Integrating External Resources into Legion

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Motivation

- Legion assumes a “closed world”

- But, applications need to interact with external data
  - e.g., files, checkpoints, databases

- Challenge
  - external interactions are expensive: the data is often huge

Motivation

- Original solution
  - Ask users to manage external I/O at application level
  - Access external data within Legion tasks
- Performance issues
  - Block computing threads, hard to hide I/O latency, hard to control resource utilization
- Correctness issues
  - Manually control external data consistency at application level

Approach

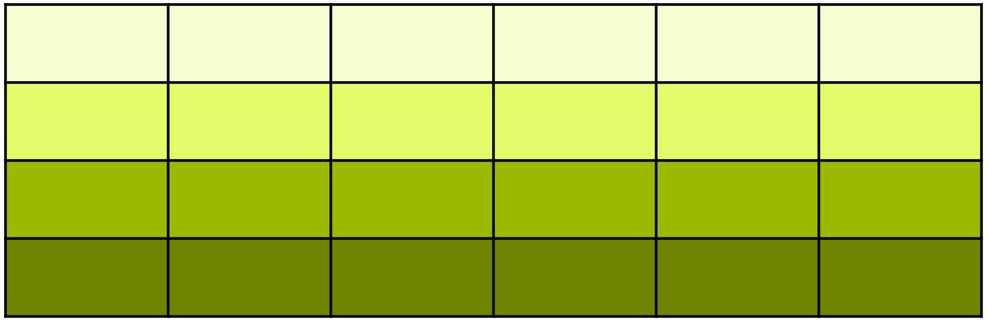
- Define semantics for external resources in Legion
  - Correctness: Legion guarantees consistency and preservation of dependencies
  - Performance: runtime automatically performs external I/O optimizations

- Idea: Integrate external resources by mapping them to regions => attach operation

Attach Operation

- **Attach external resource to a region**
  - **Normal files, formatted files (HDF5), opaque data structures**

```
PhysicalRegion attach_hdf(
        const char *filename,
        LogicalRegion lr,
        const std::map<FieldID,const char*> &fieldmap,
        AccessMode mode);
```

