POSIX Abstractions in Modern Operating Systems: The Old, the New, and the Missing

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Motivating Example: Execution of iOS Apps on Android

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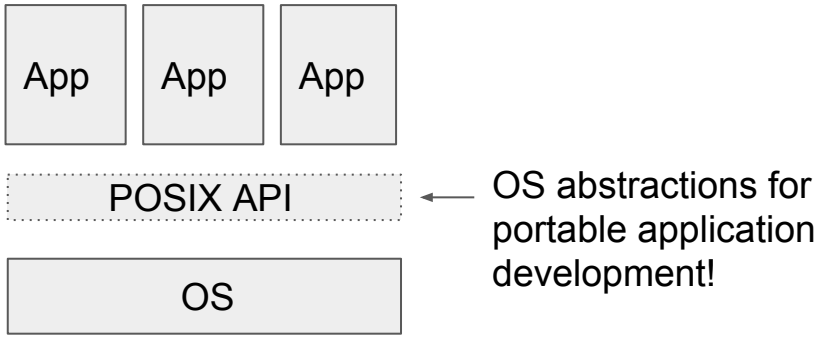
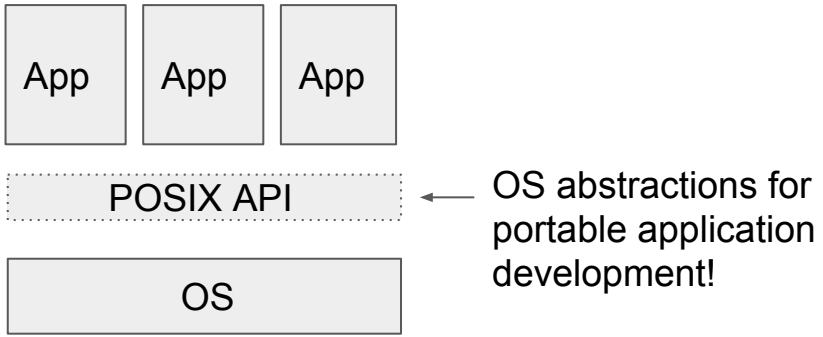


OS abstractions for portable application development!

Motivating Example: Execution of iOS Apps on Android



Initial insight

- Support translation at POSIX level
- UNIX-based systems
- Similar POSIX functionality

Motivating Example: Execution of iOS Apps on Android

Reality

- Cannot implement translation at POSIX level :-(
- iOS, Android platform-specific graphics libraries

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Solution

➢ Build compatibility at higher-level of abstraction

Study Goals

Audience: Developers, researchers, and standard bodies

- Study the evolution of abstractions in modern OSes
- Understand how modern workloads use traditional abstractions
- Identify the needs of modern applications

Study Questions

- Q1: Which POSIX abstractions are unpopular for modern apps?
- Q2: Which POSIX abstractions are popular for modern apps?
- Q3: Is POSIX missing any functionality?
- More in the paper...

Workloads & Methodology

Three Modern OSes

- Android 4.3, Ubuntu 12.04 , and OSX 10.10

Client-side Apps

- e.g., Facebook, Twitter, Skype, Chrome, Safari

Common User Workloads

- e.g., post update, tweet, video call, browse

Workloads & Methodology

Static Measurements

- Abstractions linked at large scale
- Analyze native libraries
- Android (>1M apps), Ubuntu (>70K pkgs), OSX (None)

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Dynamic Measurements

- Abstractions invoked by common workloads
- Analyze stack traces
- Android (45 apps), Ubuntu (45 apps), OSX (10 apps)

