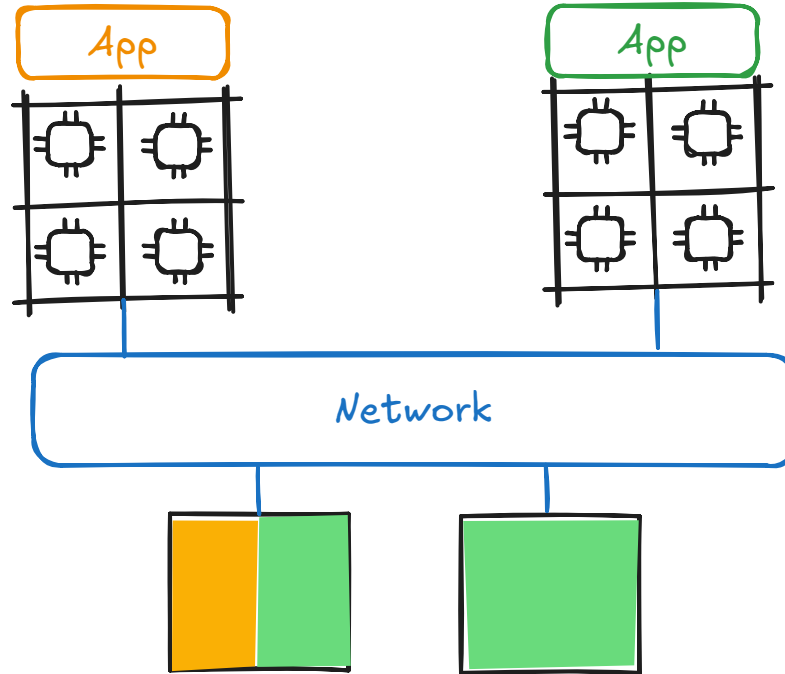


OS Memory Tiering

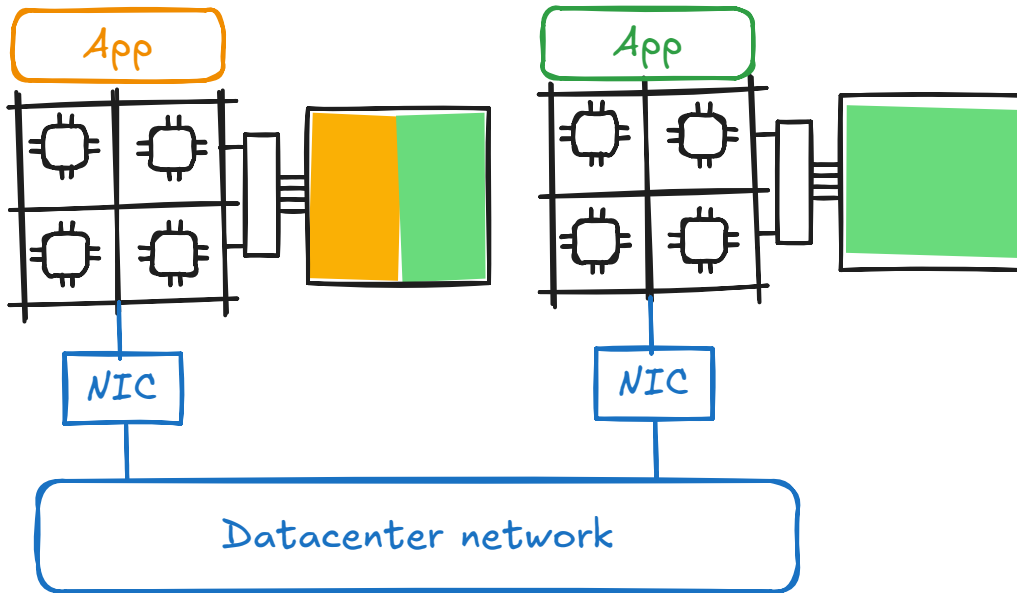
CS592: Datacenter Memory Systems, Fall 2026



