ISCA' 21

Don't Forget the I/O When Allocating Your LLC

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Shiv Bhushan Tripathi

CDOS Talk
04th July 2022

Resource Sharing in Cloud

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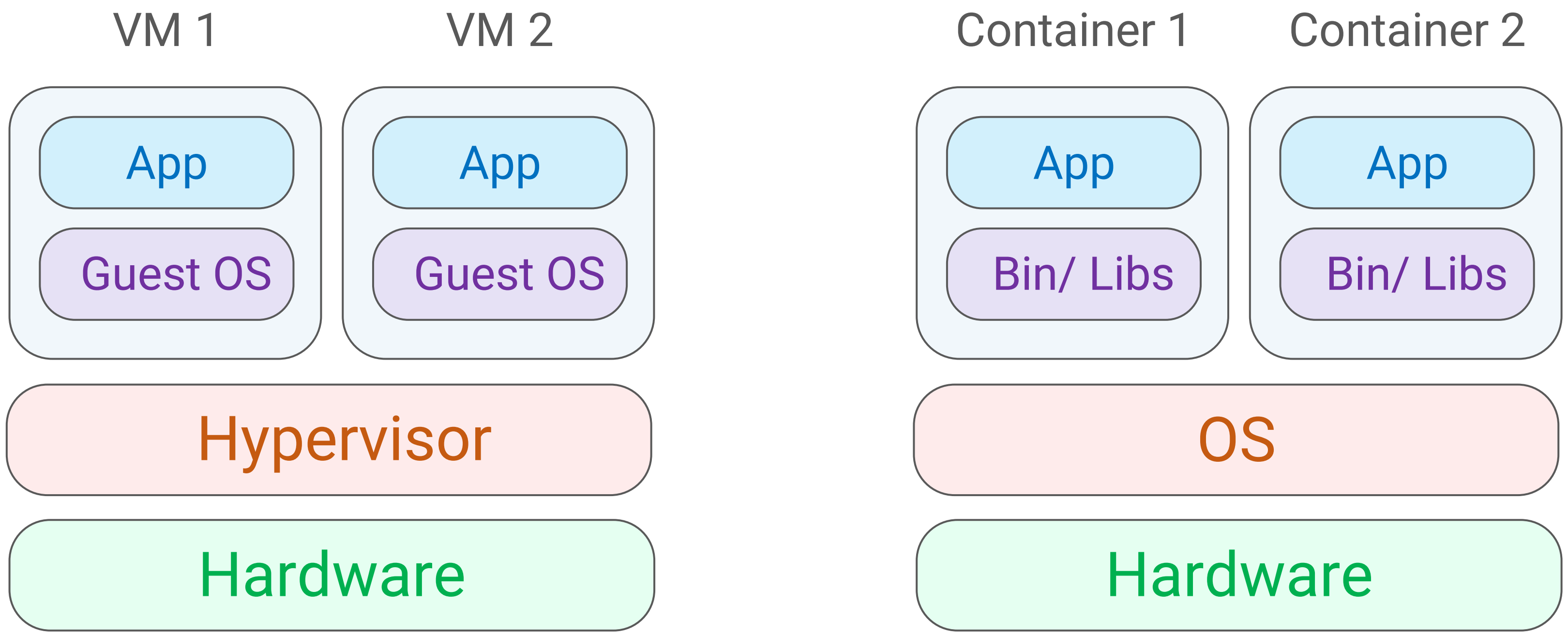


VM 1

VM 2

App

Guest OS

App

Guest OS

Hypervisor

Hardware

Container 1

Container 2

App

Bin/ Libs

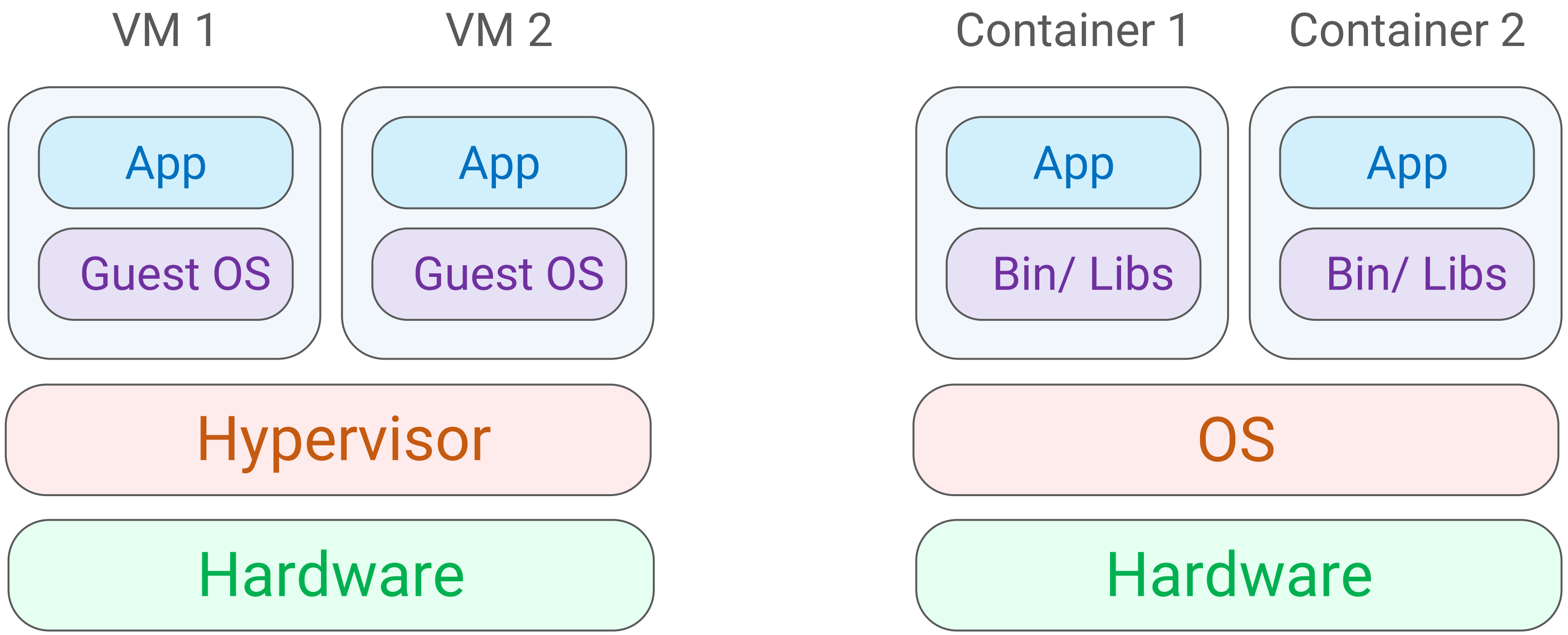
App

Bin/ Libs

OS

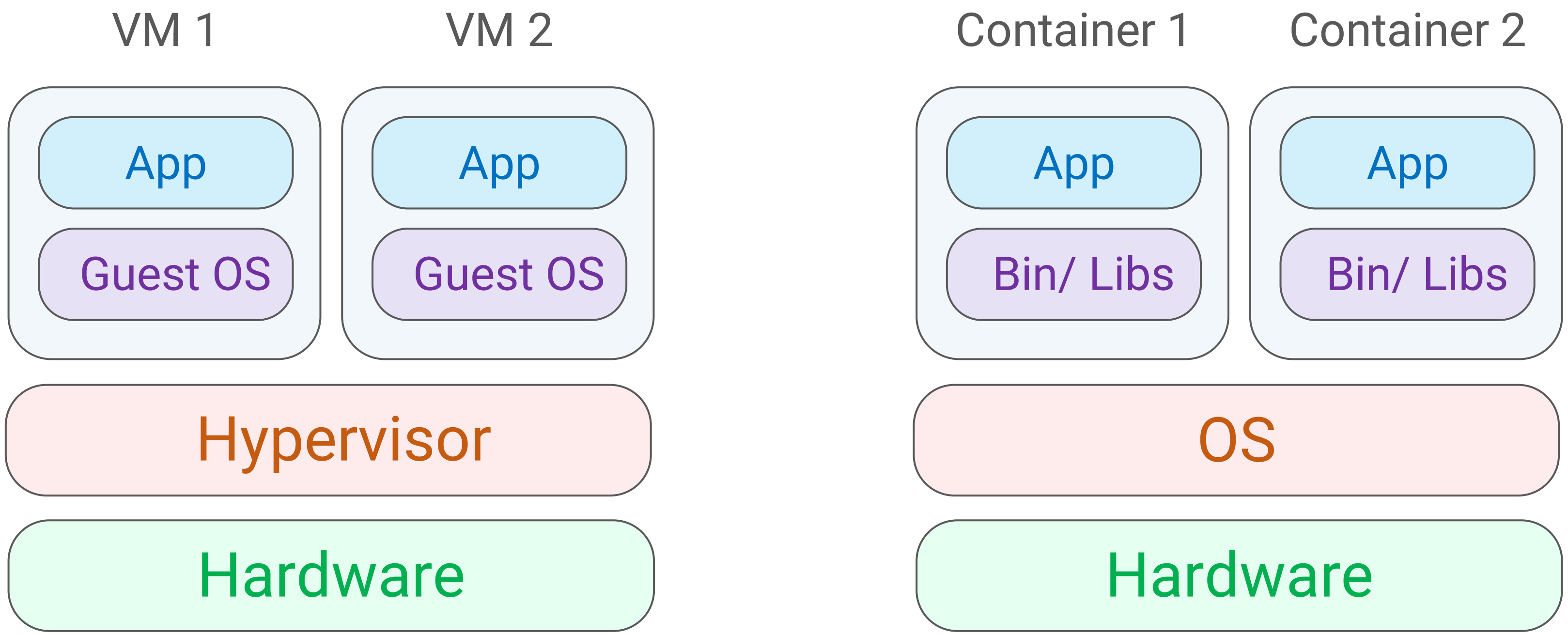
Hardware

Resource Sharing in Cloud



- Shared hardware resources for better utilization, e.g. Core, Memory, LLC, etc.

Resource Sharing in Cloud



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- Leads to interference: Causing performance degradations for tenants

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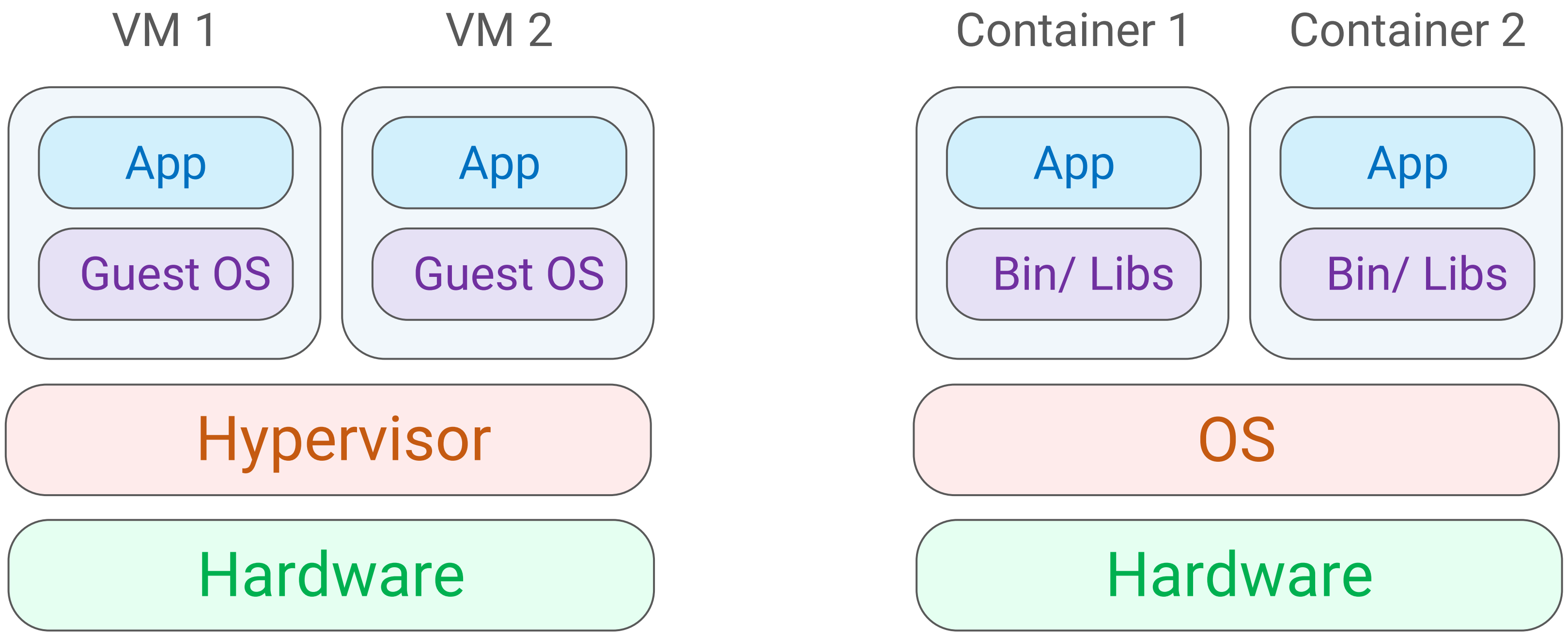

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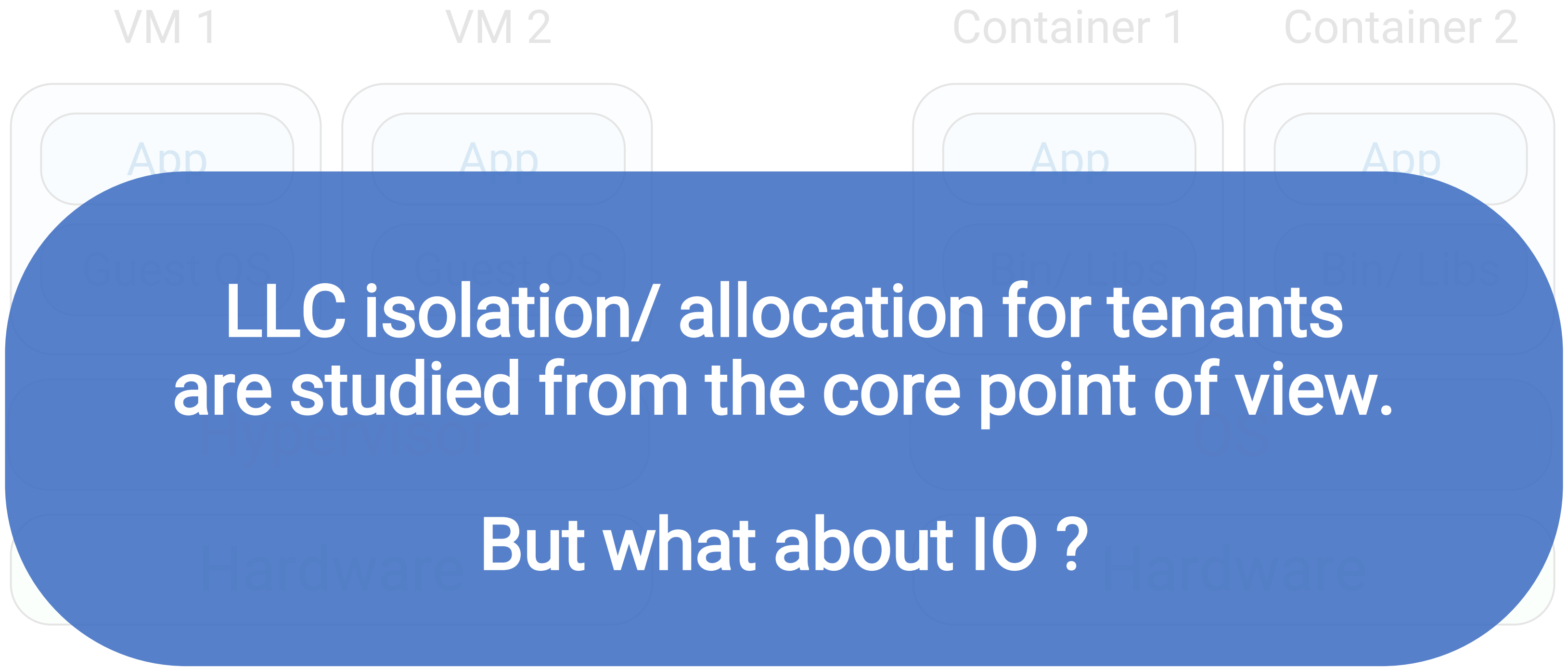
- Need to allocate and isolate for different tenants: the focus is LLC

Resource Sharing in Cloud



LLC isolation/ allocation for tenants are studied from the core point of view.

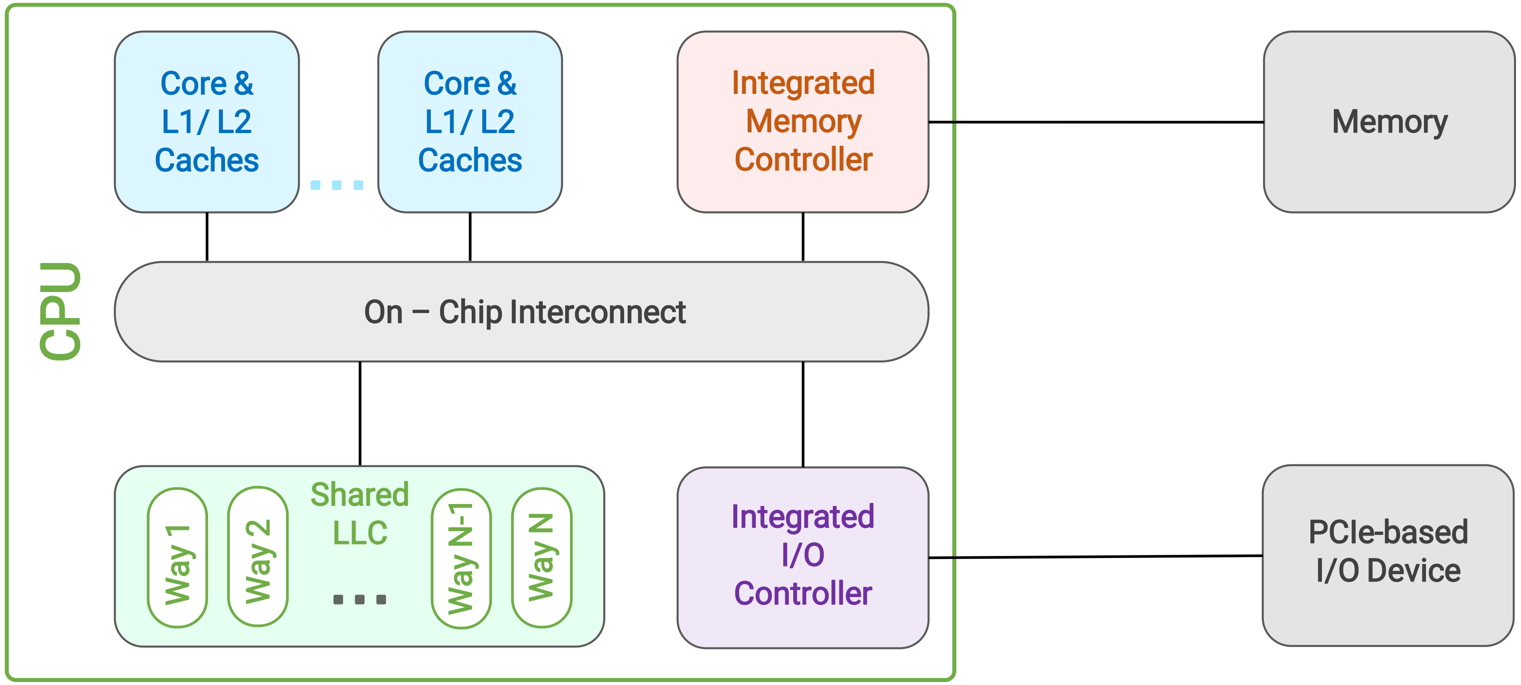
But what about IO ?

- Shared hardware resources for better utilization, e.g. Core, Memory, LLC, etc.
- Leads to interference: Causing performance degradations for tenants
- Need to allocate and isolate for different tenants: the focus is LLC

LLC Management and IO

04-July-2022

LLC Management and IO



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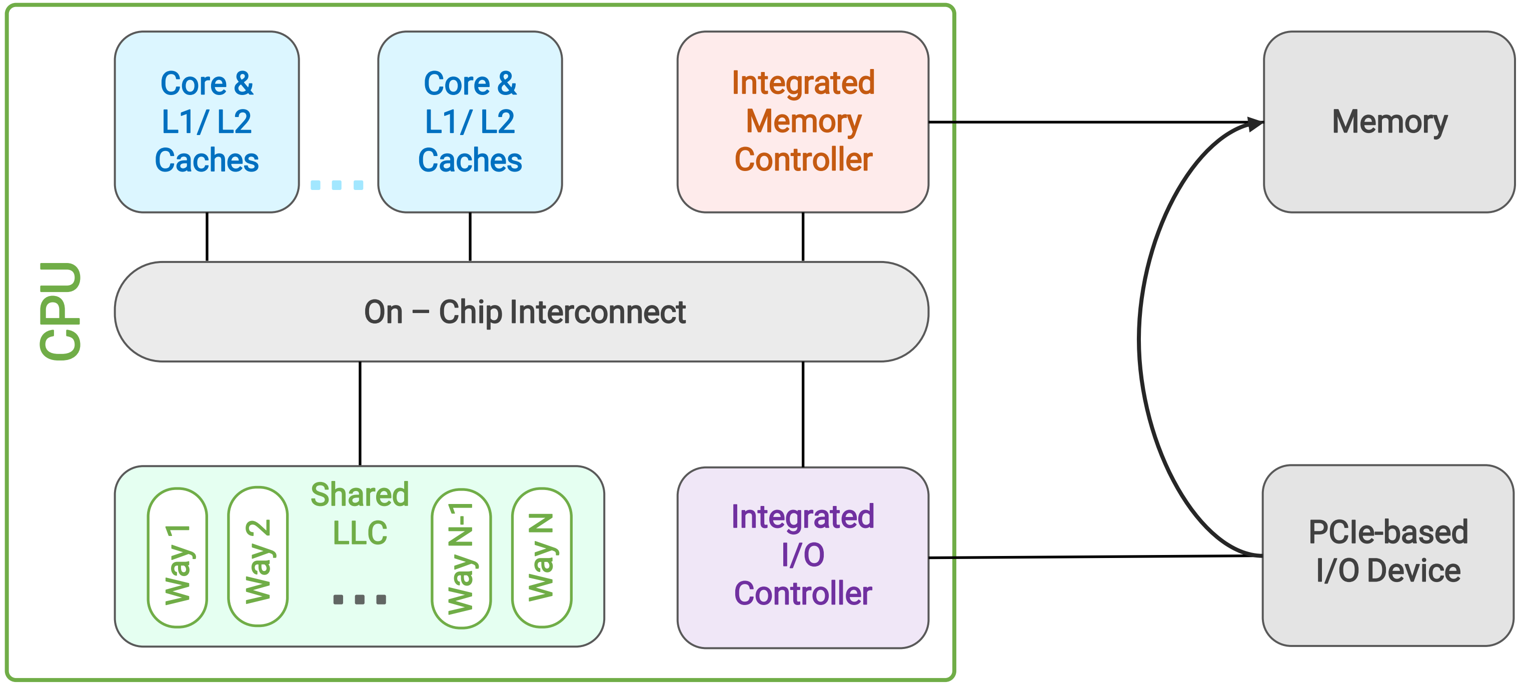
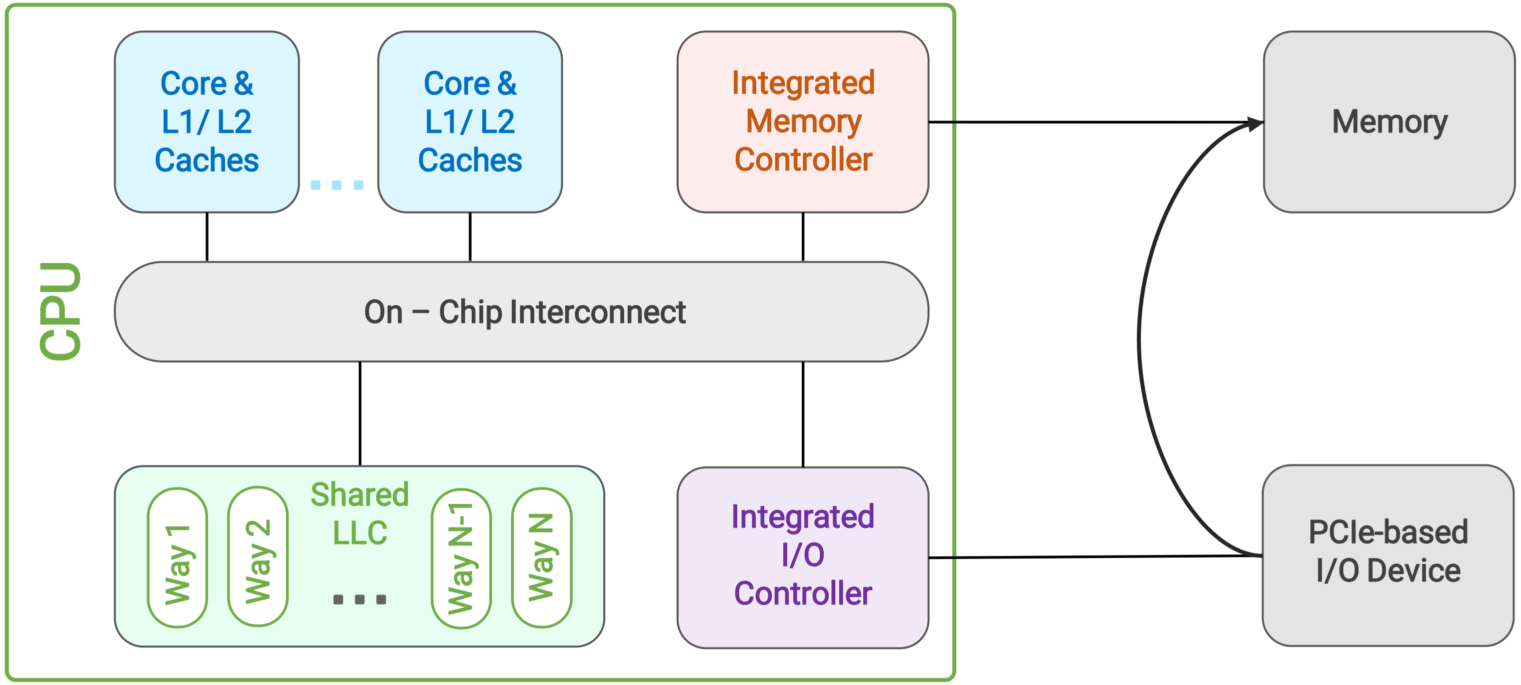
LLC Management and IO