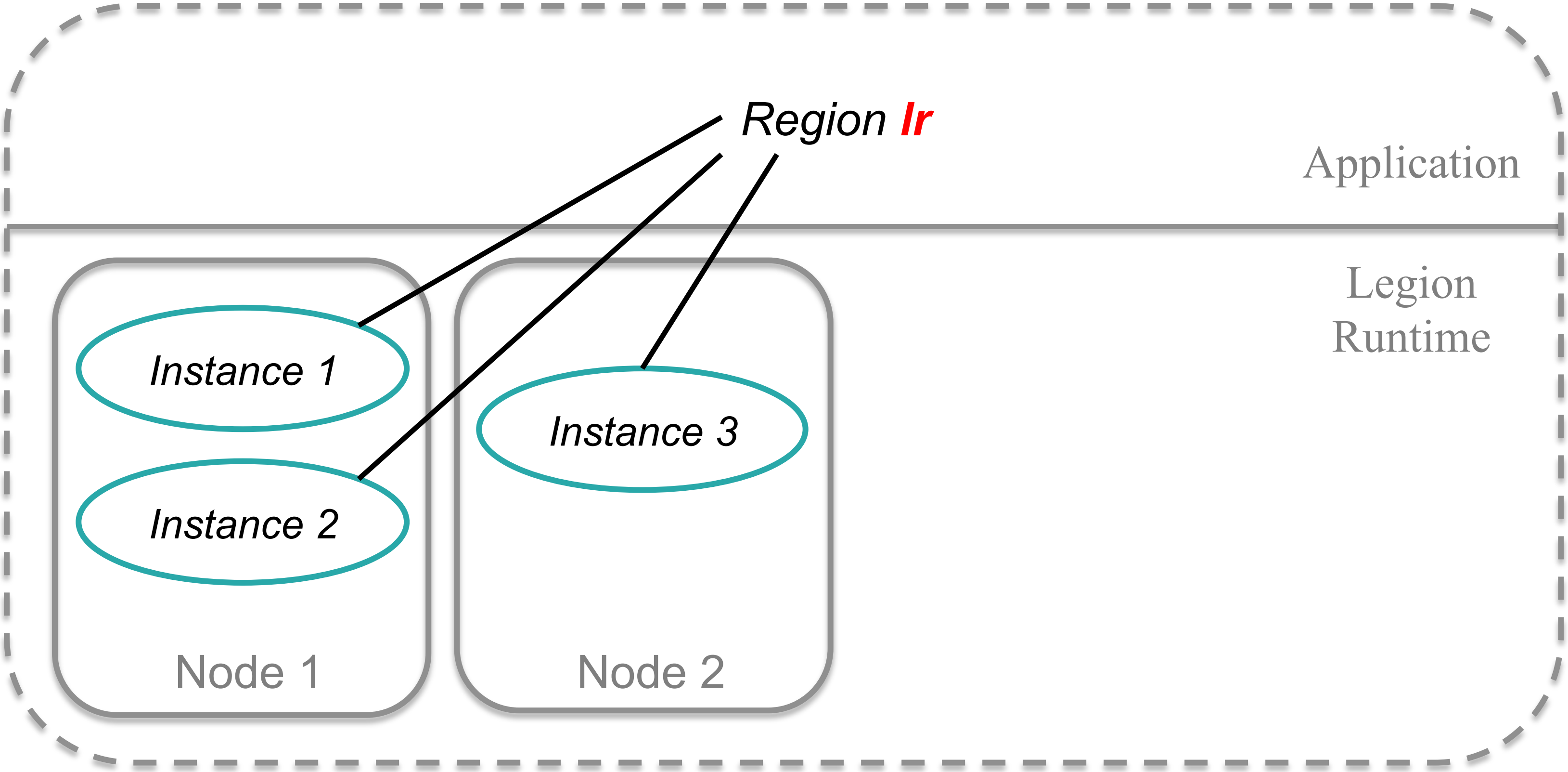


IndexSpace ⇔ HDF DataSpace

Fields ⇔ HDF Datasets

Attach Operation

- Semantics
  - Invalidate existing physical instance of *lr*
