

# Suspend-aware Segment Cleaning in Log-Structured File System



**Dongil Park, Seungyong Cheon, Youjip Won**

Hanyang University

# Outline

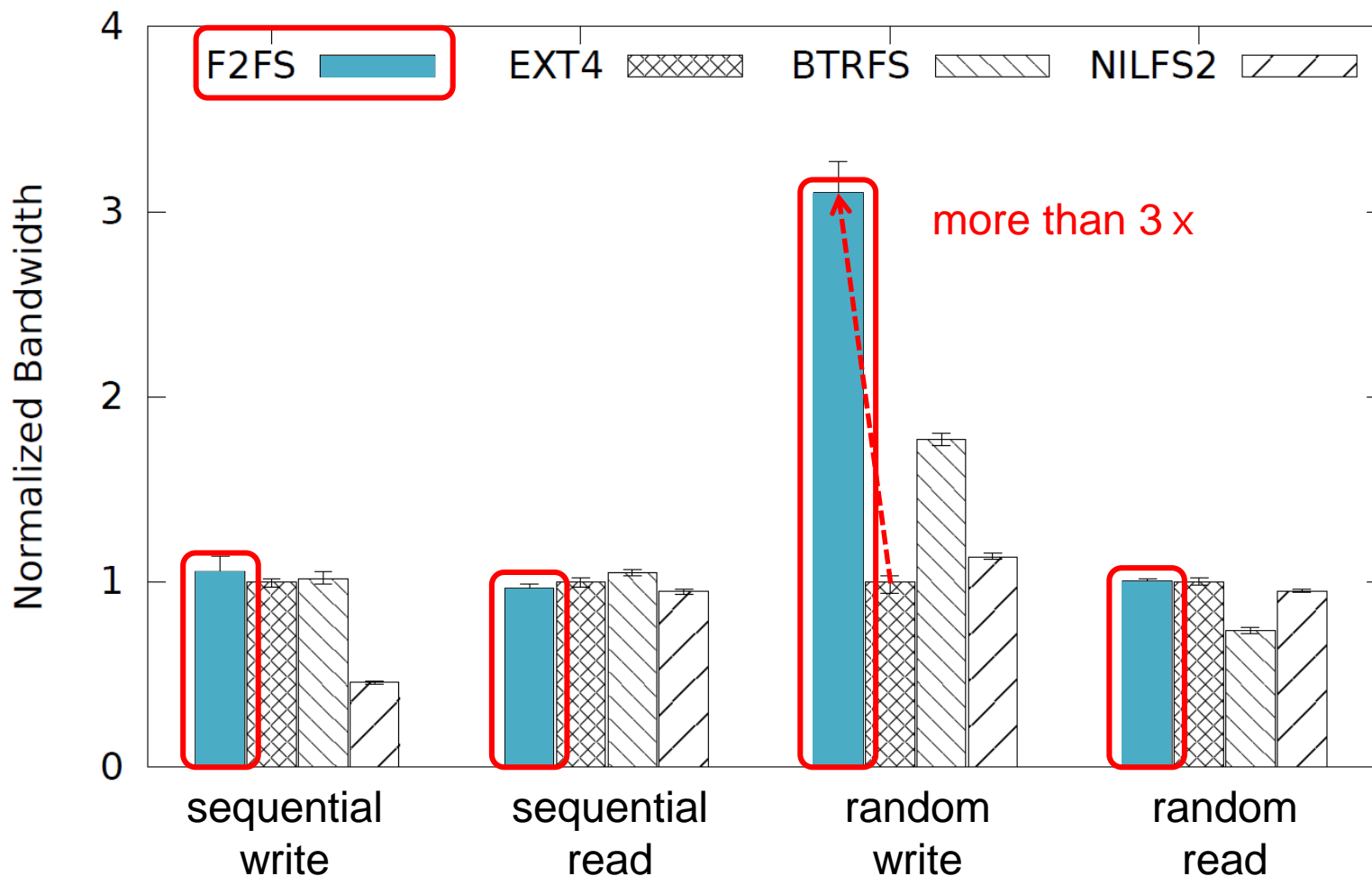
- Introduction
  - Log-structured File System and Segment Cleaning
  - Suspend Mode on Smartphone
  - Problem assessment
- Suspend-aware Segment Cleaning
  - Design
  - Virtual Segment Cleaning
  - Utilization-based Segment Cleaning
- Experiment
- Conclusion

# Introduction

- Flash memory based storage is widely used nowadays.
- Log-structured file system has been around for 20+ years.
- It has not been deployed on commercial devices.
- F2FS (Flash Friendly File System) is a log-structured file system optimized for mobile device.
- F2FS is adopted in commercial mobile devices as their stock file system.
  - Motorola Droid family
  - Motorola Moto X, Moto G, Moto E
  - Google Nexus 9

# Flash Friendly File System

F2FS shows great random write performance on flash memory.



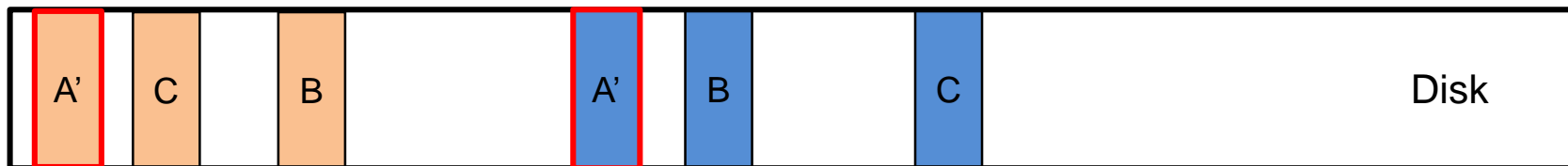
source: C. Lee et al., FAST '15

# Log-structured File System



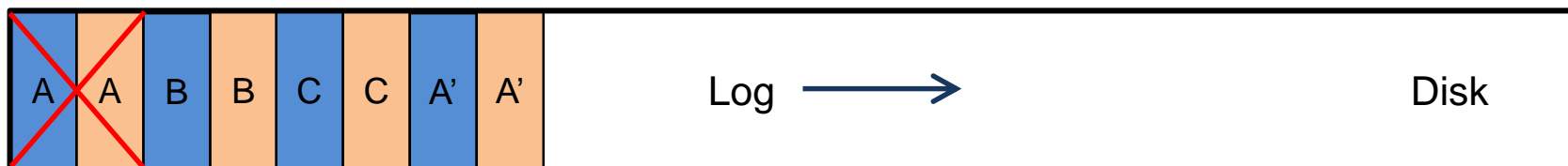
In-place update file system

update(file A)



