

# Dynamic Near Data Processing Framework for SSDs

**Gunjae Koo**<sup>\*</sup>, Kiran Kumar Matam<sup>\*</sup>, Te I<sup>†</sup>, H.V. Krishina Giri Nara<sup>\*</sup>, Jing Li<sup>‡</sup>,  
Hung-Wei Tseng<sup>†</sup>, Steven Swanson<sup>‡</sup>, Murali Annavaram<sup>\*</sup>

<sup>\*</sup>University of Southern California

<sup>†</sup>North Carolina State University

<sup>‡</sup>University of California, San Diego

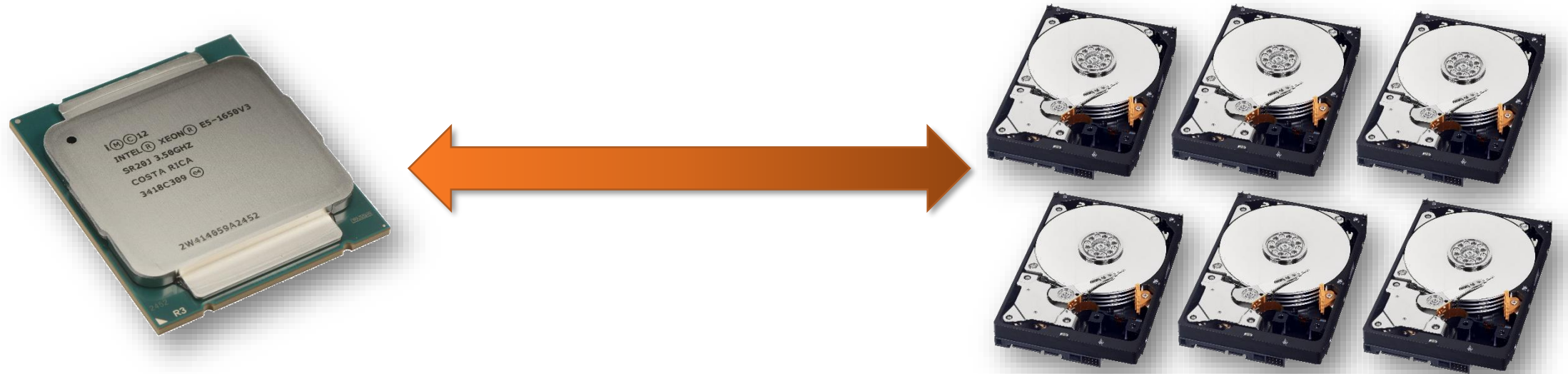
# Conventional Storage = Cheap Passive Devices



## **Conventional storage devices**

- ***Slow, limited bandwidth (SATA 150 ~ 600 MB/s)***
- ***Passive devices (read, write, erase)***

# Storage in Modern Server Systems



## **Storage devices for Big Data**

- **Huge volumes of data → slow, slower, much slower**
- **Data movement is critical for performance**

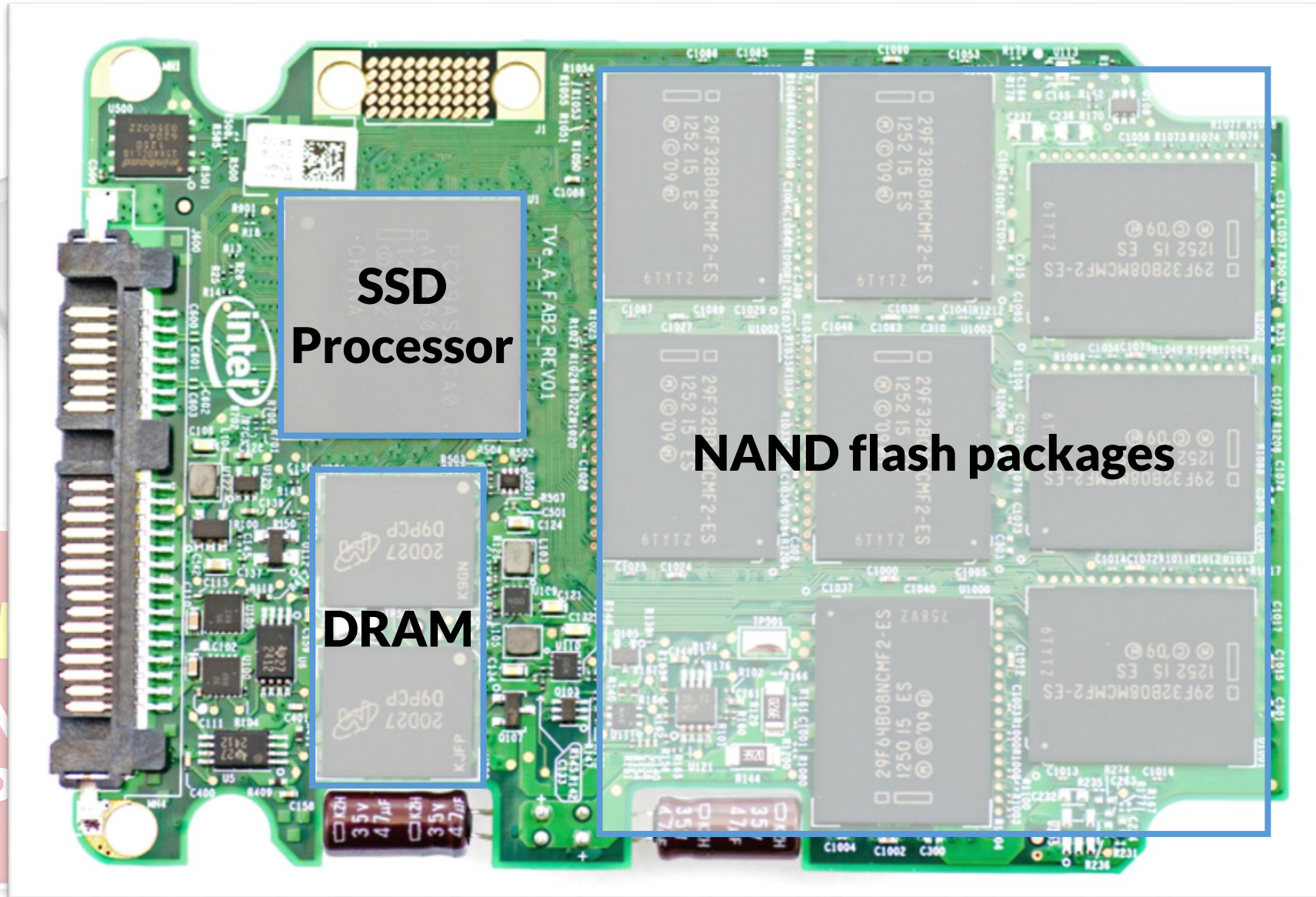


## ***NVM-based storage devices***

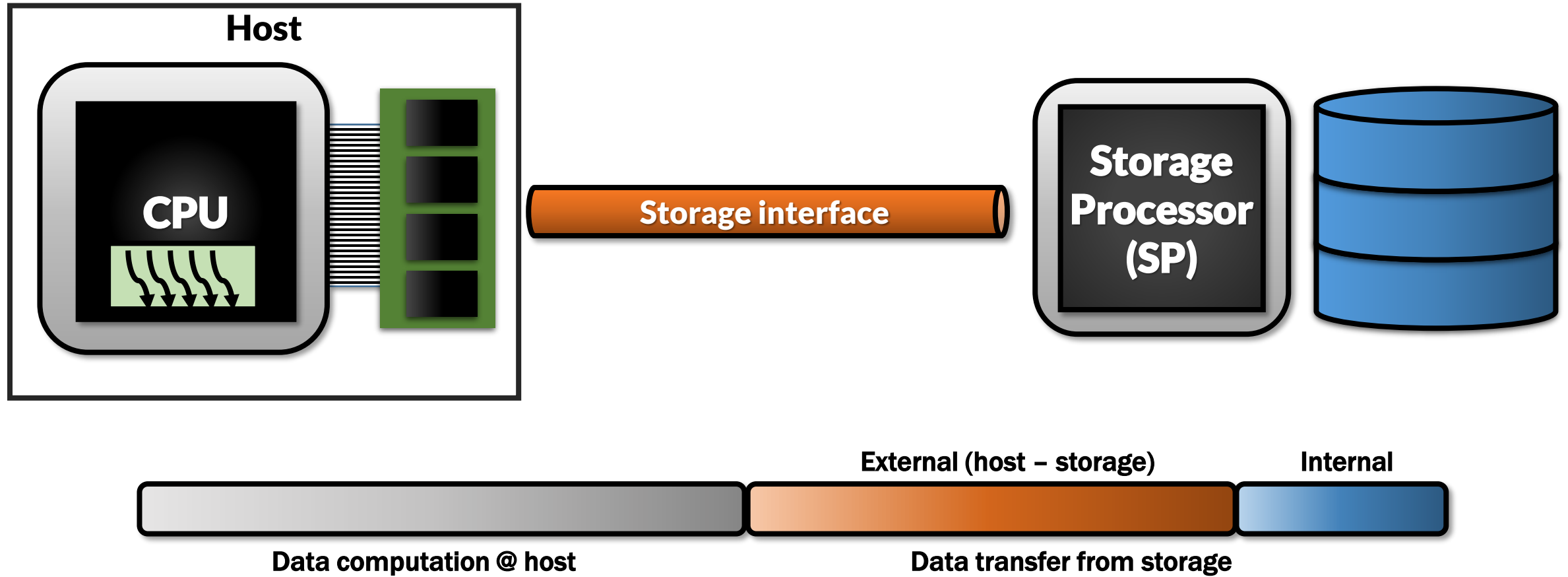
- ***No seek time, higher bandwidth over PCIe***
- ***Potential to be active systems***