  - Maps *lr* to a new physical instance that represents external data (no external I/O)



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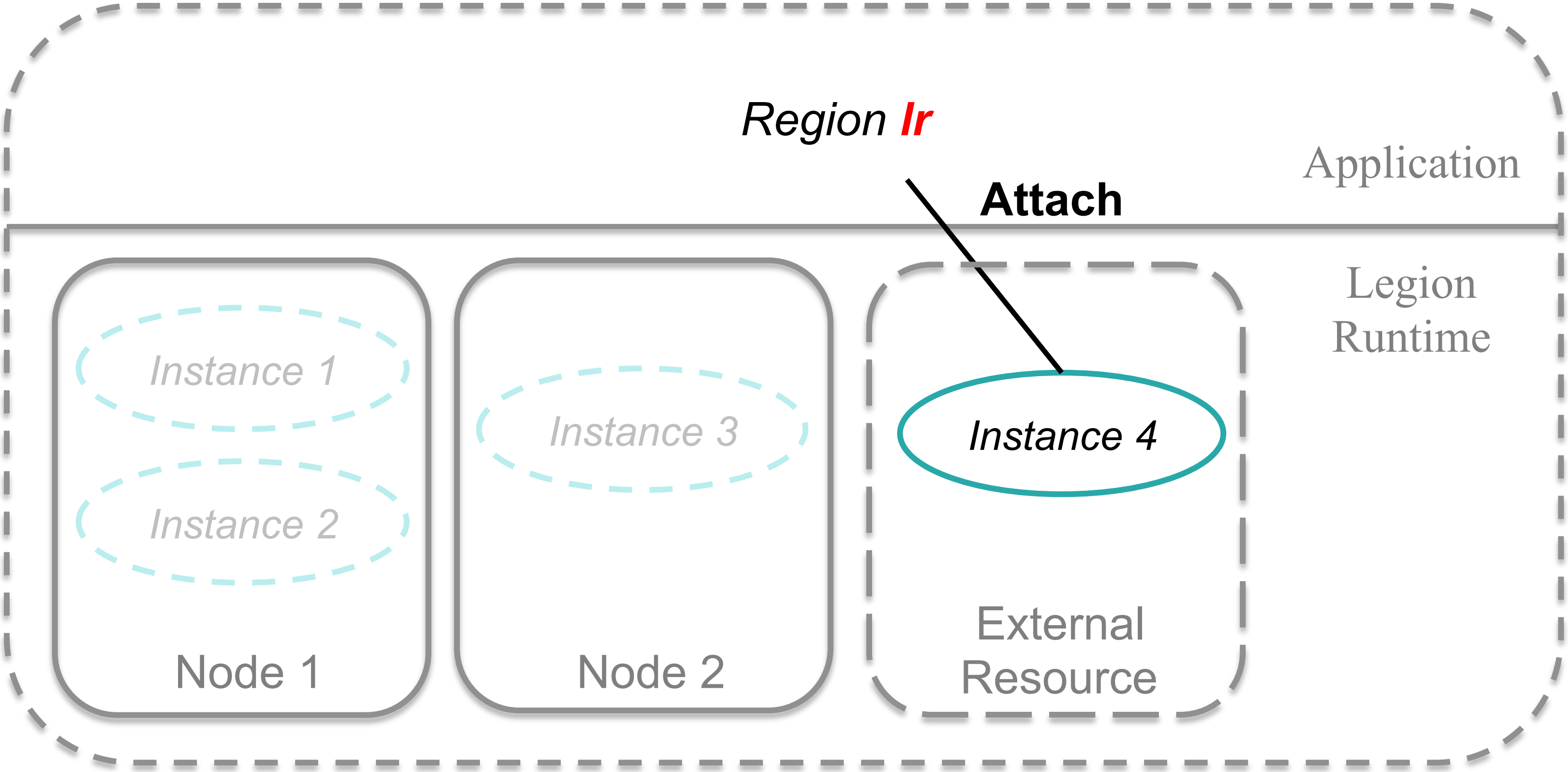


