Battery Consumption Details

Tips & Tricks
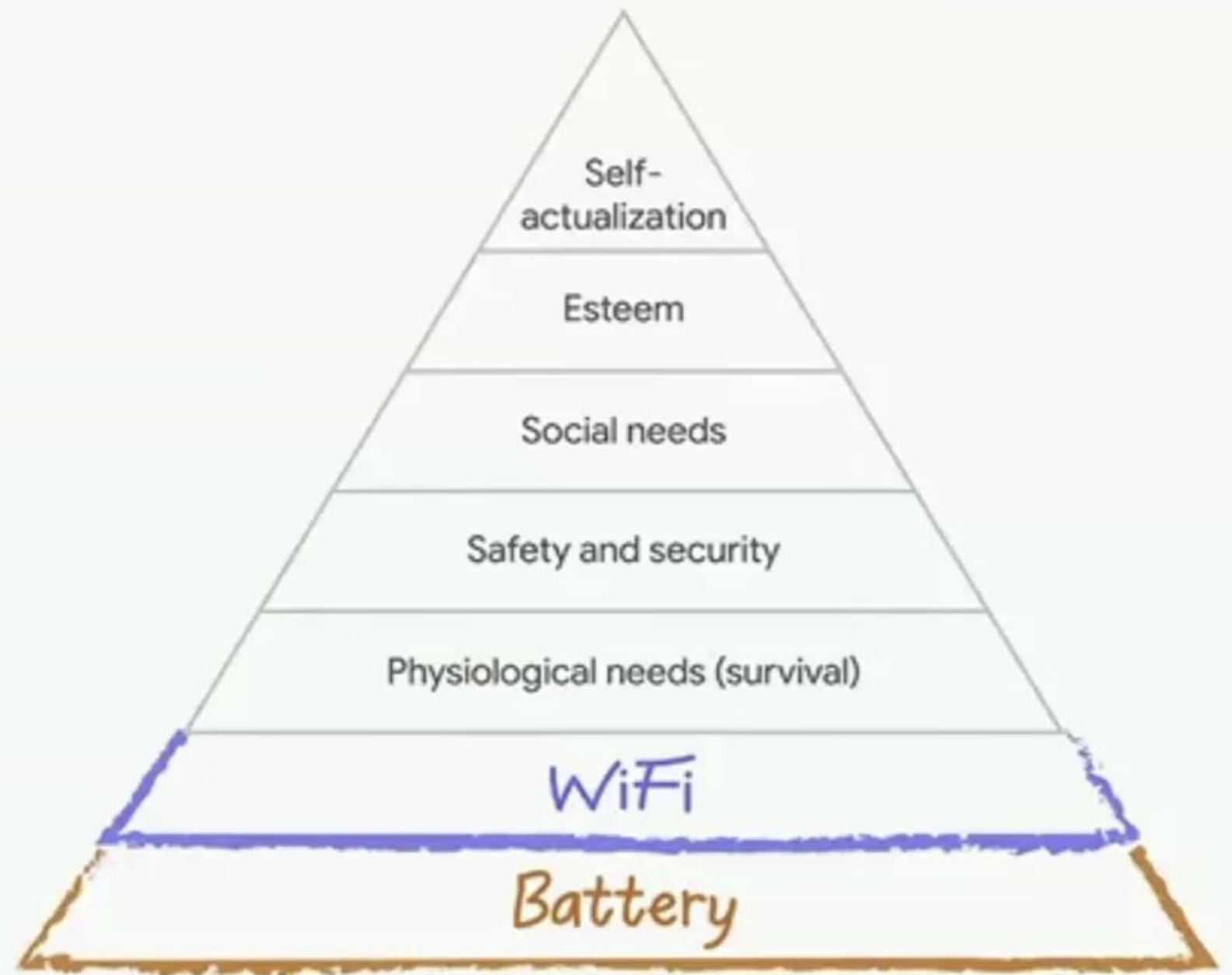
What drives battery life

display
gsm *
wi-fi *
bluetooth
gps
sensors
system

What drives battery life

display *
gsm *
wi-fi *
bluetooth
gps
sensors
system

What drives battery life

display *
gsm *
wi-fi *   Bluetooth 4 LE (2 Mbit/s)
bluetooth
                                 Bluetooth 5
gps   2x+ speed on LE
sensors
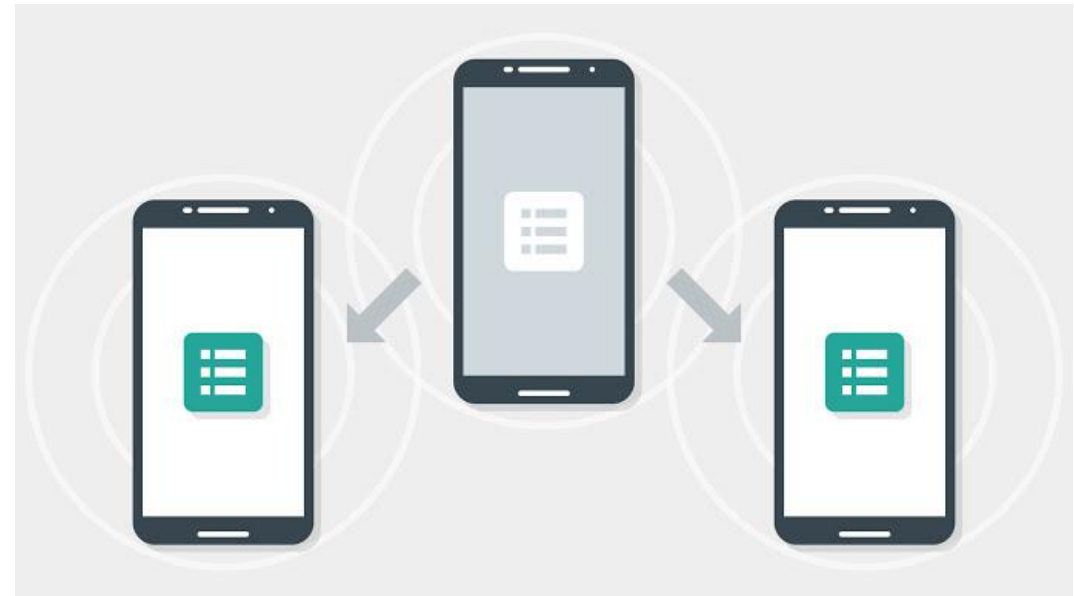system

What drives battery life

display *
gsm *
wi-fi *
bluetooth
gps
sensors
system

The Nearby Messages API from Google

Bluetooth, Bluetooth LE, Wi-Fi and near-ultrasonic audio

What drives battery life

display *
gsm *
wi-fi *
bluetooth   Fused Location Provider API
gps
sensors
system

What drives battery life

display *
gsm *
wi-fi *
bluetooth
gps
sensors
system

CPU
GPU
RAM
OS

What drives battery life

display *
gsm *
wi-fi *
bluetooth
gps
sensors
system

What drives battery life

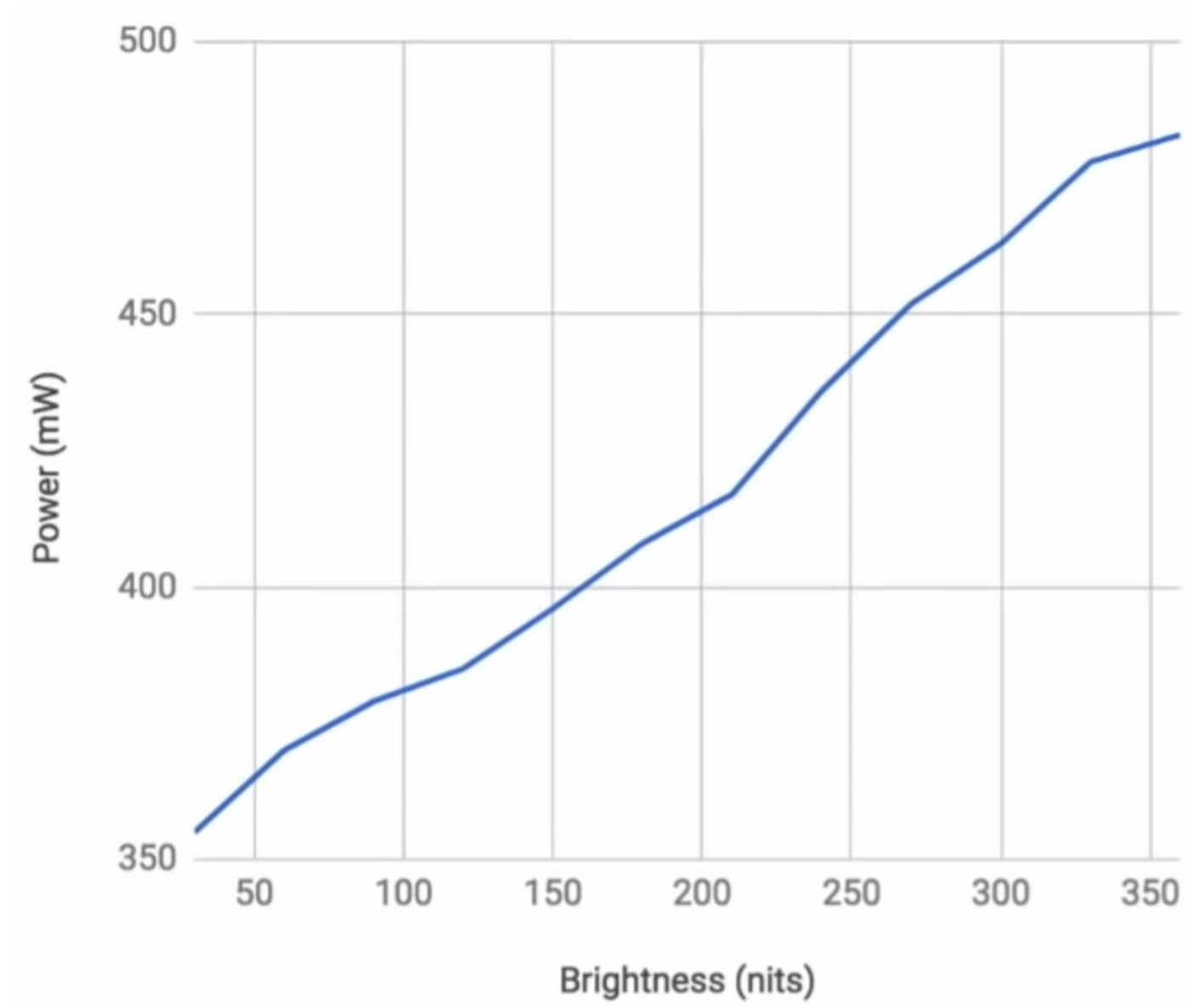**display** *
gsm *
wi-fi *
bluetooth
gps
sensors
system