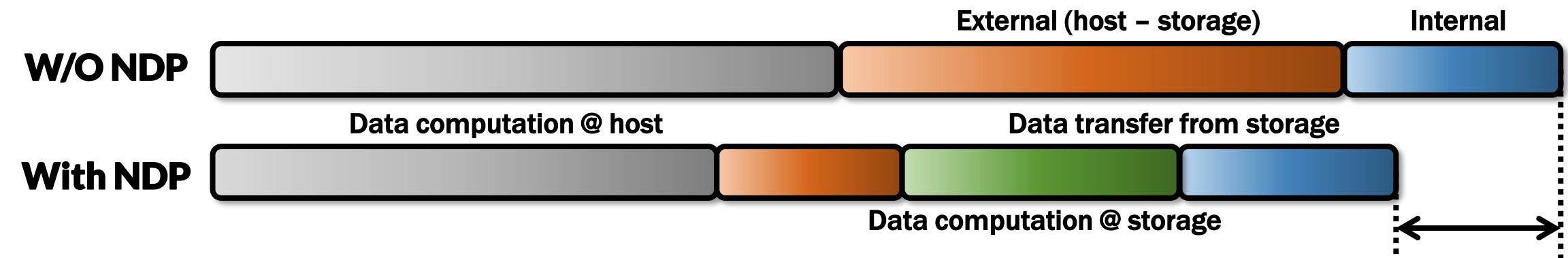
# Intelligent Storage



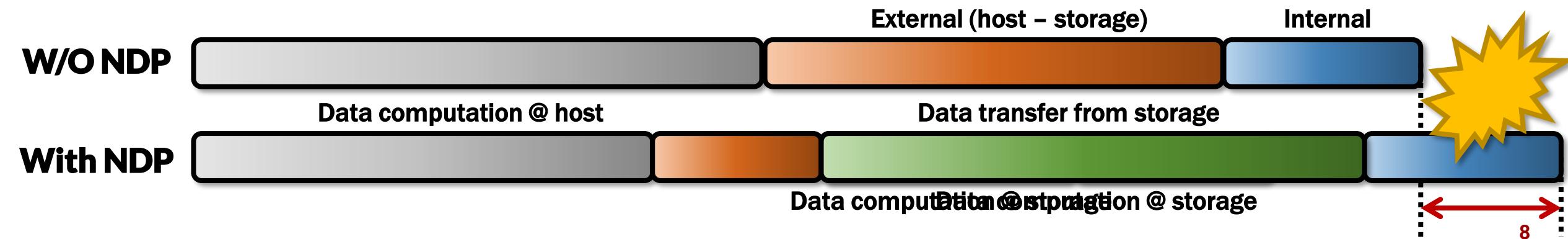
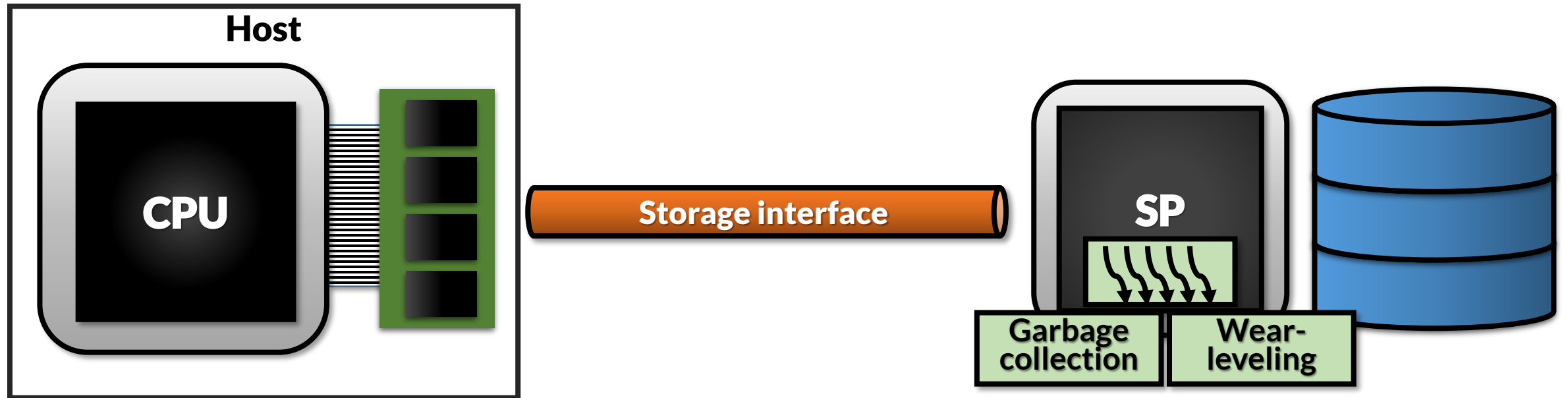
# Near Data Processing (NDP)



# Near Data Processing (NDP)



# Near Data Processing (NDP) on SSDs





# Near Data Processing (NDP) on SSDs

Host

## **Obstacles to in-SSD processing**

- *Less powerful embedded processor*
- *Dynamic computation resource availability*

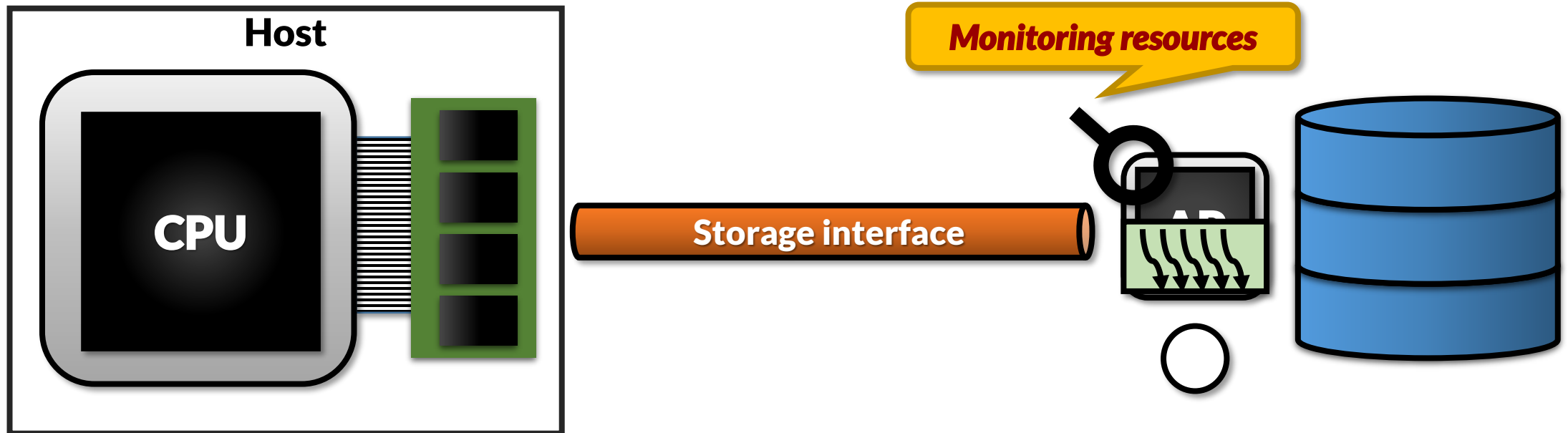
**Summarizer: Dynamic NDP framework for SSD**

