CELLS

A virtual Smartphone Architecture

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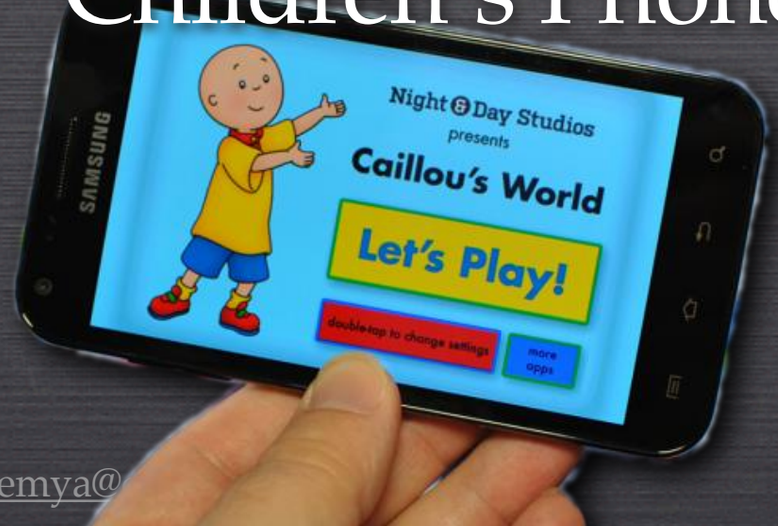
Business Phone

Personal Phone

Developer Phone

Children's Phone



Virtualization

Server Virtualization
Bare-Metal Hypervisor

poor device support / sharing

Desktop Virtualization

Hosted Hypervisor

poor device performance

host user space

Hypervisor / VMM

Host OS Kernel

kernel module

emulated devices

Hardware

Non-Virtualization
User Space SDK

no standard apps
less secure

custom user space API for isolated apps

OS Kernel

Hardware

Key Challenges

- device diversity

		microphone	headset
Power	Touchscreen	Buttons	GPS
Cell Radio	WiFi	GPU	Framebuffer
h.264 accel.	pmem	Binder IPC	Compass
camera(s)	speakers	Accelerometer	RTC / Alarms

- mobile usage model

➡ graphics-accelerated UI

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Key Observation

large: lots of windows / apps

small:

one app at a time

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Key Observation

screen real-estate is limited, and
mobile phone users are accustomed
to interacting with *one thing* at time

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Usage Model

foreground / *background*

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Complete Virtualization

- multiple, isolated virtual phones (VPs) on a single mobile device
- 100% device support in each VP
  - unique phone numbers - single SIM!
  - accelerated 3D graphics!

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Efficient Virtualization

- less than 2% overhead in runtime tests
- imperceptible switch time among VPs

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Transparent Virtualization

- each VP sees / uses all devices
- user can run any unmodified apps
- foreground VP switches like an app

