Georgia Tech School of Electrical and Computer Engineering
College of Engineering

http://synergy.ece.gatech.edu

ASTRA-SIM Description

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Georgia Institute of Technology

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Acknowledgments: Srinivas Sridharan (Facebook), Sudarshan Srinivasan (Intel)

Agenda

Time (CET)	Time (ET)	Topic	Presenter
15:00 – 16:00	9:00 – 10:00	**Introduction to Distributed Deep Learning Training Platforms**	Tushar Krishna
16:00 – 17:00	10:00 – 11:00	**ASTRA-sim**	Saeed Rashidi
17:00 – 17:10	11:00 – 11:10	**Break**	
17:10 – 17:50	11:10 – 11:50	**Demo and Exercises**	William Won and Taekyung Heo
17:50 – 18:00	11:50 – 12:00	**Extensions and Future Development**	Tushar Krishna and Saeed Rashidi

Tutorial Website

includes agenda, slides, ASTRA-sim installation instructions (via source + docker image)
https://astra-sim.github.io/tutorials/asplos-2022

Attention: Tutorial is being recorded

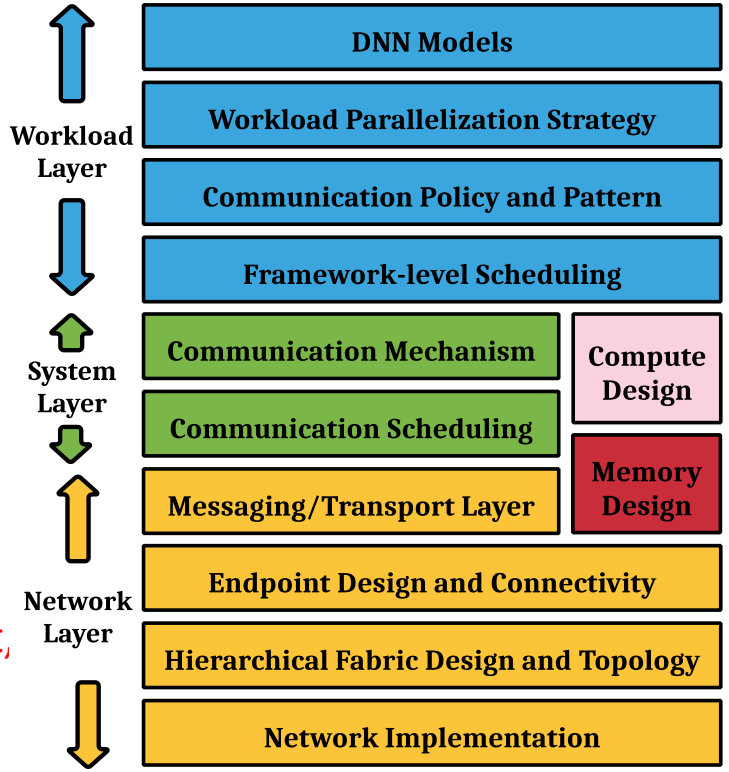
Overview

How to Model and Evaluate the Communication Effect

- It is a complex problem and can be viewed as three layers :
  - 1. Workload layer (the training loop):
    - Parallelism approach
    - Compute power
    - Communication size & type and dependency order
  - 2. System layer:
    - Collective communication algorithm
    - Chunk size, schedule of collectives
  - 3. Network layer:
    - Physical topology
    - Congestion control, communication protocol
    - Link BW, latency, buffers, routing algorithm

