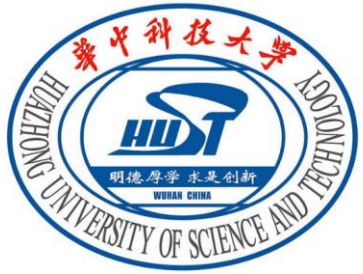

ROLEX: A Scalable RDMA-oriented Learned Key-Value Store for Disaggregated Memory Systems

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Huazhong University of Science and Technology

The USENIX Conference on File and Storage Technologies (FAST), 2023

Disaggregated Memory Systems (DMS)

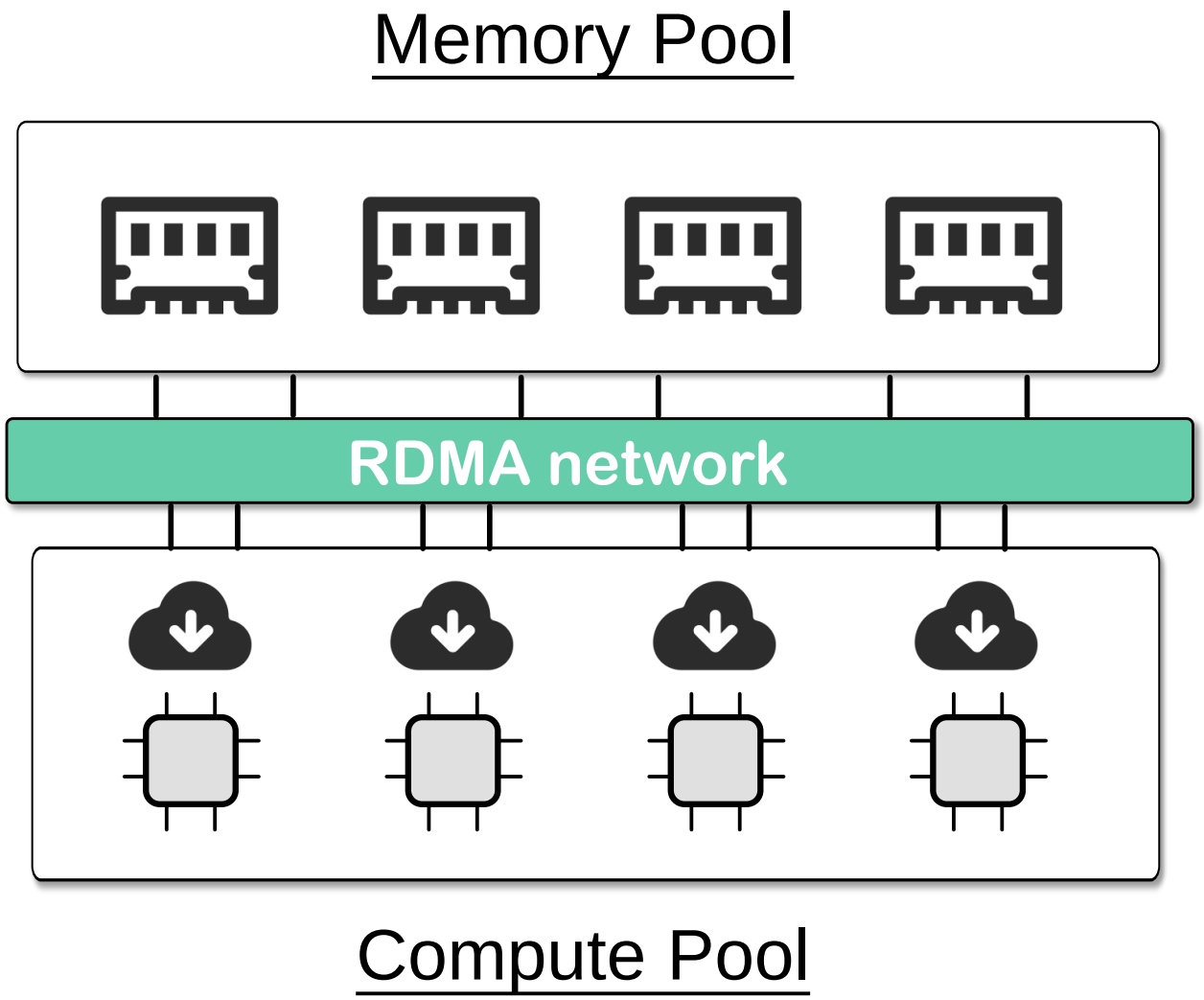
High resource utilization

Flexible hardware scalability

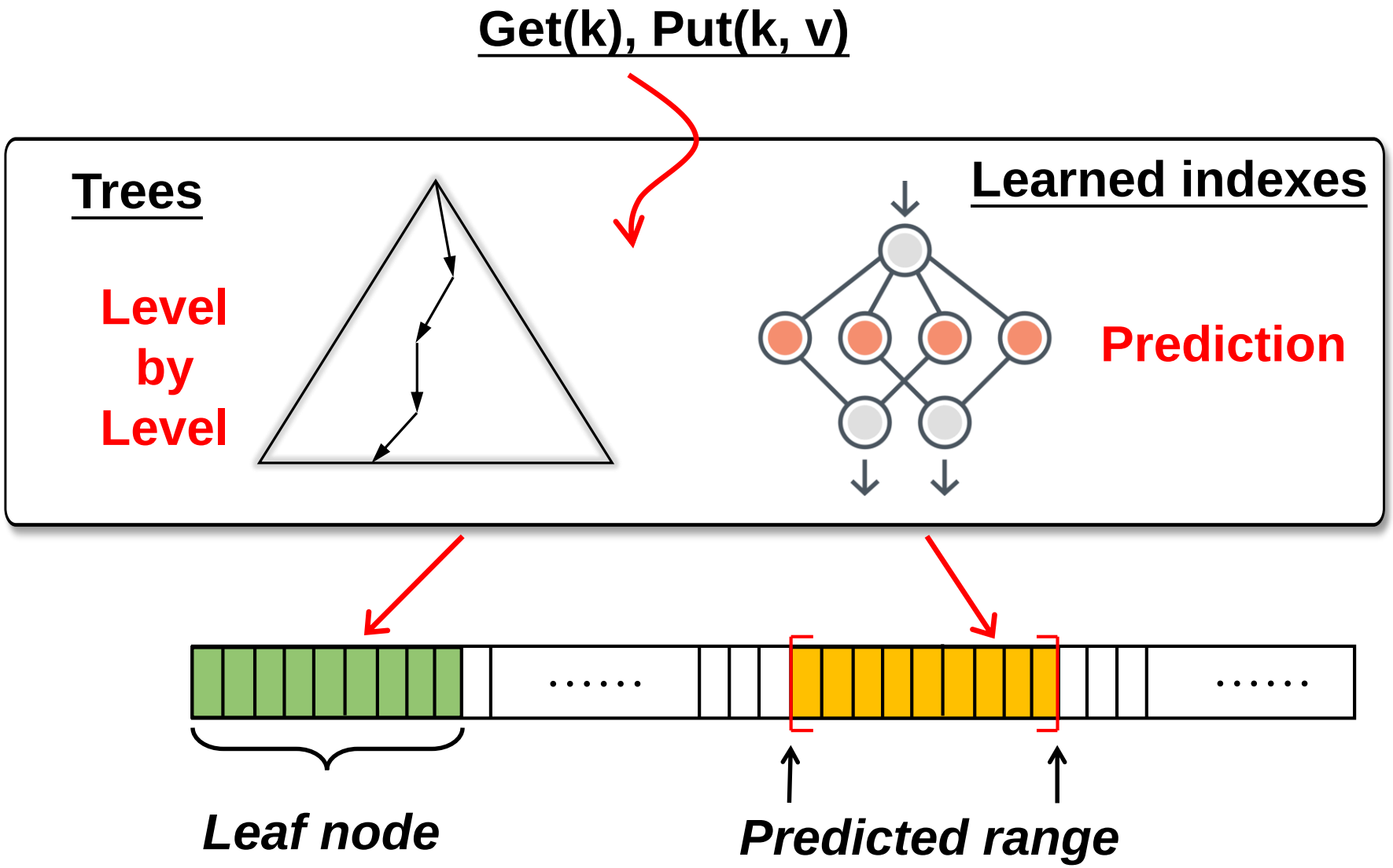
Efficient data sharing