- Study Questions
  - **Q1: Which POSIX abstractions are unpopular for modern apps?**
  - Q2: Which POSIX abstractions are popular for modern apps?
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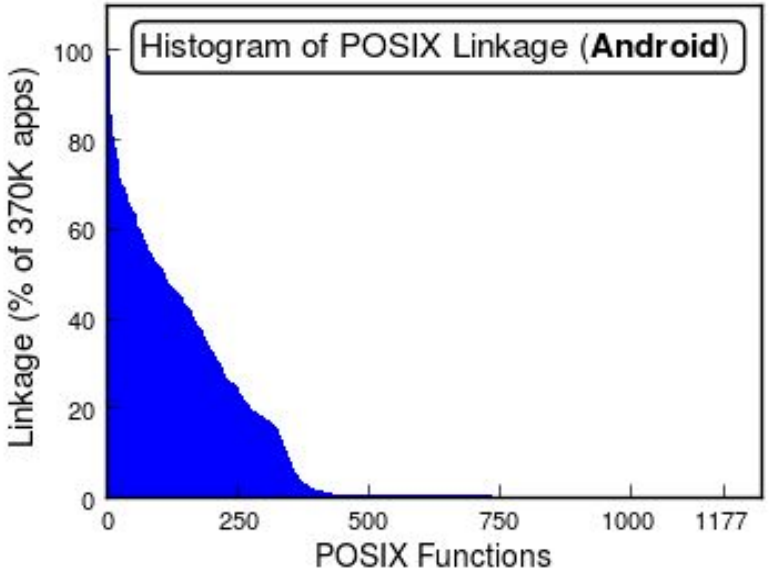
Study Questions

Q1: Which POSIX abstractions are unpopular for modern apps?



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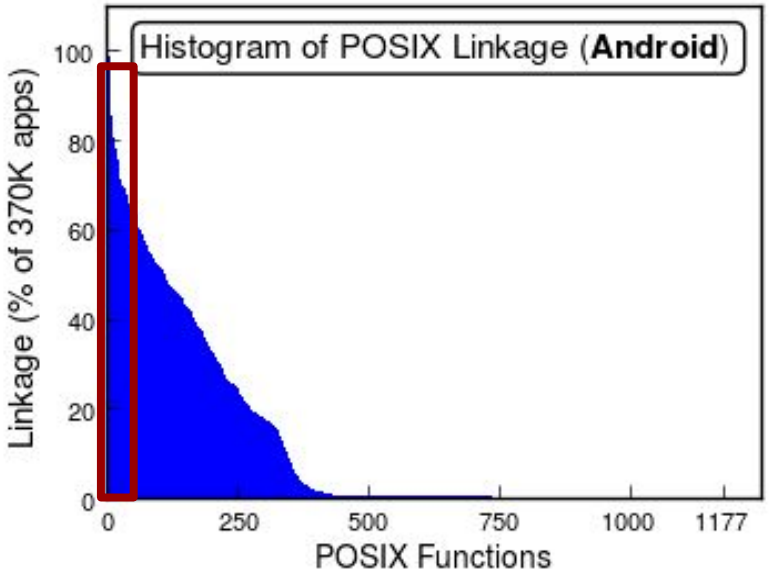
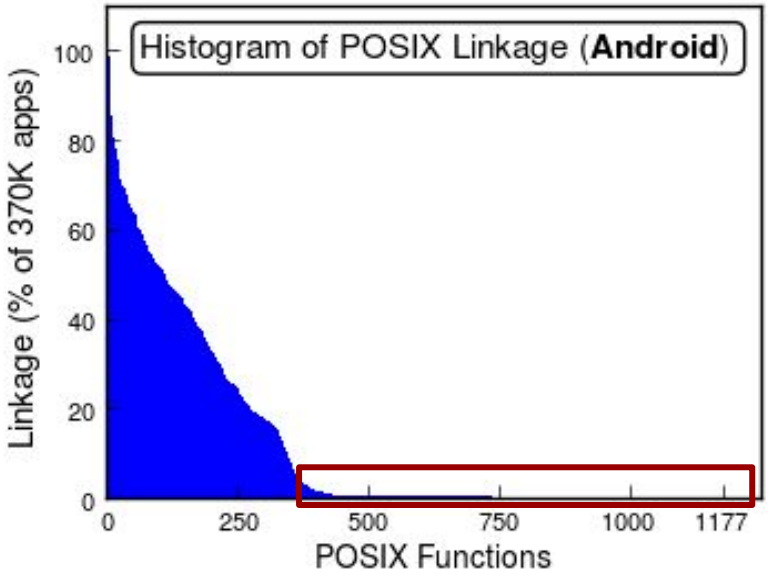


Few highly linked Interfaces

Examples

- memcpy (99% apps)
- malloc (92% apps)
- memset (90% apps)

Q1: Which POSIX abstractions are unpopular for modern apps?