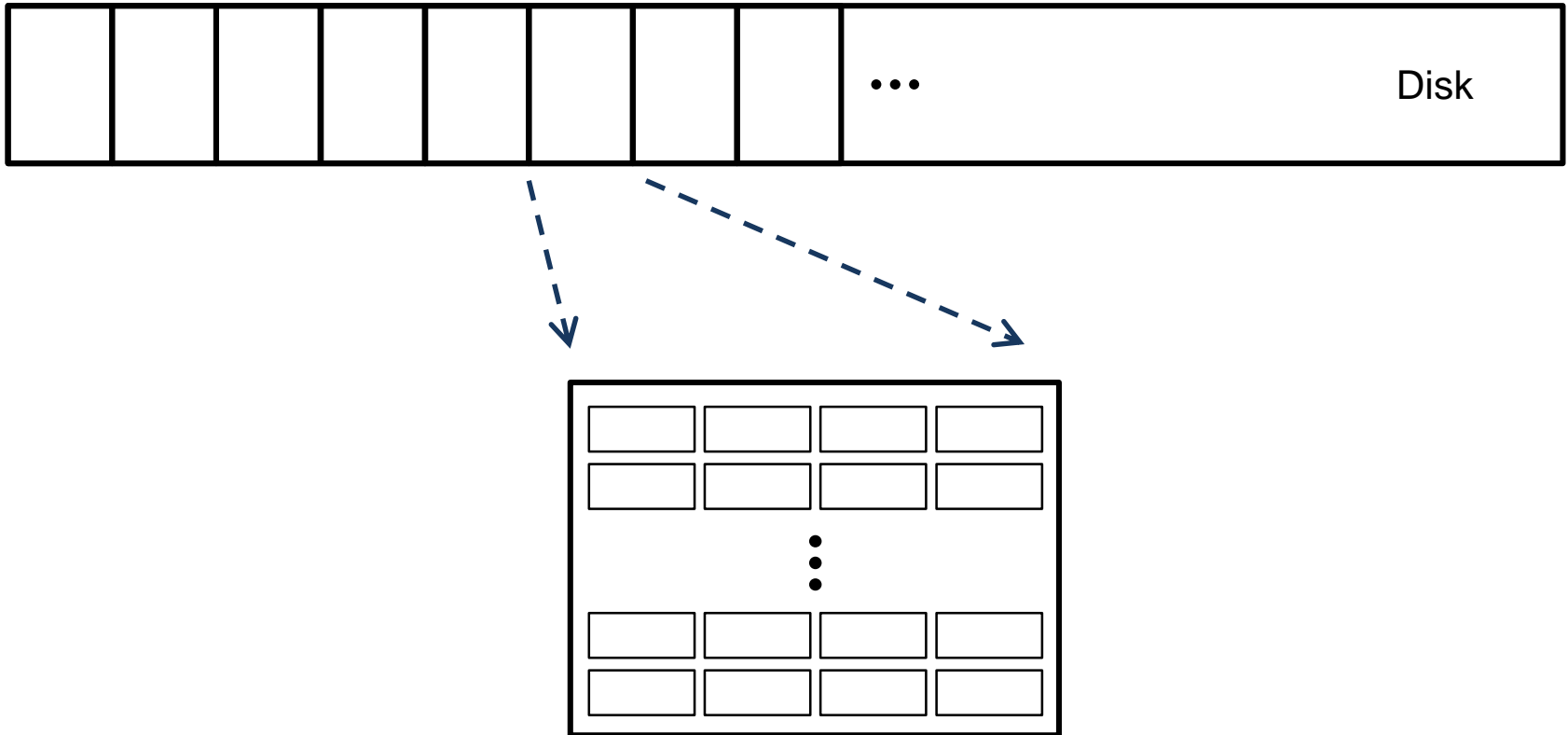
Log-structured file system

update(file A)



