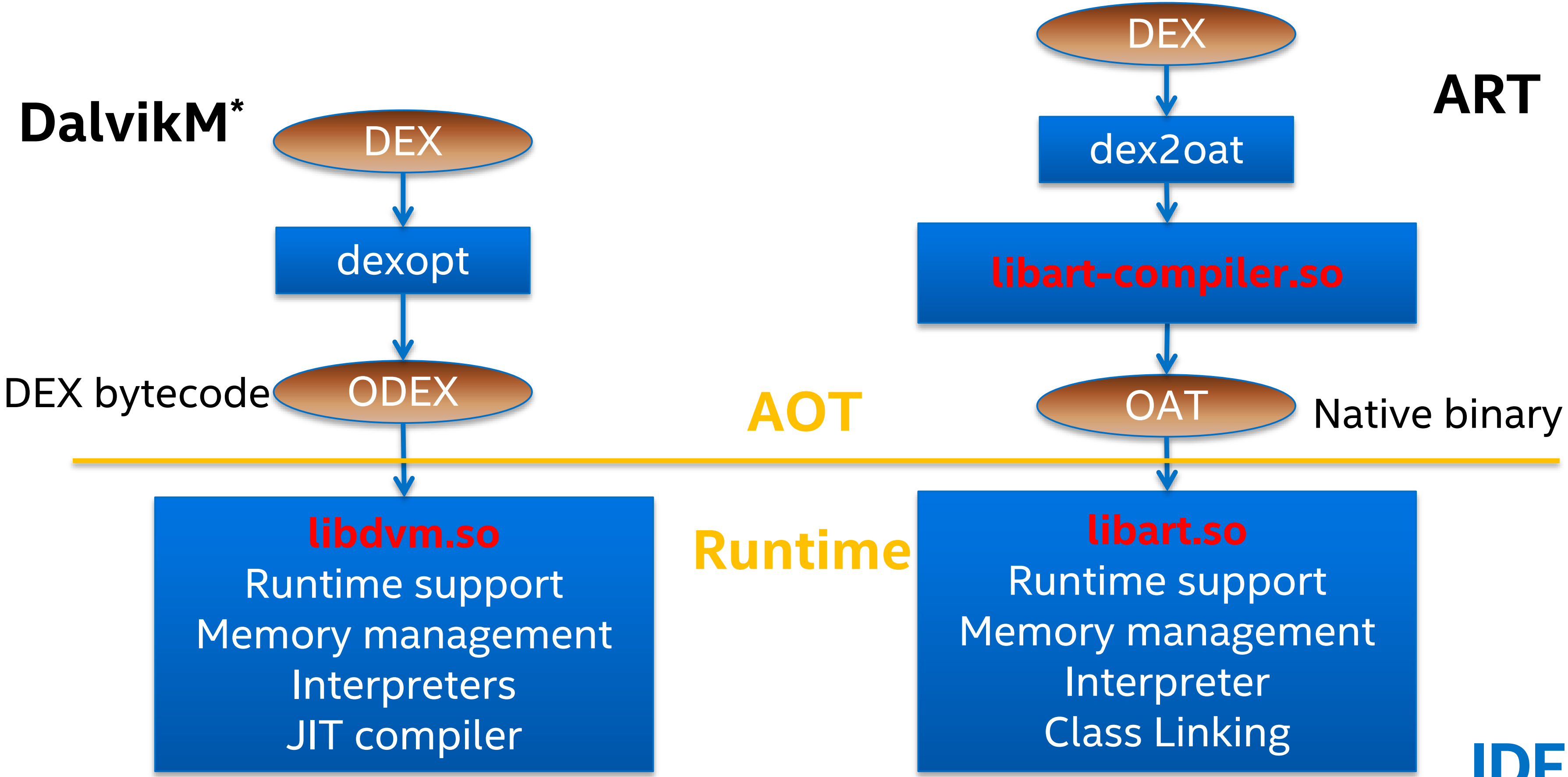
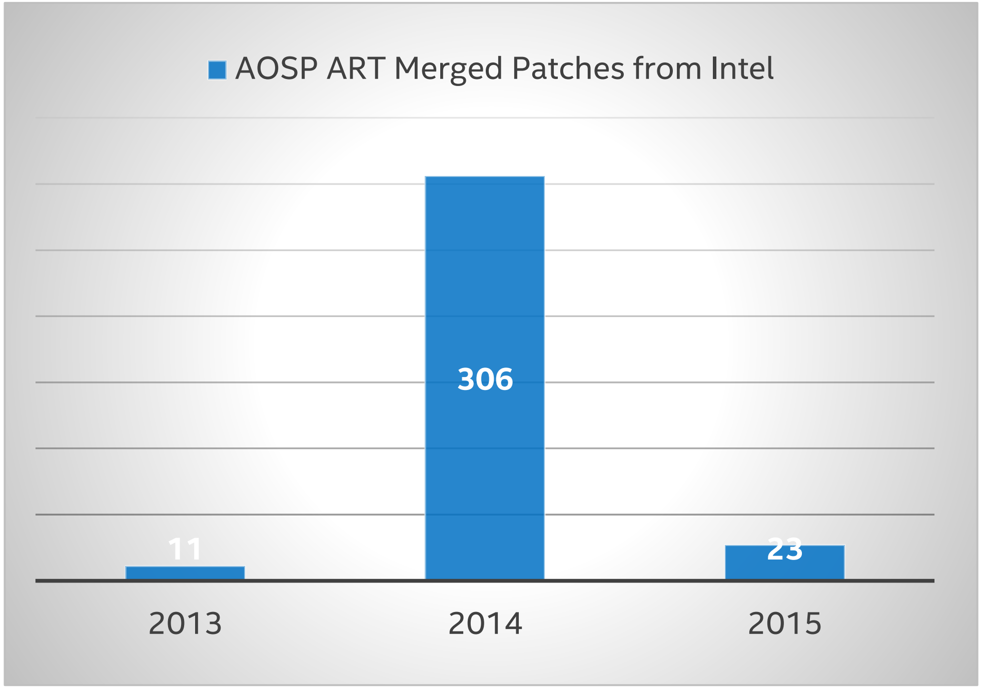
Dalvik* VM vs. Android* Runtime DEX Execution Flow