Galaxy S9

HD+ 1480x720
FHD+ 2220 x 1080
Quad HD+ 2960x1440

Display

Display

LCD
VS
OLED

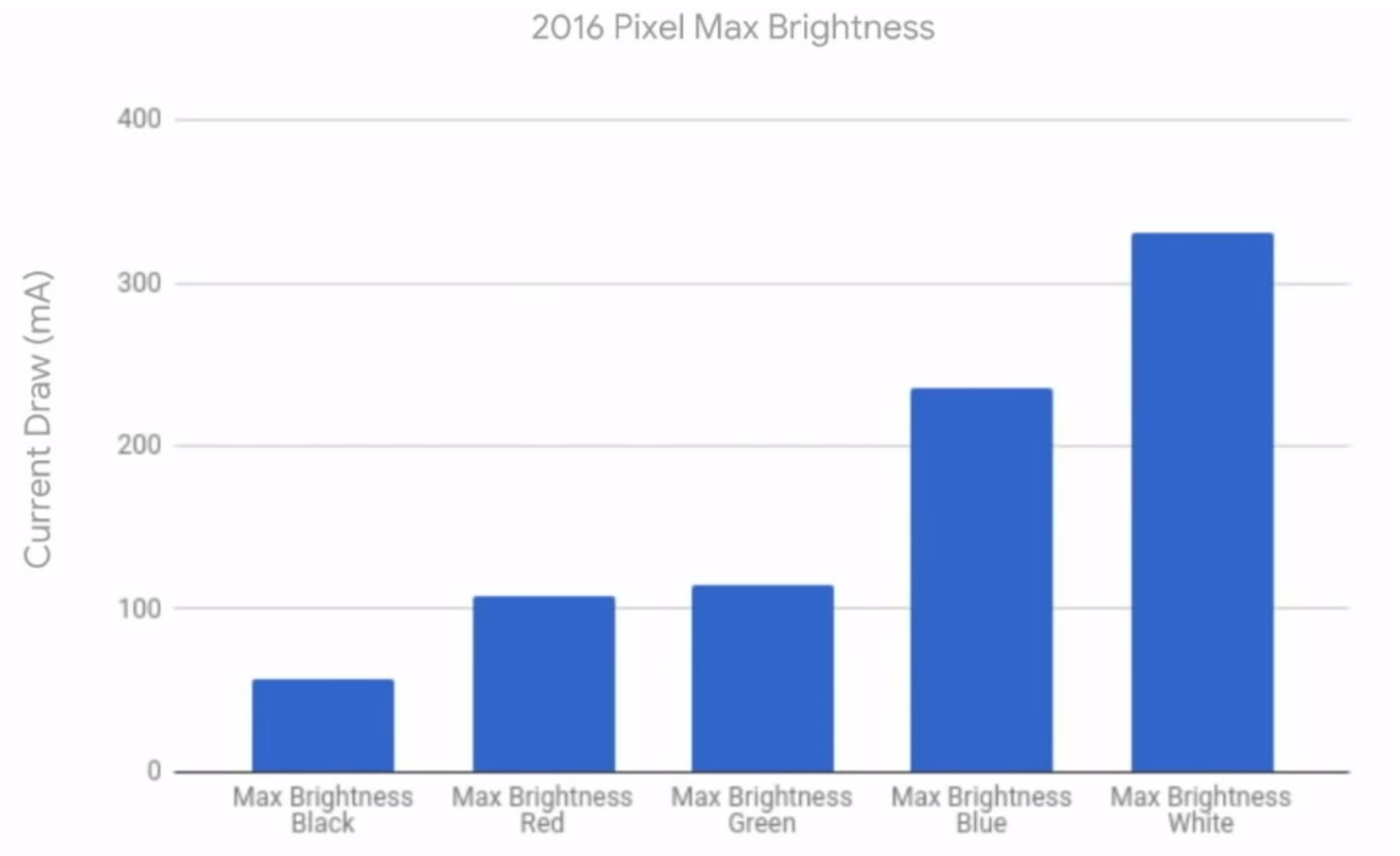Does dark mode save power?

LCD/IPS - no
AMOLED - yes

black #000000

xda 5% per hour / 18% per day

Worth it?

Display

At full brightness

R 600mW
G 580mW
B 800mW

2016 Pixel Max Brightness

Display

YouTube video playback

brightness	normal mode	dark mode	-%
50%	193 mA	185 mA	4%
100%	343 mA	197 mA	43%

YouTube video paused

brightness	normal mode	dark mode	-%
50%	93 mA	80 mA	14%
100%	239 mA	96 mA	60%

Gboard

brightness	normal mode	dark mode	-%
50%	186 mA	177 mA	5%
100%	408 mA	323 mA	21%

Maps

brightness	normal mode	dark mode	-%
50%	351 mA	323 mA	8%
100%	517 mA	356 mA	31%

Display

Dark mode

Theme.AppCompat.DayNight
-night qualifier colors.xml
since API 8

Runtime redraw

no api to check display type
🫢 gsmarena.com request

What drives battery life

display *
gsm *
wi-fi *
bluetooth
gps
sensors
system

Research

Gernot Heiser
UNSW professor, Sydney, Australia
Secure Elements co-founder, Munich, Germany

SEOS is an OS that is totally unique in that it is provably secure.
It is based on the seL4 microkernel, the world's first and still only
**general-purpose OS kernel with a mathematical proof of
bug-free implementation** extending all the way to machine
code, and mathematical proofs of enforcement of security-
relevant isolation. Being based on this rock-solid foundation,
SEOS inherits seL4's provable security and, unlike any other
OS, can guarantee system security.

Aaron Carroll, his student and PhD

Research
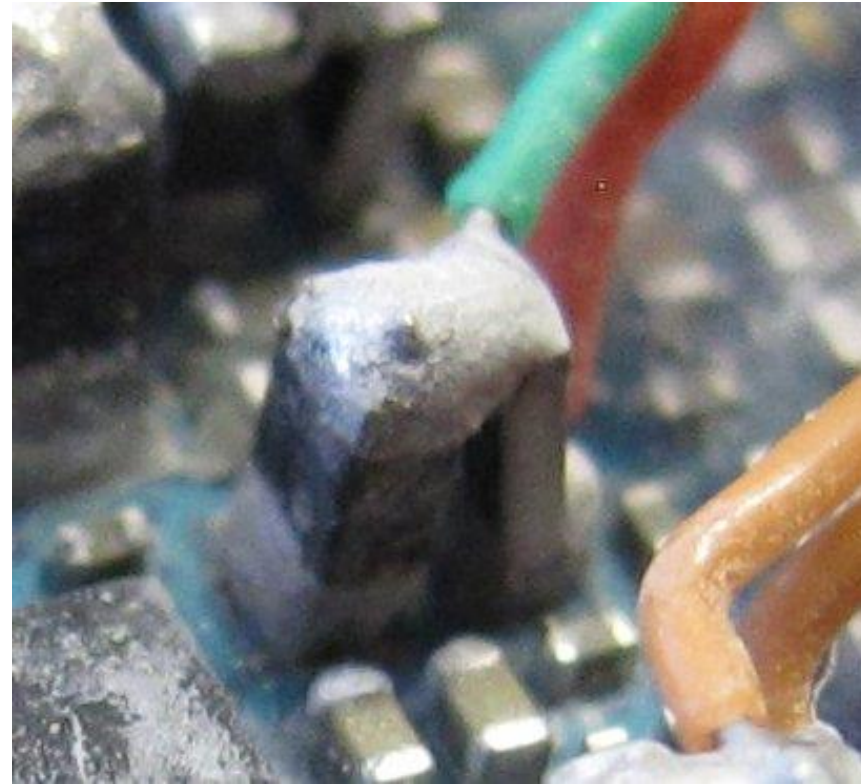
Suspended / idle
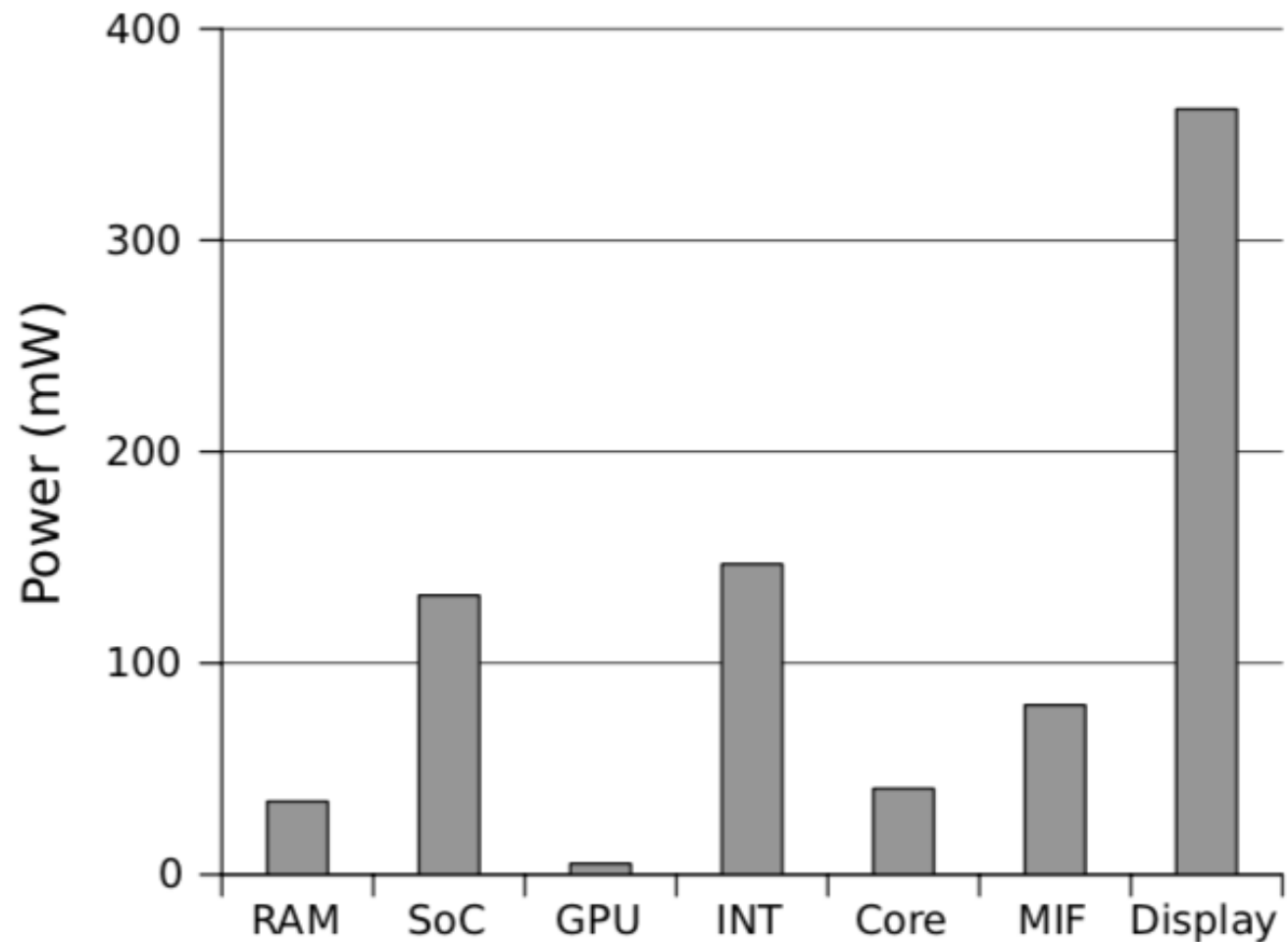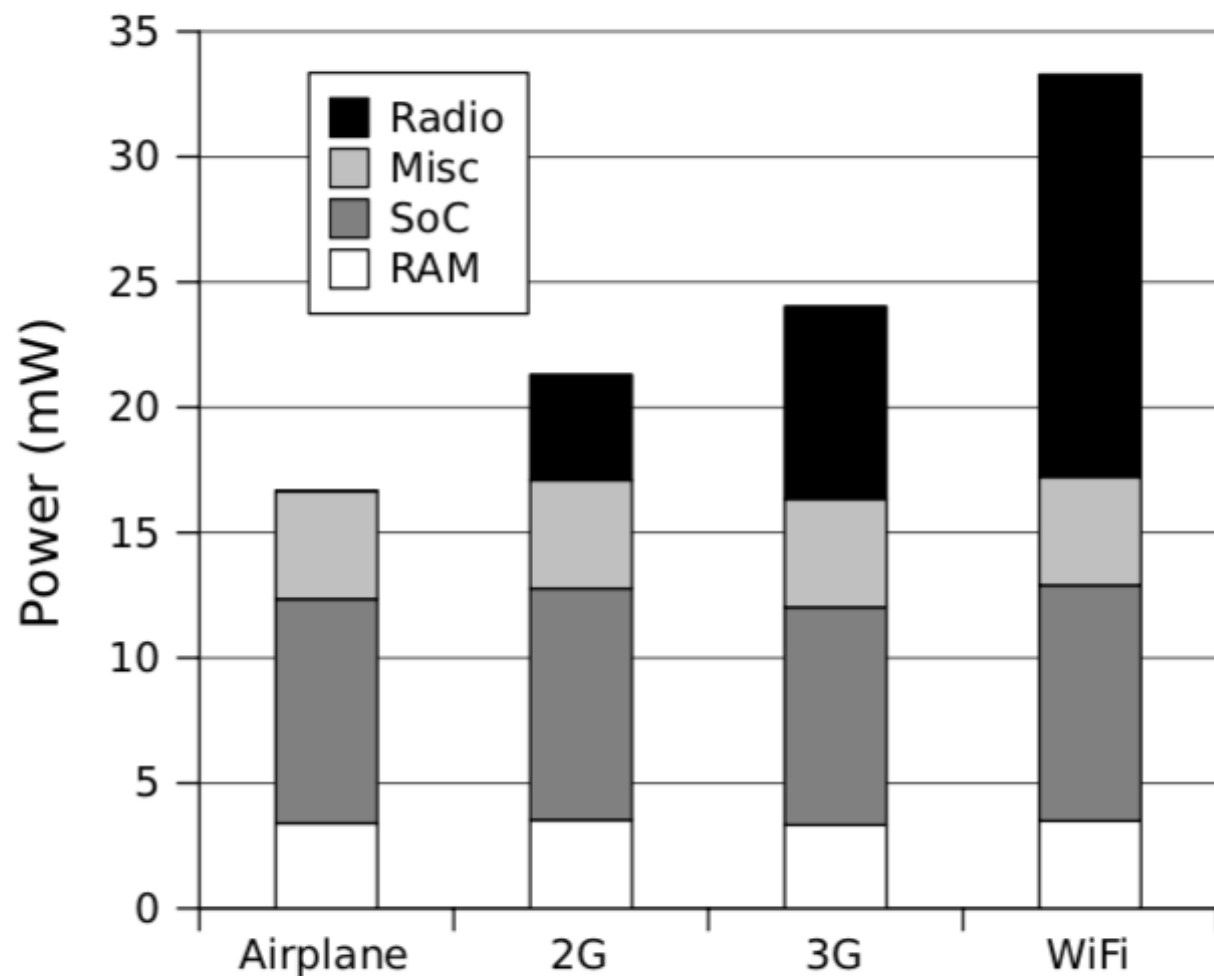
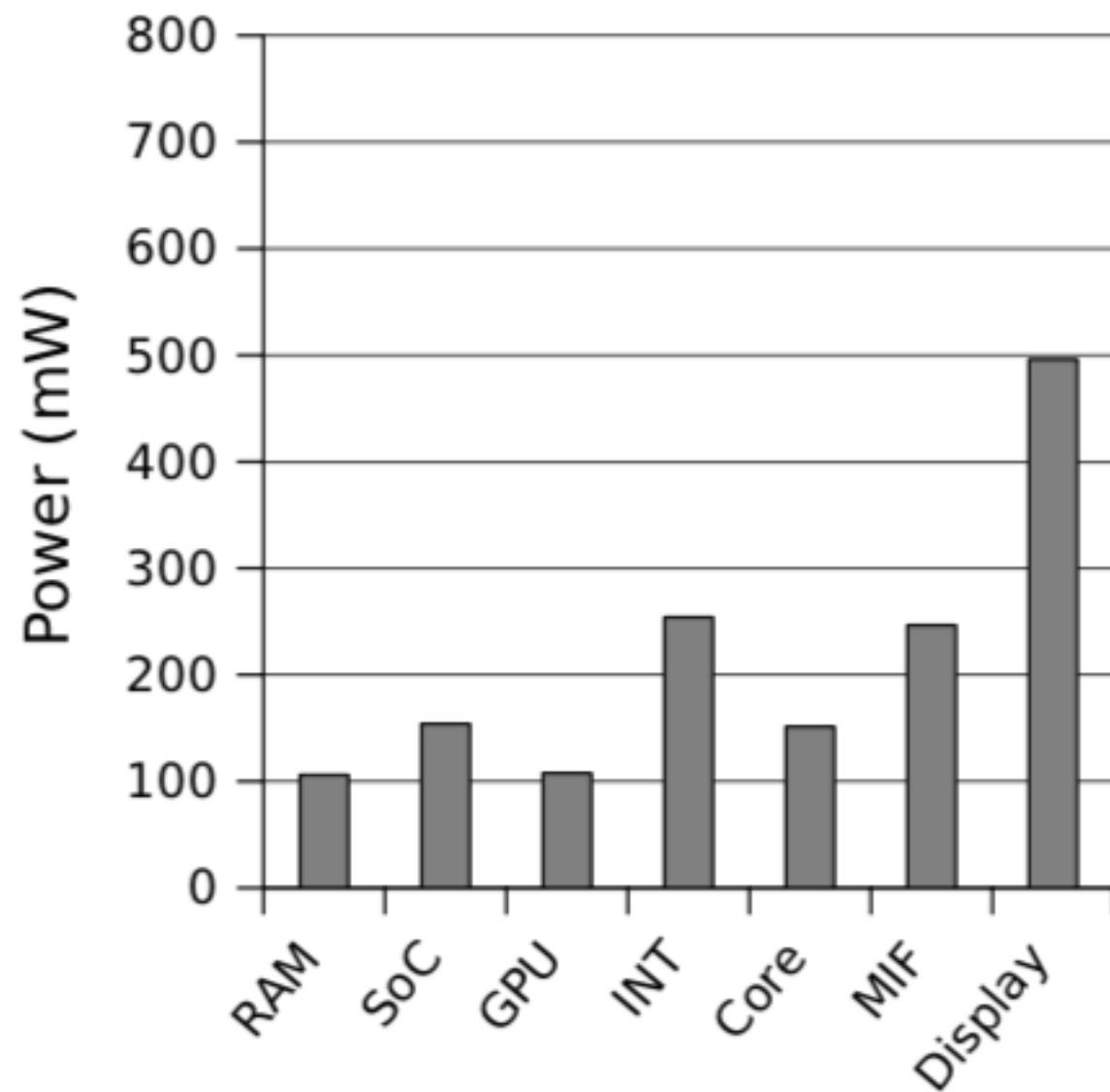**805 mW**