Last class: Memory disaggregation vision

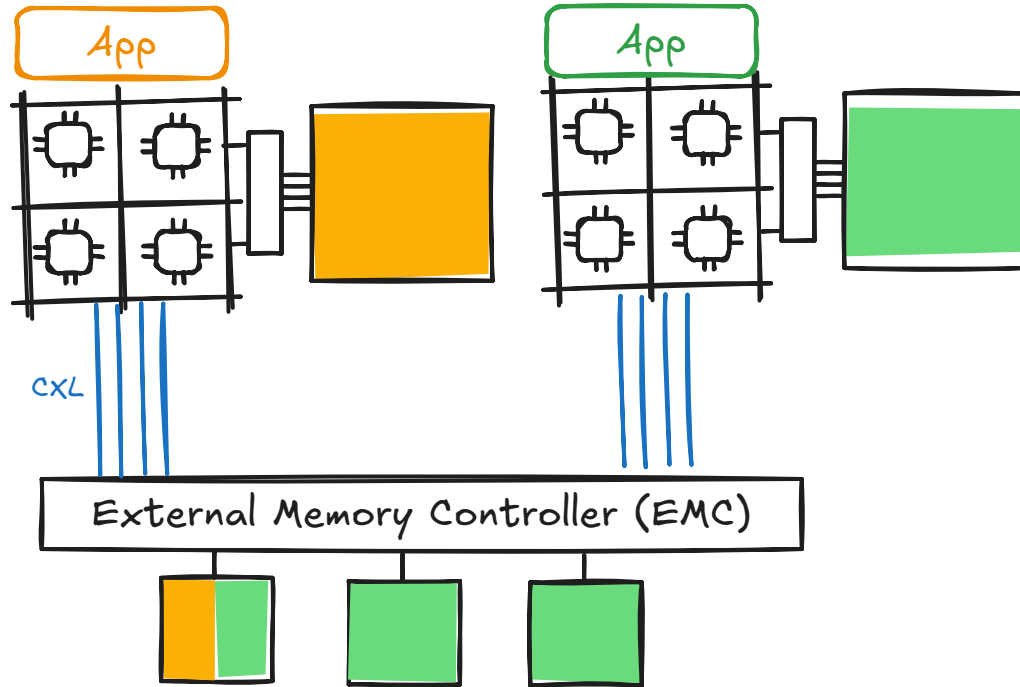


Last class: Swap-based memory disaggregation