# Log-structured File System

**Segment: unit of disk write**



**Block: unit of write operation**

# Block and Segment

Free block



No data

Valid block



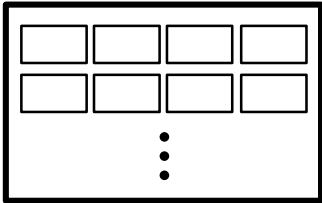
Valid data

Invalid block



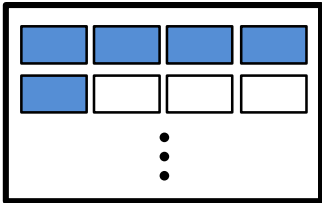
Invalid data

Free segment



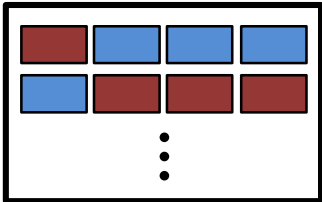
Only free blocks

Valid segment



Valid & free blocks

Invalid segment

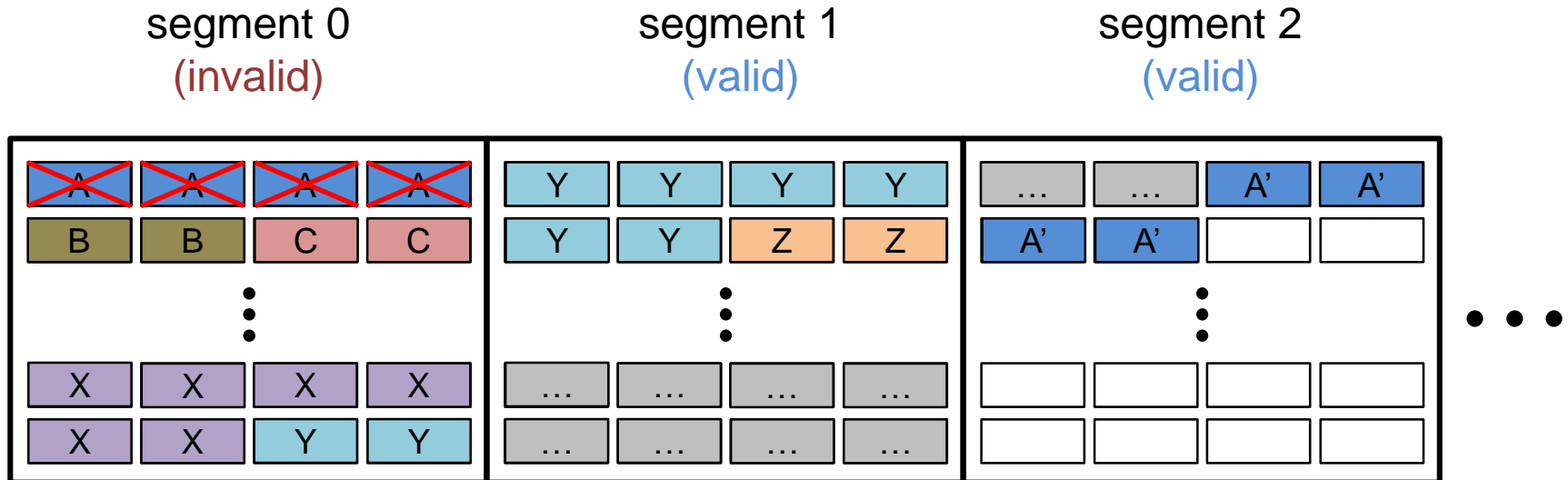


No free block

Including invalid block

# Writing in Log-structured File System

## Writing data in append-only manner

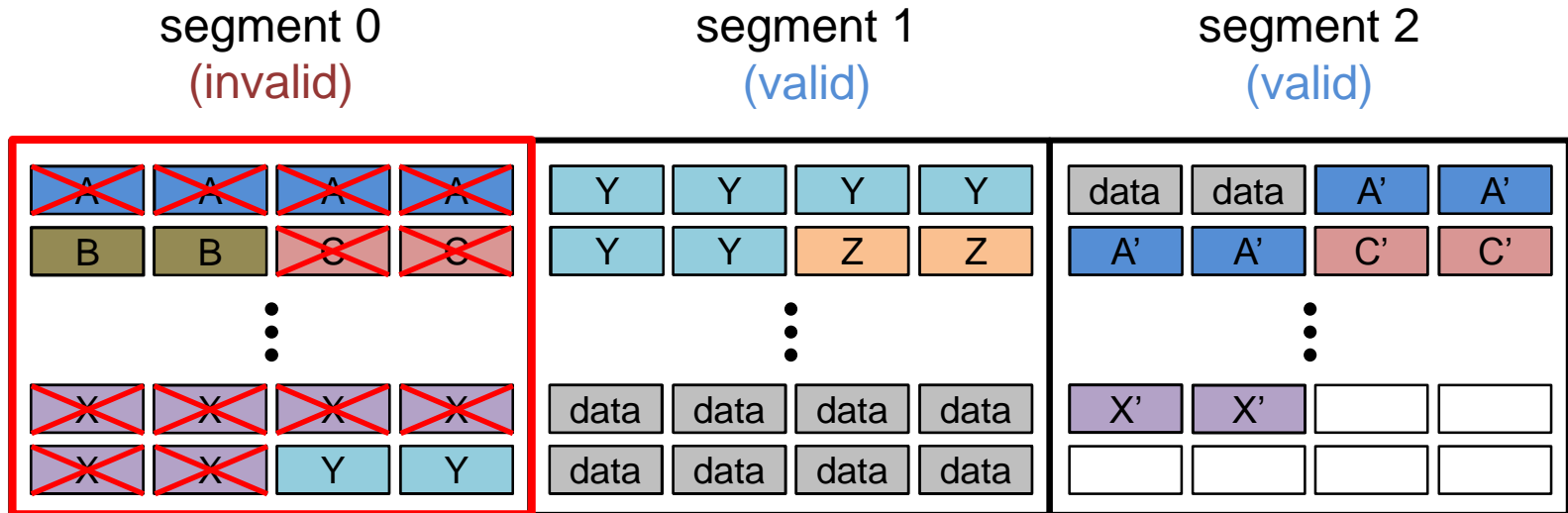


Modify A



# Segment Cleaning

## Segment cleaning

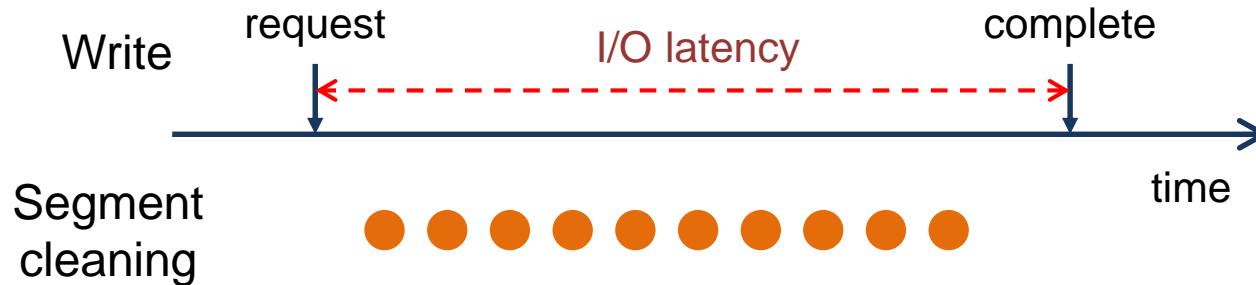


1. Select victim segment.
2. Migrate valid blocks.