Long tail of unused interfaces

IPC (only 32% implemented in Android)

- No shared_mem, mq
- Partially pipes, semaphores
- Very few apps link to mkfifo

Study Questions

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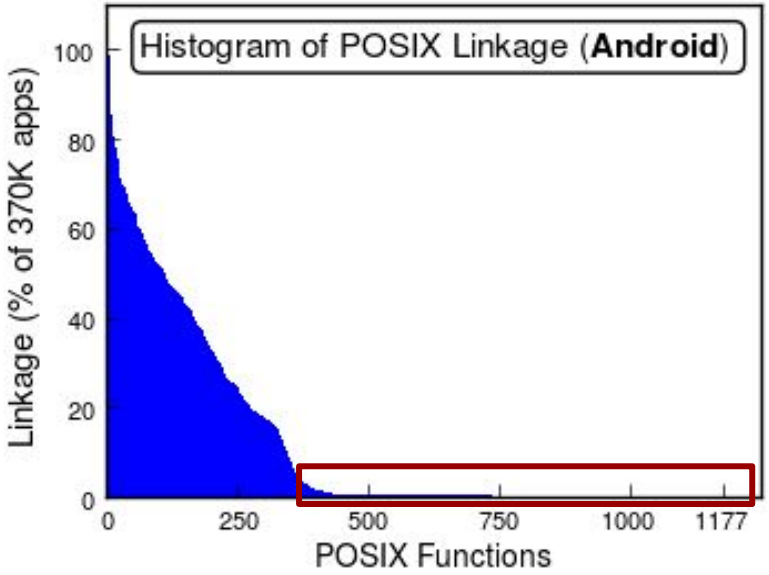

Long tail of unused interfaces

FS (76% implemented in Android)

- Missing async I/O functions (aio_*)
- No dbm functions (dbm_*)
- Very few apps link file lock functions

Study Questions

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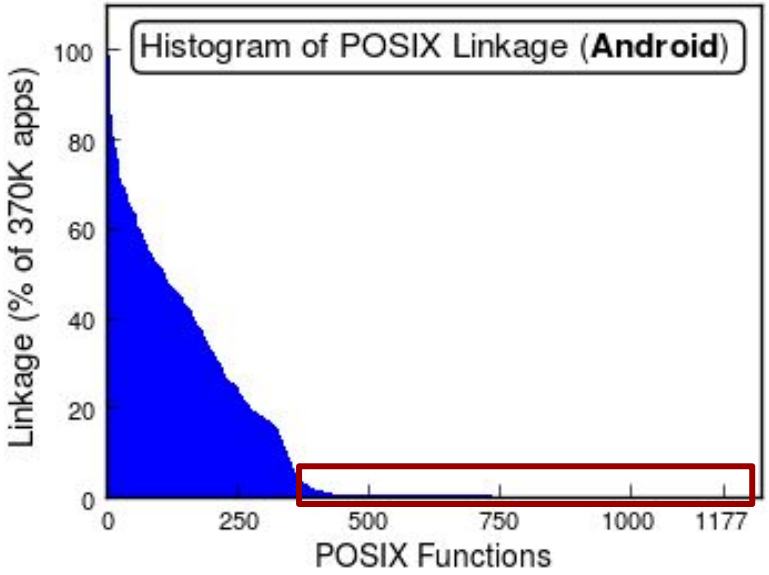

