Far Atomic Memory Operations in gem5

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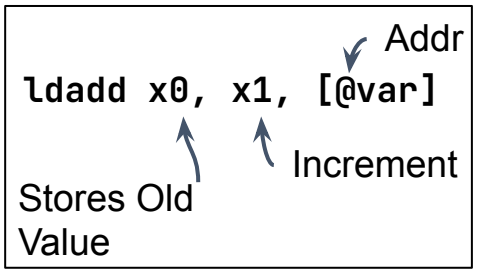
Agenda

- Introduction
- Far AMO in AMBA 5 CHI
- gem5 updates and tuning options
- Next steps

Introduction - Atomic Memory Operation (AMO)

- **AMOs**: enable programmers to develop shared memory parallel applications
  - Play a **central role** in:
    - Synchronization primitives
    - Lock-Free data structures
    - Updates to shared data

```
Atomic {
    var++;
}
```

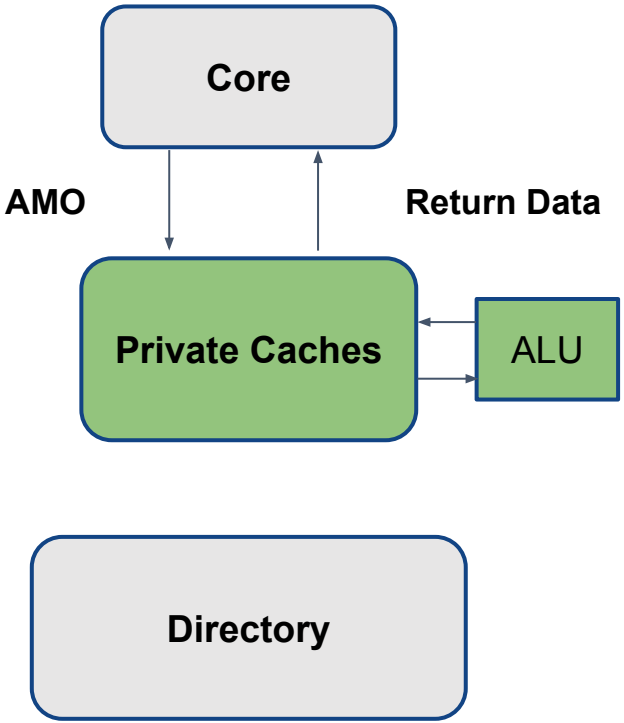


Introduction - Atomic Memory Operation (AMO)

- Different Operations:
  - SWP - Swap
  - CAS - Compare-and-Swap
  - LDADD - Fetch-and-Add
  - LDEOR - Fetch-and-XOR
  - LDCLR - Fetch-and-NAND
  - LDSET - Fetch-and-OR
  - LDUMIN - Fetch-and-Unsigned-Minimum
  - LDSMAX - Fetch-and-Signed-Maximum

Near and Far AMOs

- Two fundamental AMO execution mechanisms exist:
  - Near AMOs
  - Execute the operation in the private levels of cache



Near and Far AMOs

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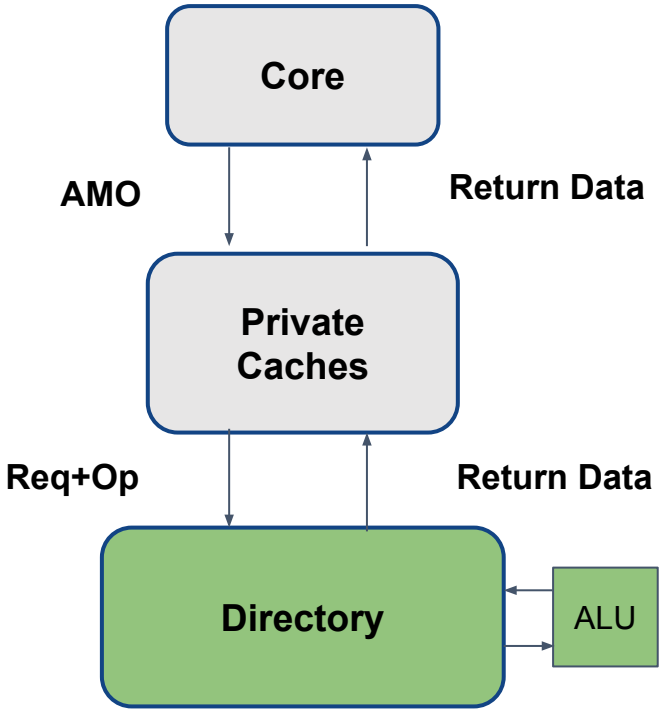