W/O NDP

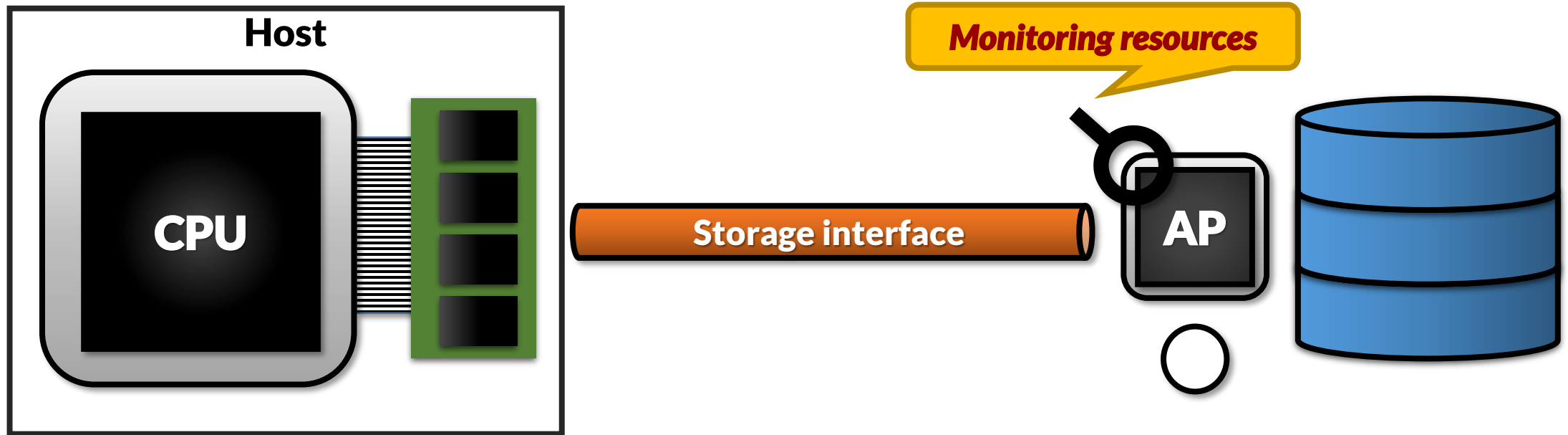
With NDP

Data computation @ storage

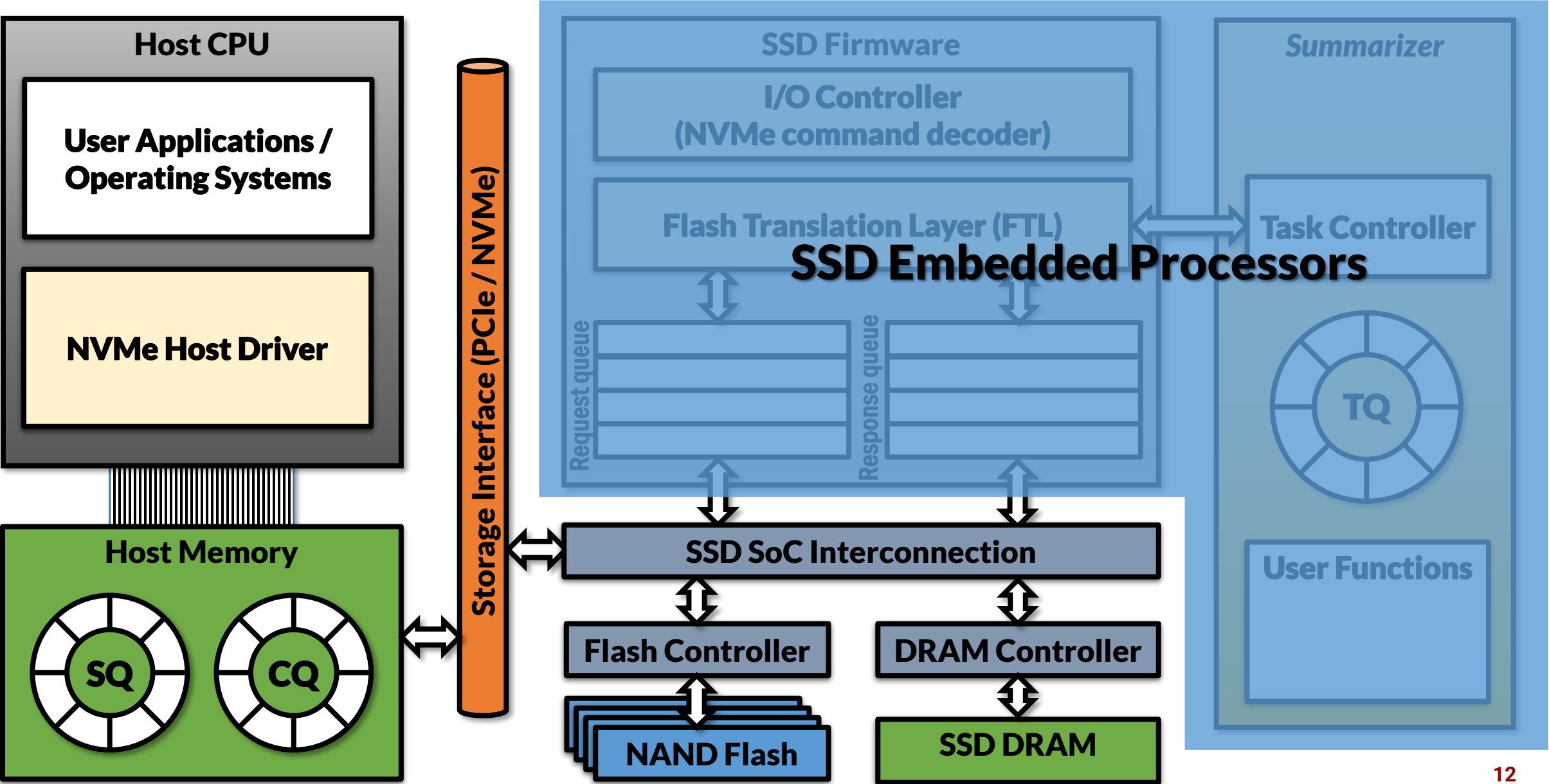
# Summarizer – Basic Concept



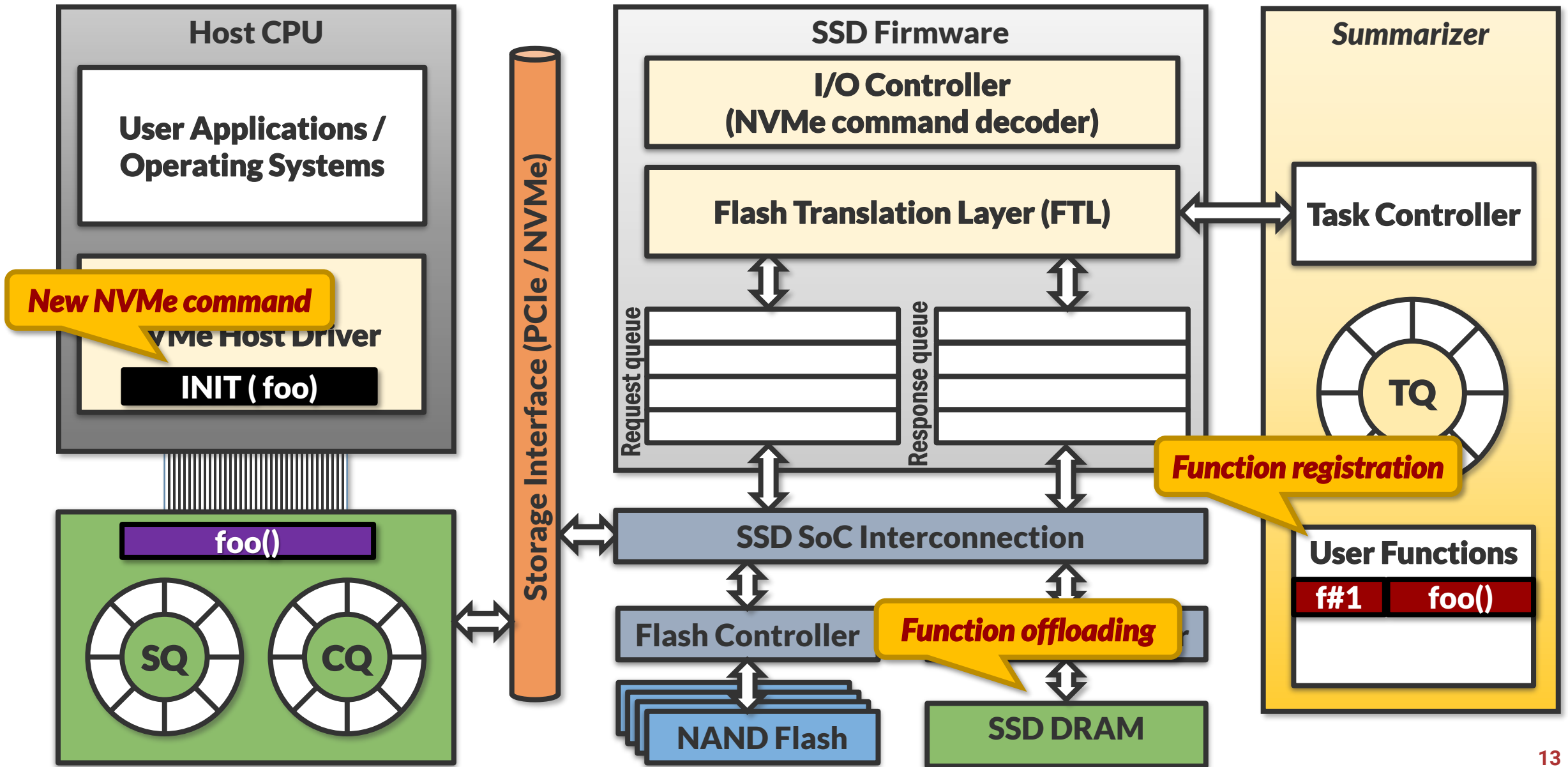
# Summarizer – Basic Concept



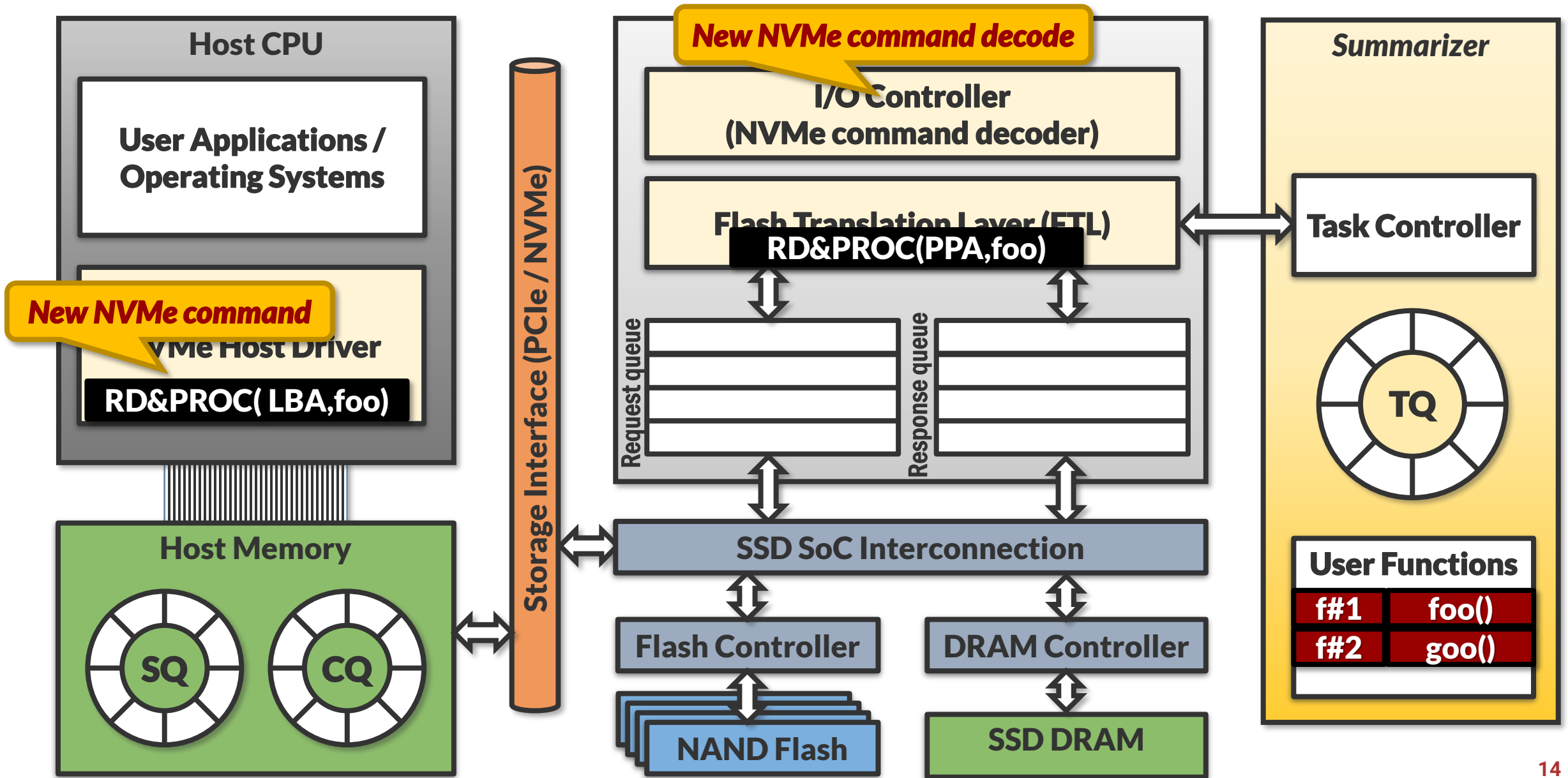
# Summarizer – Detailed Firmware Architecture



