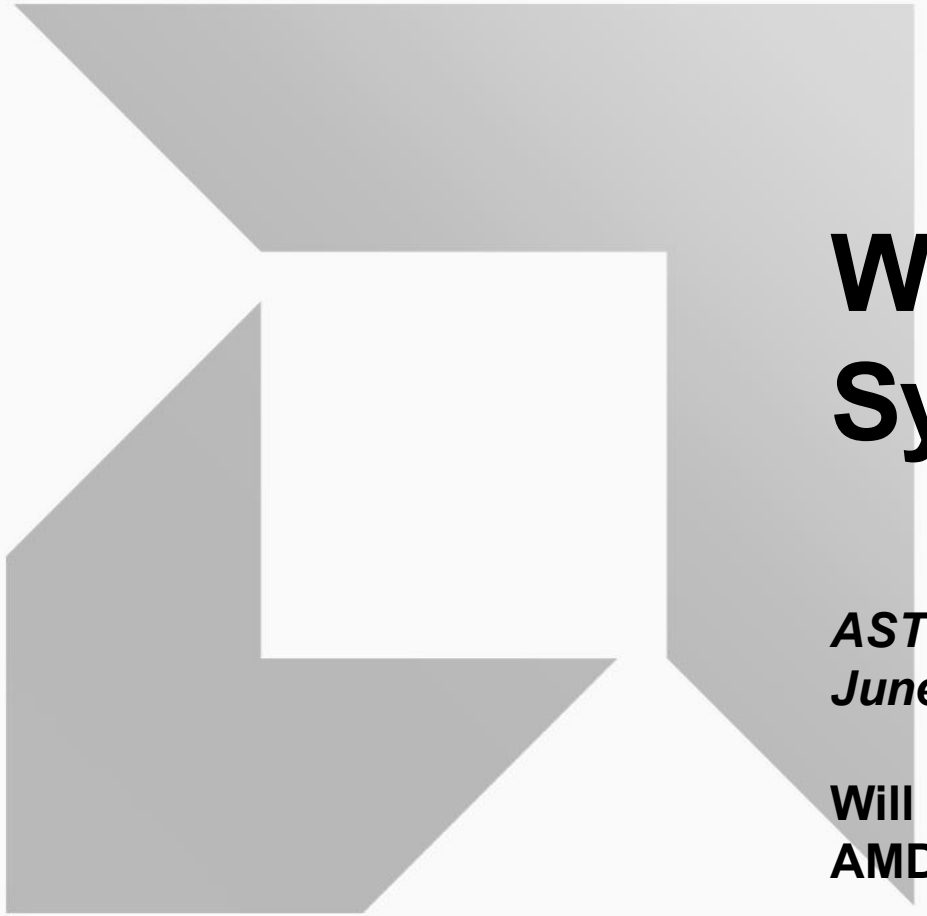

Workload and System Layers

ASTRA-sim Tutorial at ISCA '26
June 27, 2026

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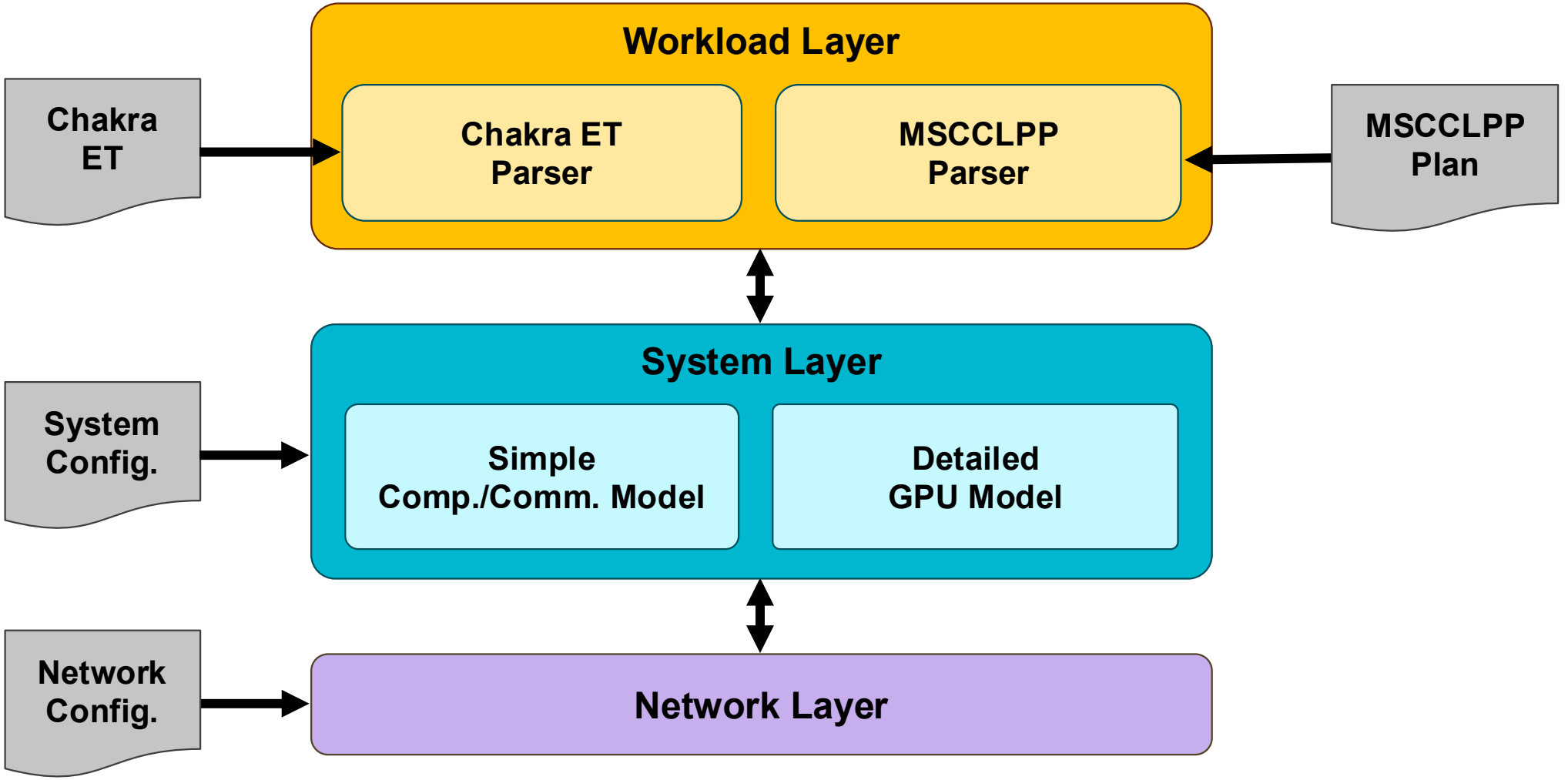
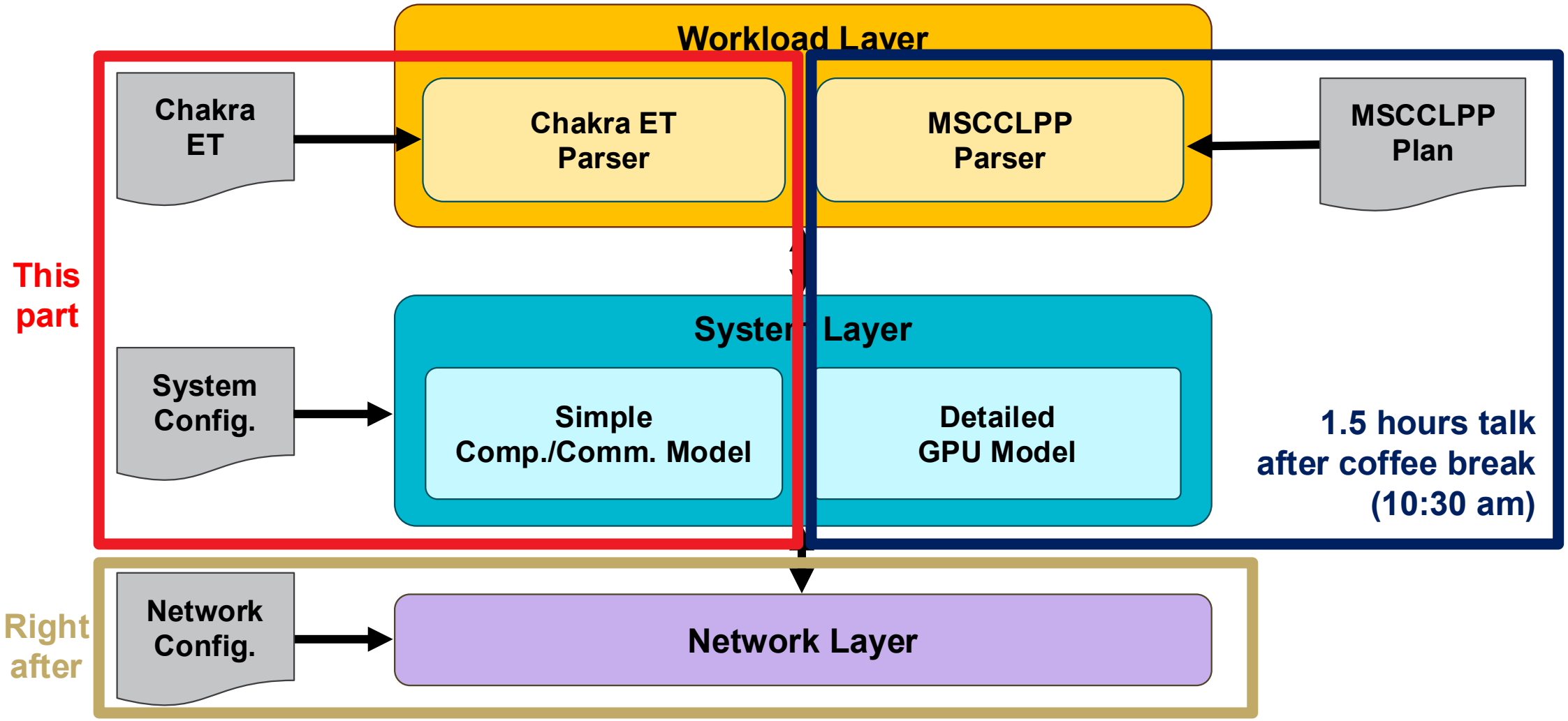
AMD Research and Advanced Development