Intel AOSP Android* Runtime Contributions

Contribution Distribution

- 64-bit enabling and optimizations
- 32-bit code generator optimizations
- Runtime/GC Optimizations
- Debugging enhancement
- Bug fixings



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Intel Android* Runtime Extensions

An extensible plugin library (libart-extension.so) based on AOSP, which adds additional compiler optimizations:

- Extensive Method Inlining
- Invariant Hoisting/Sinking
- Non-Temporal Move
- Loop Tiling
- Loop Unrolling
- Vectorization

Inside in Android* Products on Intel® platforms

Extensive Method Inliner

- Method Inlining, which replaces a function call site with the body of the callee, is a key optimizations for JVMs
- However, AOSP Method Inliner could only handle very small methods:
  - Empty methods
  - Return of constant
  - Instance getter
  - Return of parameter
  - Instance setter
- Intel's Method Inliner was architected for extensibility and used generic framework to allow inlining of any method body
- Benefits:
  - Effectively turned some methods into leaves
  - Inlining in loops exposed many opportunities

Case Study – Method Inlining and Loop Optimizations

```
int f(int i) {
  return i + 1;
}
```

Before

```
for (i = 0; i < N; i++)
{
  tab[i] = f(i);
}
```

Common Compiler Code

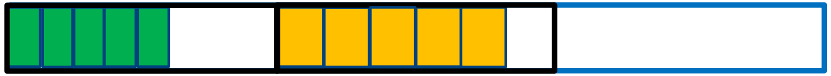
- Method Inlining
- Loop Versioning
- Null Pointer Check Elimination
- Array Bound Check Elimination
- Non Temporal Move

After

```
if (tab != nullptr && tab.length < N) {
  for (i = 0; i < N; i++) {
    // no need to check null pointer
    // no need to check array bound
    tab[i] = i + 1;  // non temporal
  }
} else {
  for (i = 0; i < N; i++) {
    tab[i] = i + 1;
  }
}
```

Case Study - Homogenous Space Compaction

- Previous Heap Space Compaction
  - Object allocation and garbage collection:



Case Study - Homogenous Space Compaction

- Previous Heap Space Compaction
  - ➢ Object allocation and garbage collection: Fragmentations!