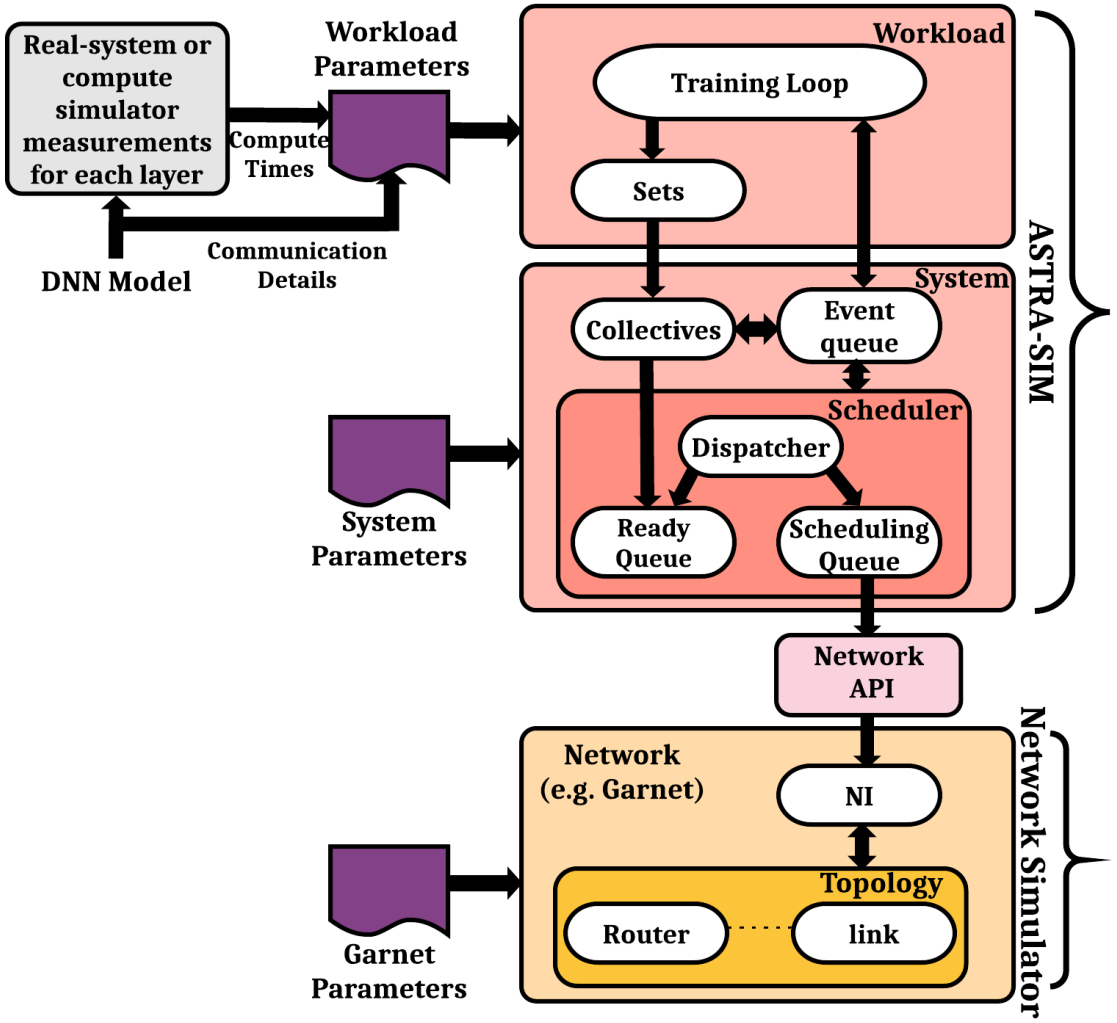
Not too many tools cover these aspects

Many tools In this area (e.g., Garnet, Analytical)