Single Kernel: Multiple VPs

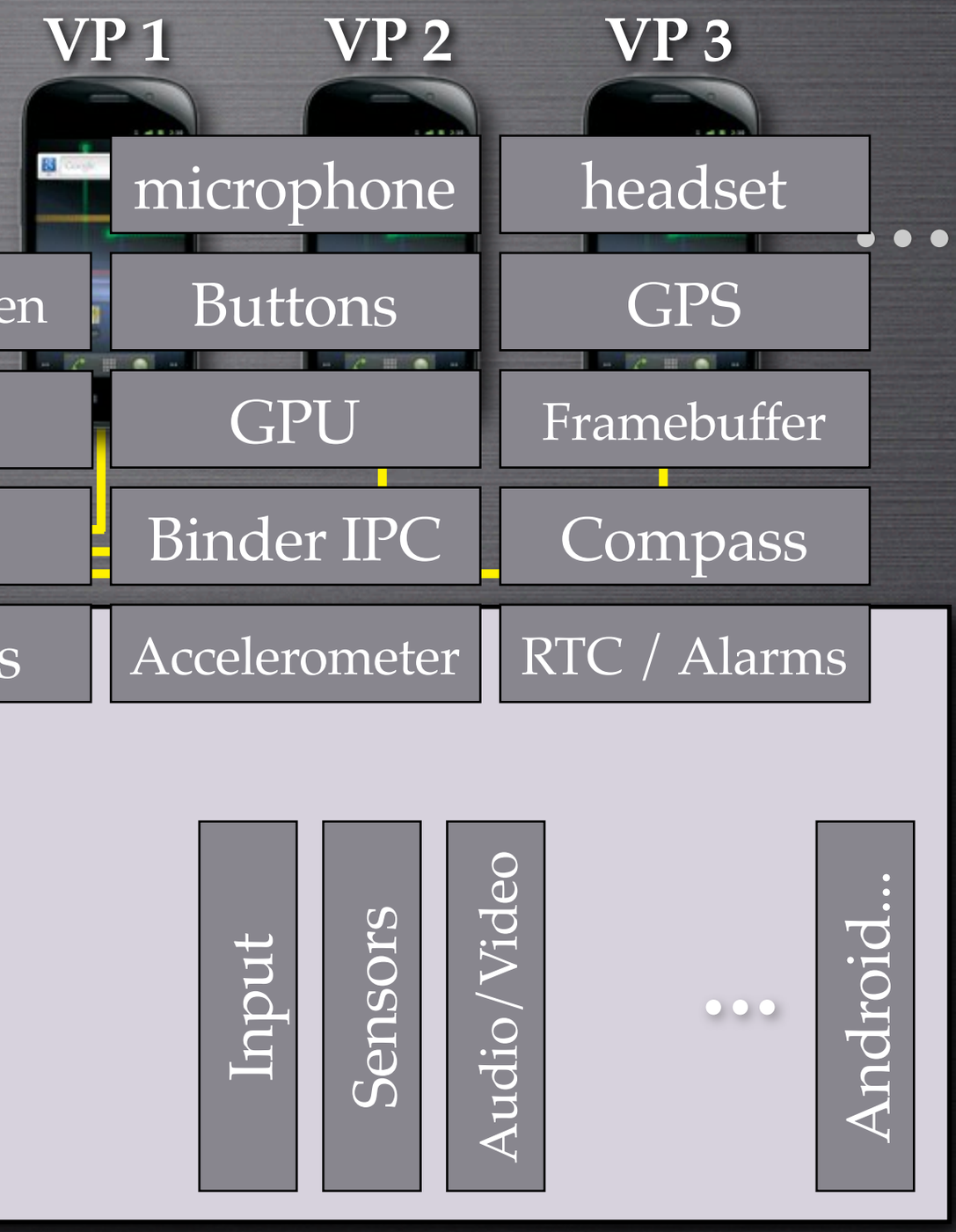
isolated collection of processes

virtualize at OS interface

Linux Kernel

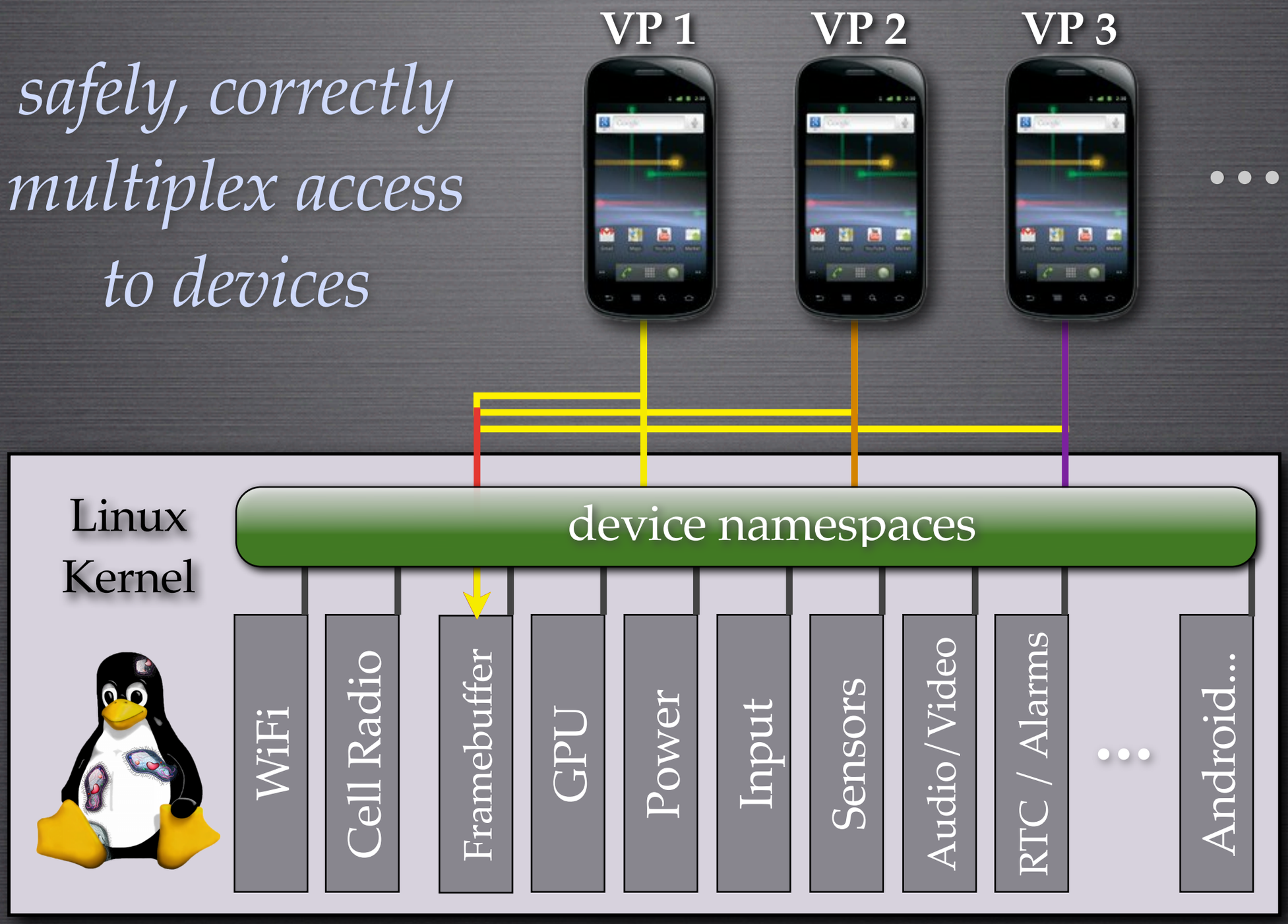
Single Kernel: Device Support

all VPs access the same device