40-400 Gbps

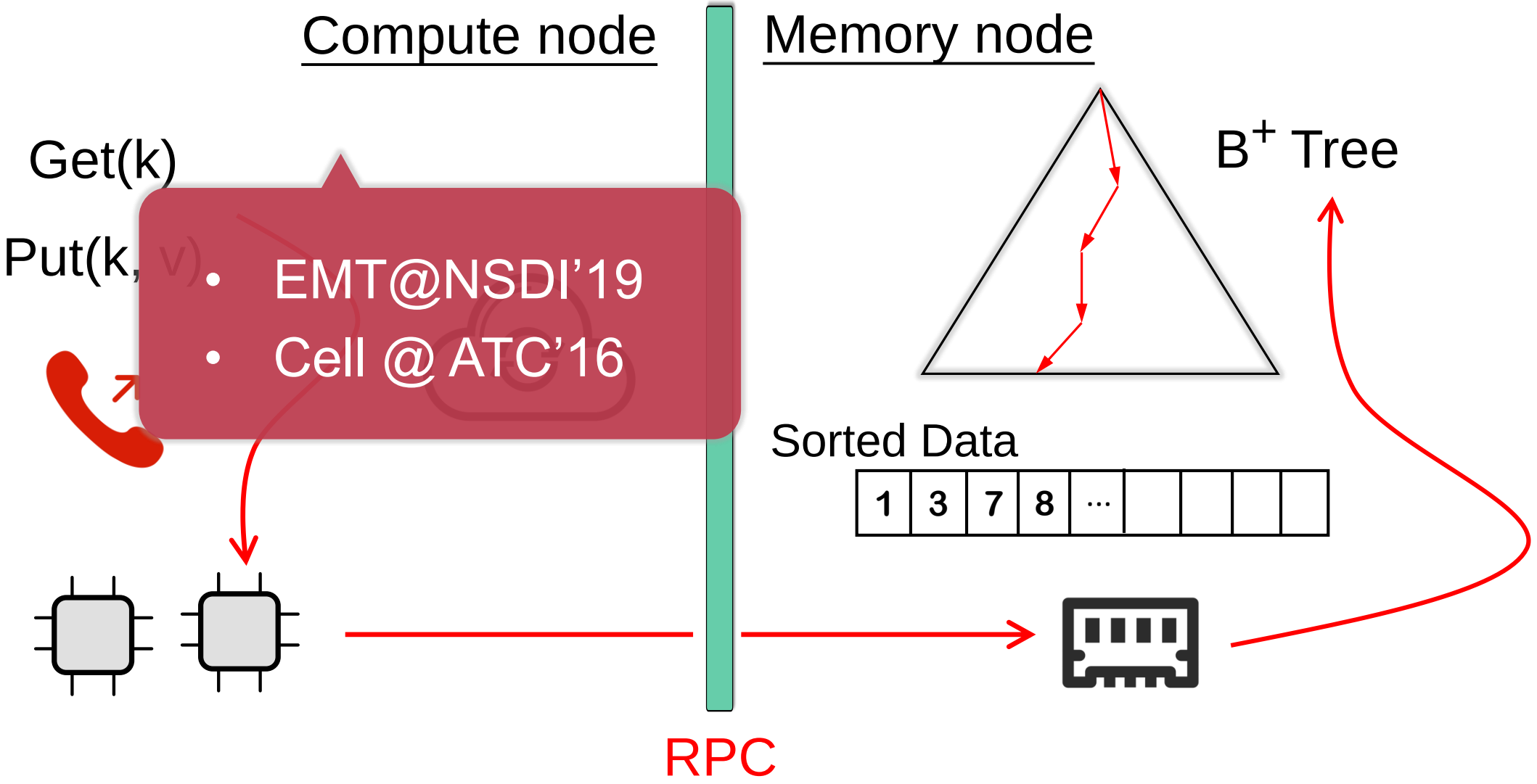
Remote CPU bypassing



Ordered KV Store



Tree-based Structures in DMS – Two Sided



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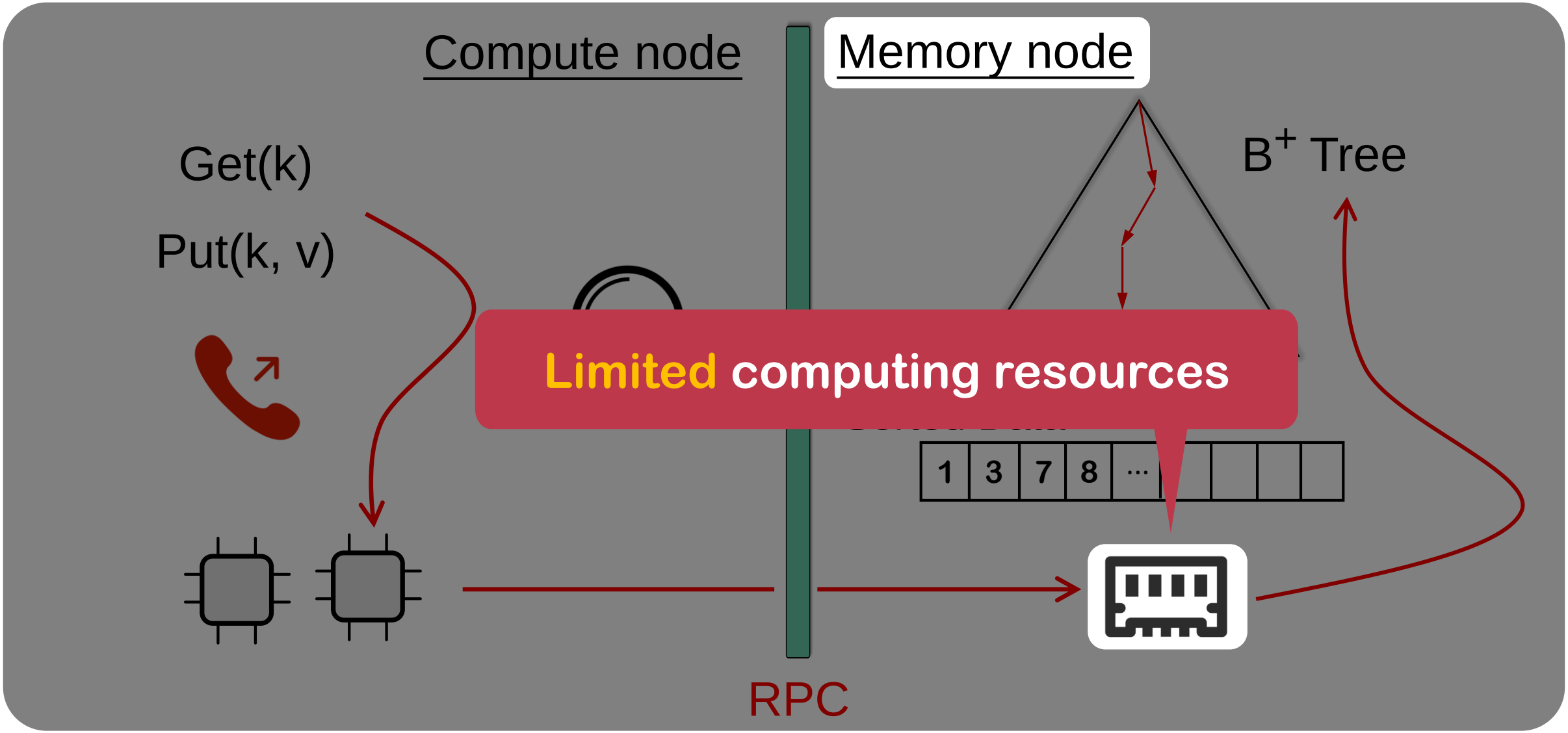
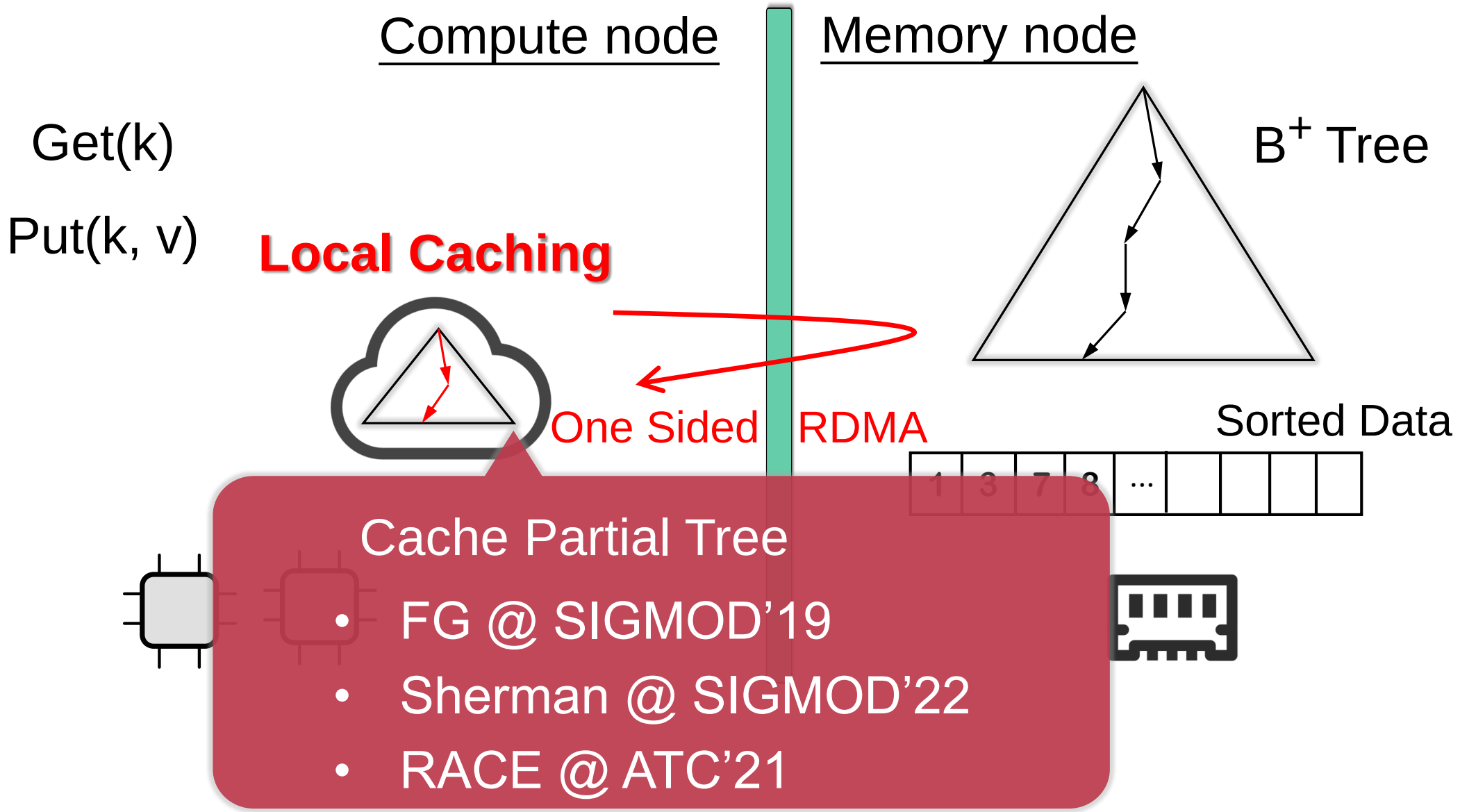
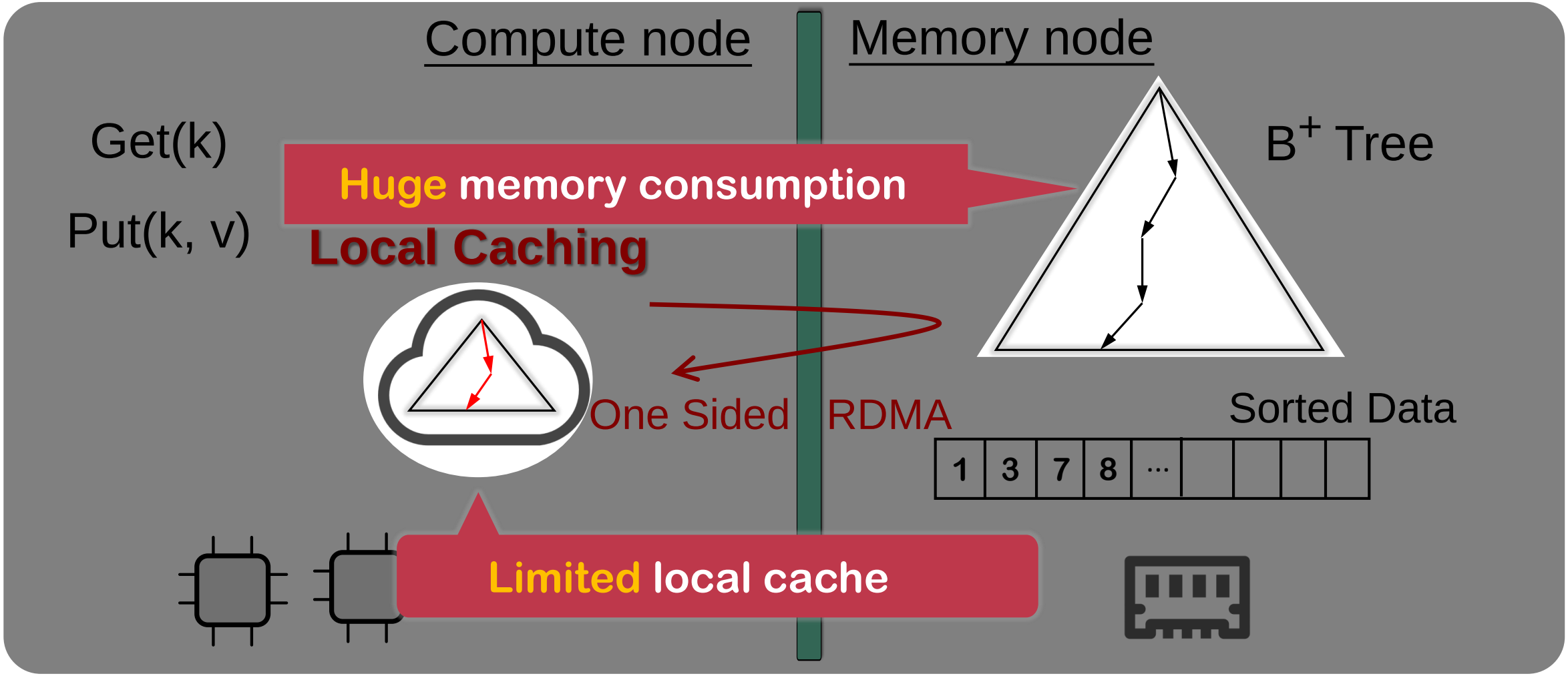


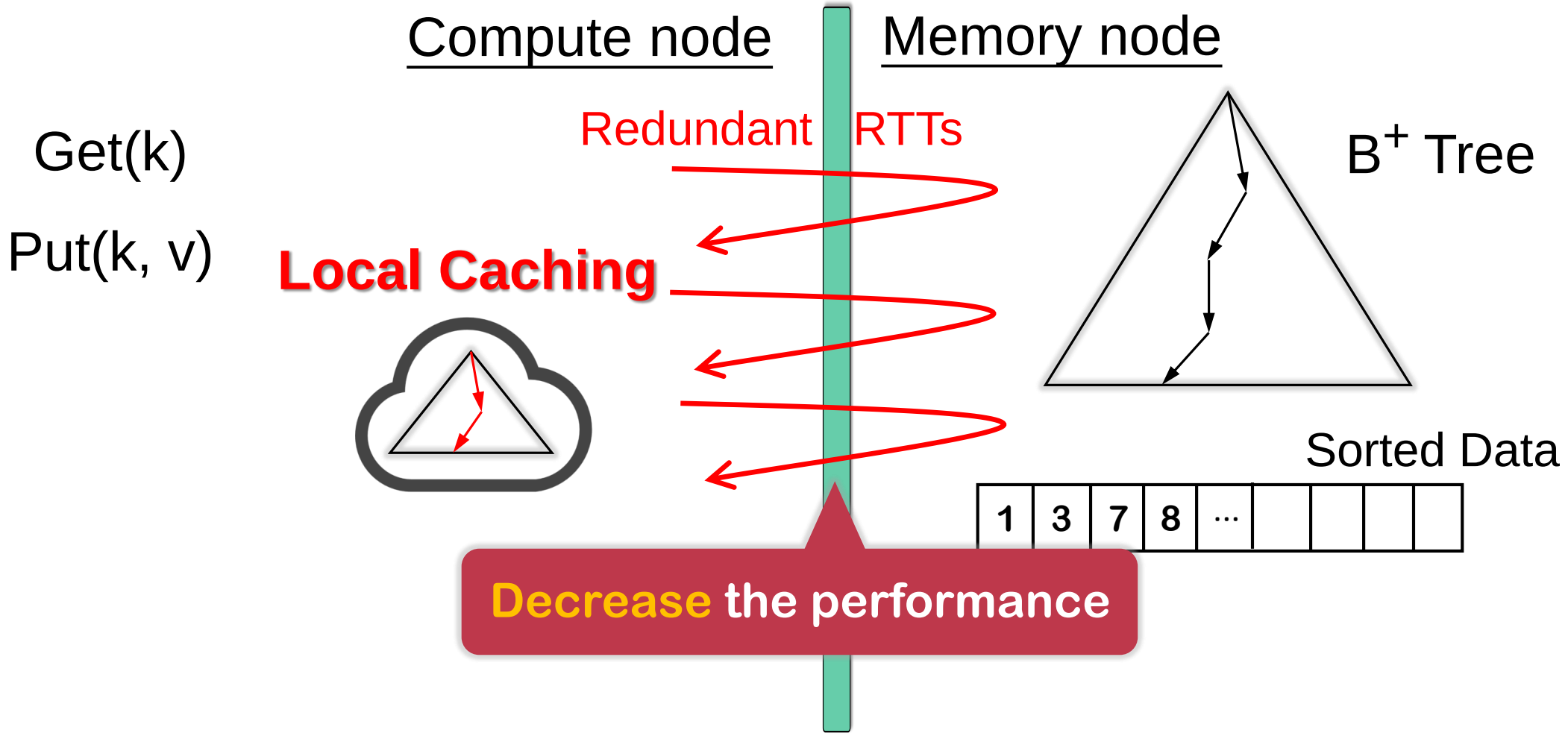
Tree-based Structures in DMS – One Sided



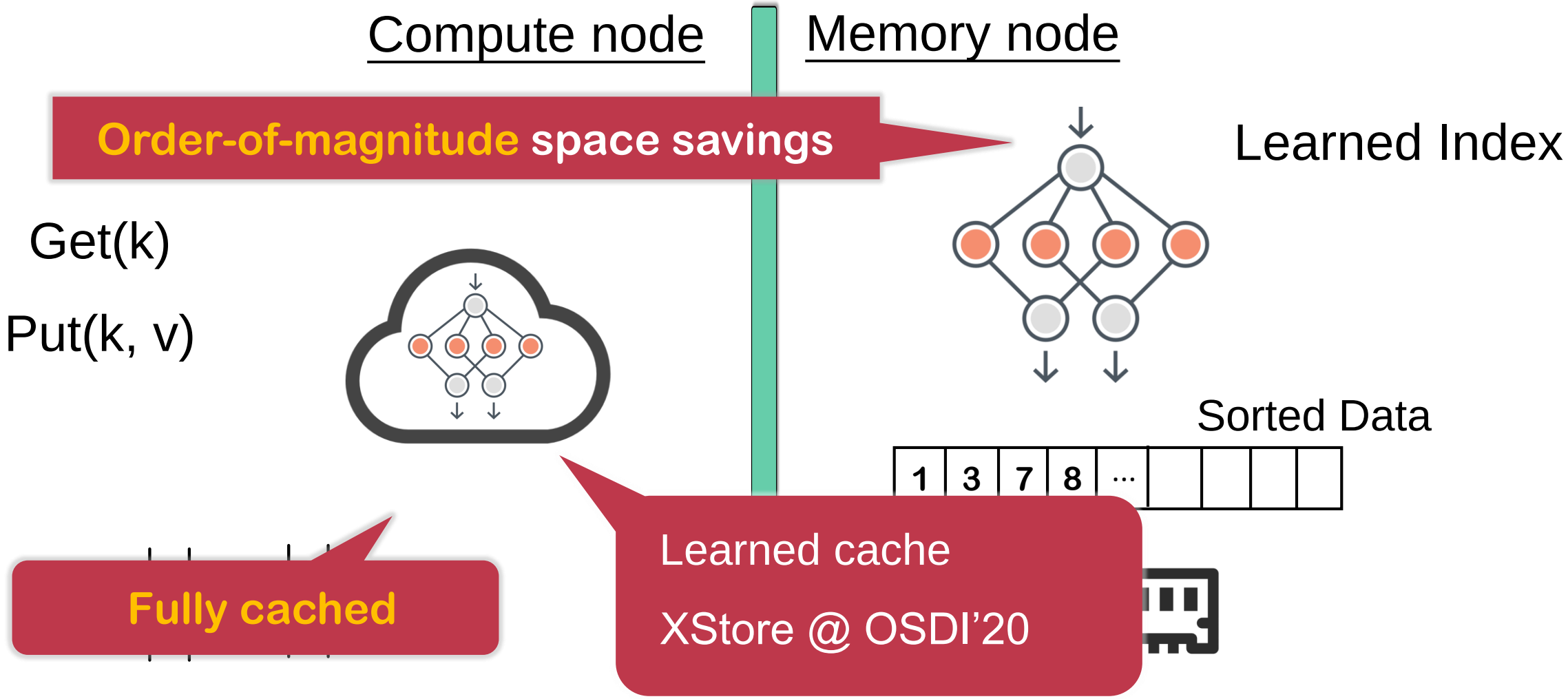
Tree-based Structures in DMS – One Sided