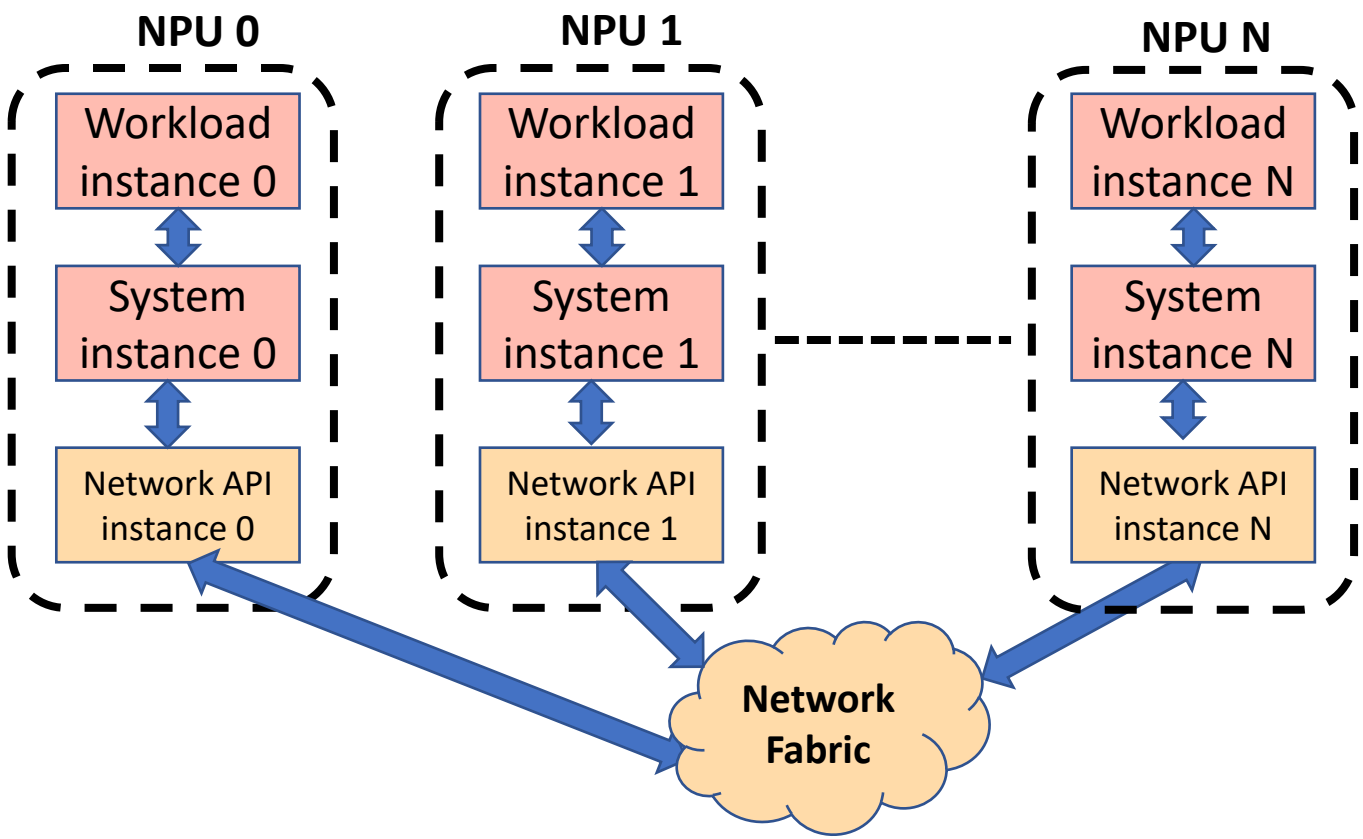
ASTRA-SIM Architecture

- Workload layer:
  - Supports Data-Parallel, Model-Parallel, Hybrid-Parallel training loops
  - Easy to add new arbitrary training loop
- System:
  - Ring based, Tree-based, AlltoAll based, and multi-phase collectives
  - Easy to add new collective communication
- Network:
  - Supports Analytical and GARNET Network simulator
  - Analytical:
    - Supports hierarchical topologies
    - Each level in hierarchy can be switch, ring, FC….
    - https://github.com/astra-sim/analytical/tree/develop
  - GARNET:
    - Supports switch-based and torus-based topologies
    - Supports credit-based flow control
    - https://github.com/georgia-tech-synergy-lab/gem5_astra/tree/reorgV2
  - Can add new topologies in both Analytical and GARNET



ASTRA-SIM Runtime Structure

- Each NPU is represented through separate instance of Workload, System, and Network API.
- Network API class is implemented by the network backend.



ASTRA-SIM Directory

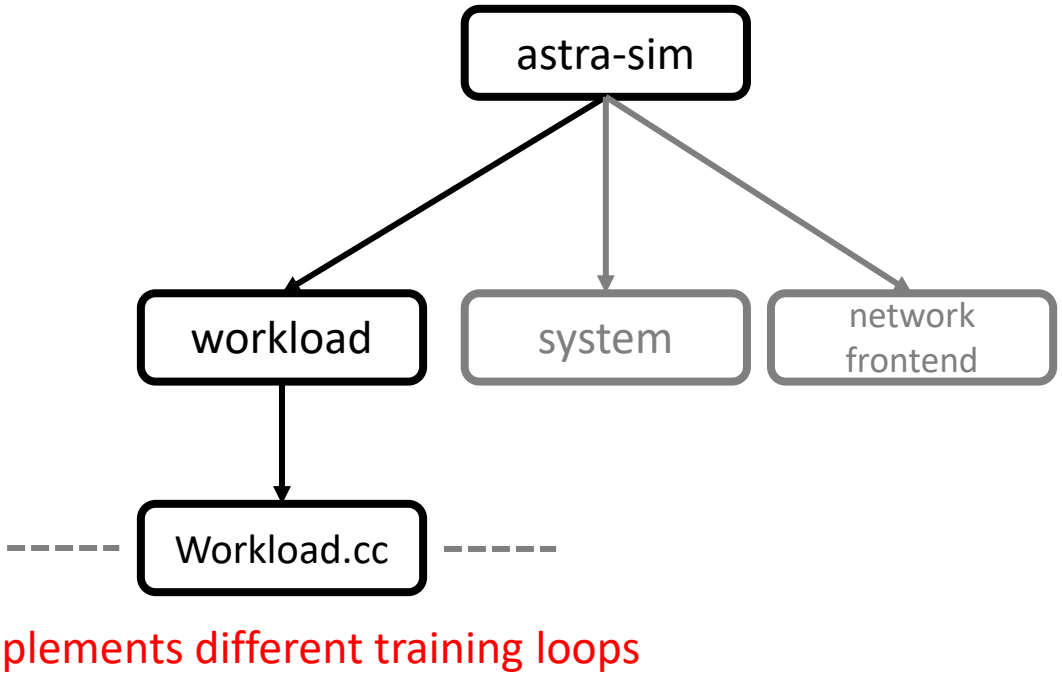
rashidi1saeed Merge pull request #44 from srinivas212/master ... f7e54a8 15 hours ago **335** commits

.github/workflows	Added GitHub Actions (#30)	8 months ago
astra-sim	CSV Writer Updated	19 hours ago
build	gem5 is now compatible with new changes	18 hours ago
docs/images	updated	9 months ago
examples	run_multi example script bug fixed	18 hours ago
extern	Merge pull request #43 from astra-sim/saeed_astra_dev	15 hours ago
inputs	Update README.md	17 hours ago
scripts/workload_generator	-:TESTED:-	last month
test	Fix formatting using clang-format	9 months ago
.clang-format	Use PyTorch .clang-format	9 months ago
.clang-tidy	Added GitHub Actions (#30)	8 months ago
.gitignore	Added GitHub Actions (#30)	8 months ago
.gitmodules	Add scale sim v2 submodule	last month
CMakeLists.txt	CMAKELists updated	yesterday
CODEOWNERS	Modify CODEOWNERS	16 hours ago
LICENSE	Update LICENSE	9 months ago
README.md	Update README.md	9 months ago