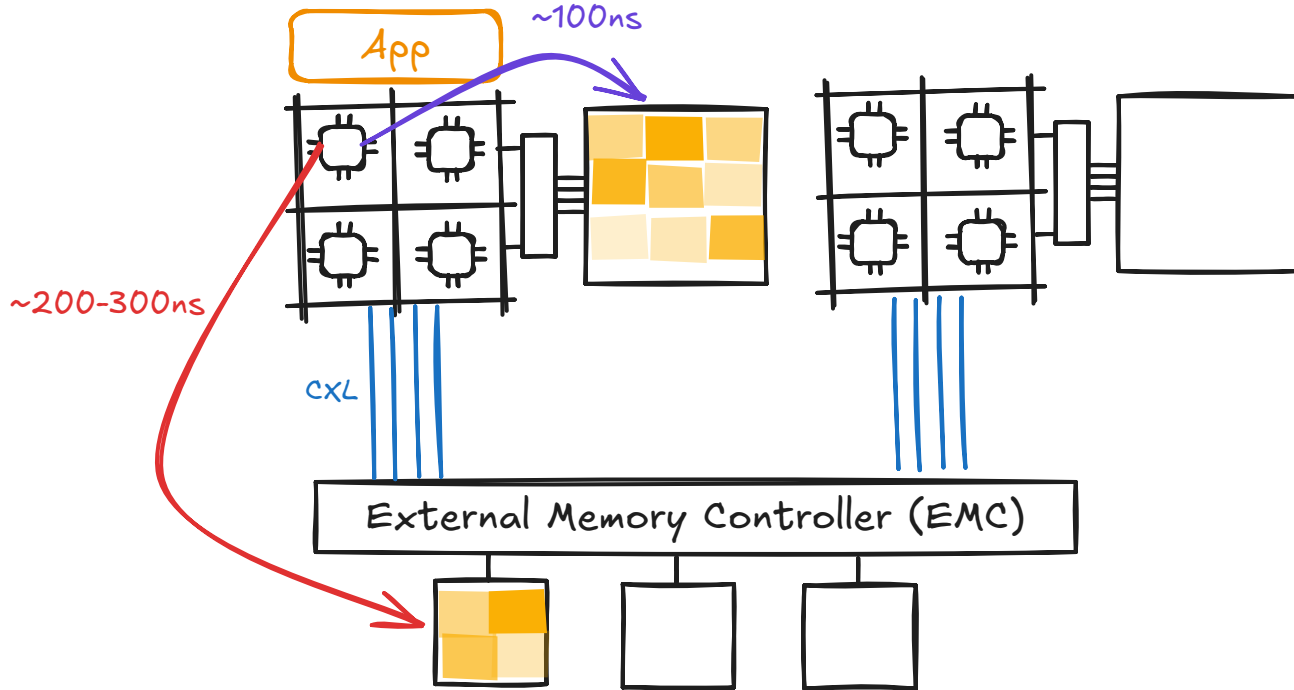


Problem?

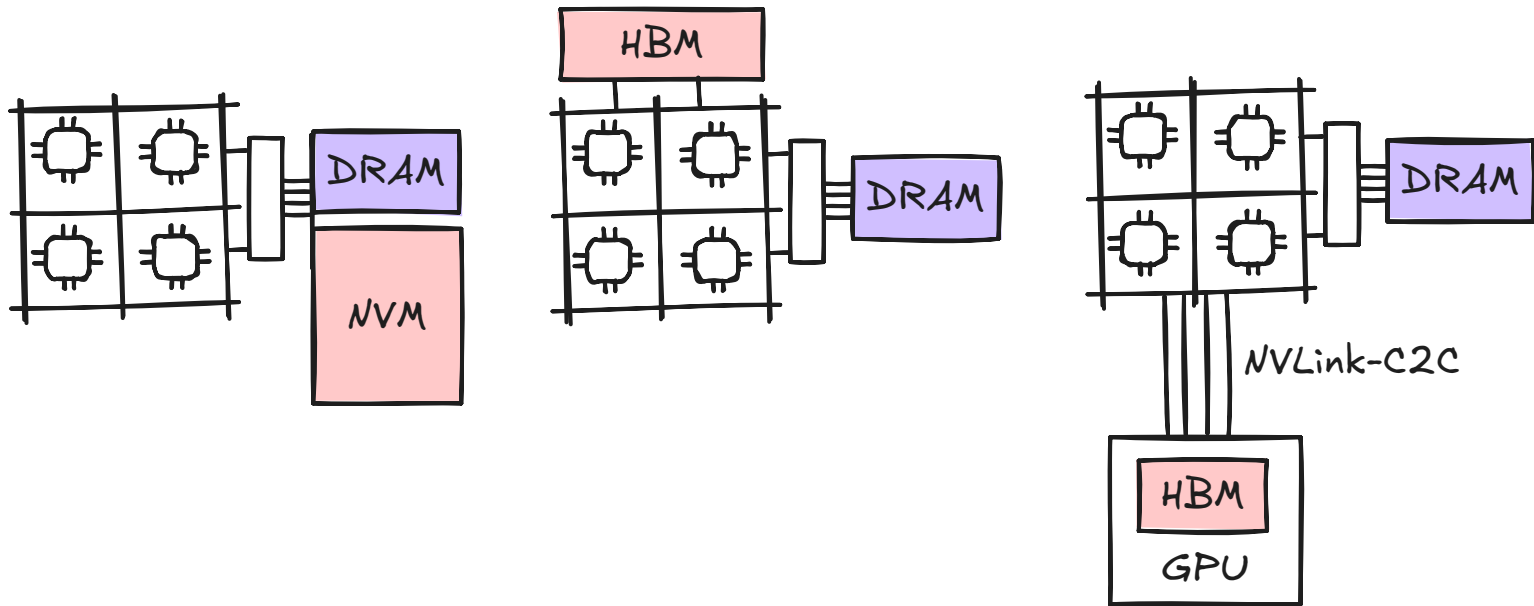
Last-class: CXL-based memory disaggregation