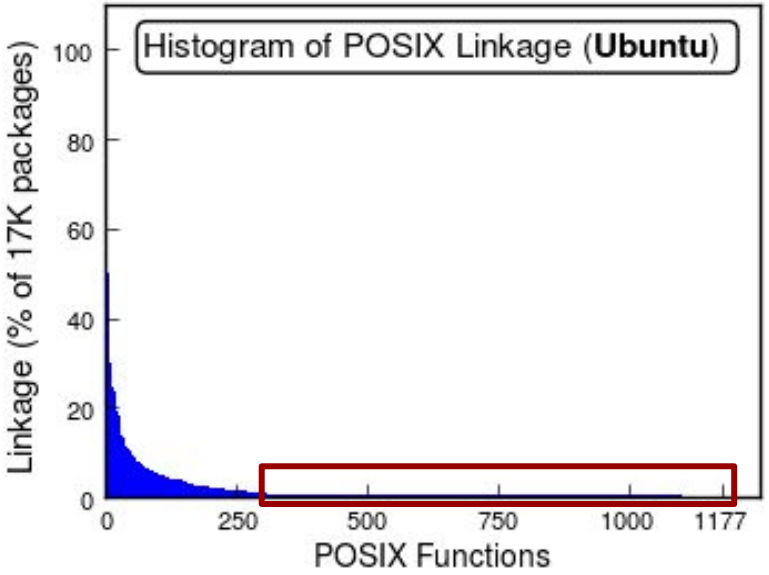

- Very few apps link to mq_*
- Very few apps link to aio_*

Study Questions

Q1: Which POSIX abstractions are unpopular for modern apps?

- Large numbers of unused or unimplemented abstractions
- Departure from traditional IPC and async I/O

- Study Questions
  - Q1: Which POSIX abstractions are unpopular for modern apps?
  - **Q2: Which POSIX abstractions are popular for modern apps?**
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Q2: Which POSIX abstractions are popular for modern apps?

Percentage of Invocations (45 Android Apps)

Memory (Examples)

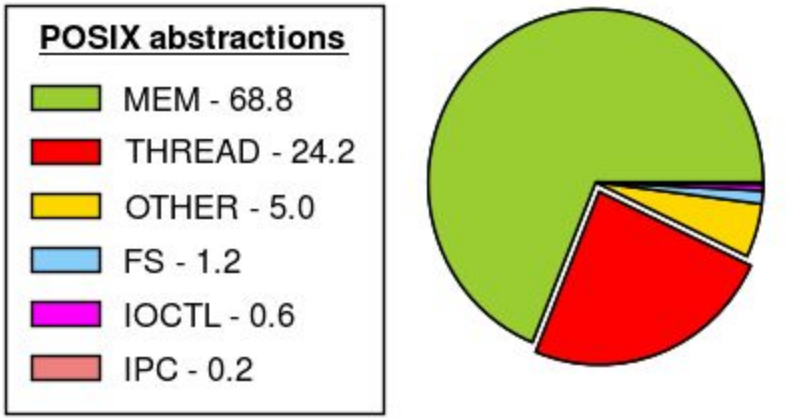
- memset, memcpy
- malloc, calloc
- mprotect, cacheflush, setjmp (JIT)

Threads (Examples)

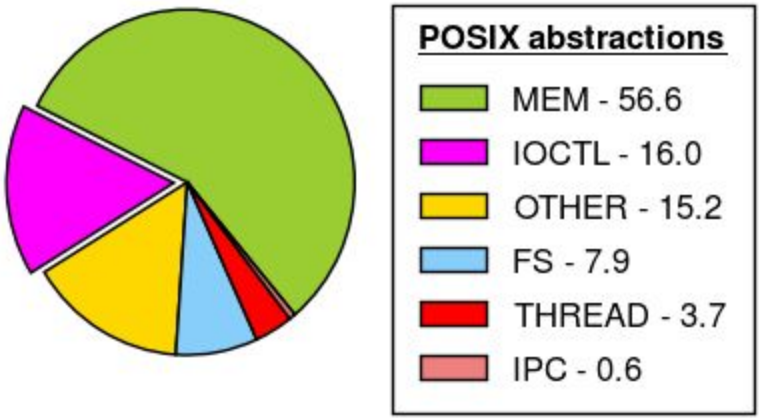
- pthread_get_specific
- pthread_cond_signal

Q2: Which POSIX abstractions are popular for modern apps?

