Qualcomm

Richmond, VA

November 14th, 2023

Dynamic DDR Memory Offlining

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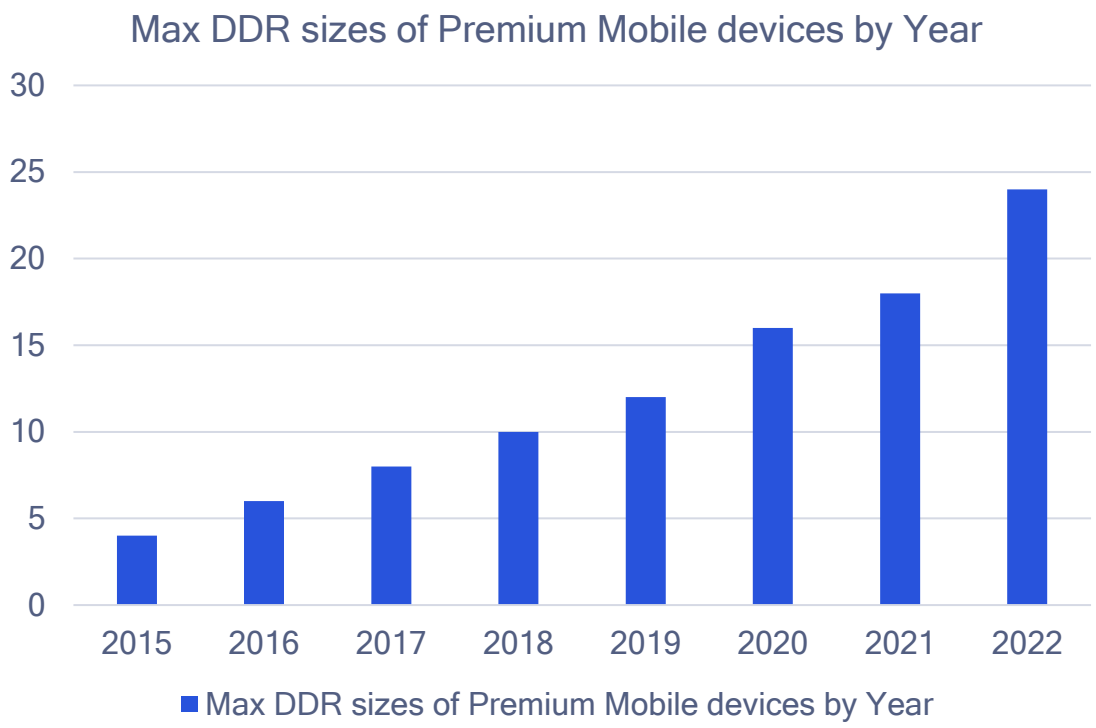
Motivation

