

# Cosmos OpenSSD: A PCIe-based Open Source SSD Platform

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# OpenSSD Introduction

# What's the OpenSSD Project

- Open-source SSD platform for research and education on the SSD technology since 2011
- New “OpenSSD platform” for developing SSD firmware, controller hardware, and host software
- Contribution
  - Indilinx (Merged to OCZ in 2012)
  - HYU (Hanyang University), Korea
  - SKKU (Sungkyunkwan University), Korea

# Why OpenSSD?

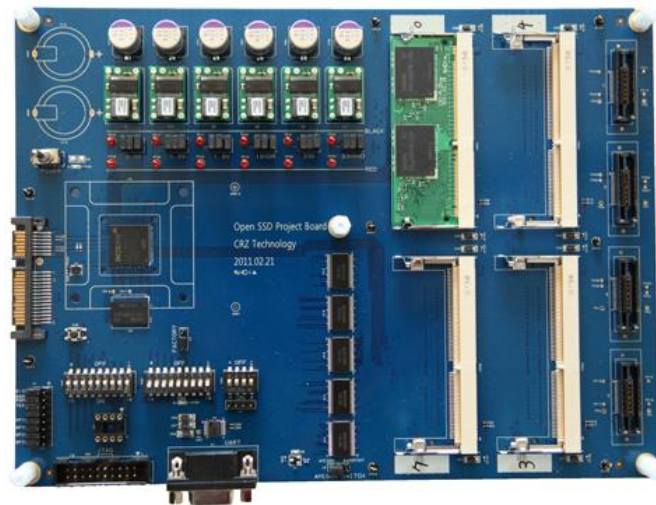
- Solve your problem in a real system
- Share your solution with people in society
- Design your own SSD controller, if possible
- Contribute to “open” community
- Use it as a PC disk
- Play for fun

# OpenSSD Project History

- Jasmine OpenSSD (2011)
  - SSD controller: Indilinx Barefoot (SoC w/SATA-2)
  - Firmware: SKKU VLDB Lab
  - Users from 10+ countries
  - 10+ papers published

**Barefoot  
Controller  
SoC**

**SATA-2  
Interface**



**NAND Flash  
Memory  
(32GB/module)**

# OpenSSD Project History

- Cosmos OpenSSD (2014)
  - SSD controller: HYU Tiger3 (FPGA w/PCIe Gen2)
  - Firmware: HYU ENC Lab, SKKU VLDB Lab
  - Users from ?? countries (at least one)
  - ?? papers to be published (at least three)

**SSD  
Controller  
In FPGA**

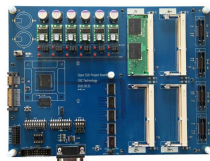
**External  
PCIe  
Interface**



**NAND Flash  
Memory  
(256GBs/module)**

# Comparison among the Platforms

	Jasmine OpenSSD	Cosmos Prototype (Tiger2)	Cosmos OpenSSD (Tiger3)
SSD Controller	Indilinx Barefoot (SoC)	HYU Tiger2 (FPGA)	HYU Tiger3 (FPGA)
Year	2011	2012	2014
Host Interface	SATA-2	PCIe Gen1.1 (AHCI Subset)	PCIe Gen2 (AHCI Subset)
Storage Capacity	128 GB	512 GB	512 GB
NAND Data Interface	Asynchronous	Asynchronous	Synchronous
DRAM Capacity	64 MB	512 MB	1 GB



# OpenSSD Project Homepage



The screenshot shows a web browser window displaying the OpenSSD Project homepage. The browser's address bar shows the URL [http://www.openssd-project.org/wiki/The\\_OpenSSD\\_Project](http://www.openssd-project.org/wiki/The_OpenSSD_Project). The page features a navigation menu on the left with links for Home, Downloads, Events, Recent changes, Random page, and Help. The main content area is titled "The OpenSSD Project" and includes a description of the project's goals and a list of contents. A green box highlights the URL <http://www.openssd-project.org>. The page also includes a search bar and a toolbox with links for What links here, Related changes, Special pages, Printable version, and Permanent link.

navigation

- Home
- Downloads
- Events
- Recent changes
- Random page
- Help

forum menu

- Forum
- Search
- Today's Posts

search

Go Search

toolbox

- What links here
- Related changes
- Special pages
- Printable version
- Permanent link

The OpenSSD Project

The OpenSSD Project is an initiative to promote research and education on the recent SSD (Solid State Drive) technology by providing easy access to *OpenSSD platforms* on which open source SSD firmware can be developed. Currently, we offer an OpenSSD platform based on the commercially successful Barefoot™ controller from [Indilinx Co., Ltd.](#) This site is also intended to be a forum to share various simulators, tools, and workload generators and traces related to SSDs, among researchers in academia and industry.

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- 1 OpenSSD Platforms
- 2 Events
  - 2.1 Past Events
- 3 Forum
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OpenSSD Platforms

**Note: A new OpenSSD platform is coming this year...**

We are preparing the second OpenSSD platform called Cosmos. The Cosmos OpenSSD platform is based on the PCIe interface and will debut in the [Flash Memory Summit](#) in August, 2014. So, stay tuned!

**Cosmos OpenSSD Platform**

Coming soon...