# Summarizer – Initialization (Function Offloading)

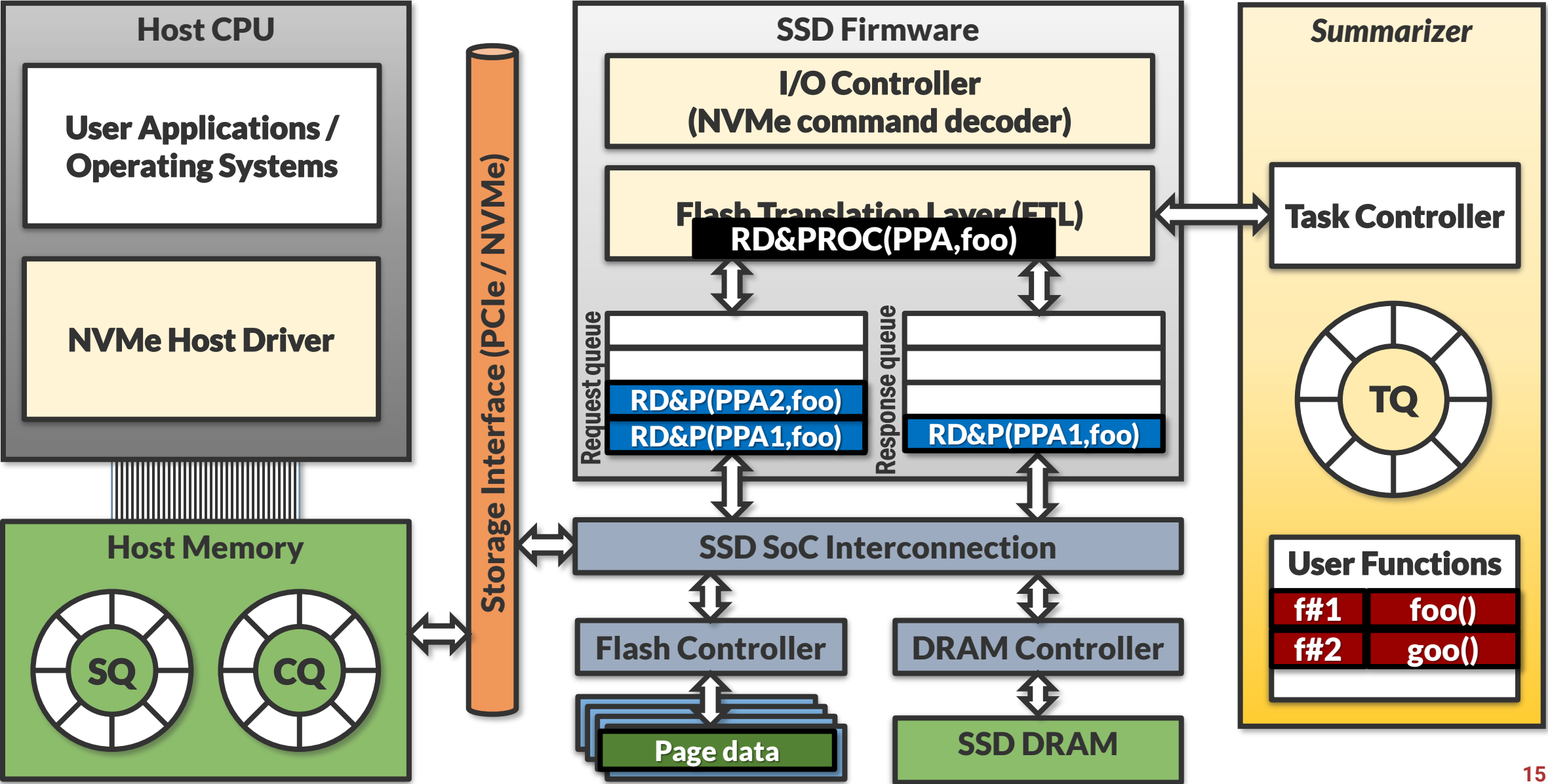


# Summarizer – Computation (Dynamic mode)

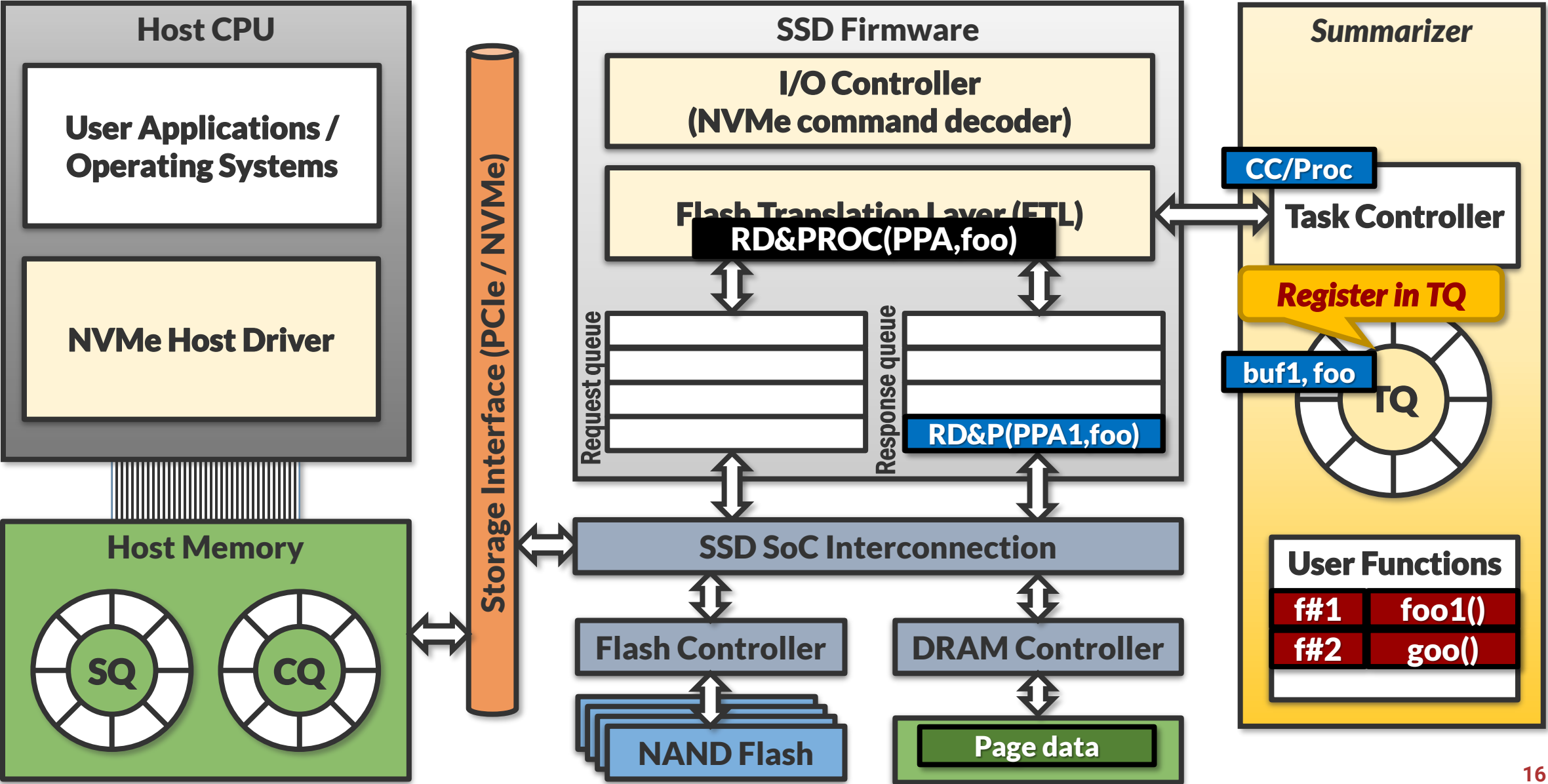




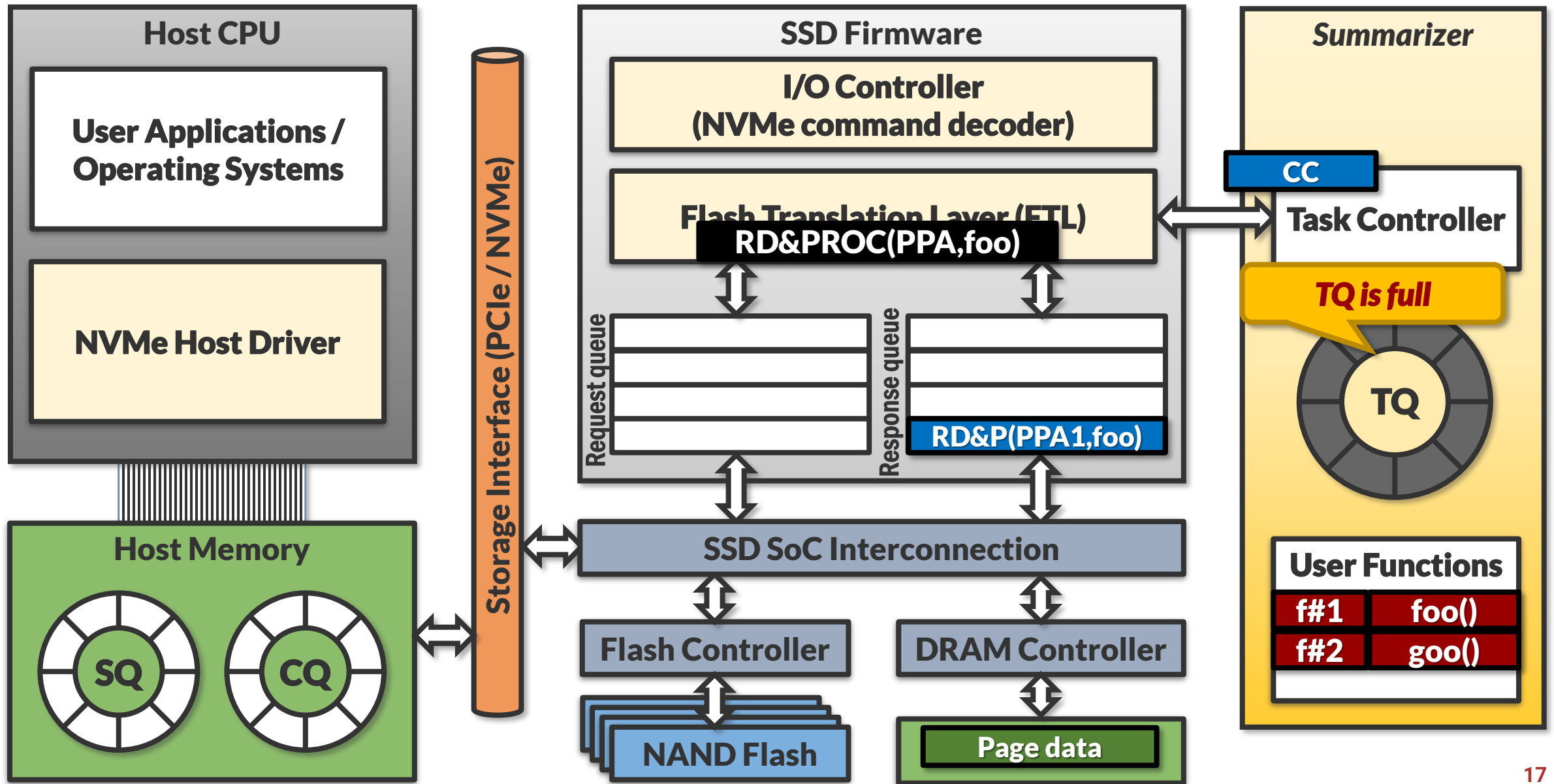
# Summarizer – Computation (Dynamic mode)



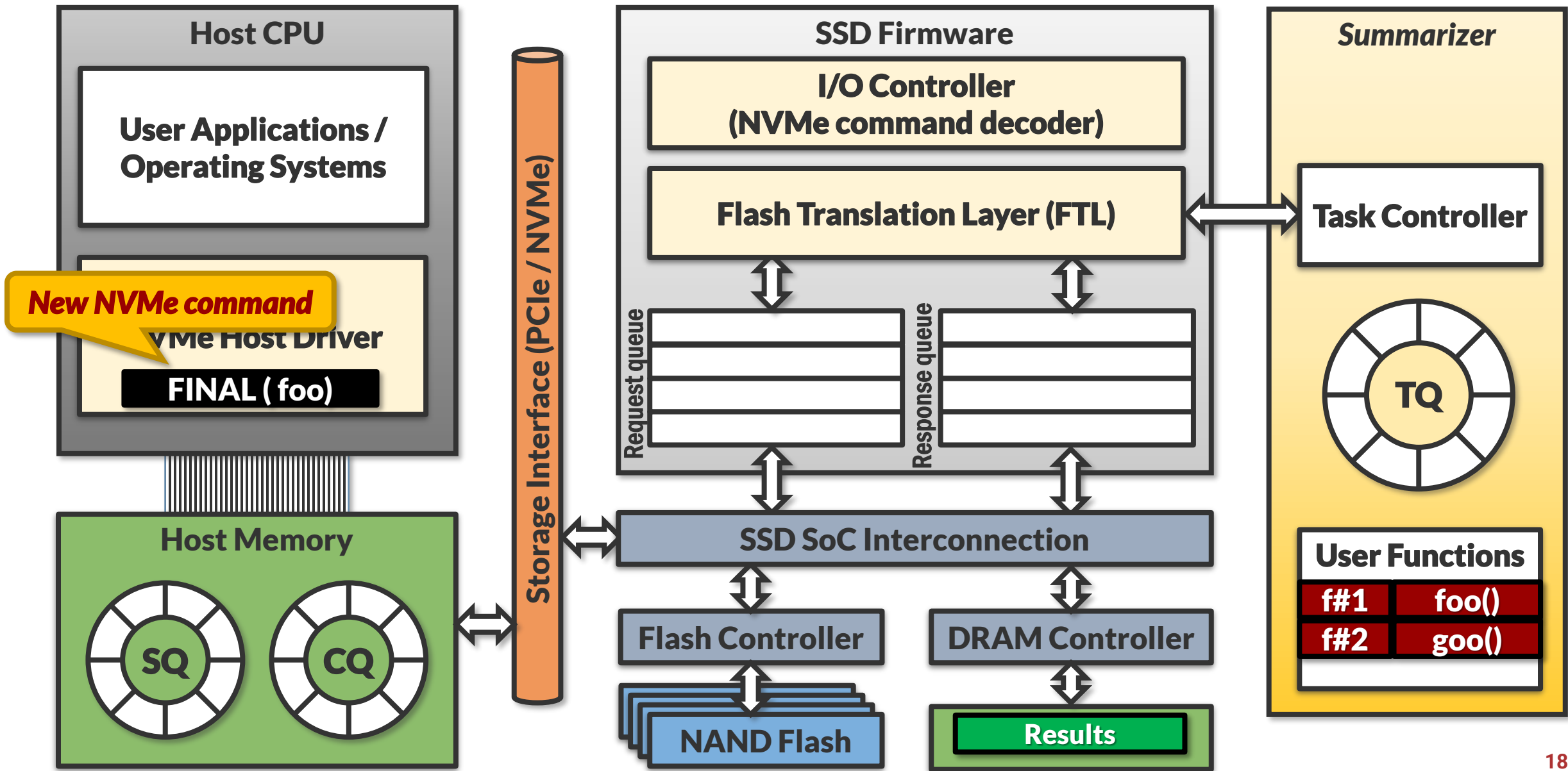
# Summarizer – Computation (Dynamic mode)