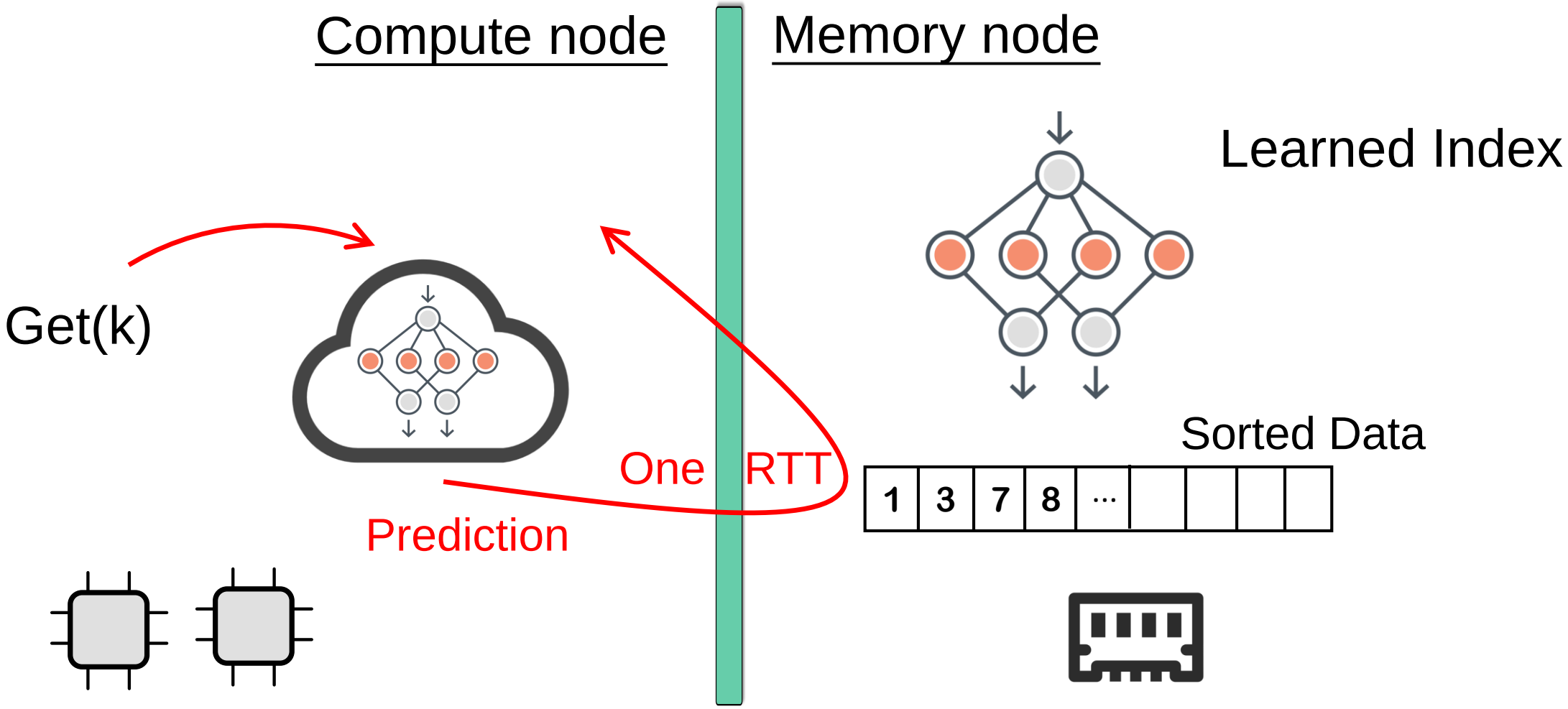
Tree-based Structures in DMS – One Sided