Device Namespaces

safely, correctly multiplex access to devices



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VP 1 VP 2 VP 3

device namespaces

\+

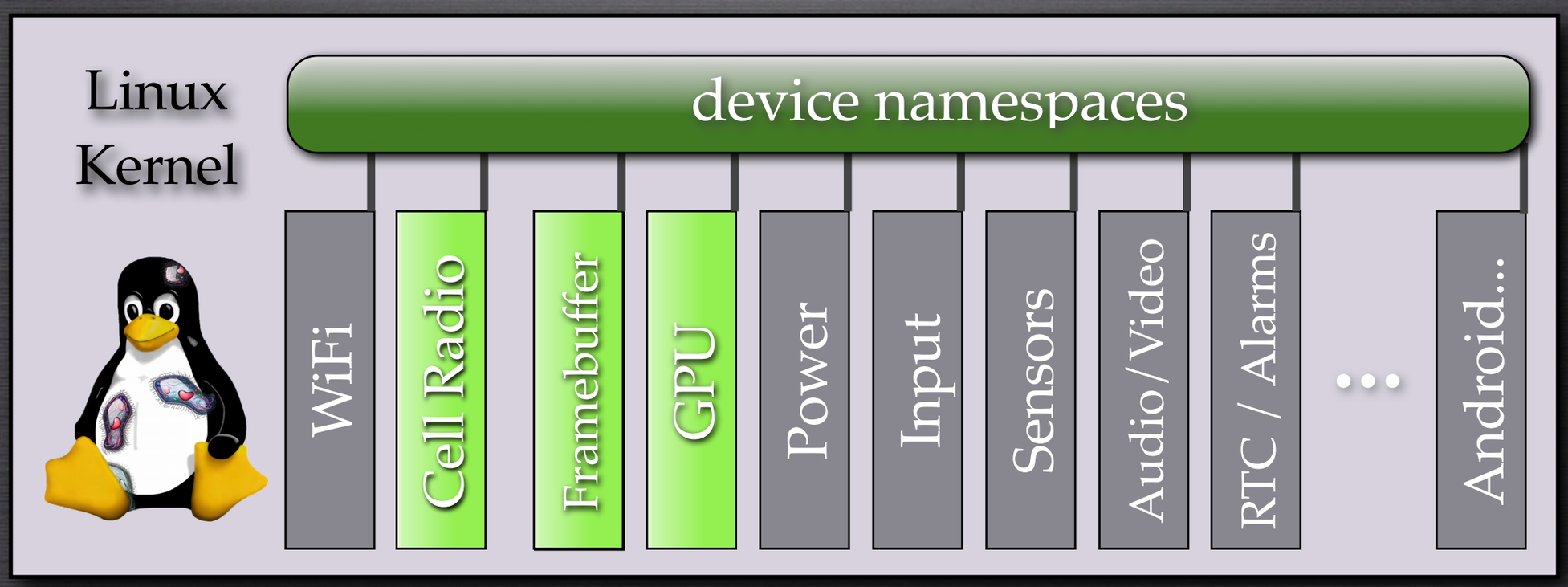
foreground / *background*

...