Percentage of Invocations (45 Android Apps)



Percentage of CPU Time (45 Android Apps)



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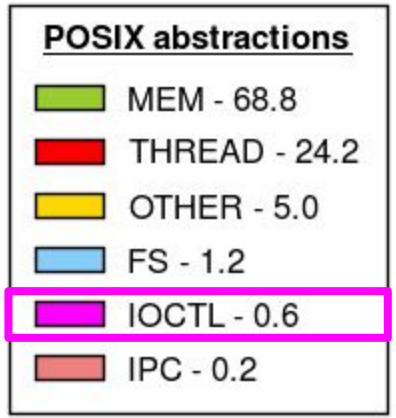

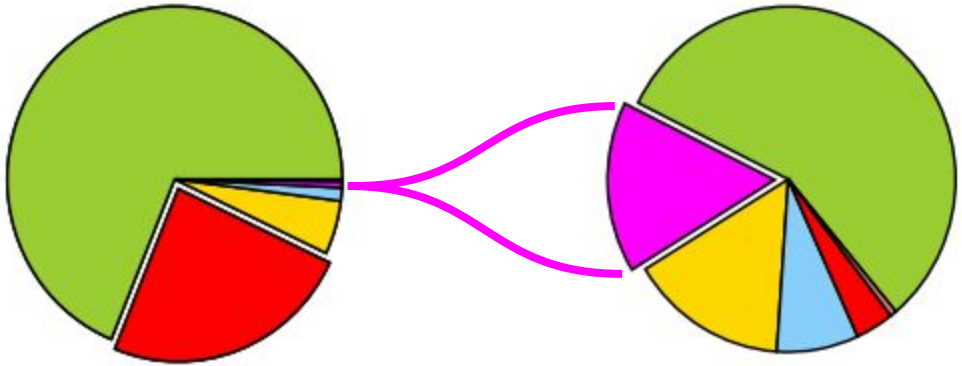

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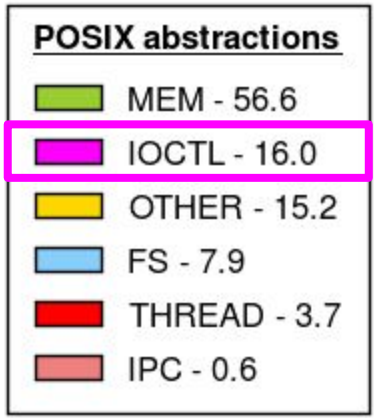

IOCTL

- Extension API used to shortcut POSIX
- Directly interact with the kernel
- Build functionality not expressed from POSIX APIs

IOCTL

- Analyze stack traces
- Identify libraries heavily invoking ioctl

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OS	1st Library	2nd Library	3rd Library
Android	Graphics (74%) (e.g., libnvrm)	Binder IPC (24%) (e.g., libbinder)	Other (2%)
Ubuntu	Graphics (52%) (e.g., libgtk)	Network (47%) (e.g., libQtNet)	Other (1%)
OSX	Network (99%) (e.g., net.dylib)	Loader (1%) (e.g., .dylib)	-

Top Libraries that Invoke IOCTL in each OS and functionality implemented

Q2: Which POSIX abstractions are popular for modern apps?

Extension APIs!!!

- Study Questions
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Graphics

- POSIX omits graphics abstractions
- OpenGL cross-platform API used by applications
- No standard interface to GPUs but ioctl
- Limited extensibility and vendor-specific APIs

IPC

- Binder IPC is a central abstraction in Android
- Android uses ioctl to build Binder in kernel
- Similar patterns in other OSes (MACH IPC, D-Bus)