Background and Goals



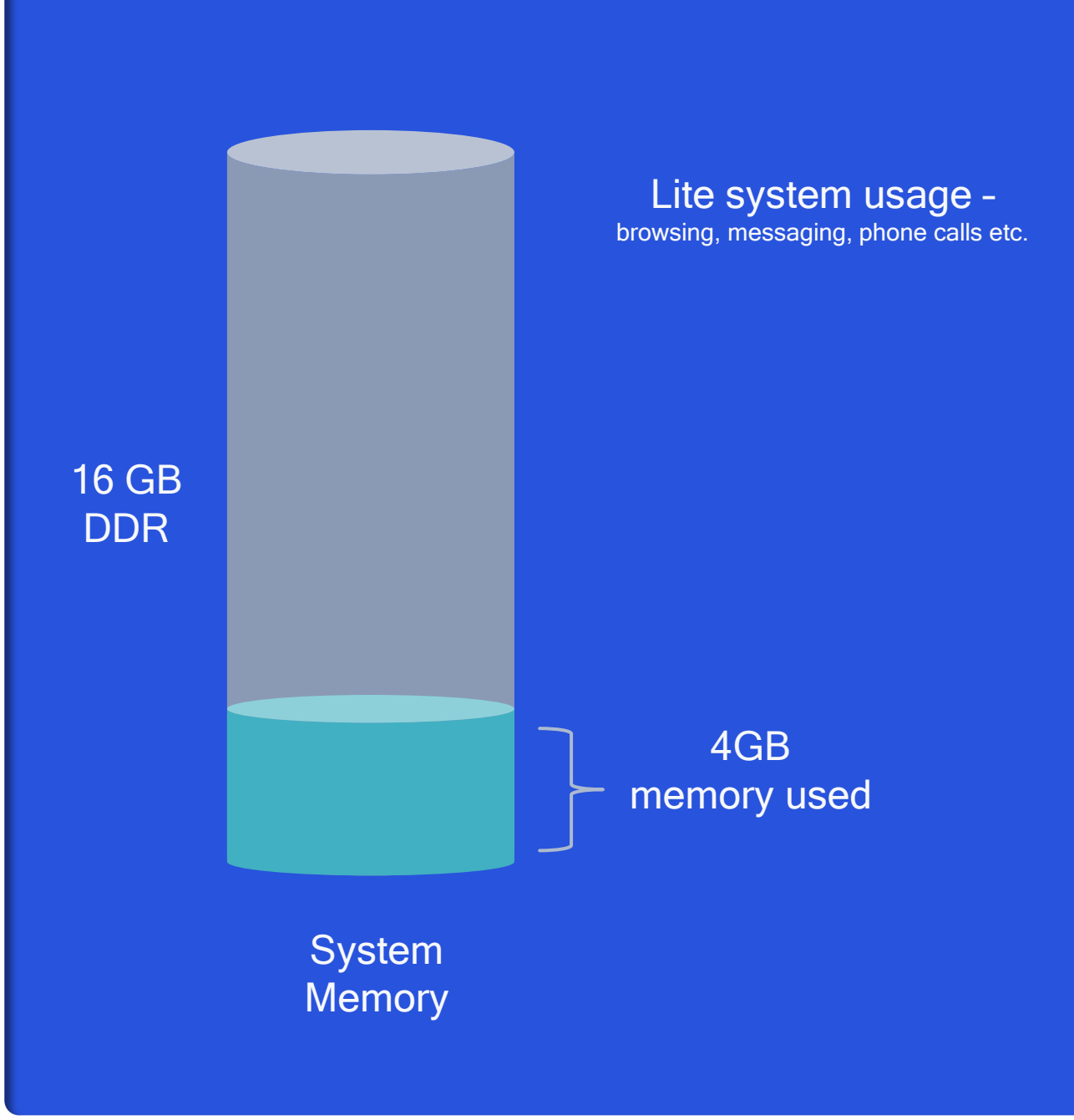
- DDR sizes are increasing significantly in mobile devices
  - (from 12GB to up to 24GB DDR)

Motivation

Background and Goals

- Minimal system usage indicate peak memory usage of ~3GB - 4GB.

- Remaining memory could be collapsed to save power in DDR rails.
  - ~12GB memory segments could be power collapsed



Partial Array Self Refresh (PASR)