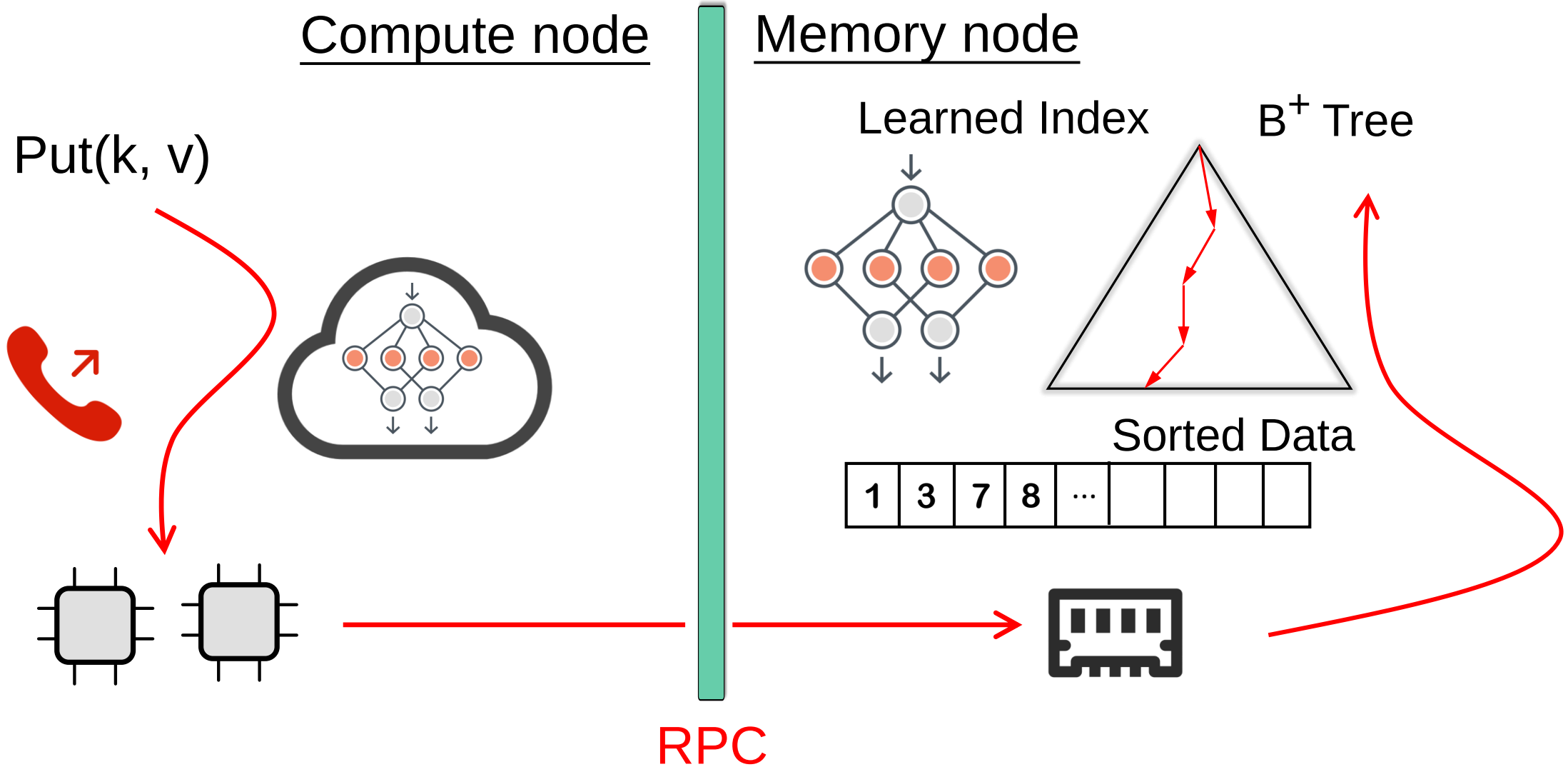
Learned-indexes in DMS



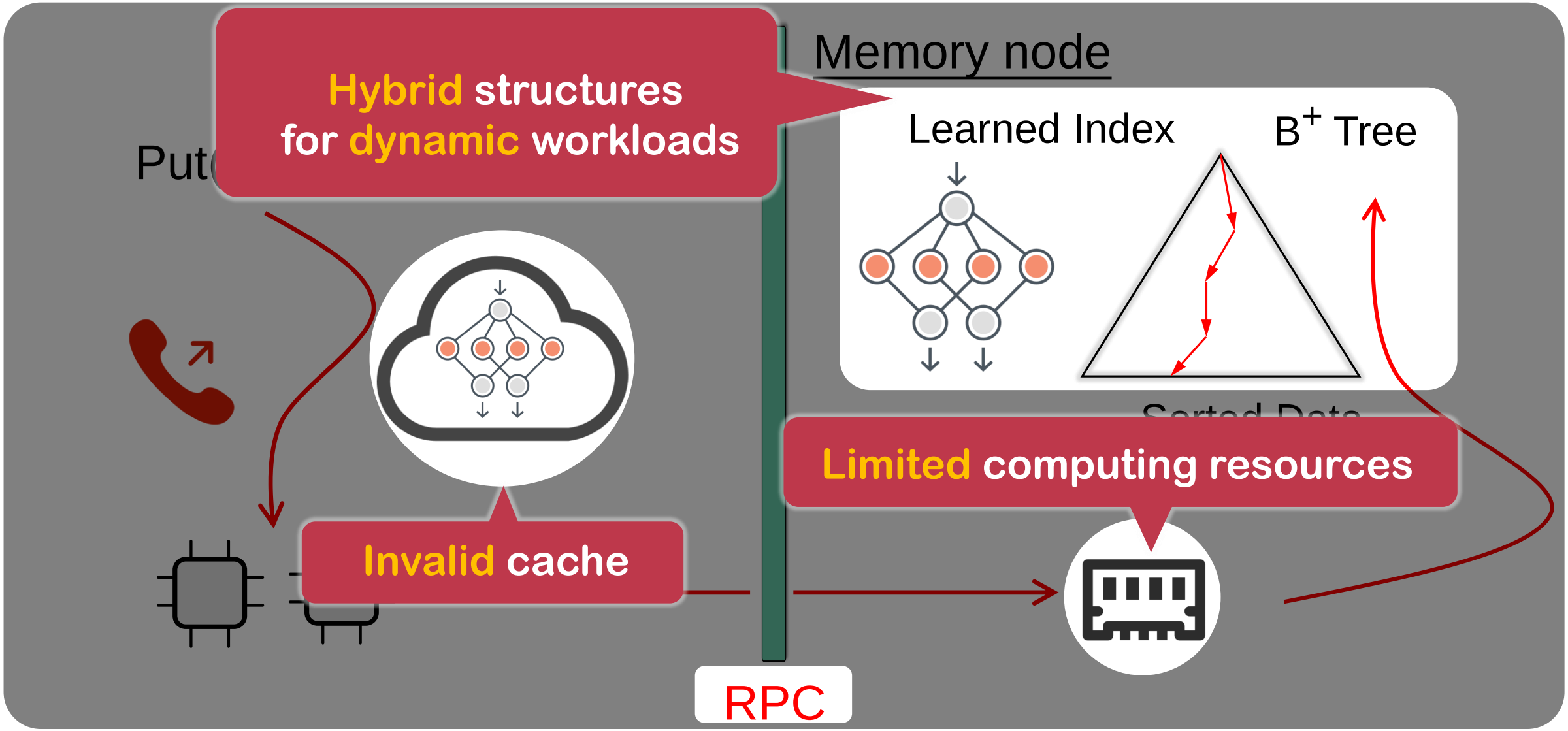
Learned-indexes in DMS



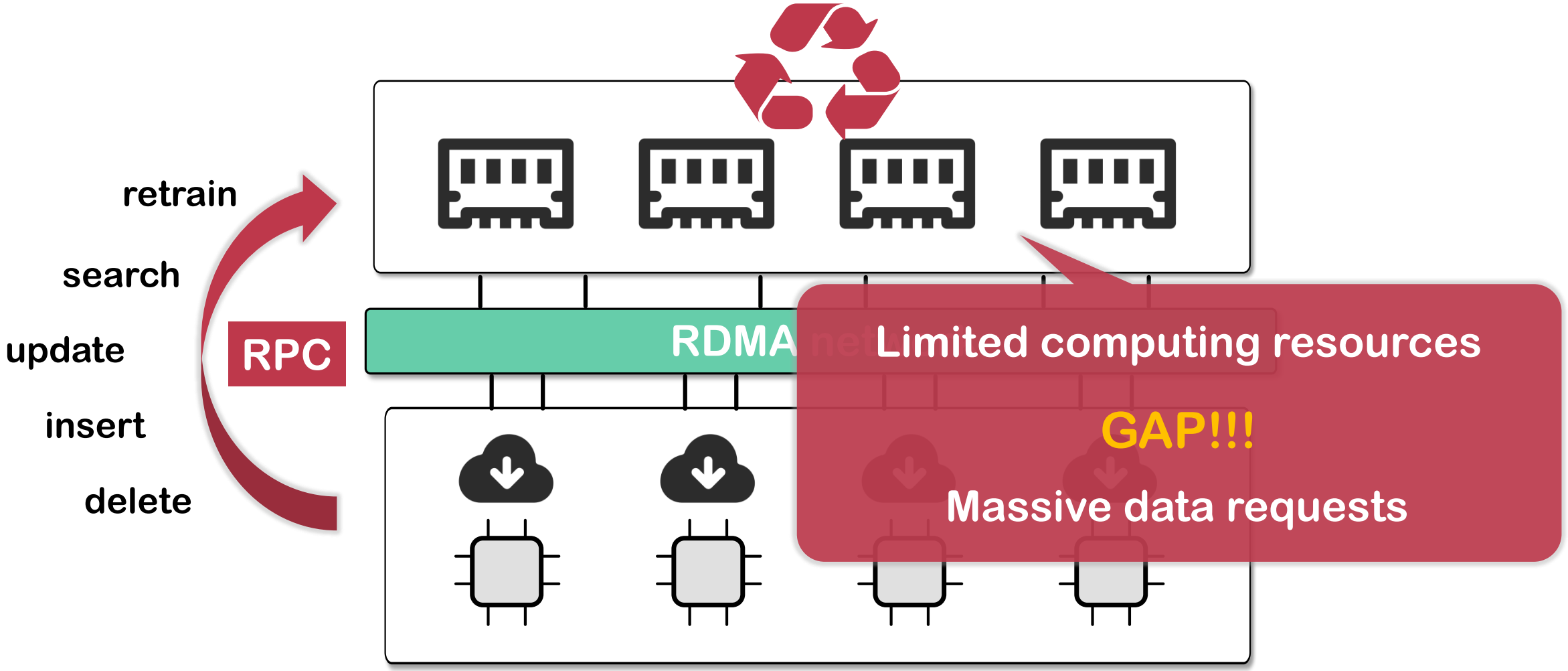
Learned-indexes in DMS



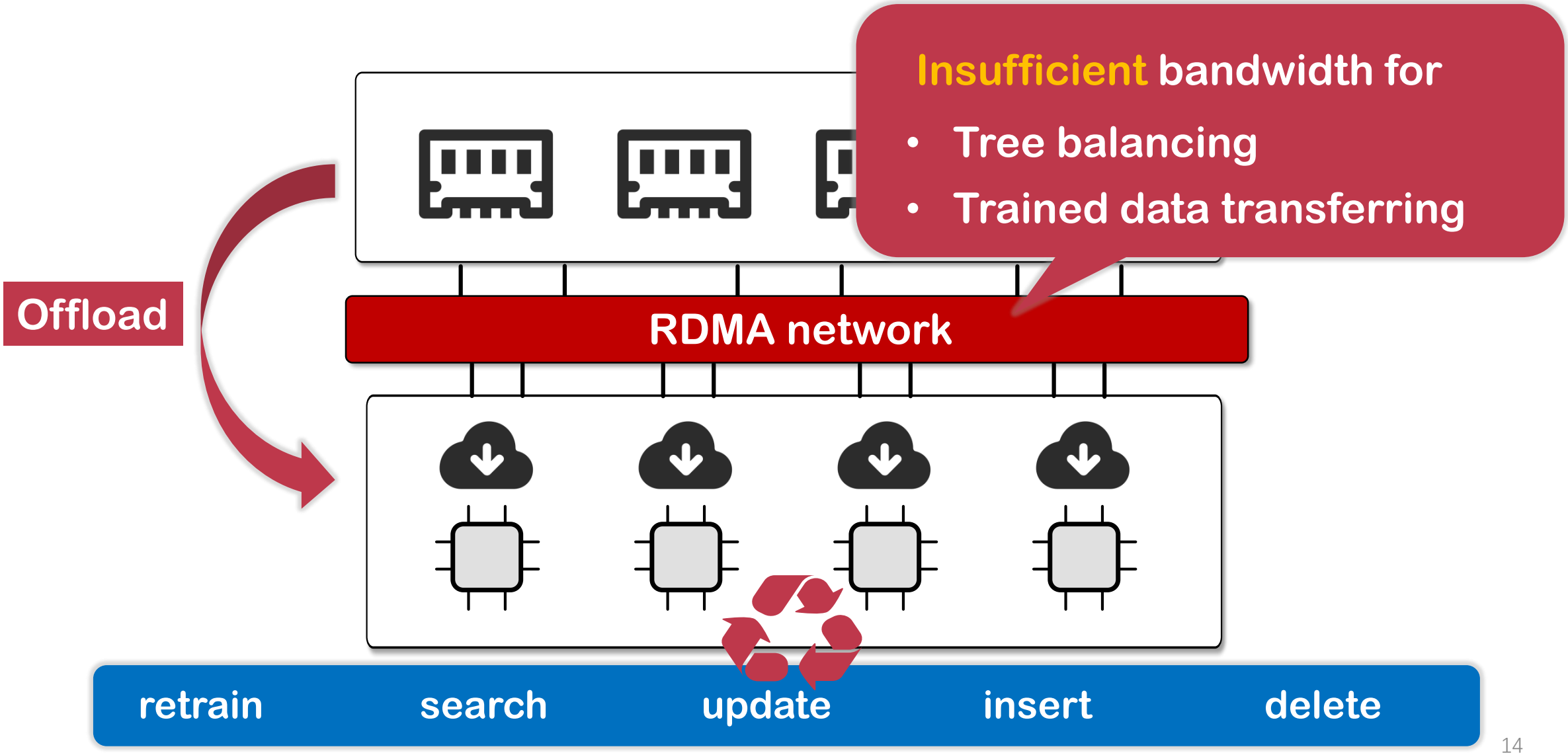
Learned-indexes in DMS



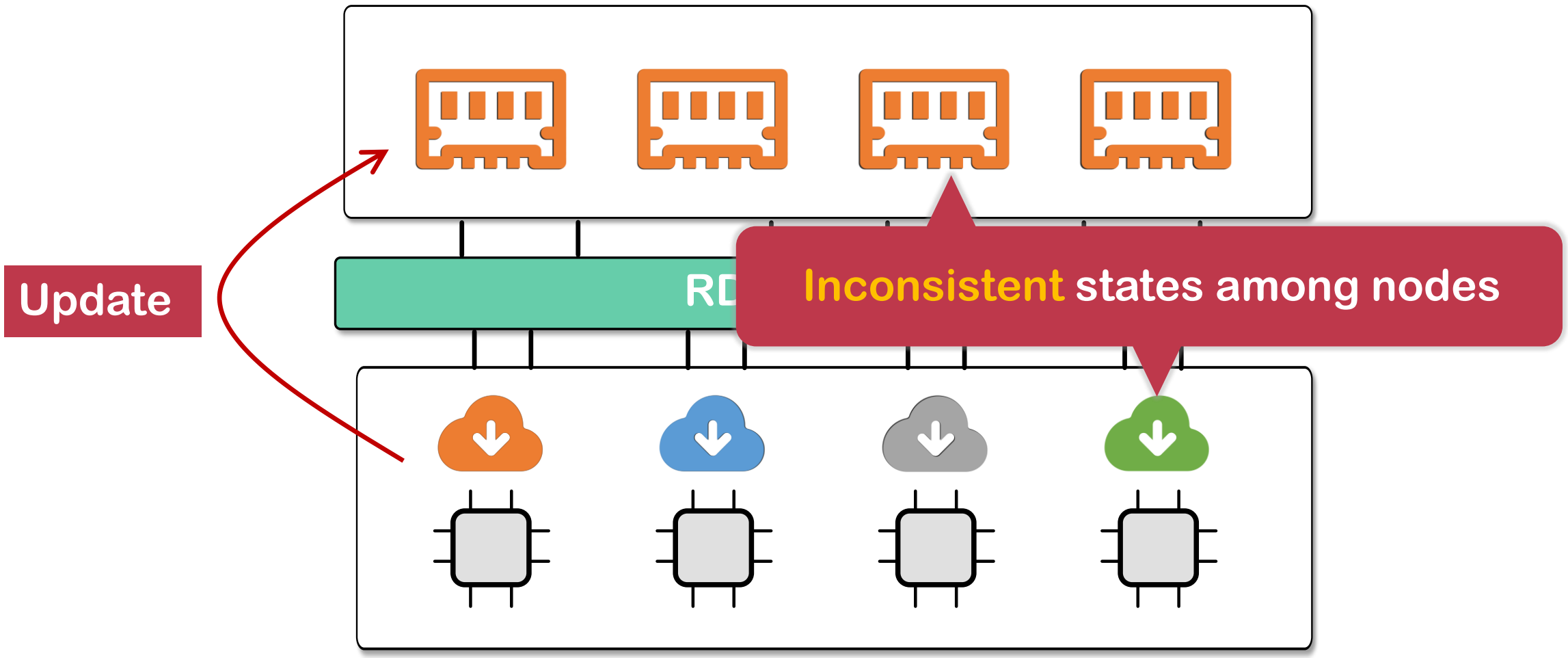
Challenge 1: Computing Bottleneck



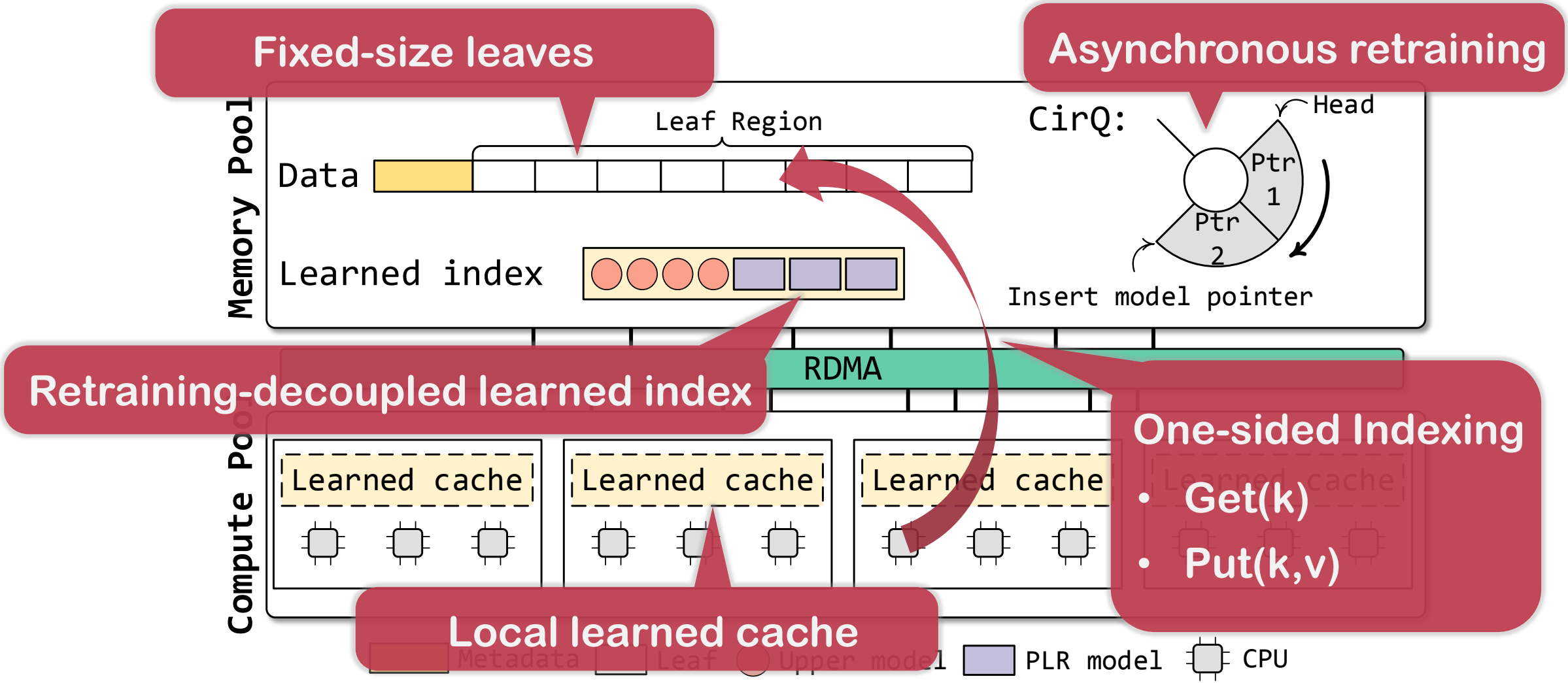
Challenge 2: Overloaded Bandwidth



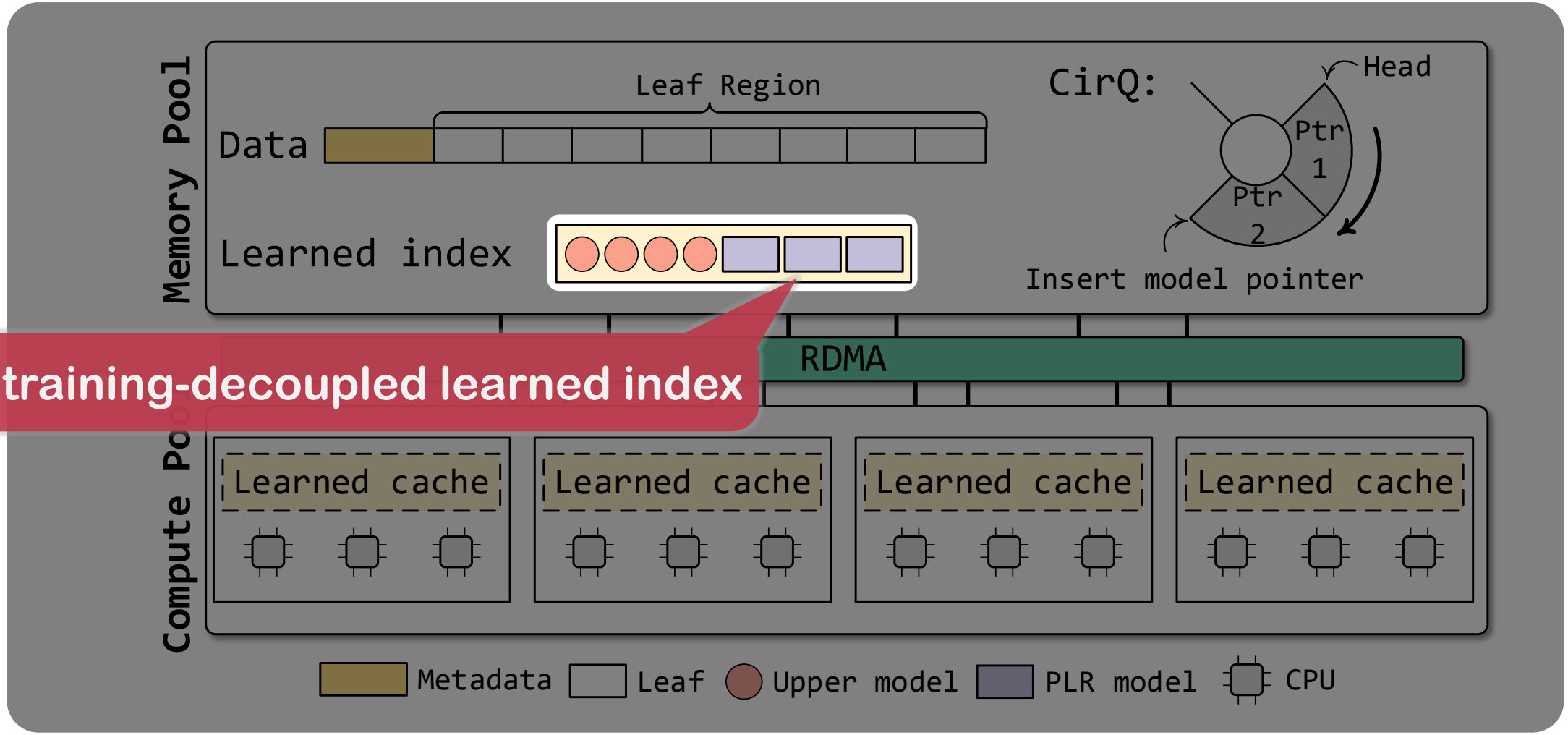
Challenge 3: Inconsistency Issues



RDMA-Oriented KVS Using Learned Indexes (ROLEX)