Workload Layer

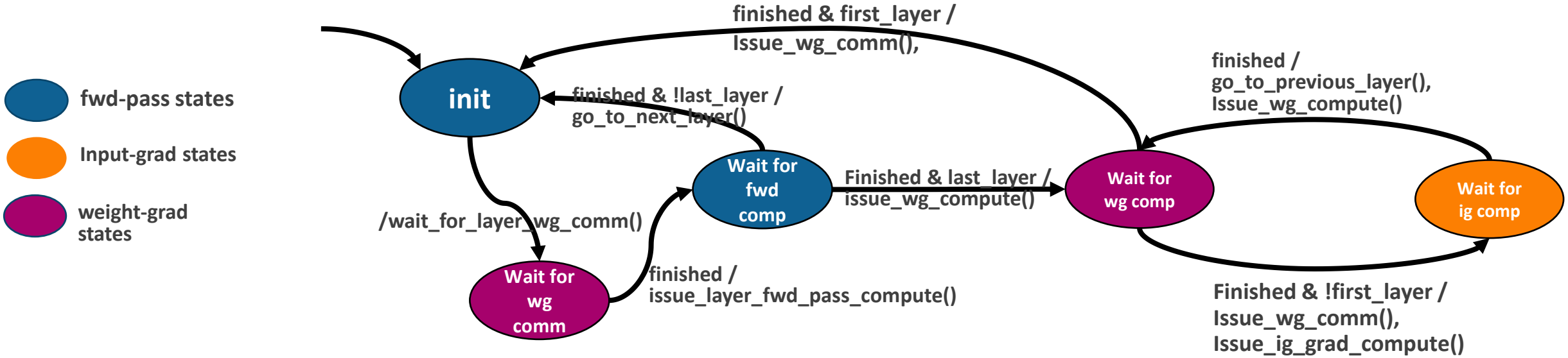
Workload Layer Training Loop

- Code Structure



Workload Training Loop: Data-Parallel Example

- Different training loops can be captured using state machines.



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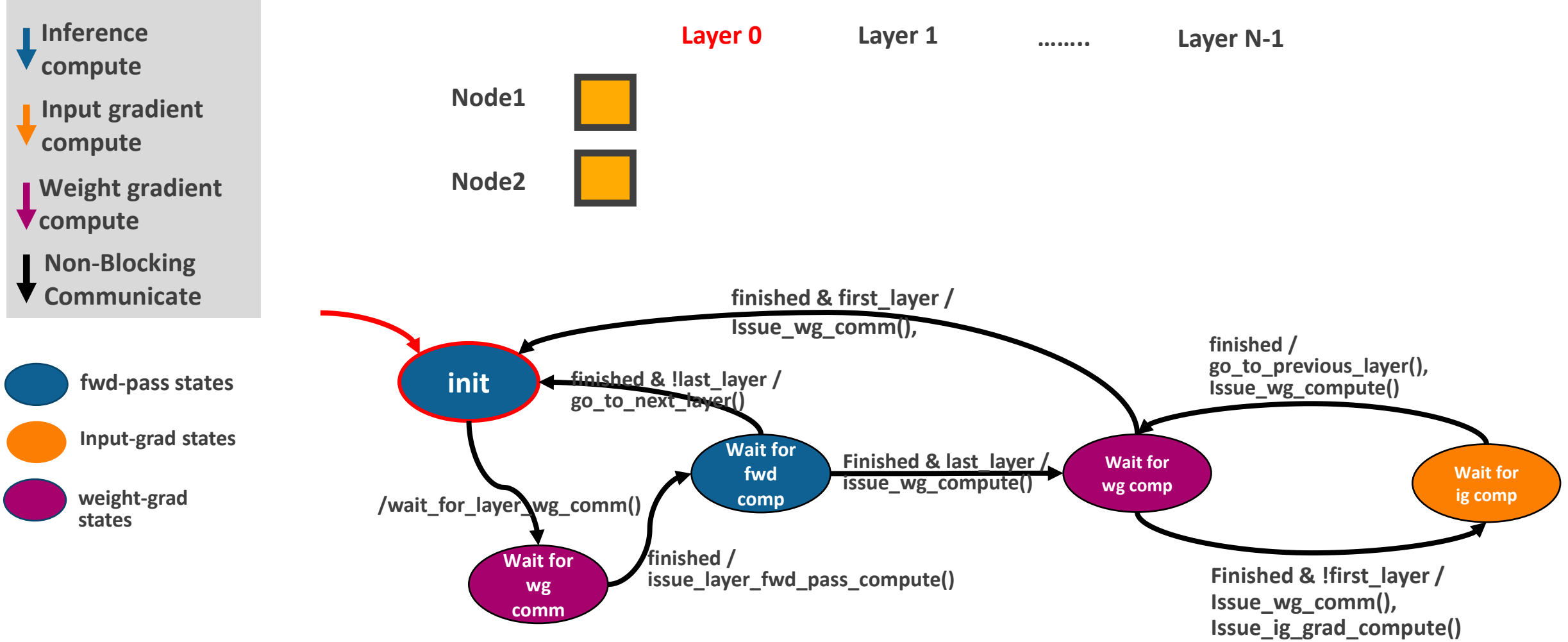