**Jasmine OpenSSD Platform**





# Cosmos OpenSSD Platform Features

## Design Objective

- A simple NAND storage platform to be used for
  - Firmware development and evaluation
  - Controller architecture exploration
  - New controller design (e.g. Intelligent SSD)
  
- ➔ An open-source SSD platform with AP-class CPUs and other hardware resources

# Cosmos SSD Hardware Features

<b>FPGA</b>		Xilinx Zynq-7000 series
<b>MCU</b>	<b>Type</b>	Cortex™- A9
	<b>Clock Frequency</b>	667 MHz
<b>Storage</b>	<b>Total Capacity</b>	512 GB
	<b>NAND Organization</b>	4-Channel / 8-Way
<b>DRAM</b>	<b>Device Interface</b>	DDR3 (533 MHz)
	<b>Total Capacity</b>	1 GB
<b>Bus</b>	<b>System</b>	AXI-Lite (Bus width: 32 bits)
	<b>Storage Data</b>	AXI (Bus width: 64 bits, Burst Length: 256)
<b>SRAM</b>		256 KB (FPGA Internal)
<b>Error Correction Code</b>		BCH 32 bits/2 KB
<b>Host Interface</b>		PCI-Express Gen2 4-Lane (2 GB/s)
<b>Power Measurement</b>		NAND Flash and Board Power Measurement (External ADC Module or NI DAC)

# NAND Flash

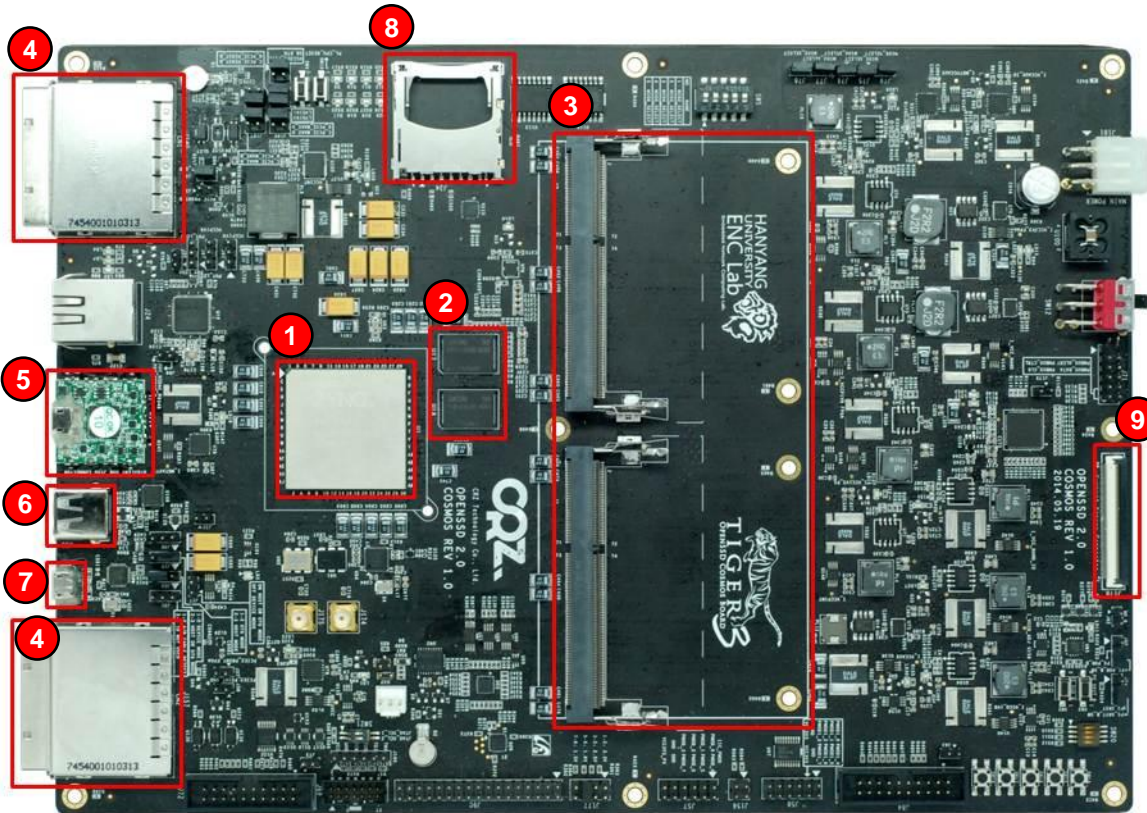
## NAND Flash Memory Specification

<b>Vendor / Model</b>	SK Hynix / H27QDG8VEBIR-BCB	
<b>Device Interface</b>	Synchronous (ONFI 2.2)	
<b>Cell Technology</b>	MLC (2 Bits/cell)	
<b>Capacity</b>	16 GBs/package	
<b>Page Size</b>	Data Area	8192 Bytes/page
	Spare Area	640 Bytes/page
<b>Dies per Package</b>	4 dies (QDP)	
<b>Data Cycle</b>	20 ns (DDR: 10 ns)	
<b>Page Read</b>	70 us (typical)	
<b>Page Program</b>	1400 us (typical)	
<b>Block Erase</b>	3.5 ms (typical)	
<b>Speed</b>	NV-DDR100	