AMD
together we advance_

ASTRA-sim Overview



ASTRA-sim Overview



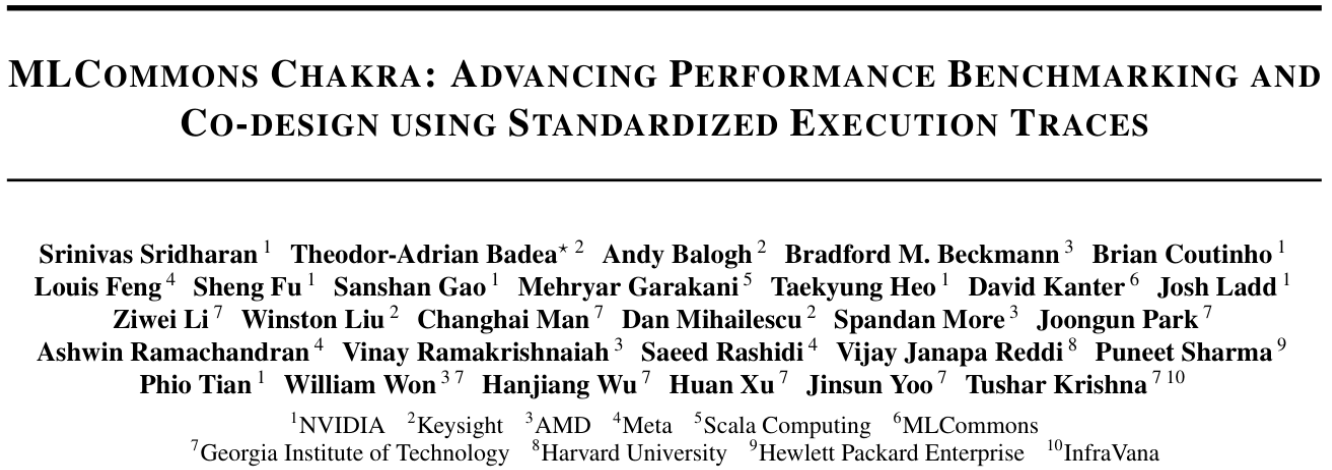
Workload and System Layers

- Workload layer captures/simulates kernel-level, workload-specific characteristics
  - ML **model**
  - **Parallelization** strategies
  - Compute and communication **orders**
  - **Dependencies** across different kernels

- System layer executes the kernel, dispatches events to the simulation backend
  - **Compute** kernel → **estimates compute time**
  - **Communication** kernel → **breaks down collective** into network simulation units, **delegates** to the network simulator

Chakra Execution Trace

- Workload trace representation: **MLCommons Chakra** execution trace (ET)
  - **Standardized** traces for distributed ML workload representation
- Check the:
  - Working group: **https://mlcommons.org/working-groups/research/chakra/**
  - MLSys paper: **https://doi.org/10.48550/arXiv.2605.11333**
  - GitHub: **https://github.com/mlcommons/chakra**