amps = watts / volts
0.805 / 3.8 = 0.2118 amps
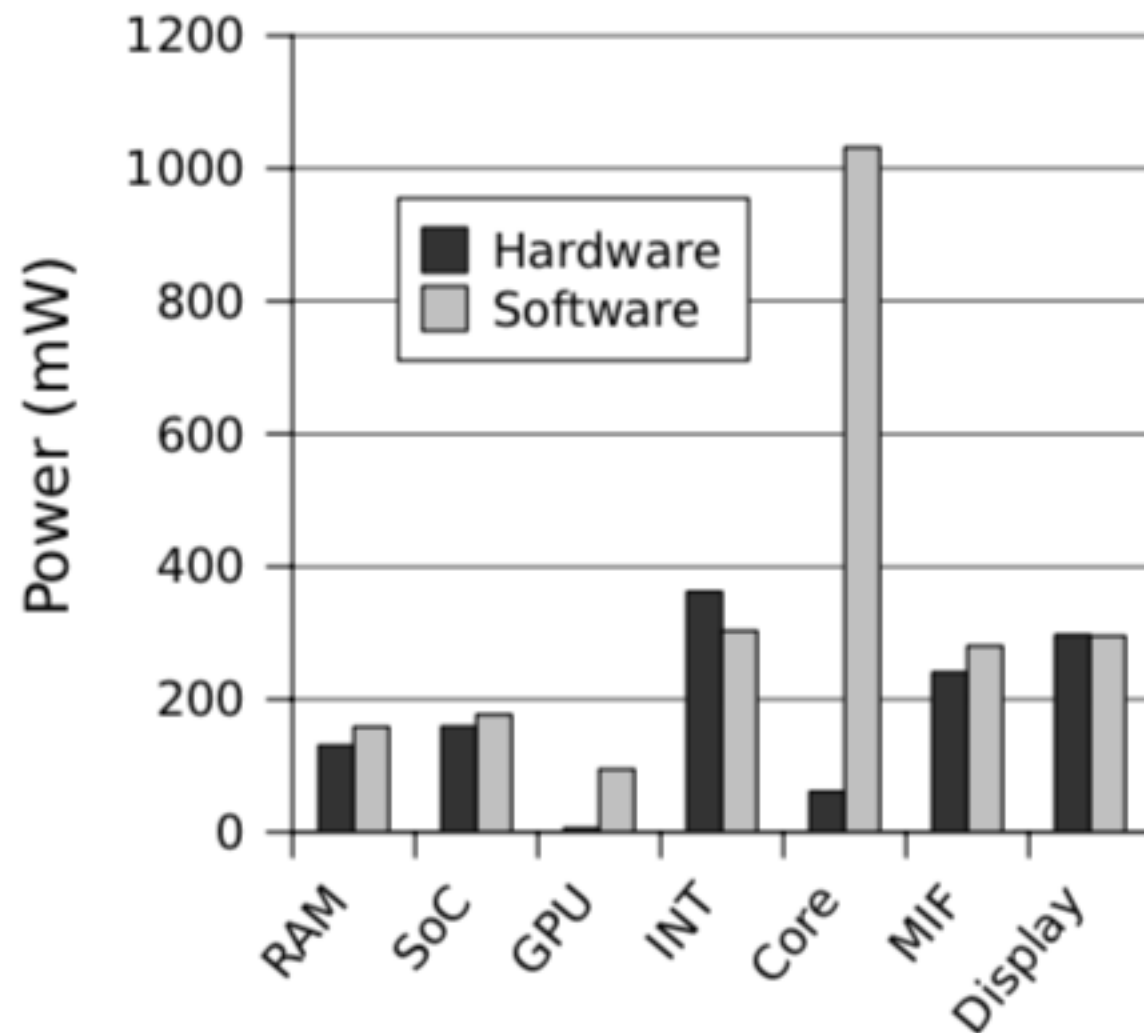2100 / 211.8 = 10 h
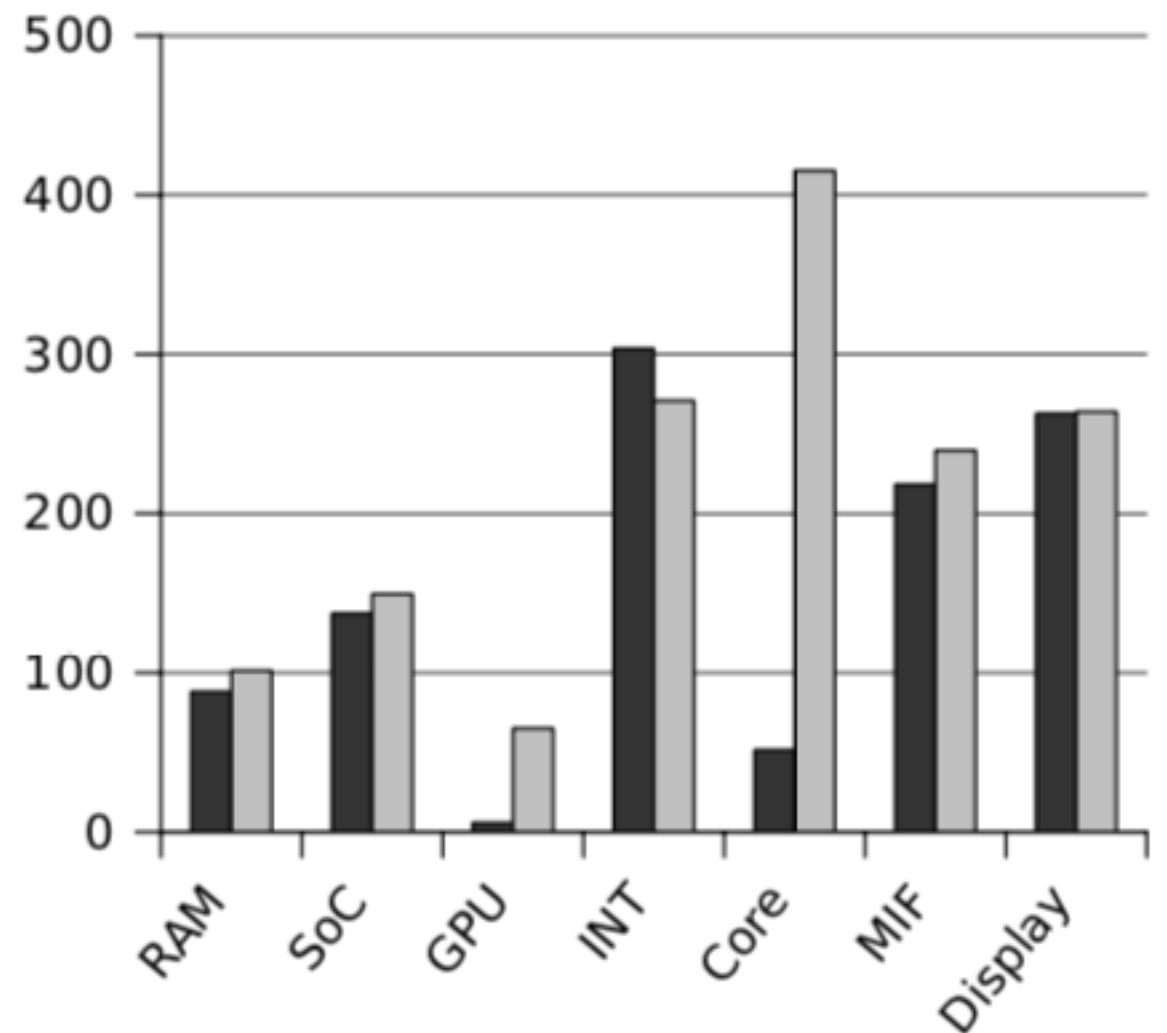
Games