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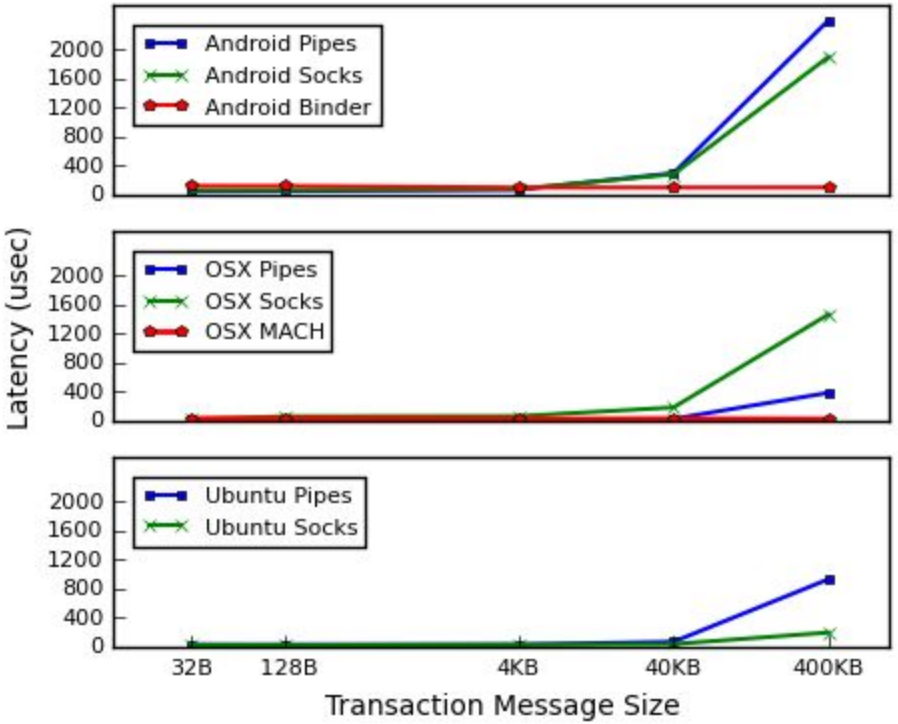
➢ But why not traditional IPC, e.g, pipes?

IPC



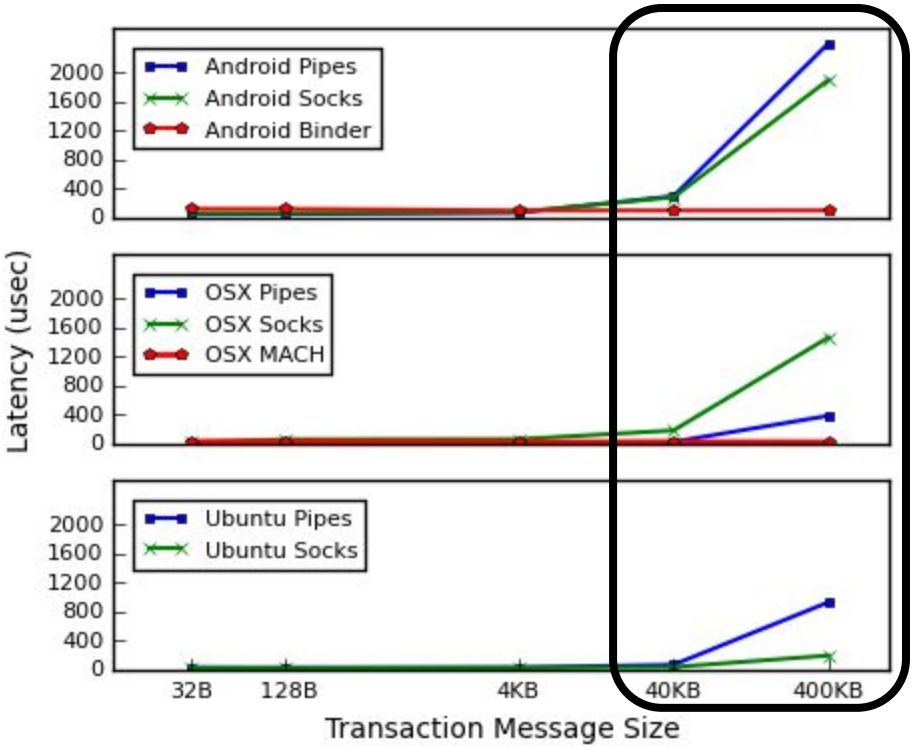
Benchmarks

- Measure latency of transactions
- Binder benchmark from Android source
- MACH using MPMMTest from XNU