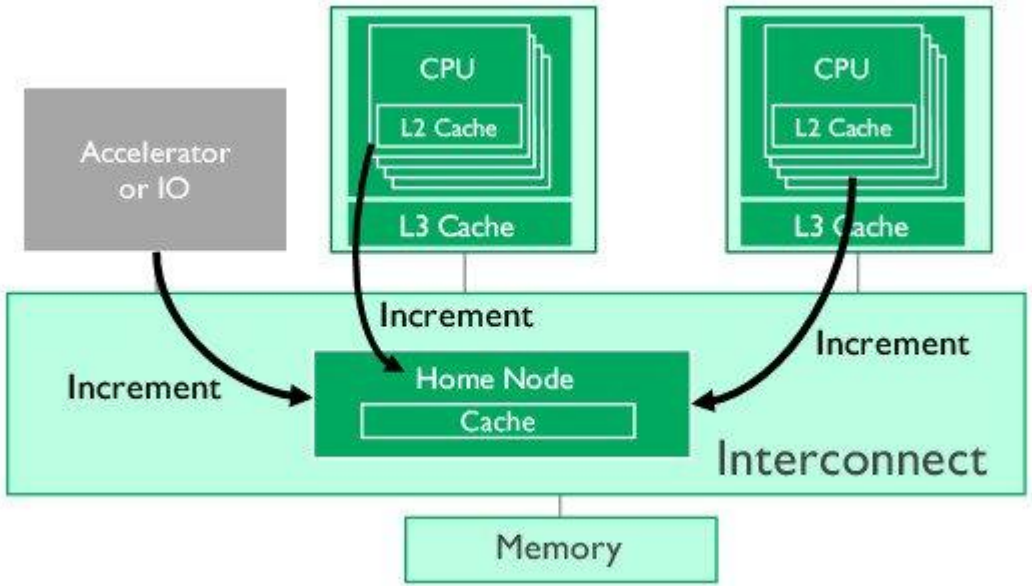
  - Far AMOs
  - Execute the operation in the directory

Introduction - gem5's CHI

- **Arm's CHI** (Coherent Hub Interface) latest NoC architecture
- Targets high performance and scalability
- MESI and MOESI cache models
- Fully parameterized Ruby implementation **available since gem5-21.0**

Specs that support Near and Far AMOs

- Recent Arm's AMBA 5 CHI includes support for both operations

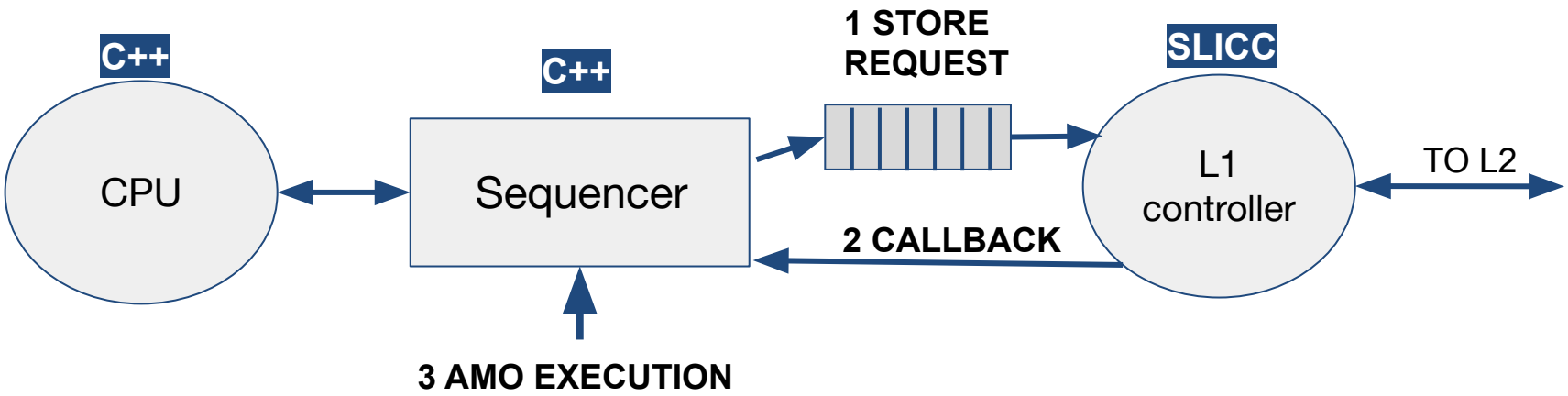


Introduction - gem5's CHI

- **Arm's CHI** (Coherent Hub Interface) latest NoC architecture
- Targets high performance and scalability
- MESI and MOESI cache models
- Fully parameterized Ruby implementation **available since gem5-21.0**
  - **Partially supported *near* AMOs**
  - **No support for *far* AMOs**