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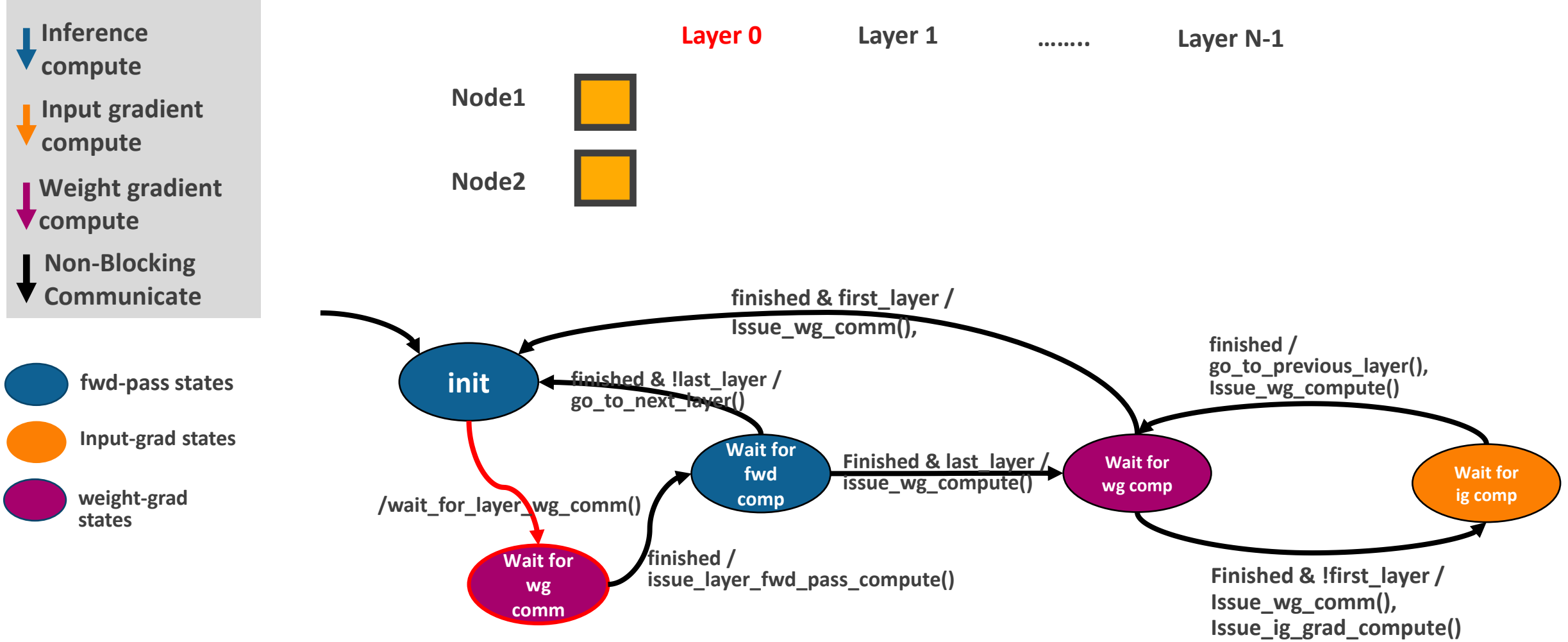