Consumer Devices

- Nexus-7, MacBook Air, Dell XPS

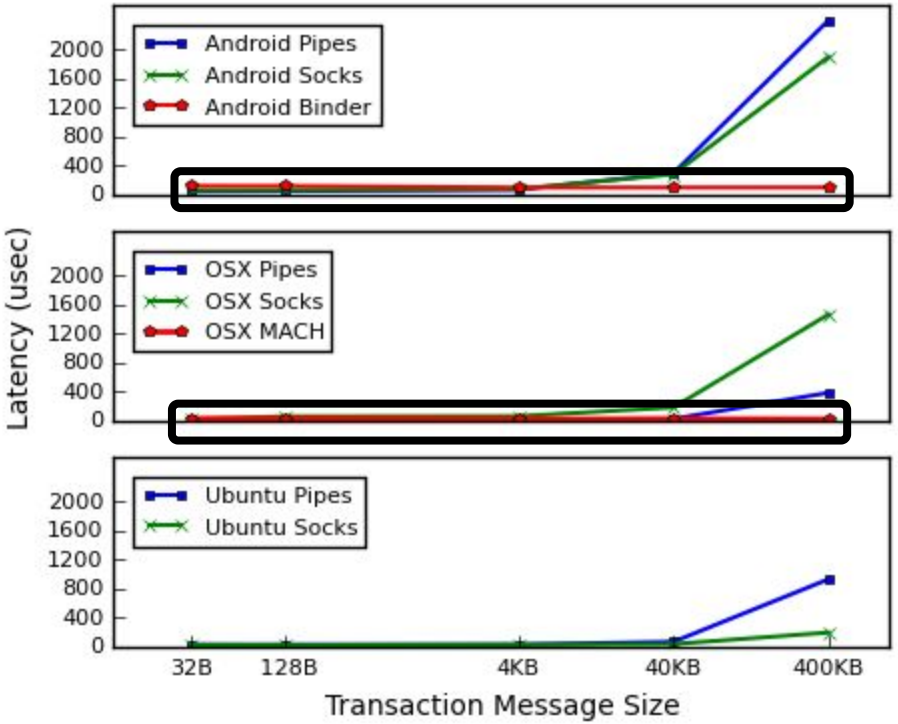
IPC



Limitations of traditional IPC

- Similar scalability issues across the three OSes
- High-latency for large transaction sizes

IPC



Benefits of new IPC

- Perform with near-constant latency
- Leverage in-kernel single- and zero-copy mechanisms

Threads

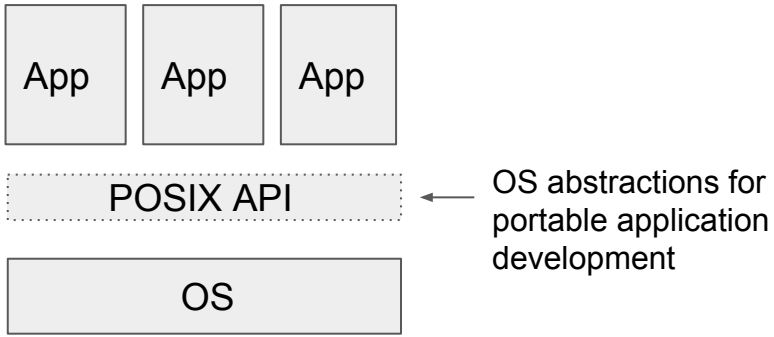
- GUI apps require low-latency UI threads
- Dispatching events is the new paradigm
- High-level event and thread management APIs
  - Android: ThreadPool and EventLoop
  - Ubuntu: ThreadPool and EventLoop
  - OS X: Grand Central Dispatch

Q3: Is POSIX missing any functionality?