(a) Angry Birds 1516 mW
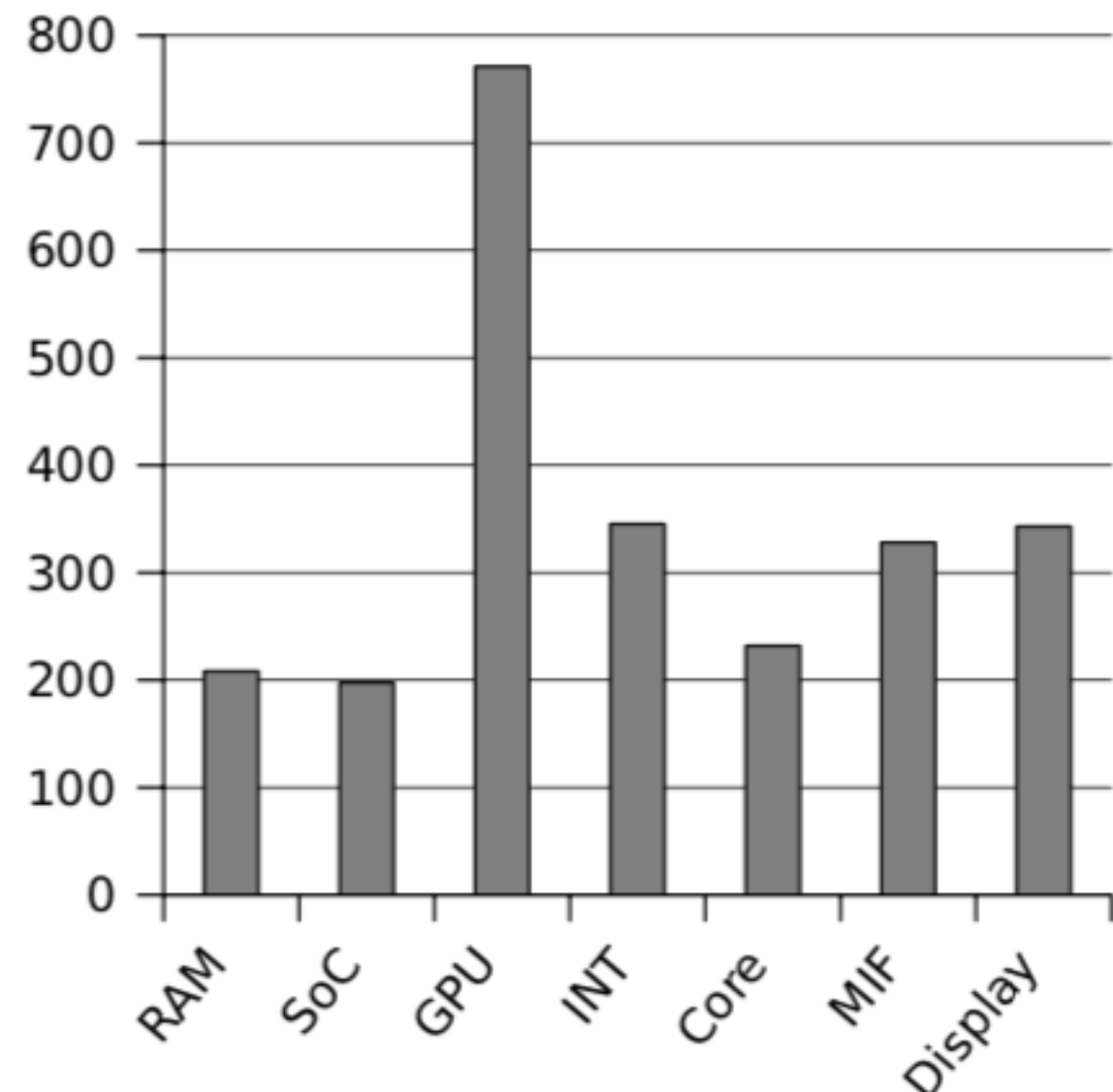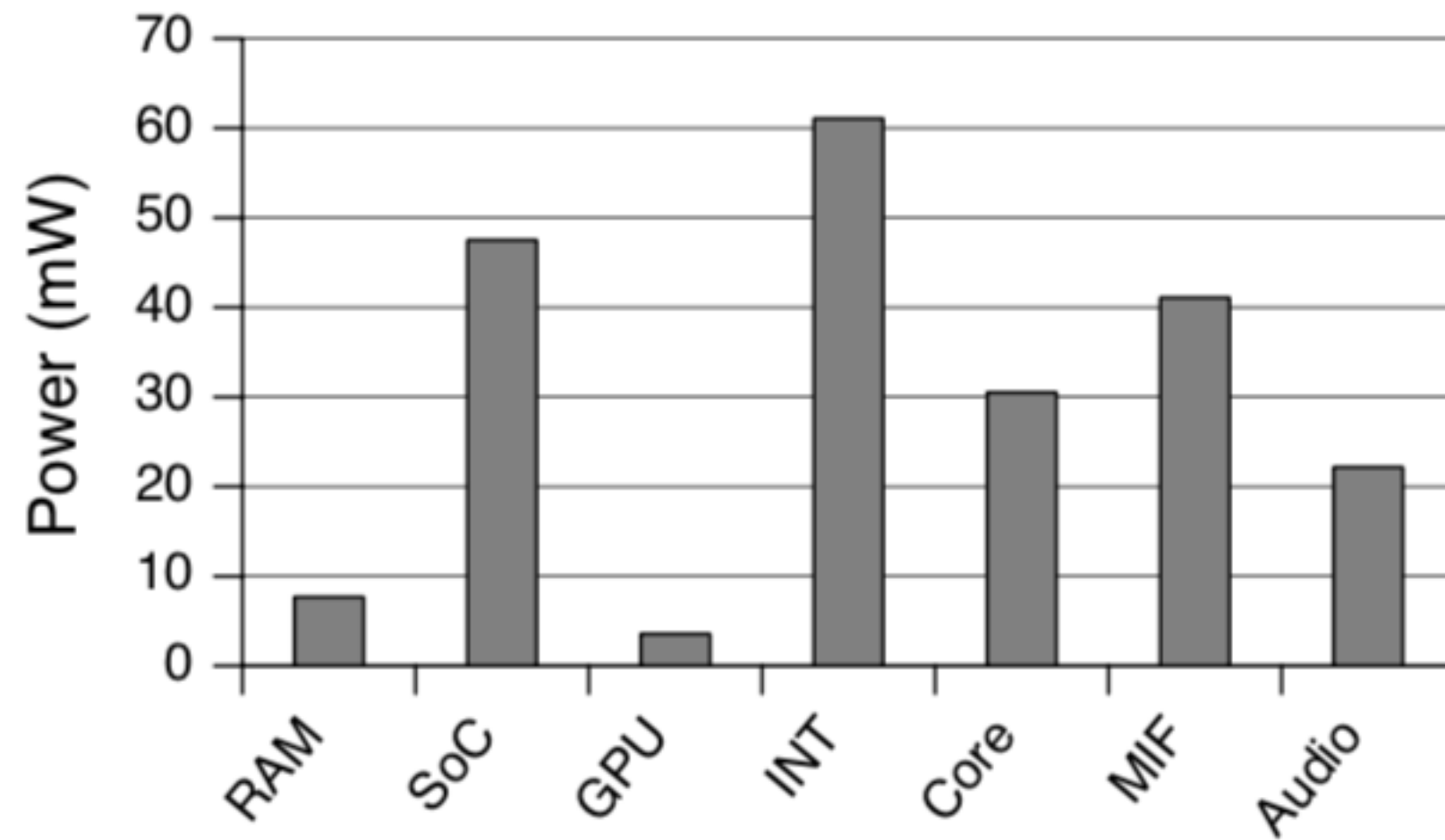
(b) Need for Speed 2425 mW