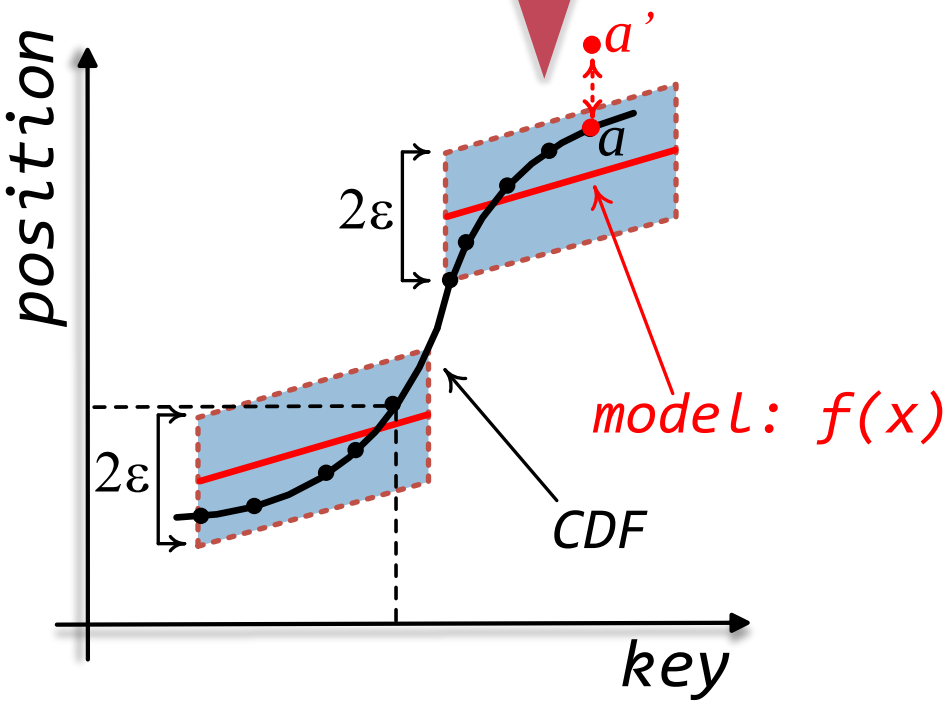


Retraining-Decoupled Learned Indexes

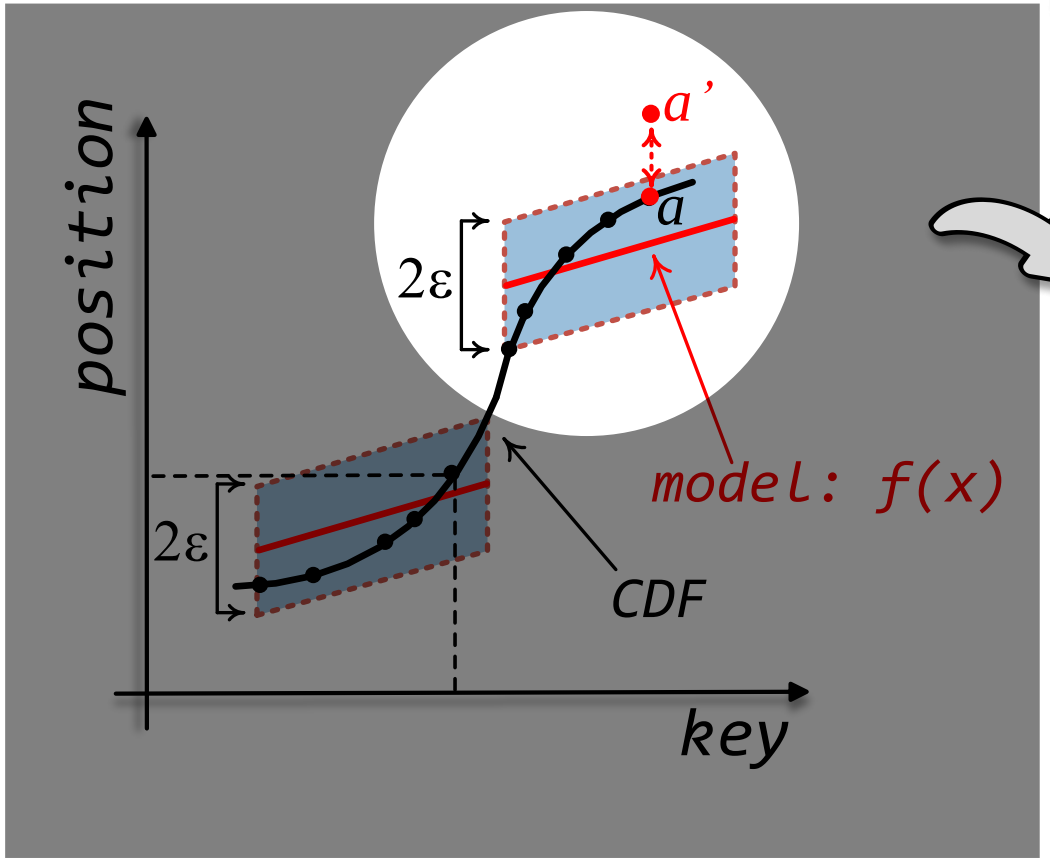


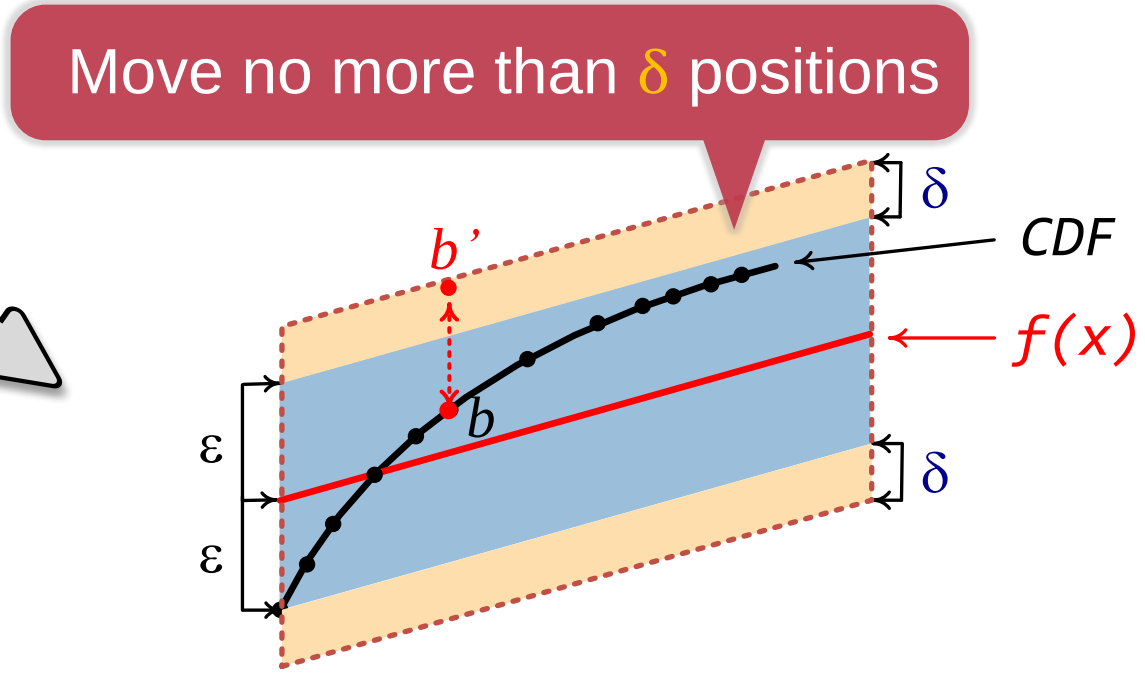
Retraining-Decoupled Learned Indexes

Error! out of prediction range

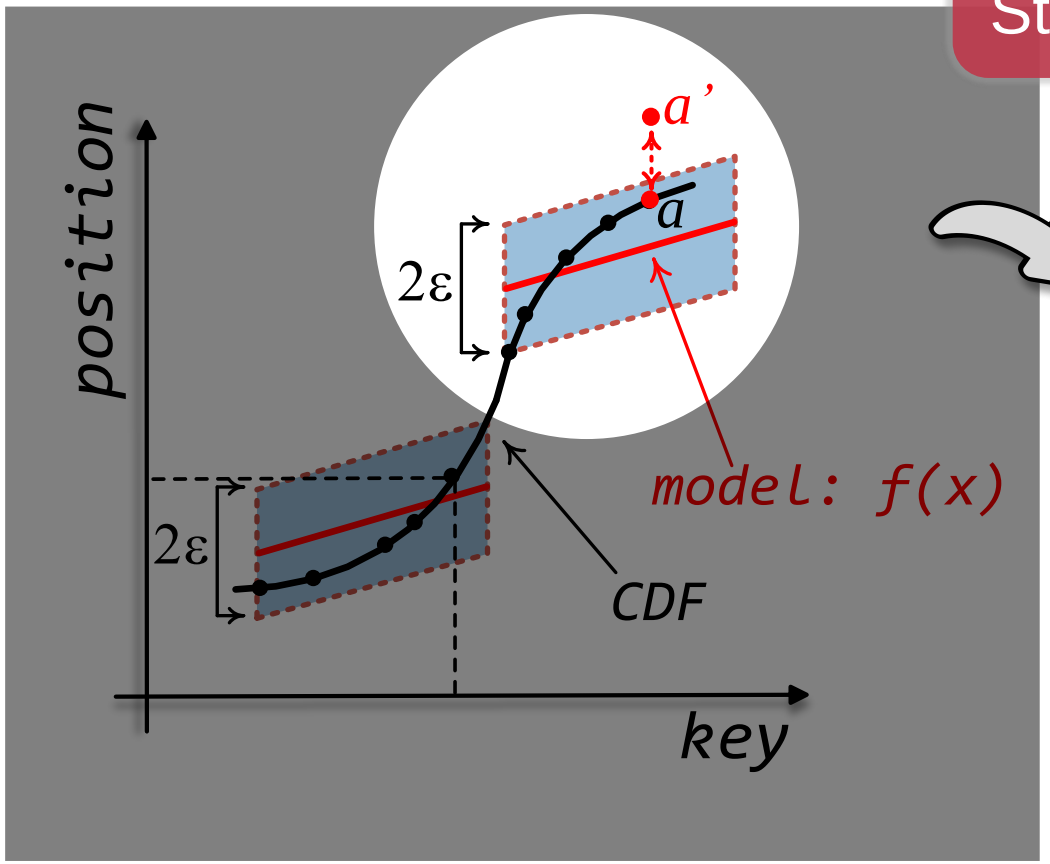


Retraining-Decoupled Learned Indexes

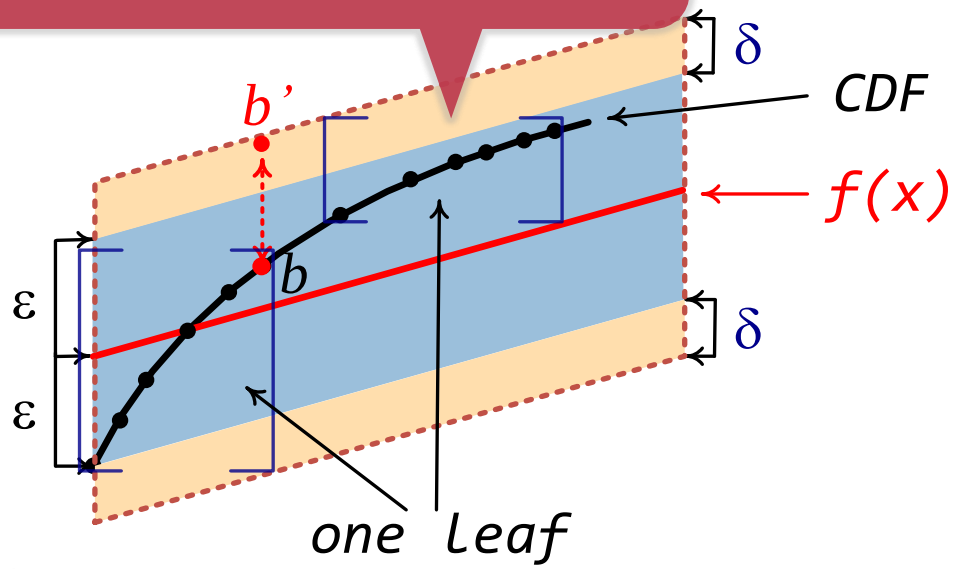




Retraining-Decoupled Learned Indexes