Data placement critically impacts app performance

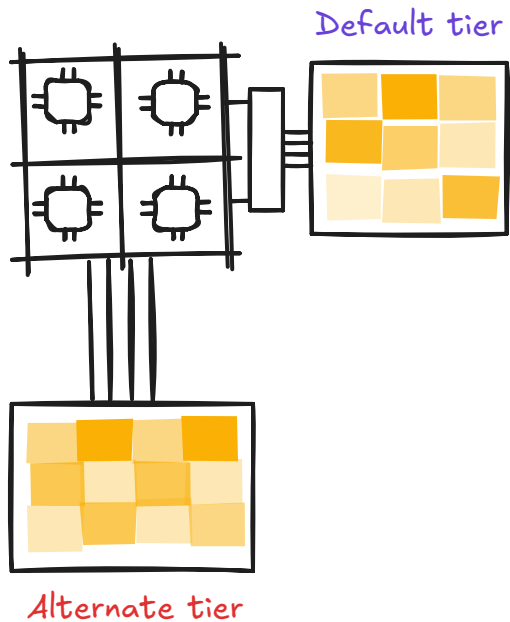


Data placement problem is more general



Processor has access to different "memory tiers"

OS Tiered Memory Management



Memory tiers

Cache-coherent access via load/store

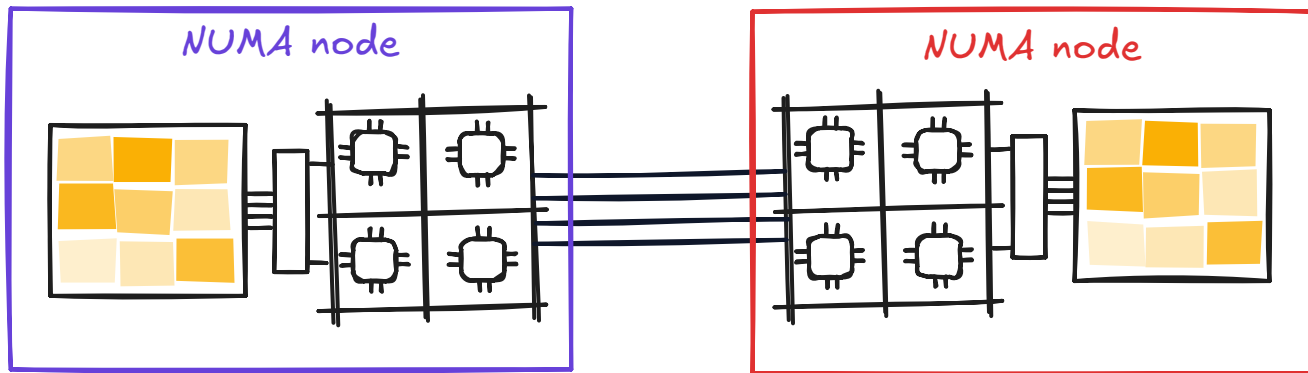
Uniform memory consistency semantics

Different performance (latency, bandwidth)