## DRAM Memory Specification

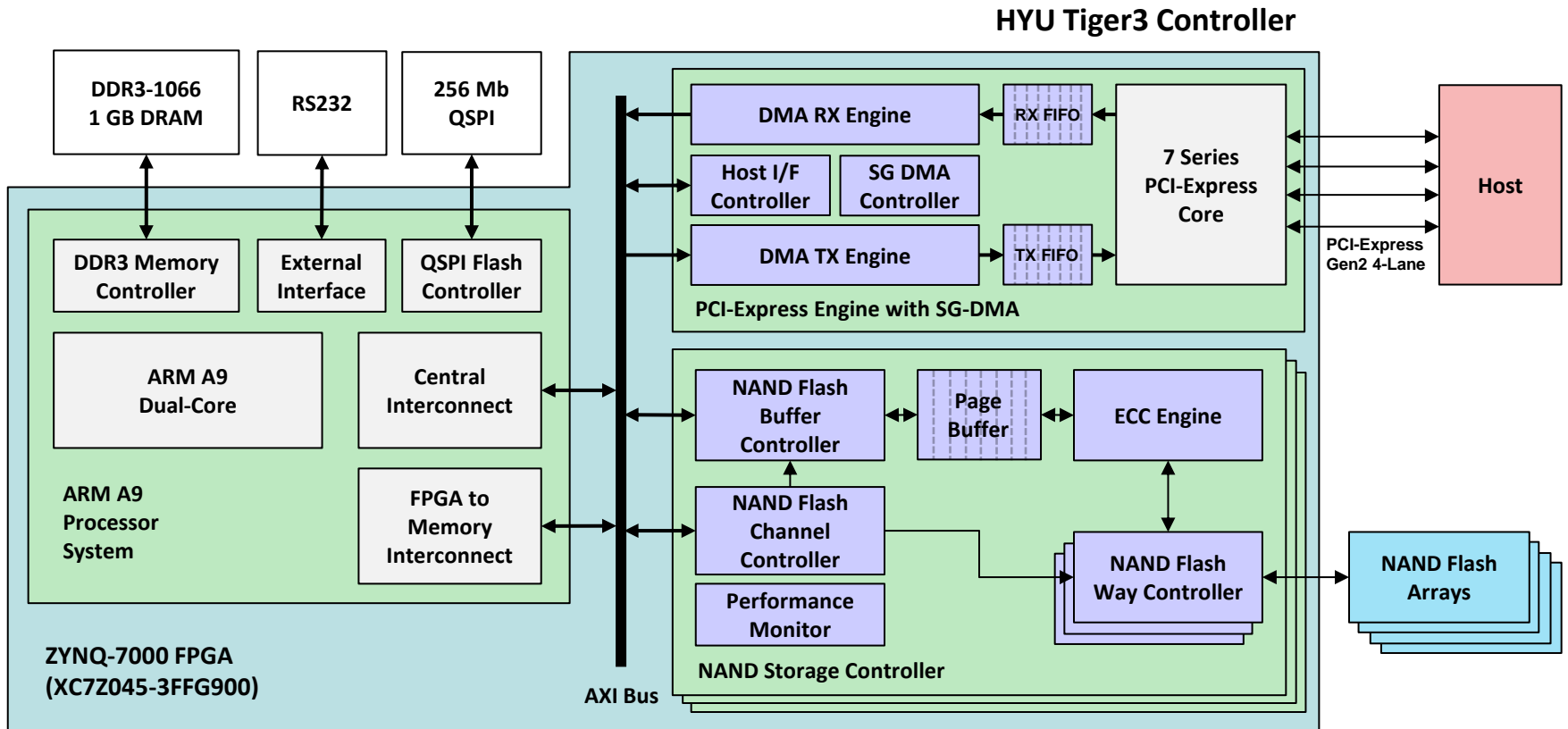
<b>Vendor</b>	Samsung (K4B4G1646B-HCK0)
<b>Device Interface</b>	DDR3-1066F
<b>DRAM Device Bus Width</b>	16 Bits
<b>Capacity</b>	1 GB (512 MBs x2)
<b>CAS Latency</b>	7 Cycles
<b>CAS Write Latency</b>	6 Cycles
<b>RAS to CAS Delay</b>	7 Cycles
<b>Precharge Time</b>	7 Cycles
<b>Throughput</b>	8.5 GB/s