- Memory involvement for IO (DMA)

LLC Management and IO



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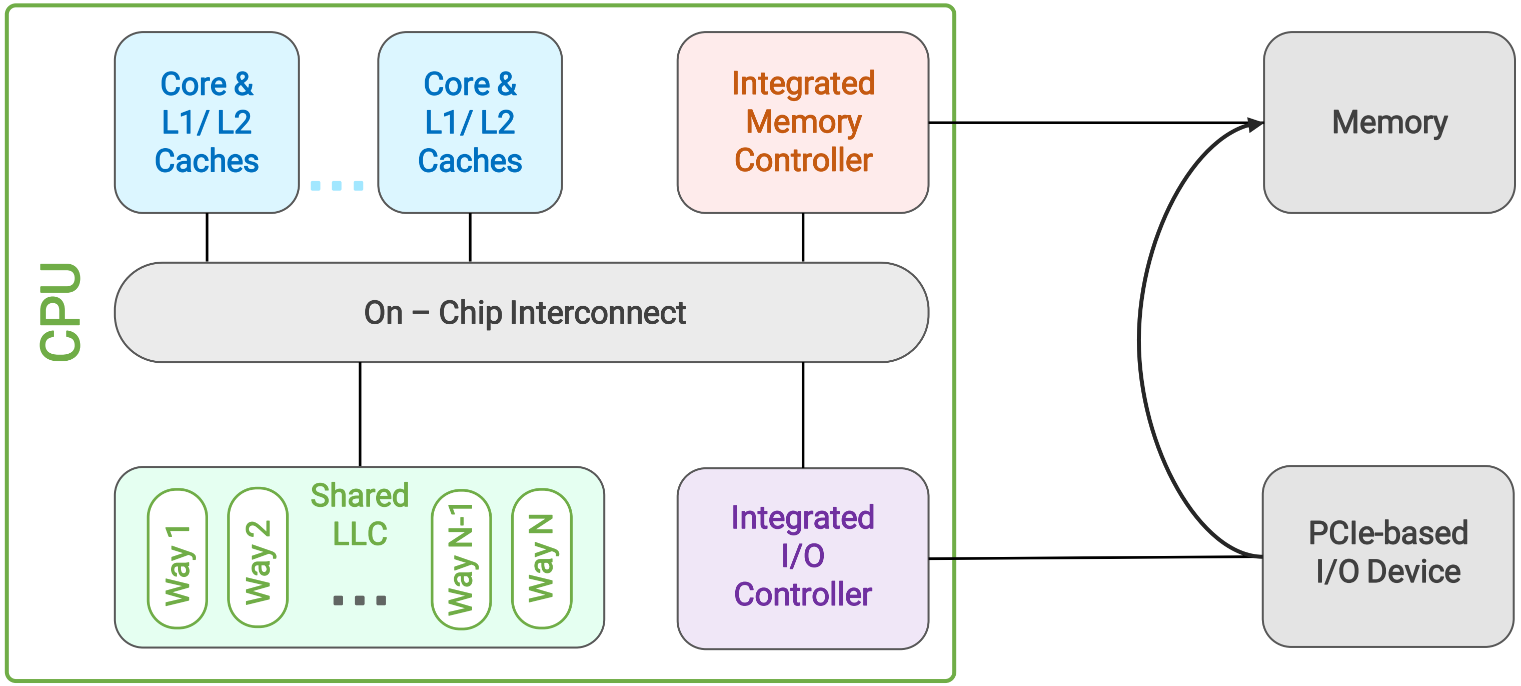

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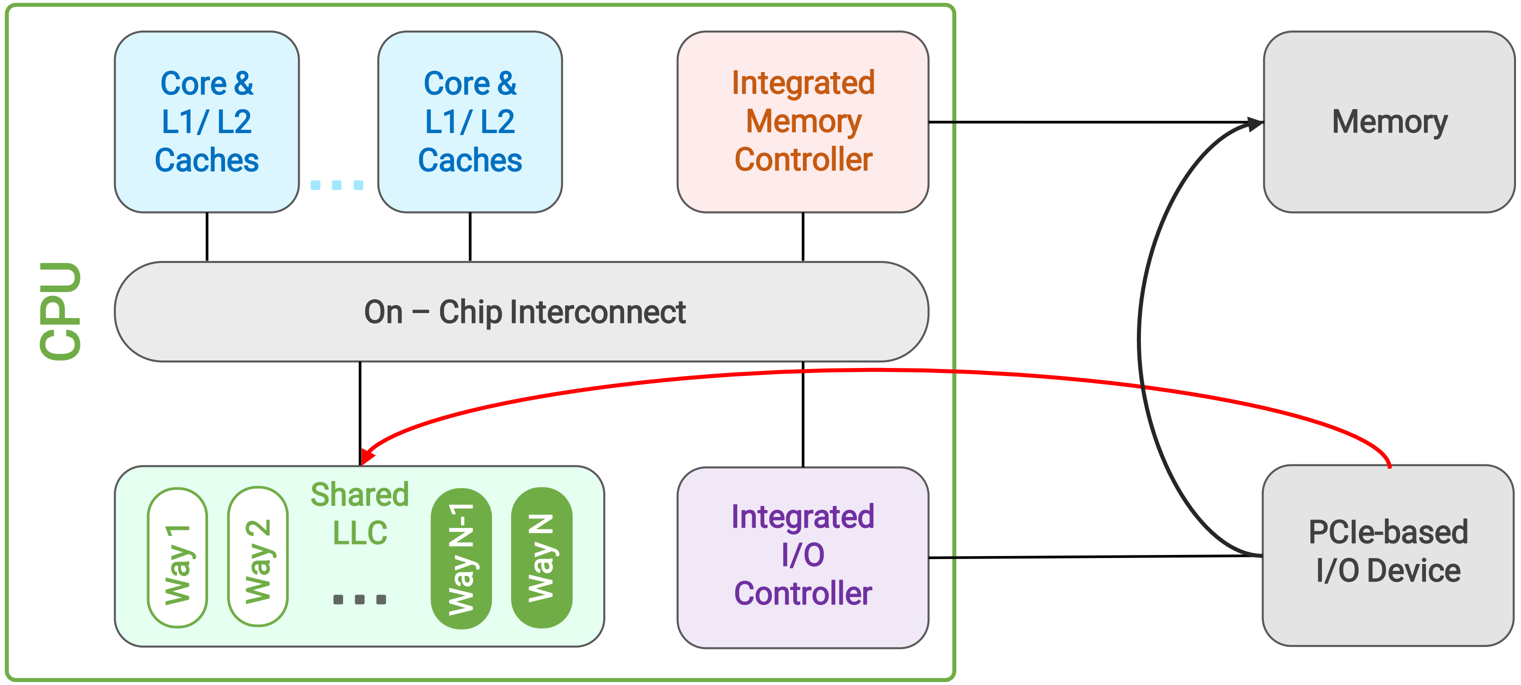
LLC Management and IO



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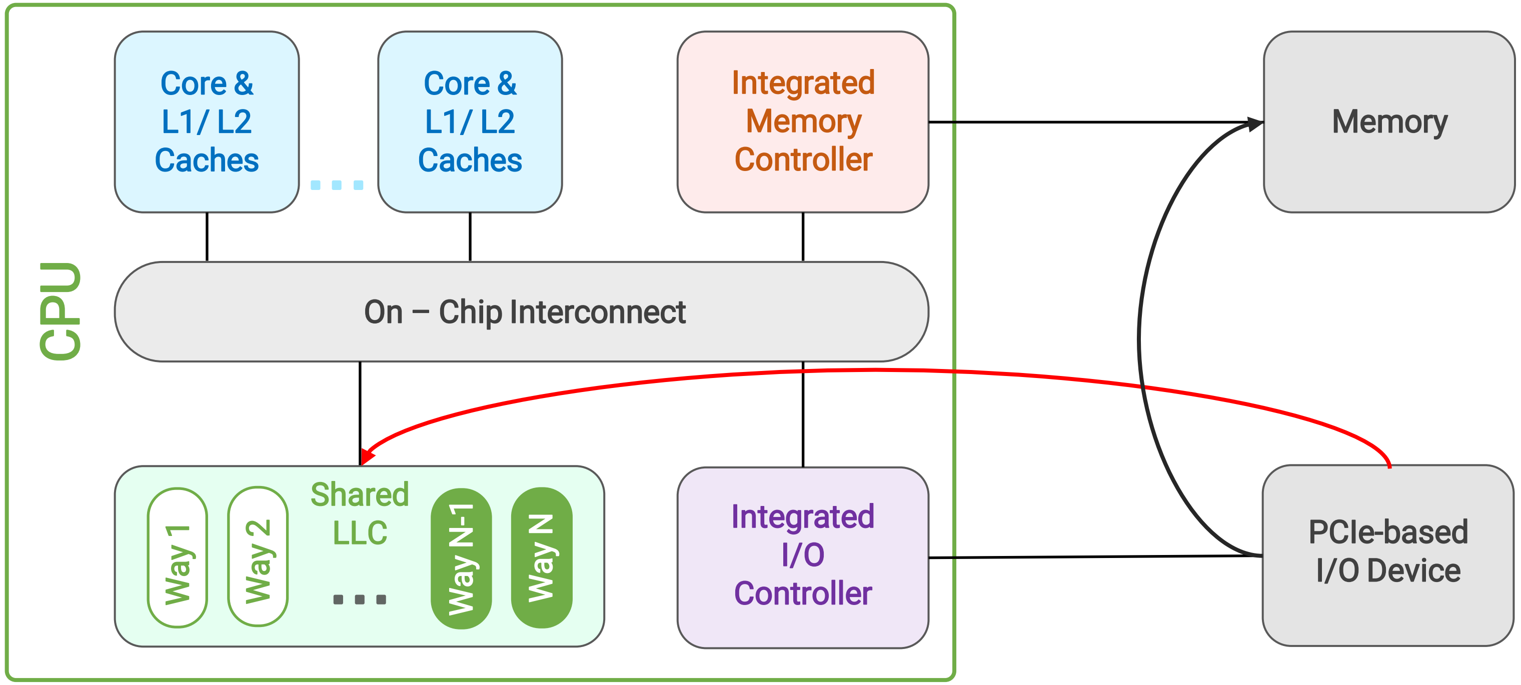
- DDIO (2 LLCs ways)

LLC Management and IO



- Memory involvement for IO (DMA)
- Problems: High Speed Devices (NIC, SSDs), Poor memory bandwidth utilization
- DDIO (2 LLCs ways): introduces new challenges

Challenge 1: Leaky DMA

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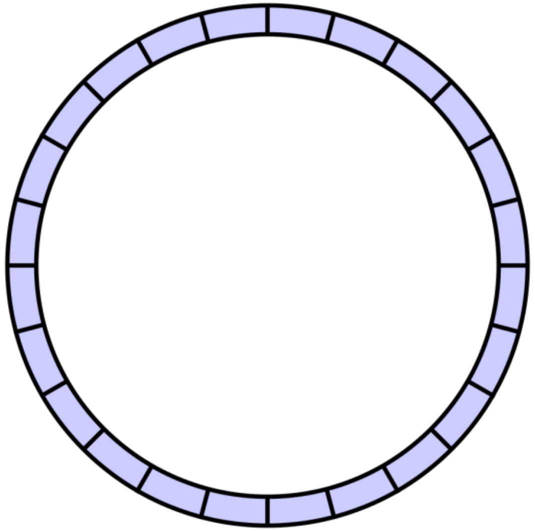
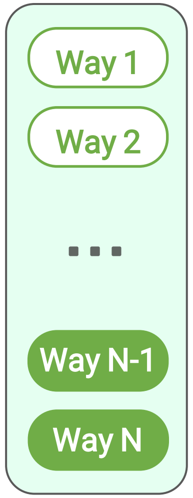
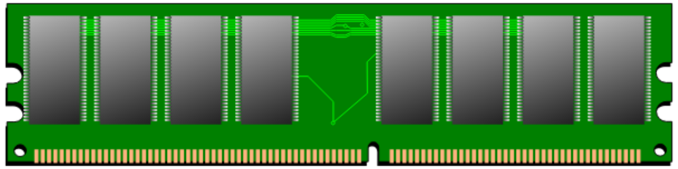


Rx Ring Buffer

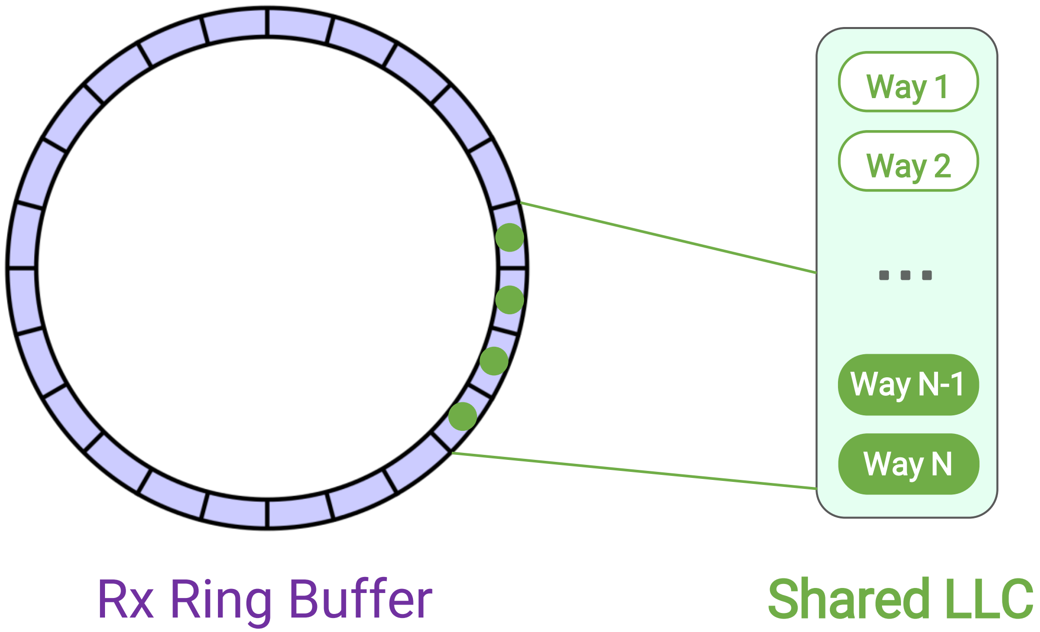


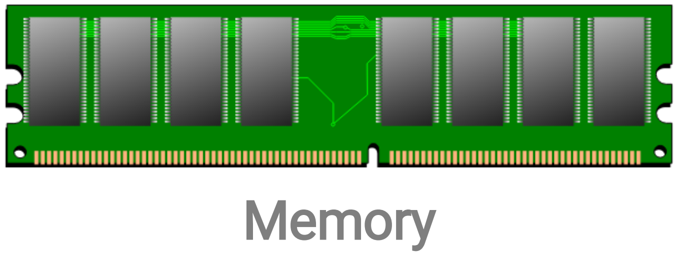
Shared LLC



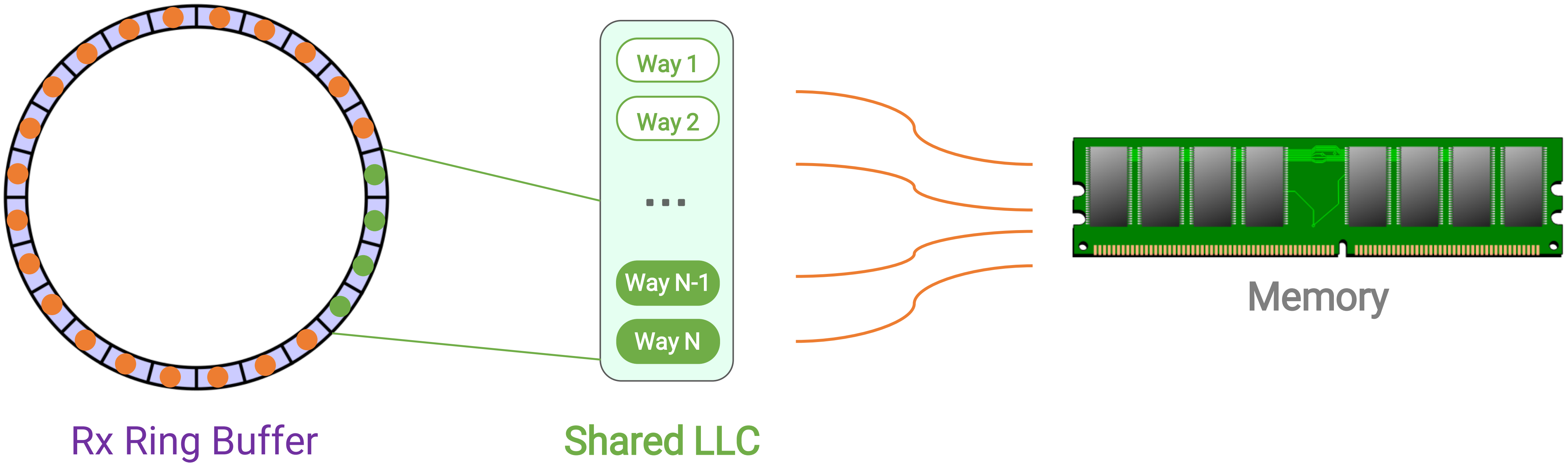
Memory

Challenge 1: Leaky DMA





Challenge 1: Leaky DMA



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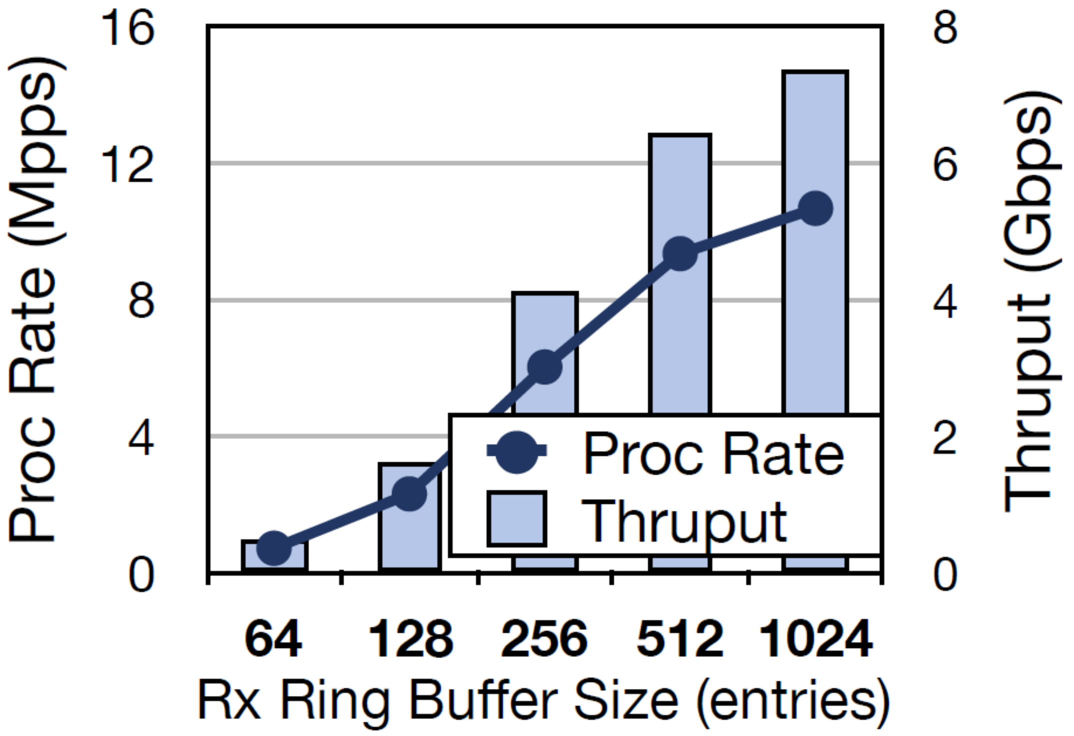

(a) 64B small packet.