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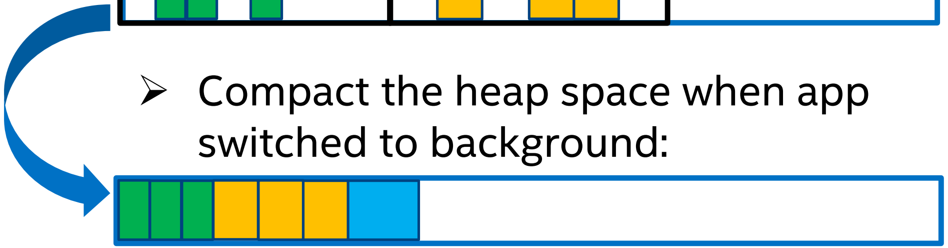
Case Study - Homogenous Space Compaction

- Previous Heap Space Compaction
  - ➢ Object allocation and garbage collection: Fragmentations!

  - ➢ Compact the heap space when app switched to background:



  - ➢ Re-construct the heap space when app switched to foreground:

Case Study - Homogenous Space Compaction

- Previous Heap Space Compaction
  - ➢ Object allocation and garbage collection: Fragmentations!

  - ➢ Compact the heap space when app switched to background:

  - ➢ Re-construct the heap space when app switched to foreground:

Case Study - Homogenous Space Compaction

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  - ➢ Compact the heap space when app switched to background:

  - ➢ Re-construct the heap space when app switched to foreground: Pause!

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- Homogenous Space Compaction
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Case Study - Homogenous Space Compaction

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  - ➢ Compact the heap space when app switched to background:

  - ➢ Re-construct the heap space when app switched to foreground: Pause!

- Homogenous Space Compaction
  - ➢ Object allocation and garbage collection: Fragmentations!

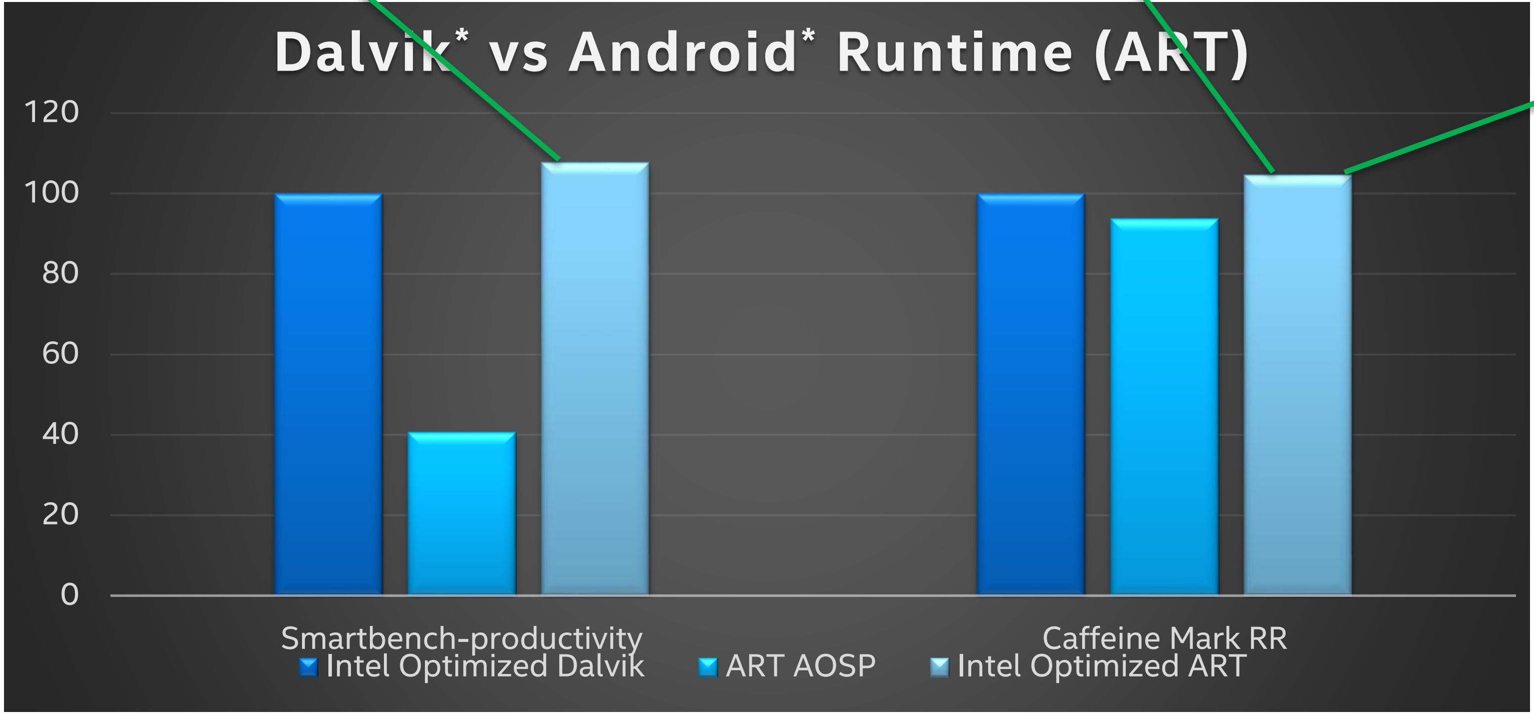
  - ➢ Compact the heap space when app switched to background:

  - ➢ No pause as we do not need to re-construct the heap space, this improves the responsiveness.

Performance Data with Intel Optimized Android* Runtime

Method Inlining
Tiling
Invariant Hoisting/Sinking

Select Optimization
Full Unroller
CSE



Normalized to Dalvik: Above 100 means ART is better

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Emerging Technologies and Innovations in Web

App (HTML/JS/CSS)

- WebRTC
- asm.js
  - Towards speed of native
  - Emscripten, etc.
- web components
  - Create your own HTML tag
  - polymer etc.

```
<my-tag content="hello world"></my-tag>
```

Web Runtime	Hardware & OS

- 64-bit Android*
- Chromium* WebView

	WebView v30	WebView v33	WebView v36
WebGL	×	×	√
WebRTC	×	×	√
WebAudio	×	×	√

source: Google (link)

Intel Embraces and Optimizes them for Better User Experience

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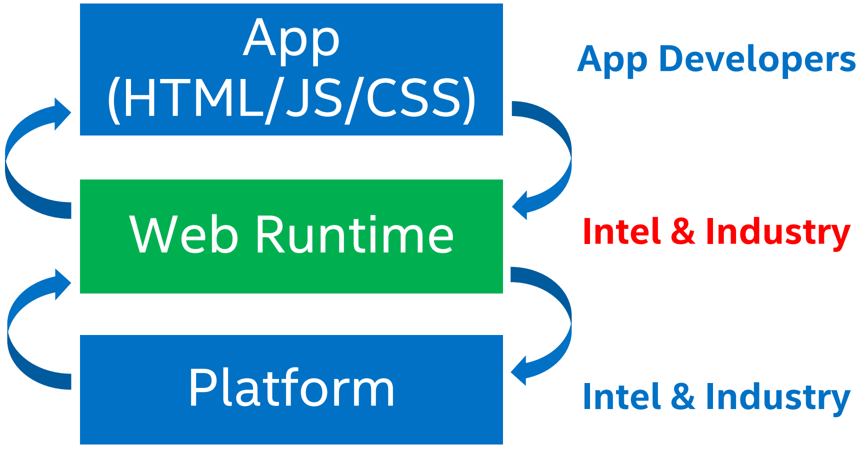
User Experience of HTML5 Applications

- User Experience is correlated to Performance, Power Efficiency, and Resource Utilizations

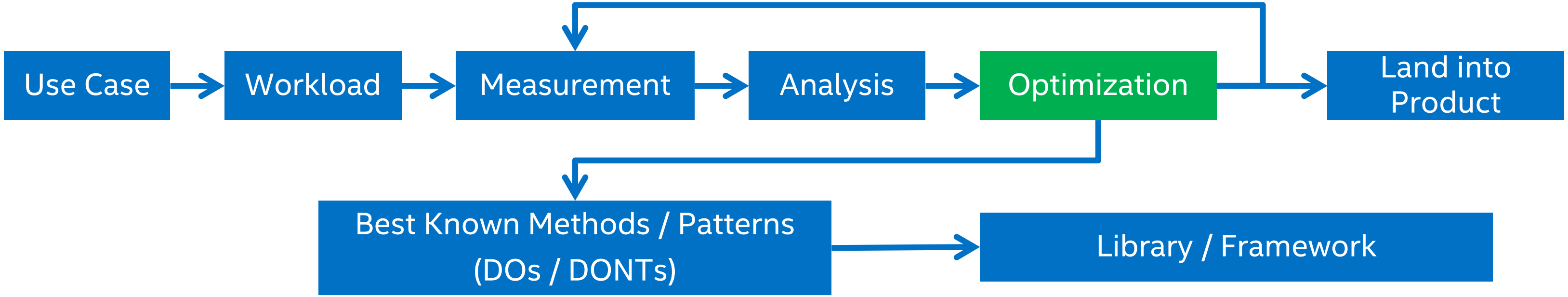
User Experience	Correlated To
Response Time	Performance
Smooth Animation	Performance
Battery Life	Power Efficiency
Navigating among multiple web sites	Memory Footprint
...	...