Attach Operation

- Attached region accessed using *simultaneous coherence*
  - Different tasks access the region simultaneously
  - Requires that all tasks must use the *only valid* physical instance

- *Copy restriction*
  - Simultaneous coherence implies tasks cannot create local copies
  - May result in inefficient memory accesses

- To address inefficiency => acquire/release

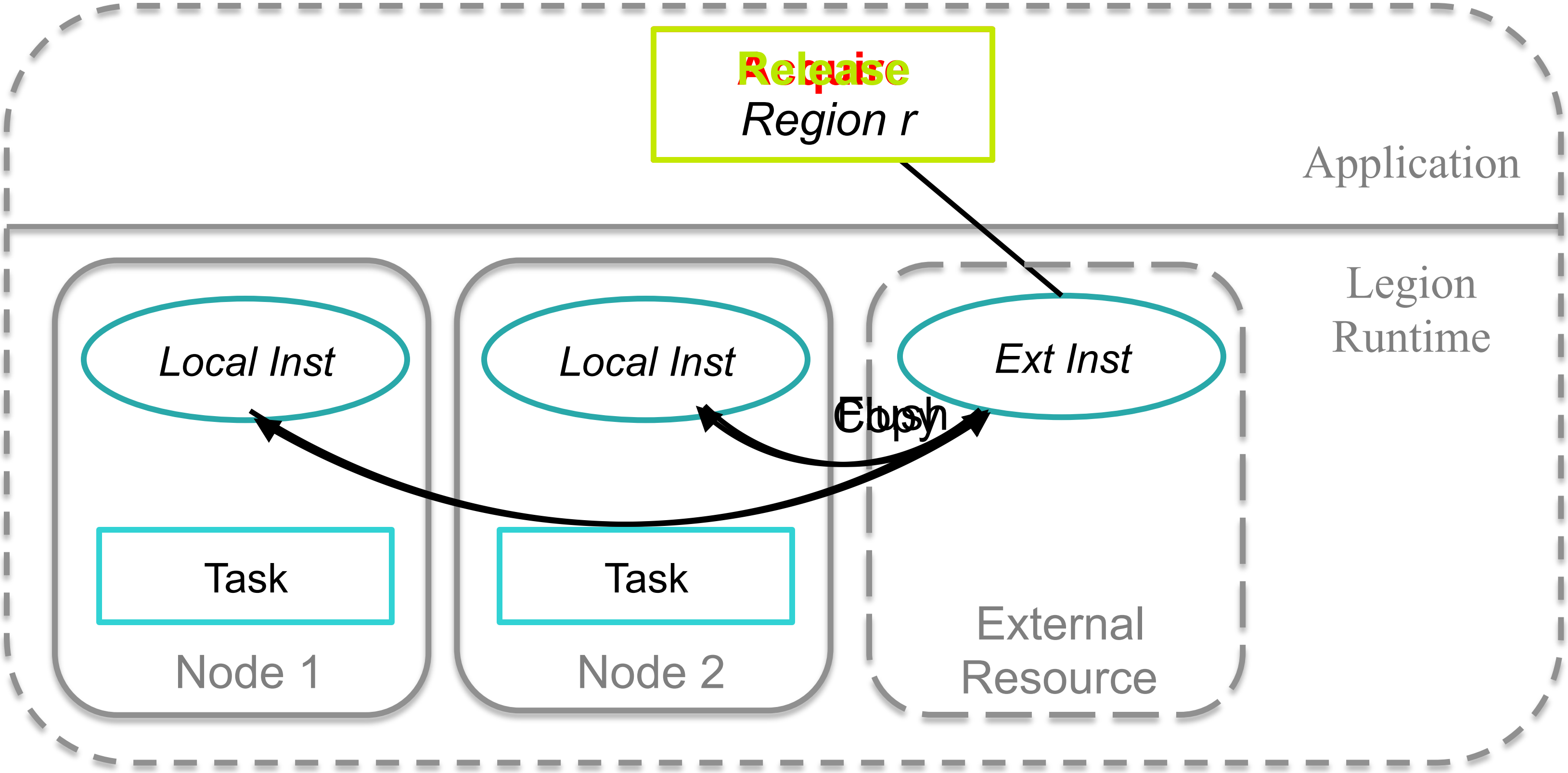
Acquire/Release

- Mechanism to notify Legion runtime when it is safe to allow local copies

- Acquire removes copy restriction
  - Can create a copy in any memory

- Release restores copy restriction
  - Invalidates all existing local copies
  - Flushes dirty data back to external resource

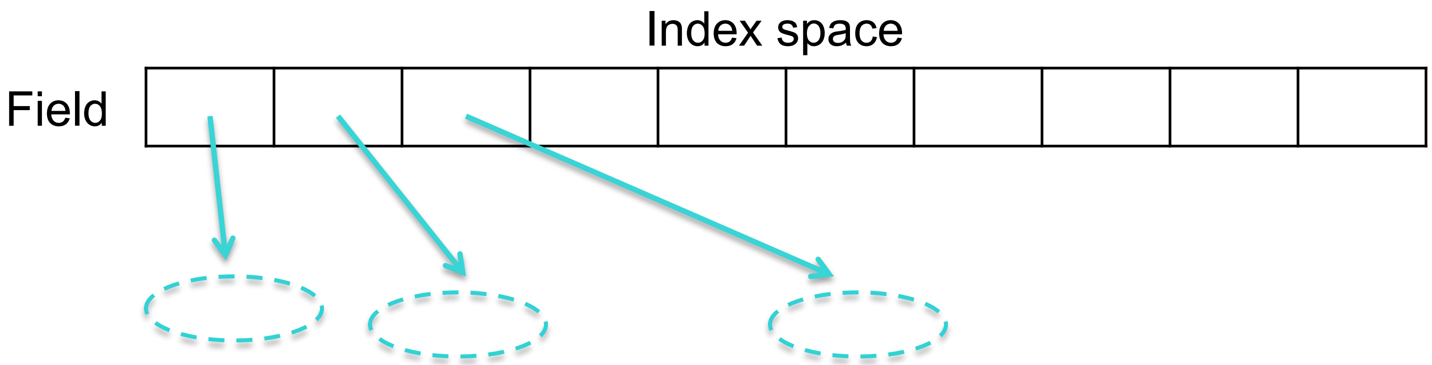
Acquire/Release Example



More on Attach Semantics

- Attach to in-memory opaque data structures
  - External data comes from other applications
  - Legion may not understand the data format

- User could attach opaque data structures to regions



  - Field holds pointers/refs to the opaque data structures

Custom SerDes

- **Bit-wise copy no longer work**
- **Legion requires custom SerDes methods for fields requiring non-trivial copies**
- **Users define a class with SerDes methods**

```
class SerDesObject {
    static size_t serialized_size(const FIELD_TYPE& val);
    static size_t serialize(const FIELD_TYPE& val, void *buffer);
    static size_t deserialize(FIELD_TYPE& val, const void *buffer);
    static void destroy(FIELD_TYPE& val);
}
```