# Summarizer – Computation (Dynamic mode)

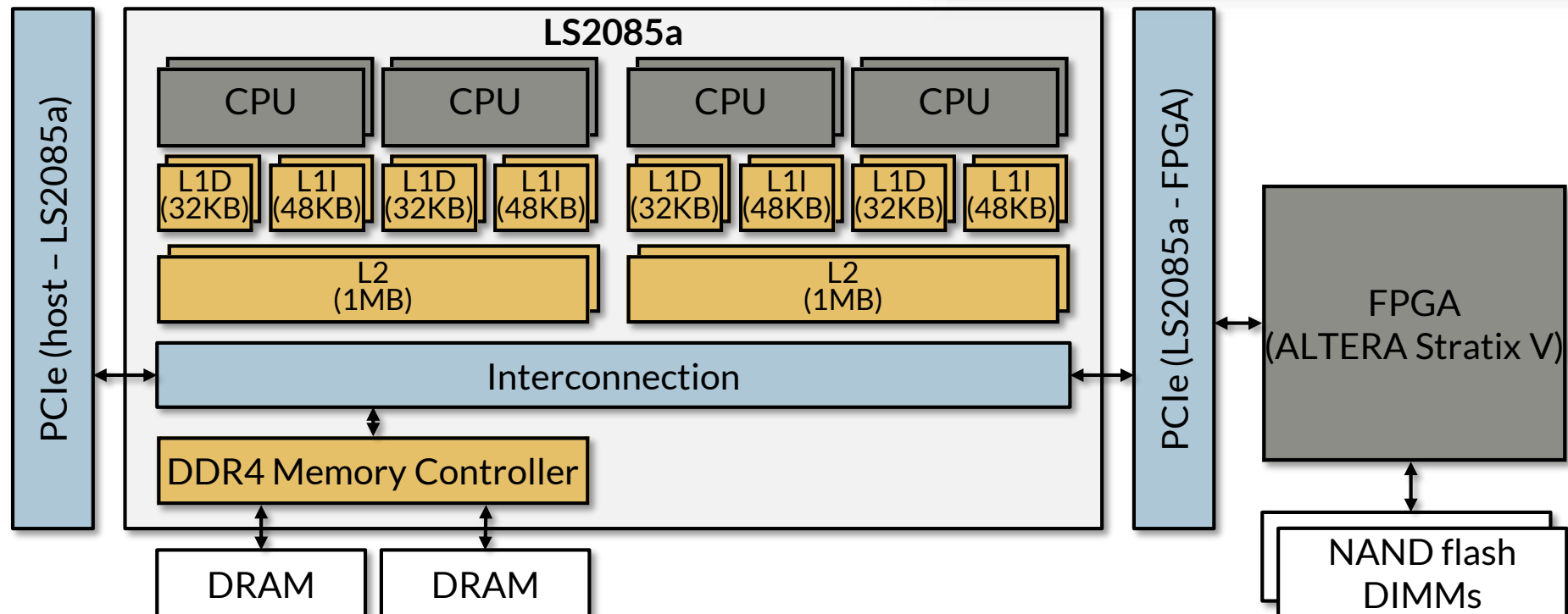


# Summarizer – Finalization



# Evaluation Platform

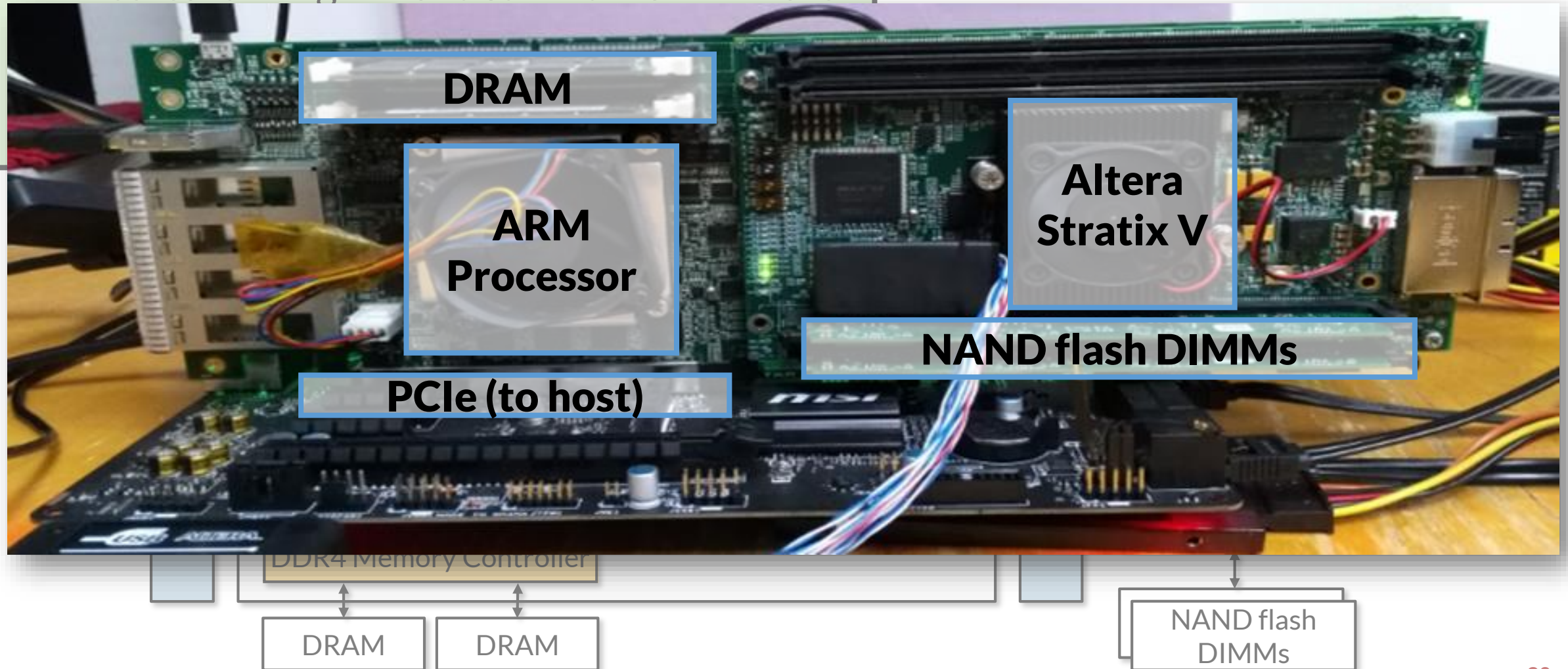
- LS2085a intelligent SSD development platform
- ARM cores running FTL and *Summarizer* firmware
- FPGA implementing NAND flash controller
- PCIe Gen. 3 4x lanes for host communication