efficient basic graphics virtualization

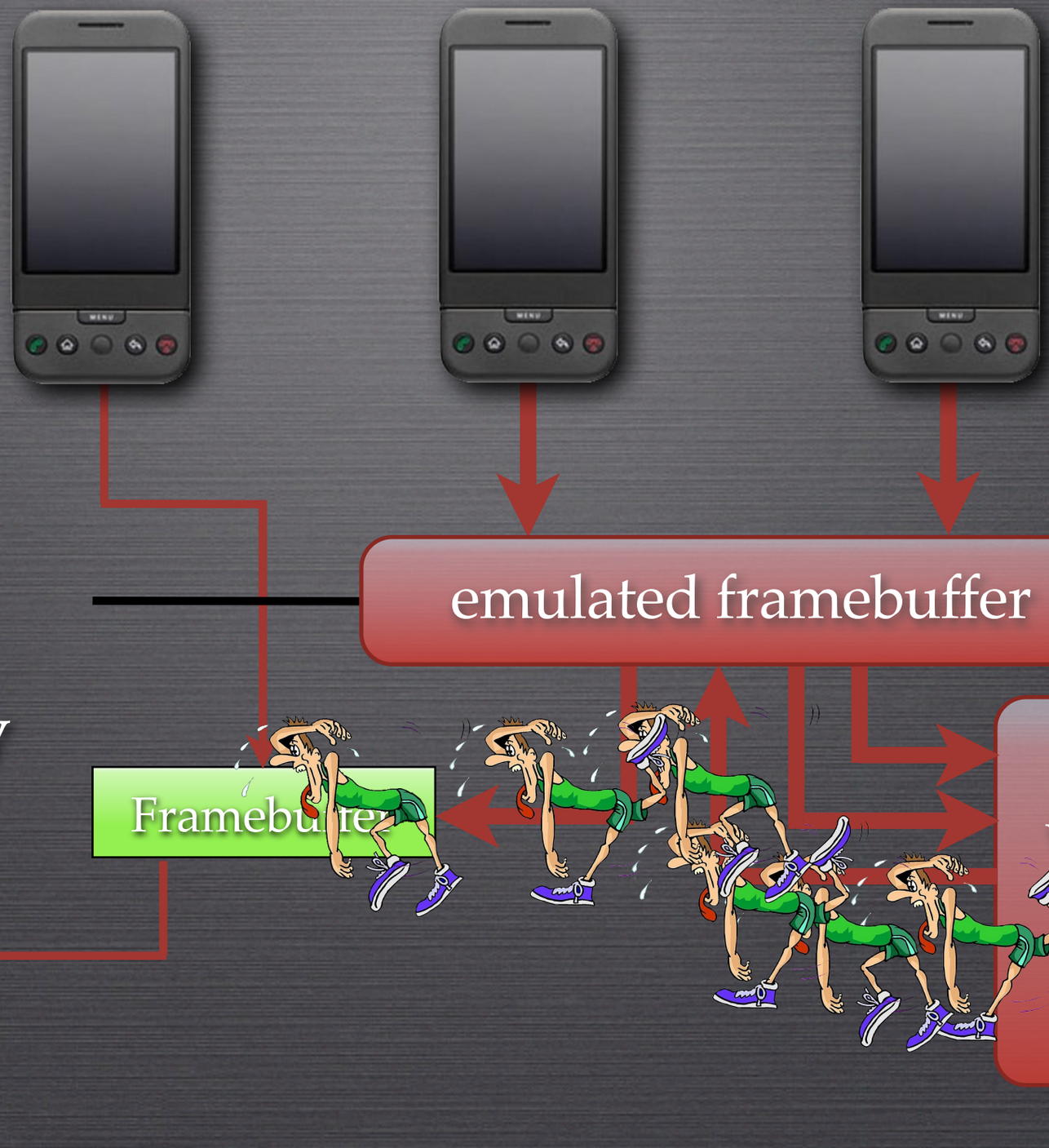
hardware accelerated graphics

proprietary / closed interface



Approach 1: Single Assignment

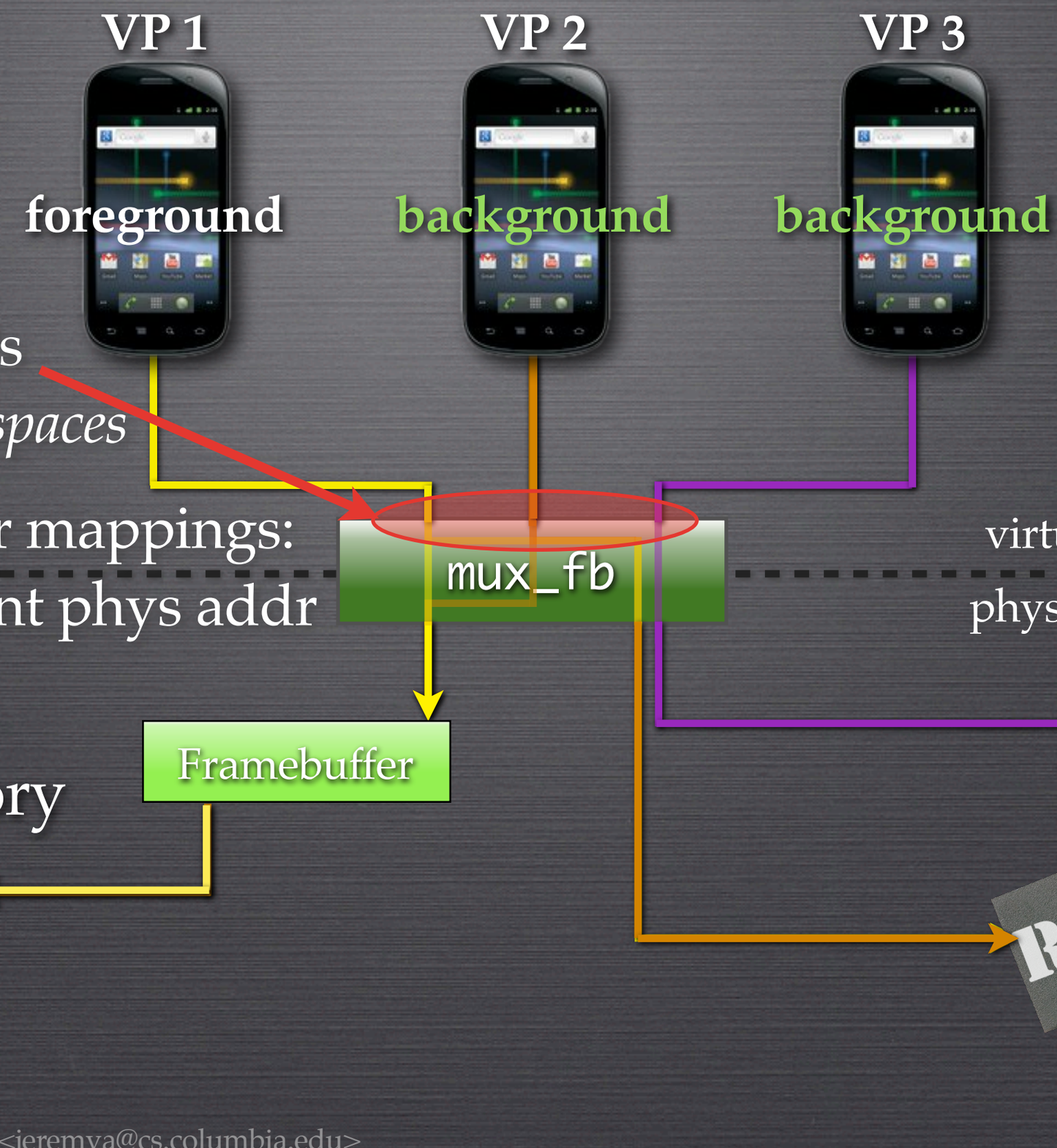
Approach 2: Emulated Hardware



Cells: Device Namespaces

`mux_fb` presents identical device interface to all VPs using *device namespaces*

swap virt addr mappings: point to different phys addr



Accelerated Graphics

VP: just a set of processes!