- **SerDes registration is similar to reduction operation**

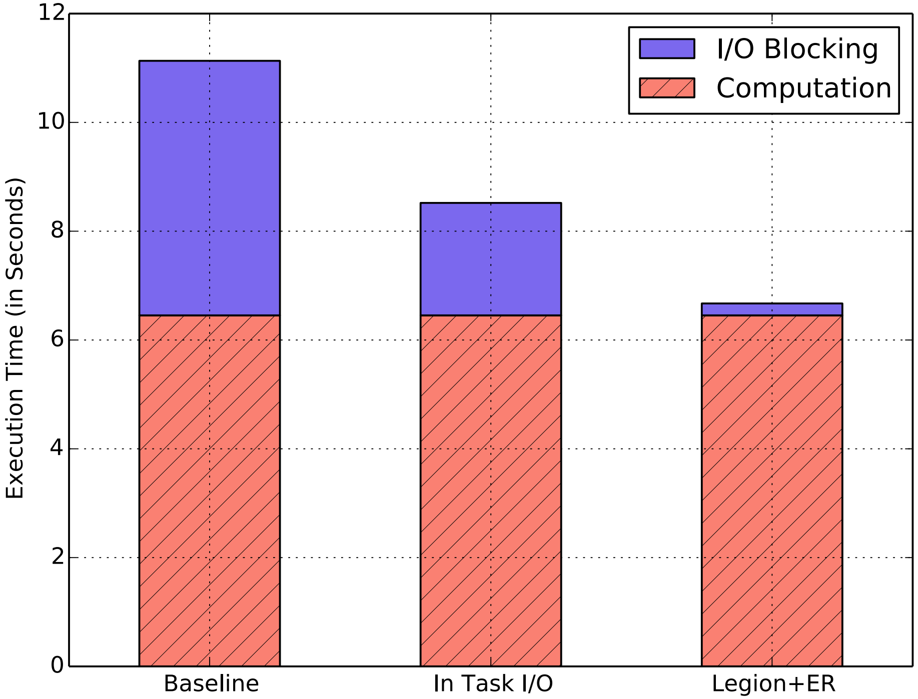
```
runtime->register_custom_serdes_op<SerDesObject>(serdes_id);
```

- **Specify SerDes methods when allocating fields**

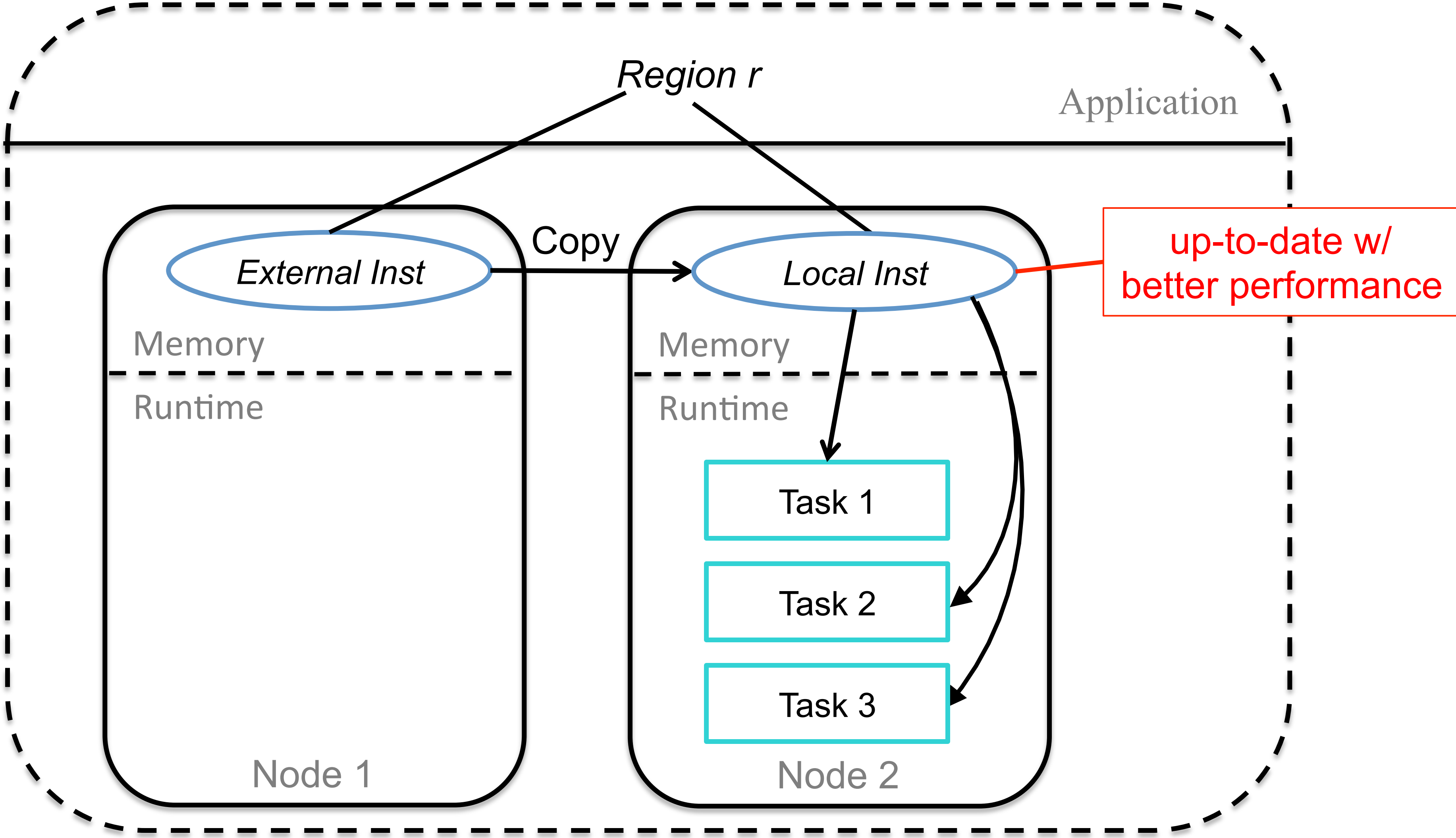
```
allocate_field(sizeof(FIELD_TYPE), field_id, serdes_id);
```