Introduction - Atomic Memory Operations in Ruby

- Current gem5 implementation of Ruby treats AMOs as **stores**
- AMOs are executed in the Sequencer



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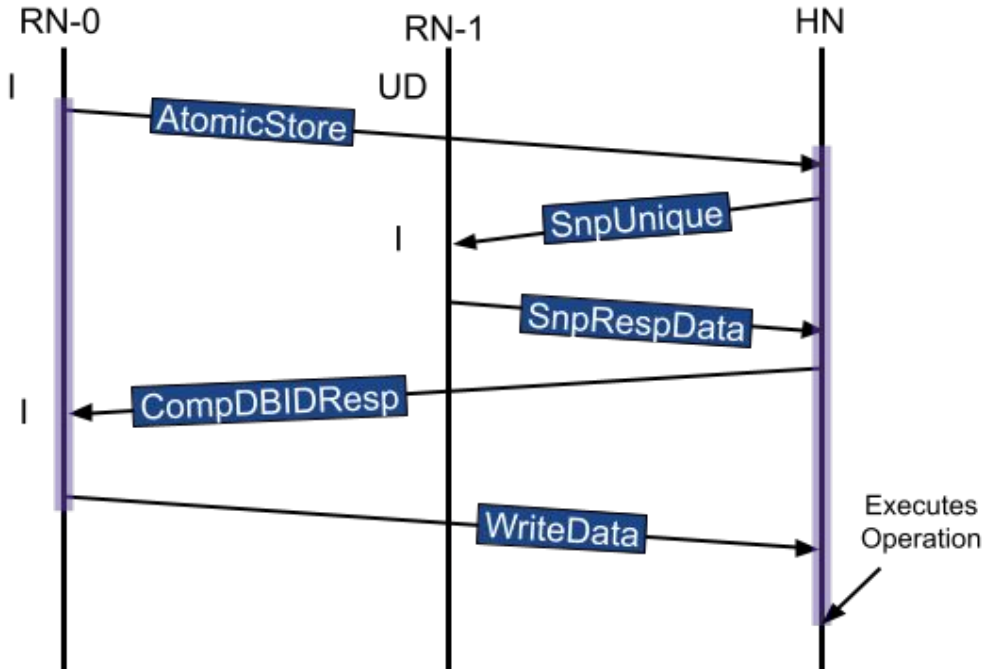
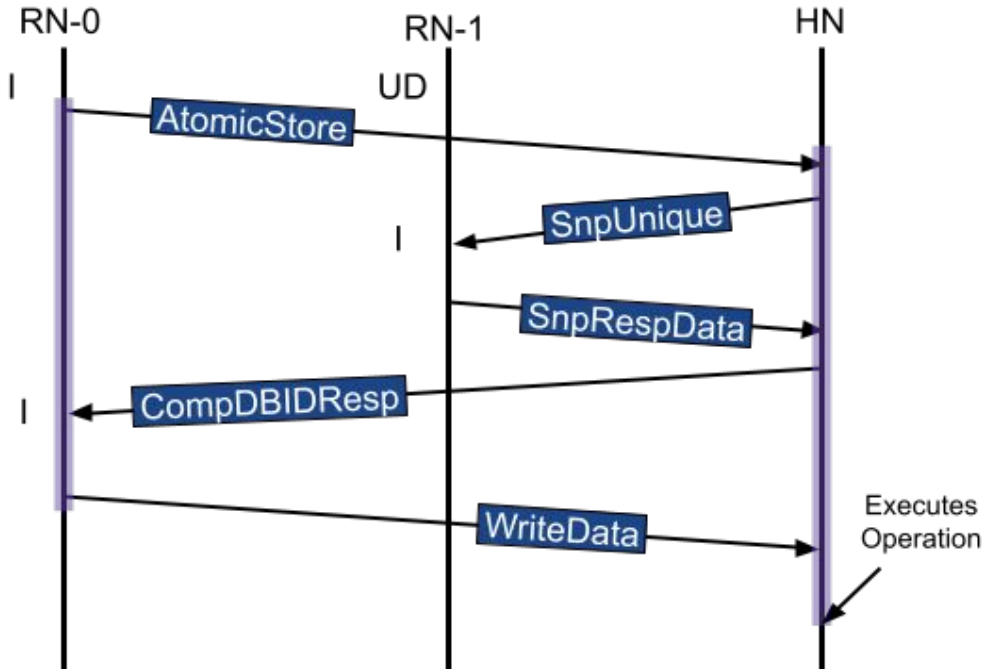
Introduction - AMBA 5 CHI Far AMOs