Challenge 1: Leaky DMA

- ResQ proposes to reduce Rx buffer size:
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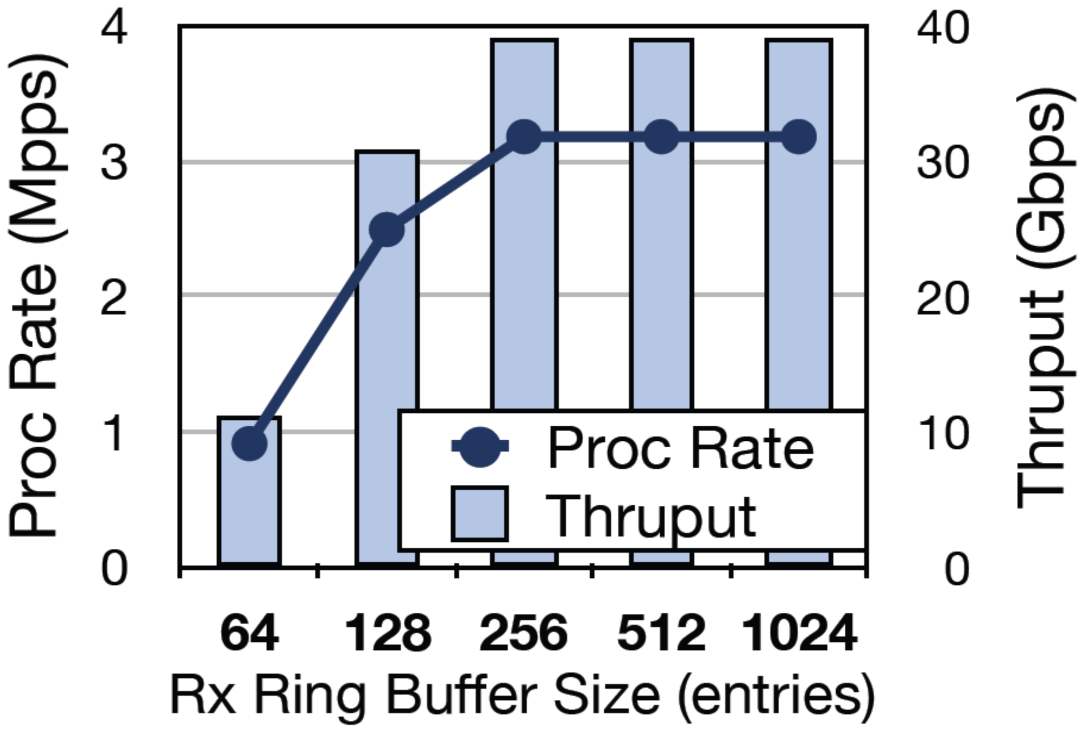
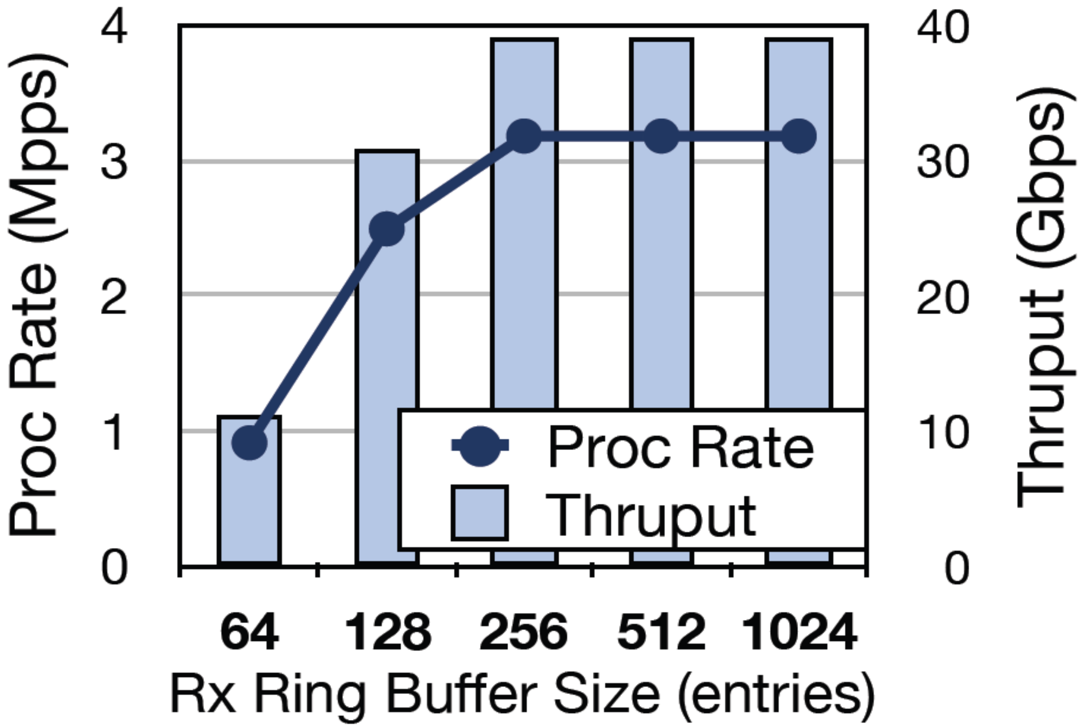
  - Throughput drop



(b) 1.5KB large packet.

Challenge 1: Leaky DMA

- ResQ proposes to reduce Rx buffer size:
    - Very less buffer size for multiple tenants
    - Throughput drop
- **How to adaptively change DDIO ways ?**



(b) 1.5KB large packet.

Challenge 2: Latent Contender

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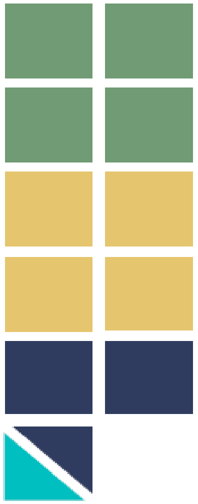
- Overlapping of DDIO ways with Core affect performance



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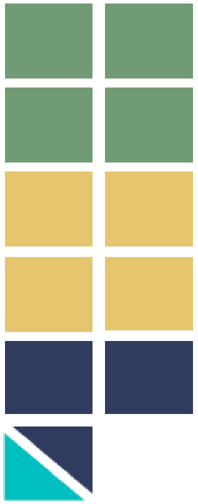
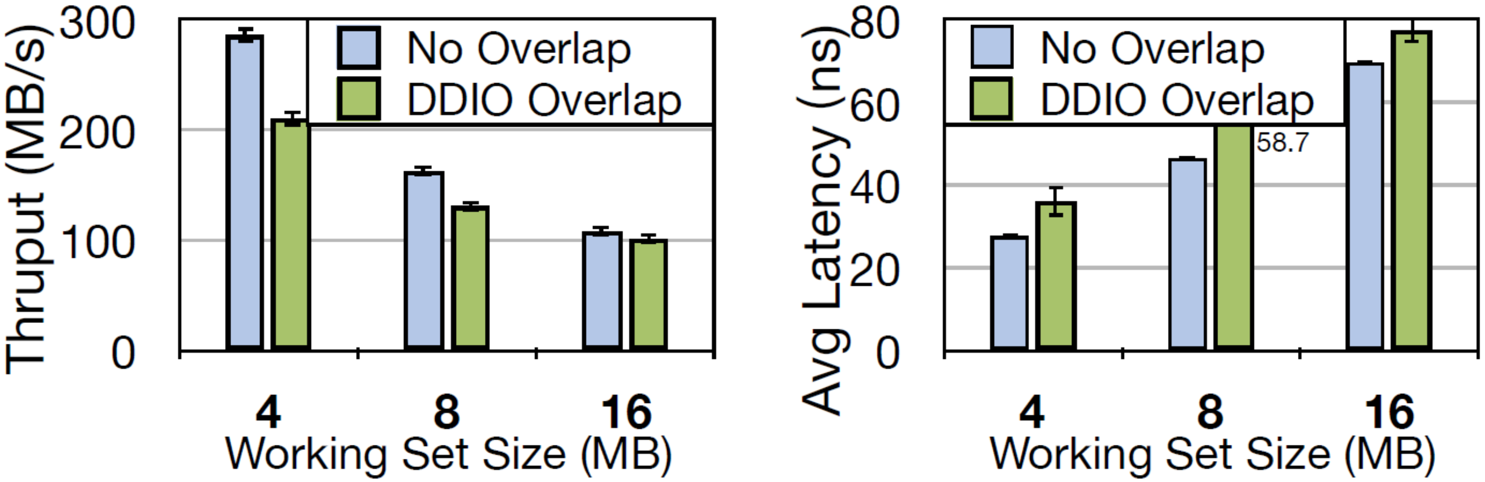




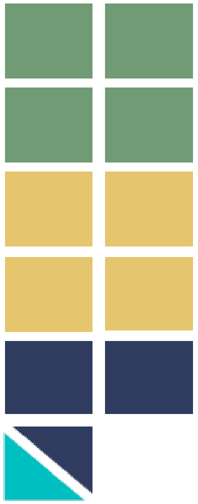
(a) Throughput.

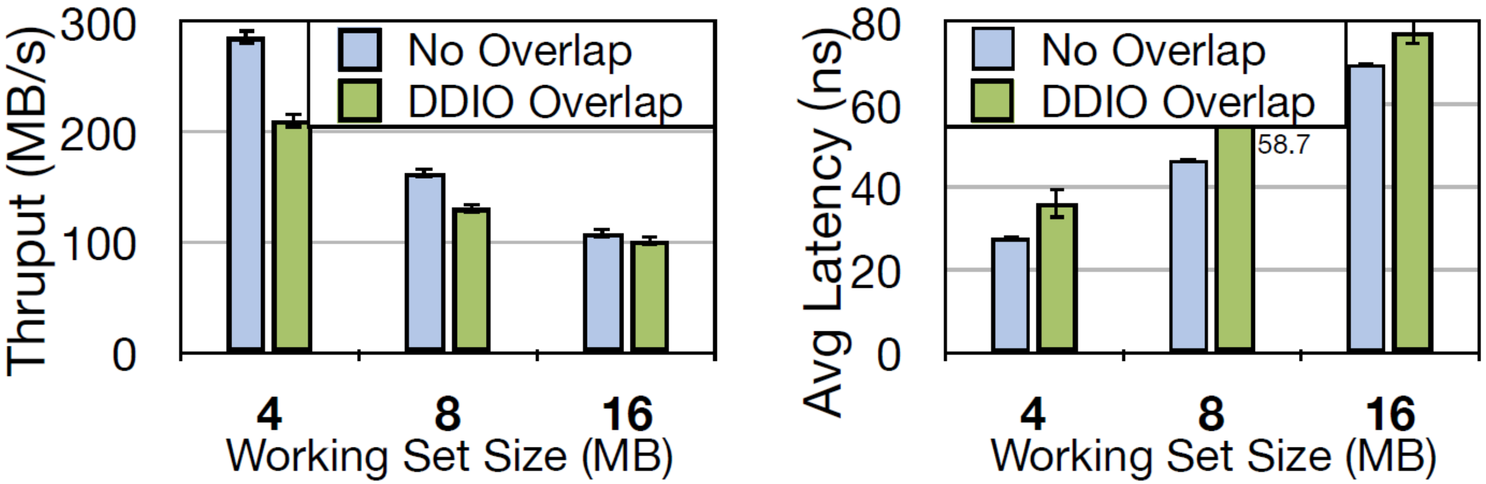
(b) Latency.

- DDIO overlap worsen the X-Mem's (random read pattern) throughput and avg latency

Challenge 2: Latent Contender

- Overlapping of DDIO ways with Core affect performance

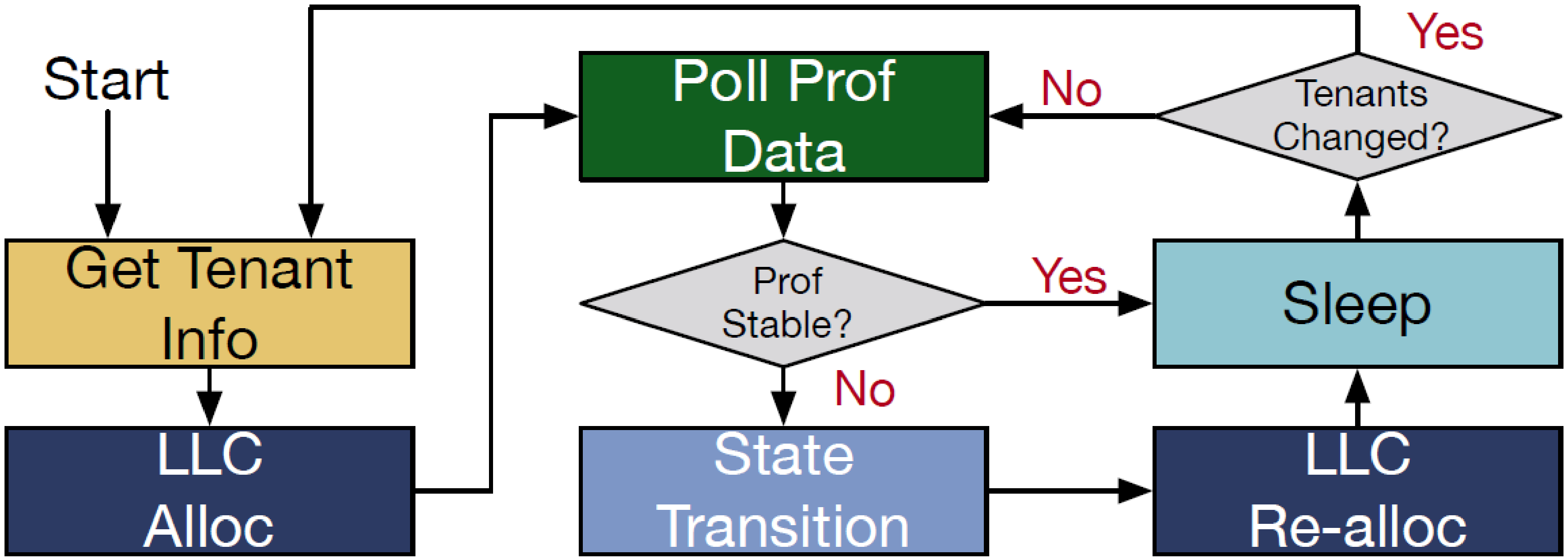




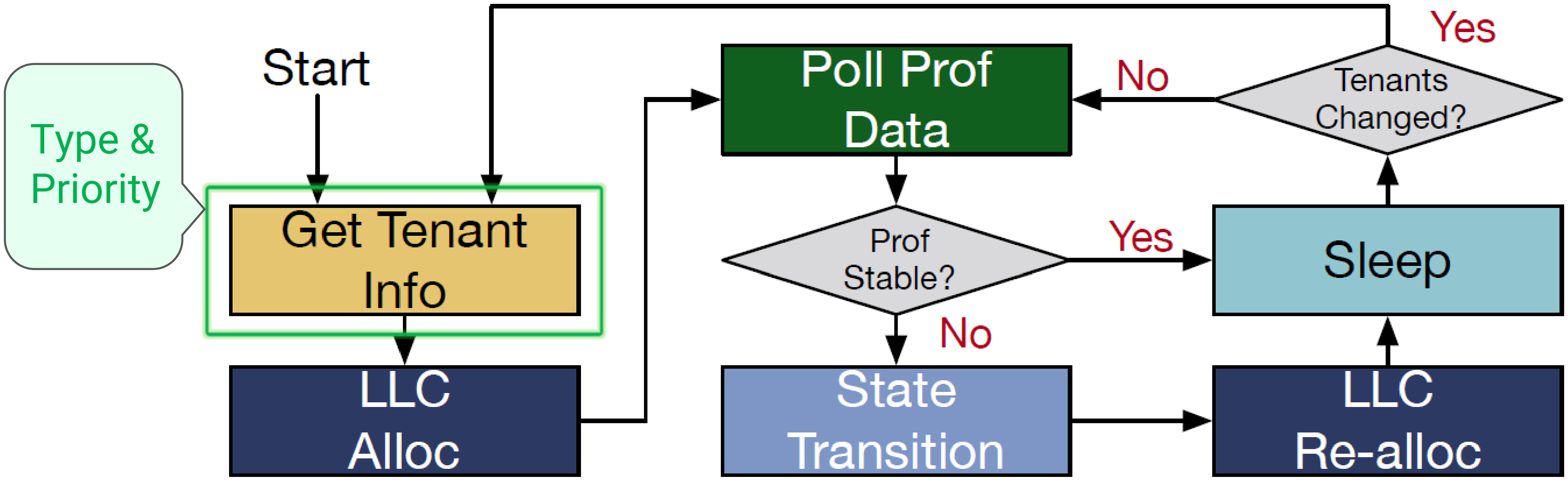
(a) Throughput. **(b)** Latency.

- DDIO overlap worsen the X-Mem’s (random read pattern) throughput and avg latency
- **How to share LLC ways with DDIO ?**

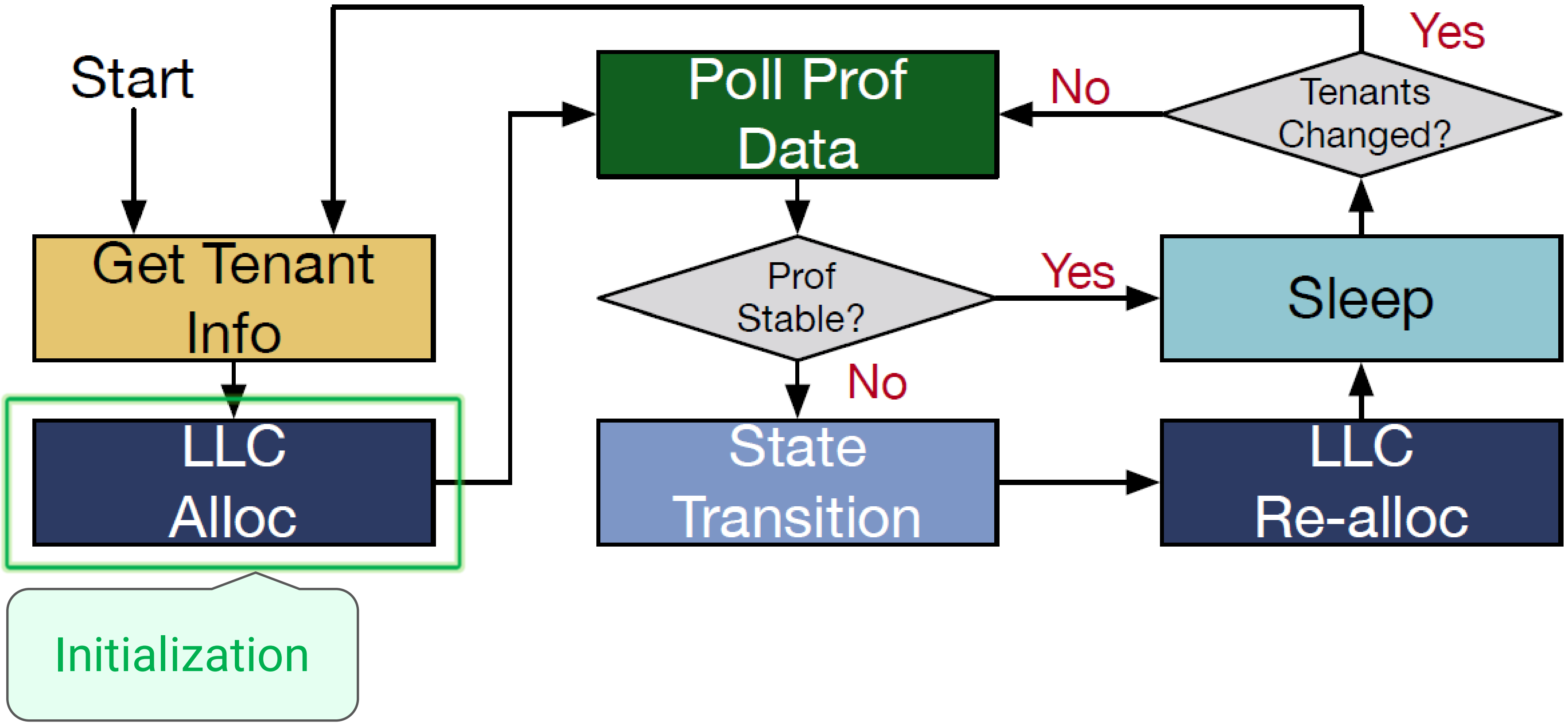
IAT: Design


Start
Get Tenant Info
LLC Alloc
Poll Prof Data
Prof Stable?
Yes
No
State Transition
Sleep
LLC Re-alloc
Tenants Changed?
No
Yes

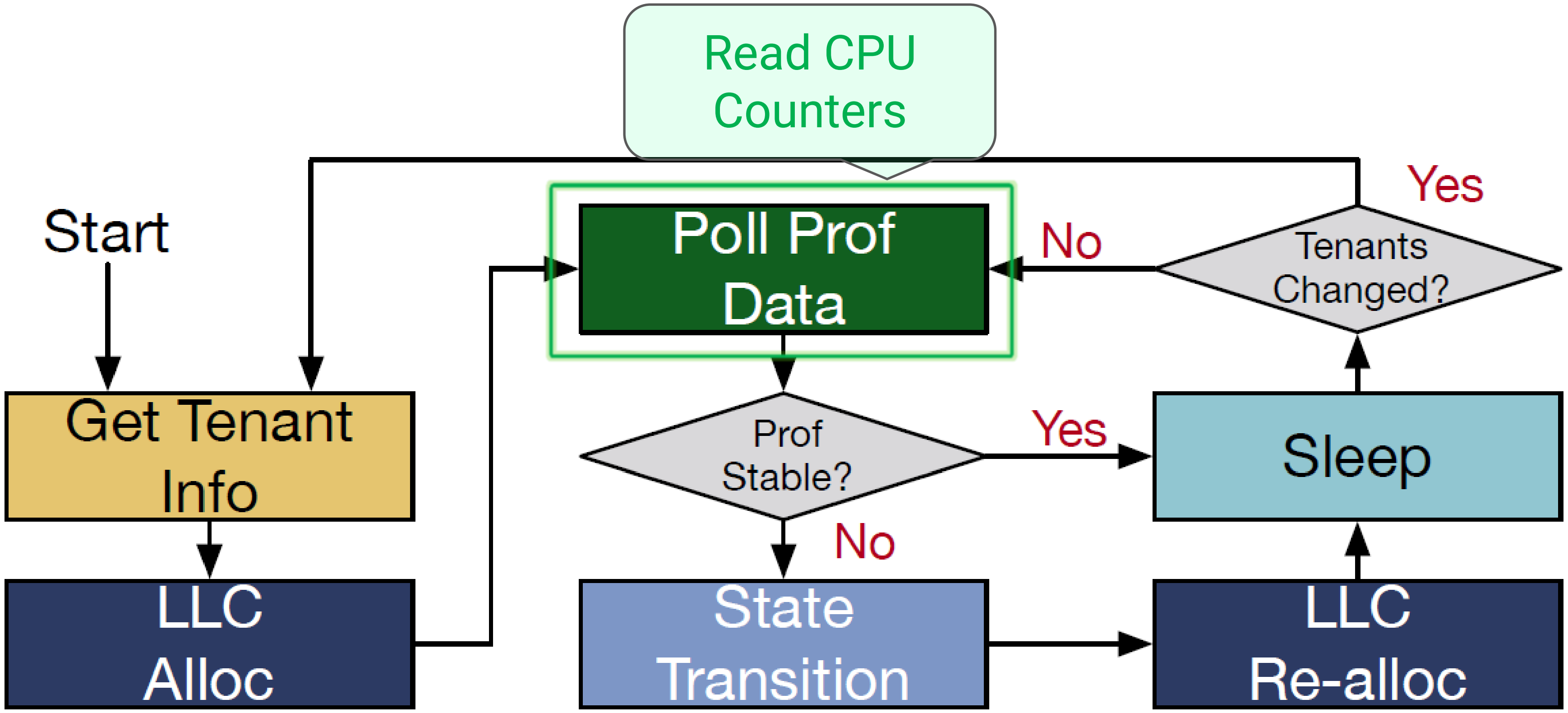
IAT: Design


Type & Priority
Start
Get Tenant Info
LLC Alloc
Poll Prof Data
Prof Stable?
Yes
No
State Transition
Sleep
LLC Re-alloc
Tenants Changed?
No
Yes