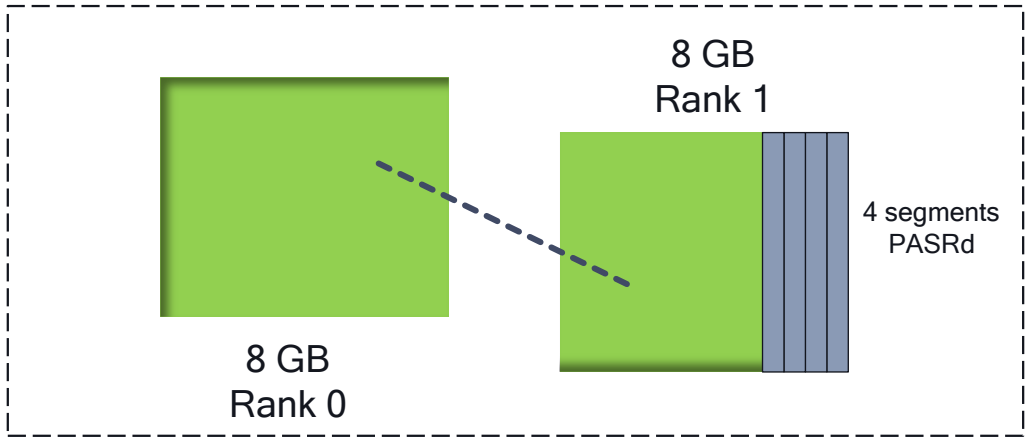
and

Full Rank Down (FRD)

DDR Technologies used for memory offlining

PASR

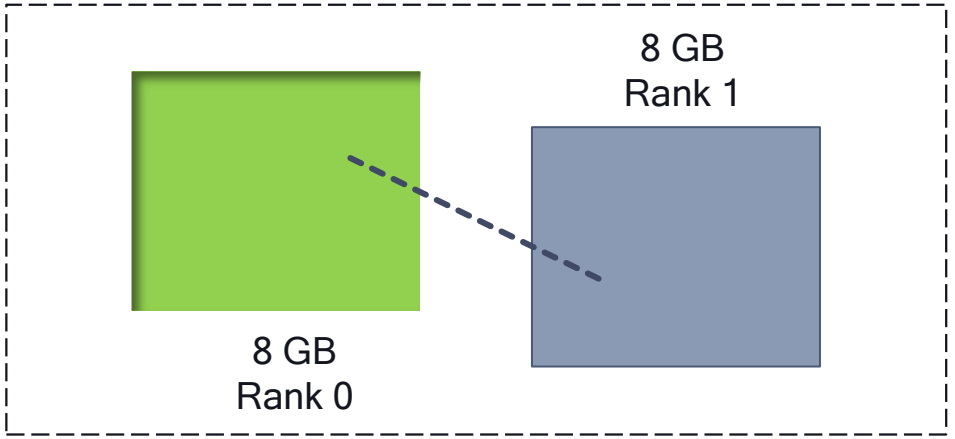
Partial Array Self Refresh



16 GB DDR
Dual Rank Symmetric

FRD

Full Rank Down



16 GB DDR
Dual Rank Symmetric

Memory Offlining Idea

- Most of the time, the system doesn't need the entire RAM for its normal user operations.
- Example: On 12GB device with 5GB PASR, the Android system may not need the entire 12GB RAM during minimal active operations (browser, calculator, messages etc.).
- Hence, Offline certain memory regions even when system is active, and Online them back when system is under memory pressure (i.e. system needs more memory) and when User interaction occurs.
- When OFFLINE?
  - When system enters Doze and on Screen ON
  - Display Screen OFF
  - For each idle system memory pressure
- When ONLINE?
  - User interactions – Screen ON, App launches
  - PSI memory pressure is detected
- Memory Hotplug in Linux kernel is used for software offlining and page isolation and migration.
- Movable Zone is used as offlinable region.

PASR/FRD Usage Modes

- **Power Save Mode** - UI Option via Settings
  - Enable PASR/FRD for DDR power reduction based on android user space triggers
  - Off-lining of memory can occur whilst DDR is Active (D0)
  - Enter PASR on No Motion Detect
  - On-lining of memory can start only when we hit a certain memory usage threshold

- **Night-time Mode**
  - Enable PASR/FRD during night time focusing power reduction
  - have it disabled during day-time focusing of performance

- **Low Battery < 15% Mode**
  - Enable PASR/RFD with aggressive memory re-claim to PASR/RFD as much memory as possible

- **Normal Mode**
  - Enable PASR/FRD only when DDR enters Deep Doze Mode (D3)
  - On-lining of PASR/FRD memory when Display comes ON