3. Mark victim segment as free.

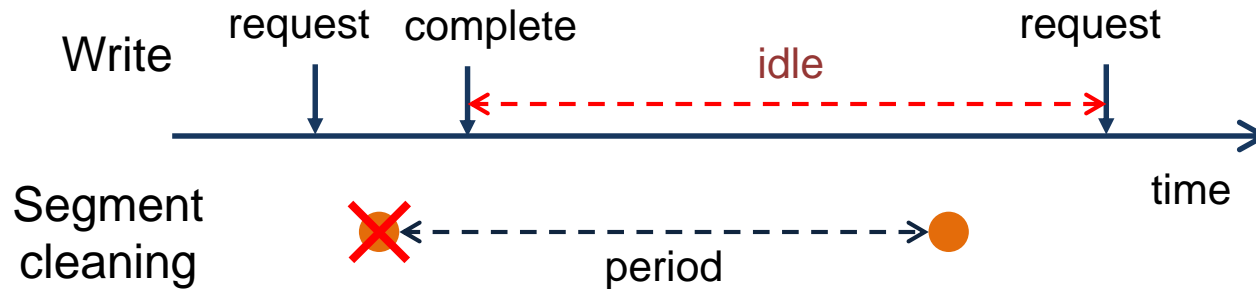
# Segment Cleaning

## Two types of segment cleaning

Foreground segment cleaning: on-demand

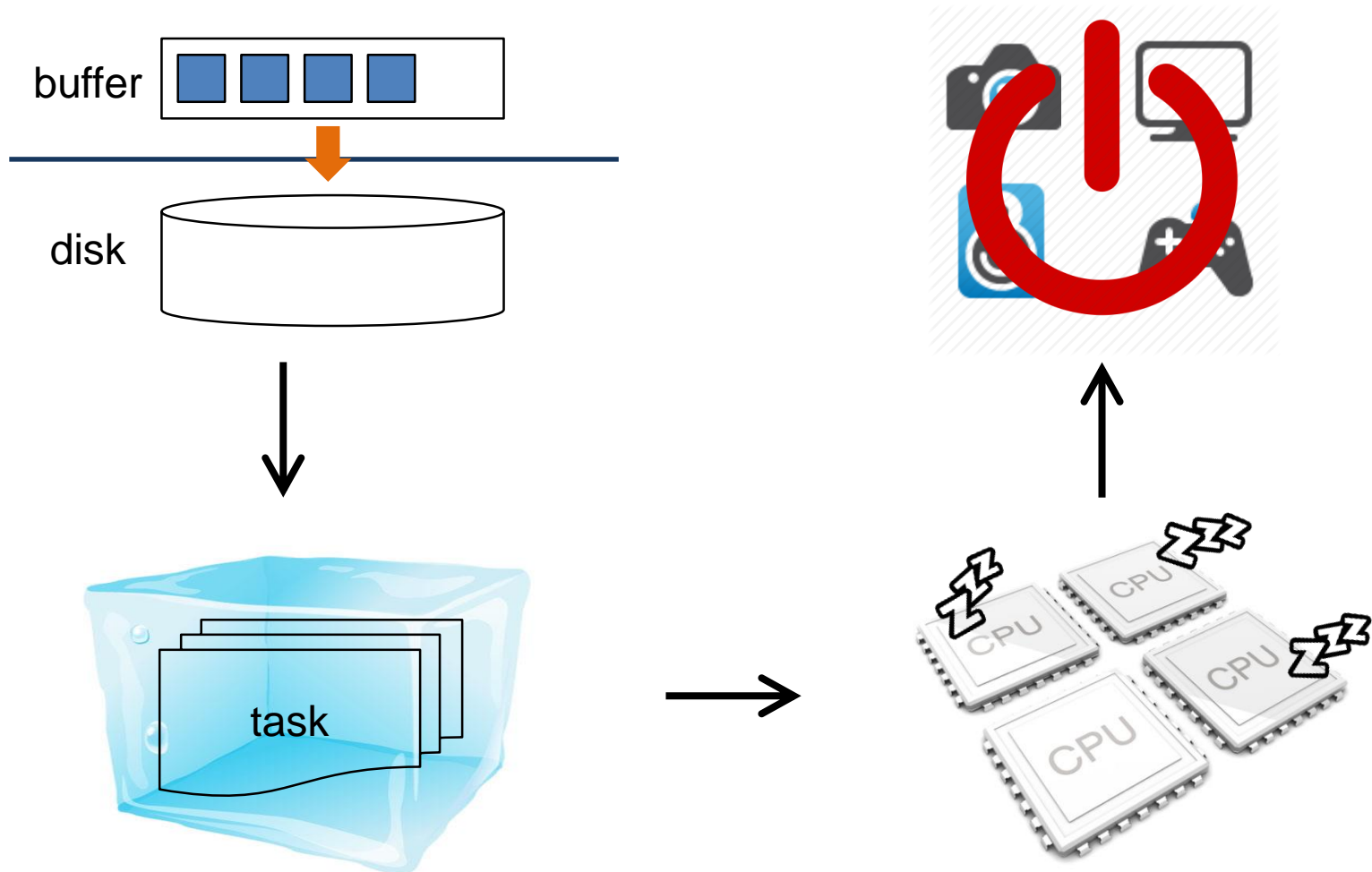


Background segment cleaning: periodically



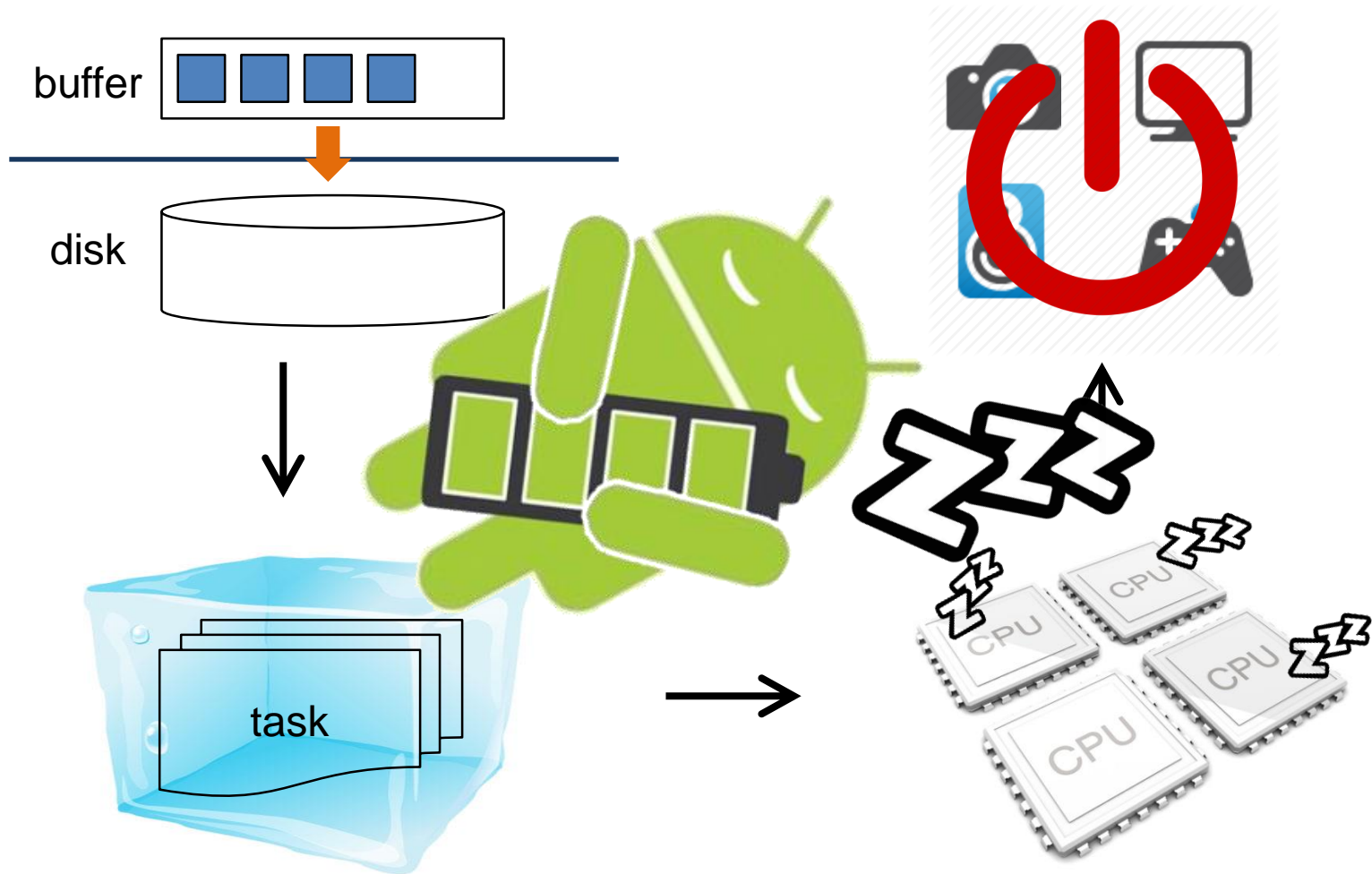
# Suspend Mode of Smartphone

Android adopts Suspend Mode to save battery



# Suspend Mode of Smartphone

Android adopts Suspend Mode to save battery



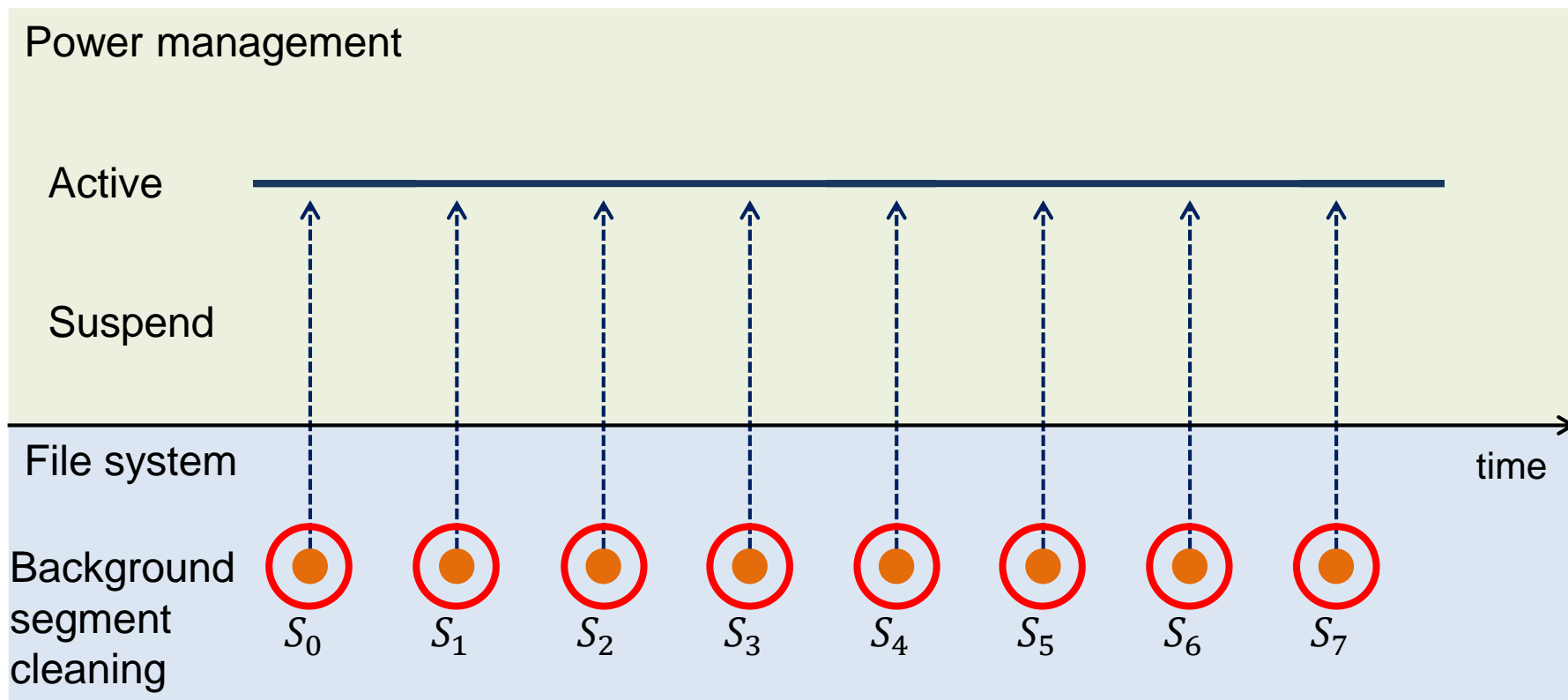
## Log-structured File System vs. Android

Log-structured file system needs **segment cleaning** to generate free space

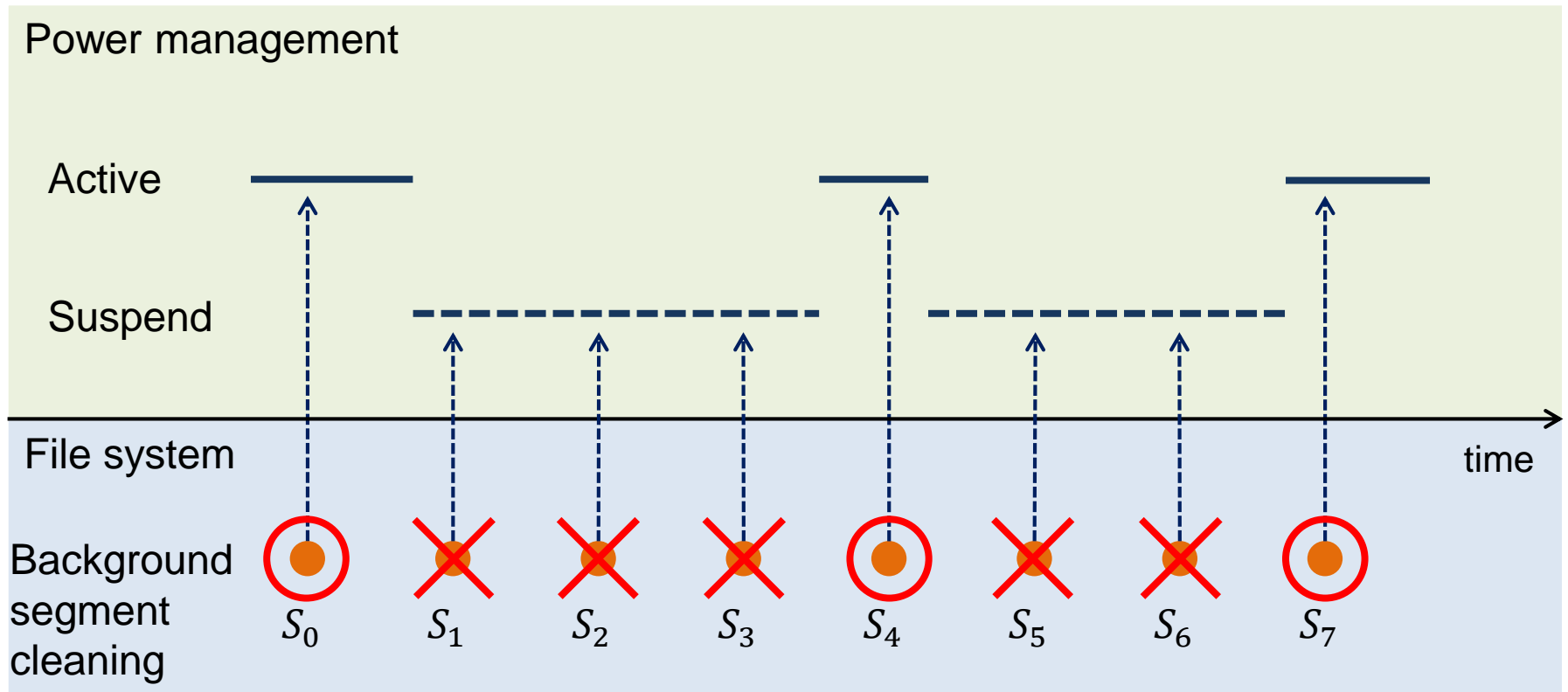
Android smartphone is **suspended** when screen is turned off

Does segment cleaning works well when smartphone is suspended?