MLCOMMONS CHAKRA: ADVANCING PERFORMANCE BENCHMARKING AND CO-DESIGN USING STANDARDIZED EXECUTION TRACES

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Louis Feng [4] Sheng Fu [1] Sanshan Gao [1] Mehryar Garakani [5] Taekyung Heo [1] David Kanter [6] Josh Ladd [1]
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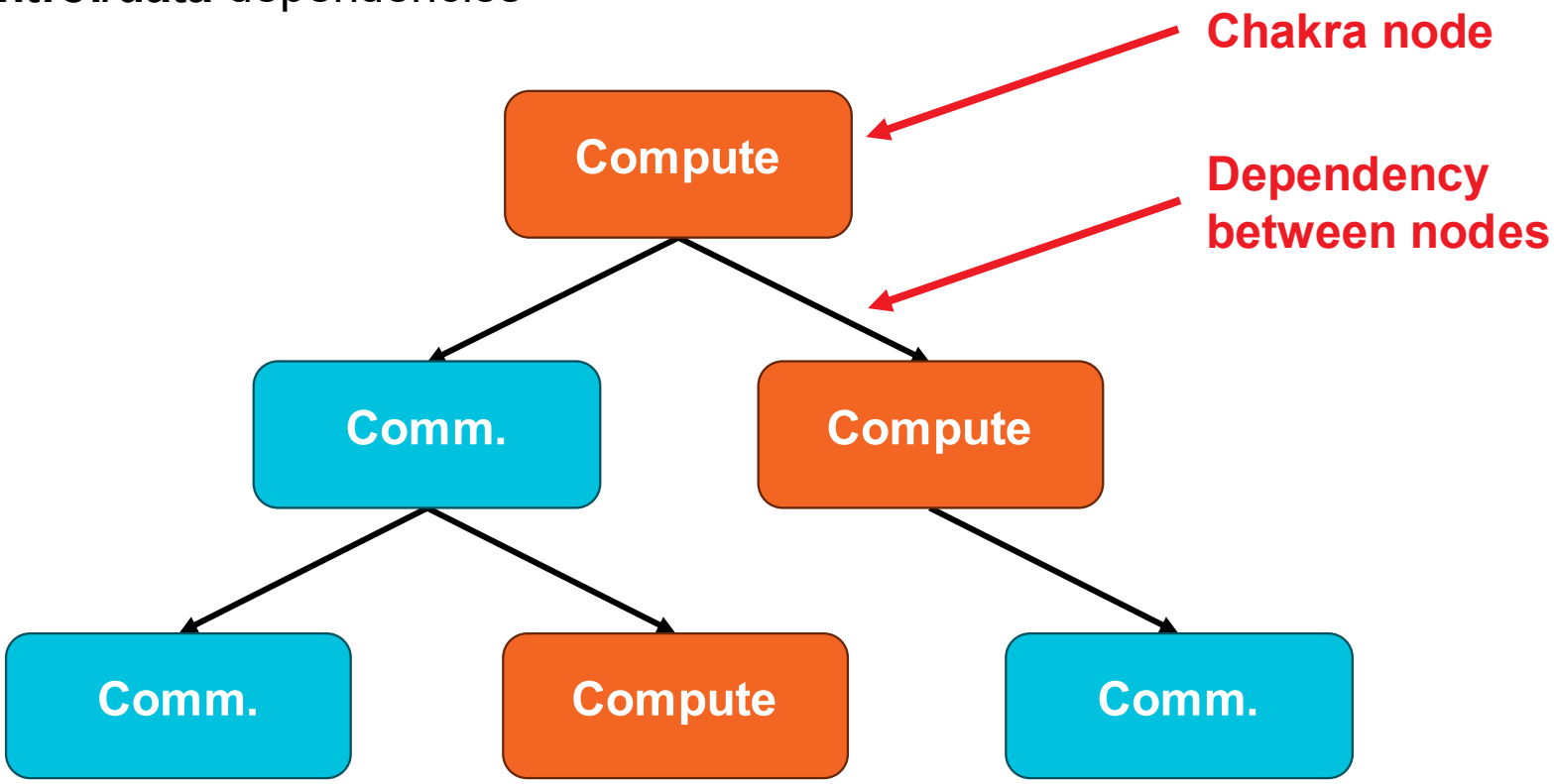
S. Sridharan et al., "MLCommons Chakra: Advancing Performance Benchmarking and Co-design using Standardized Execution Traces," in Proc. of the 9th Conference on Machine Learning and Systems (MLSys), 2026.

Chakra ET: Structure

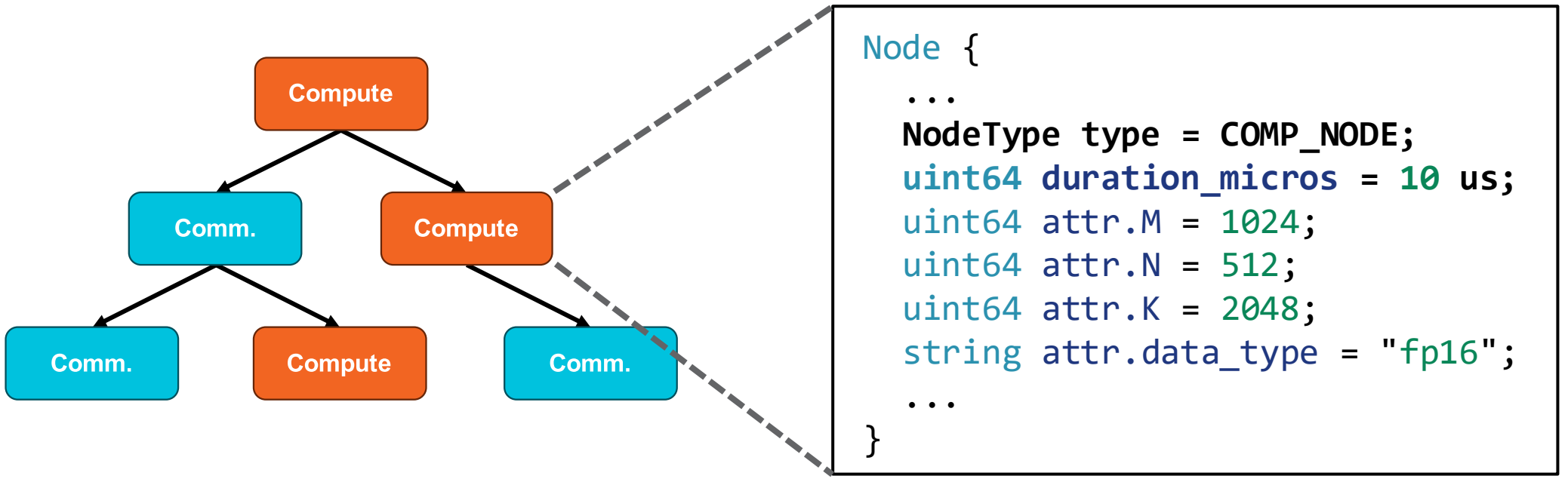
- A directed acyclic graph (DAG) of Chakra **nodes**
- Edges represent **control/data** dependencies