Memory Pressure Detection using PSI (Pressure-Stall Information)

PSI (Pressure Stall Information)

PSI

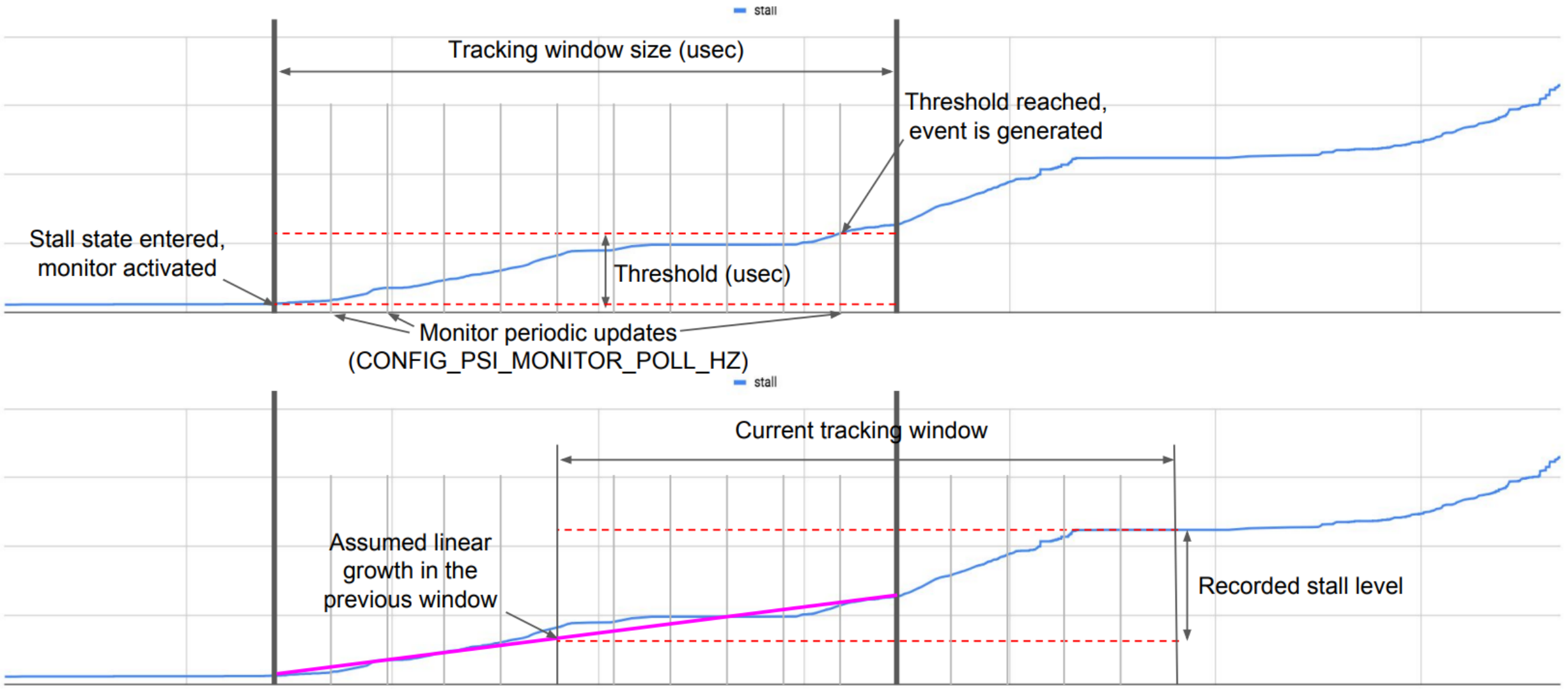
- Introduced in 4.20 Linux kernel onwards
- PSI measures amount of time tasks are stalled as a result of resource contention such as IO, CPU or memory.
- It is recorded as total stall time and averages over 10, 60 and 300 secs are provided.
- PSI separately records complete (FULL) and partial (SOME) stall amounts.

```
# cat /proc/pressure/memory
some avg10=70.24 avg60=68.52 avg300=69.91 total=3559632828
full avg10=57.59 avg60=58.06 avg300=60.38 total=3300487258
```