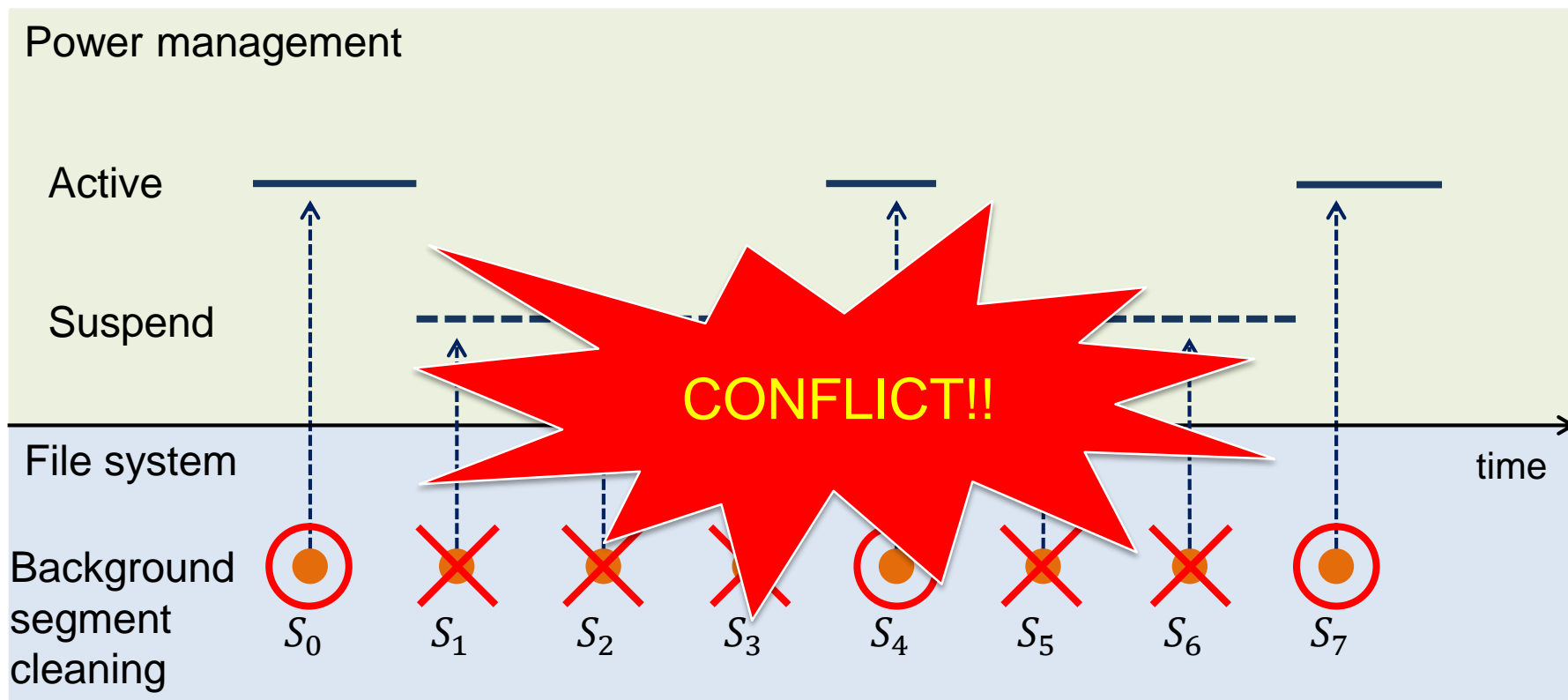
# Segment Cleaning and Suspend Mode



# Segment Cleaning and Suspend Mode



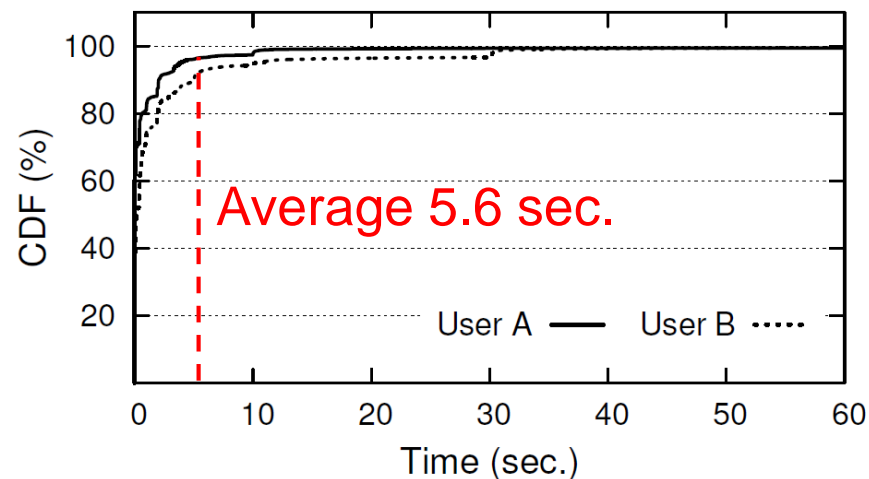
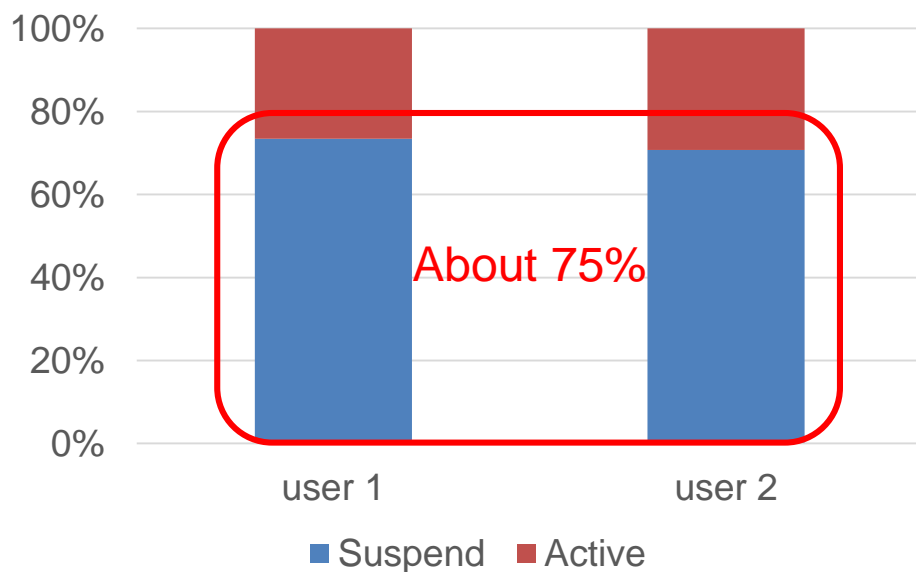
# Segment Cleaning and Suspend Mode