Video

(a) high quality   hw 1270 mW
sw 2329 mW

(b) low quality   hw 1084 mW
sw 1571 mW

Audio

mp3 226 mW

Call, sms
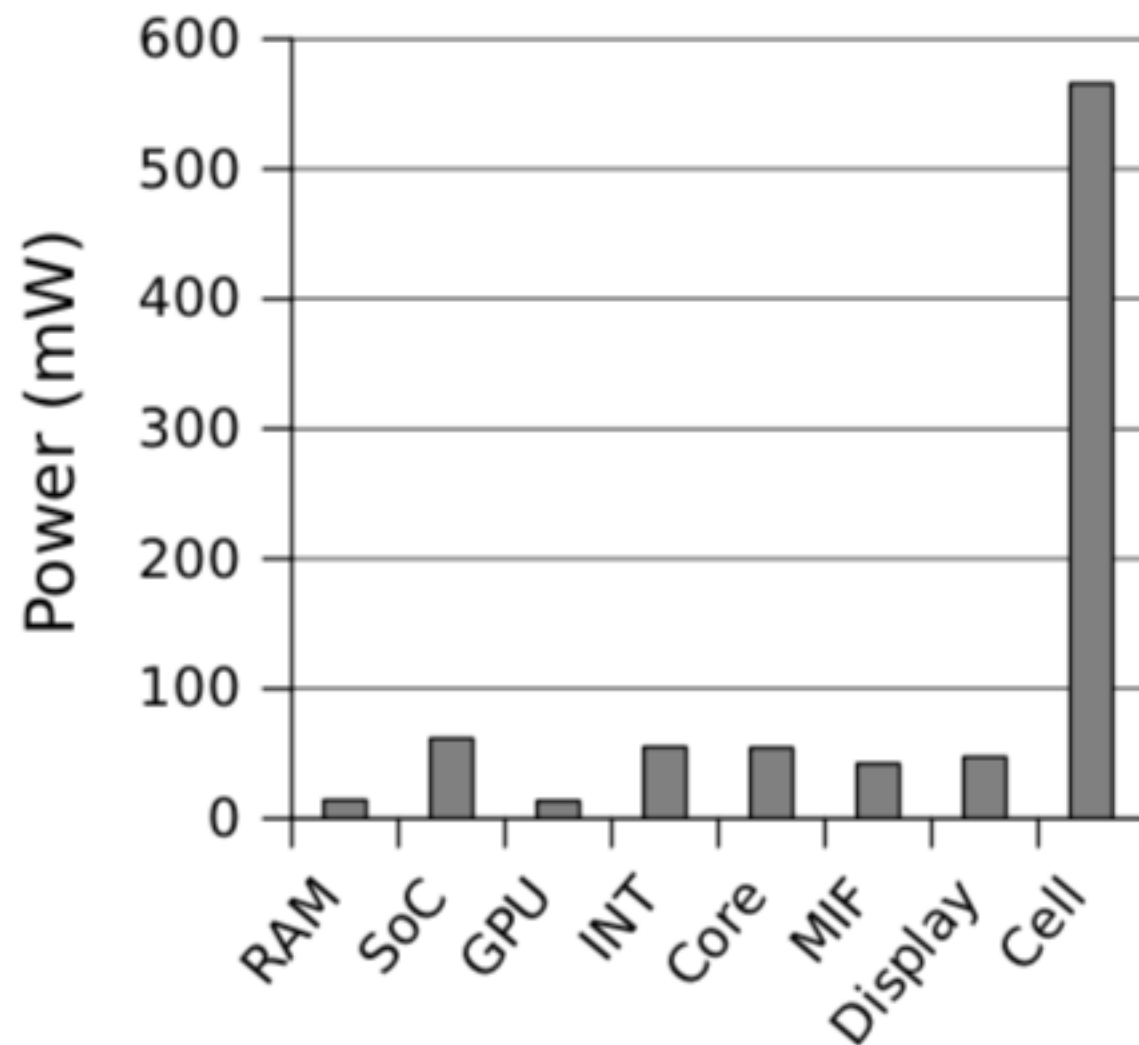
(a) call   865 mW
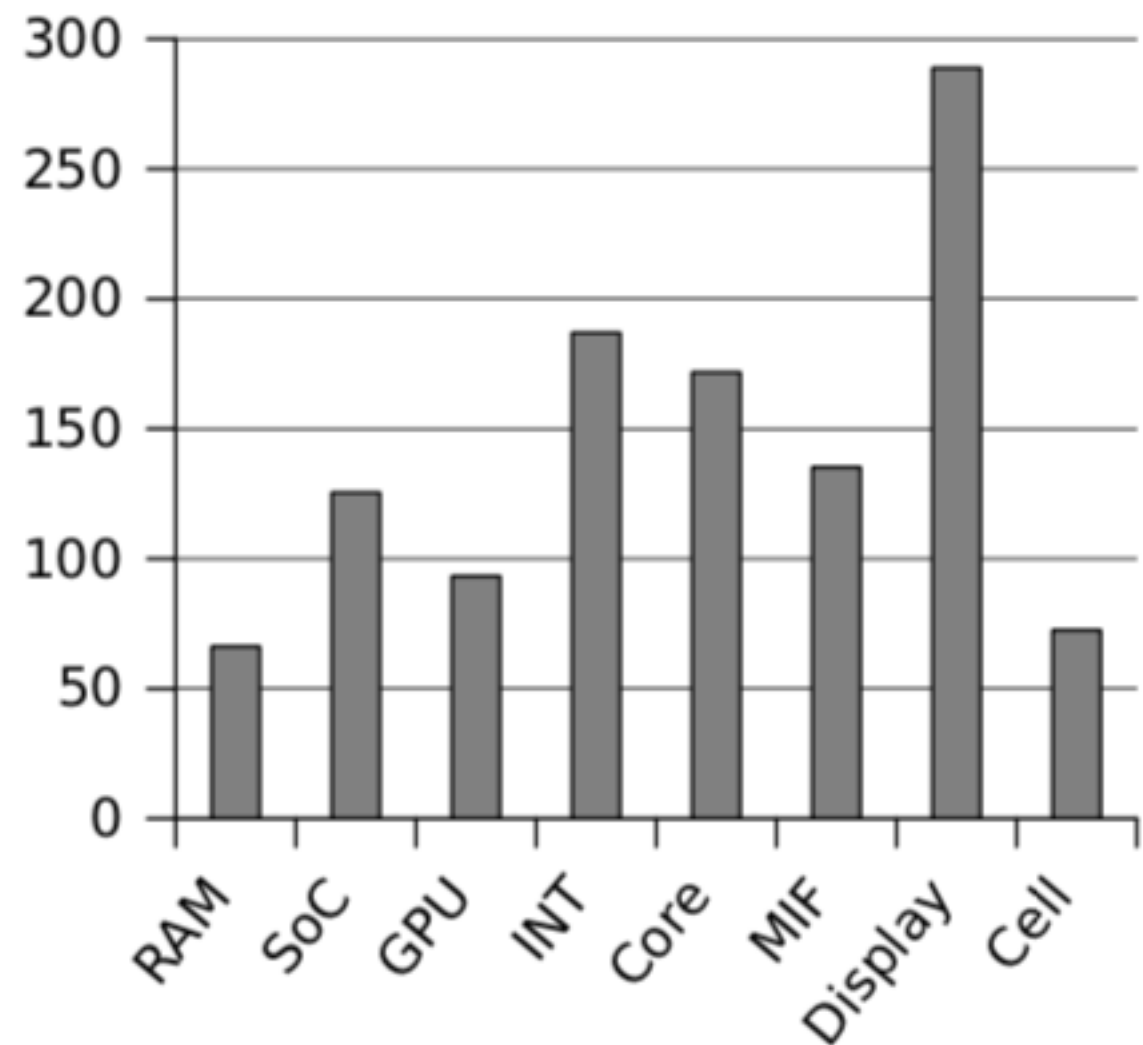
(b) SMS   3g 1140 mW