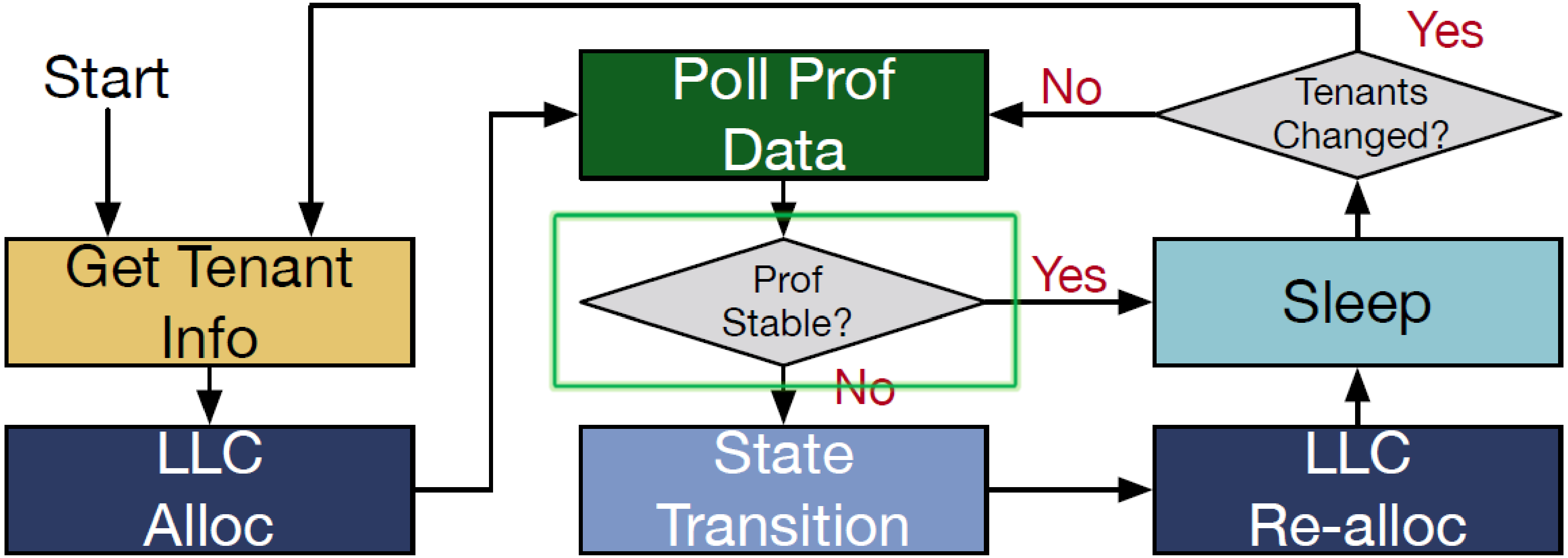
IAT: Design


Start
Get Tenant Info
LLC Alloc
Initialization
Poll Prof Data
Prof Stable?
Yes
No
State Transition
LLC Re-alloc
Sleep
Tenants Changed?
No
Yes

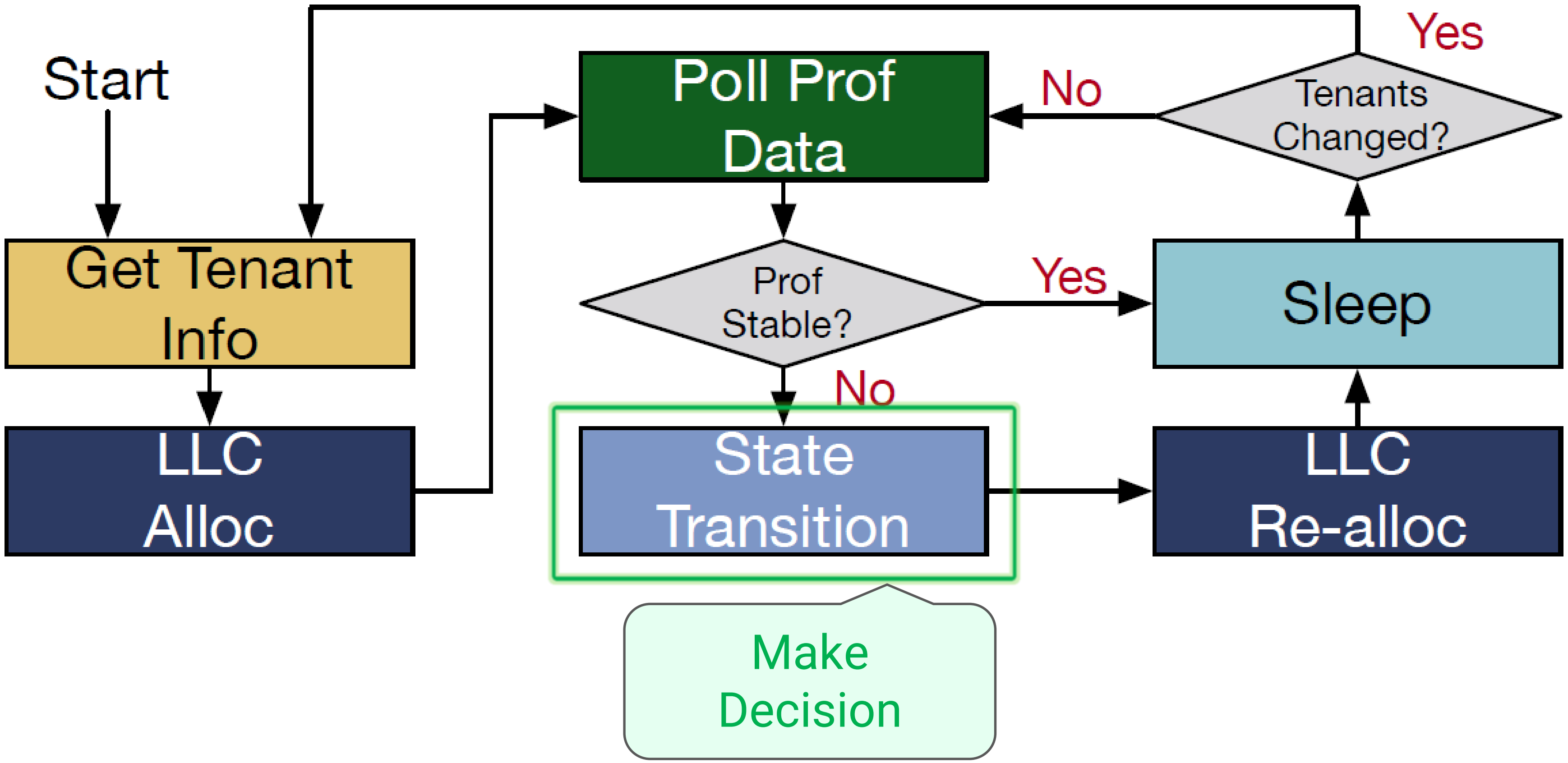
IAT: Design


Read CPU Counters
Start
Poll Prof Data
No
Tenants Changed?
Yes
Get Tenant Info
Prof Stable?
Yes
Sleep
No
LLC Alloc
State Transition
LLC Re-alloc

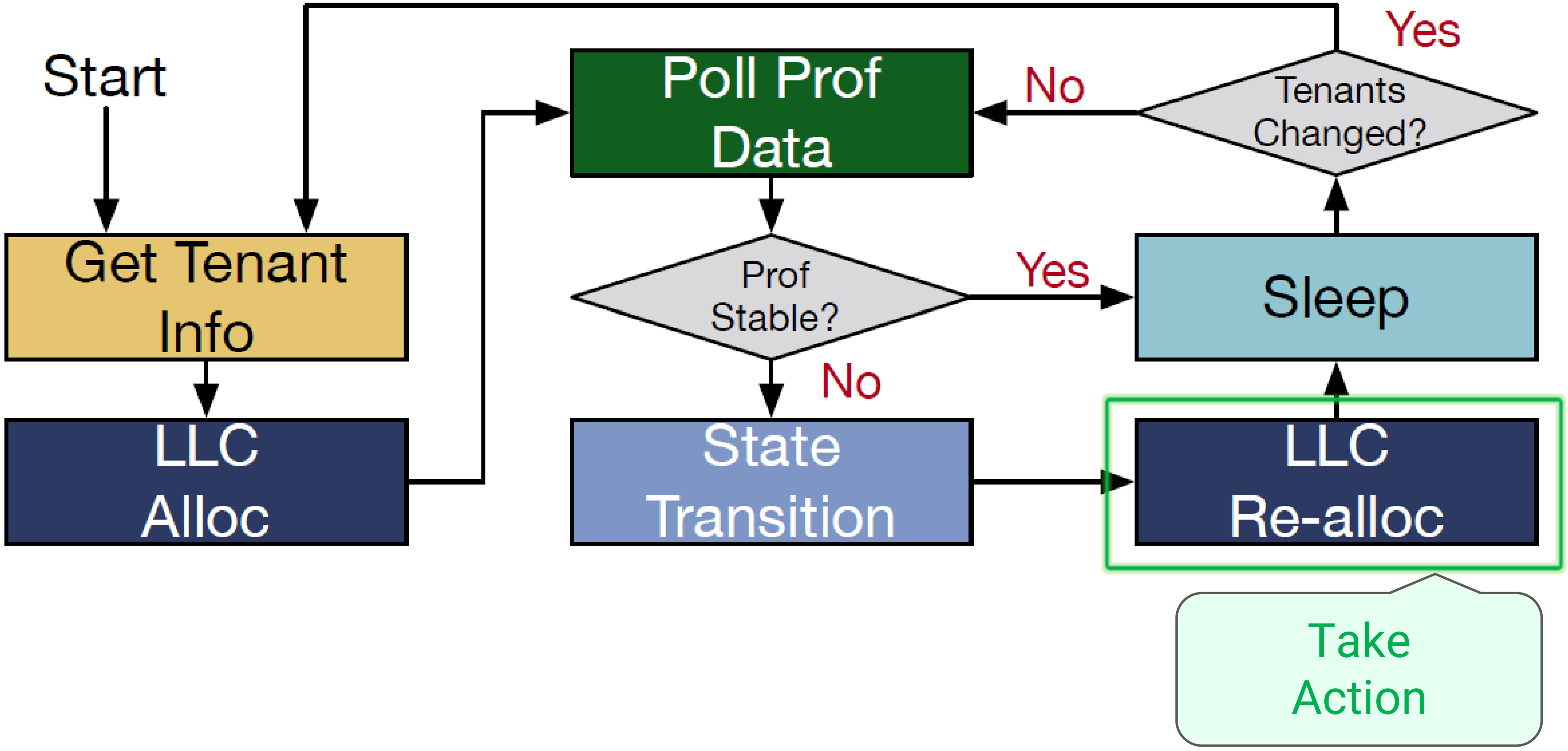
IAT: Design


Start
Get Tenant Info
LLC Alloc
Poll Prof Data
Prof Stable?
Yes
No
State Transition
Sleep
LLC Re-alloc
Tenants Changed?
Yes
No

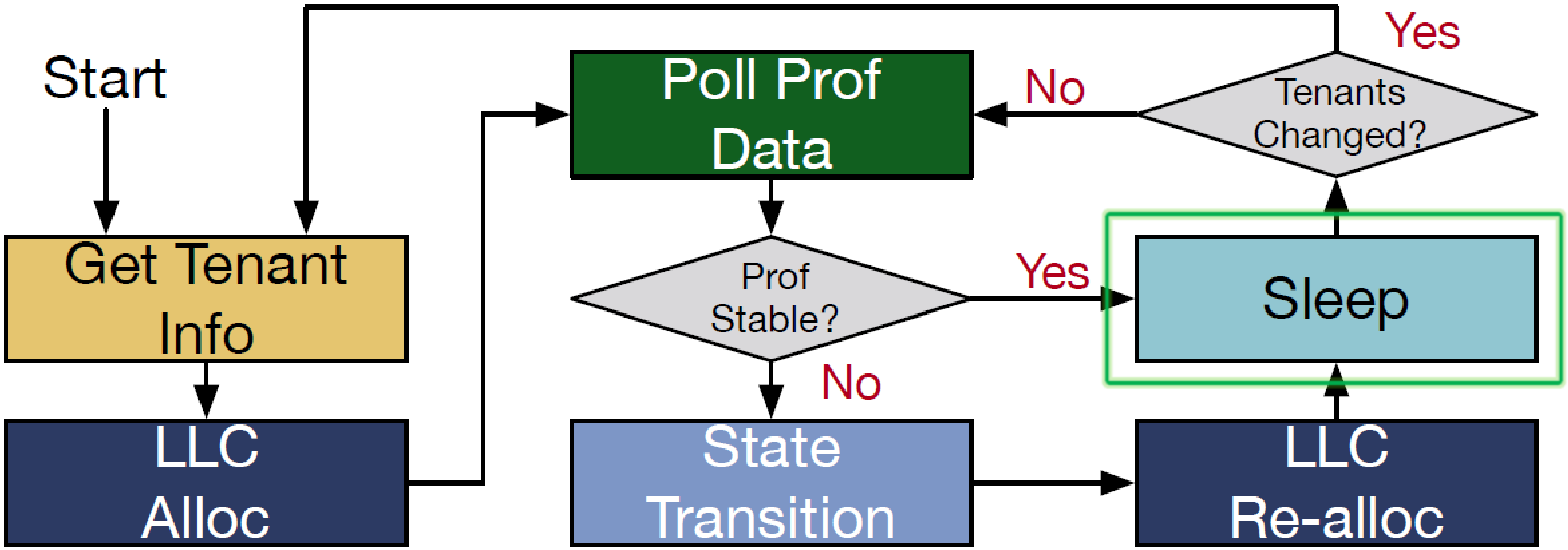
IAT: Design


Start
Get Tenant Info
LLC Alloc
Poll Prof Data
Prof Stable?
Yes
No
State Transition
Sleep
LLC Re-alloc
Tenants Changed?
Yes
No
Make Decision

IAT: Design


Start
Get Tenant Info
LLC Alloc
Poll Prof Data
Prof Stable?
Yes
No
State Transition
Sleep
LLC Re-alloc
Tenants Changed?
No
Yes
Take Action

IAT: Design


Start
Get Tenant Info
LLC Alloc
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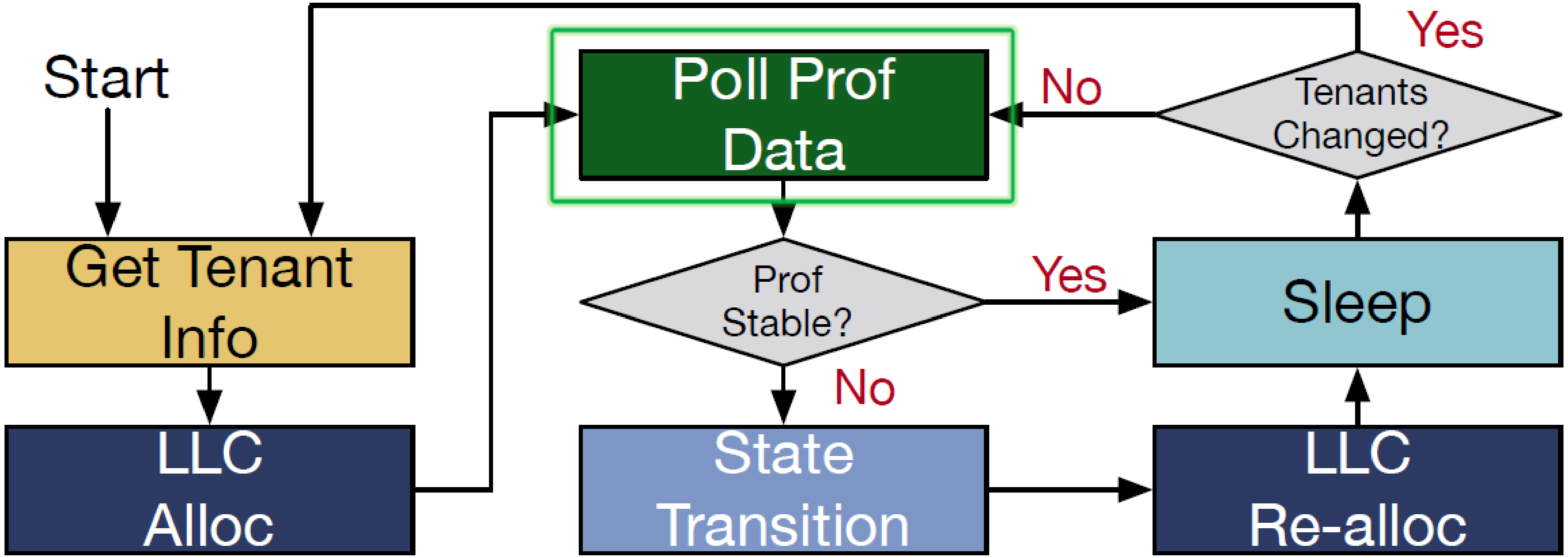
Prof Stable?
Yes
No
State Transition
Sleep
LLC Re-alloc
Tenants Changed?
Yes
No

IAT: Poll Prof Data



IAT: Poll Prof Data

○ IPC

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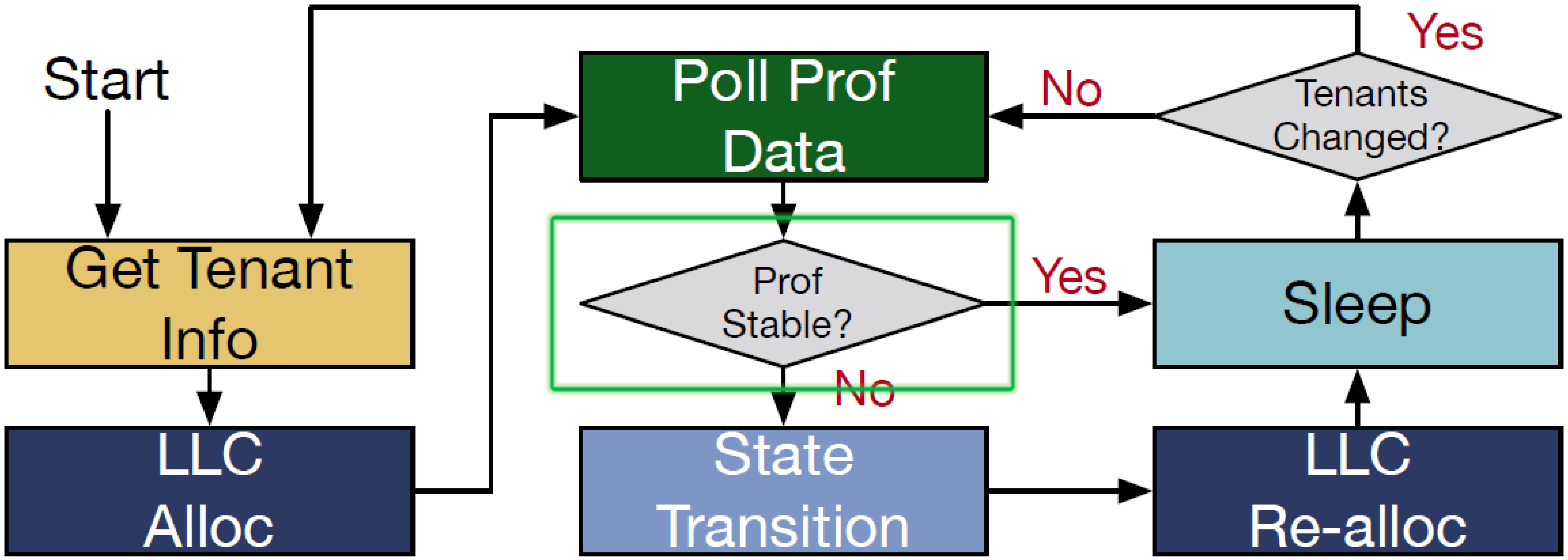
- IPC: performance of an application
- LLC ref and miss: memory/ cache access characteristics of a workload
- DDIO hit and miss (chip wide metrics):
  - Hit when targeted cache-line in LLC
  - Miss when a victim has to be evicted for DDIO
  - Tells about IO pressure on LLC

IAT: State Transition



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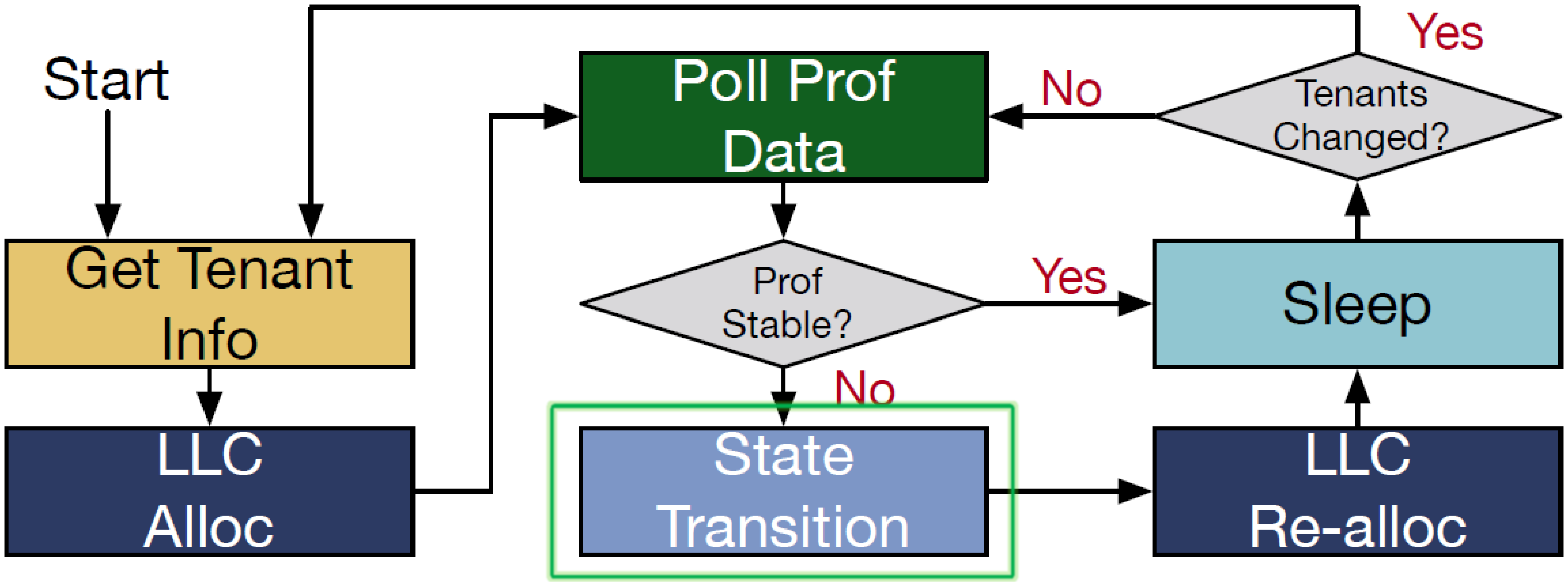