Example Chakra ET with six nodes

Chakra ET: Compute Node

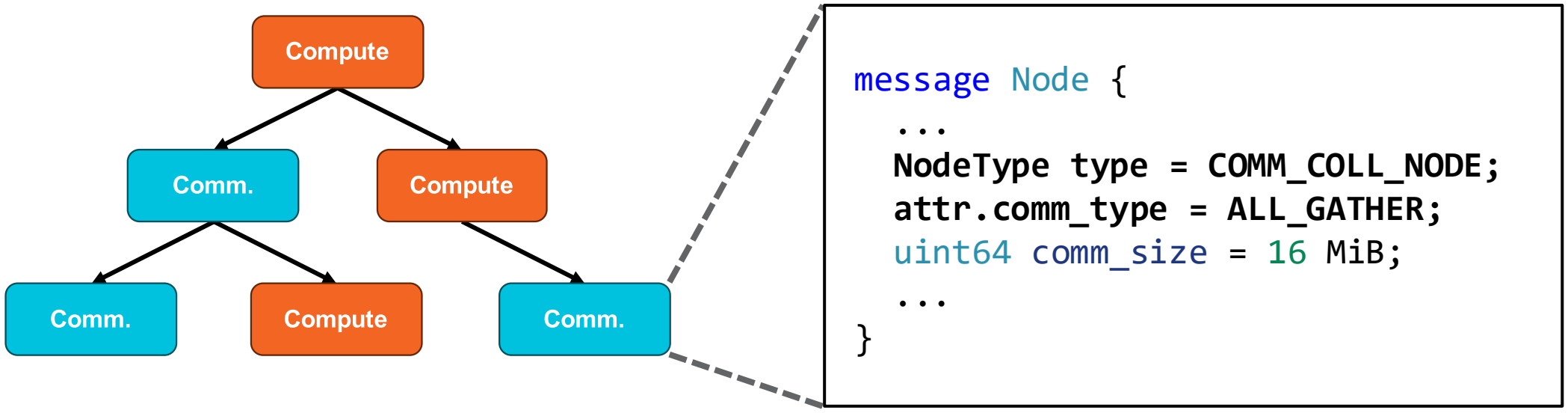
- Captures **compute kernel metadata**
  - e.g., (measured) compute durations, GEMM size, data types



Example compute node

Chakra ET: Communication Node

- Captures **communication kernel metadata**
  - e.g., collective type, buffer size, source/destination GPUs

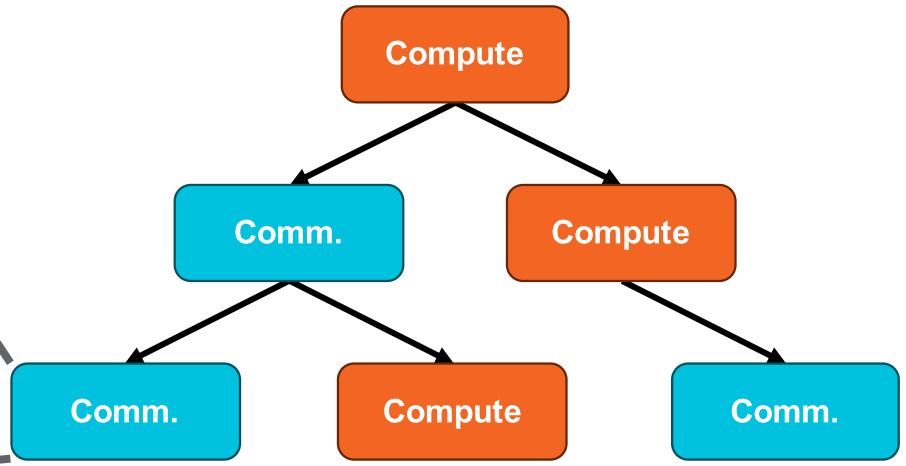


Example: All-Gather node

Chakra ET: Communication Node (cont'd)

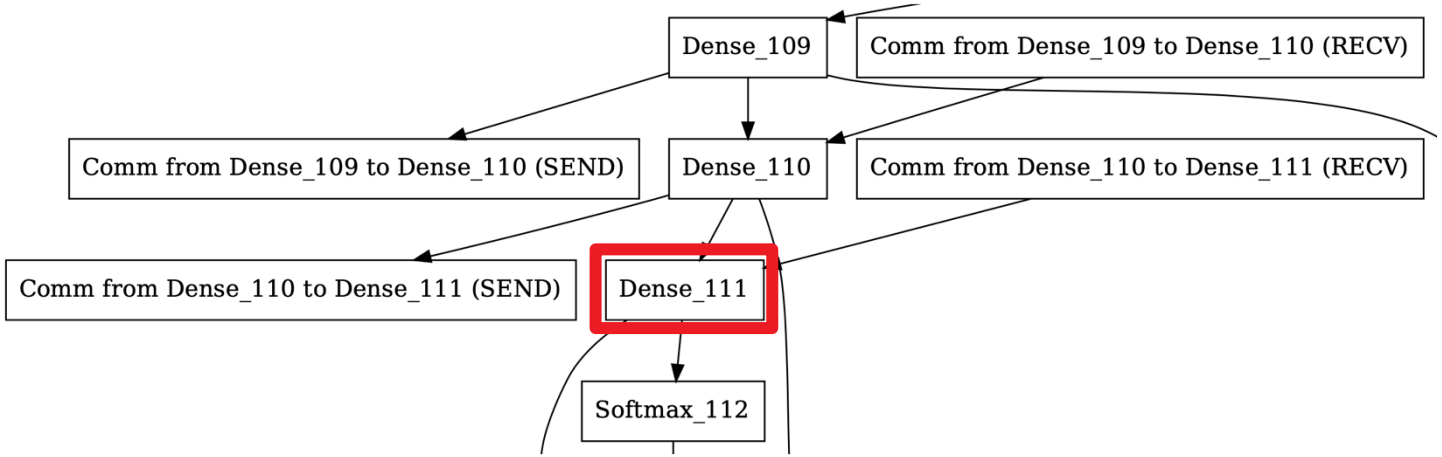
- Captures **communication kernel metadata**
  - e.g., collective type, buffer size, source/destination GPUs

```
message Node {
  ...
  NodeType type = COMM_SEND_NODE
  uint32 attr.comm_dst = GPU 5;
  uint64 comm_size = 1 MiB;
  ...
}
```



Example: single send node

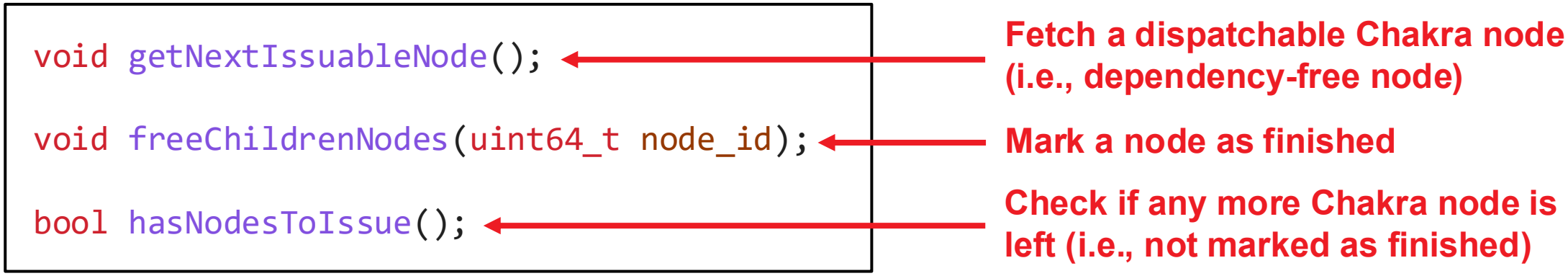
Chakra ET Example




```
"id": "5526",
"name": "aten::transpose",
"type": "COMP_NODE",
"dataDeps": [
  "5525"
],
"inputs": {
  "values": "[[5524, 5133, 0, 829
  "shapes": "[[288, 288], [], []]
  "types": "['Tensor(c10::BFloat16
},
"outputs": {
  "values": "[[5528, 5133, 0, 82944
  "shapes": "[[288, 288]]",
  "types": "['Tensor(c10::BFloat16)
},
"attr": [
  {
    "name": "is_cpu_op",
    "boolVal": true
  },
```