Goal

Transparently adapt data placement
to maximize application performance

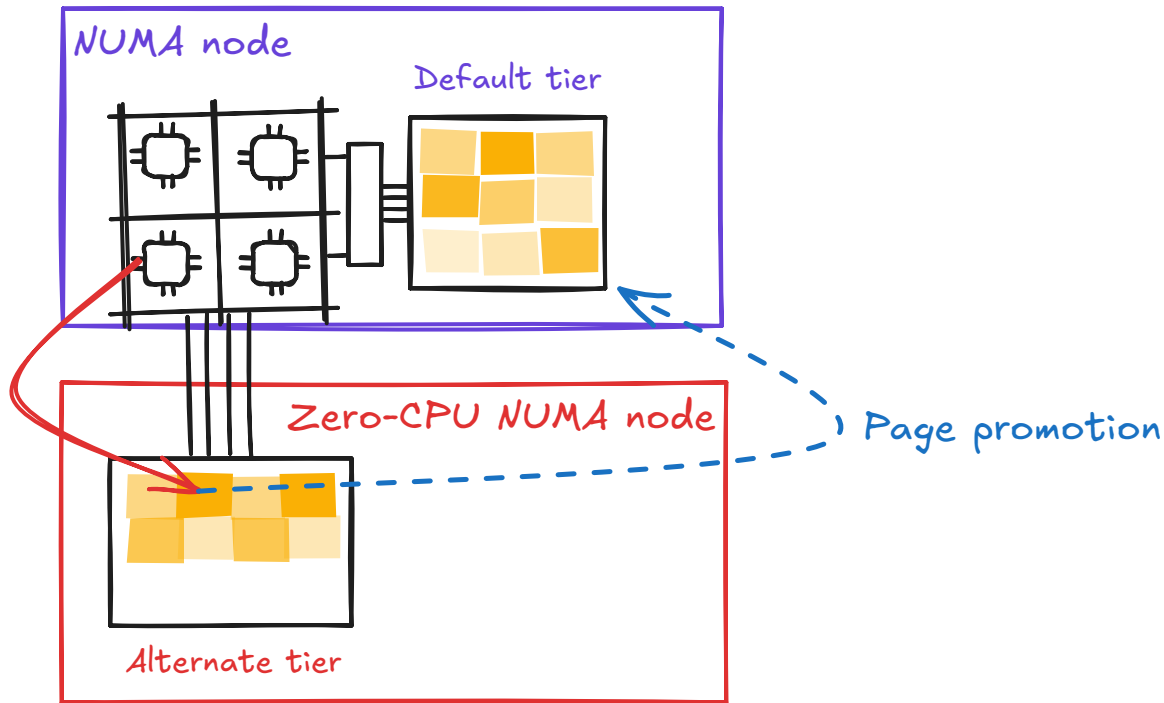
Recap: NUMA memory management



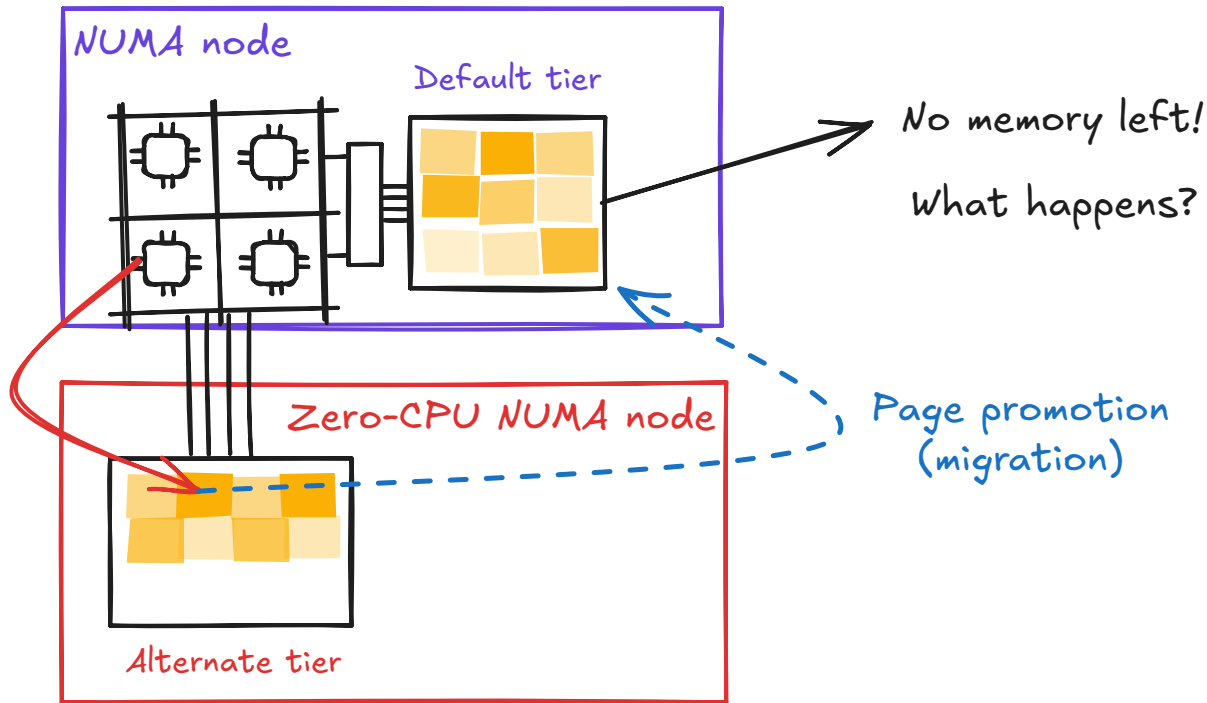
Mechanisms: Access tracking, page migration