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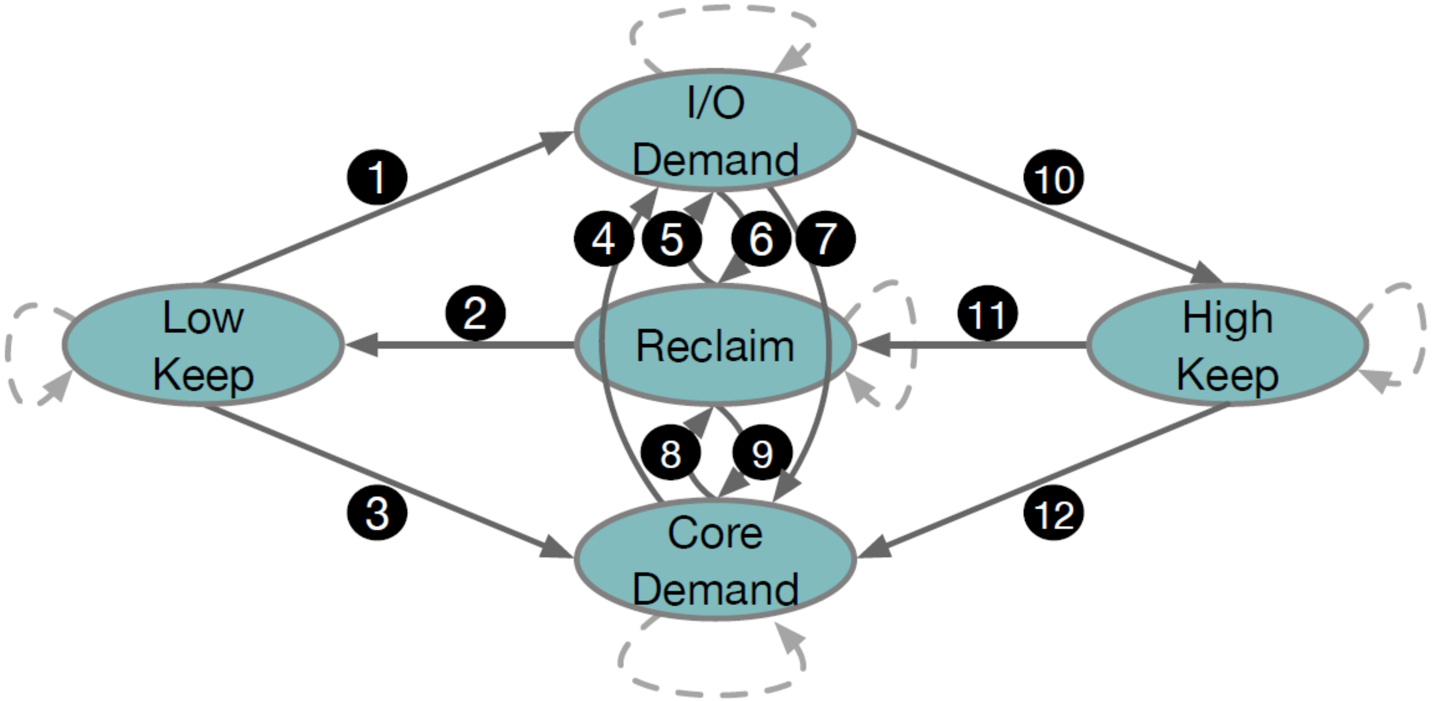

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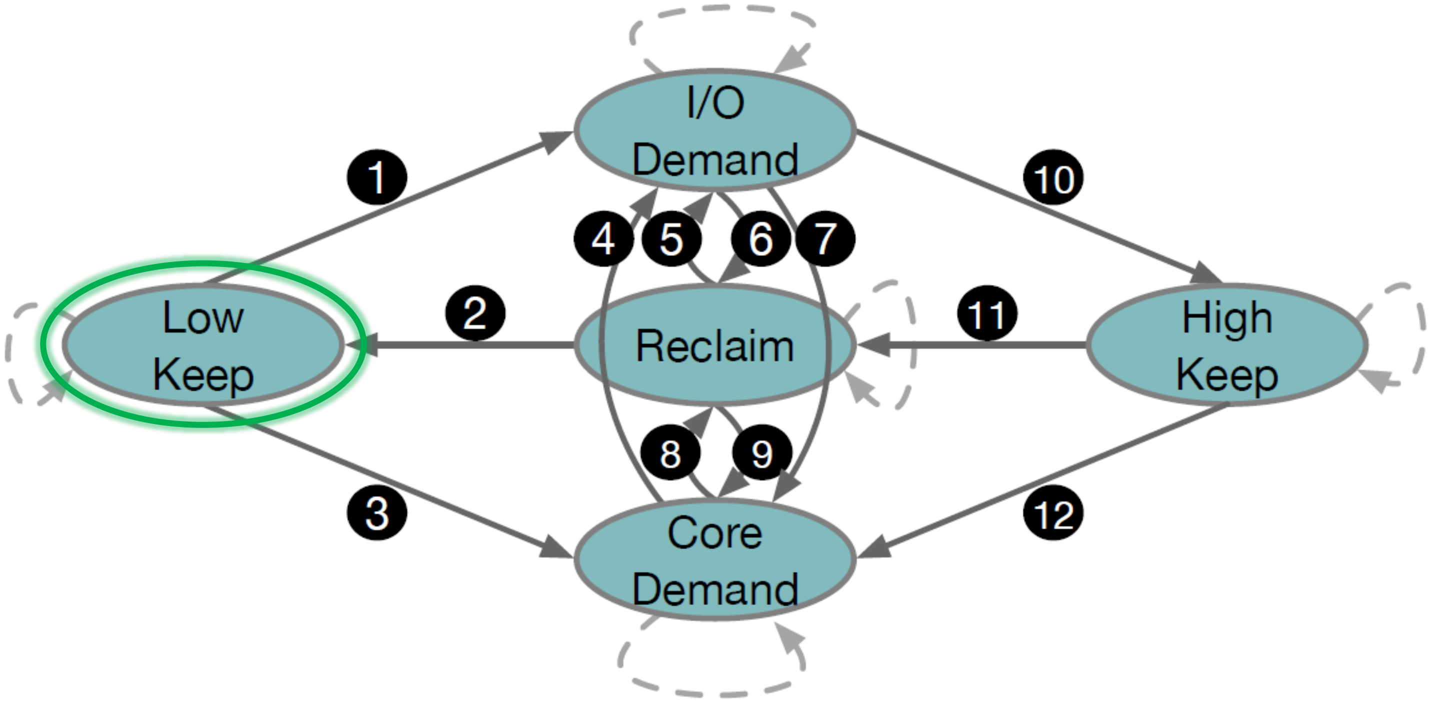

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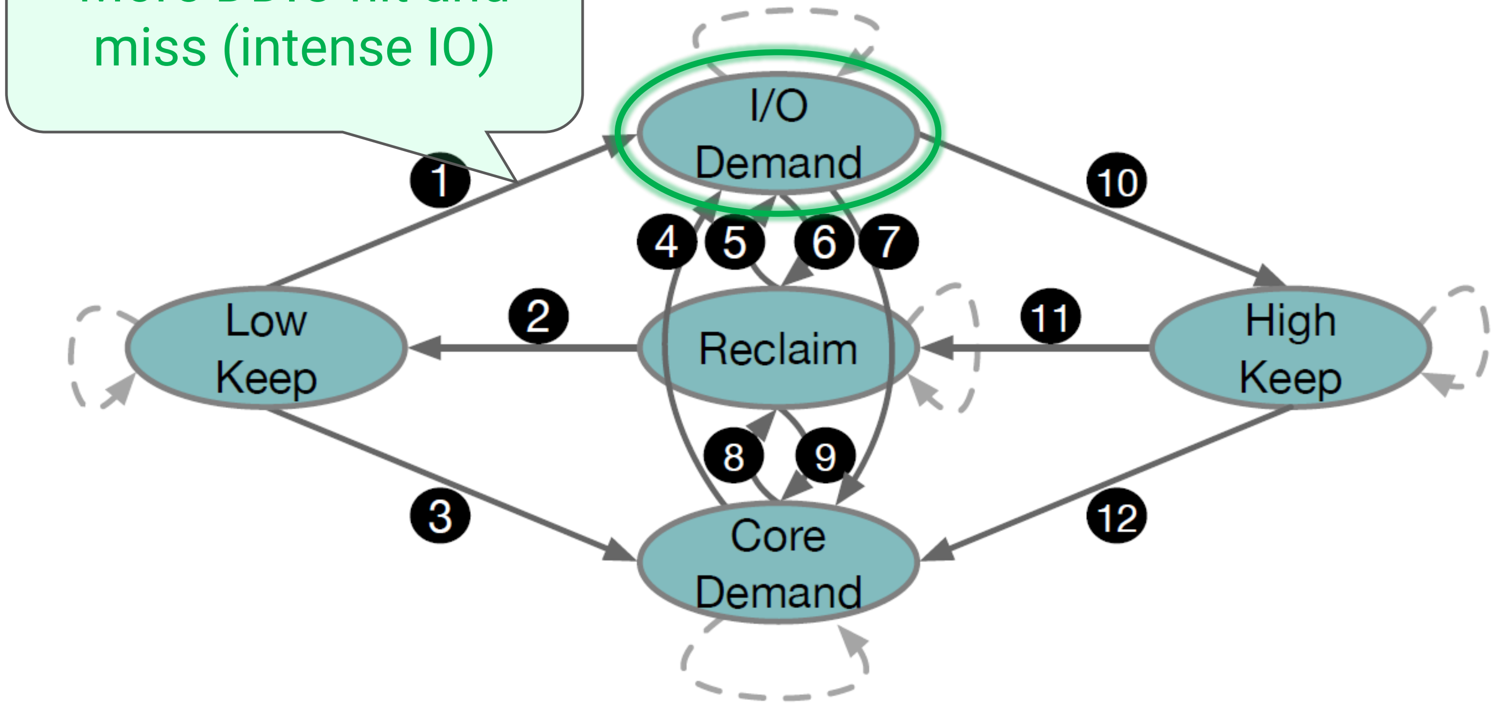
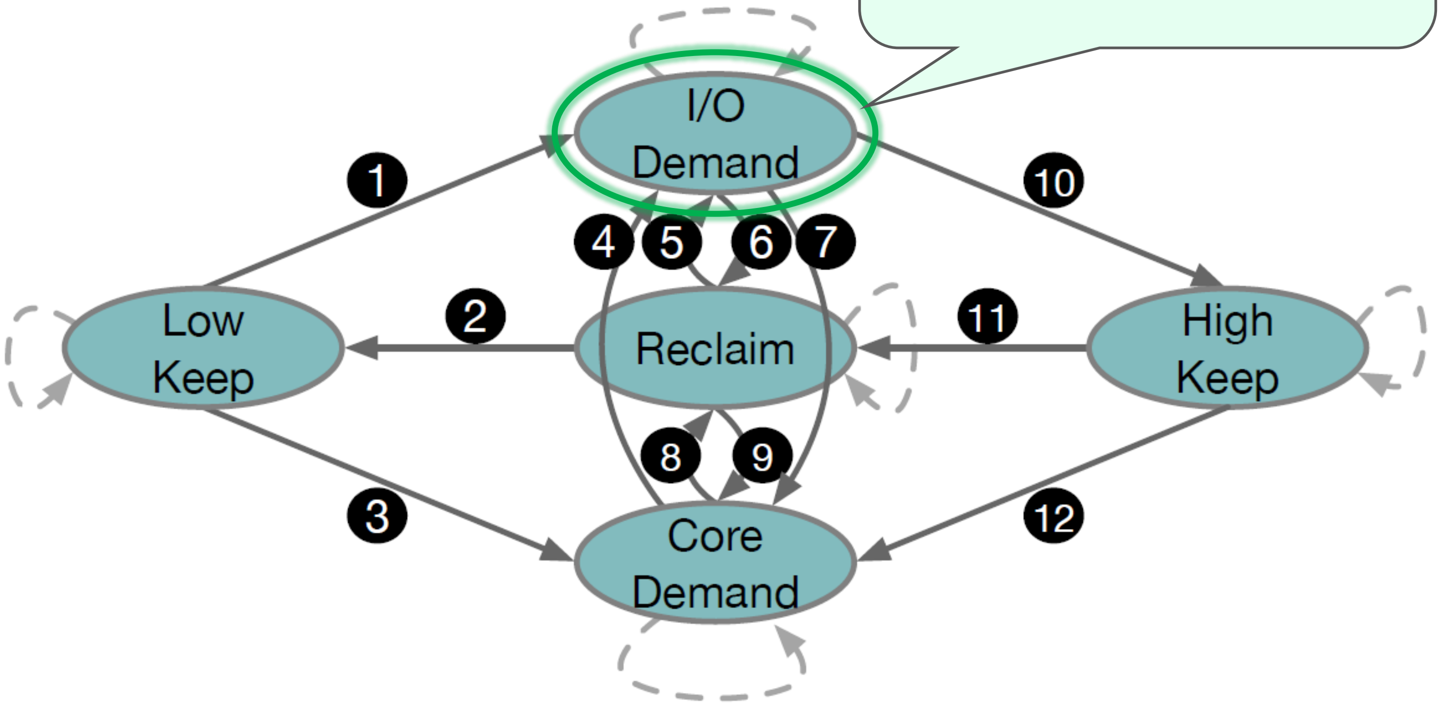


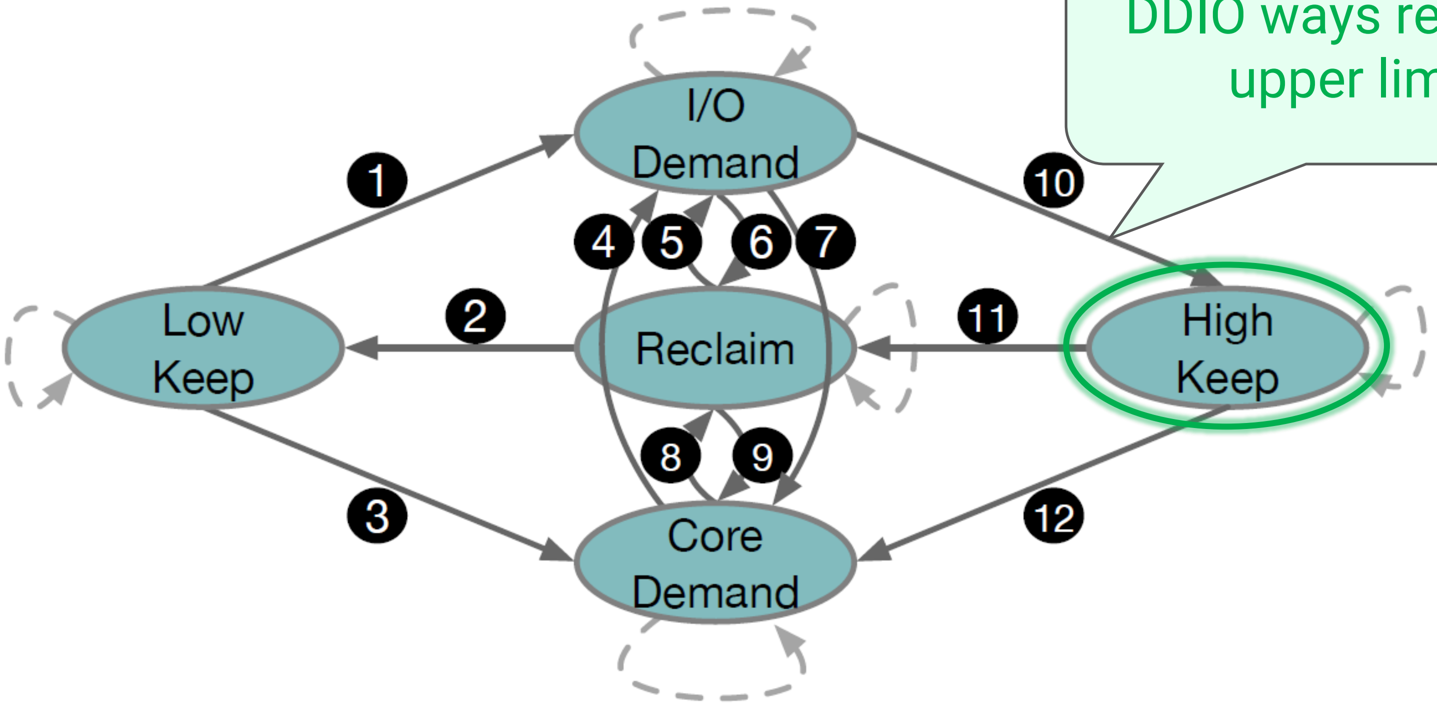
More DDIO hit and miss (intense IO)