Web browsing
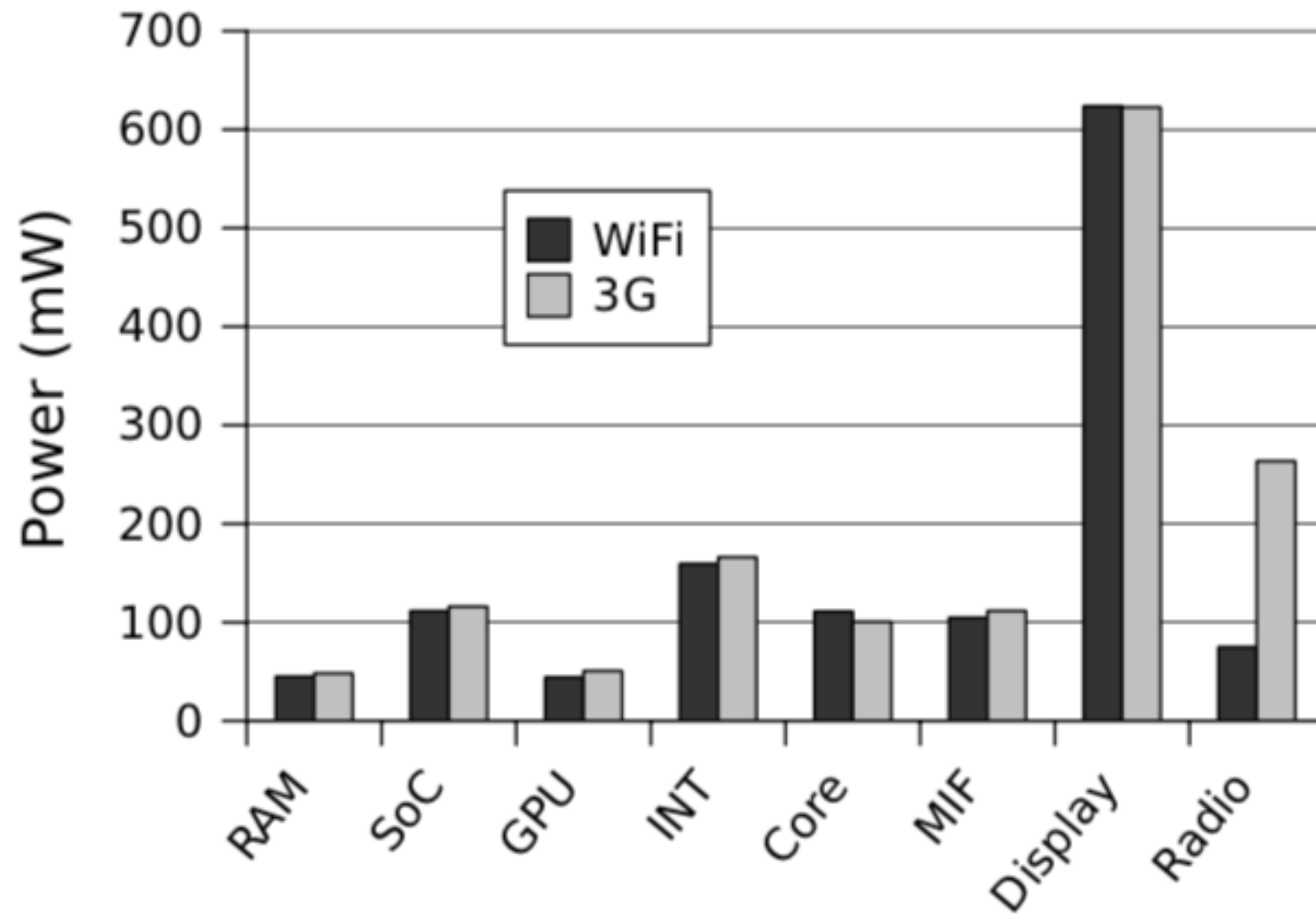
wi-fi 1275 mW / 3g 1479 mW

Email
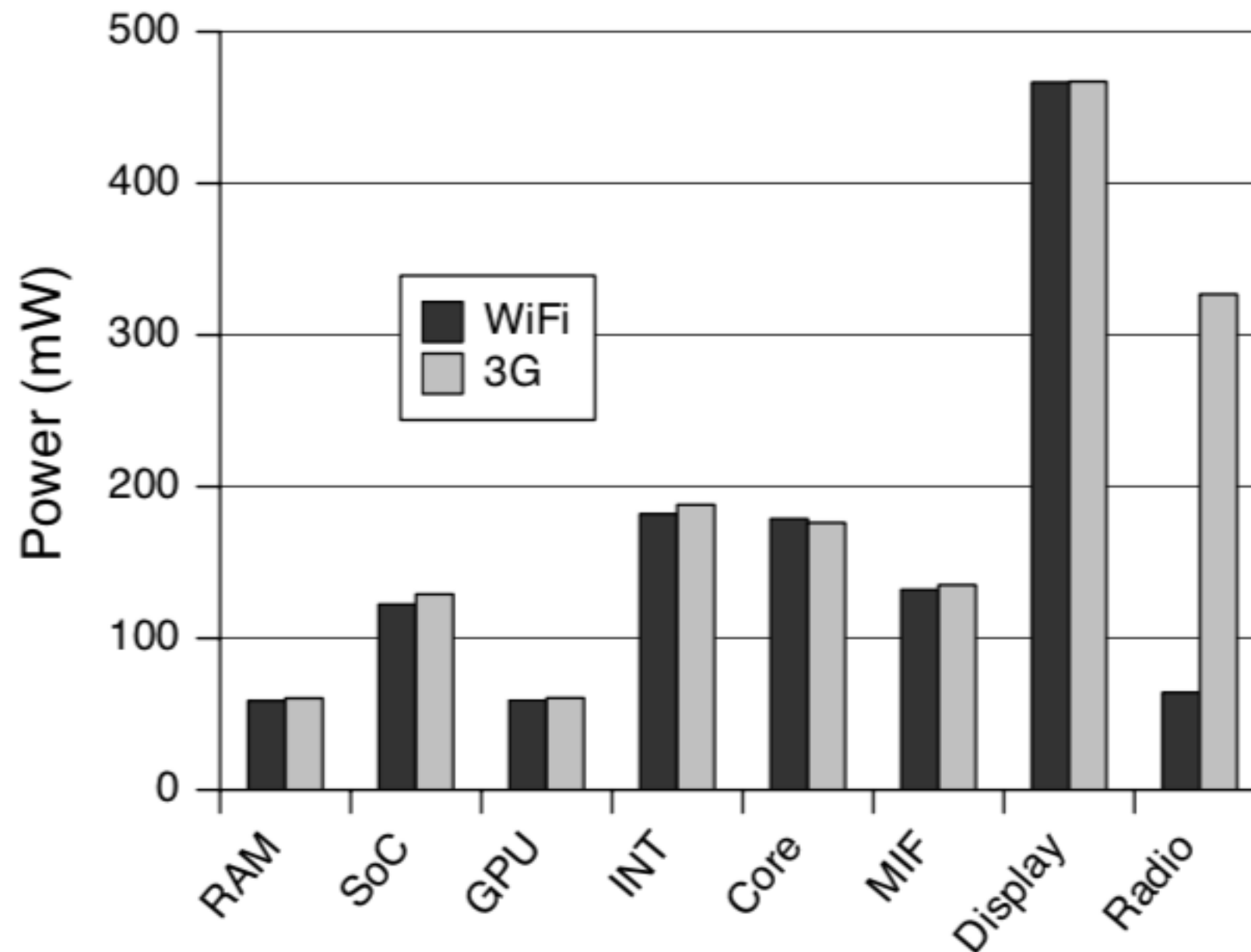
wi-fi 1264 mW / 3g 1543 mW

Camera
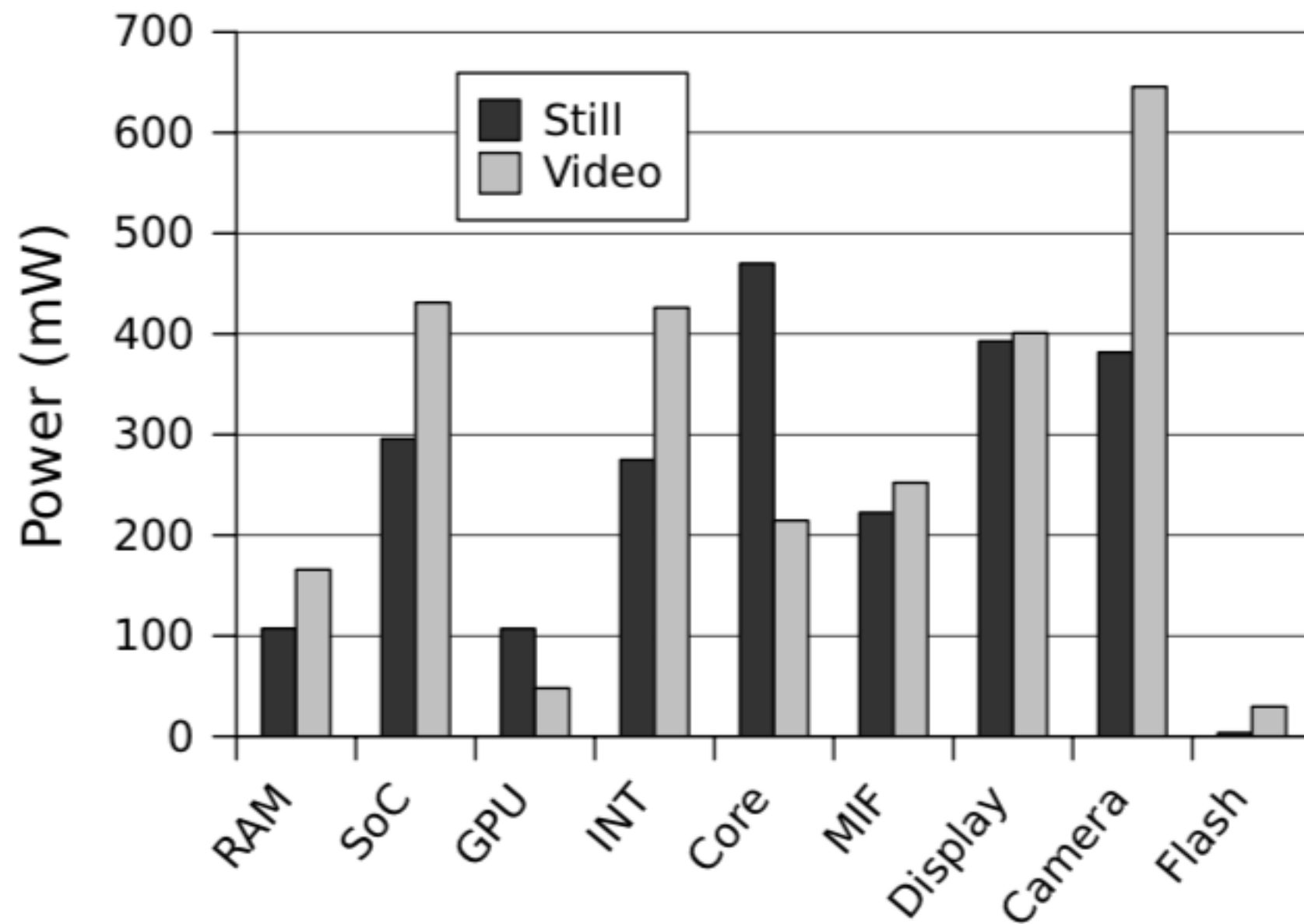
still 2256 mW / video 2614 mW

Misc

	Upload	Download
Throughput (kbps)	547 ± 149	1317 ± 814
Cell power (mW)	1137 ± 372	768 ± 64
Efficiency (kb/J)	481	1715

Sensor	Power (mW)
Accelerometer	5 ± 2.3
Gyroscope	30 ± 1.3
Light	3 ± 1.7
Magnetometer	12 ± 0.6
Barometer	1 ± 0.7
Proximity	7 ± 2.2

Mode	Power (mW)
Acquisition	386 ± 19.5
Tracking	433 ± 21.5

Component	Power (mW)	Workload
Core	2845	AnTuTu Benchmark
RAM	208	Need for Speed
GPU	1415	AnTuTu 3DRating
3G	1137	Speedtest.net (upload)
Display	1124	White screen, bright

XG

3G vs 4G LTE

XG

3G vs 4G LTE

5G
≈ twice faster, up to 1 Gbit/s
theoretical peak ≈ 20 Gbit/s

My measures

battery-drain app git.io/fAFq2

Nexus 5, Pixel, 1400 requests

https://jsonplaceholder.typicode.com/photos/13

```
{
  "albumId": 1,
  "id": 13,
  "title": "repudiandae iusto deleniti rerum",
  "url": "https://via.placeholder.com/600/197d29",
  "thumbnailUrl": "https://via.placeholder.com/150/197d29"
}
```

My measures

Requests	Nexus 5	Google Pixel
1 per 10s	24.26 %	32.67 %
3 per 30s	12.70 %	17.15 %
6 per 60s (1m)	8.13 %	12.42 %
12 per 120s (2m)	6.00 %	(11.99 %*) 10.50 %
24 per 240s (4m)	5.65 %	12.20 % *
48 per 480s (8m)	3.97 %	8.52 %
96 per 960s (16m)	2.54 % (1700)	7.69 %
192 per 1920s (32m)	2.14 % (1700)	
384 per 3840s (64m)	1.88 %	

Android

Reduce Defer Coalesce

L JobScheduler
M Doze / App Standy / pushes
N Doze on-the-go
O Background limits
P ?

Android P

fast file system work
small core / big core
cpu boosts

battery drain $\propto$ apps count
errors / aggressive apps / use cases

adaptive battery
buckets (active, working set, frequent, rare) +
machine learning

battery saver (location off when screen off)

Android P

App Standby Buckets

	Jobs	Alarms	High Priority FCM	Network
Active	Unrestricted			
Working Set	Restricted		Unrestricted	
Frequent	Restricted			Unrestricted
Rare	Restricted			

Android P

Moving apps between buckets
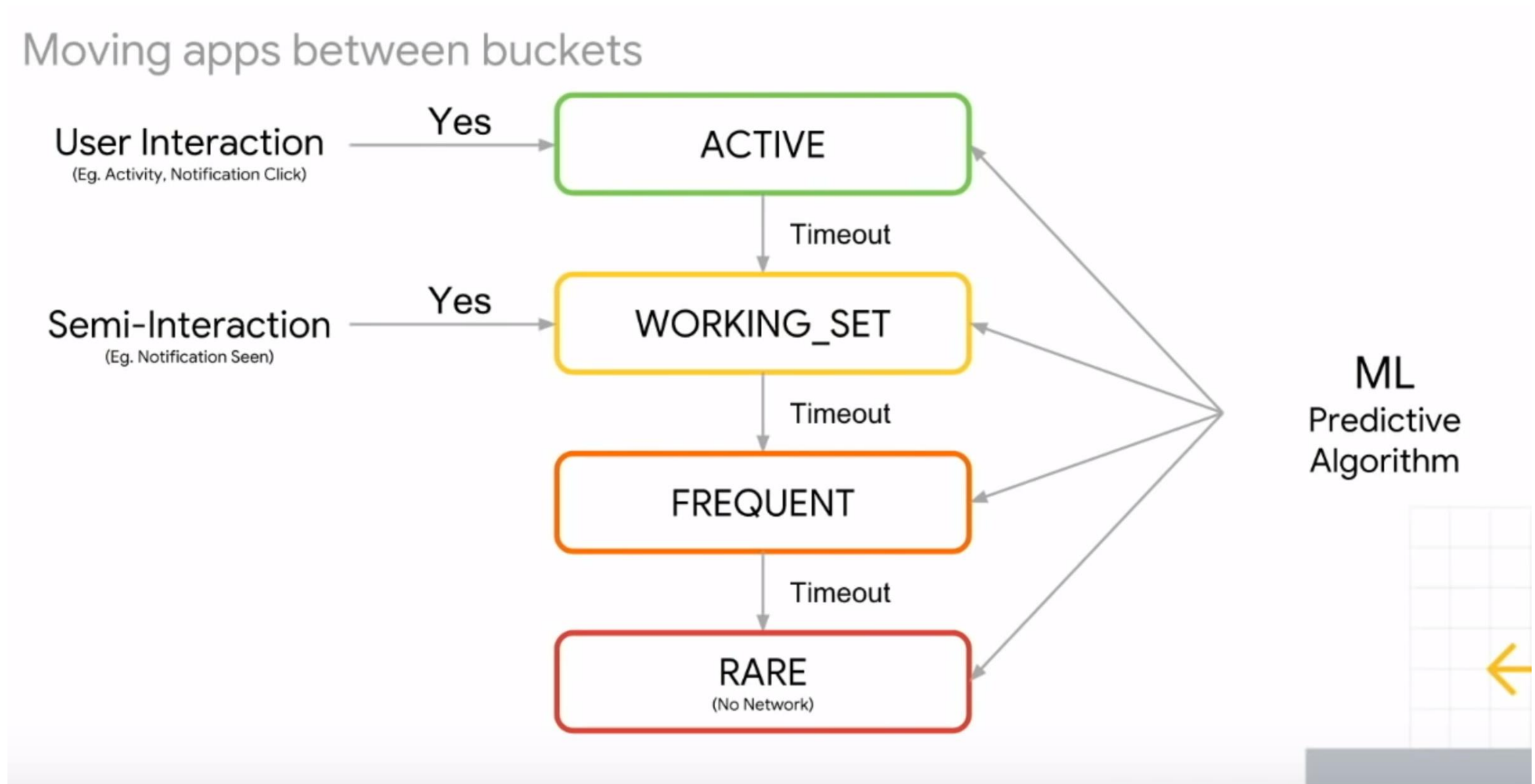
© Evolution of Standby Mode

Android P

3:35 🕐 🔕 📶 📶 🔋 20%

← **Battery** 🔍 ❓ ⋮

20%
Should last until about 6:45 PM based on your usage

🔋 **Restrict 4 apps**
4 apps have high background battery usage

Battery Saver
Will turn on at 15%

Adaptive Battery
2 apps restricted

Battery percentage
Show battery percentage in status bar 🔵
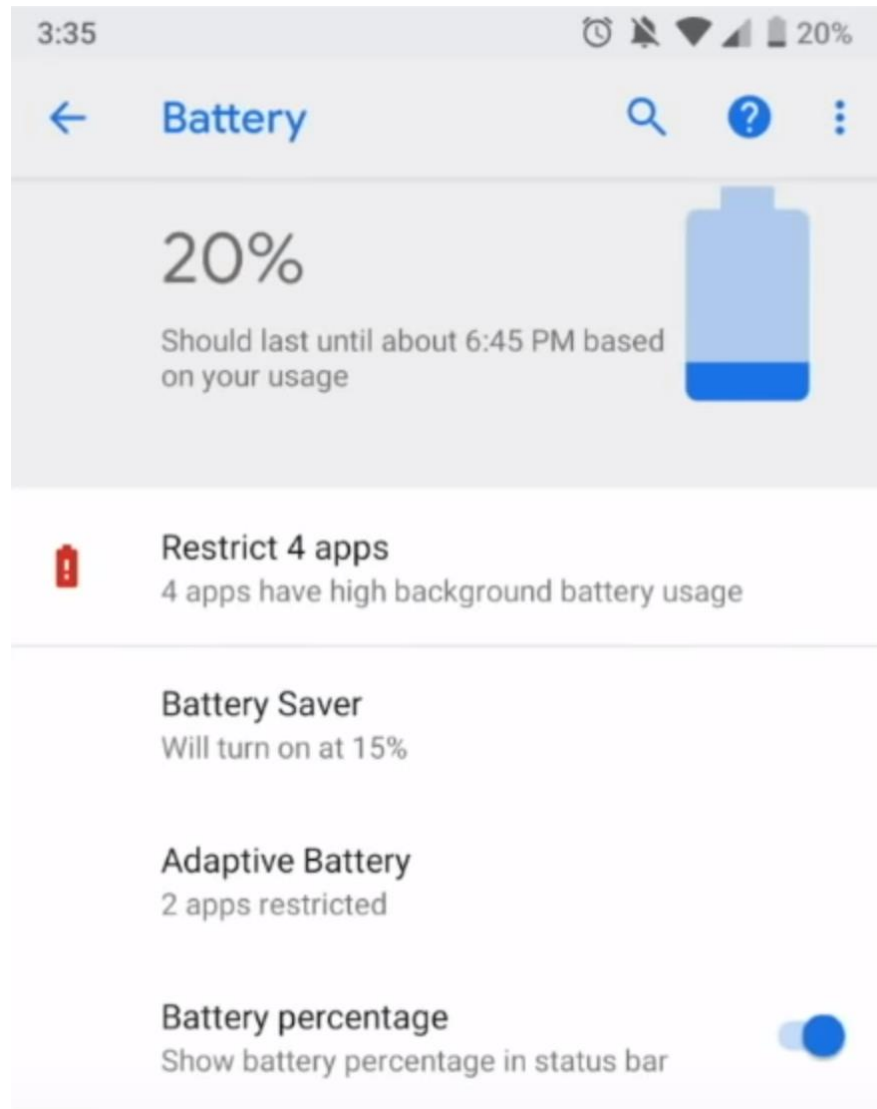
😲 **also when charging!**

**OEMs will add own criterias
foreground services
FCM messages since Jan 2019**

How are apps restricted?
- Restricted by user
- Suggested by system based on criteria
  - Eg. Excessive wakelocks

What is restricted?
- Jobs, Alarms, Services
- Network, FCM*
- Location updates
- **Even while charging**

Battery saver

- Similar to app restrictions but applies to all apps
  - Foreground services are ok
  - No restrictions on FCM messages
- Network restricted
- Alarms, Jobs restricted
- No location when screen is off

Android P

Android vitals

Android 9 makes a number of improvements to battery saver mode. AOSP builds restrictions:

aggressive app standby mode
background limits regardless of their target API level
location services disabled when the screen is off
background apps do not have network access
device-specific power optimizations

https://developer.android.com/topic/performance/power/power-details

App vs system

battery optimizations whitelist

REQUEST_IGNORE_BATTERY_OPTIMIZATIONS

```
new Intent(Settings.ACTION_REQUEST_IGNORE_BATTERY_OPTIMIZATIONS)
  .setData(Uri.parse("package:"+pkg));
```

Ignore battery optimizations?