Chakra APIs

- Chakra's `ETFeeder` provides application programming interfaces (APIs) to query Chakra ET

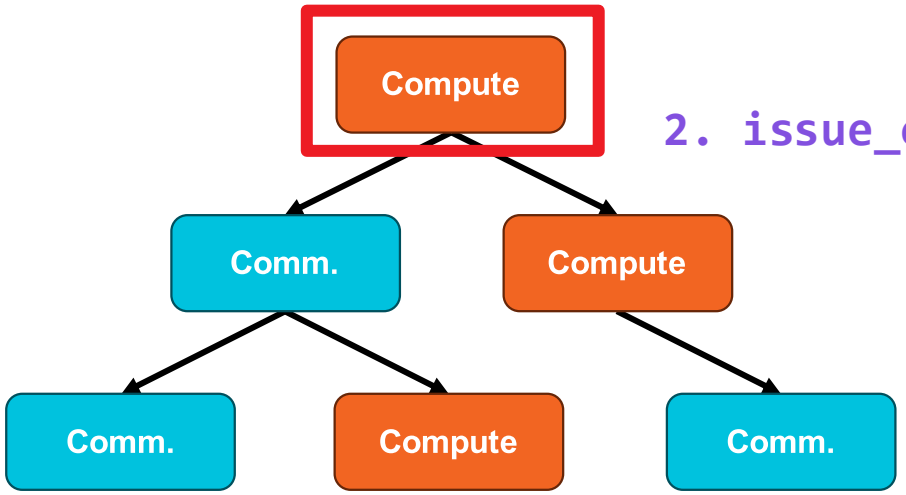


`Chakra:src/feeder/wrapper_node.h`

Workload Layer: Issuing a Node

- First, **query** the Chakra ET, retrieve a dispatchable Chakra node
- Then, **issue** the Chakra node to the system layer

```
1. getNextIssuableNode();
```

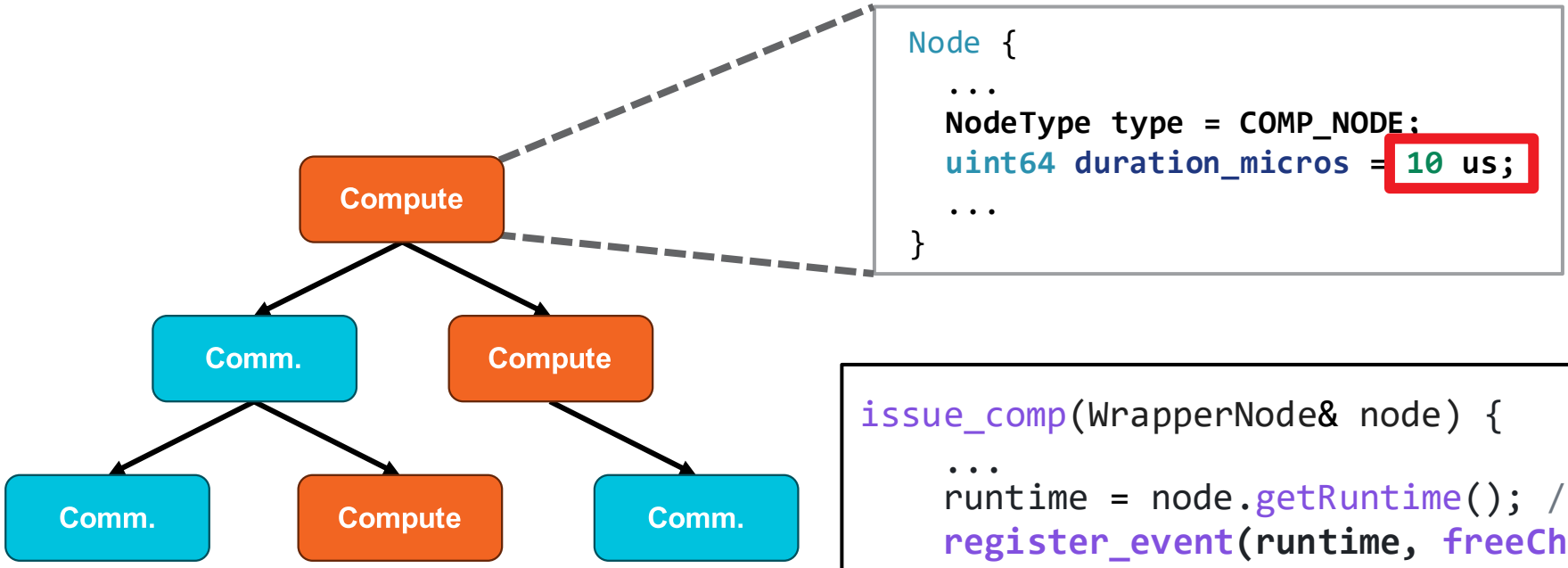



```
2. issue_comp();
```

Delegates compute modeling to the system layer

System Layer: Simple Compute Model

- Parse compute kernel information
  - Either (1) **replay** compute duration or (2) use **roofline** model to estimate compute time
- Retire compute node after this duration



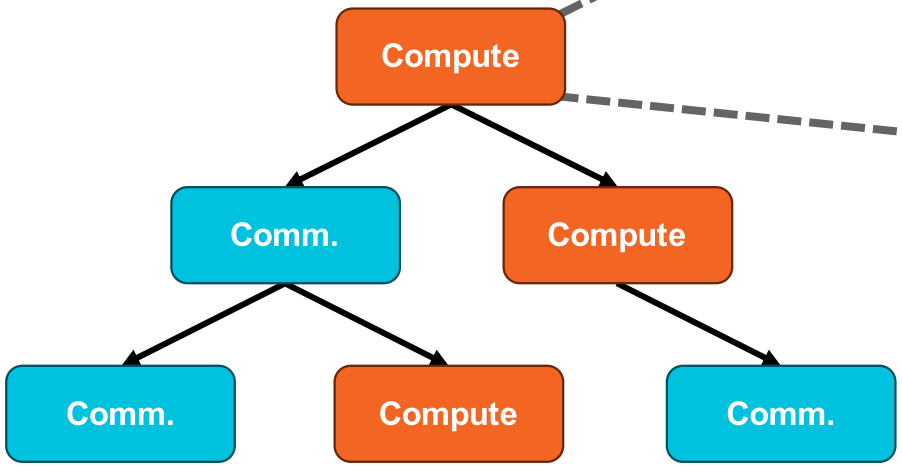

```
Node {
  ...
  NodeType type = COMP_NODE;
  uint64 duration_micros = 10 us;
  ...
}
```

```
issue_comp(WrapperNode& node) {
    ...
    runtime = node.getRuntime(); // 10 us
    register_event(runtime, freeChildrenNodes(node.id));
}
```

System layer: simple compute model

System Layer: Simple Compute Model

- Parse compute kernel information
  - Either (1) **replay** compute duration or (2) use **roofline** model to estimate compute time
- Retire compute node after this duration