process isolation

Framebuffer

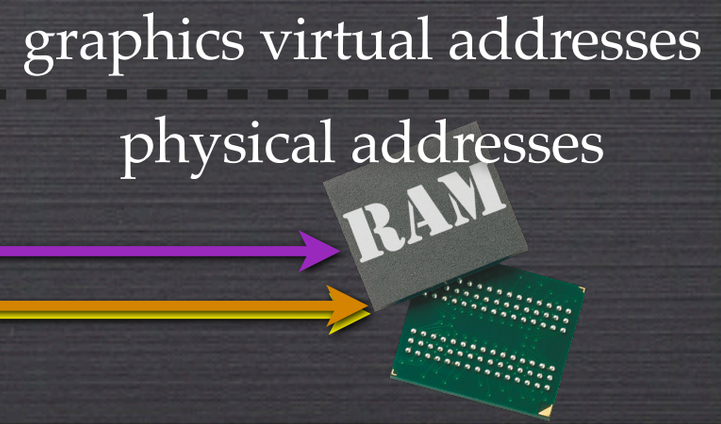
MMU

GPU

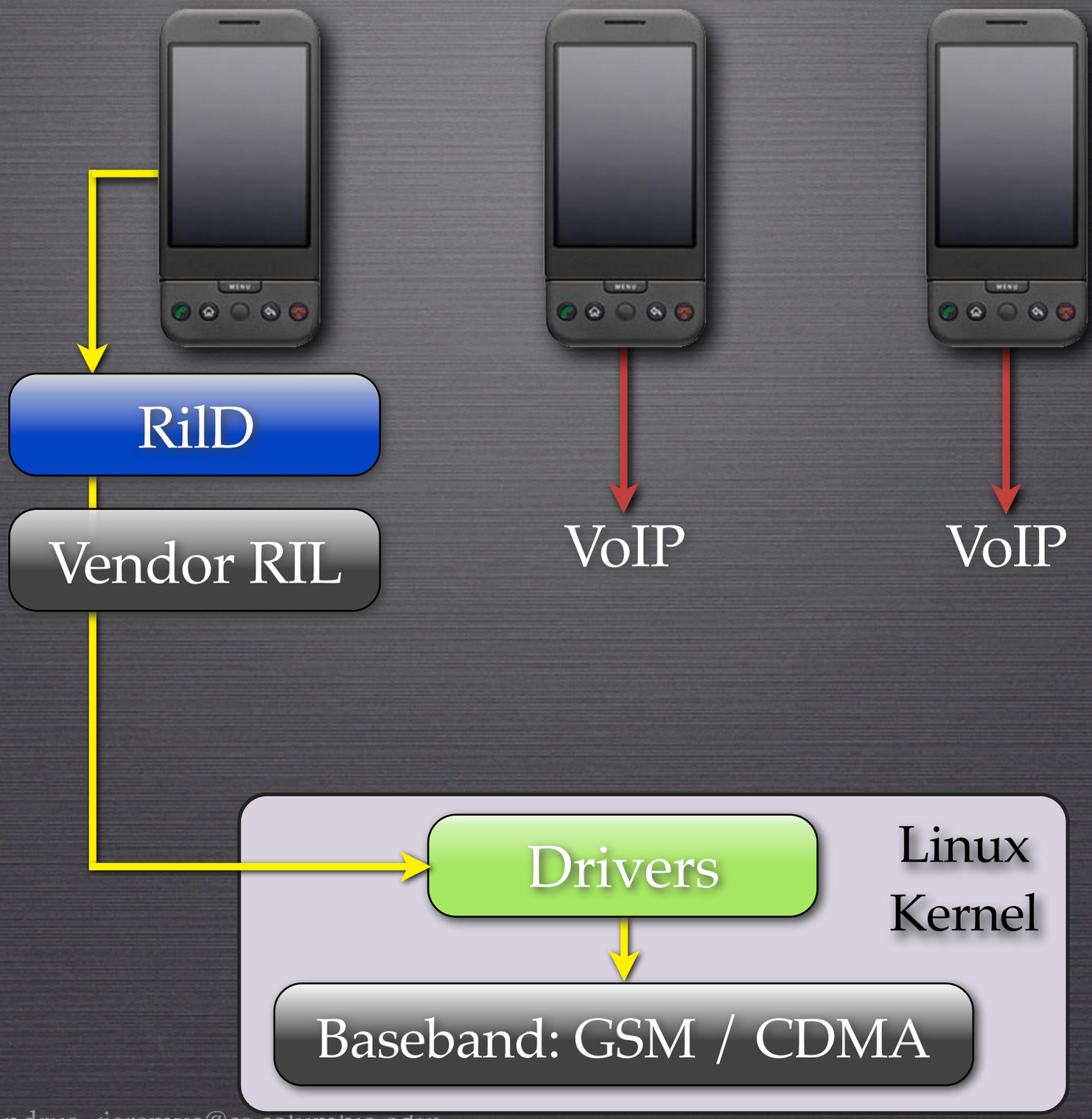
graphics virtual addresses