Let app AntiDoze Demo stay connected in the background? This may use more battery.

NO   YES

https://git.io/fAFZY

Xiaomi Auto Start and Battery usage monitoring and Power settings

```
new Intent("miui.intent.action.POWER_HIDE_MODE_APP_LIST").addCategory(Intent.CATEGORY_DEFAULT)
new Intent("miui.intent.action.OP_AUTO_START").addCategory(Intent.CATEGORY_DEFAULT)
new Intent().setComponent(ComponentName("com.miui.securitycenter", "com.miui.powercenter.PowerSettings"))
```

Optimizations

passive

active

Passive optimizations

protocol
compression
serialization
media formats
tls connection

Protocol

http overhead
socket / web socket
bi-directional
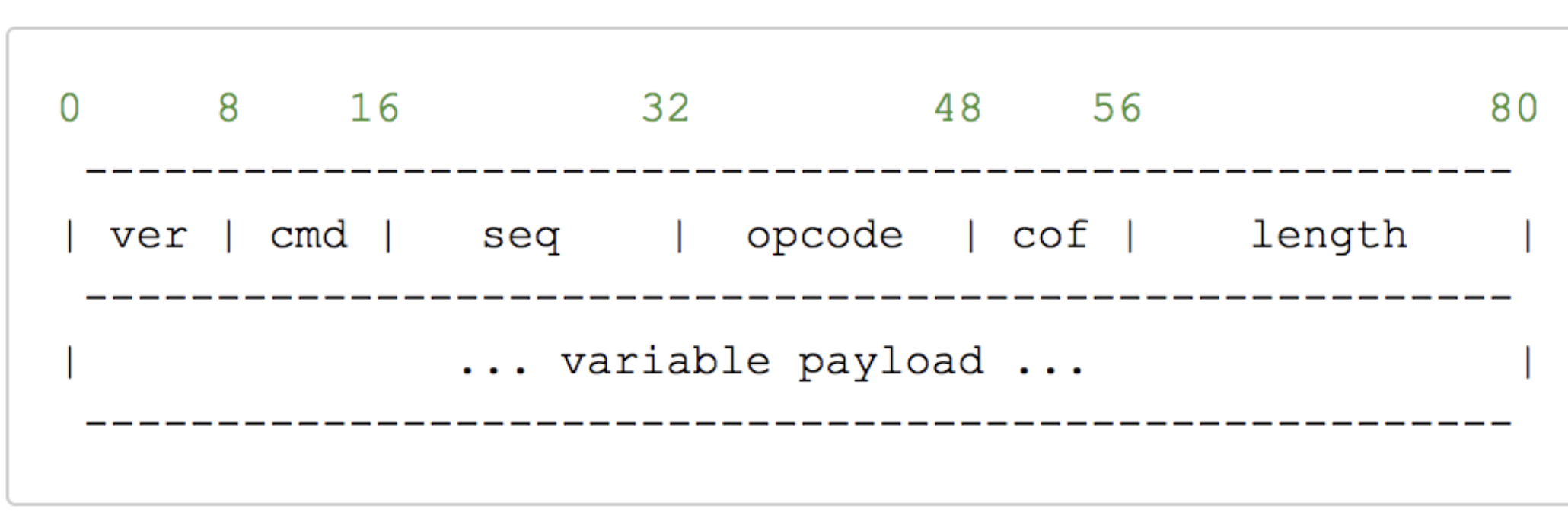
```
0       8      16              32              48      56              80
 ------------------------------------------------------------------------
| ver  | cmd  |     seq       |    opcode     | cof  |      length    |
 ------------------------------------------------------------------------
|                       ... variable payload ...                      |
 ------------------------------------------------------------------------
```

Compression & serialisation

https://eng.uber.com/trip-data-squeeze/
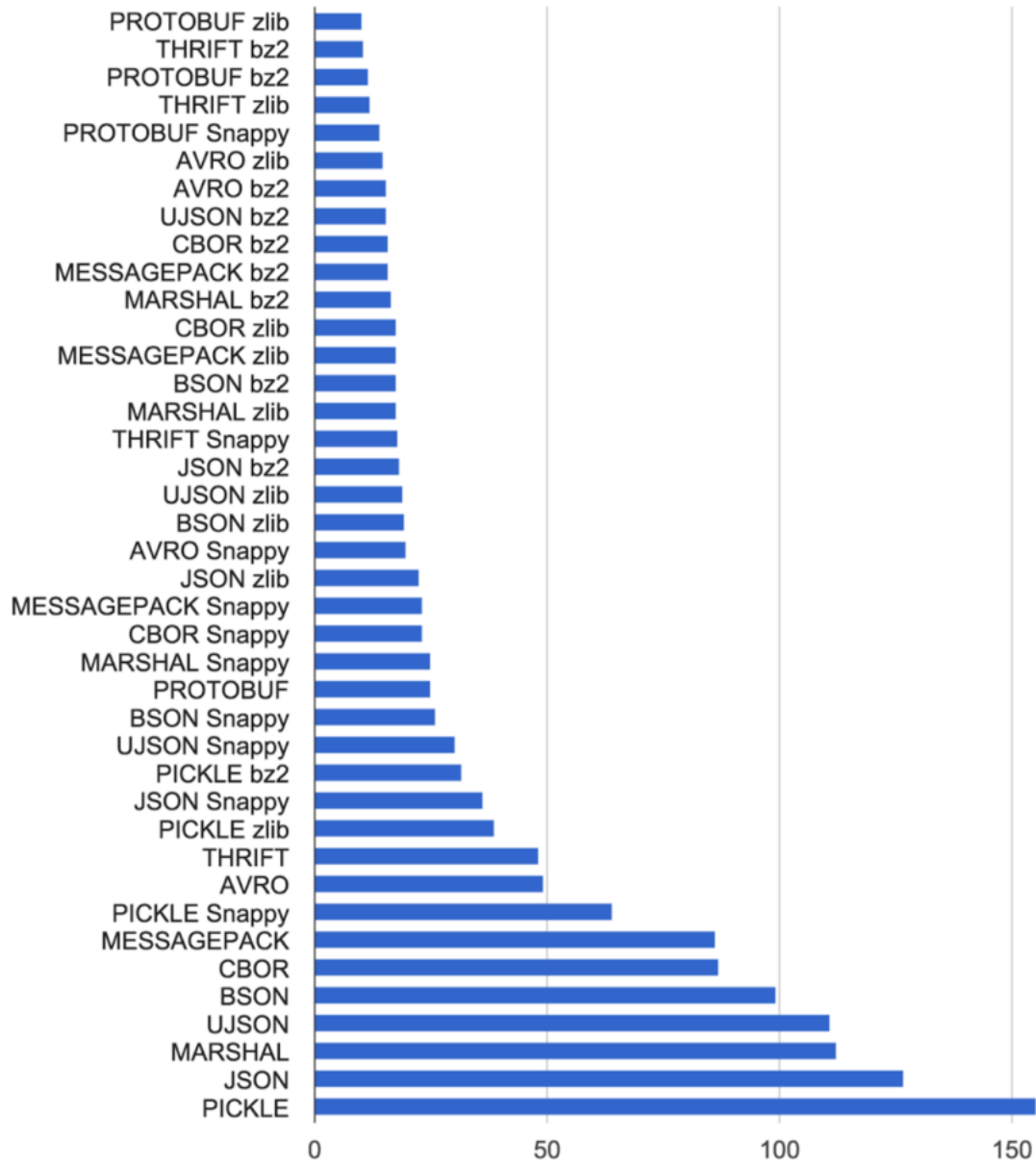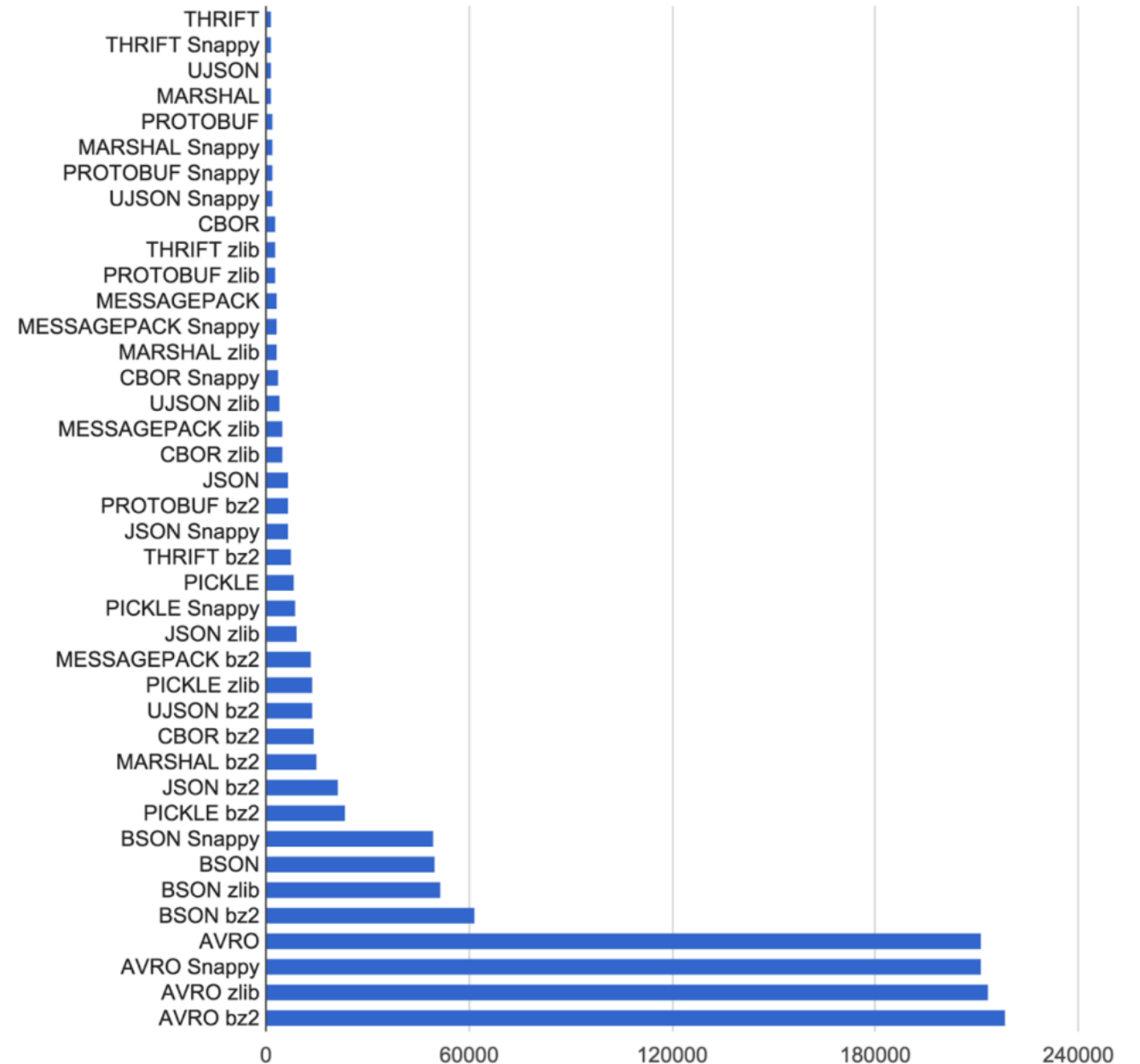
Compression & serialisation

message pack
protobuff

LZ4

https://indico.cern.ch/event/631498/contributions/2553033/attachments/1443750/2223643/zlibvslz4presentation.pdf