# Cosmos SSD Platform Board



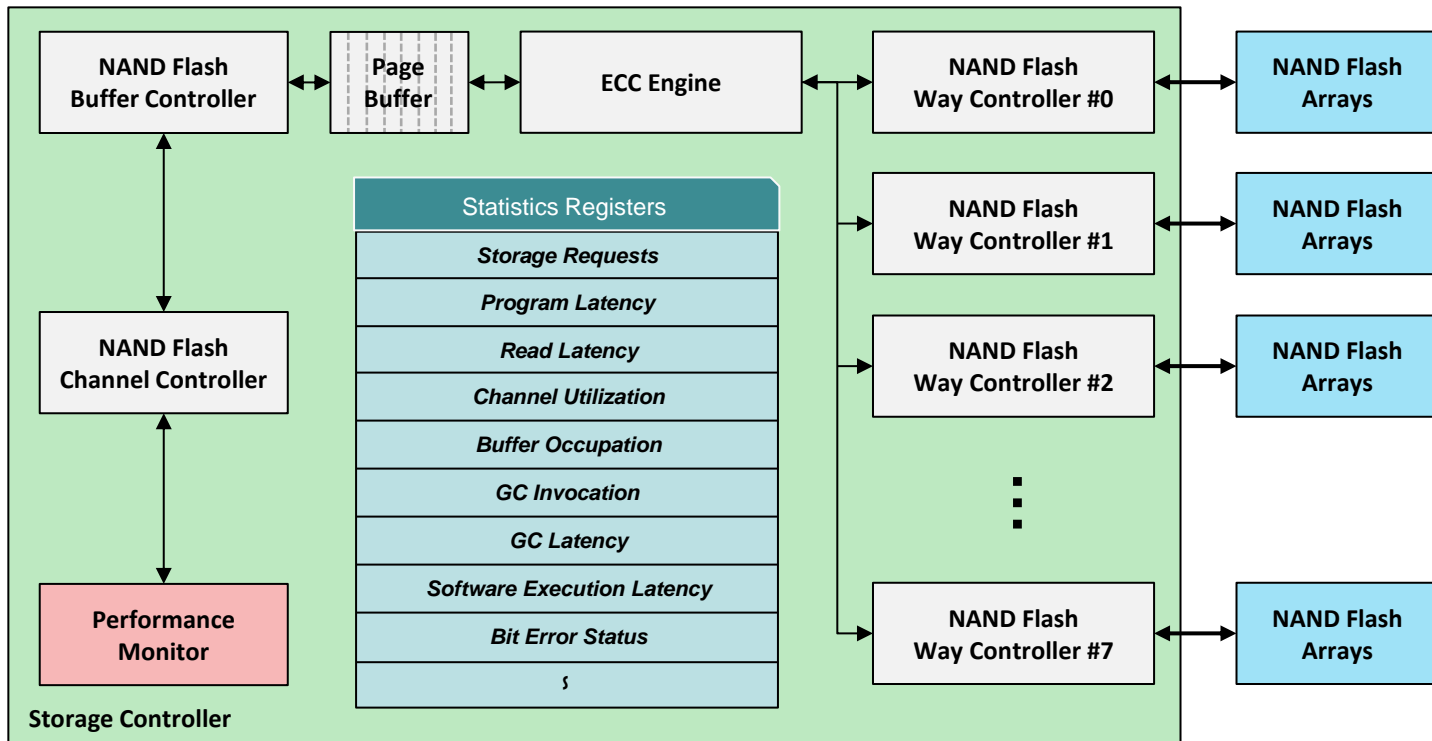
No.	Information
1	Xilinx Zynq-7000 (HYU Tiger3 Controller)
2	DDR3 (512 MB x2)
3	NAND SODIMM x2
4	External PCIe x2
5	USB JTAG
6	UART
7	USB 2.0 OTG
8	SD Card
9	Power Measurement Connector