- Optimization Opportunities comes from Entire Stack



Methodology of Optimization

- Shared Wisdom in optimizing both App and Web Runtime



<u>Use Case</u>

```
var x, y;
// what is the
actual type of
x and y?
```

<u>Analysis</u>

Type in JavaScript*

- Flexible for Developers
- Challenge for Performance

<u>Optimizations</u>

- Raw Idiom for Developers

  ```
  var x = x | 0;
  ```

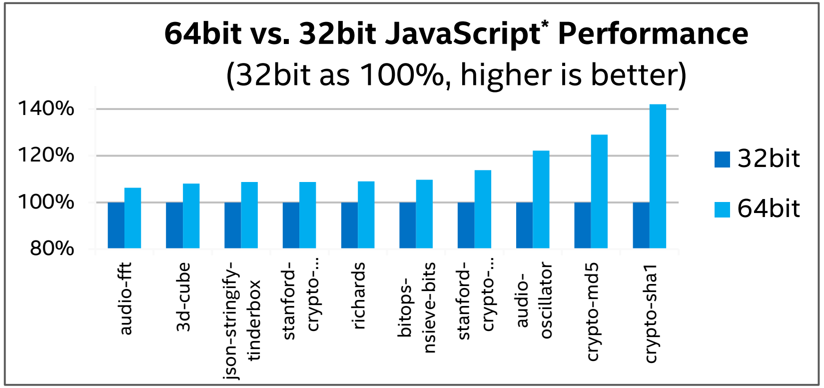
- Idioms → Library (& tools) for Developers
  - asm.js + Emscripten
- New APIs by Runtime for Developers
  - TypedArray: `var array = new Int32Array(buffer)`
- Runtime (transparent for Developers)
  - JIT + Type Speculation in V8

Case Study – Performance Optimization

- → 64bit
  - Performance boost due to more registers in wider length etc.
  - Web Runtime to assist the transition, e.g., sign extension

32bit	-1			FFFF	FFFF
64bit					
2^{32}-1		0000	0000	FFFF	FFFF
	-1	FFFF	FFFF	FFFF	FFFF

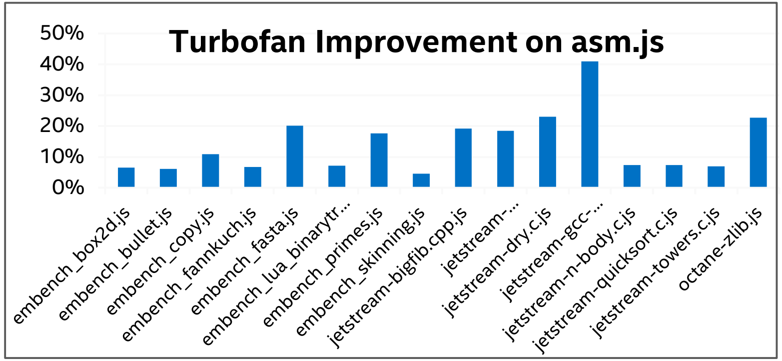
optimization



source: Intel, measured on Intel® N2820 @2.13GHz with Ubuntu 13.10 and V8 r26534

- No need for positive
- A number only need extend once → Merge

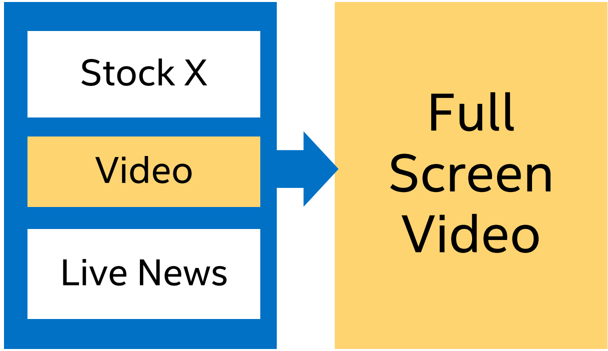
- → TurboFan of V8
  - Powerful IR (Sea of Nodes)
  - First Milestone targeting asm.js
  - Intel optimizations in codegen
- → SIMD.js etc. (Session SFTS004)



source: Intel, measured on Intel® N2820 @2.13GHz with Ubuntu 13.10 and V8 (x64) r26534