PSI Monitor

- Monitoring of pressure thresholds within a given tracking window
- Allows userspace to register for memory pressure events for given set of thresholds
- `echo "some 150000 1000000" > /proc/pressure/memory`
  monitor partial memory stall of 150ms within 1s tracking window
- Activates only when monitored metric enters stall state and deactivates upon exit
- Provides per-monitor configurable threshold and tracking window size

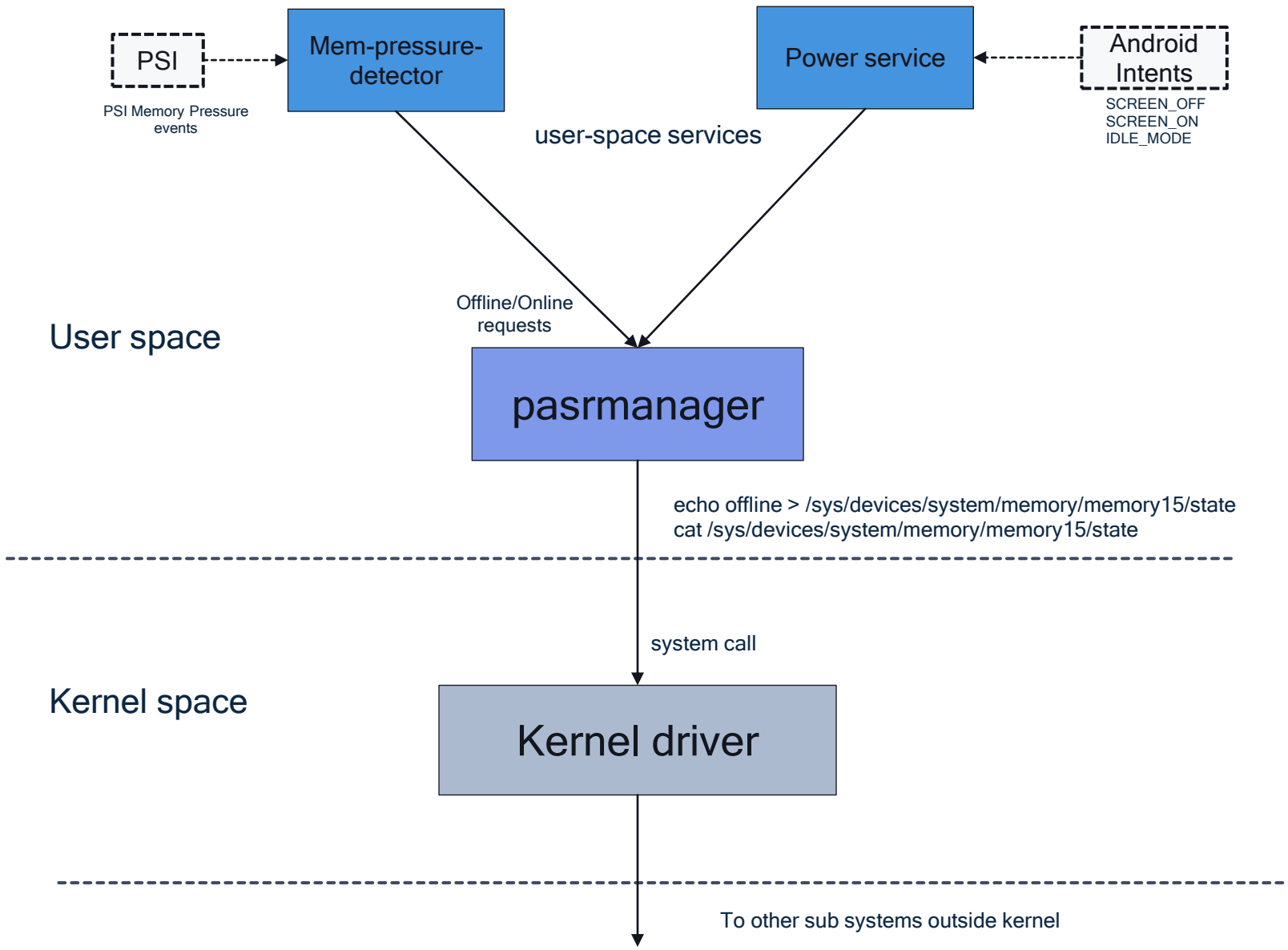
PSI (Pressure Stall Information)