Policies: When to migrate? Which pages to migrate?

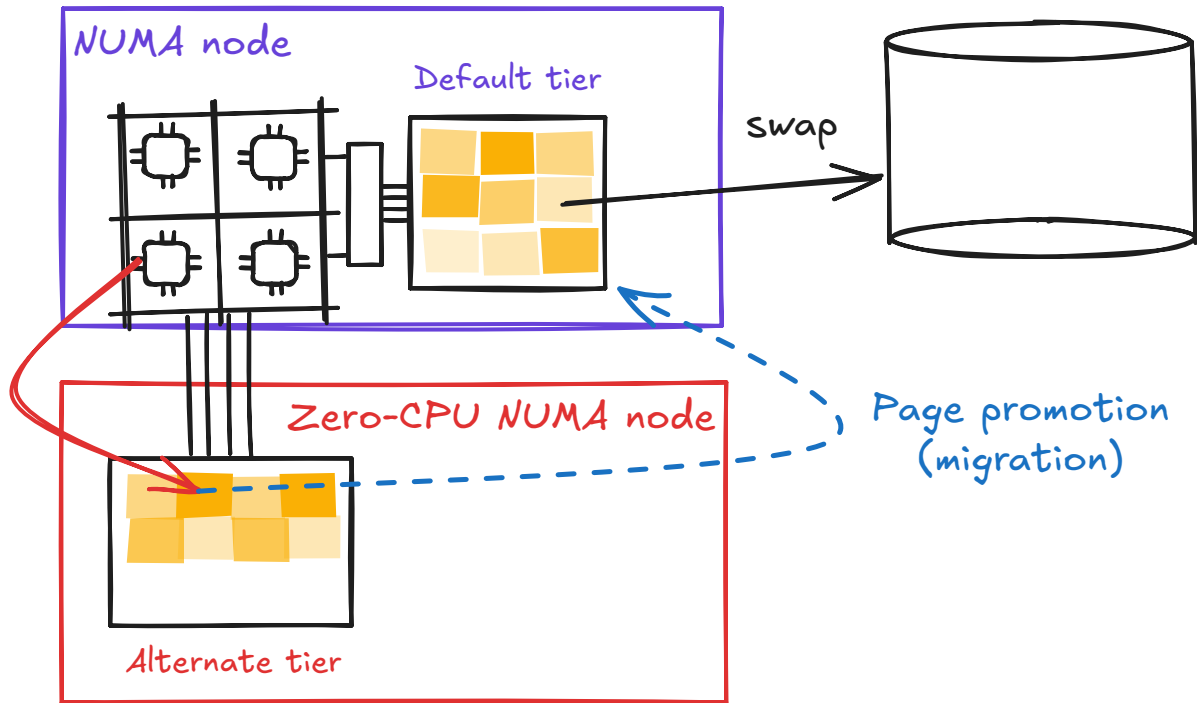
Why not just use NUMA memory management?



Why not just use NUMA memory management?



Why not just use NUMA memory management?