# HYU Tiger3 Controller



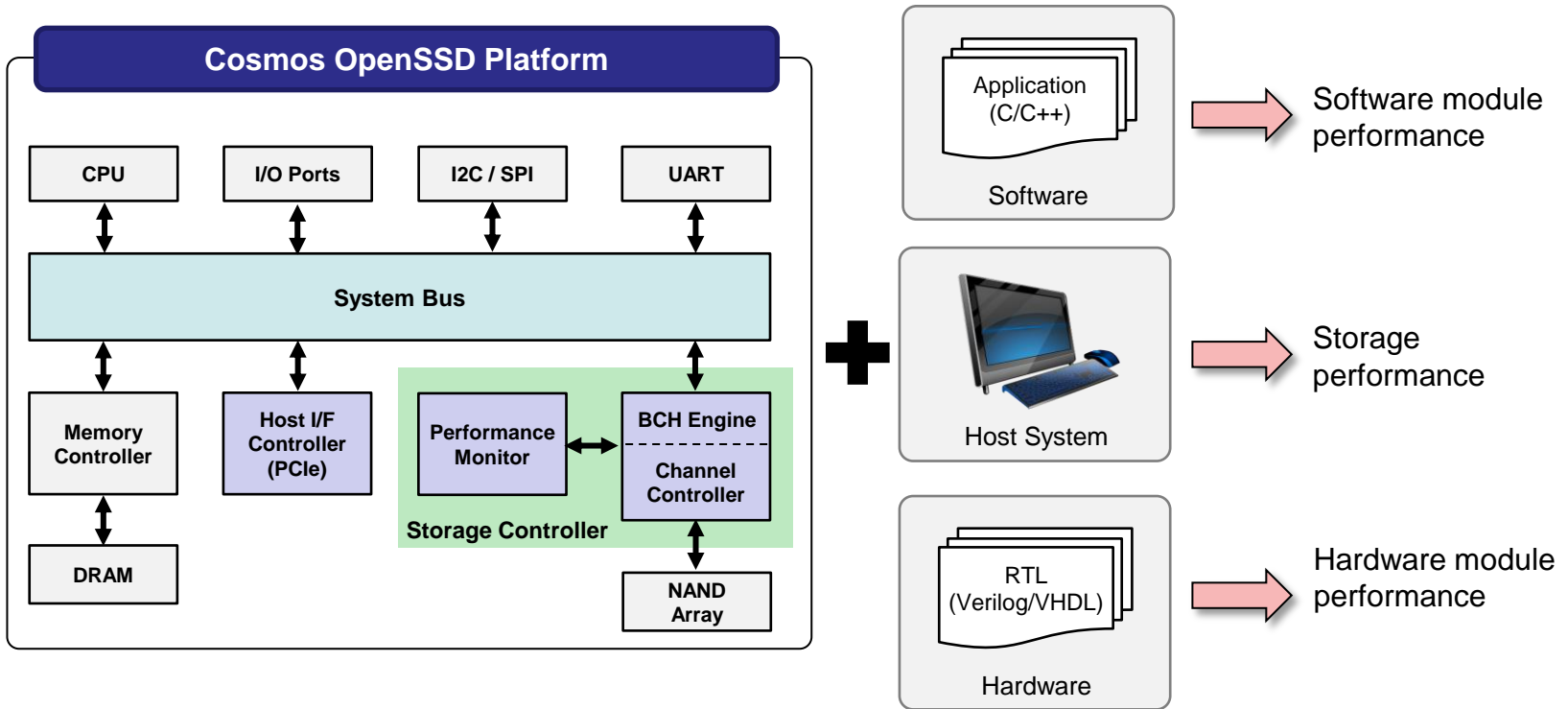
# Storage Performance Monitor

Statistics on the performance and utilization of hardware resources

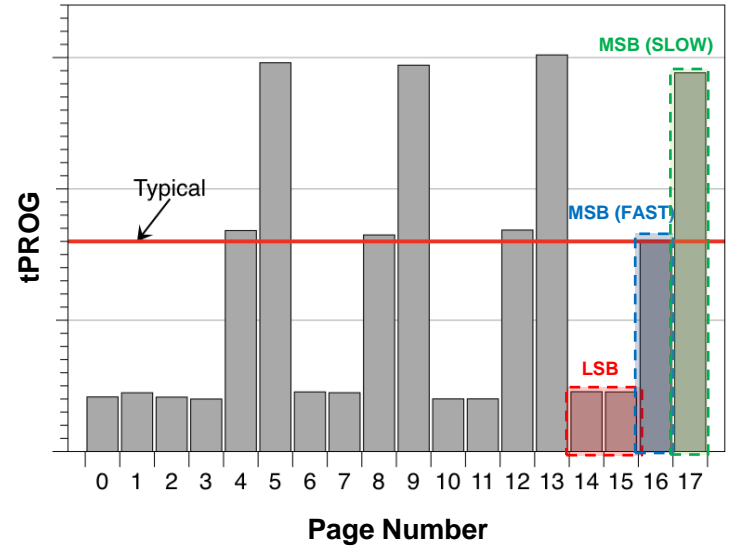
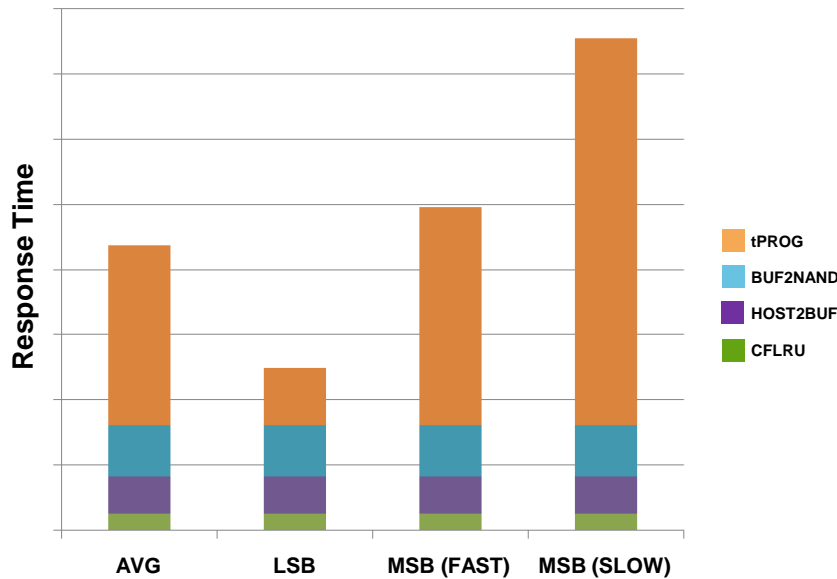
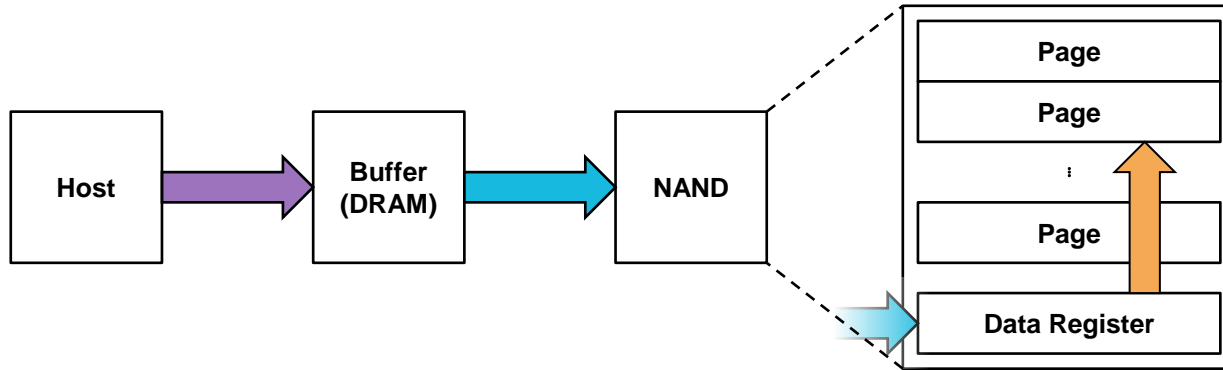