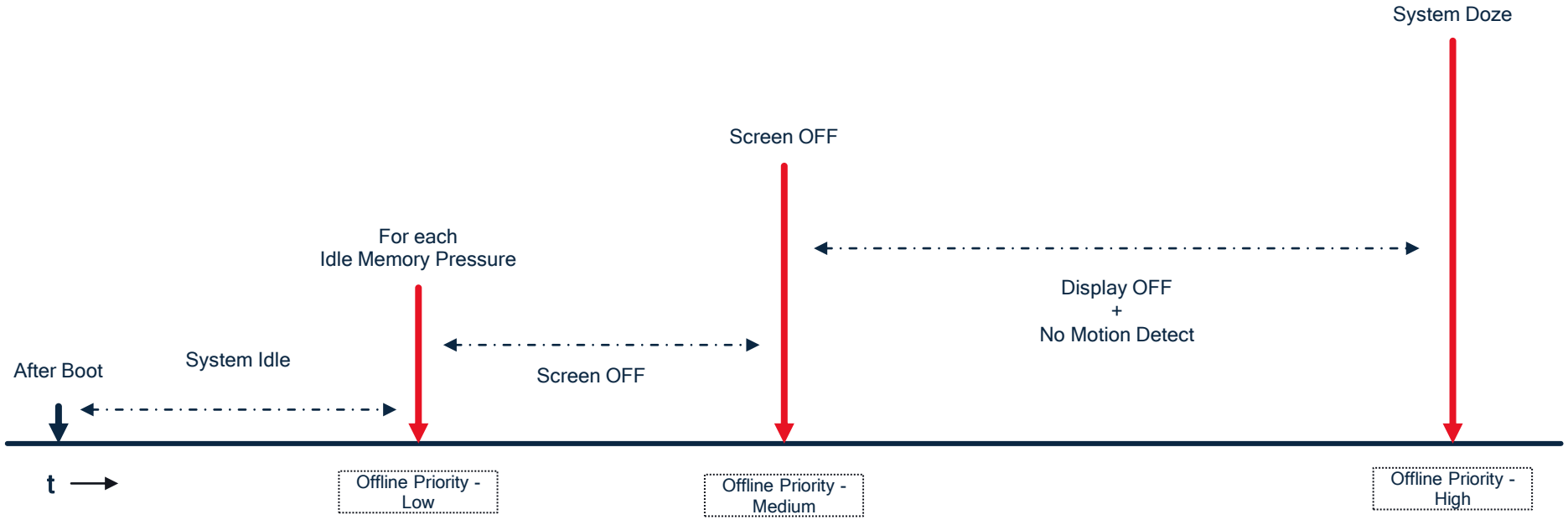
Source: https://linuxplumbersconf.org/event/2/contributions/221/attachments/45/52/02._PSI_monitor_for_memory_pressure_detection.pdf