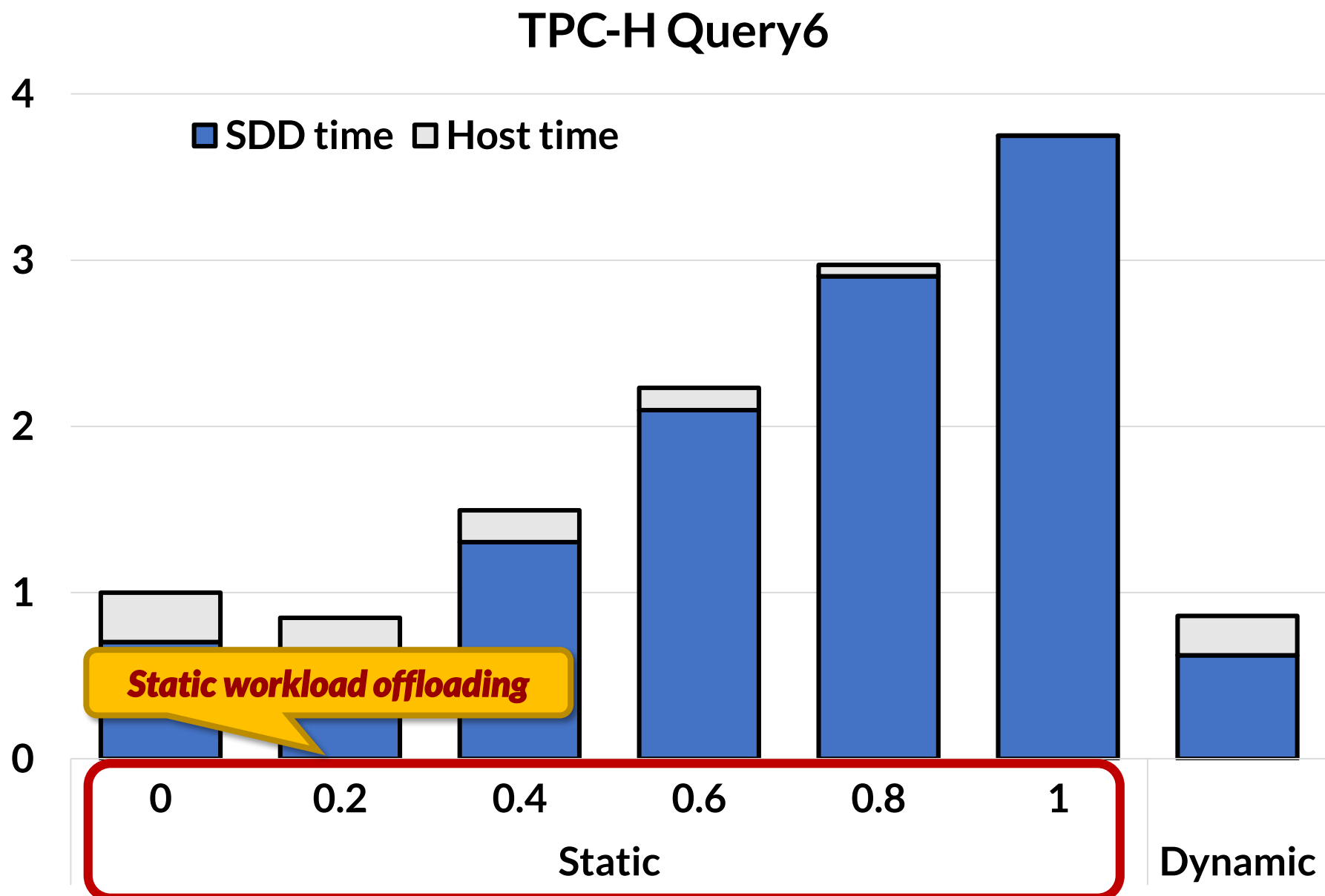


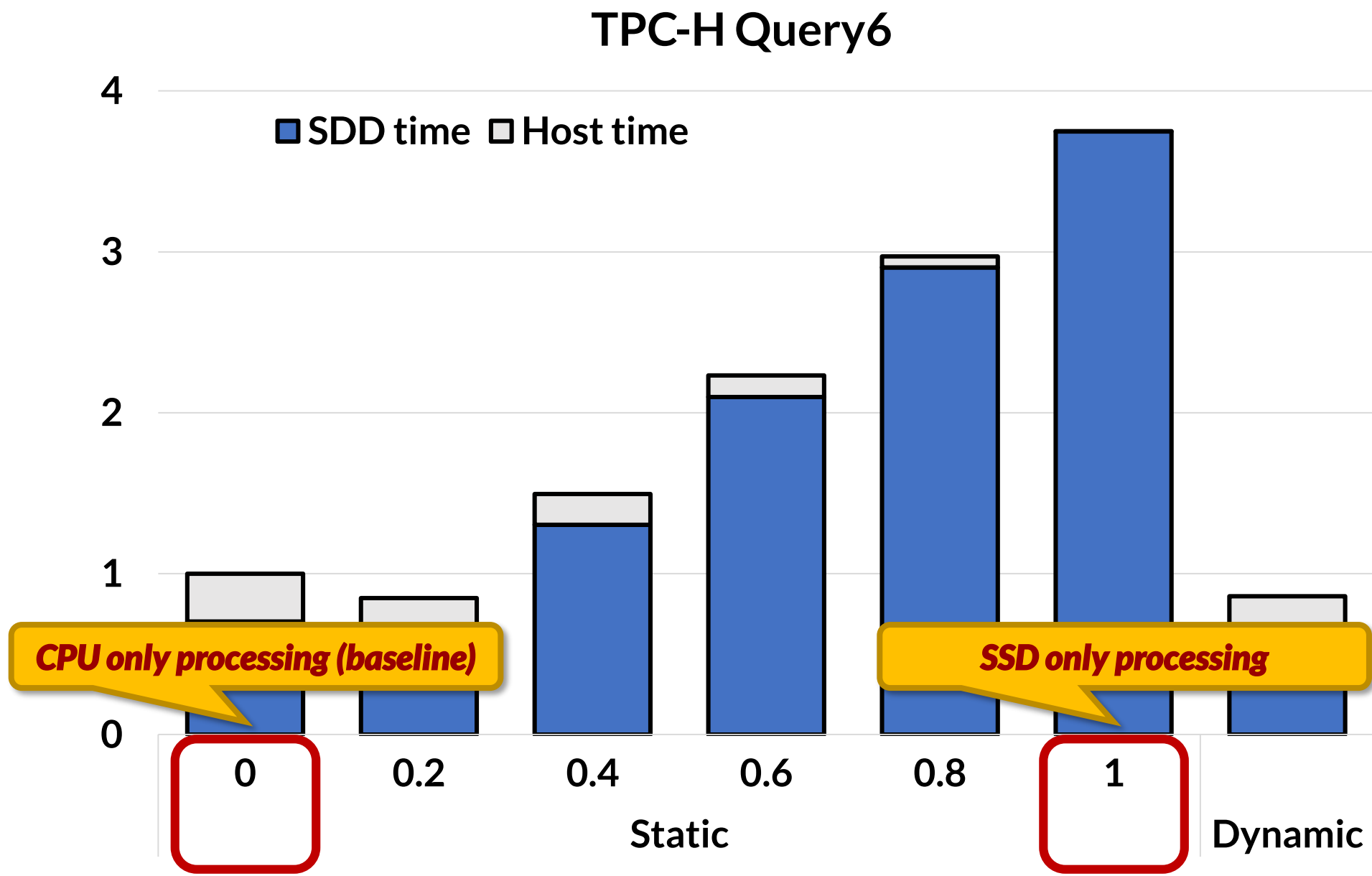
# Evaluation Platform

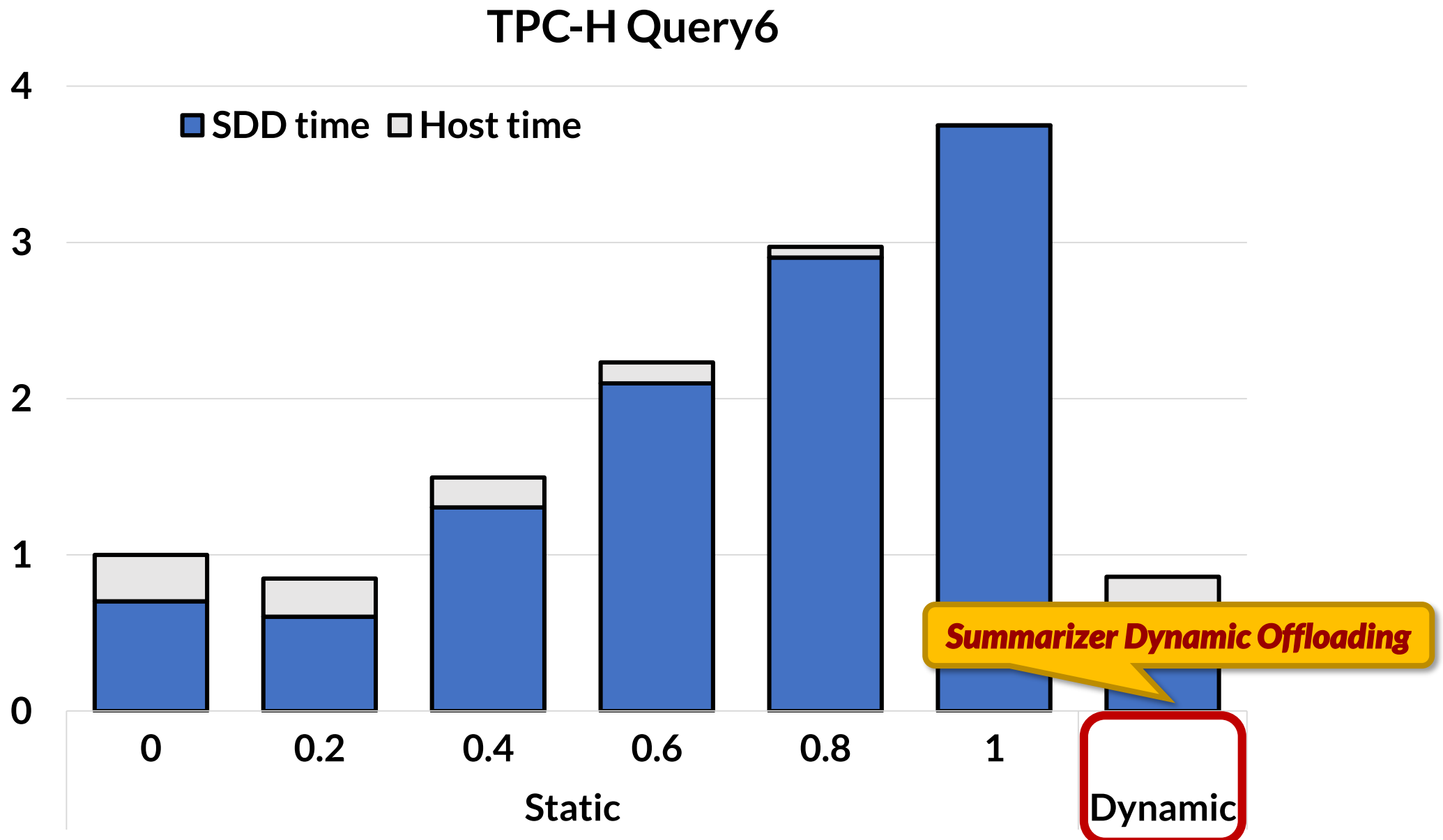
- LS2085a intelligent SSD development platform
- ARM cores running FTL and *Summarizer* firmware
- 
- 