- Graphics support
- New IPC mechanisms
- Threading APIs for event-driven programming

Evolution of systems and applications

In the past



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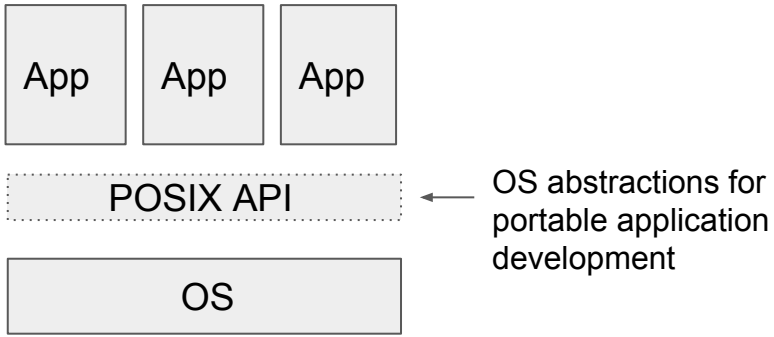
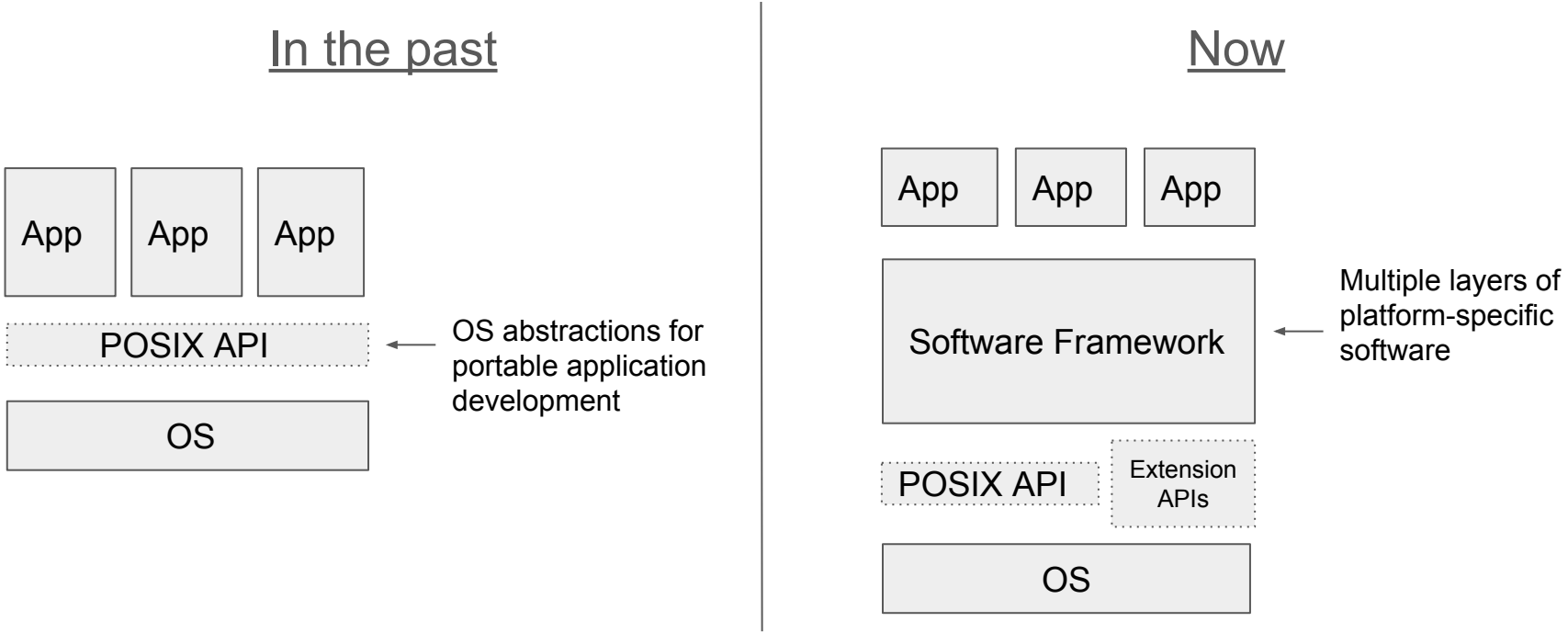


"... the major good idea with UNIX was its clean and simple interface: open, read, and write"

~K. Thompson. Unix and Beyond, 1999

Evolution of systems and applications



Contributions & Future Work

- Tools and methodology for static and dynamic analysis
- Identified **popular**, **unpopular**, and **missing** POSIX abstractions
- Open sourced tools and data:
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➢ Revisit OS abstractions for IPC, Threads, and Graphics