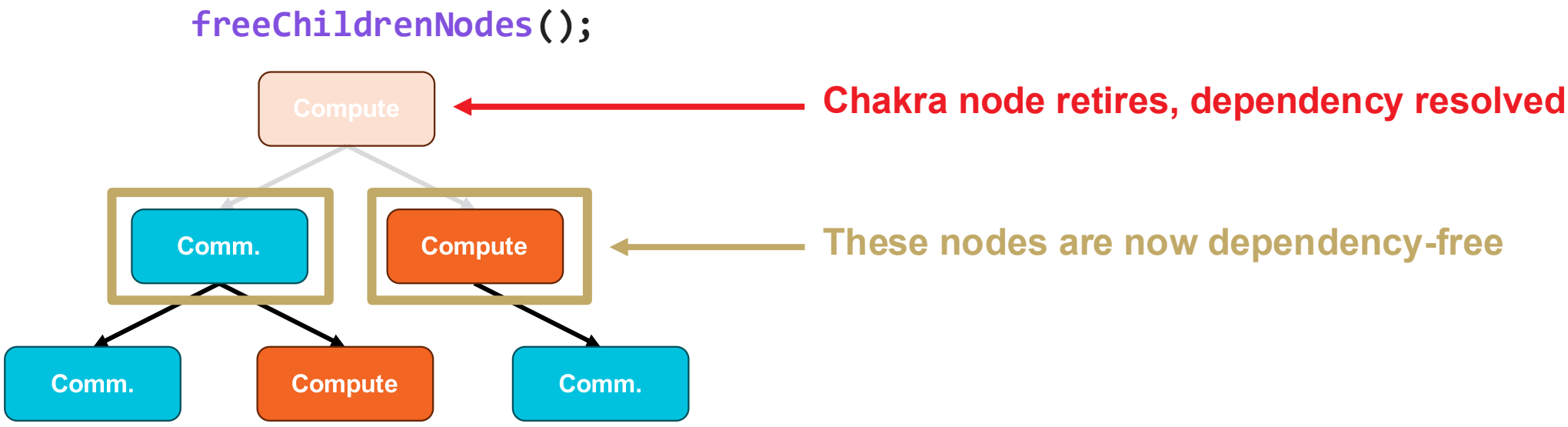

```
Node {
  NodeType type = COMP_NODE;
  uint64 attr.M = 1024;
  uint64 attr.N = 512;
  uint64 attr.K = 2048;
  string attr.data_type = "fp16";
}
```

```
issue_comp(WrapperNode& node) {
    ...
    runtime = roofline(1024, 512, 2048, "fp16");
    register_event(runtime, freeChildrenNodes(node.id));
}
```

System layer: simple compute model (roofline)

Workload Layer: Freeing a Node

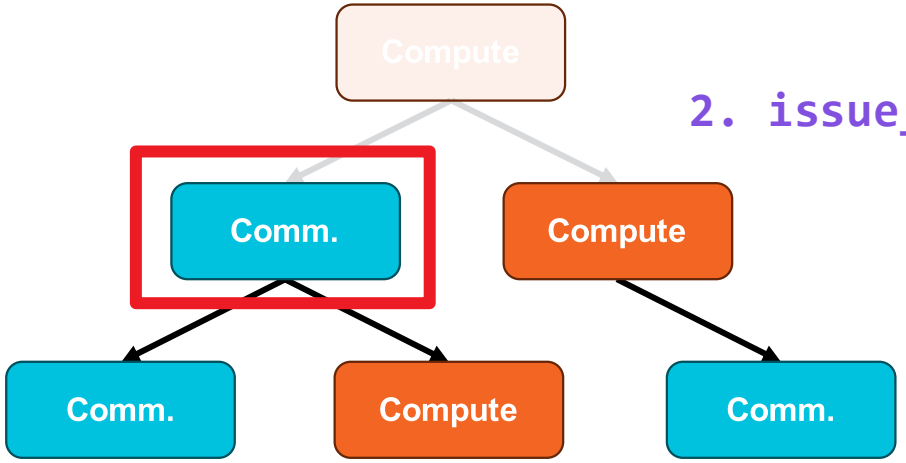
- **Retire** the Chakra node
- Mark the **dependency as resolved**



Workload Layer: Issuing Next Node

- Query and issue a **next issuable node**
  - Among the dependency-free nodes, one is randomly chosen

```
1. getNextIssuableNode();
```

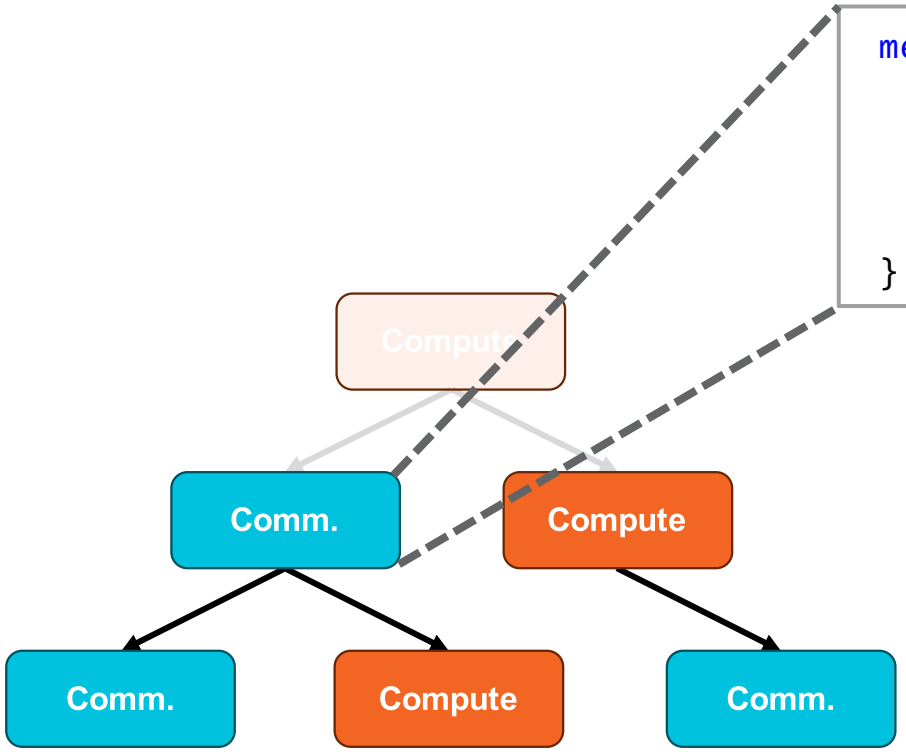



```
2. issue_comm();
```

Delegates communication modeling to the system layer

System Layer: Single Send/Receive

- Request the network backend to simulate a single network transfer




```
message Node {
  NodeType type = COMM_SEND_NODE
  uint32 attr.comm_src = GPU 2;
  uint32 attr.comm_dst = GPU 5;
  uint64 comm_size = 16 MiB;
}
```

```
issue_comm(WrapperNode& node) {
    ...
    sim_send(from: 2, to: 5, size: 16 MiB,
             callback: freeChildrenNodes(node.id));
}
```