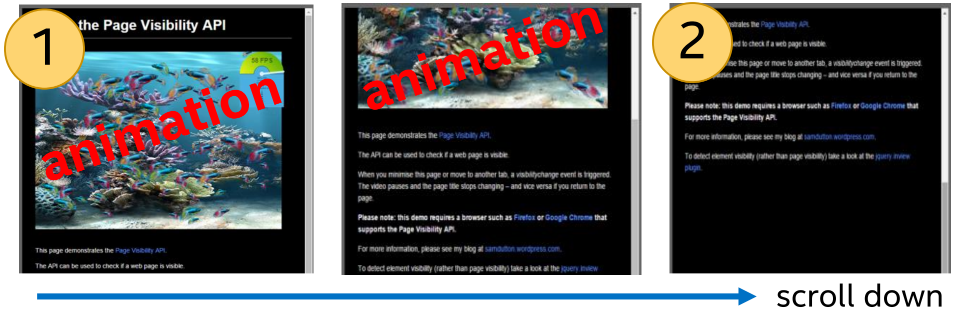
Case Study – Power Optimization

- Do Less – Example of Video



- [Optimization] Put Video in an Overlay to directly composite by HWC, rather than go to GLES first
- [Optimization] If Full Screen, No need to render underlying content
- About 30%† power saving in total

- Do Less – Example of Web Surfing
  - Page Visibility 2 (at iframe level)



  - [Optimization]
    - Runtime tracks this and notifies visibility change
    - App (code by developers) watches it and stops animation accordingly
  - About 60%† power saving in prototype
  - Discussion in W3C

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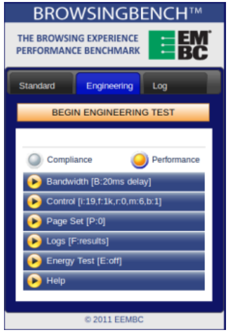
† source: Intel, measured on Intel® Atom™ with Android* 4.4 and Chrome* M40

Case Study – Memory Optimization

- Memory Footprint – important for web surfing user experience
  - Chrome*: Normally, one tab → One Process
  - Avoid Memory Bloat: Android* LMK (Low Memory Killer) may pick and kill process under memory pressure → Re-spawn & load again when revisit page

Use Case
(10 pages x load 7 times)



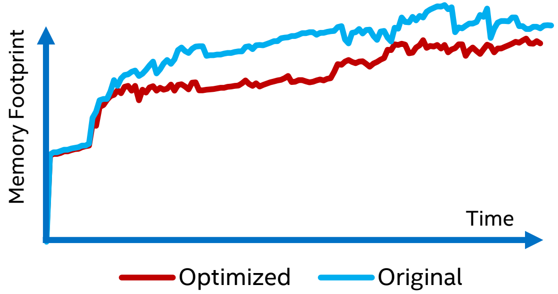
screenshot of EEMBC* browsingbench*

Data, Analysis and Optimization

- Cache ⇔ Performance Tradeoff
- Opportunities of Better Purge Strategy
  - Data of GIF Decoding
  - Data not referenced by any web page
  - JavaScript* GC
  - Shared Memory between processes

Result: Similar Perf. & >10% less footprint

Memory Footprint of Page Loading
(Lower is Better)



source: Intel, measured on Intel® Atom™ with Android 4.4 and Chrome M40

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Summary & Next Steps

- For the Android* Lollipop release, Intel put enormous efforts to make sure both Android Runtime (ART) and Web Runtime are highly optimized on Intel® Architecture based devices
- Intel optimized Android Runtime with a better AOT compiler and enhanced GC and will work with partners to optimize it further
- Web Apps' User Experience is improved by optimizations from both and runtime that Intel and industry is continuously enhancing
- For Application Developers, know and practice more about:
  - 64bit, asm.js, SIMD.js etc. for better performance
  - Hardware Acceleration, Page Visibility, etc. for power efficiency
  - Cache and GC strategy etc. to satisfy the budget of resource like memory