Design and Implementation

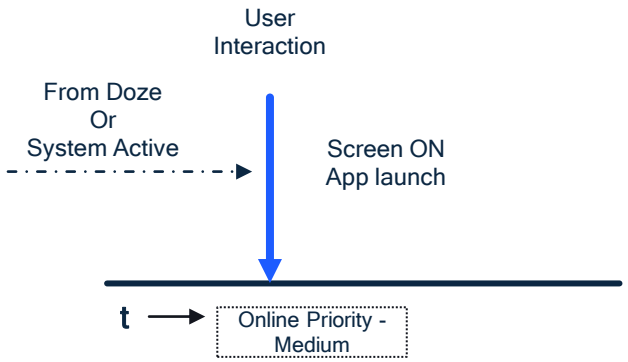
Memory Offlining Design

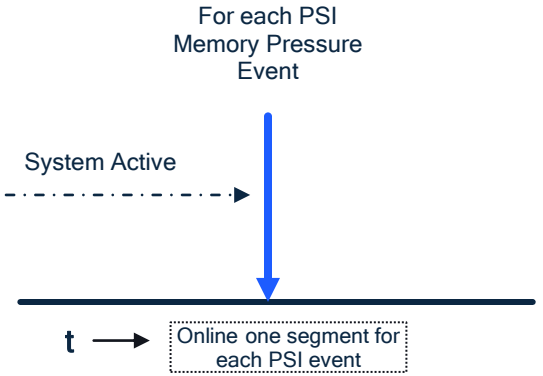


Memory Offlining Design



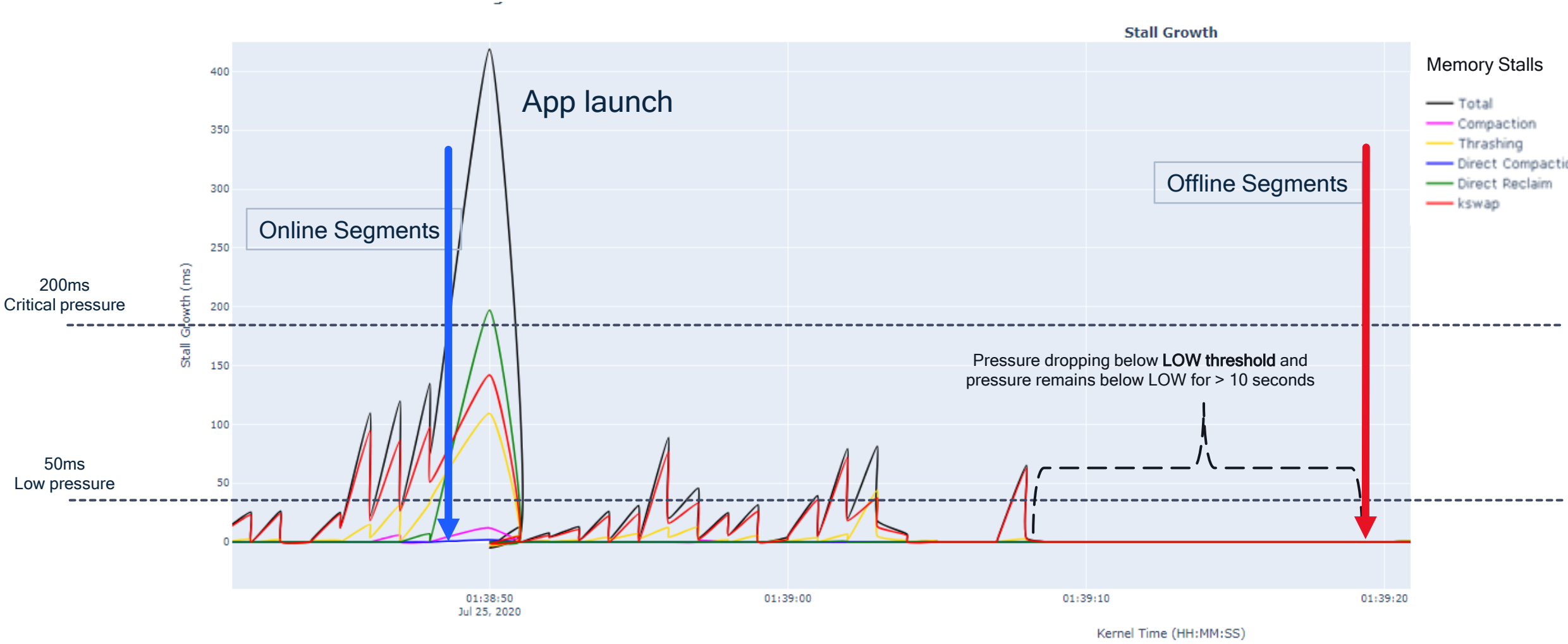
PASR Entry -





PASR Exit -

Memory Pressure Detection