Optimization: Deferred Execution

- Legion runtime manages/reschedules external I/O
  - maximize resource utilization
  - overlap external I/O with computation
- Matrix multiplication
  - Load large input matrices from files on disk



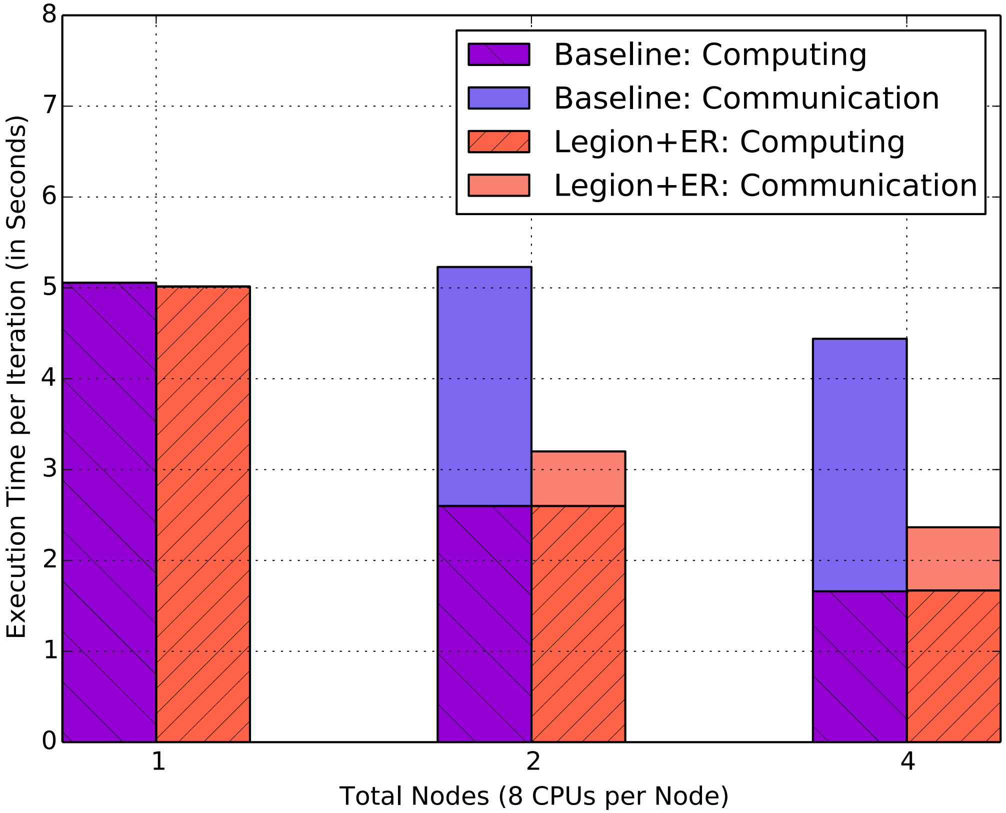