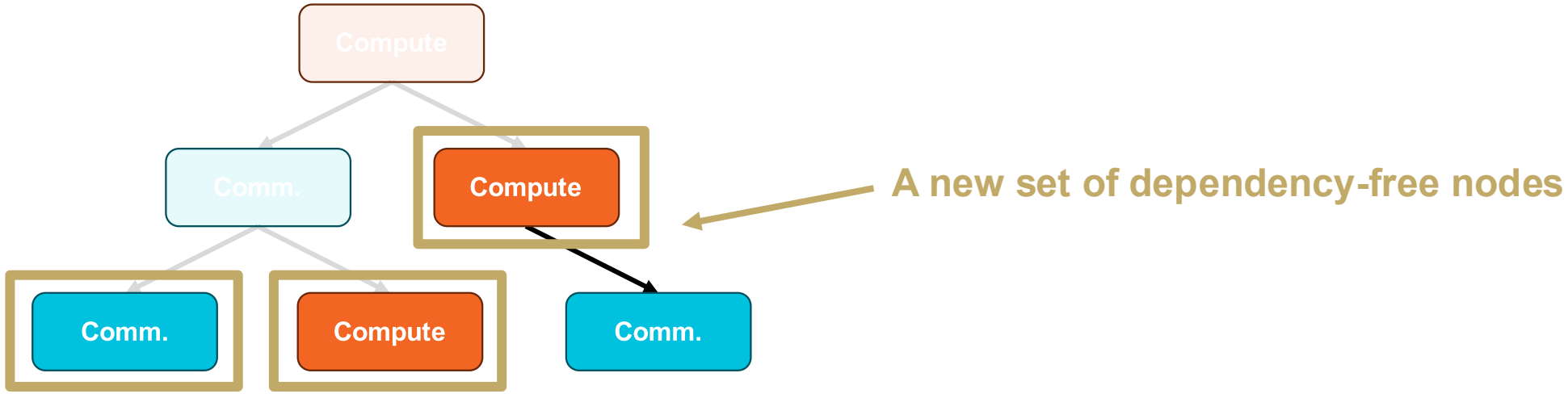
System layer: simple communication model

Further delegates actual network simulation to the network layer (later talk)

Workload Layer: Freeing a Node

- **Retire** the Chakra node and mark **dependency as resolved**

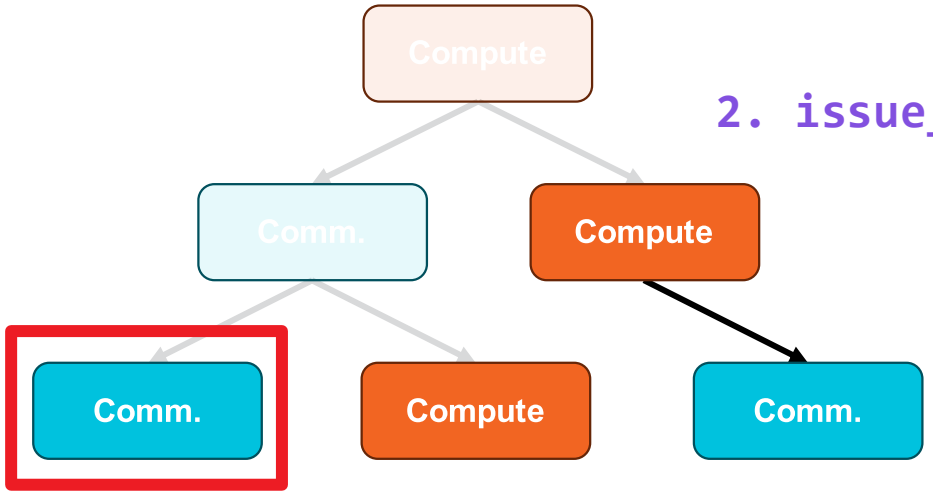
```
freeChildrenNodes();
```



Workload Layer: Freeing a Node

- Repeat the process: issue a new dependency-free Chakra node

```
1. getNextIssuableNode();
```

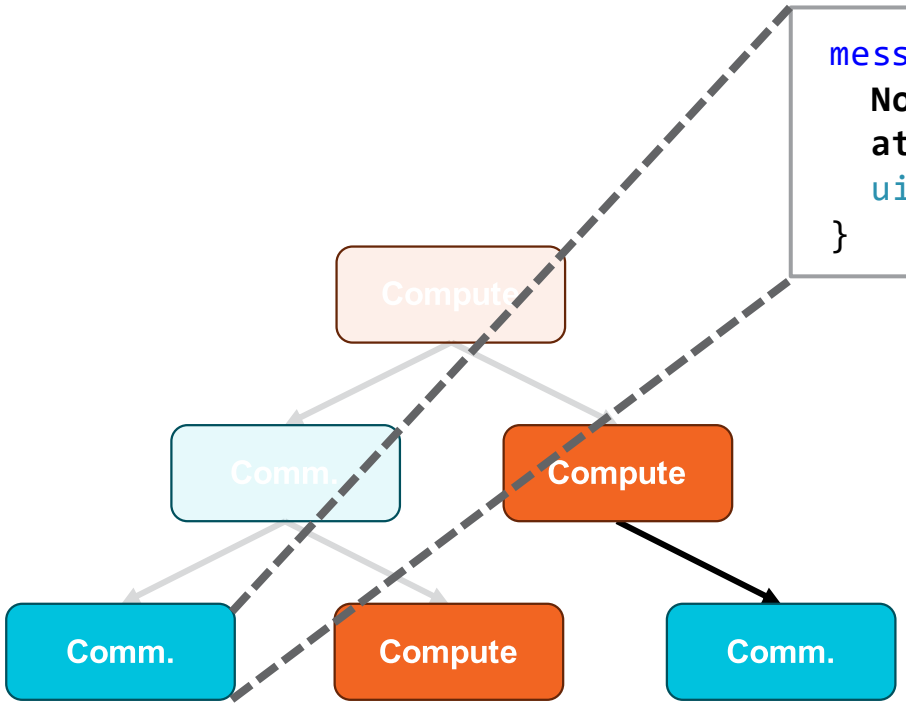



```
2. issue_comm();
```

Delegates communication modeling to the system layer

System Layer: Collective Communication

- Based on collective type and algorithm, call the appropriate **finite state machine (FSM)**