# Observation

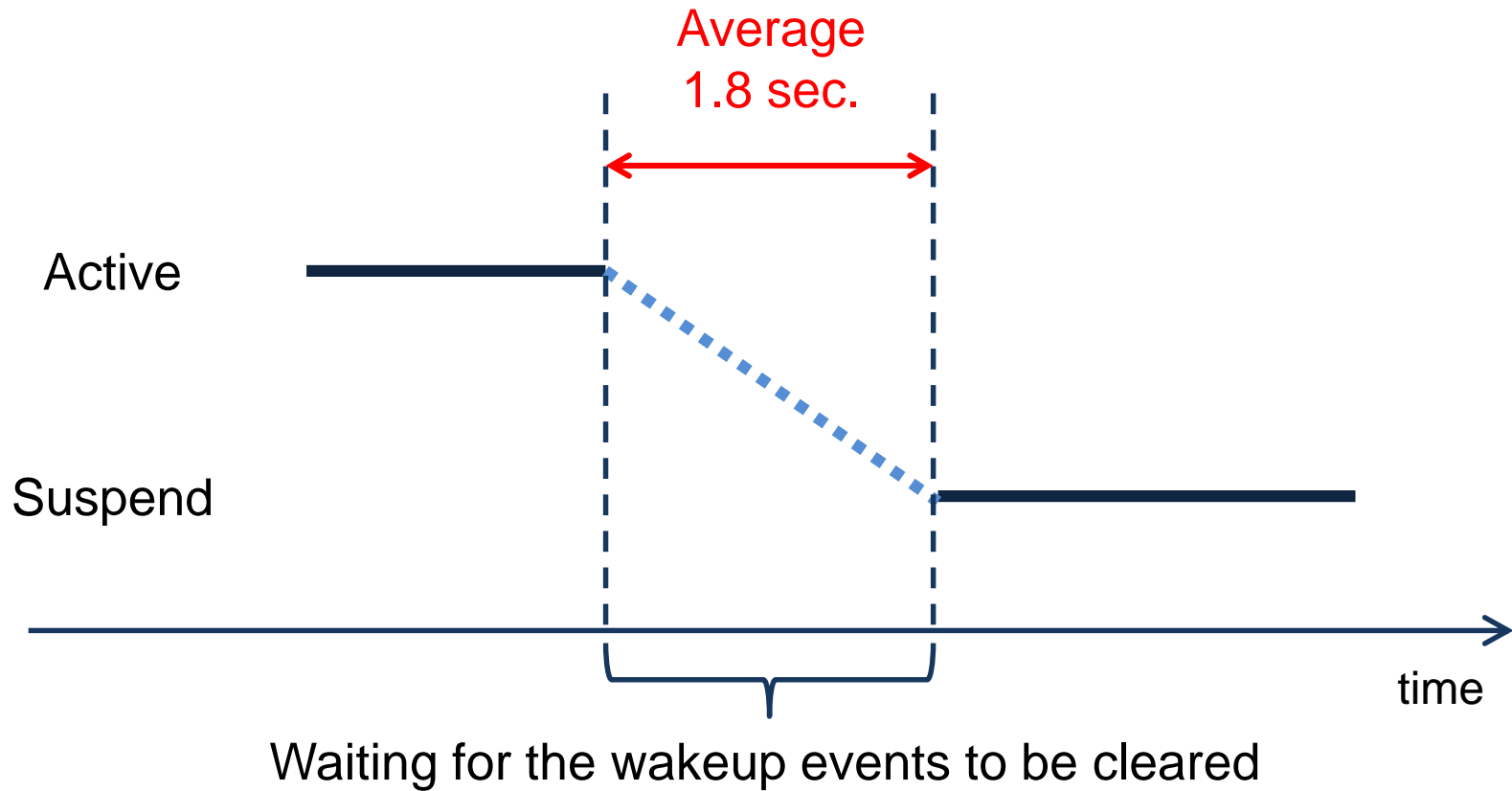
## Active period in real setting



**Device may be in suspend state when  
Background Segment Cleaning is activated.**

# Observation

There is a large time slack

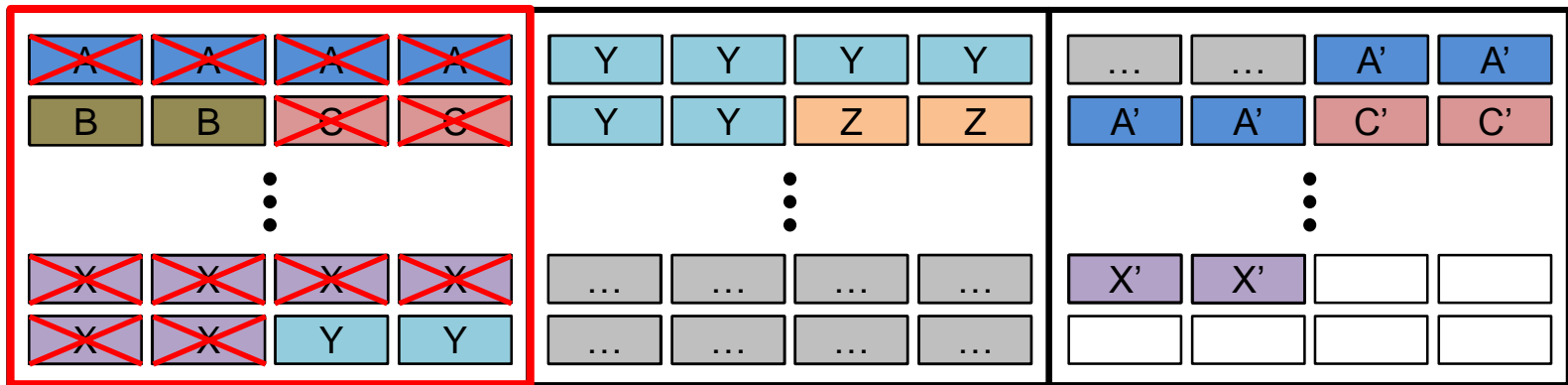


Use the time between LCD off and entering suspend!

- CPU and I/O devices are still awoken
- Does not interfere with user and foreground apps
- Perform segment cleaning when suspending device

