Building a Distributed Database on a CXL Pod: Synchronizing Data Accesses without Networks

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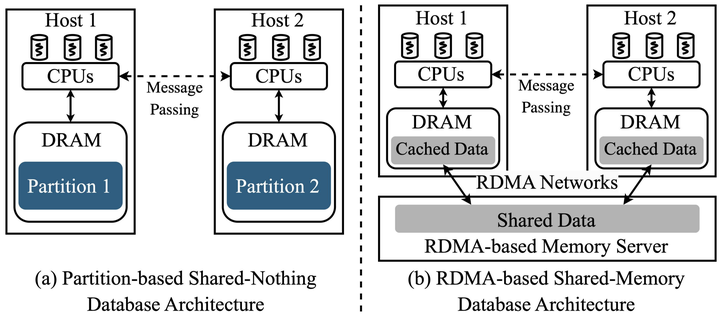
Motivation

How to scale a single-node DB to multiple nodes?

Existing work synchronize data accesses via networks, leading to numerous message exchanges and inevitable overhead



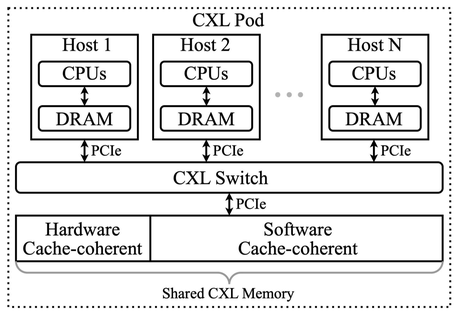
(a) Partition-based Shared-Nothing Database Architecture

(b) RDMA-based Shared-Memory Database Architecture

- (a) Partition-based Shared-nothing Architecture
  - sends messages for synchronization (e.g., 2PC)
  - bad for non-partitionable workloads
- (b) RDMA-based Shared-memory Architecture
  - uses one-sided RDMA
  - suffers from the high latency of RDMA

A New Opportunity: CXL Pod

- A collection of hosts connected to a shared CXL memory device
- Hardware-based cache coherence across hosts
- Better performance than RDMA



Sync over Memory >>> Sync over Network

- Sync over memory: shared data structure + atomic operations
- Sync over network: message passing with multiple roundtrips

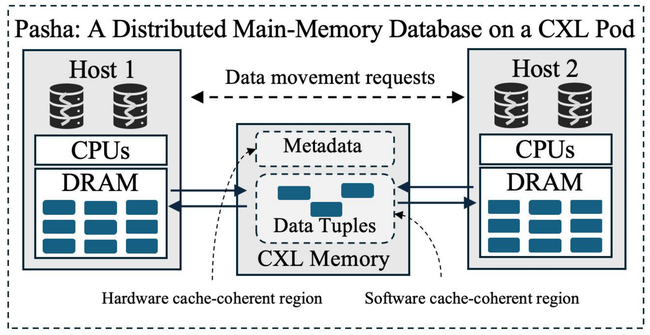
But CXL Memory has Limitations...

1. Limited hardware cache-coherence across hosts
2. 2-4× higher latency than local DRAM

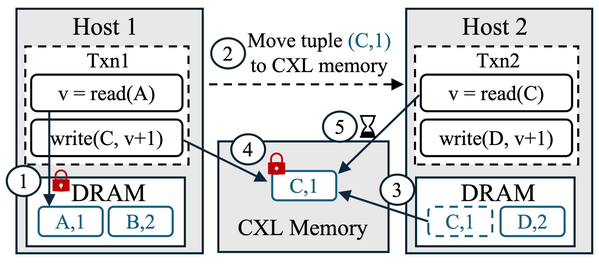
Key Insight

We only need to maintain CAT in CXL memory
(CAT: Cross-host Active Tuples)

Design & Example



- Initially, data is partitioned and stored in local DRAM
- Tuples are moved in upon requests and moved out based on policies
- Use software cache-coherence for data to reduce data movement
- Adopt 2PL and enhance it to efficiently coordinate concurrent accesses

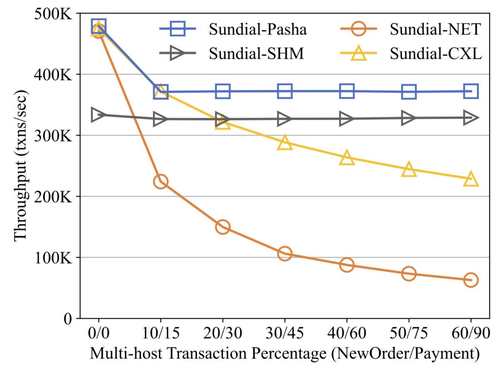


Evaluation

- Experiment Setup
  - Use VMs and a CXL 1.1 memory module for CXL pod emulation
  - Use SR-IOV to emulate Ethernet

Component	Description
OS (Kernel)	Ubuntu 22.04.2 LTS (Linux kernel v5.19)
CPU (Intel SPR)	2× Intel® Xeon 8460H CPUs @2.2 GHz [42] 40 cores and 105 MB LLC per CPU
RAM	8× DDR5-4800 channels on each socket (16 in total) 1× DDR5-4800 CXL memory with PCIe 5.0 ×8
NIC	ConnectX-6, 100 Gbps (MCX653106A-ECAT)

- Prototype and Baselines
  - Sundial-Pasha - Pasha prototype based on Sundial
  - Sundial-NET - Sundial using network as a transport
  - Sundial-CXL - Sundial using CXL as a transport
  - Sundial-SHM - Sundial adopting a shared-memory architecture
- TPC-C with different percentages of distributed transactions



- YCSB (RW = 1:1, uniform distribution) with different percentages of distributed transactions