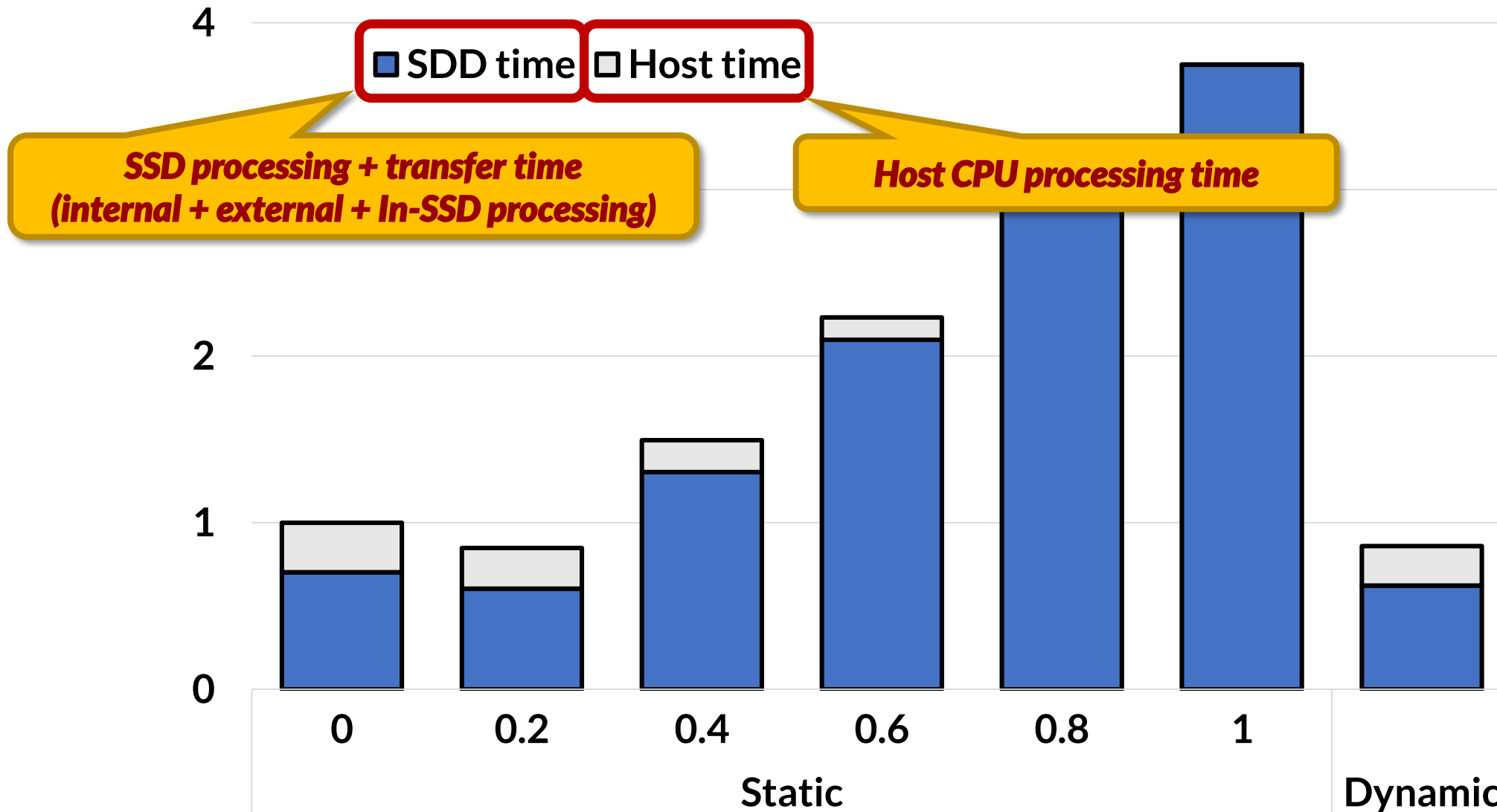


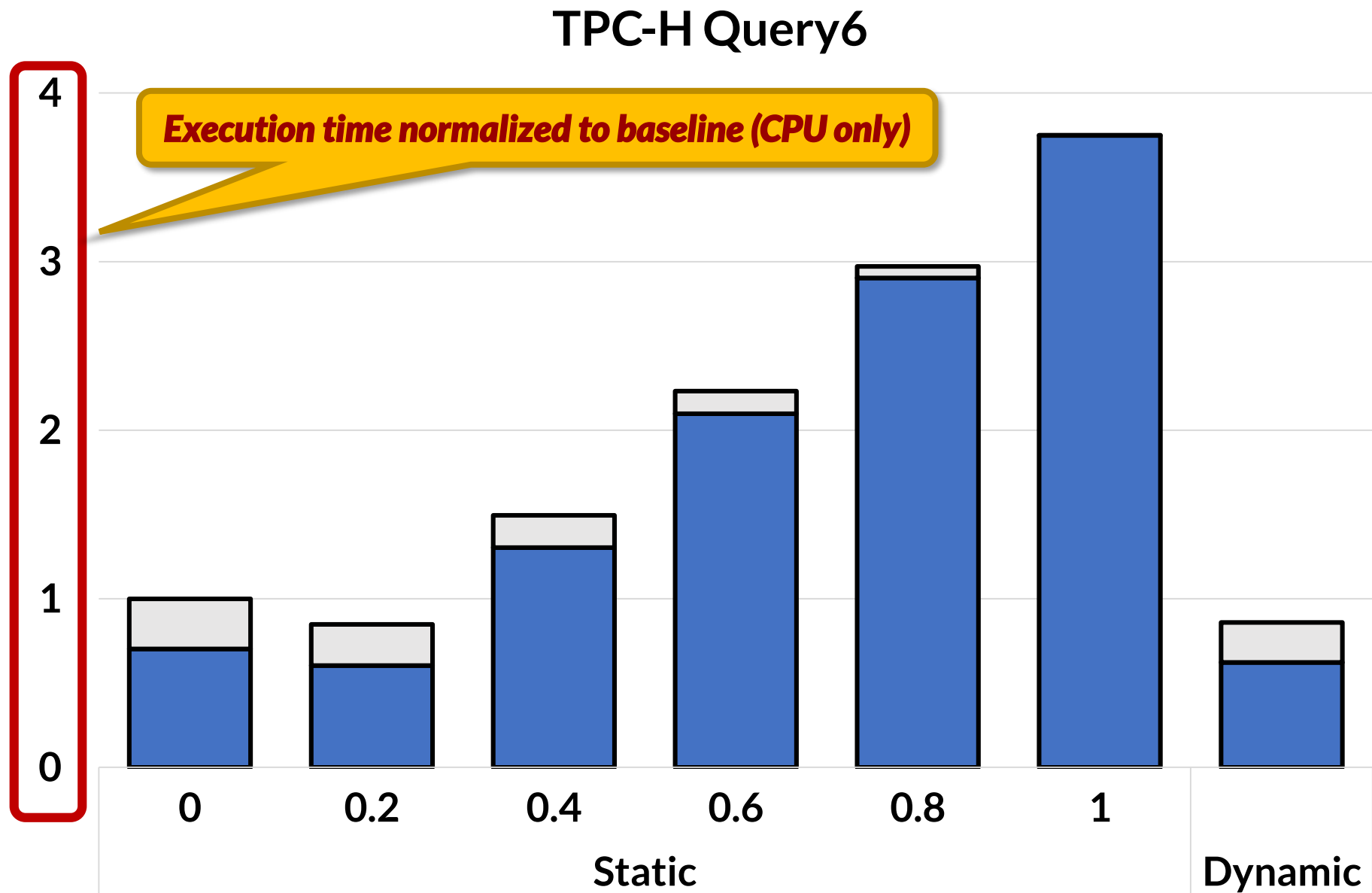


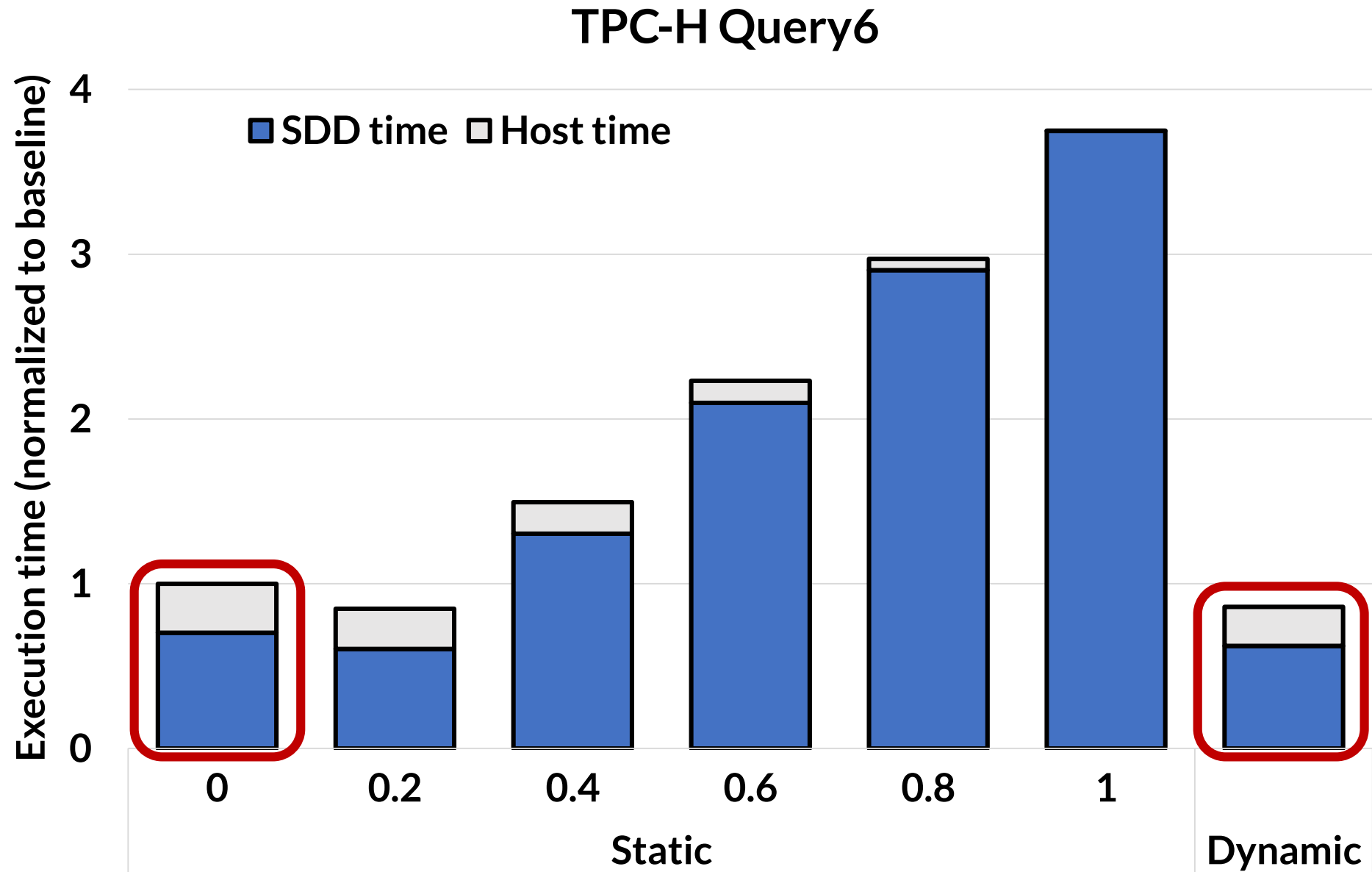




## TPC-H Query6

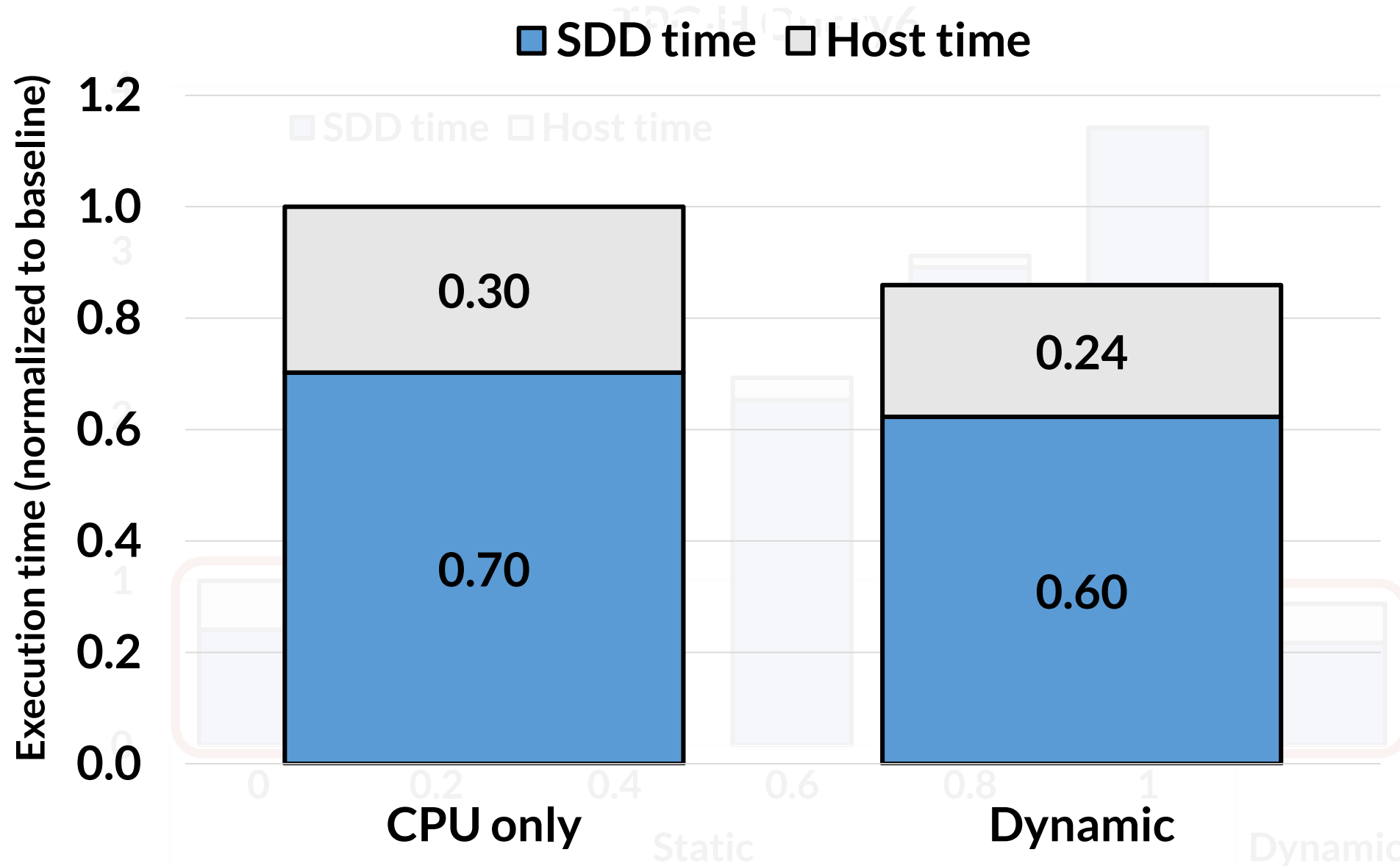




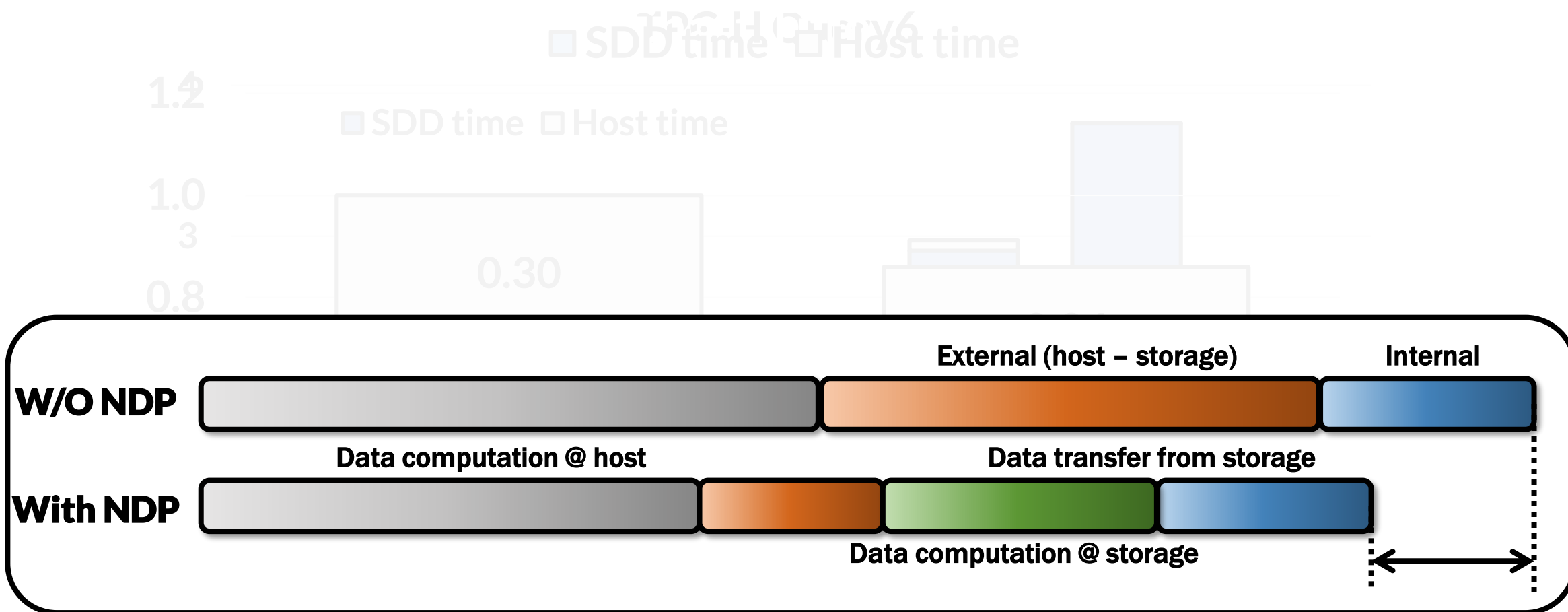


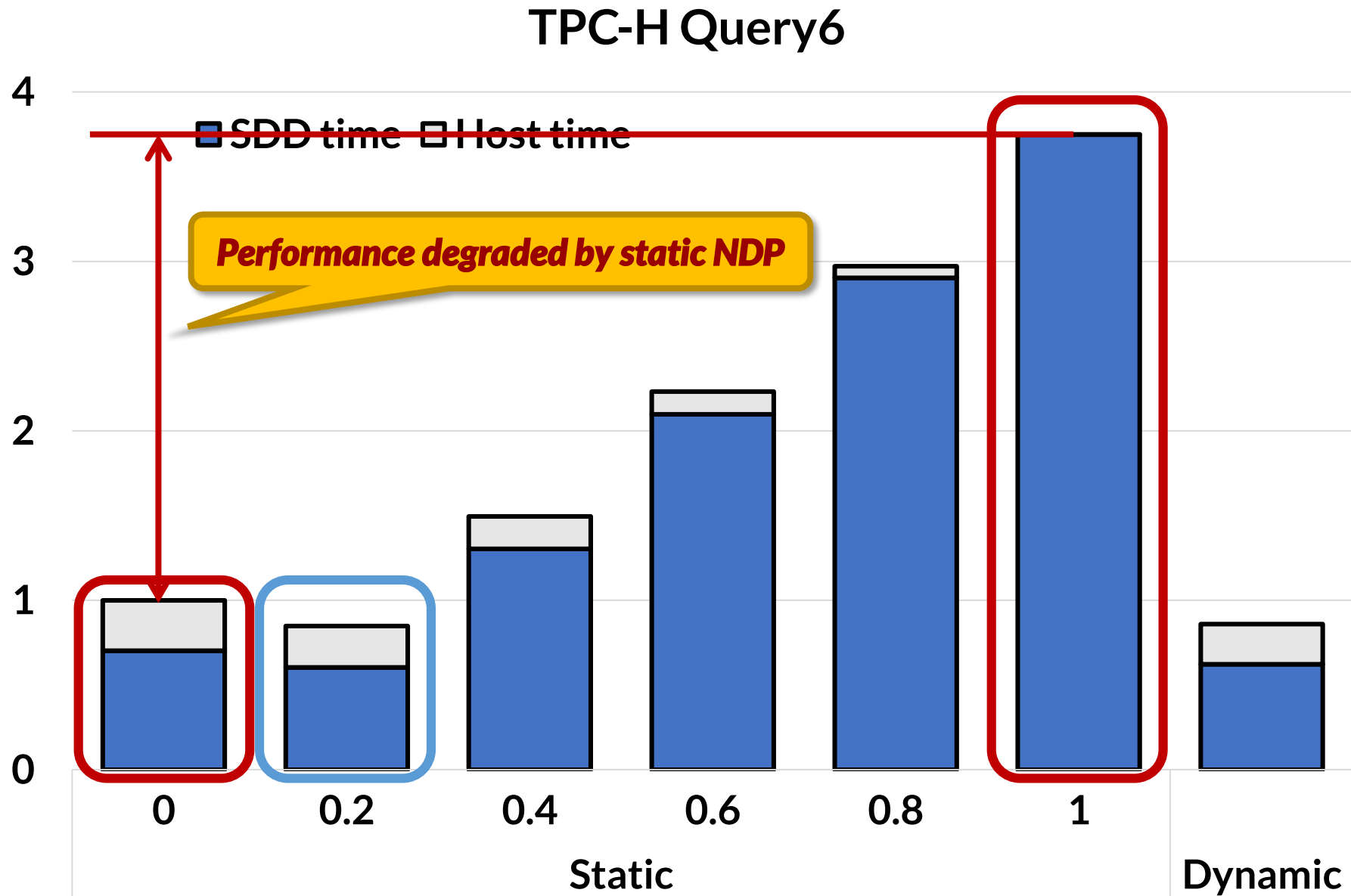


# Evaluation - Performance

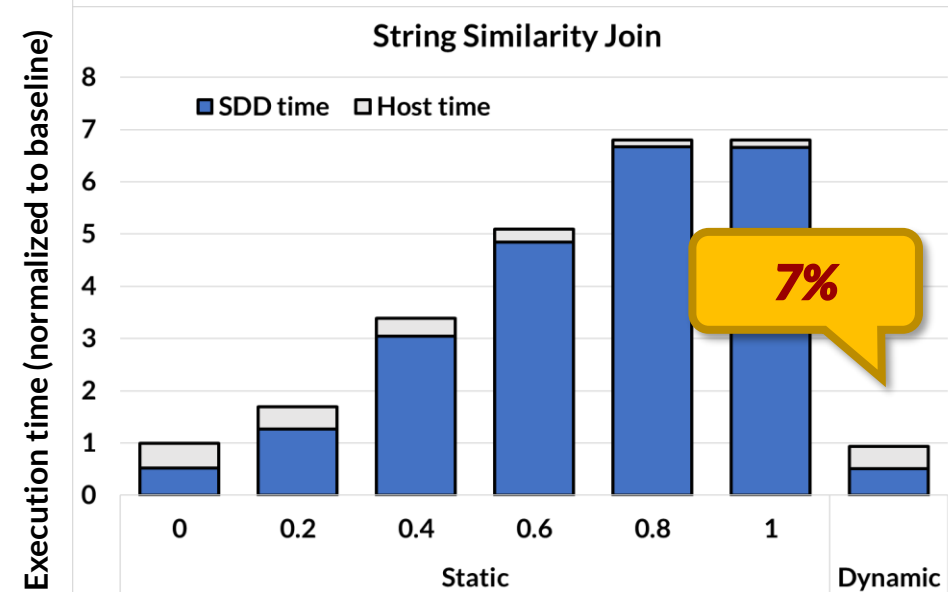
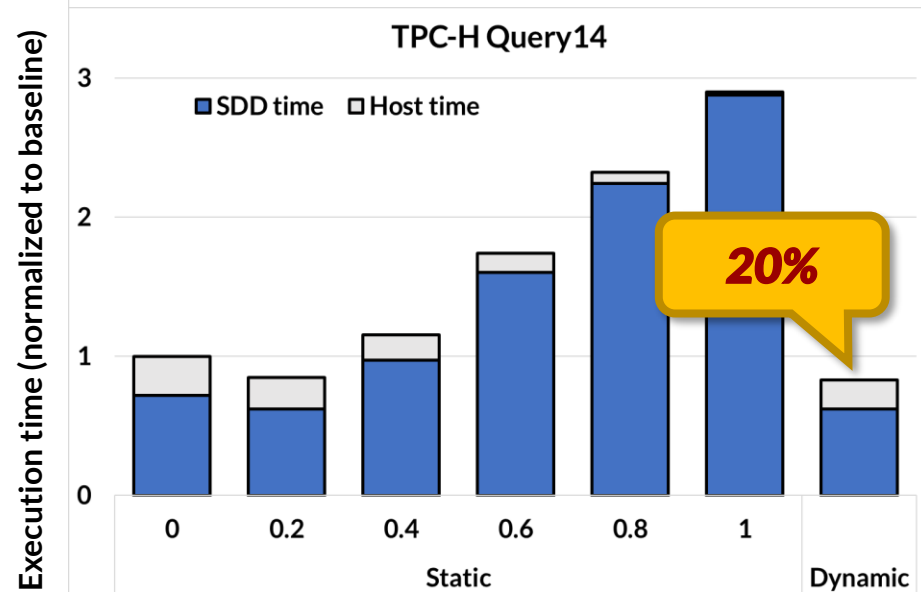
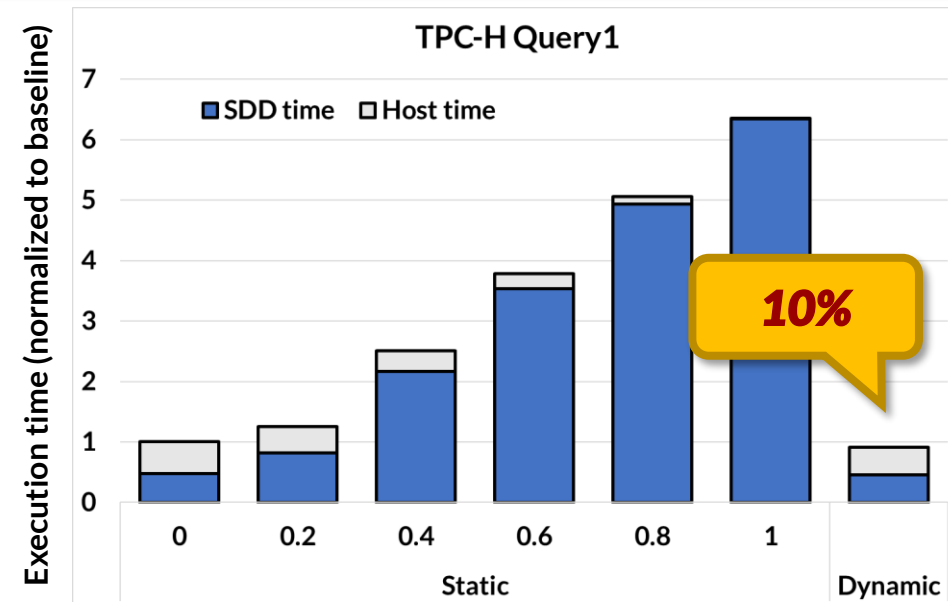
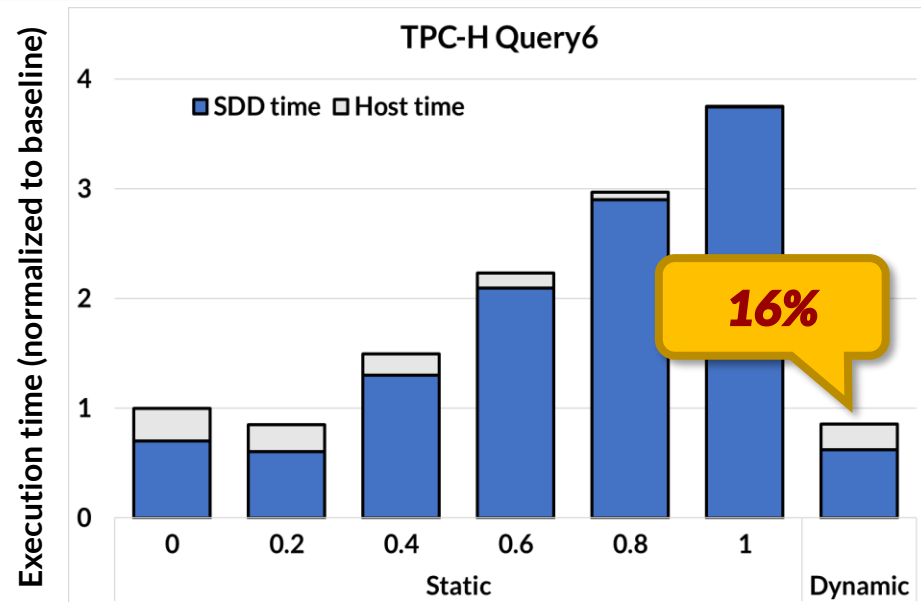


# Evaluation - Performance





# Evaluation - Performance

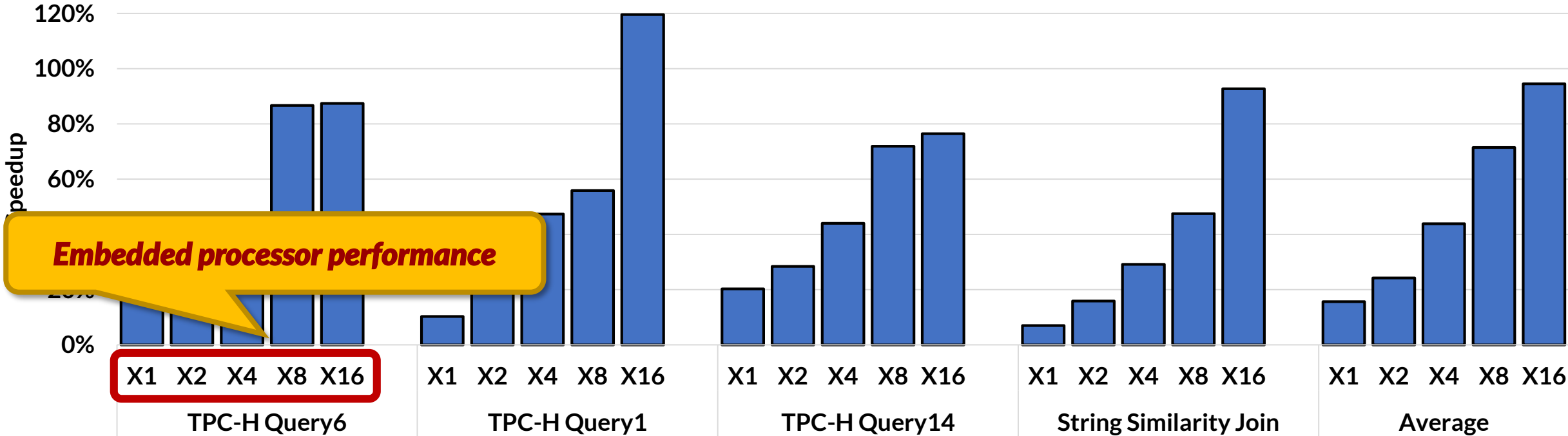


# Design Exploration – Better SSD Processor



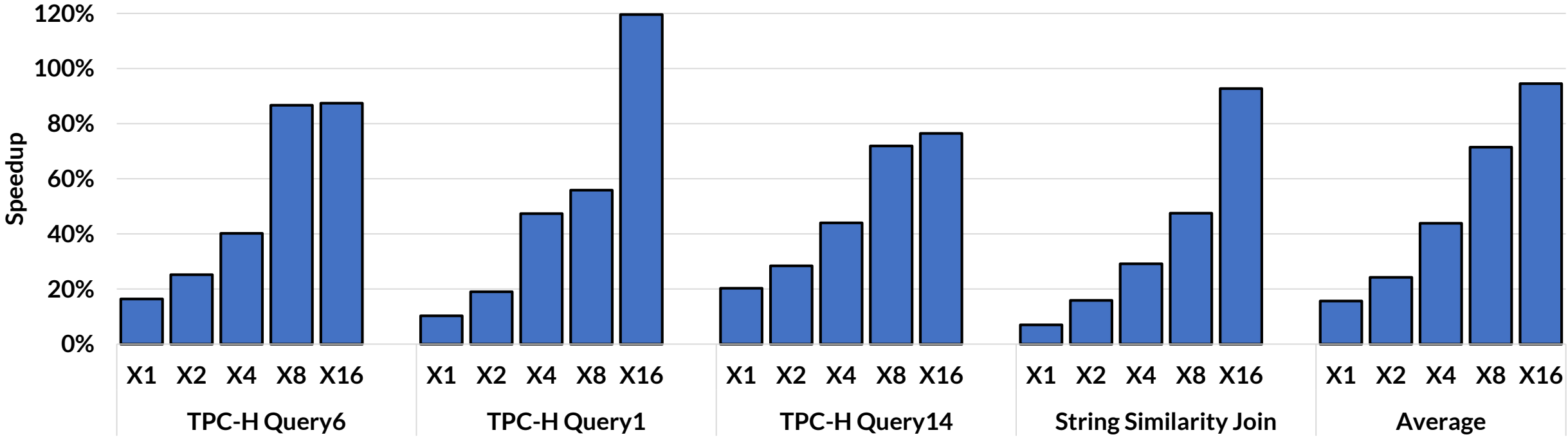
***Better embedded processor is cost effective***

# Design Exploration – Higher Internal Bandwidth





*Summarizer is a cost effective NDP solution with powerful storage processors*



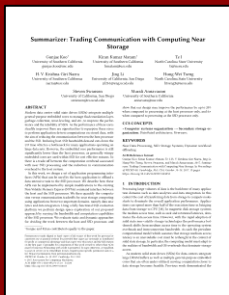
## ✓ ***Dynamic NDP framework for SSDs***

- Opportunistically enables in-SSD processing
- Page-level NDP control
- Automatic workload partitioning

## ✓ ***Summarizer programming model***

- Evaluation on the real development platform
- Explored design space for future SSDs

# Thank you



## Summarizer: Trading Communication with Computing Near Storage (MICRO '17)

(We thank to Dell EMC for supporting the SSD development board)