# Virtual Segment Cleaning

Do not migrate valid block directly



victim  
segment

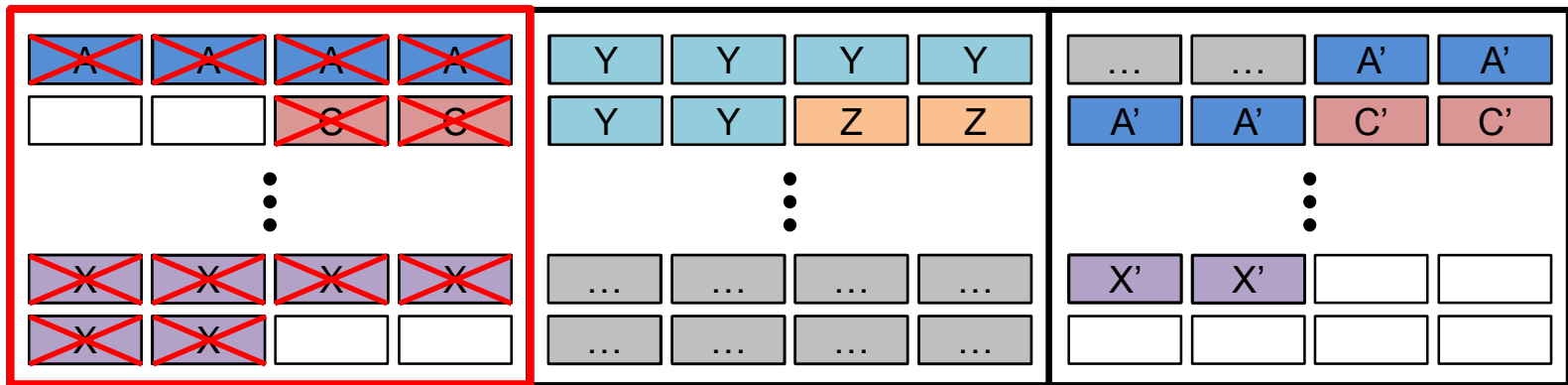
page cache



# Virtual Segment Cleaning

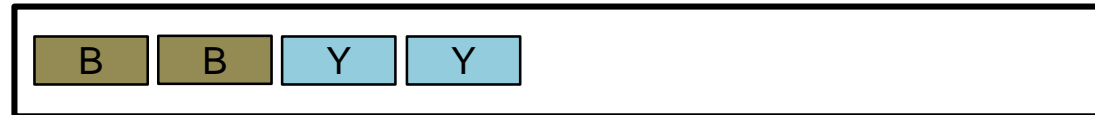
Do not migrate valid block directly

Suspend routine start



victim  
segment

page cache

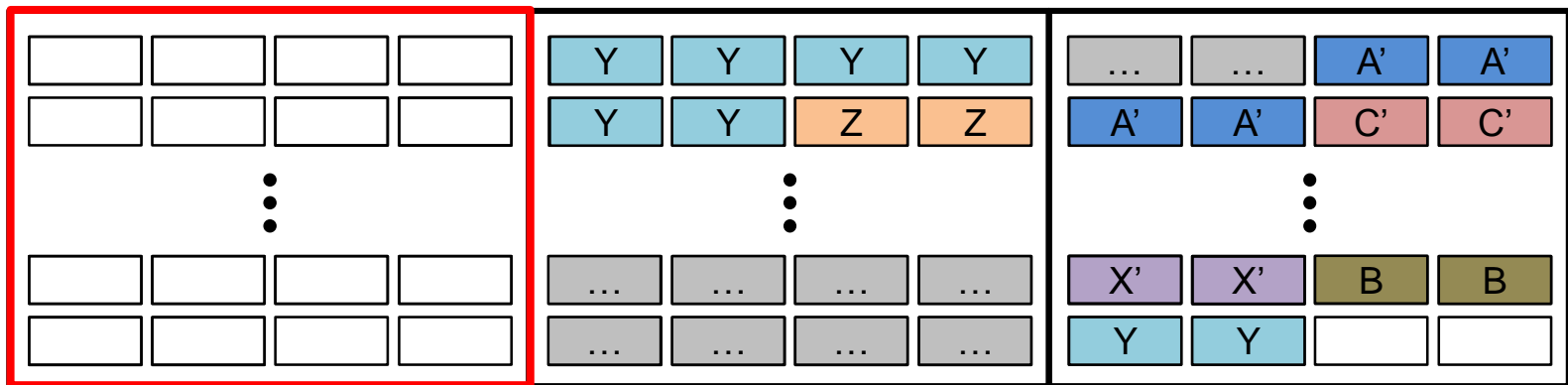


Mark page cache entry as dirty

# Virtual Segment Cleaning

Do not migrate valid block directly

Call `sys_sync()`



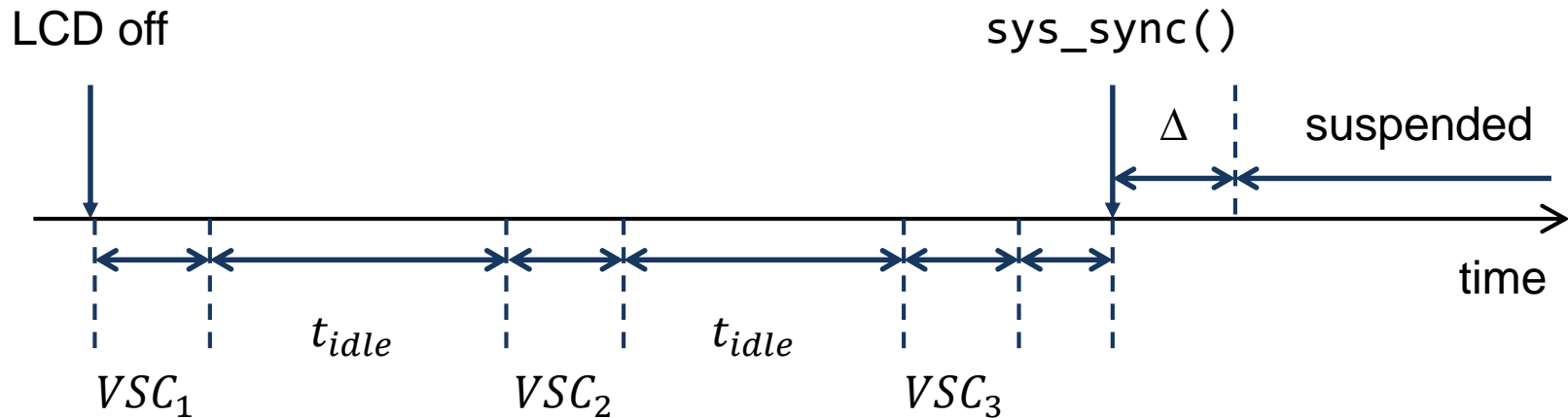
victim  
segment

page cache



Mark page cache entry as dirty

# Virtual Segment Cleaning



$\Delta$  : Time for processing other suspend routine

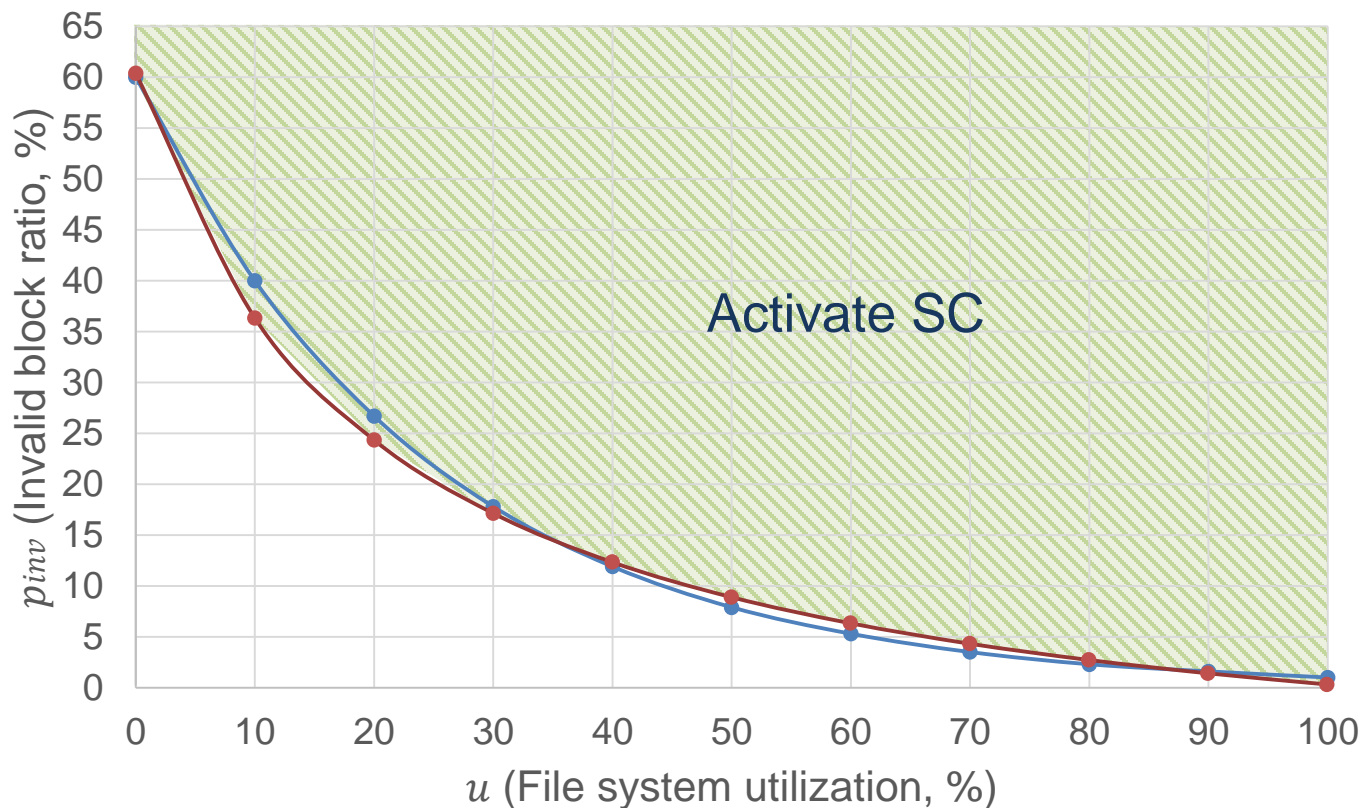
$VSC_i$  :  $i_{th}$  Virtual Segment Cleaning

$t_{idle}$  : Idle period to throttle the amount of reclaimed segments

Too frequent segment cleaning may leads to the reduction of the NAND flash lifetime