- Far AMOs delegate op and data to the directory
  - RN - Core, L1, and L2
  - HN - Directory (Optionally L3)



Introduction - AMBA 5 CHI Far AMOs

- Far AMOs delegate op and data to the directory
- Comprises 3 mandatory messages:
  - Request (AtomicStore)
  - Ack (CompDBIDResp)
  - Operand (WriteData)



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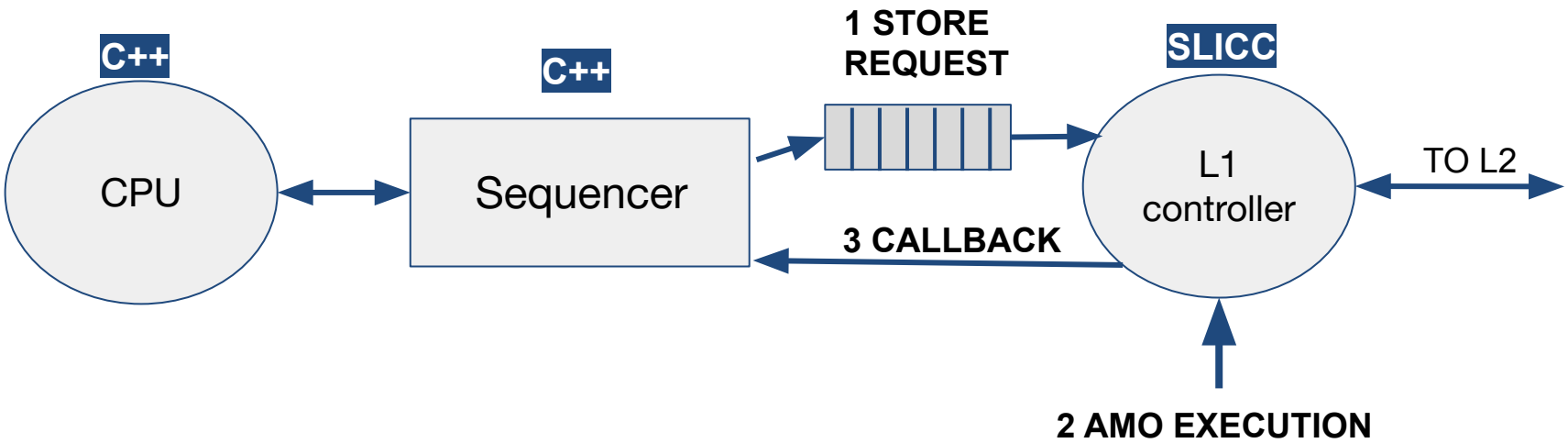
Introduction - Atomic Memory Operations in Ruby

- Near AMOs are executed in the L1 Controller
- We model a variable AMO latency



Static AMO Policies

- For each cache state AMOs can either be executed ***Near*** or ***Far***
- **Graviton 3 (Arm Neoverse Arch.)** implements **All Near** and **Unique Near** static policies
- We include Present Near, our policy that outperforms All Near and Unique Near

Policy Name	UC	UD	SC	SD	I
All Near	N	N	N	N	N
Unique Near	N	N	F	F	F
Present Near	N	N	N	N	F

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Next Steps

- **Accepted paper at ISCA'23:**
  - **DynAMO: Improving Parallelism Through Dynamic Placement of Atomic Memory Operations**
  - **Session 1B: CPU Microarchitecture**

Next Steps

- Far AMOs available in gem5:
  - We are preparing a patch to main branch
  - To appear in gem5 23.1 at the end of the year

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Thanks