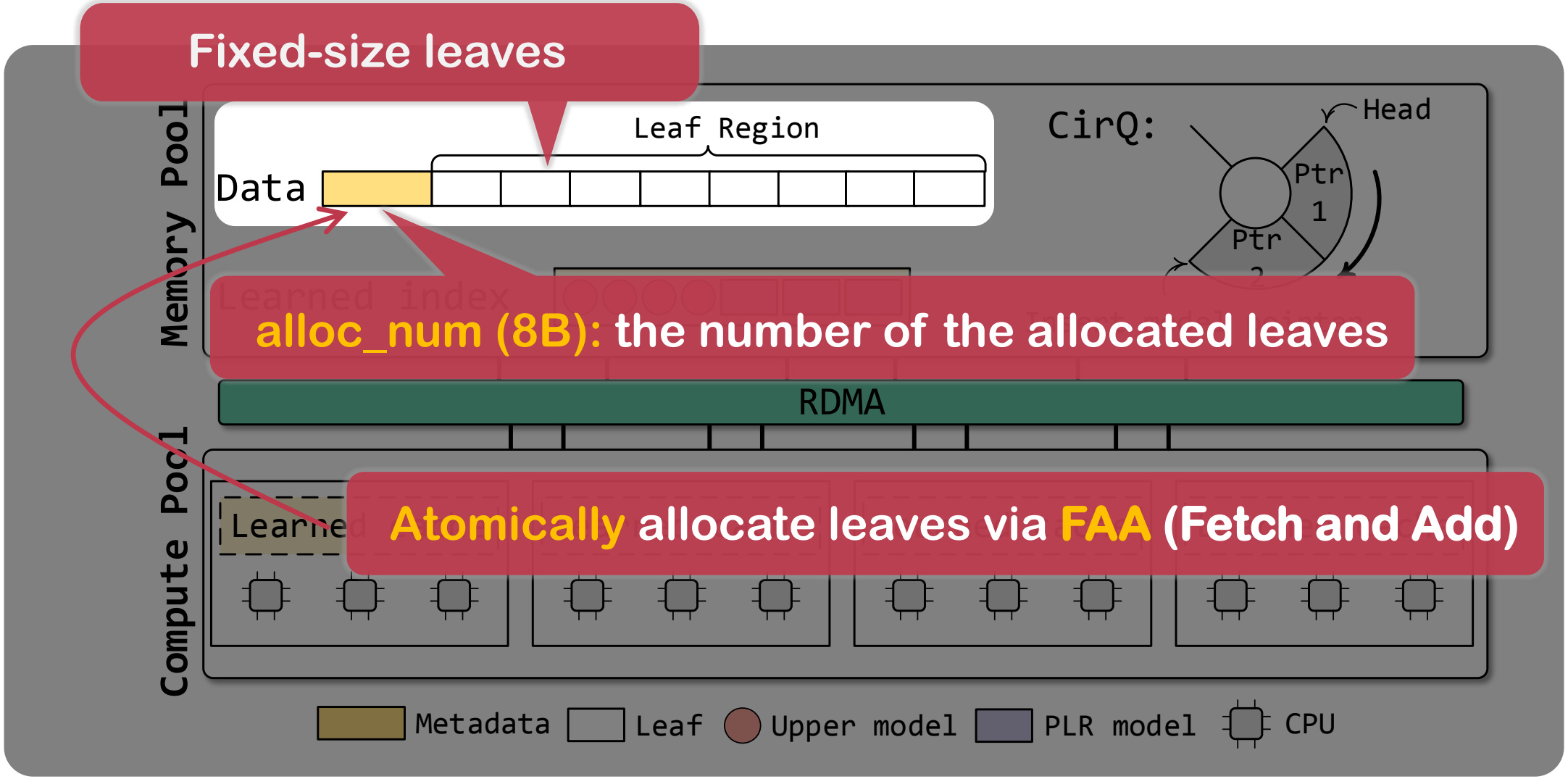
Store data into fixed-size leaves



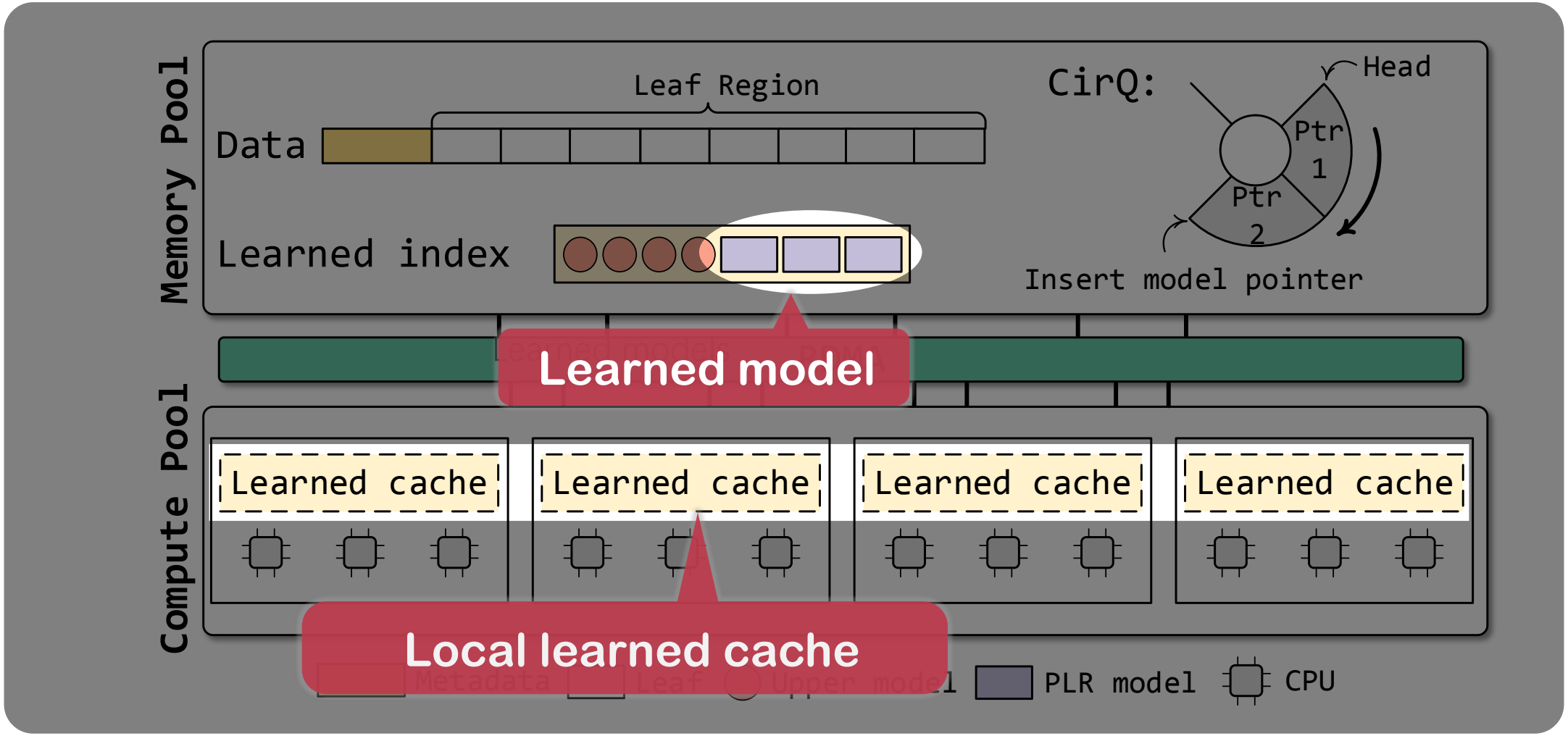
Data-movement constraints

- Moving within fixed-size leaves
- Synonym-leaf sharing

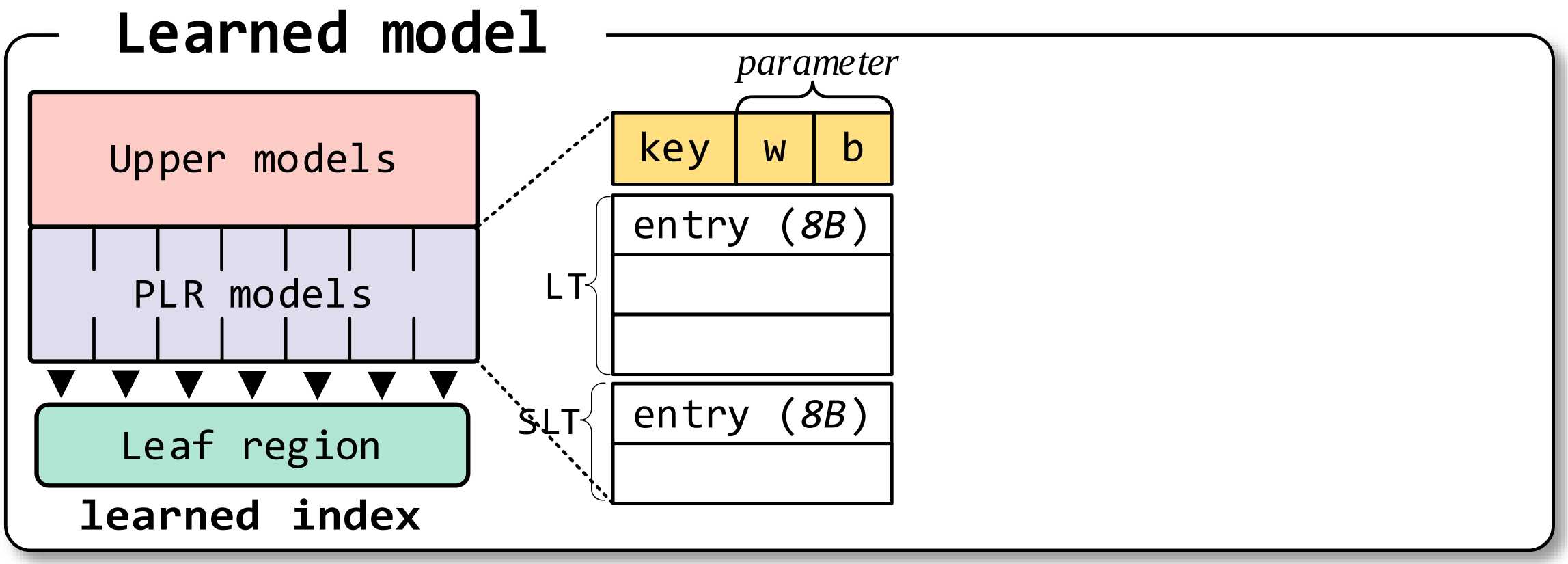
Memory Pool Stores Data



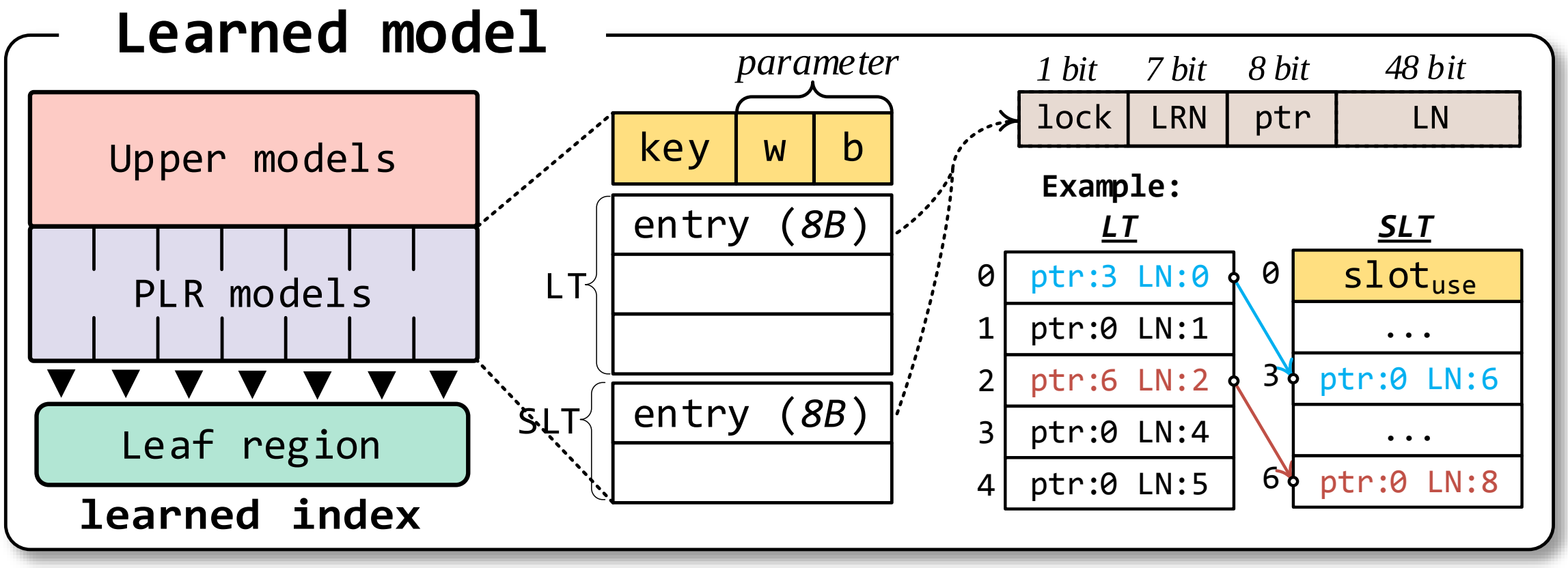
Learned Model



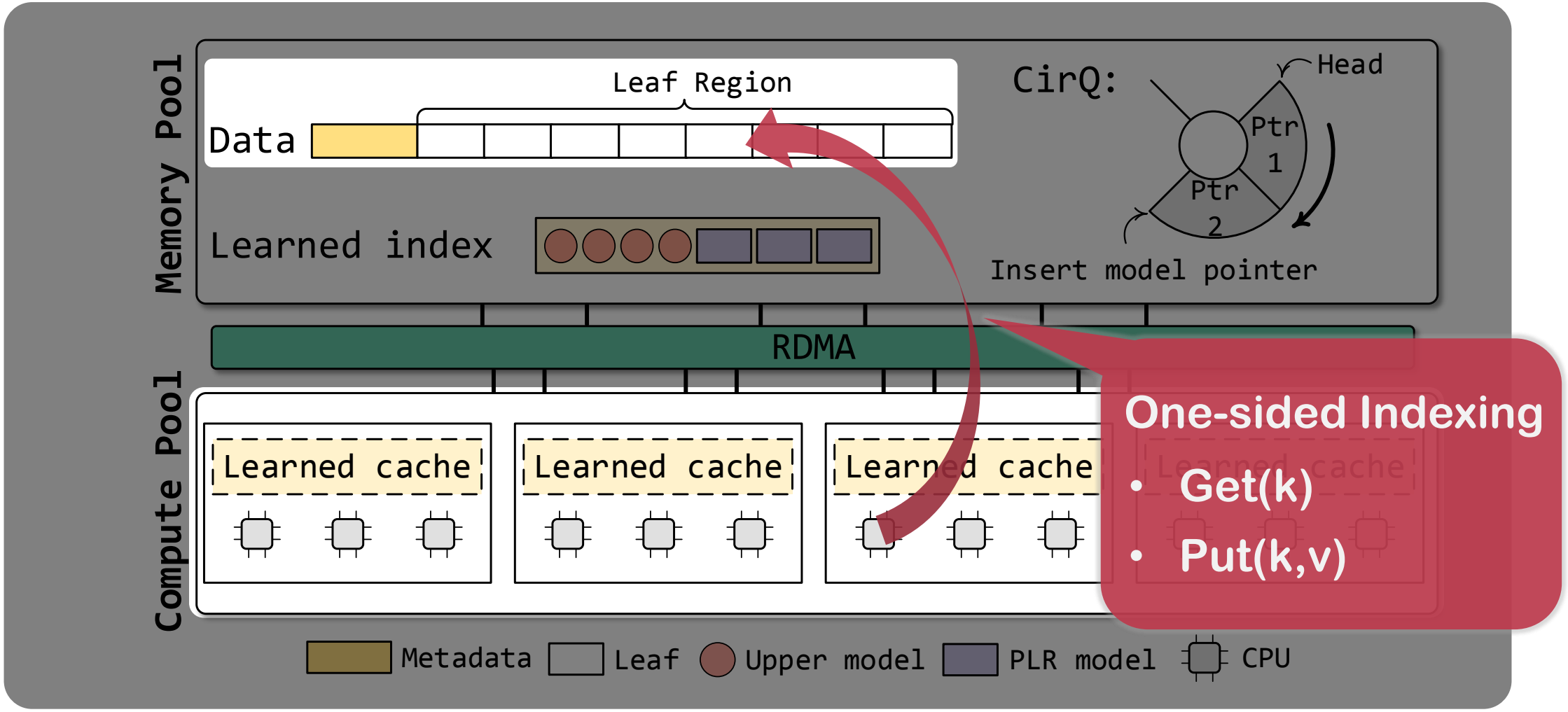
Learned Model – Piecewise Linear Regression Models