# Use of Performance Monitor



# Example: Operation Time Breakdown

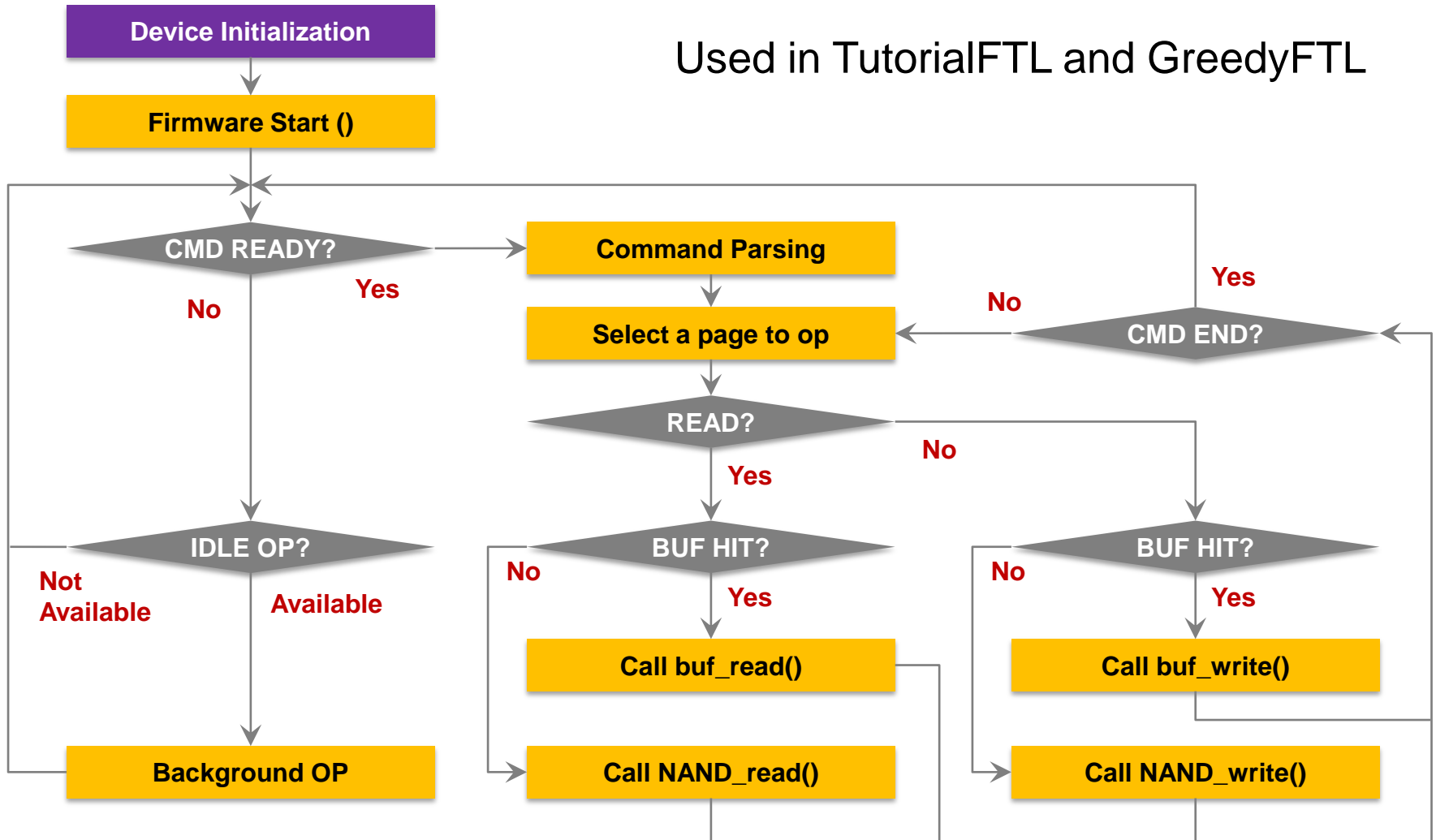


## Available FTLs (under GPL)

- TutorialFTL (by HYU ENC Lab)
  - Page-mapping FTL w/o GC
  - Device initialization and interface definition
- GreedyFTL (by HYU ENC Lab)
  - Page-mapping FTL w/ Greedy GC
- DramDisk (by HYU ENC Lab)
  - DRAM Disk for measuring maximum read/write performance (PCIe + DRAM)

# Common Operation Flow

Used in TutorialFTL and GreedyFTL



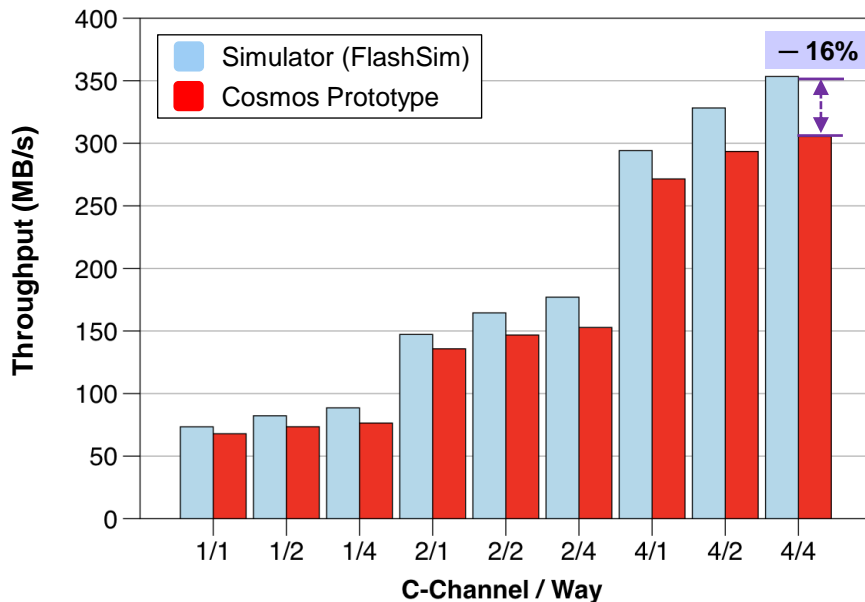
- AS-IS
  - Makes the storage work as a drive
  - Handles read/write requests from kernel
  - Needs to install storage-specific device driver
    - Windows7 64-bit device driver (by HYU ENC Lab)
    - Linux 3.2.X kernel device driver (by HYU ENC Lab)
- TO-BE
  - Compatible with PCIe system drivers
    - AHCI support
    - NVMe support