TPP [ASPLOS'23]

TPP: Transparent Page Placement for CXL-Enabled Tiered-Memory

Hasan Al Maruf
University of Michigan
USA

Hao Wang
NVIDIA
USA

Abhishek Dhanotia
Meta Inc.
USA

Johannes Weiner
Meta Inc.
USA

Niket Agarwal
NVIDIA
USA

Pallab Bhattacharya
NVIDIA
USA

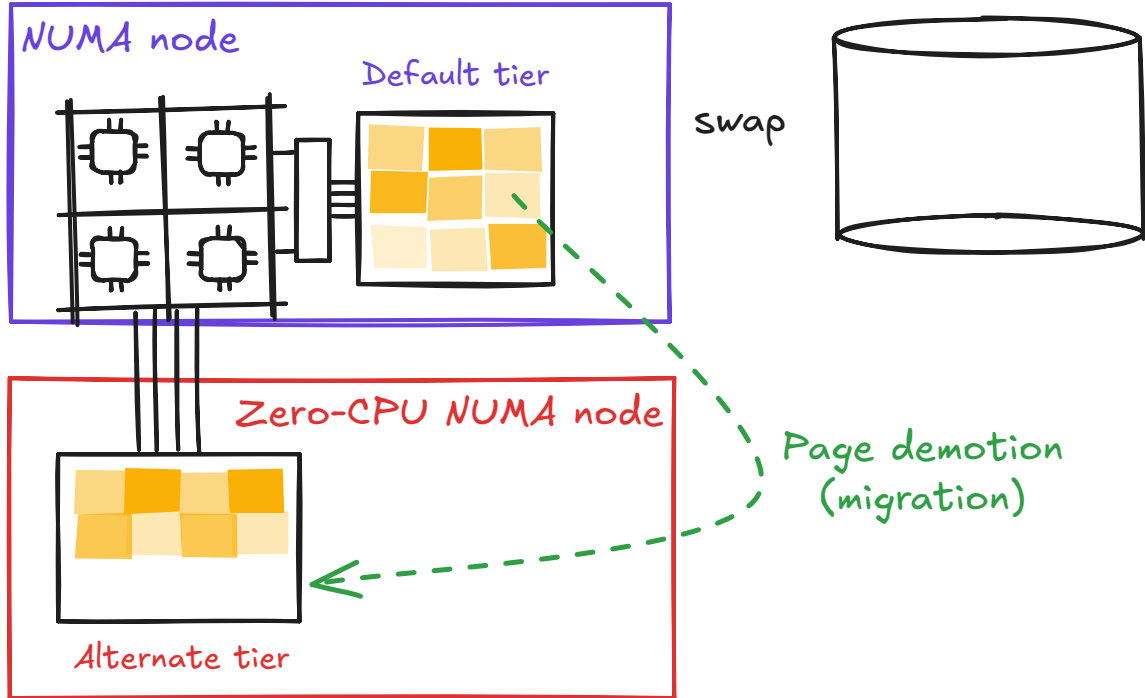
Chris Petersen
Meta Inc.
USA

Mosharaf Chowdhury
University of Michigan
USA

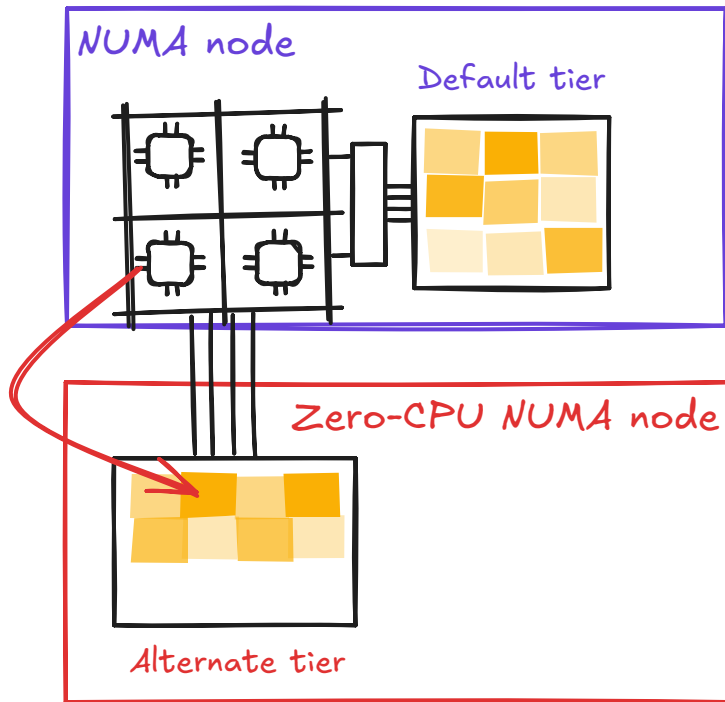
Shobhit Kanaujia
Meta Inc.
USA

Prakash Chauhan
Meta Inc.
USA

TPP: Page demotion



TPP: Access tracking



Identifying cold pages

Page access bits

LRU lists

Active 

Inactive 

Identifying hot pages

Hint page faults

TPP: Other aspects

Decoupling allocation and reclaim watermarks