physical addresses

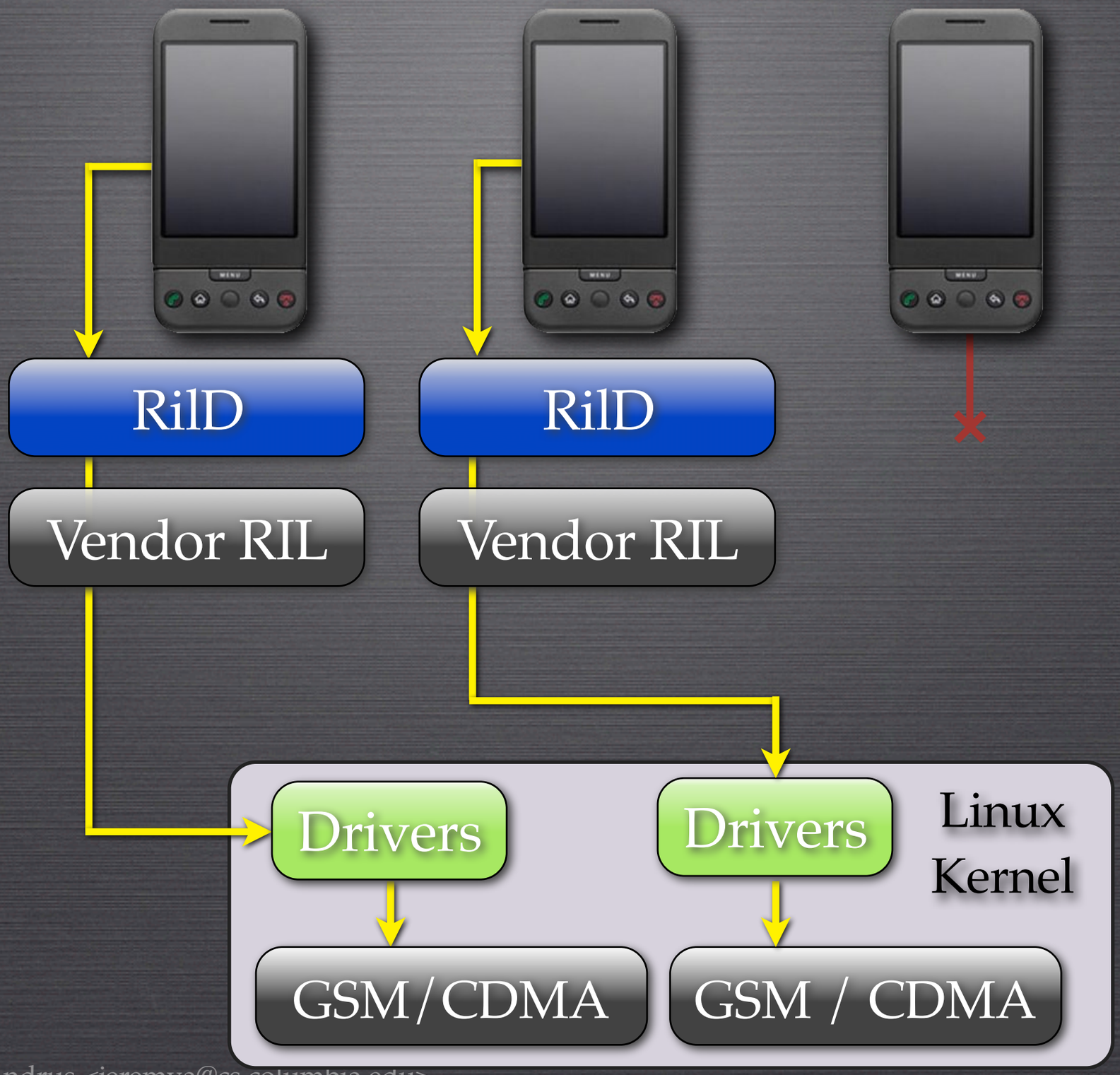
Device Namespace + Graphics Context



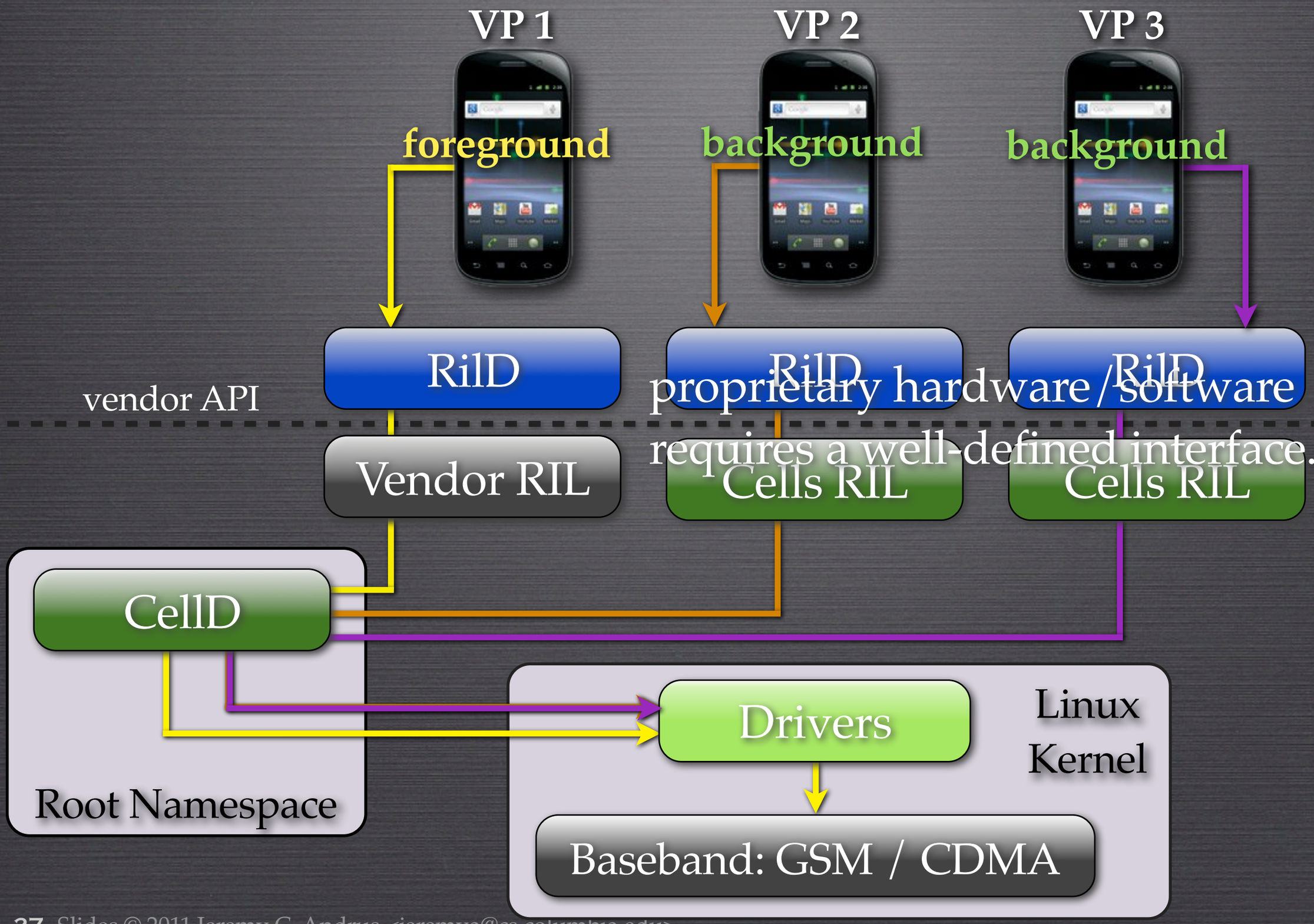
VoIP?