Optimization: Reduce Data Transfer



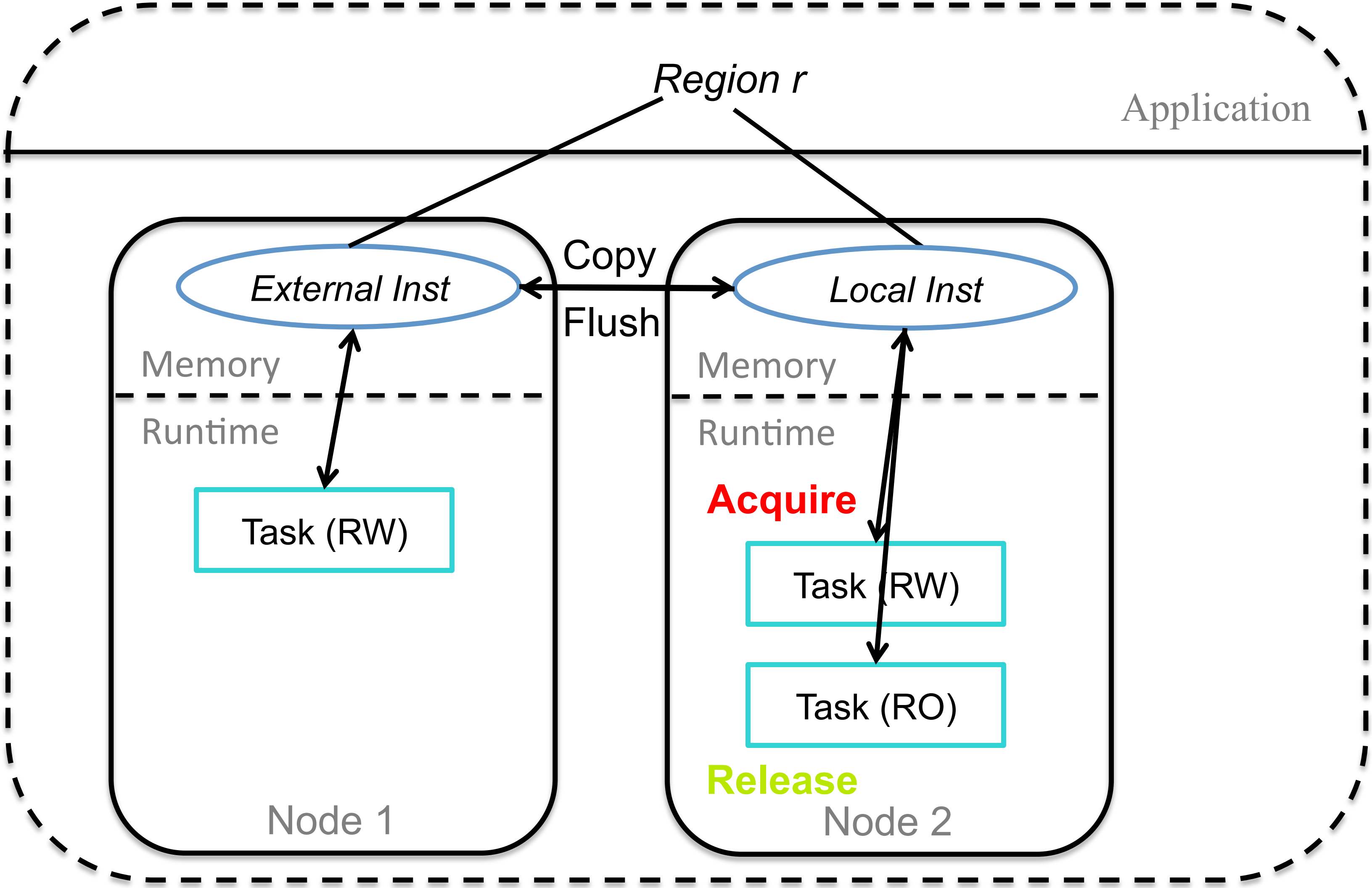
up-to-date w/ better performance

Optimization: Reduce Data Transfer

- Distributed graph rendering
  - Each node renders a portion of the screen
  - Communication: copy physical objects between nodes