Page type aware allocation

Thoughts on TPP paper?

HeMem [SOSP'21]

HeMem: Scalable Tiered Memory Management for Big Data Applications and Real NVM

Amanda Raybuck

The University of Texas at Austin

Tim Stamler

The University of Texas at Austin

Wei Zhang

Microsoft

Mattan Erez

The University of Texas at Austin

Simon Peter

The University of Texas at Austin

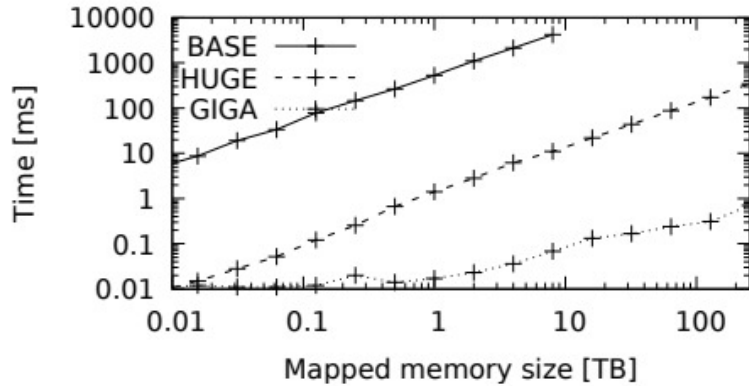
HeMem key contributions

Access tracking via memory access sampling

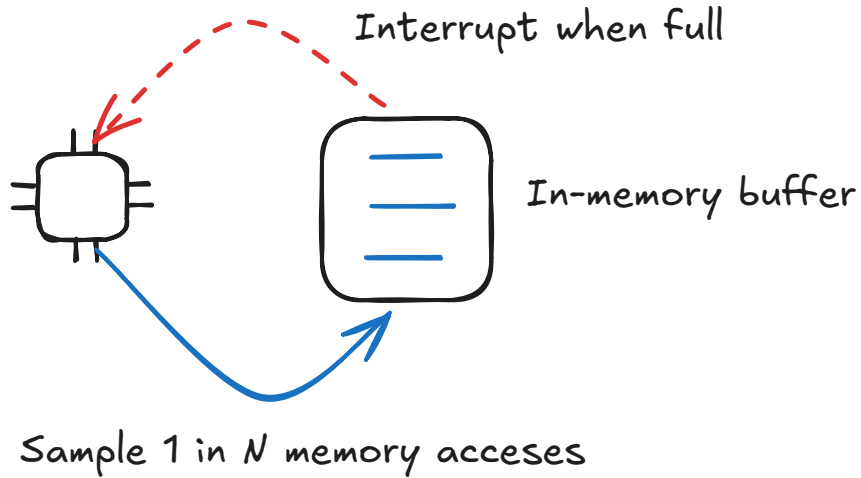
Page migration using DMA engines

Userspace implementation

HeMem access tracking motivation



HeMem: PEBS-based access tracking



HeMem: Page migration using DMA engines

HeMem: Userspace implementation