Dual-SIM?



Cells: User-Level Namespace Proxy



Experimental Results

Setup

- Nexus S
- *five* virtual phones
- overhead vs. stock ⟨*Android 2.3*⟩

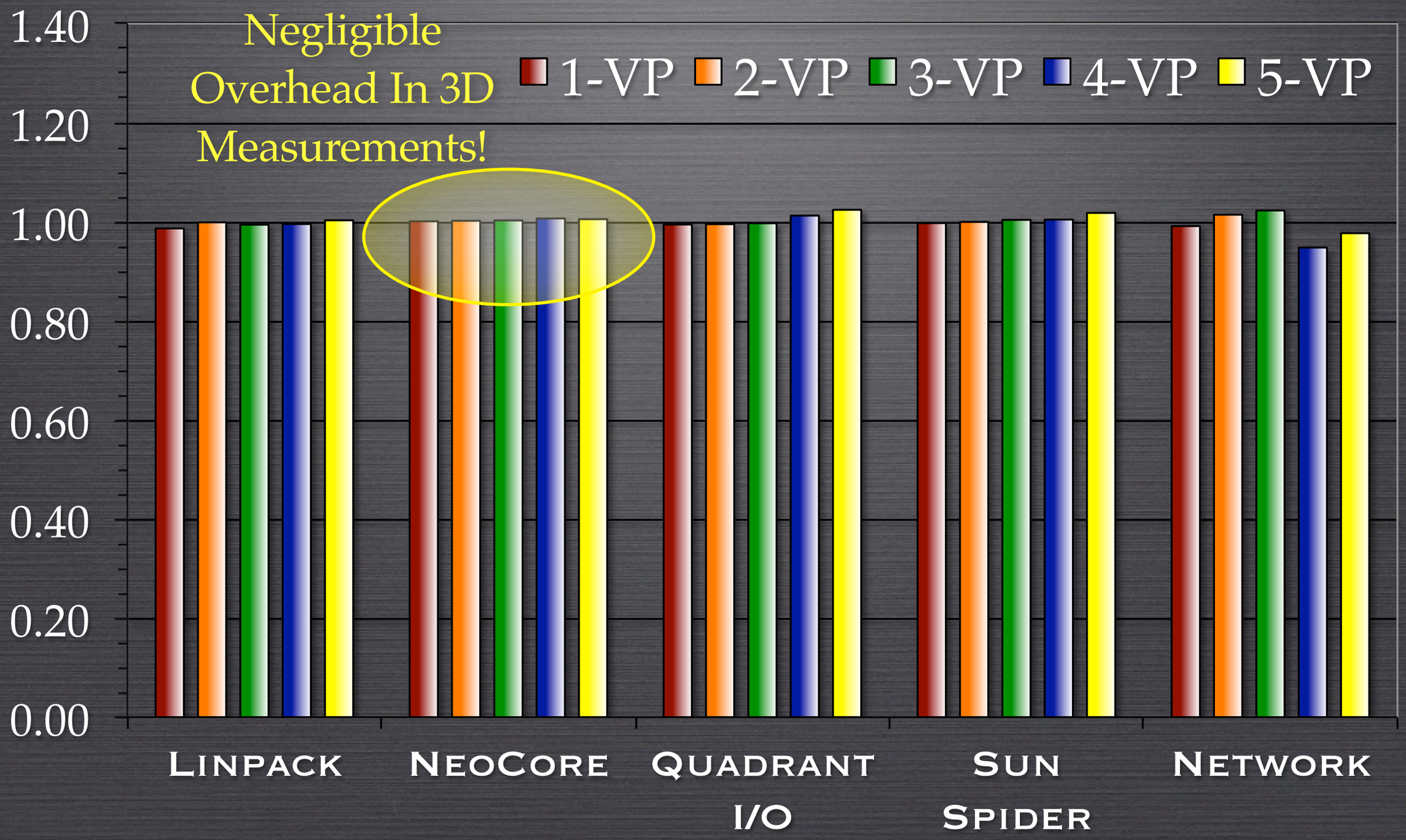
Experimental Results

Setup

- CPU ⟨*Linpack*⟩
- graphics ⟨*Neocore*⟩
- storage ⟨*Quadrant*⟩
- web browsing ⟨*Sun Spider*⟩
- networking ⟨*Custom WiFi Test*⟩

Experimental Results

Runtime Overhead



Demo

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Complete, Efficient, Transparent Mobile Virtualization

- device namespaces
  - safely and efficiently share devices
- foreground / background
  - designed specifically for mobile devices
- implemented on Android
- less than 2% overhead on Nexus S

More Info

Software Systems Laboratory

cells.cs.columbia.edu

CELLROX

cellrox.com