IAT: State Transition



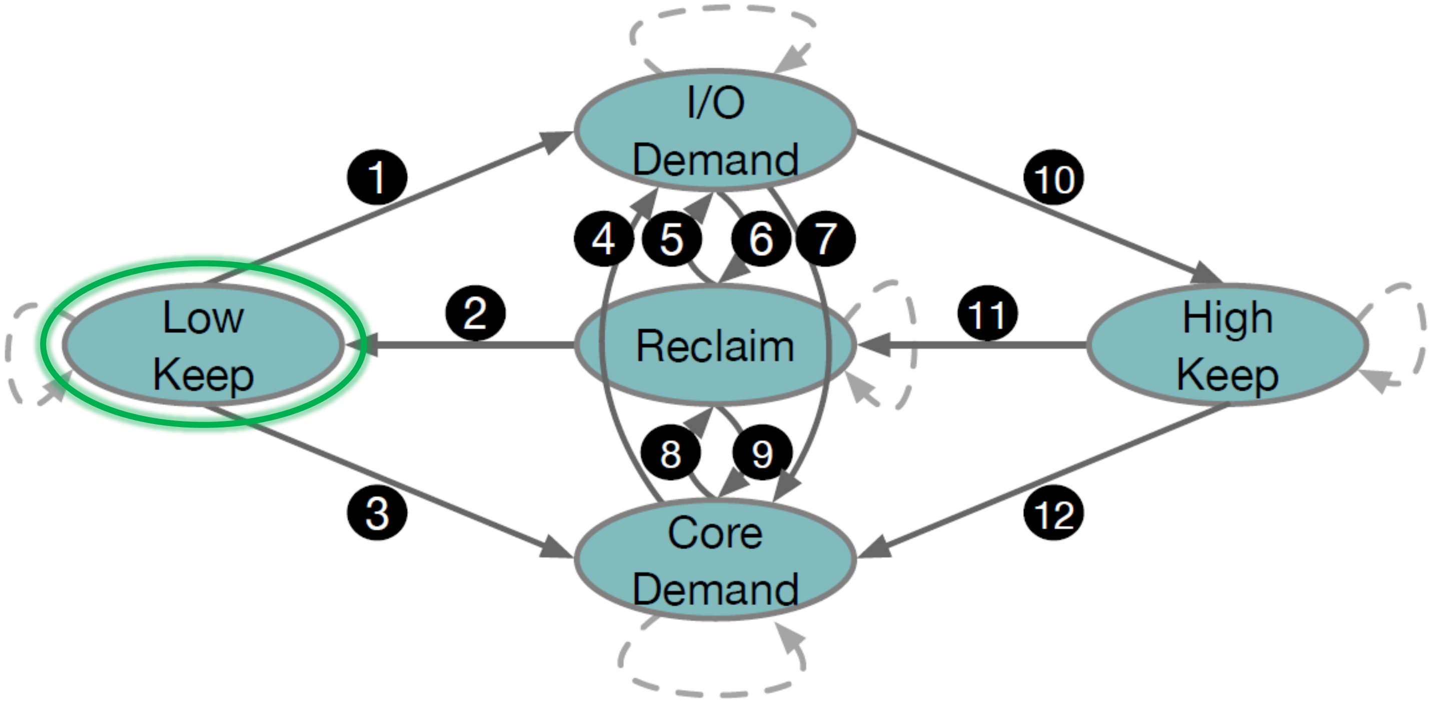
Keep on Increasing DDIO ways

IAT: State Transition

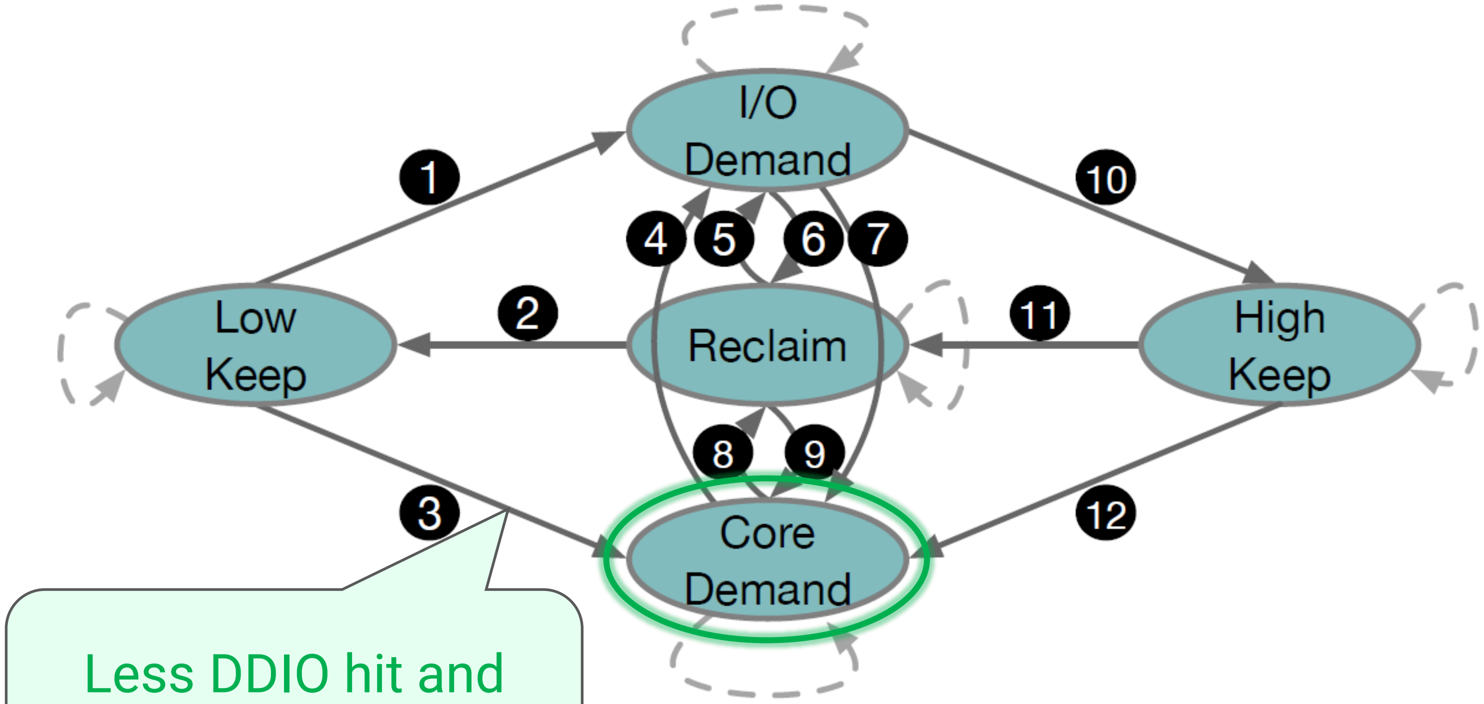


DDIO ways reaches upper limit

IAT: State Transition

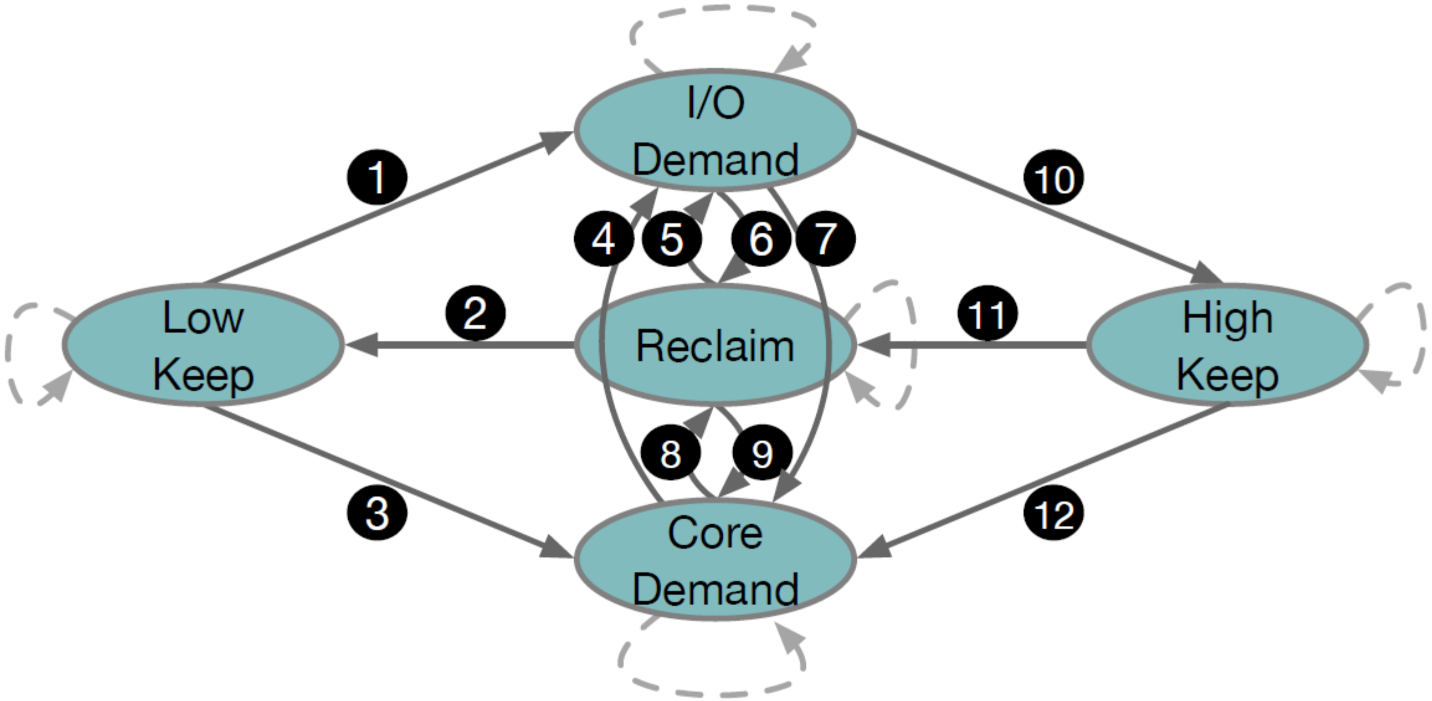


IAT: State Transition

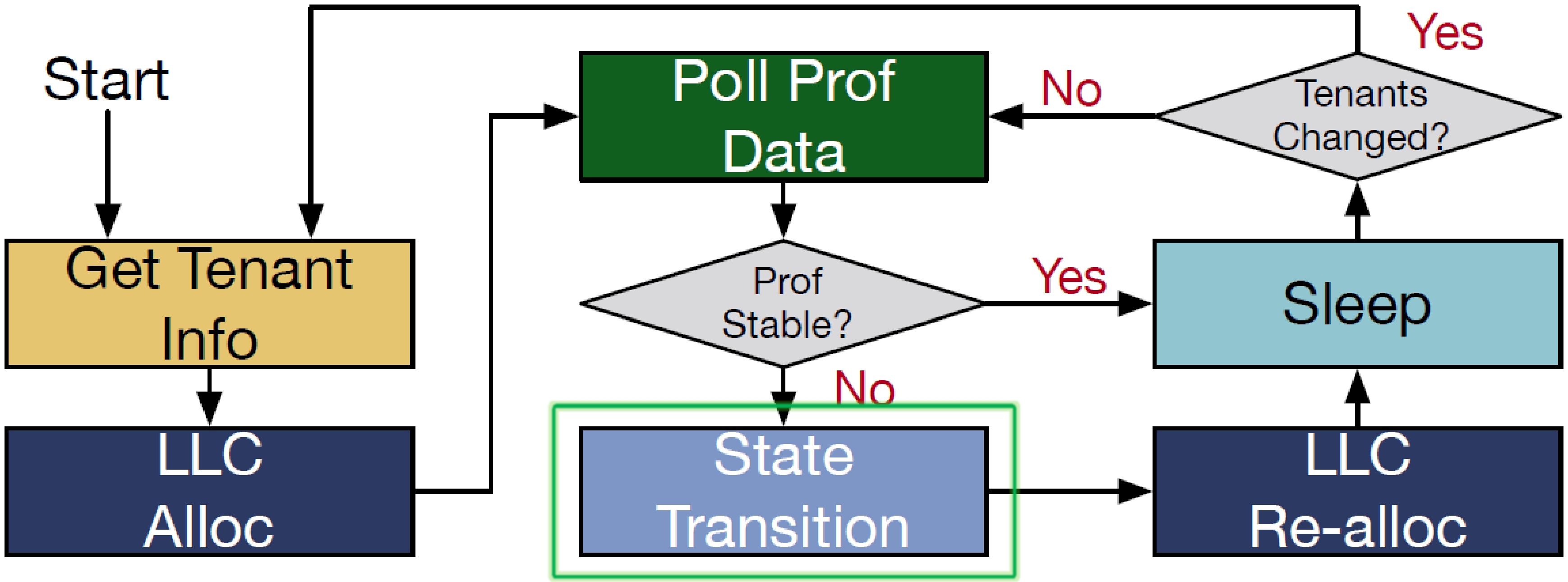


Less DDIO hit and more LLC ref

IAT: State Transition



IAT: LLC Re – alloc



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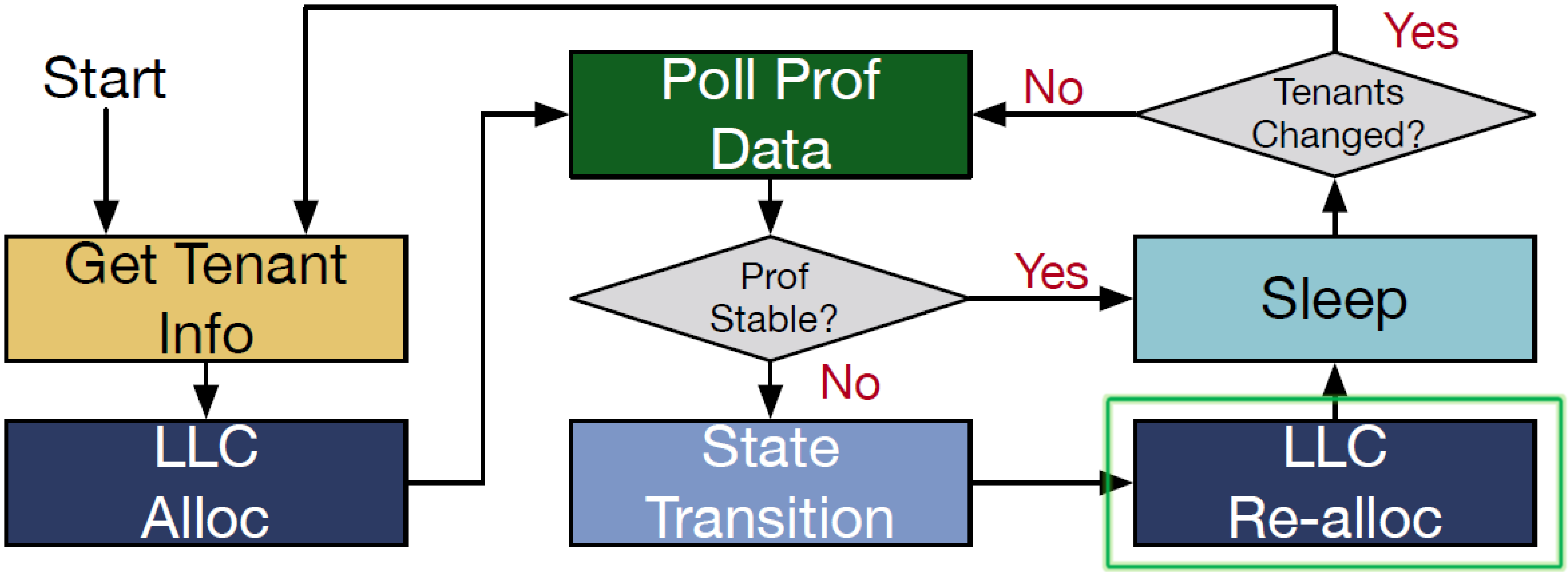
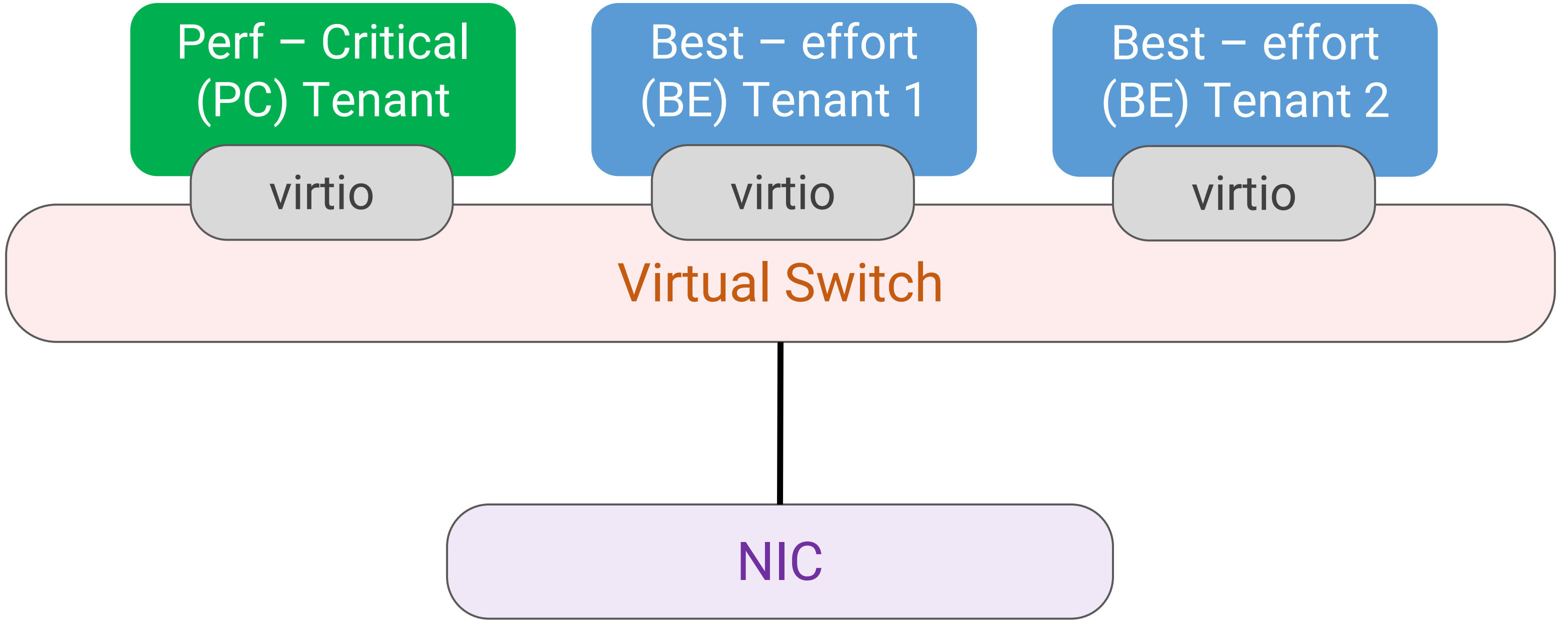
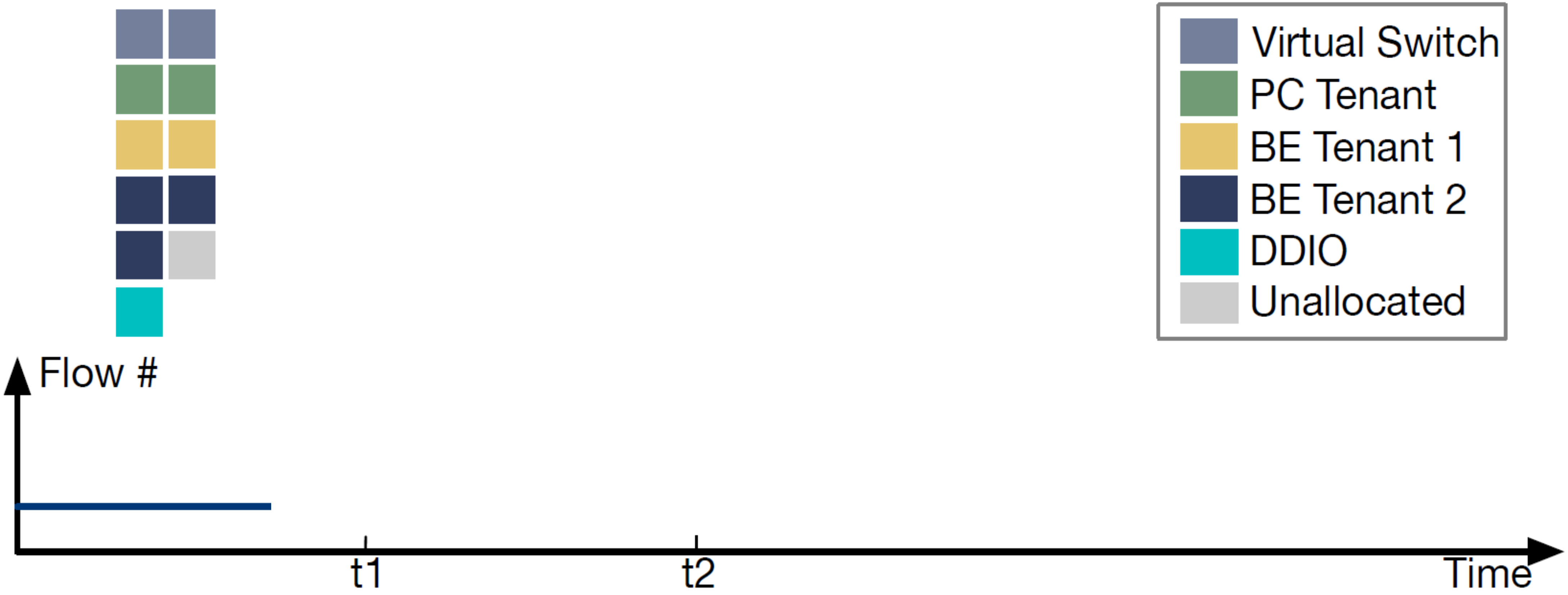


IAT: LLC Re – alloc (Example 1)


Perf – Critical (PC) Tenant
Best – effort (BE) Tenant 1
Best – effort (BE) Tenant 2
virtio
virtio
virtio
Virtual Switch
NIC

Example 1: Aggregation Model

IAT: LLC Re – alloc (Example 1)



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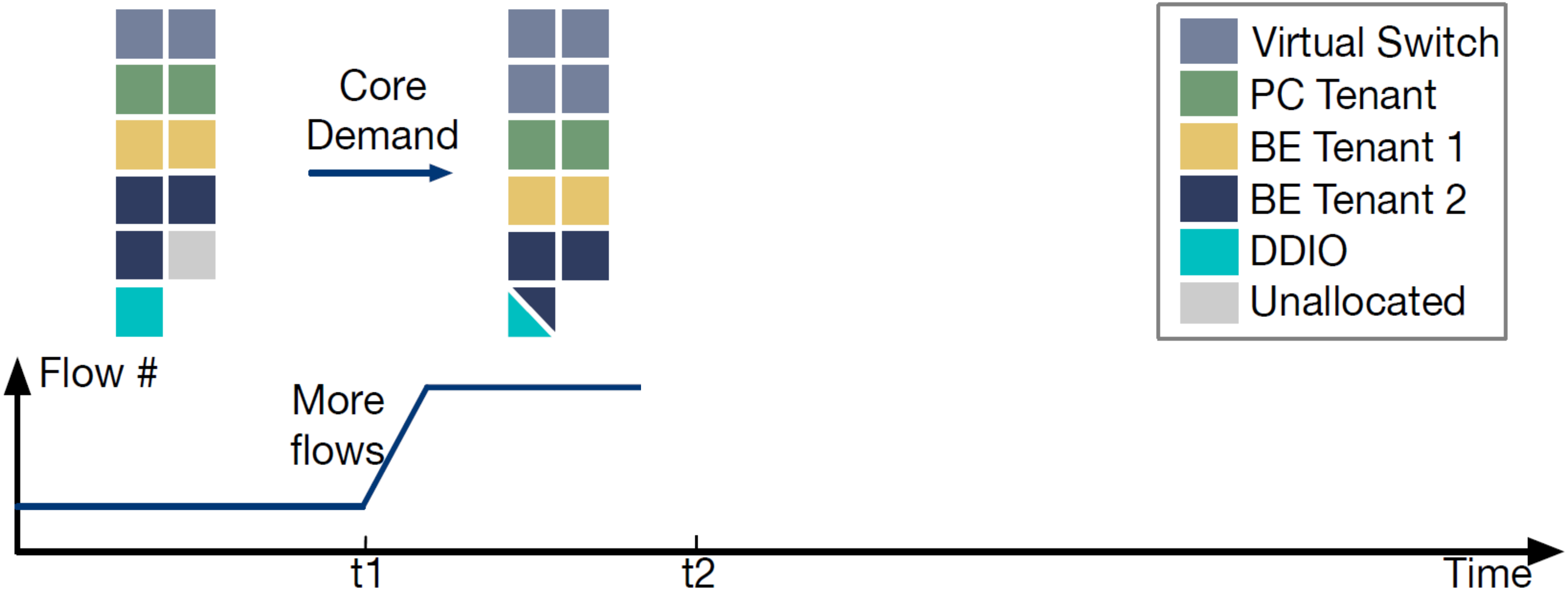

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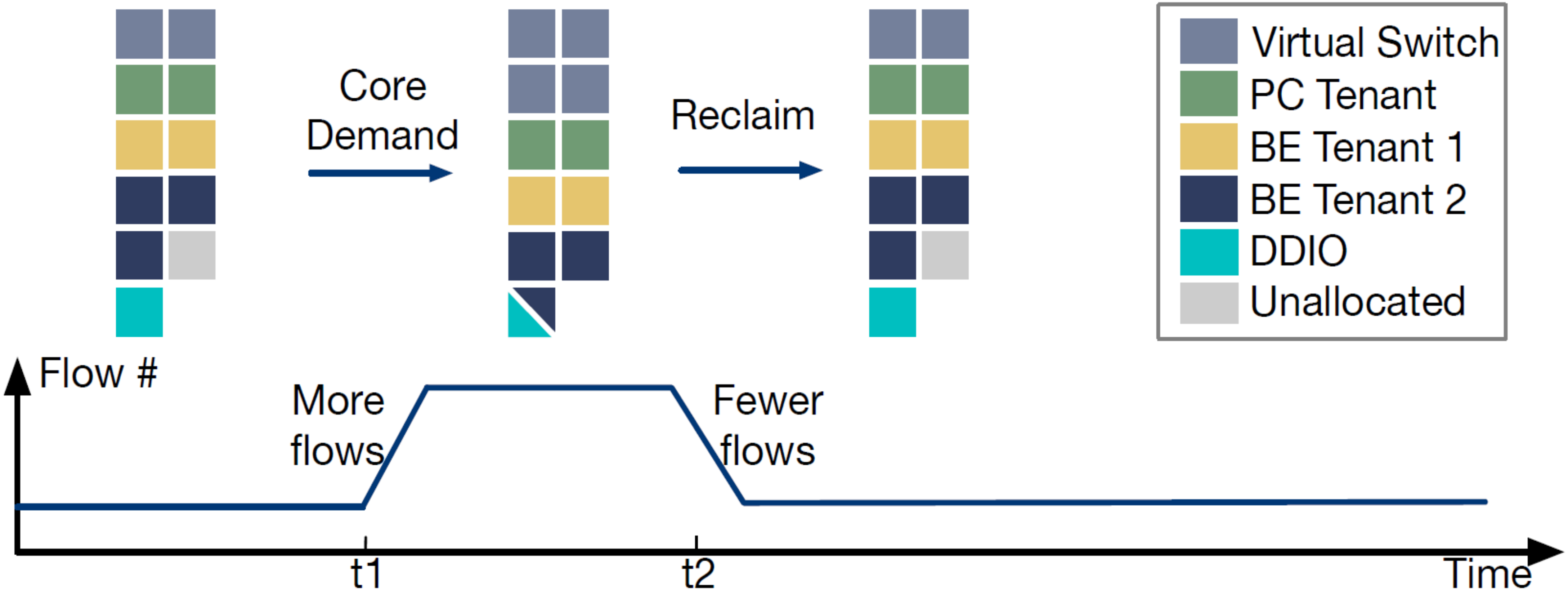
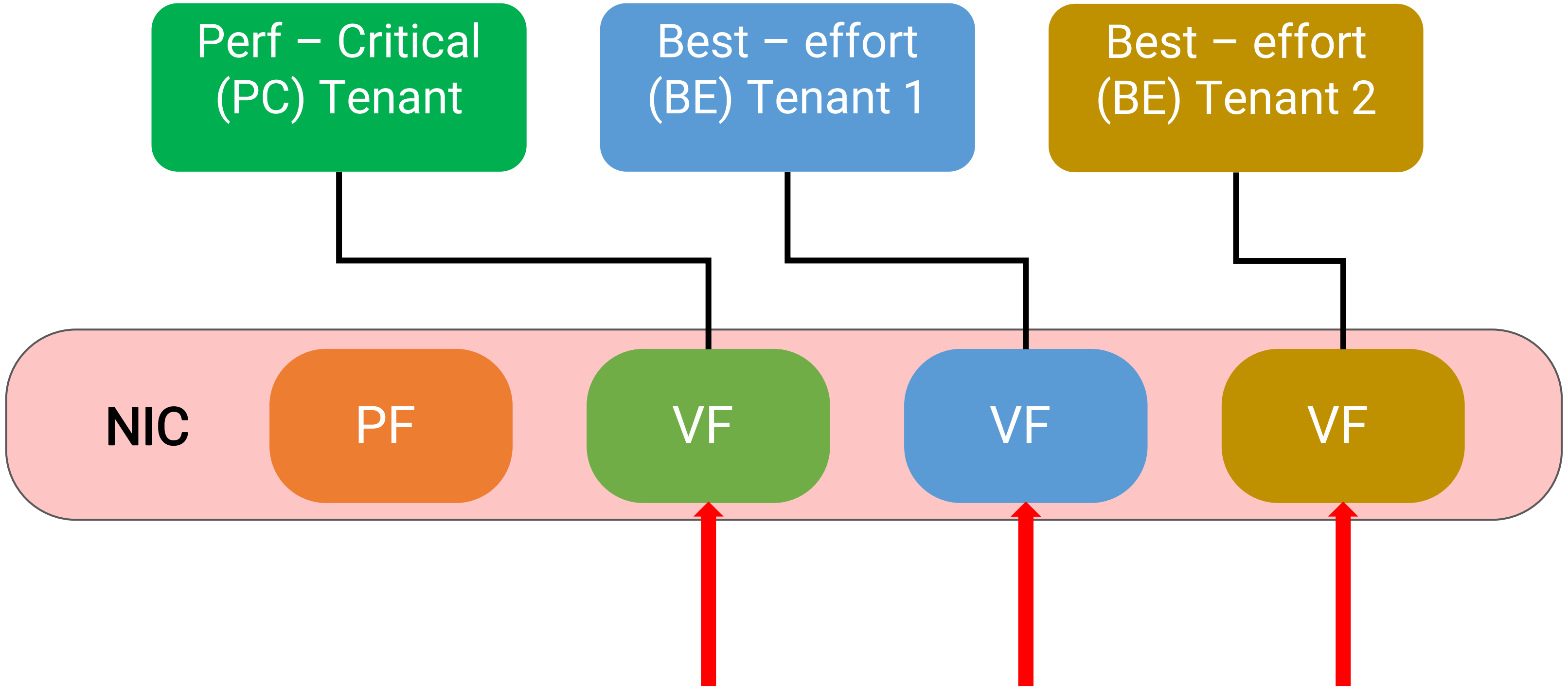
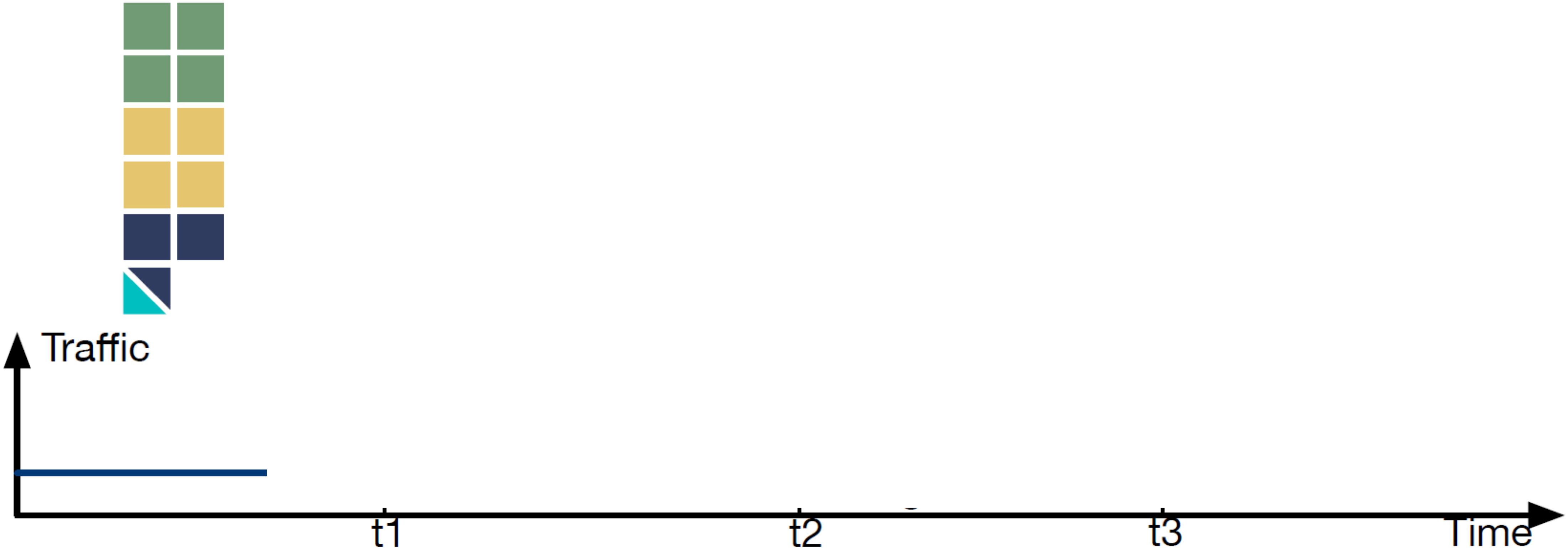