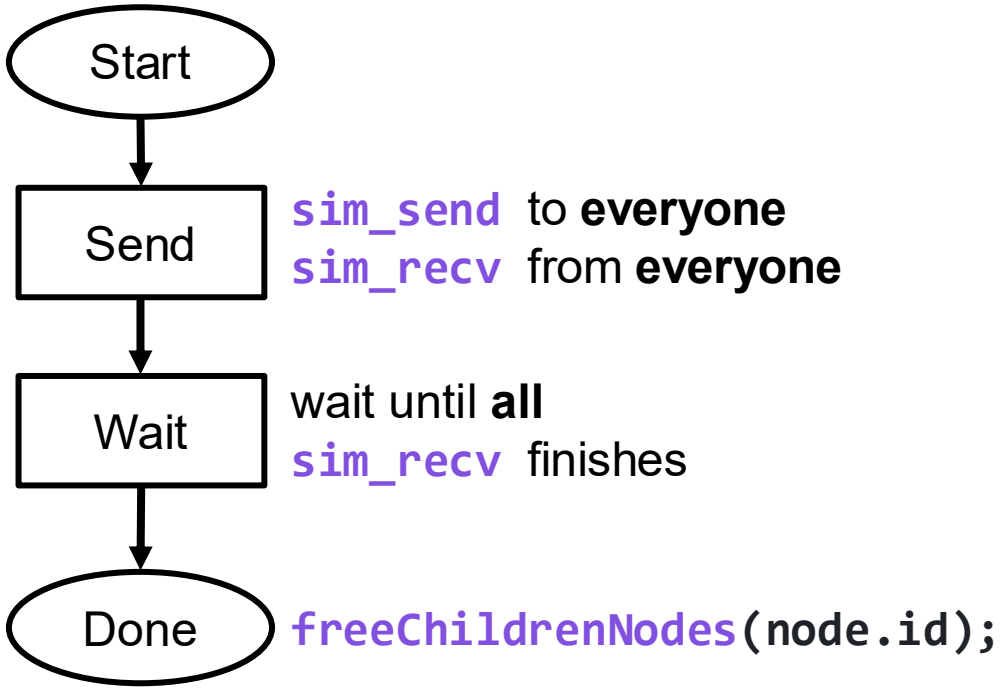

```
message Node {
  NodeType type = COMM_COLL_NODE;
  attr.comm_type = ALL_GATHER;
  uint64 comm_size = 16 MiB;
}
```

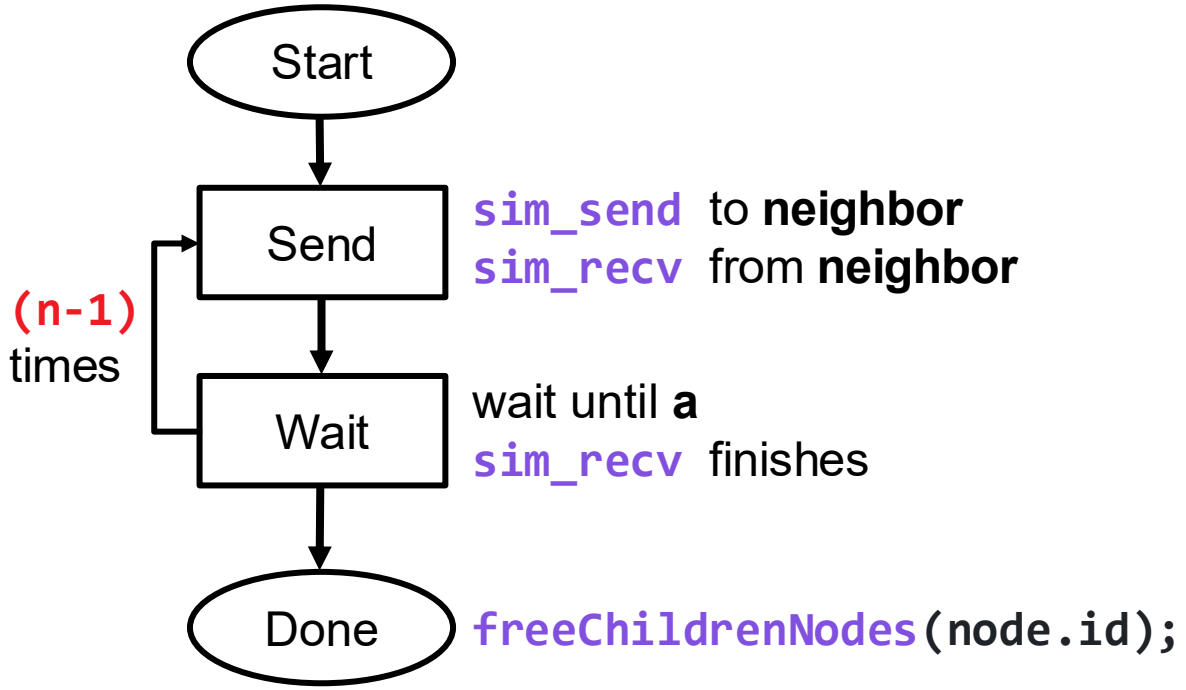
```
issue_comm(WrapperNode& node) {
    ...
    generate_all_gather(size: 16 MiB,
                        algorithm: "all-pairs");
}
```

System layer: simple communication model

System Layer: Collective Communication (cont'd)

- Each collective algorithm is an FSM
  - **Dispatches** simulation request to the network layer
  - Finally, **free the Chakra node** when FSM finishes



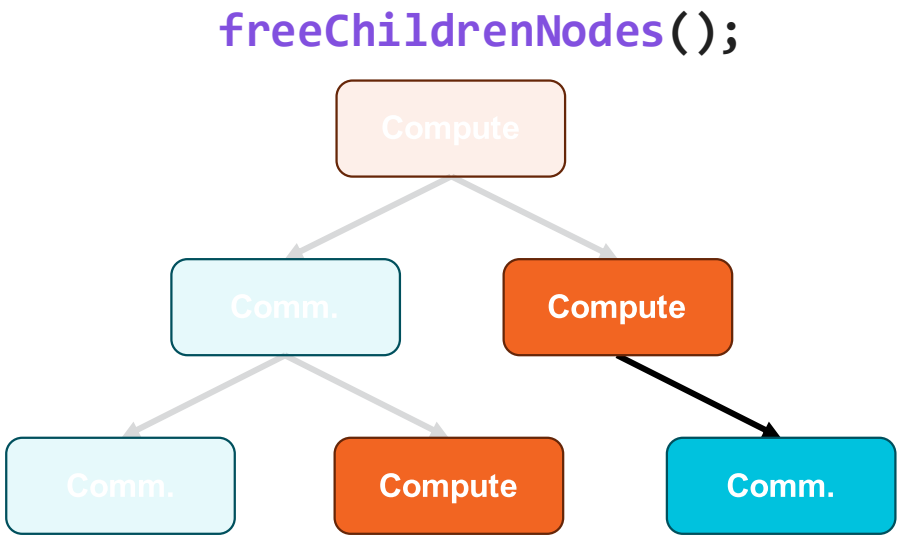



```
generate_all_gather(algorithm: "all-pairs");
```

```
generate_all_gather(algorithm: "ring");
```

Workload Layer: Freeing a Node

- ASTRA-sim simulation runs until all Chakra nodes are executed
  - When `hasNodesToIssue()` returns `false`, simulation ends.



Summary: Workload and System Layers

```
while (hasNodesToIssue()) {
    node = getNextIssuableNode();
    if (node.getNodeType() == COMP_NODE) {
        issue_comp(node);
    } else if (node.getNodeType() == COMM_NODE) {
        issue_comm(node);
    }
}
```

Workload layer

```
issue_comp(WrapperNode& node) {
    ...
    runtime = node.getRuntime();
    register_event(runtime, freeChildrenNodes(node.id));
}
```

System layer: simple compute model

```
issue_comm(WrapperNode& node) {
    ...
    generate_all_gather(size: 16 MiB, alg: "all-pairs");
}

generate_all_gather() {
    ...
    // finite state machine dispatching sim_send/recv
    freeChildrenNodes(node.id));
}
```

System layer: simple communication model

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