# Utilization-based Segment Cleaning

## Threshold of file system utilization to activate SC



$u$ : File system utilization

$p_{inv}$ : Invalid block ratio

Idea threshold

Approximated threshold



# Utilization-based Segment Cleaning

## Idle period between segment cleaning

- Reclaim 2 ~ 6 free segments at once
- Adaptive with file system utilization and invalid block ratio
- Using time slack between LCD off and entering suspend



$$300 \text{ ms} < t_{idle} < 900 \text{ ms}$$

Segment cleaning is activated with threshold and idle period is  $t_{idle}$

# Experiment

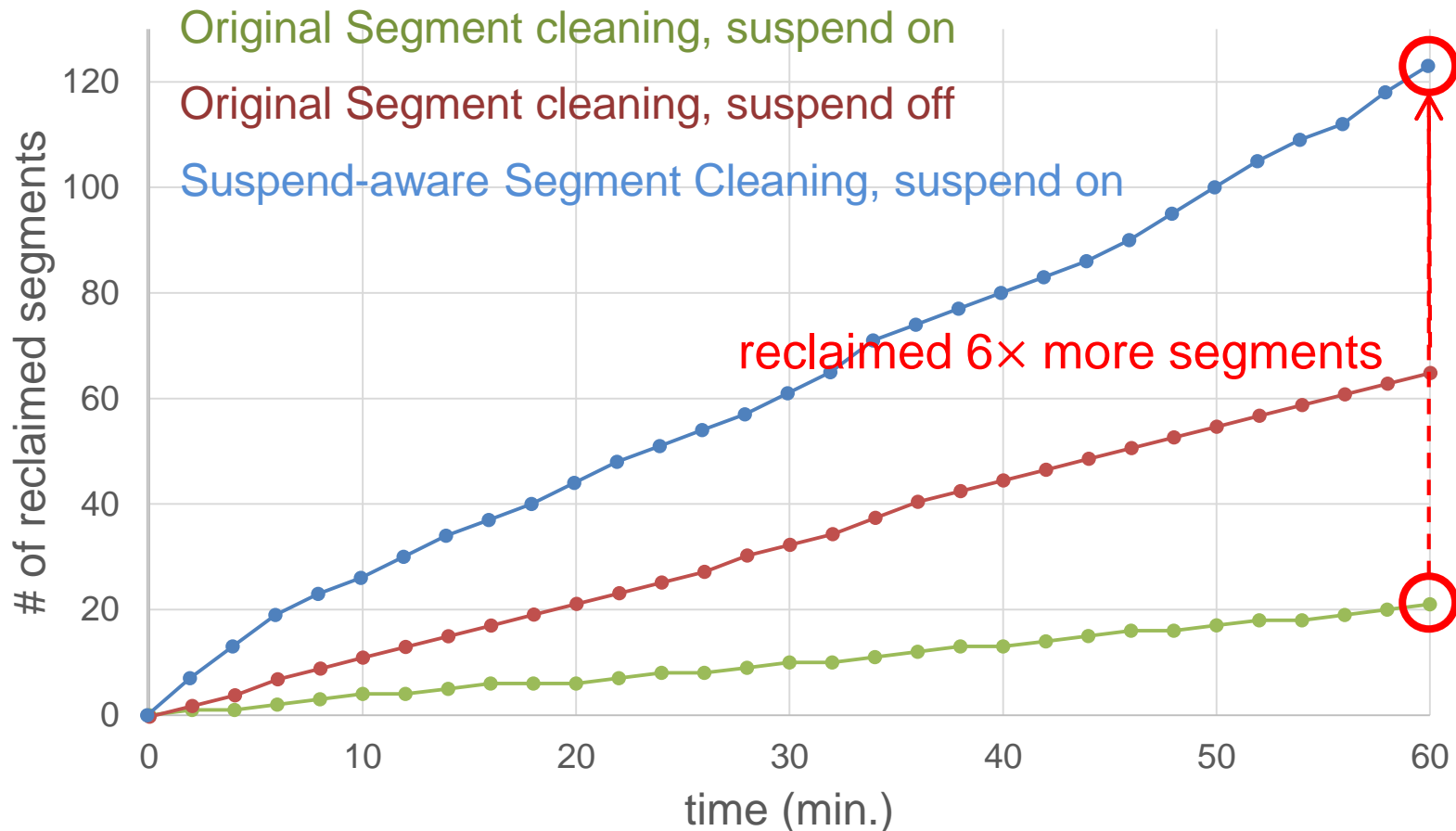
## Motorola Moto G (KK 4.4.2, Linux 3.4)



Component	Specification
AP	Qualcomm Snapdragon 400
CPU	Cortex-A7 1.2GHz Quad-core
RAM	1GB
Internal storage	8GB eMMC
File system	F2FS (data), EXT4 (others)

# Experiment

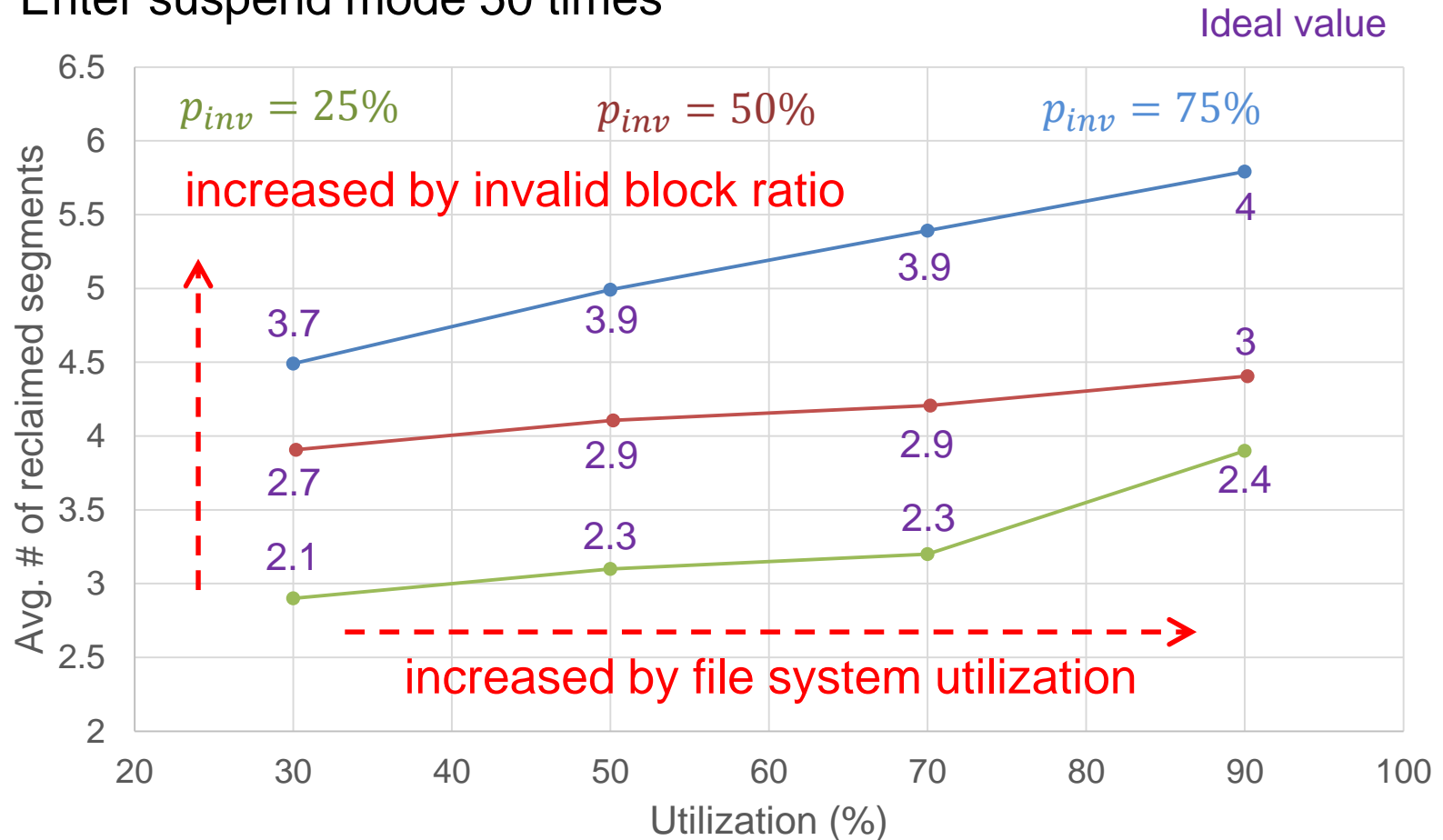
## Number of reclaimed segments



# Idle Period Model Verification

## Number of reclaimed segments vs. File system utilization

- Vary the file system utilization and the fraction of invalid blocks
- Enter suspend mode 50 times



# Conclusion

- Background segment cleaning of log-structured file system and suspend feature of Android system directly conflict with each other.
- Suspend-aware Segment Cleaning seamlessly reclaims free segments with suspend module of the smartphone

**Suspend-aware Segment Cleaning claims  
6× as many segments as  
the stock background segment cleaning does.**