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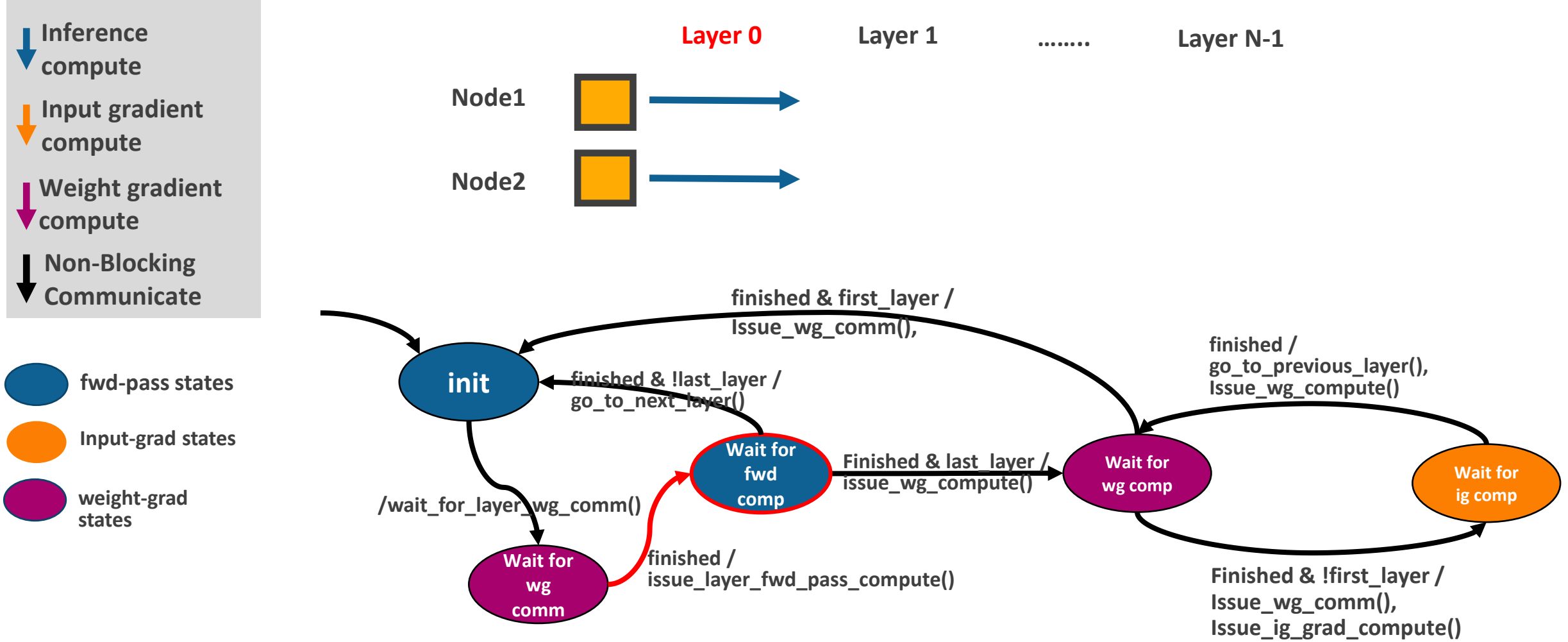

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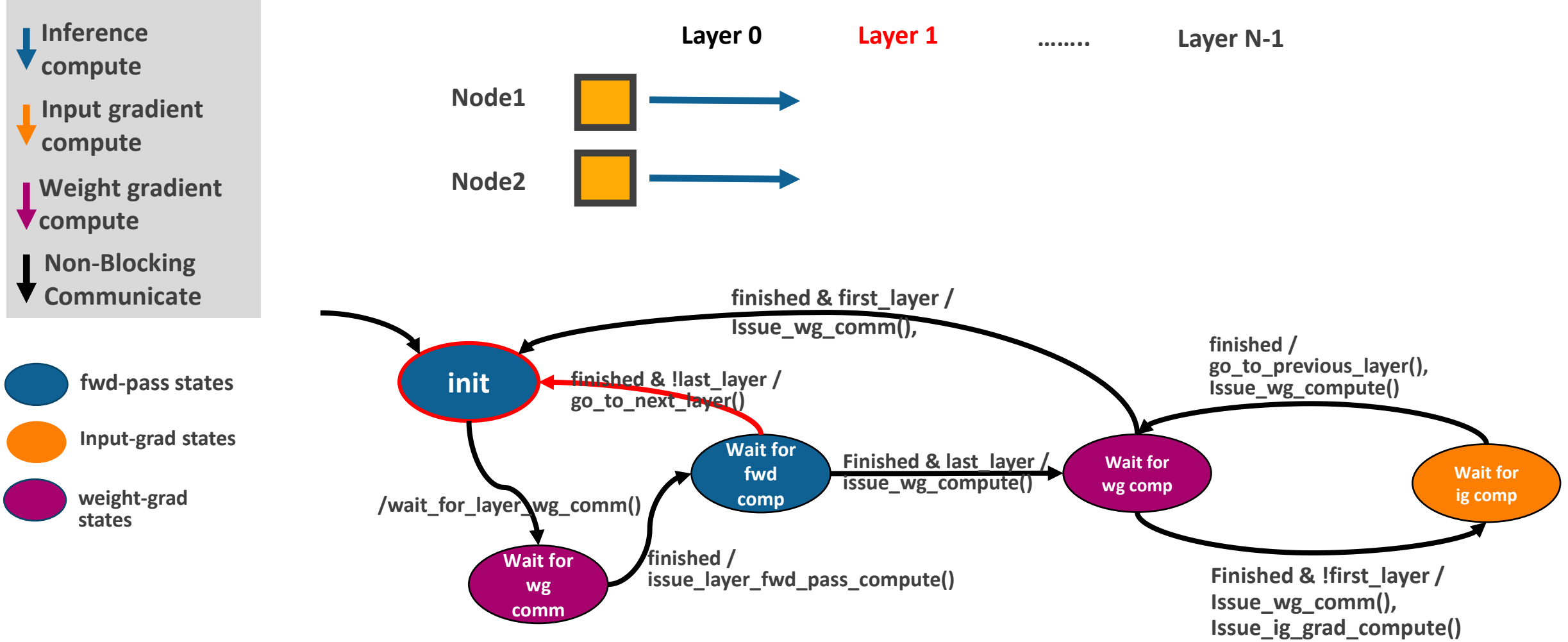