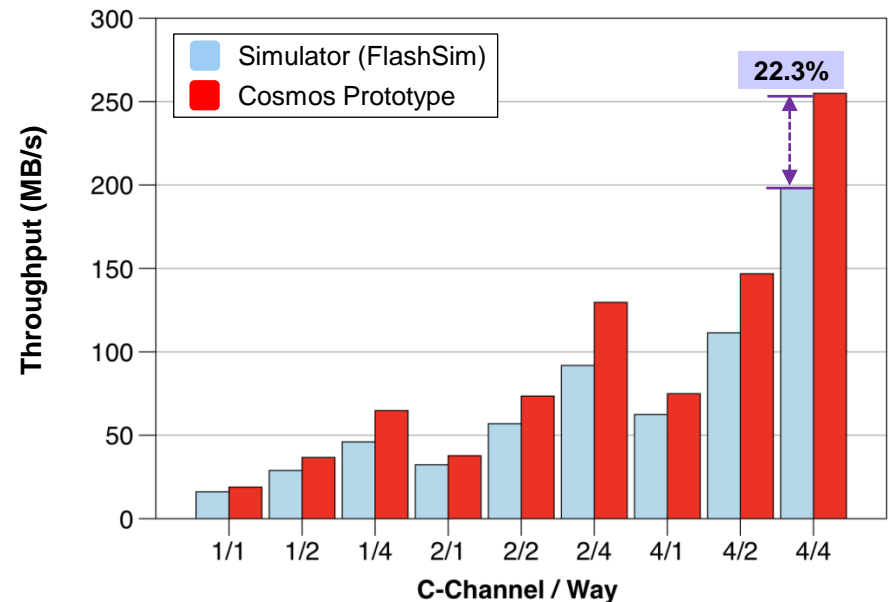
# Some Use Cases

# Cosmos Prototype (Tiger2) Architecture Exploration

## Sequential Read



## Sequential Program

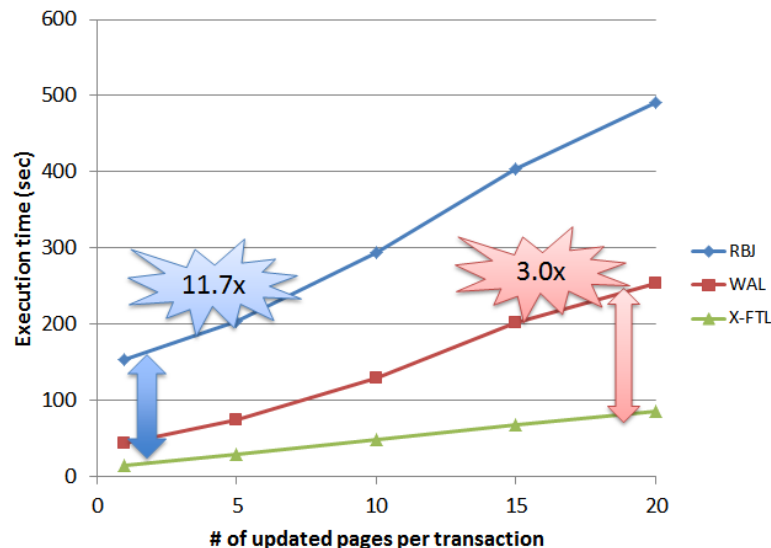


- When compared to the simulator, the performance of cosmos prototype is 16% lower and 22.3% higher in read and program operations, respectively