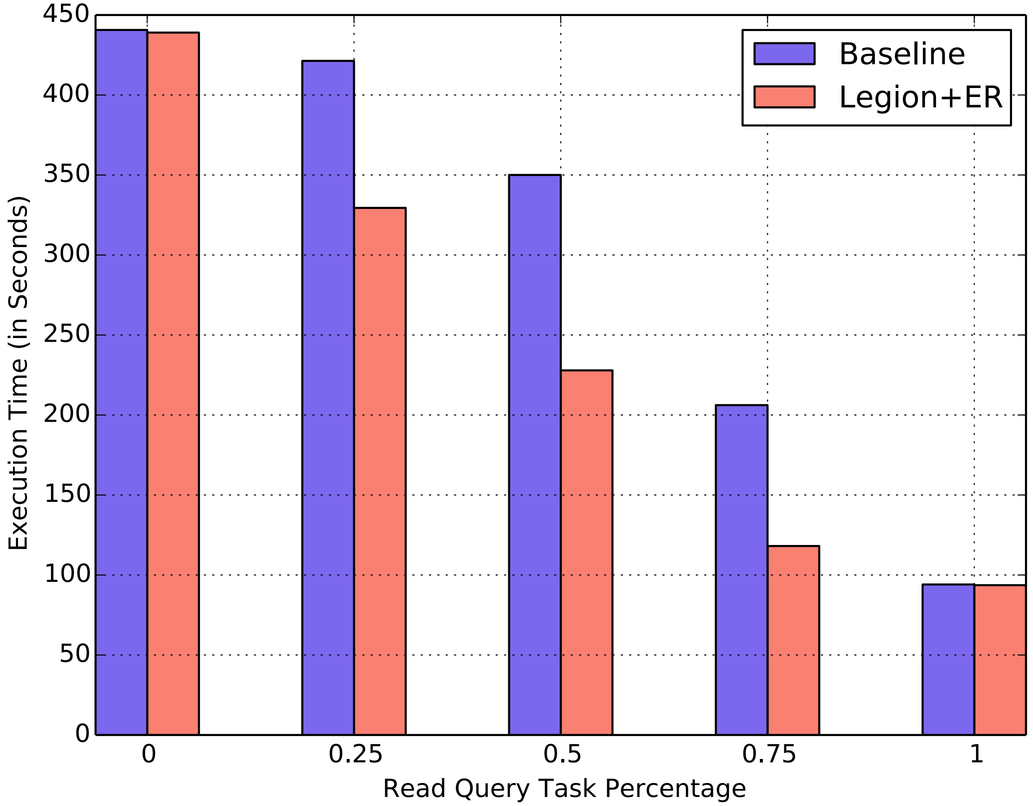


Optimization: Write-After-Read



Optimization: Write-After-Read

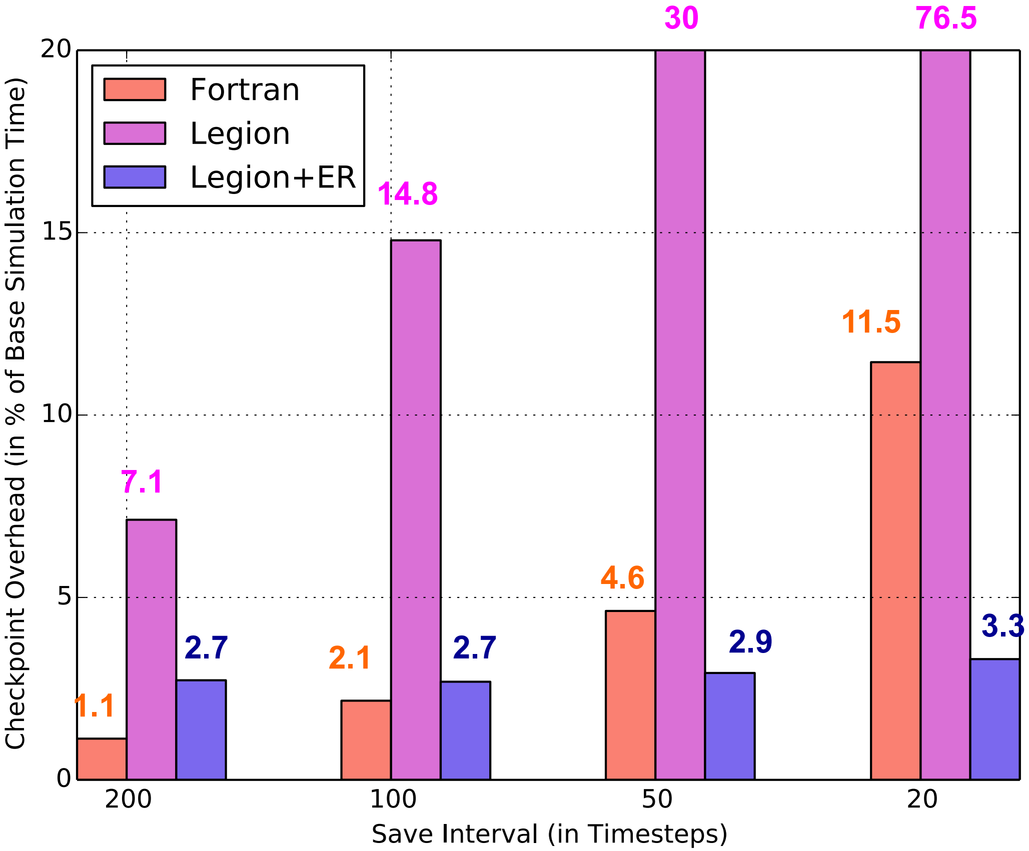
- Database benchmark
  - Perform read queries and read/write queries on external databases on disk



http://legion.stanford.edu

S3D

- A production combustion simulation
- Checkpoint after fixed time steps
- Legion implementation is 7X faster than Fortran



Questions