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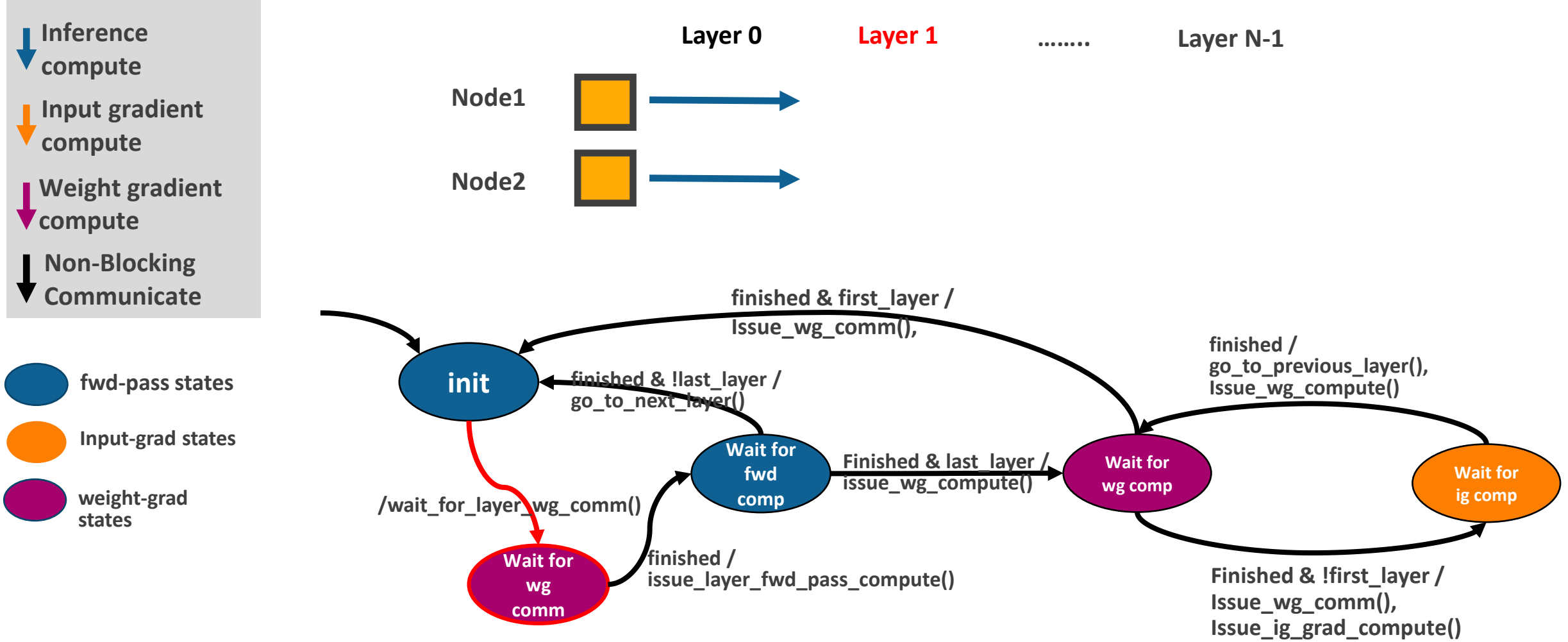