Data formats

WebP lossless images are 26% smaller in size compared to PNGs

WebP lossy images are 25-34% smaller than comparable JPEG images at equivalent SSIM quality index

Supports transparency (alpha channel) at a cost of just 22% additional bytes

TLS connection

connection reuse
session ids
session tickets

https://blog.cloudflare.com/tls-session-resumption-full-speed-and-secure/

Active optimizations

caching
batching
thumbnails & tiles
notifications
deferred tasks
roaming
background data restrictions
power changes
connections
wakelocks

Cache

- What's the name of your friend?
- It's Cache

HTTP: If-Modified-Since and

ETag headers

Batching

Disk I/O impact on power consumption

1 GB with 1KB buffer **2x** more expensive as with 10Mb buffer

1 GB with 100 B budder **5x** more expensive as with 1KB buffer

batching db I/O in transactions, cache writing (log), larger buffers

Batching

Network on/off

full power
low power
standby mode

Thumbnails

Don't download it until you really need it

Ask about quality

Cache and hash

DownloadManager for long running http

Push notifications

high-priority fcm pushes
disabled notifications (since api 24)
data in notifications

Active optimizations

caching
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notifications
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wakelocks

Active optimizations

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Active optimizations

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power changes
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wakelocks

```
/**
 * @return true, если background data выключена, устройство на мобильной сети и соединение
 * не установлено; false во всех остальных случаях
 */
public boolean isBackgroundDataDisabledAndOnMobileNetwork() {
    boolean result = !device.isBackgroundDataEnabled()
            && (!isOnline() || !device.isAppVisible())
            && isOnMobileNetwork();
    Log.d(TAG, "isBackgroundDataDisabledAndOnMobileNetwork: %b, isOnline=%b, appIsVisible=%
            "isOnMobileNetwork=%b", result, isOnline(), device.isAppVisible(), isOnMobileNe
    return result;
}
```

Active optimizations

caching
batching
thumbnails & tiles
notifications
deferred tasks
roaming
background data restrictions
power changes
connections
wakelocks

PowerManager.isPowerSaverMode()
ACTION_POWER_SAVE_MODE_CHANGED
BATTERY_LOW
ACTION_POWER_CONNECTED

Active optimizations

caching
batching
thumbnails & tiles
notifications
deferred tasks
roaming
background data restrictions
power changes
connections
wakelocks

force disconnect
shouldConnect

Active optimizations

caching
batching
thumbnails & tiles
notifications
deferred tasks
roaming
background data restrictions
power changes
connections
wakelocks

release
keepScreenOn

How Android measures

oem's power profile

screen.on	Additional power used when screen is turned on at minimum brightness.	200mA
screen.full	Additional power used when screen is at maximum brightness, compared to screen at minimum brightness.	100mA-300mA
wifi.on	Additional power used when Wi-Fi is turned on but not receiving, transmitting, or scanning.	2mA
wifi.active	Additional power used when transmitting or receiving over Wi-Fi.	31mA
wifi.scan	Additional power used when Wi-Fi is scanning for access points.	100mA

```
App power =
    cpuTime[freq] * CPU_POWER[freq]
  + sensorTime[type] * SENSOR_POWER[type]
  + mobileRxPackets * MOBILE_RX_POWER
  + mobileTxPackets * MOBILE_TX_POWER
  + wifiRxPackets * WIFI_RX_POWER
  + wifiTxPackets * WIFI_TX_POWER
  + wakeLockTime * WAKE_LOCK_POWER
  + ...
```

BATTERY USAGE

10h 5m 59s on battery

Screen	Used for 1 h 17 min	12%
Android System		4%
Device idle	Used for 10 h 6 min	3%
Android OS	Used for 4 min	3%
Cell standby		3%
Google Play services		1%
TamTam	Used for 16 min	1%
Voice calls	Used for 8 min	1%

How to measure

TrafficStats.*getUidTxBytes*(***uid***)
TrafficStats.*getUidRxBytes*(***uid***)

statistics

UsageStatsManager
google sample: git.io/v5tVf

logs

battery historian

How to measure

statistics

logs

battery historian

```sh
#!/bin/sh
set -eu

if [ $# -gt 0 ]; then
    FILE=$1
    if [ ! -f $FILE ]; then
        echo "File $FILE not found!"
        exit 1
    fi

    echo "Log from" $(head -n 1 $FILE | cut -c 1-18) to $(tail -n 1 $FILE | cut -c 1-18) "\n"

    COUNT=$(egrep -c ' received:' $FILE || true)
    echo "Total commands received: $COUNT"

    cat "$FILE" | egrep -o "opcode=[A-Z_]+" | cut -d '=' -f 2 | sort | uniq -c | sort -r
    echo

    COUNT=$(grep -c 'fcm push' $FILE || true)
    echo "FCM pushes received: $COUNT"

    COUNT=$(grep -c 'app enter foreground' $FILE || true)
    echo "Foreground sessions: $COUNT"

    COUNT=$(grep -c 'App onCreate' $FILE || true)
    echo "App created: $COUNT"

else
```

```
Log from 09-25 19:11:58.946 to 09-25 21:39:0

Total commands received: 593
 158 NOTIF_PRESENCE
  65 NOTIF_MARK
  39 NOTIF_MESSAGE
  35 PING
  33 ASSETS_UPDATE
  29 MSG_TYPING
  29 CONTACT_PRESENCE
  28 CHAT_MARK
  24 CHAT_INFO
  19 CONTACT_SORT
  15 NOTIF_TYPING
  15 LOGIN
  15 LOG
  15 CONTACT_INFO
  14 CONFIG
  12 NOTIF_CALL_COMMAND
  11 CHAT_HISTORY
  11 CALL_COMMAND
   9 MSG_SEND
   8 VIDEO_CHAT_HISTORY
   8 MSG_GET
   1 NOTIF_CALL_START

FCM pushes received: 51
Foreground sessions: 6
App created: 20
```
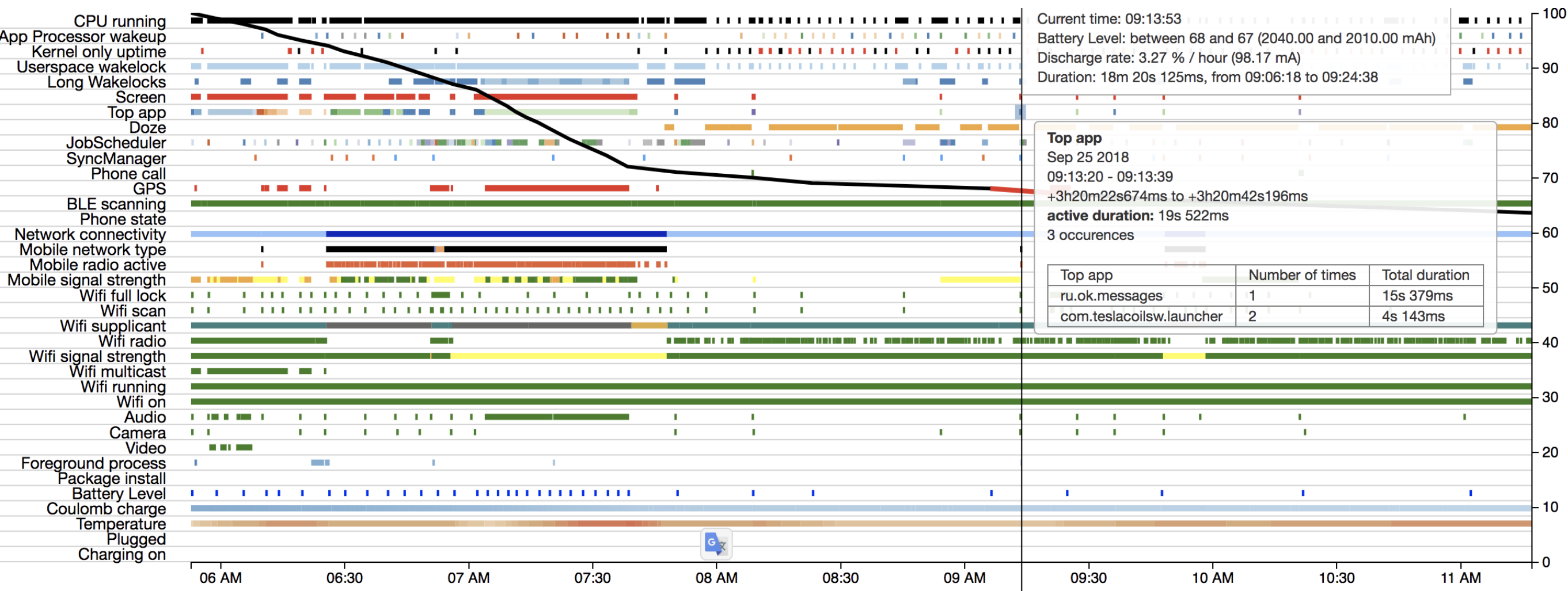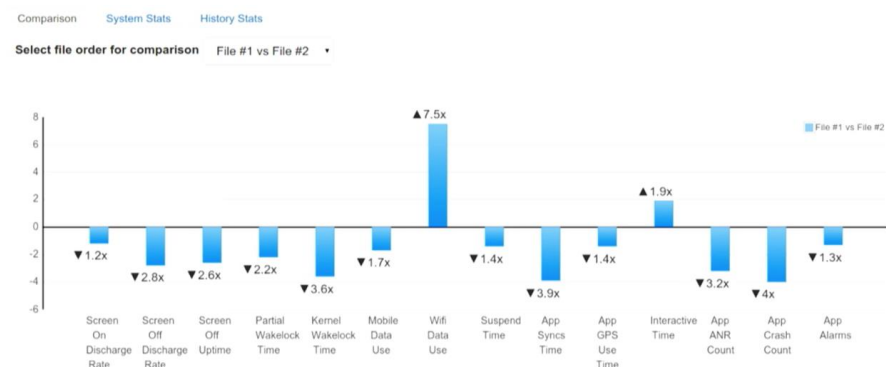
Battery historian

+ Bugreport comparison

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X. Chen, Y. Chen, Z. Ma, Felix Fernandes. How is Energy Consumed in Smartphone Display Applications. http://www.hotmobile.org/2013/papers/full/17.pdf

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https://www.youtube.com/watch?v=kGWT99eMgyM

Android battery and memory optimizations, Google I/O 2016.
https://www.youtube.com/watch?v=VC2Hlb22mZM

https://www.weboost.com/blog/does-4g-use-more-battery-power-than-3g

https://source.android.com/devices/tech/power/device

https://eng.uber.com/trip-data-squeeze/

https://www.weboost.com/blog/does-4g-use-more-battery-power-than-3g

https://www.androidcentral.com/heres-thing-about-dark-themes-and-battery-savings

https://forum.xda-developers.com/showthread.php?t=660853

https://developers.google.com/location-context/fused-location-provider/

https://github.com/melnikovdv/battery-drain

https://commonsware.com/blog/2015/11/11/google-anti-trust-issues.html

https://github.com/dirkam/backgroundable-android

https://blog.cloudflare.com/tls-session-resumption-full-speed-and-secure/

https://www.ibm.com/support/knowledgecenter/en/SSFKSJ_7.1.0/com.ibm.mq.doc/sy10660_.htm

https://github.com/dirkam/backgroundable-android

https://github.com/googlesamples/android-AppUsageStatistics

https://www.youtube.com/watch?v=-7eZL3XRqas

https://www.youtube.com/watch?v=N_6sPd0Jd3g

Questions

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