IAT: LLC Re – alloc (Example 2)


Perf – Critical (PC) Tenant
Best – effort (BE) Tenant 1
Best – effort (BE) Tenant 2
NIC
PF
VF
VF
VF

Example 2: Slicing Model

IAT: LLC Re – alloc (Example 2)



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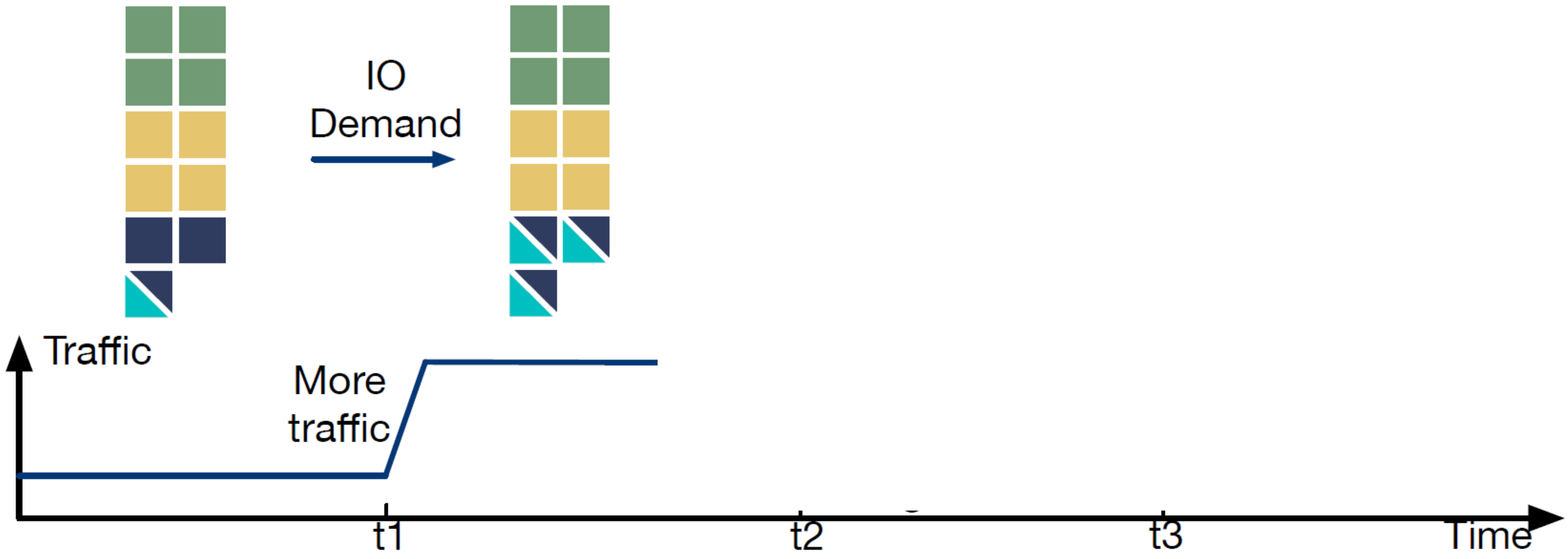

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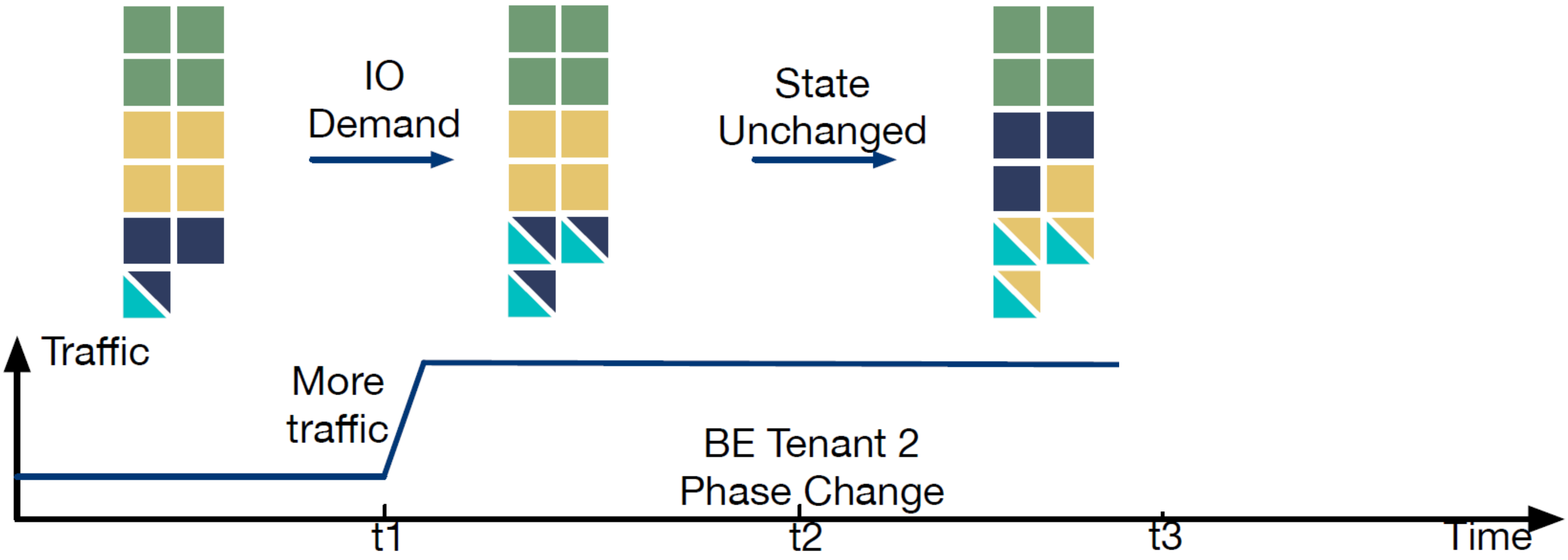

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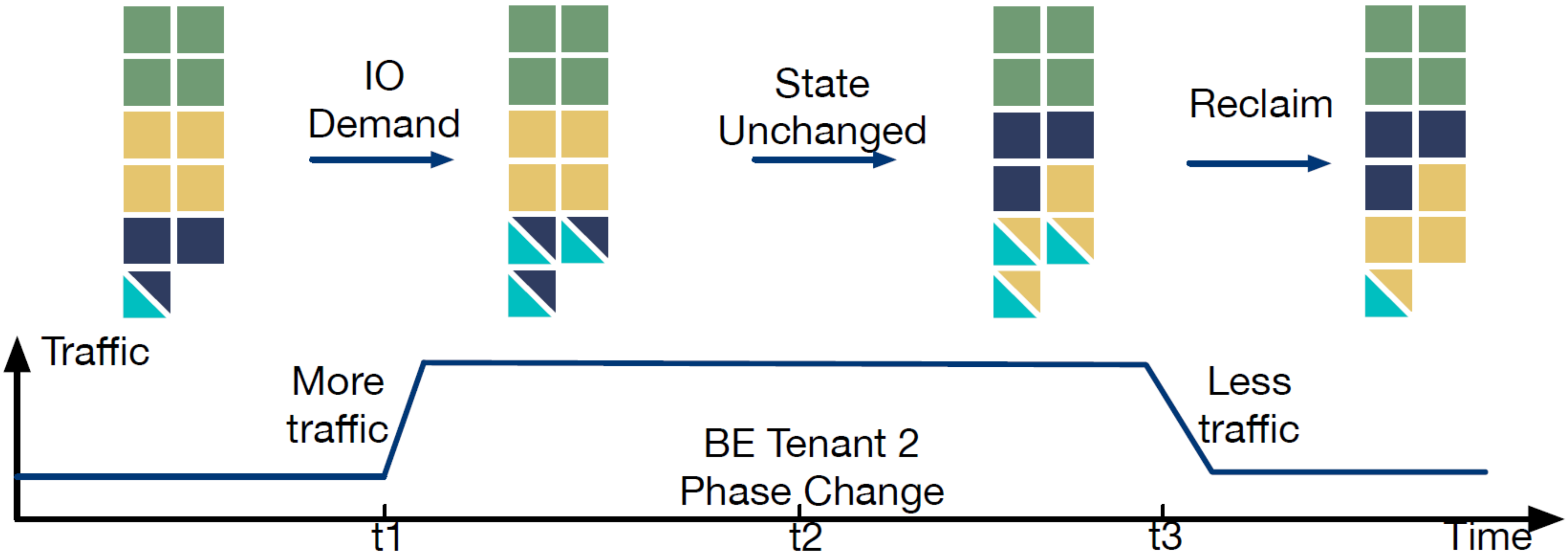
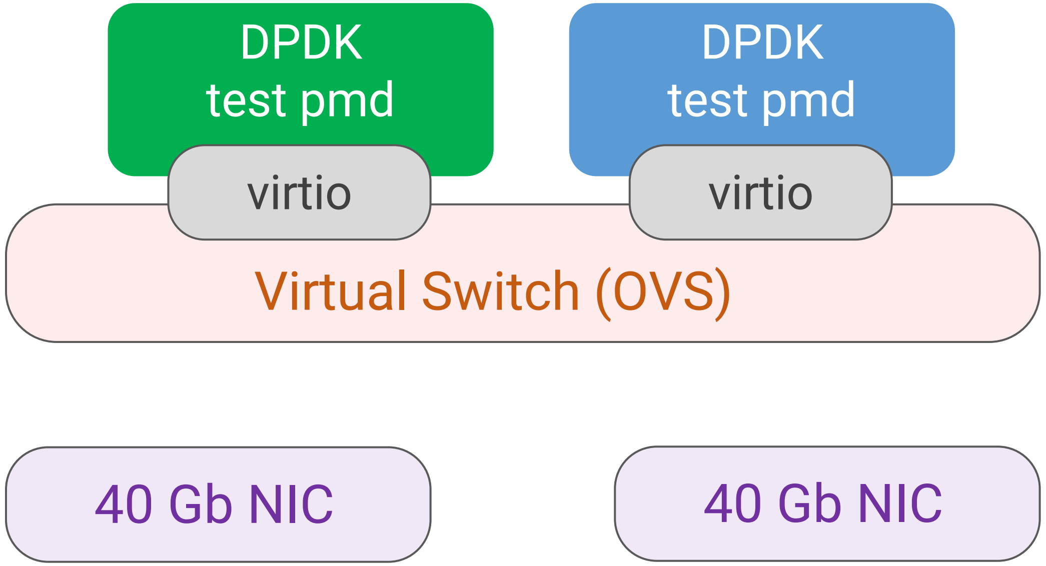
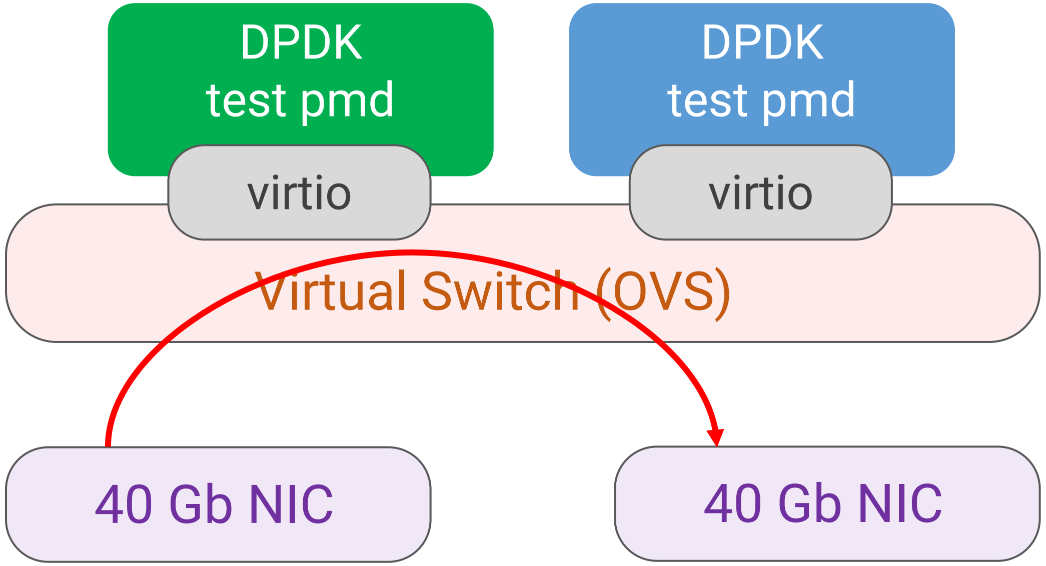


IAT: Solving Leaky DMA Problem



IAT: Solving Leaky DMA Problem



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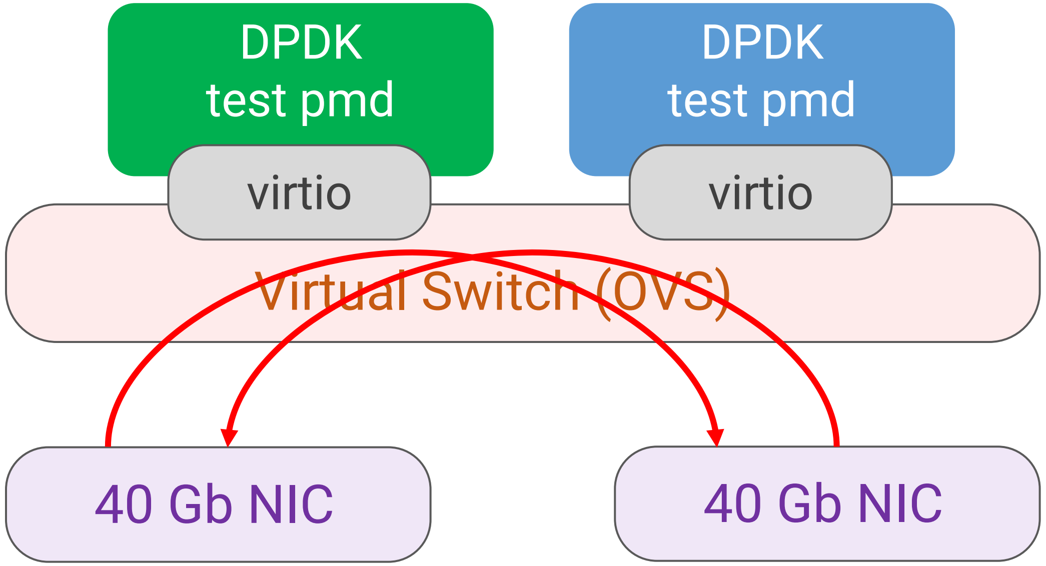

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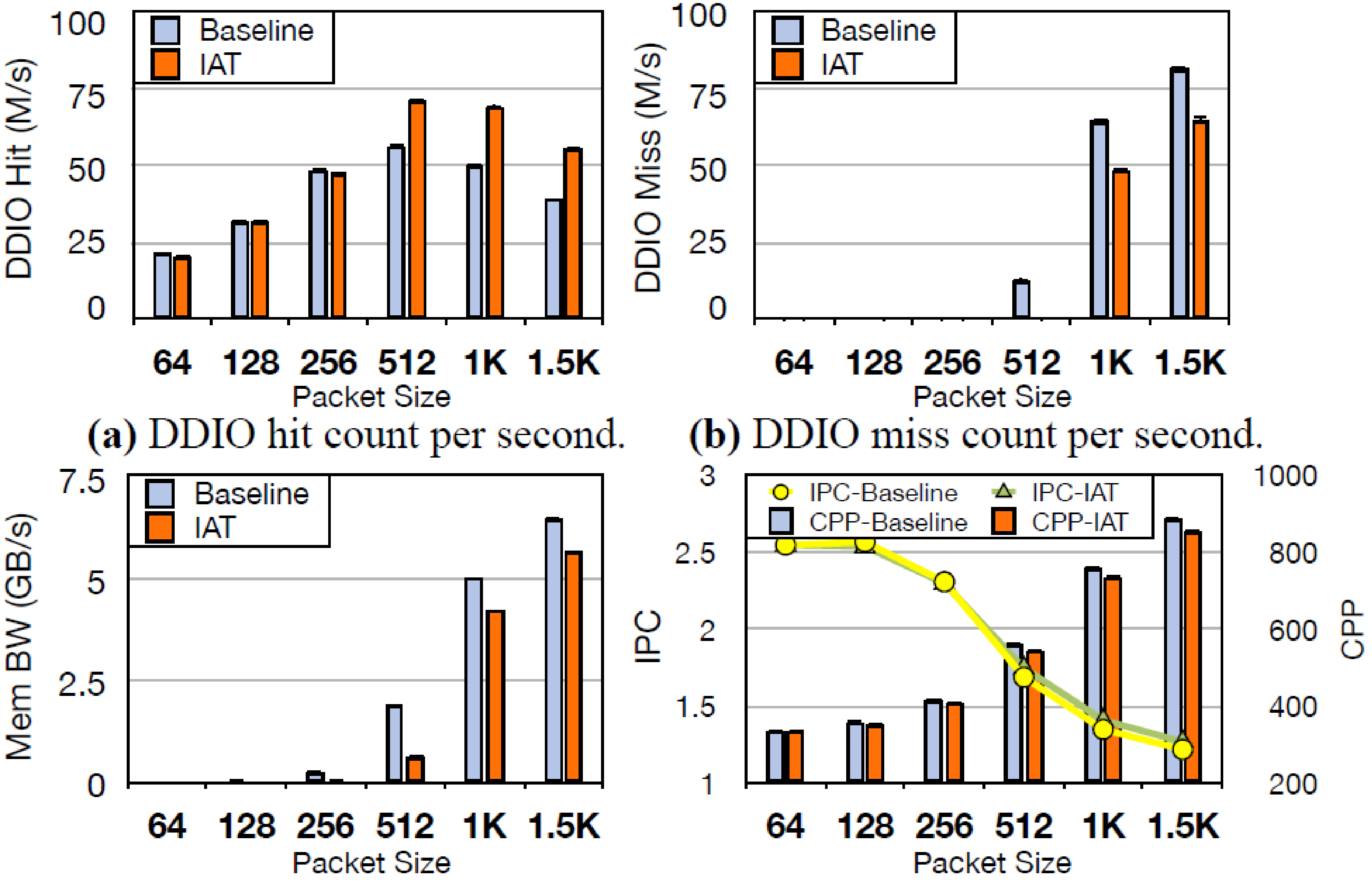

(a) DDIO hit count per second.

(b) DDIO miss count per second.

(c) Memory bandwidth consumption.

(d) OVS IPC and CPP.