Note: Cosmos prototype is used in this experiment

*C-Channel: Clustering-Channel*

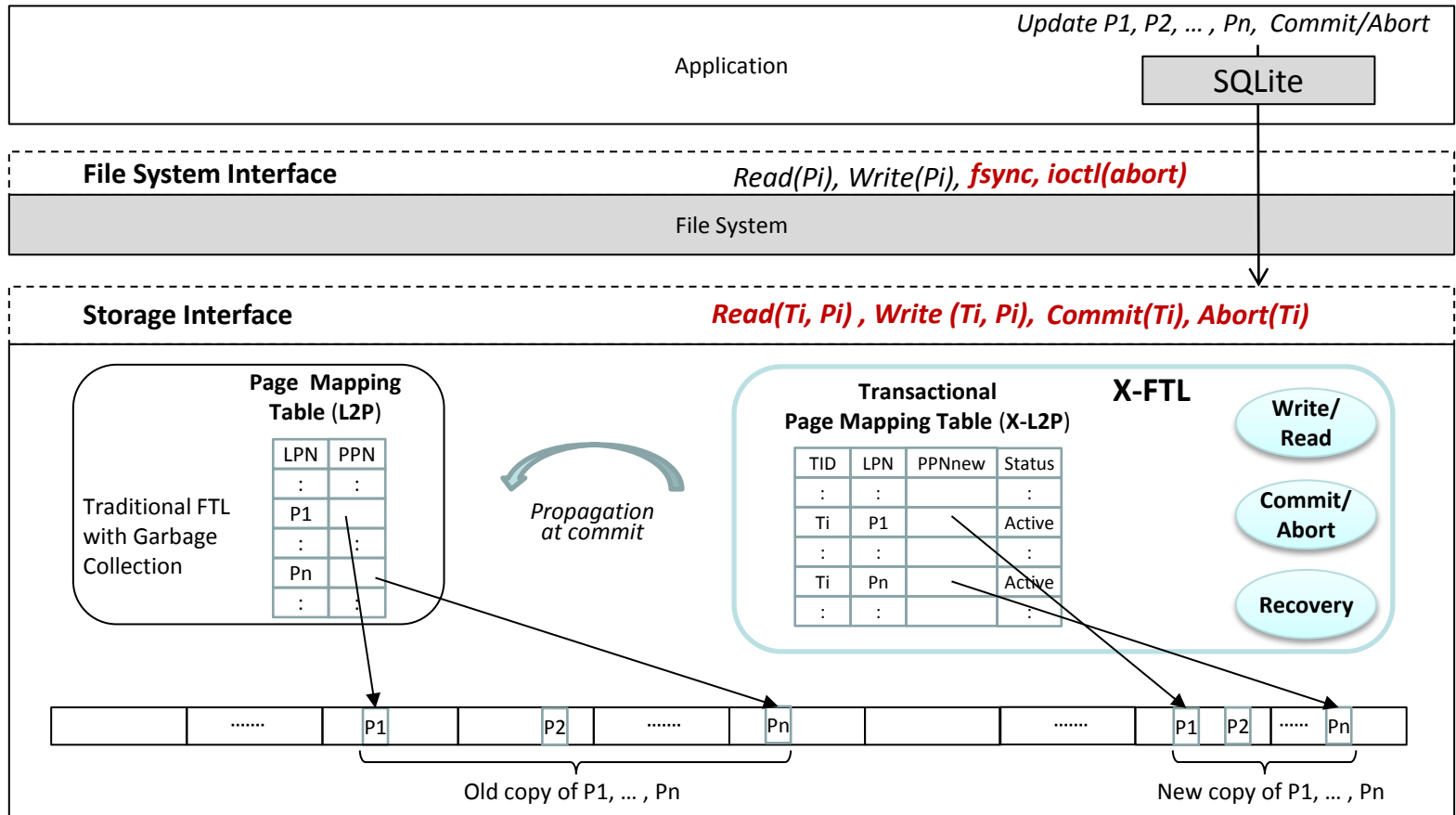
- Transactional FTL for SQLite (SIGMOD 2013)
  - Atomic write of data pages
    - Offload the semantic of all-or-nothing propagation of data pages carried out in host system down to FTL layer
    - Avoid “redundant writes”
  - Originally on top of Jasmine OpenSSD; now in porting to Cosmos



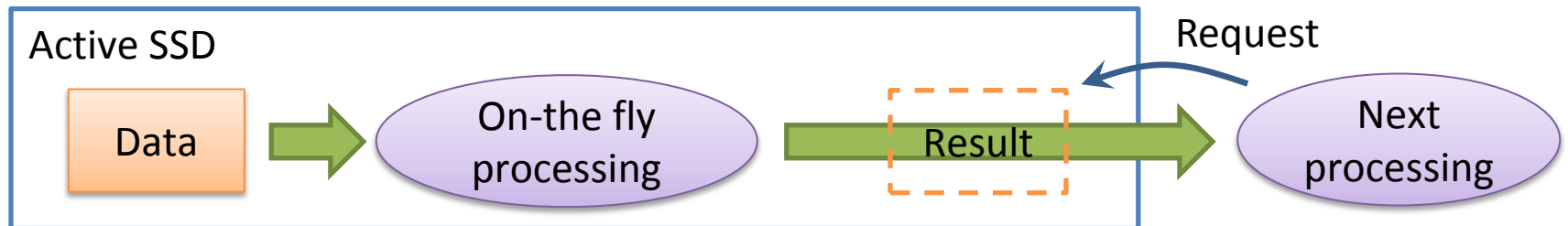


# X-FTL (Continued)

## Architecture



- ActiveSort (HotStorage 2014)
  - Accelerates external sorting
  - Performs on-the-fly merge inside the SSD when the results are requested
  - Eliminates extra data transfer
  - Increases the lifetime of SSDs



## Stay Tuned

- Sources will be available soon at the OpenSSD webpage
- Sources could be updated by other users except us (welcome all the time!)
- And more activities will be posted to the webpage as well



# Call For Participation

- Welcome any contributions from
  - SSD manufacturers
  - NAND flash vendors
  - Research groups
  - Individual developers
  - ...

# Contributors



Prof. Yong Ho Song Ph.D.  
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Prof. Sang-Won Lee Ph.D.  
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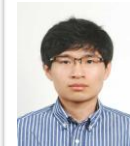
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System Architecture  
& SSD SW Firmware



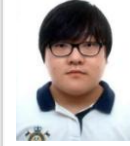
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& PCIe Interface



Youngnam Kim  
SSD HW Architecture



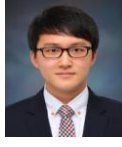
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& ECC Engine



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Luis Cavazos  
Active SSD



Gi-Hwan Oh  
xFTL Design



Young-Sik Lee  
Active SSD



Sung-Rae Kim Ph.D.  
ECC Algorithm



# Thank you

For further information,  
visit <http://www.openssd-project.org>