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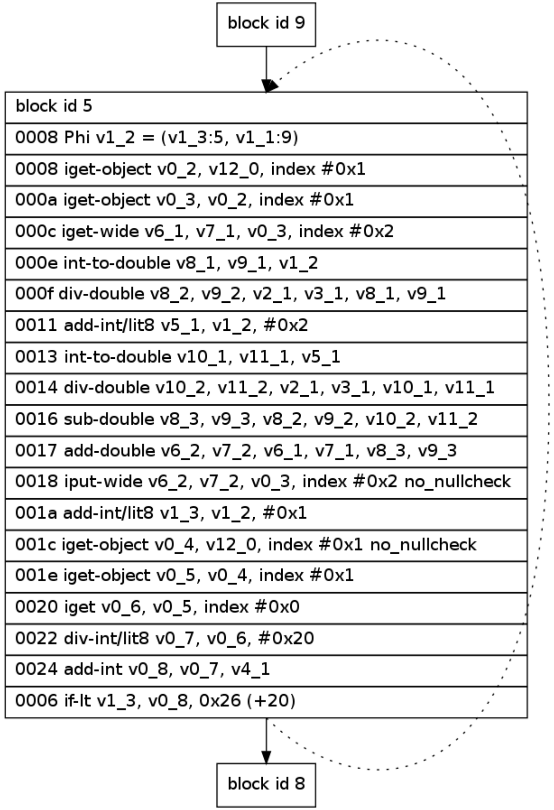
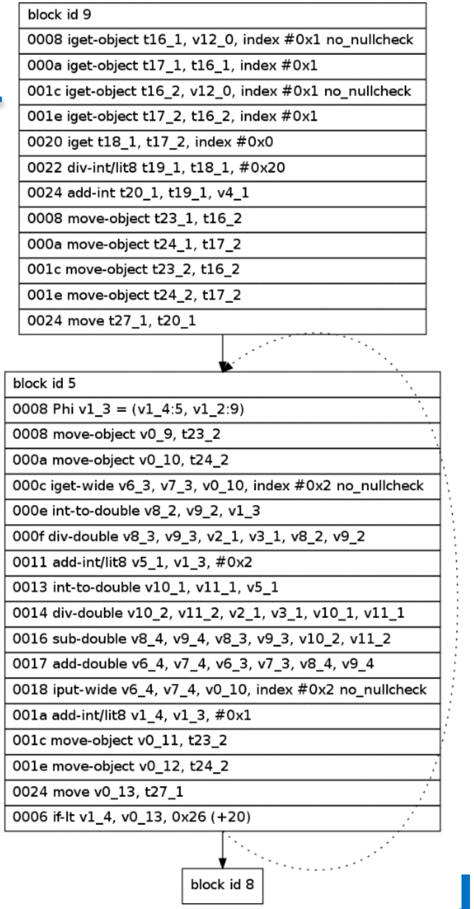
Backup

Case Study on Compiler Optimization Part 1



Hoisted the invariants
No RA so there are a few useless moves here

Move objects in loop to respect GC requirements



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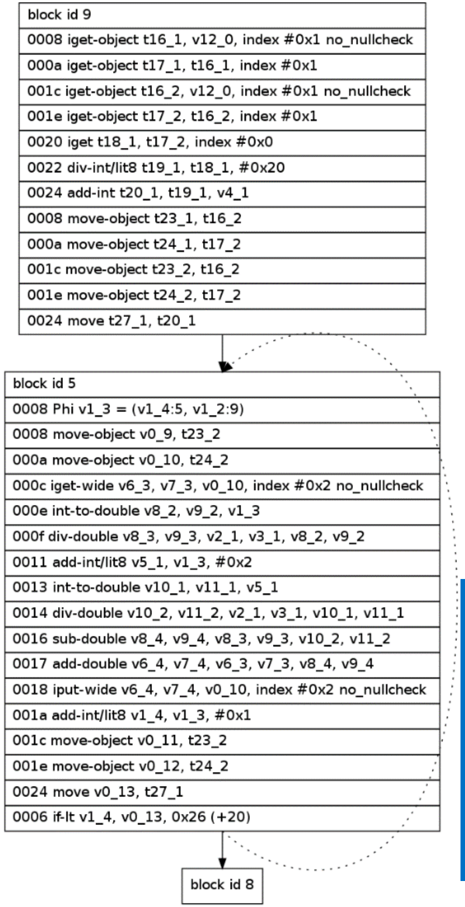
Case Study on Compiler Optimization



Invariants Hoisted

Tiling:

- Provides a means to remove the suspend check
- This enables loop optimizations for the loop

Registerization Done

Tiled Loop