IAT: Solving Latent Contender Problem

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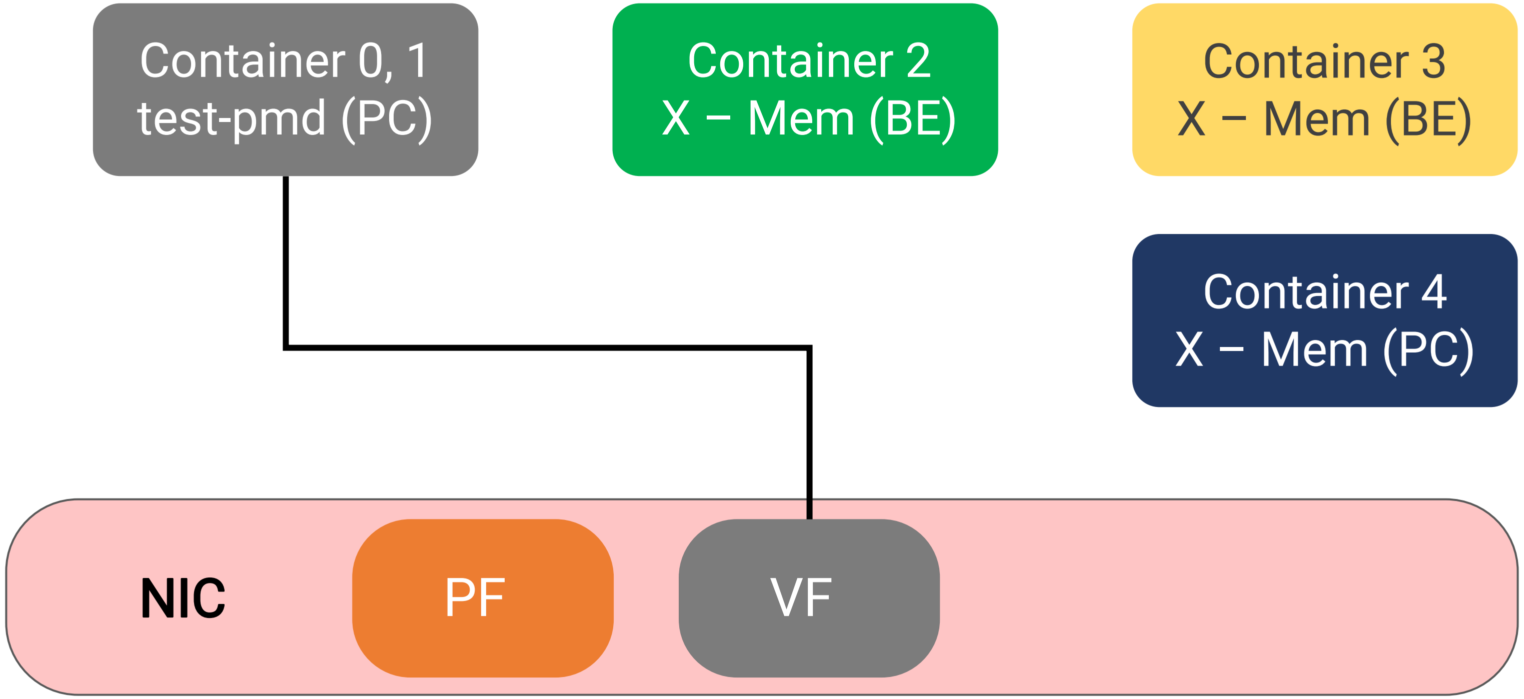

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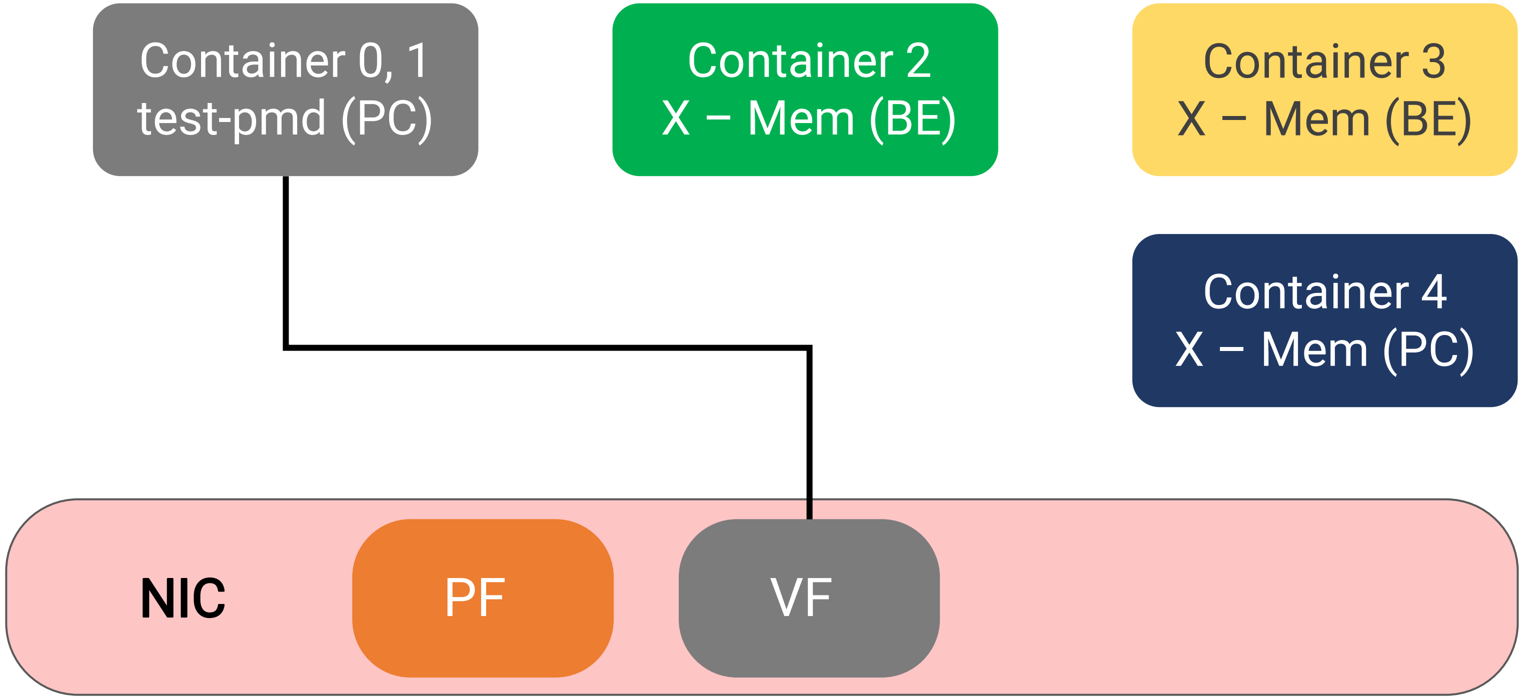
- Change in X-Mem working set size and DDIO ways at different time interval: **Container 4**



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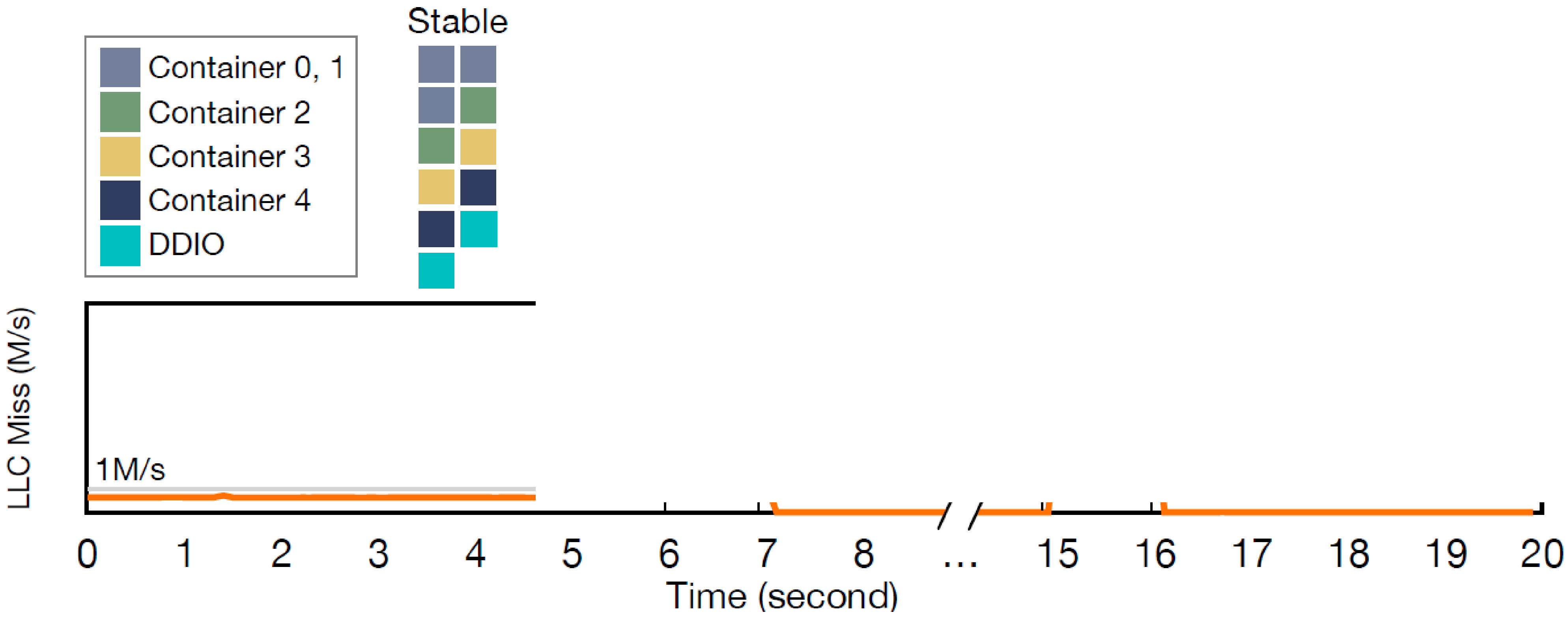

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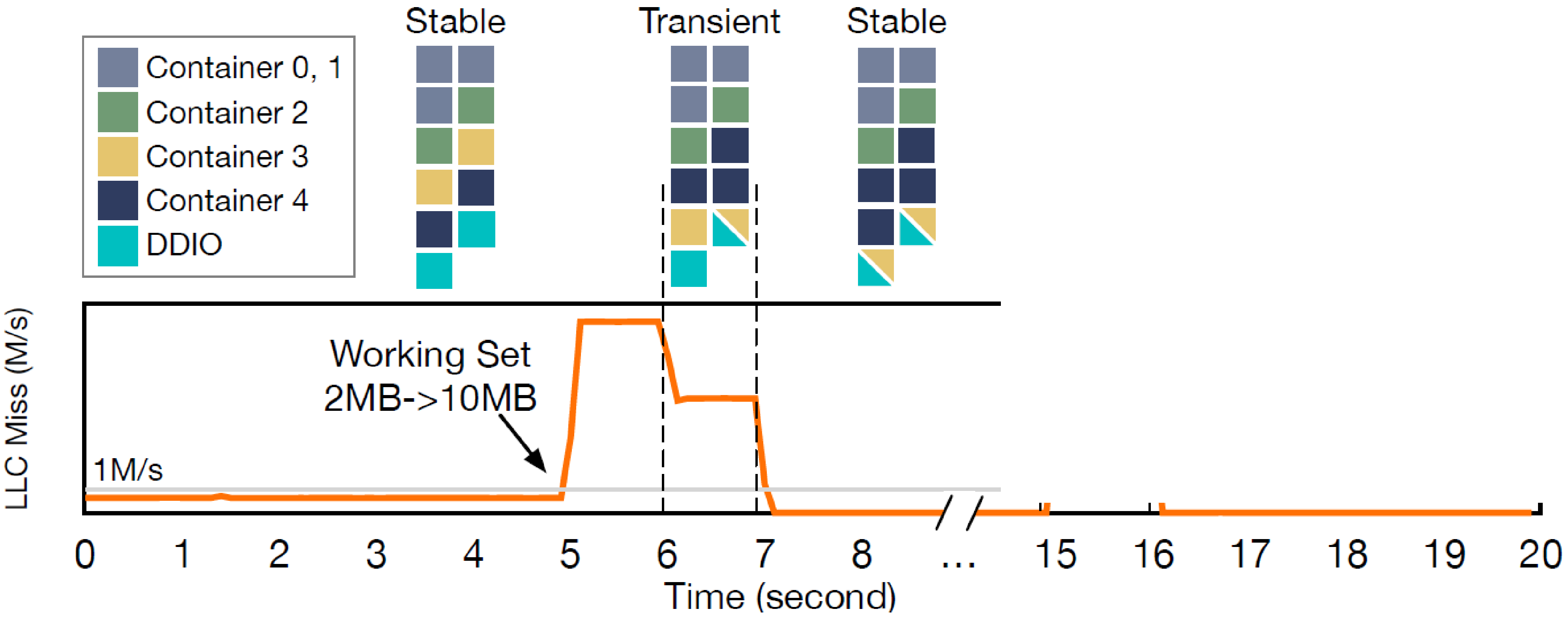

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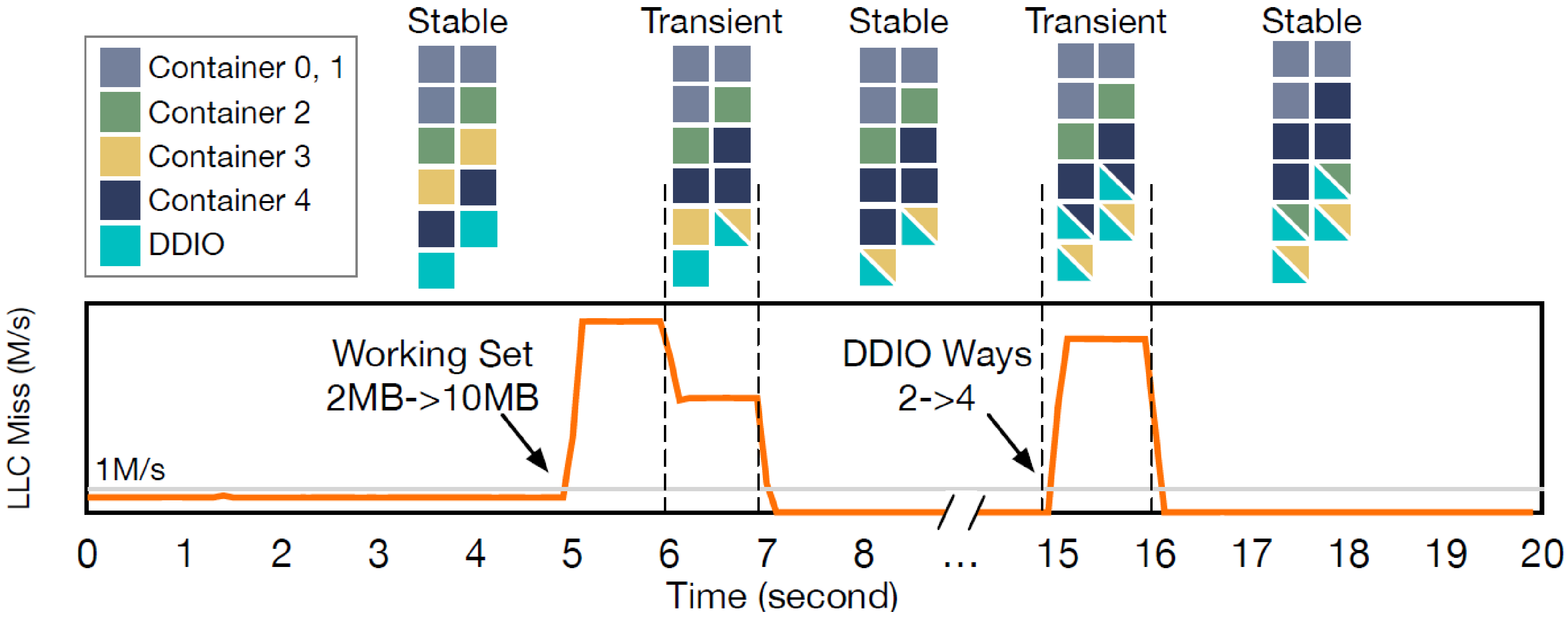

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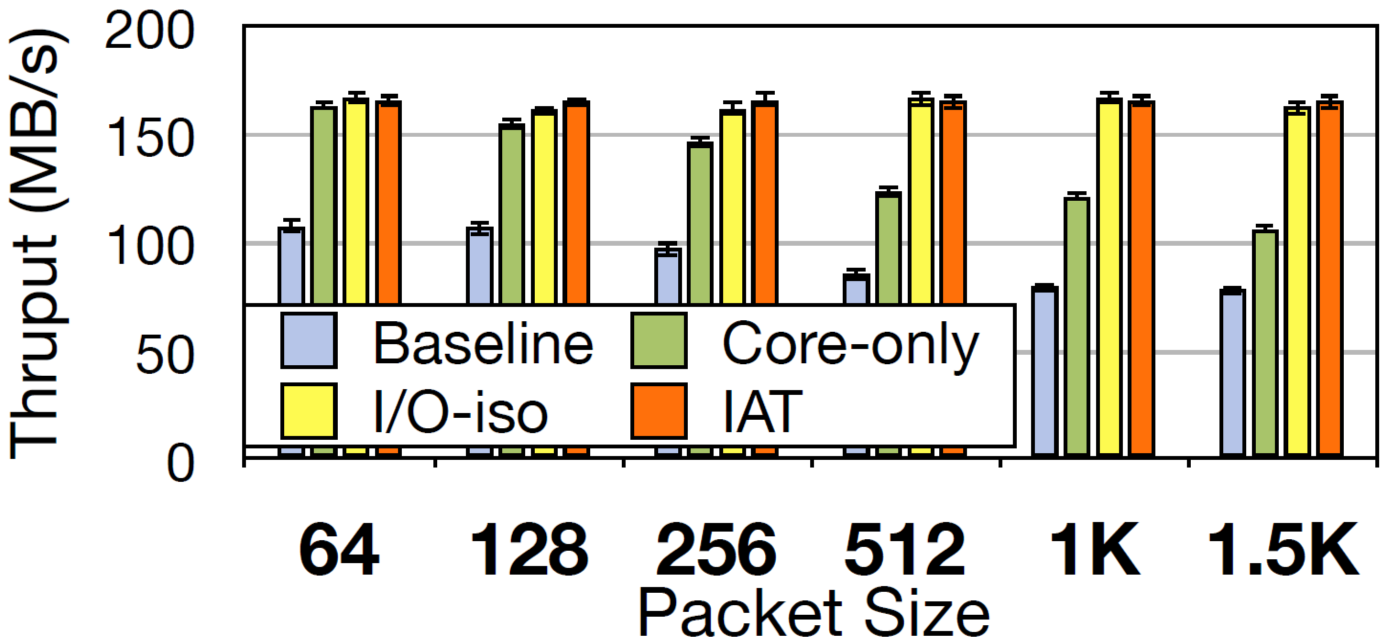

(a) Throughput between 5s and 15s.

IAT: Solving Latent Contender Problem

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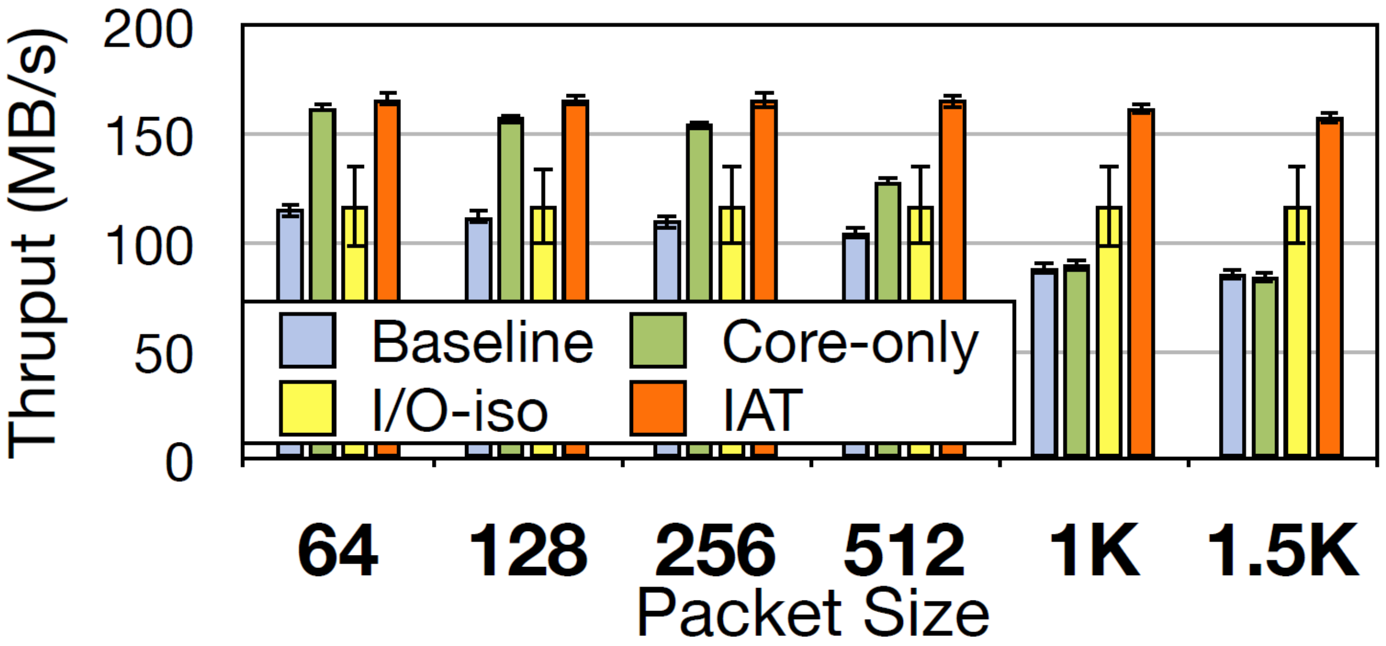

(c) Throughput after 15s.

IAT: Overhead

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○ Implemented as user – space daemon in Ubuntu

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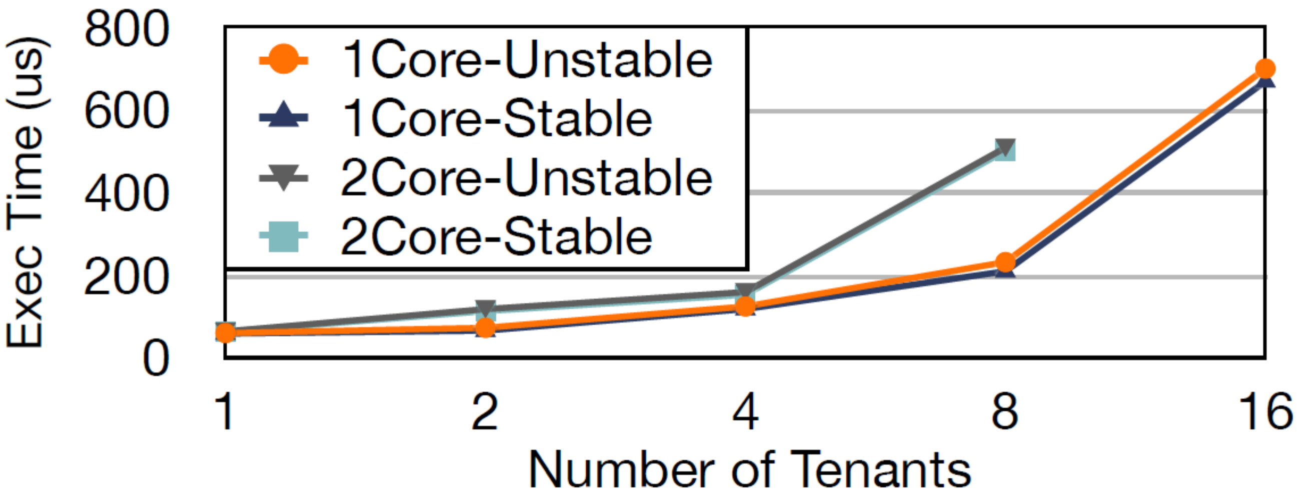

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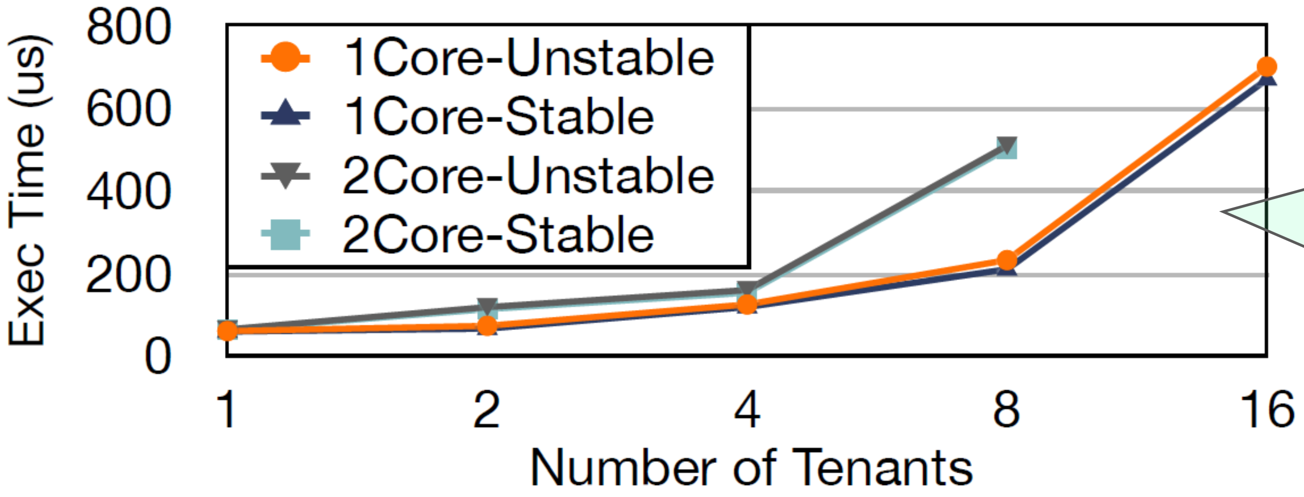

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Conclusion

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- Both the problems, Leaky DMA and Latent Contender, are solved by IAT
- IAT reduces interference caused by DDIO with negligible overhead

Questions ?

Thank You