Learned Model – Leaf Table



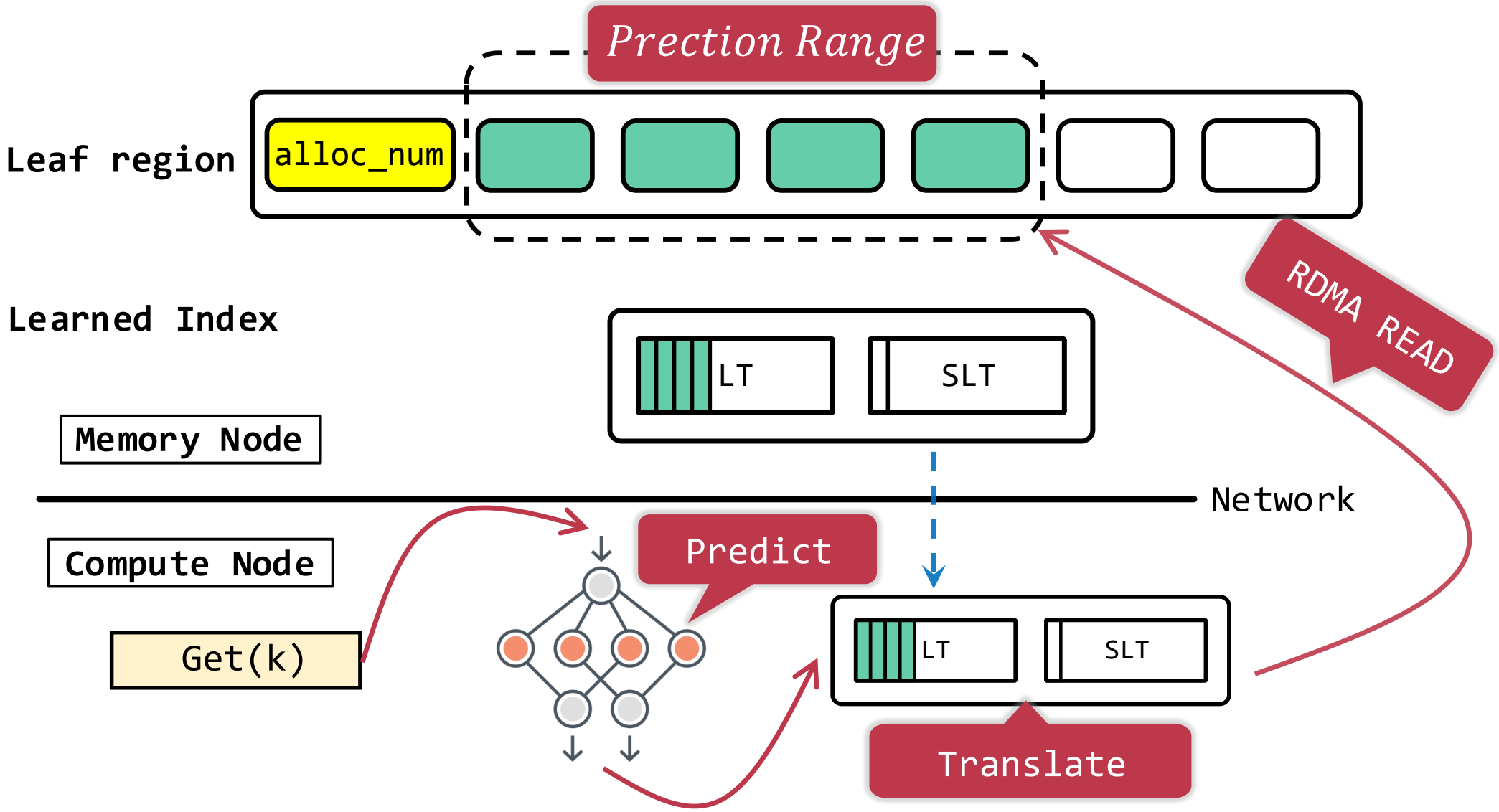
One-sided Indexing



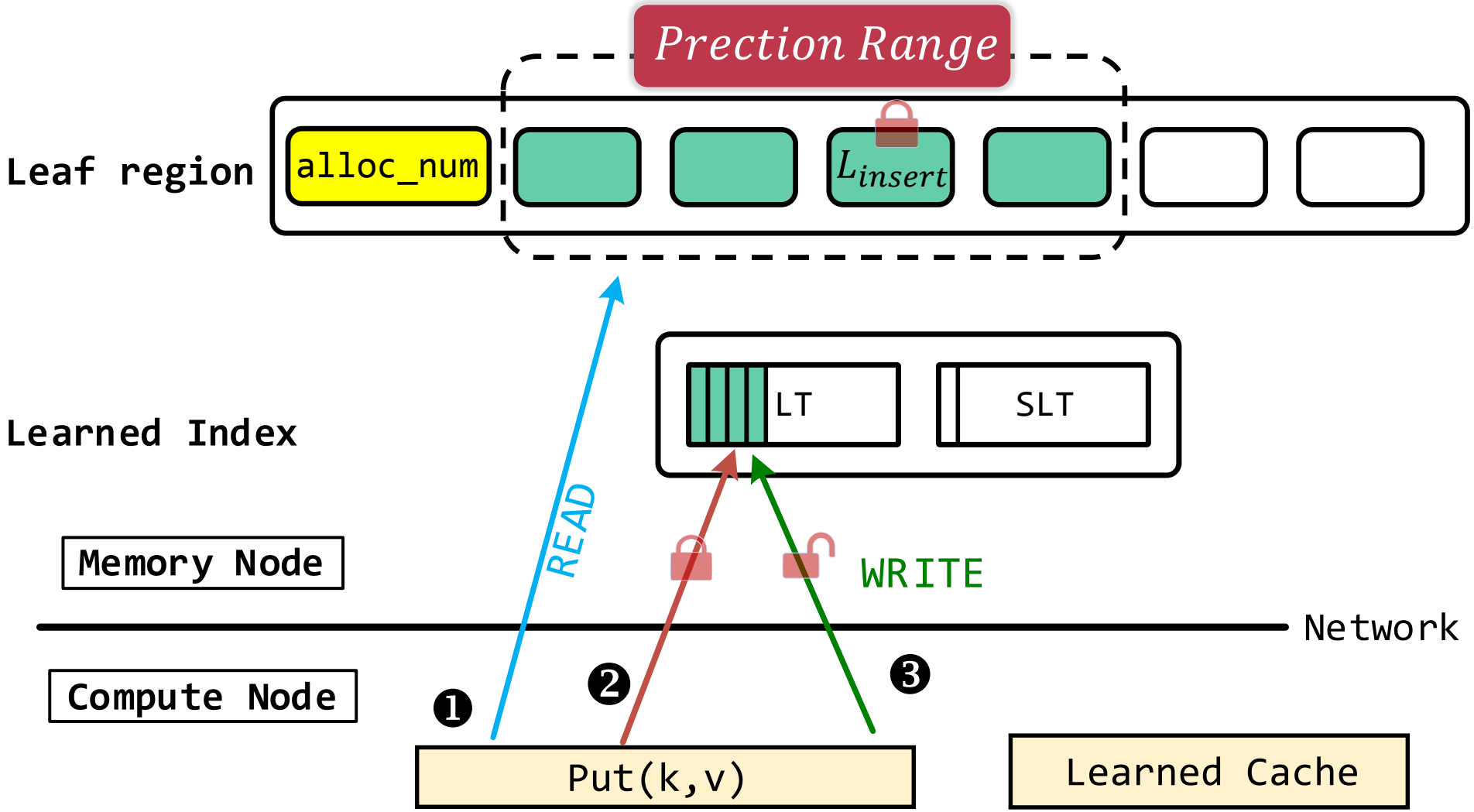
One-sided Indexing

- Get(k)
- Put(k,v)

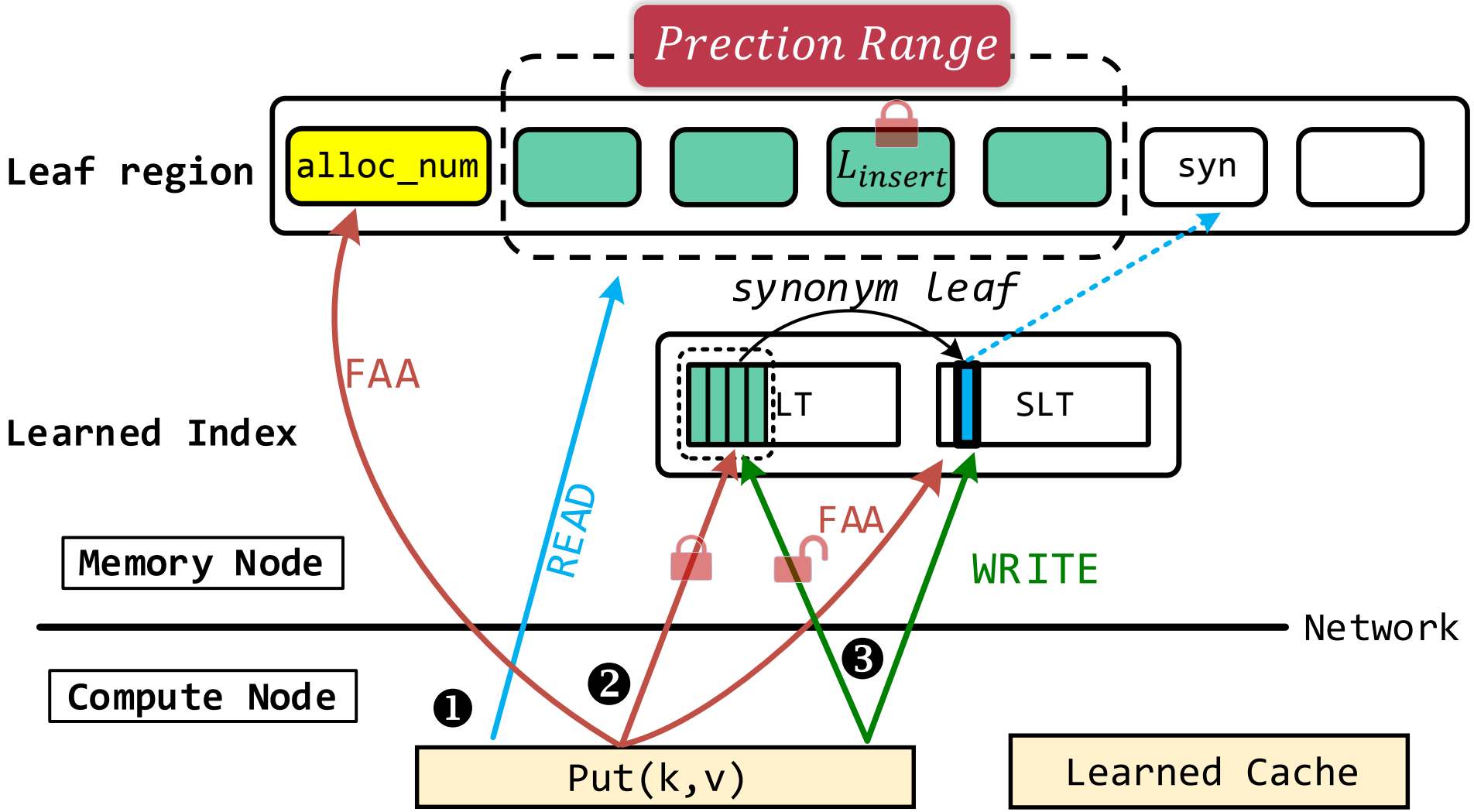
One-sided Indexing – Get (k)



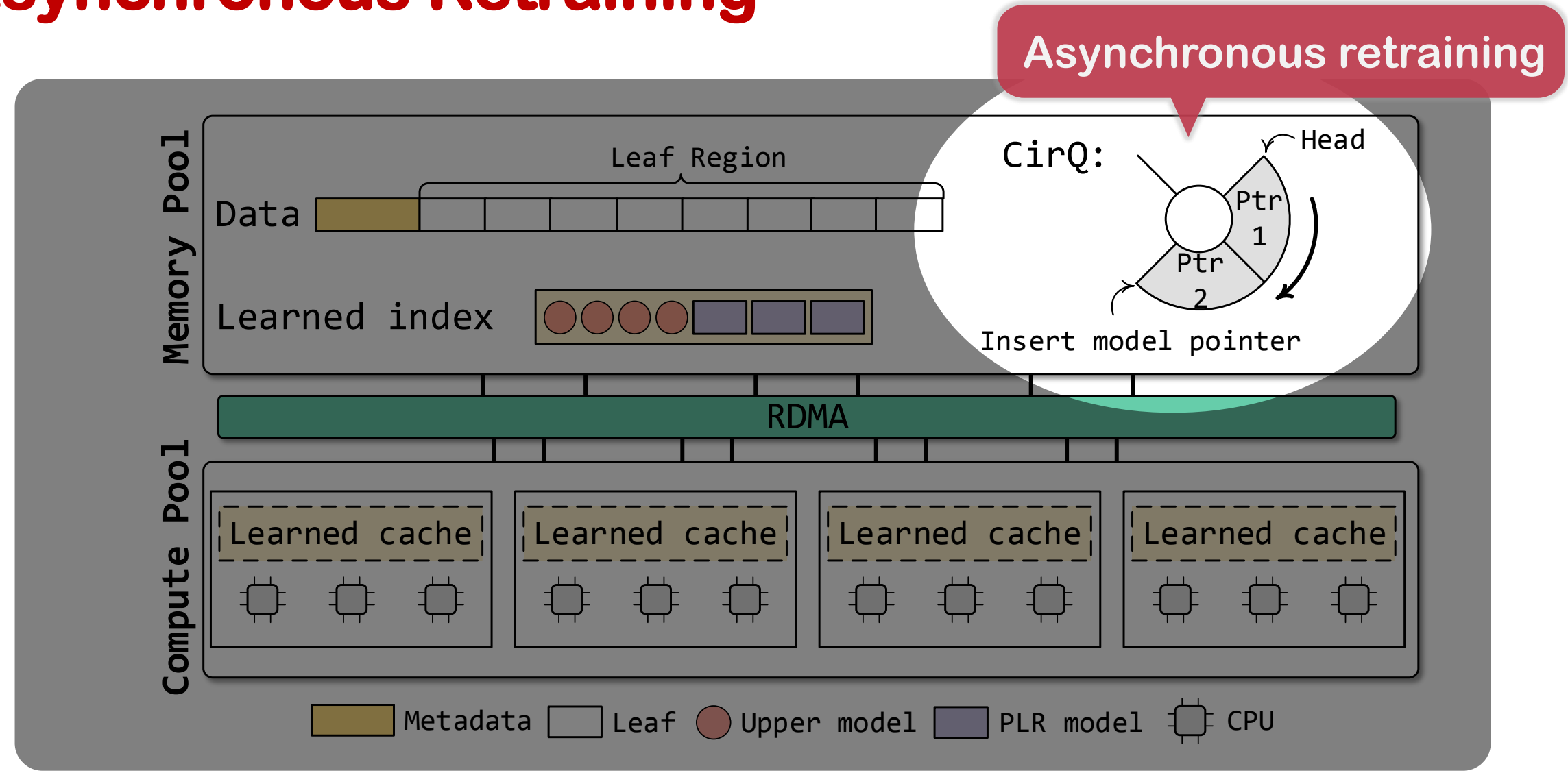
One-sided Indexing – Put (k, v)



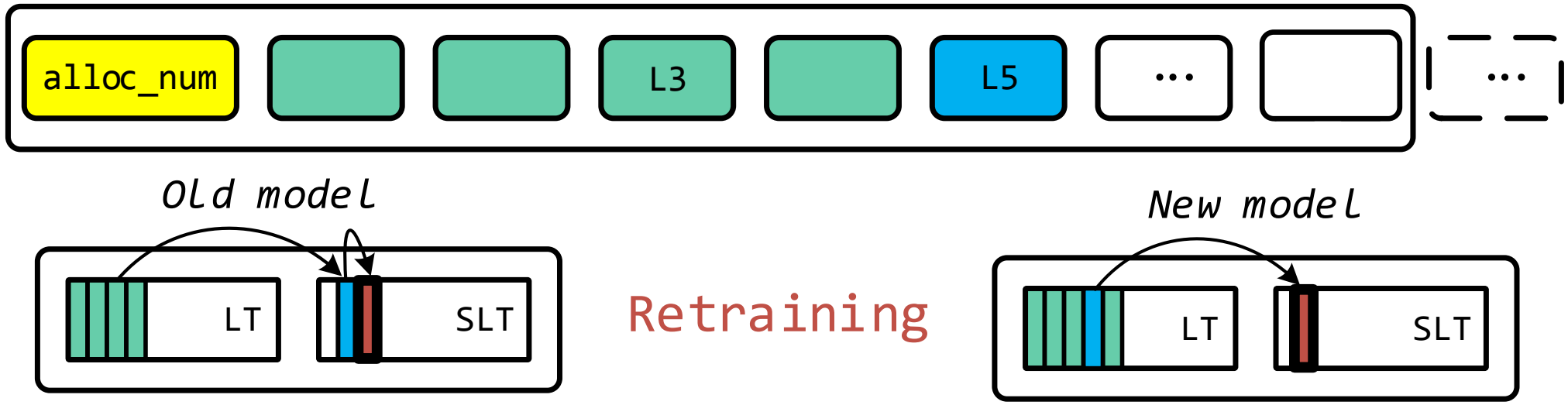
One-sided Indexing – Put (k, v)



Asynchronous Retraining



Asynchronous Retraining – Consistency Guarantee

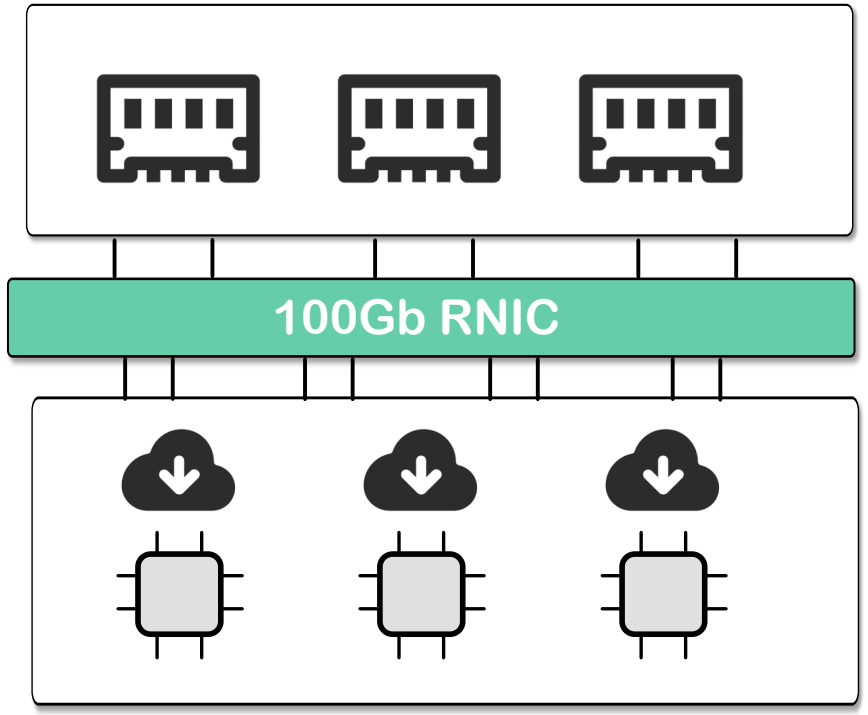


Identify the modified data

- Checking old LT and SLT
- Insert new leaf into new SLT

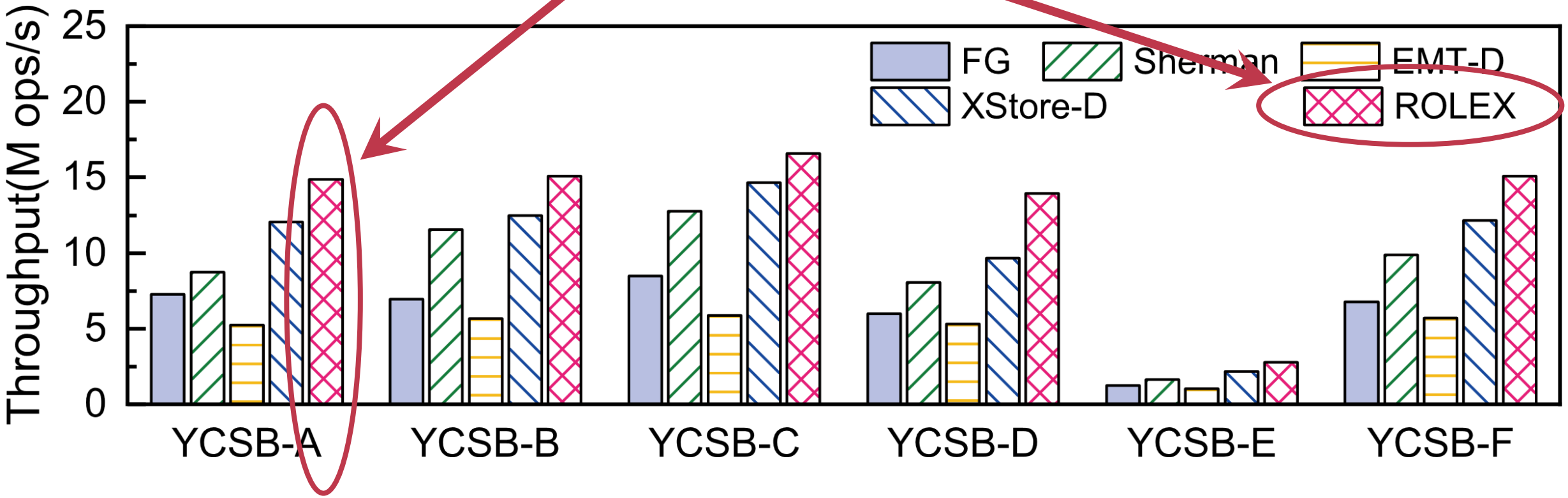
Experimental Setup

- **Testbed**
  - 3 compute nodes + 3 memory nodes
  - 100Gb Mellanox ConnectX-5 IB RNIC
- **Workloads**
  - YCSB; Lognormal & Normal distributions
  - 8B keys and values
- **Comparisons**
  - XStore-D [OSDI'20]
  - Sherman [SIGMOD'22]
  - EMT-D (eRPC + Masstree) [NSDI'19]
  - FG (Fine-grained B-link Tree) [SIGMOD'19]