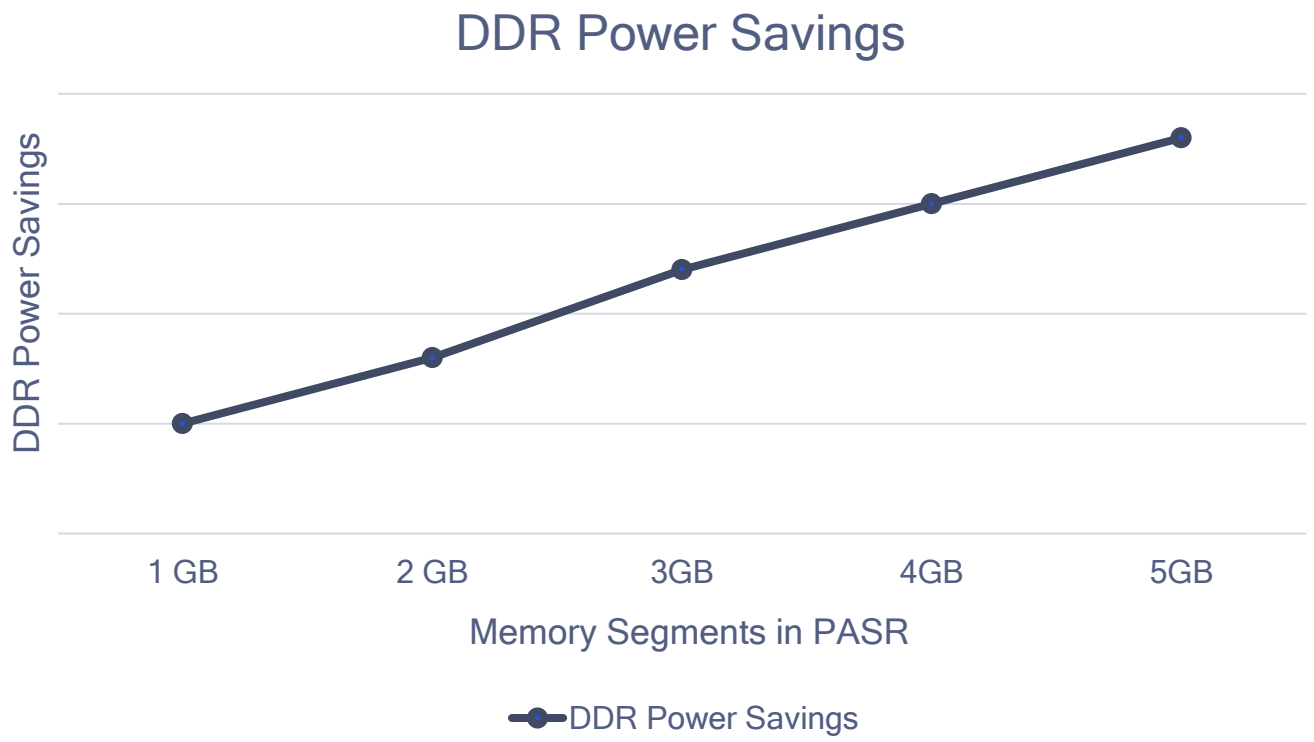
Power Savings

Power Savings

Measured Over Battery

Usecase -

- Airplane Mode with Display OFF
- 12 GB Dual Rank DDR



Questions?

Thank you

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