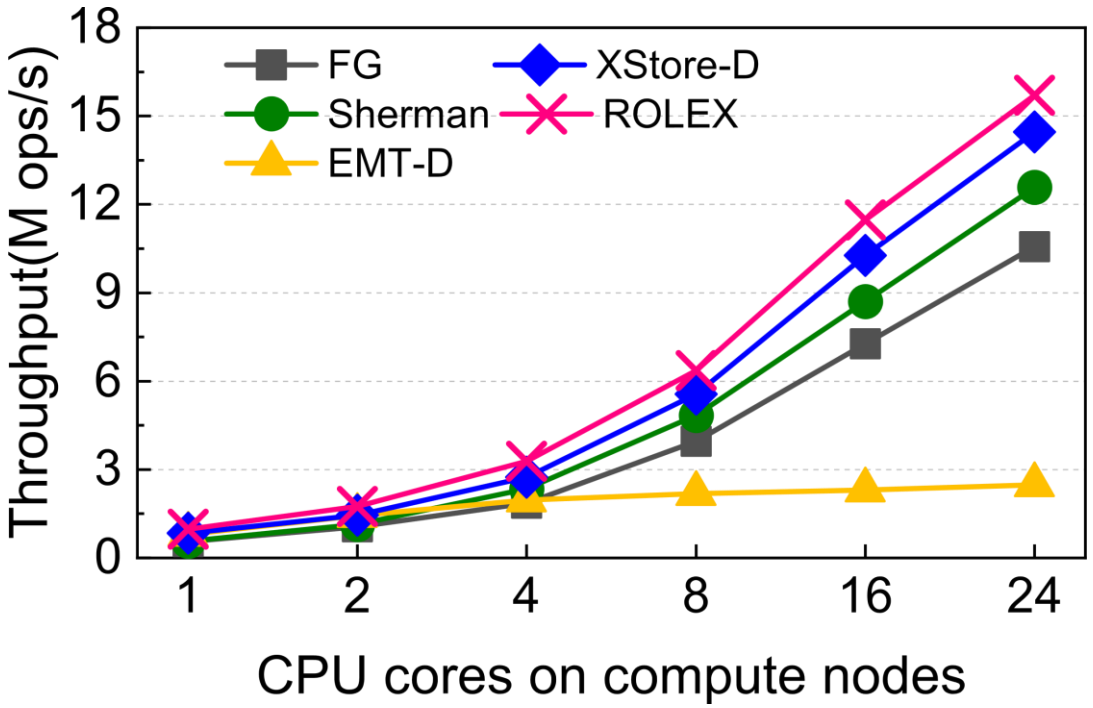
Performance on YCSB

- Competitive performance on static workloads
- 1.3x~2.8x improvements on dynamic workloads

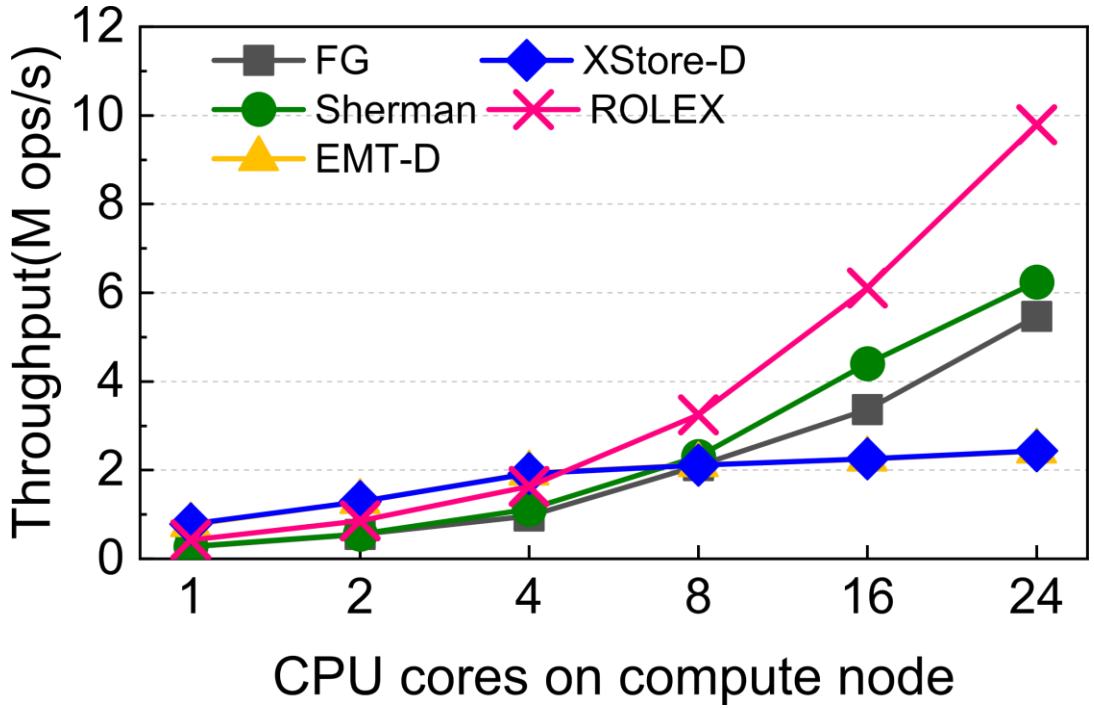


Scale with CPU cores on compute nodes

- ROLEX efficiently scale with computing resources



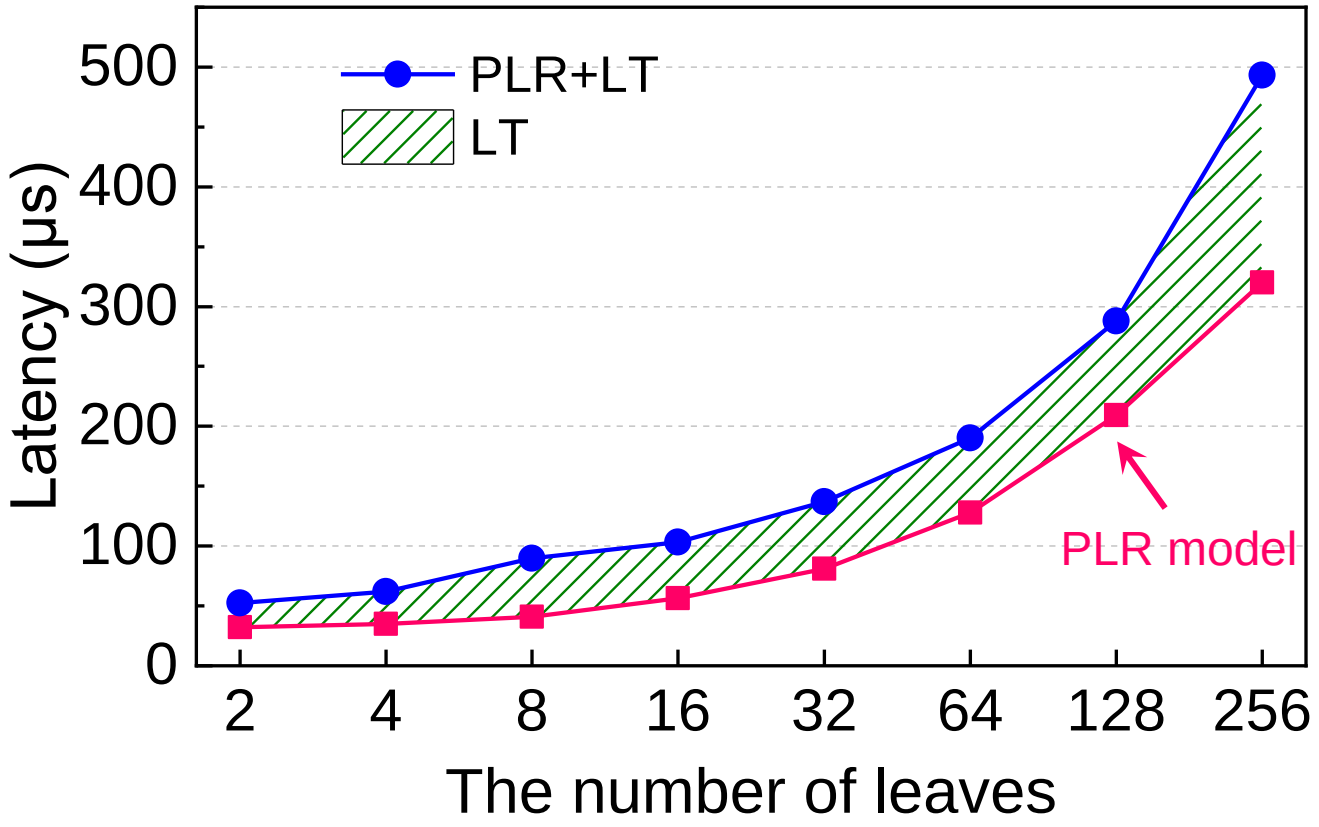
(a) Read performance



(b) Write performance

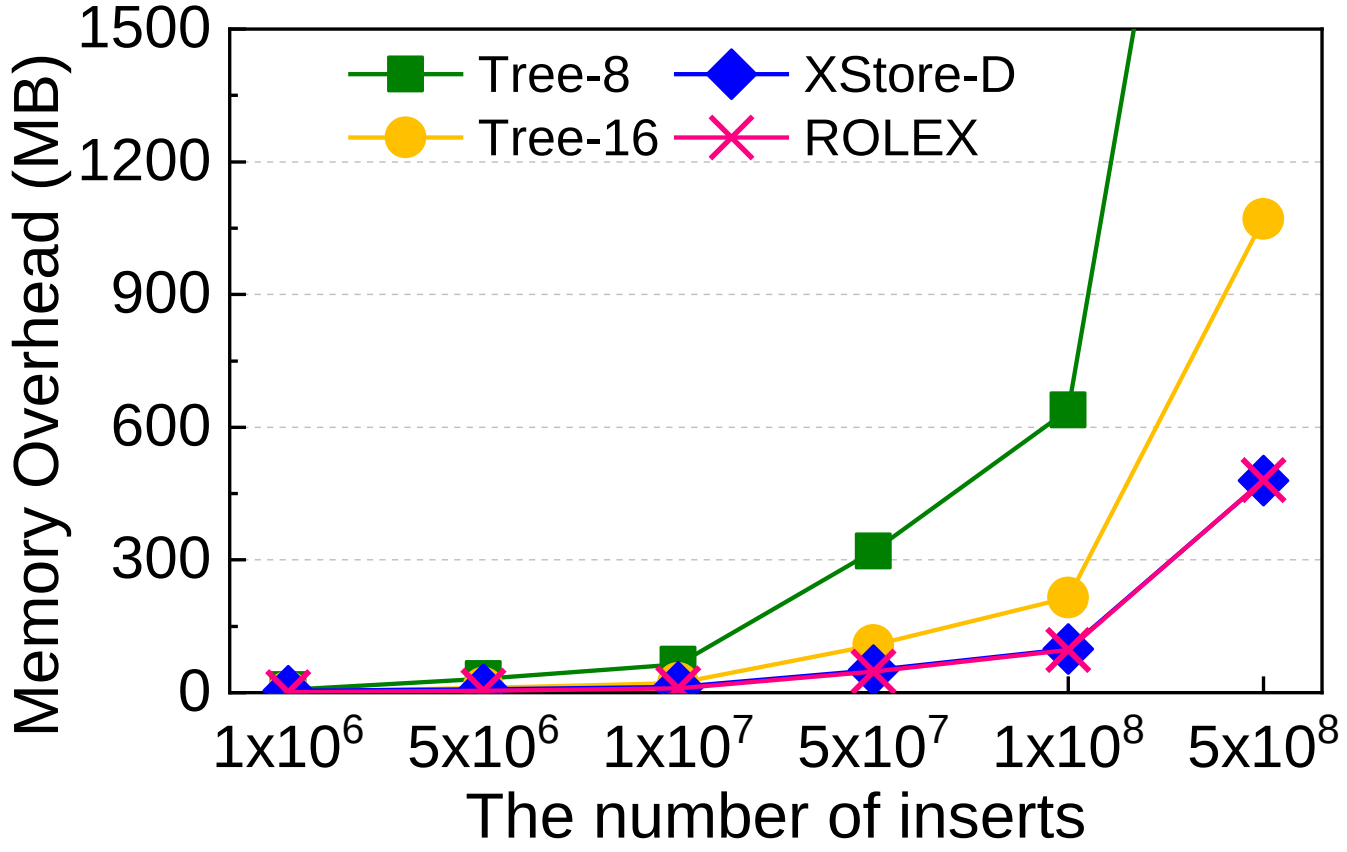
Training Latency

- Training 128 leaves consumes about 300μs
- Retraining a PLR model is efficient



Memory Overhead

- (S)LT accounts for 98% memory overhead
- Learned models save order-of-magnitude space



Conclusion

- **Disaggregated memory systems require efficient one-sided operations**
  - Tree-based structures incur multiple RTTs
  - Learned indexes fail to dynamically change with one-sided operations
- **ROLEX: a scalable RDMA-oriented KV store using learned indexes**
  - Operation decoupling
  - One-sided indexing
  - Asynchronous retraining
- **1.3x~2.8x improvements on the dynamic workloads**
  - Check ROLEX @ https://github.com/iotlpf/ROLEX

Thanks!

Q & A

cspfli@hust.edu.cn