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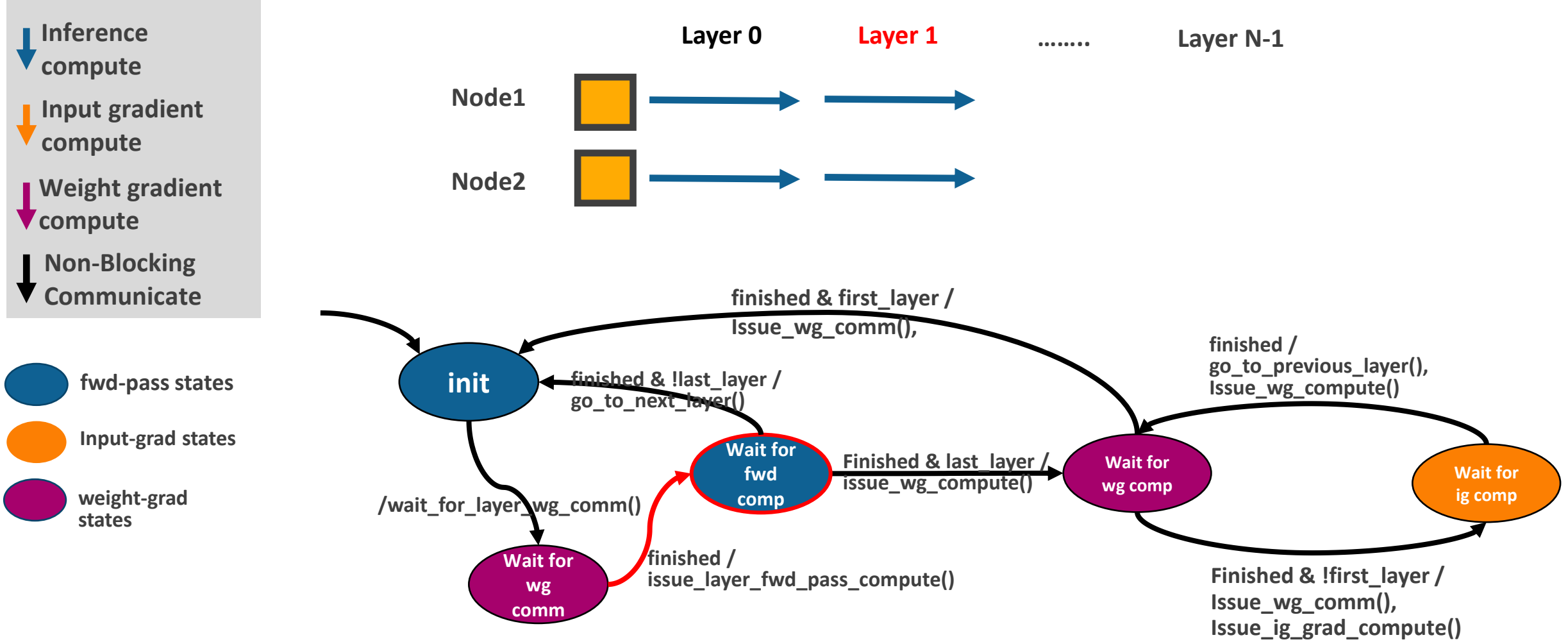

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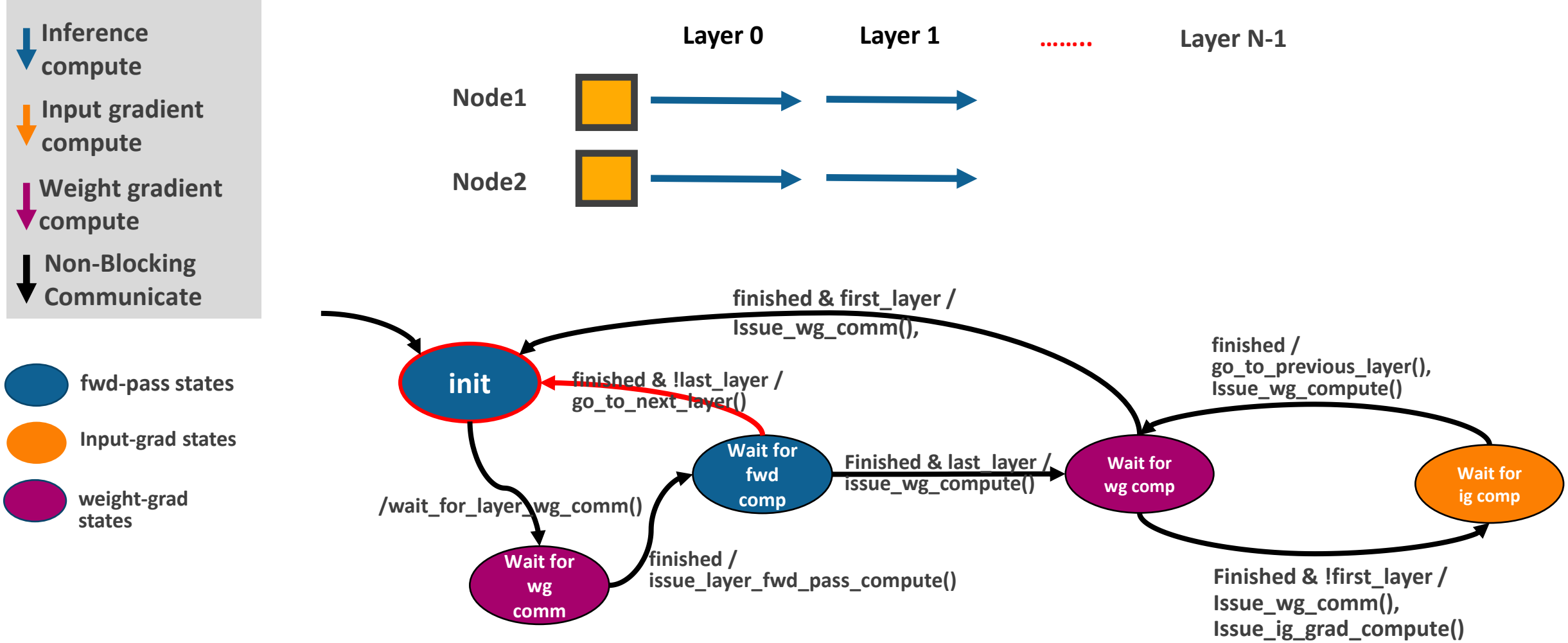

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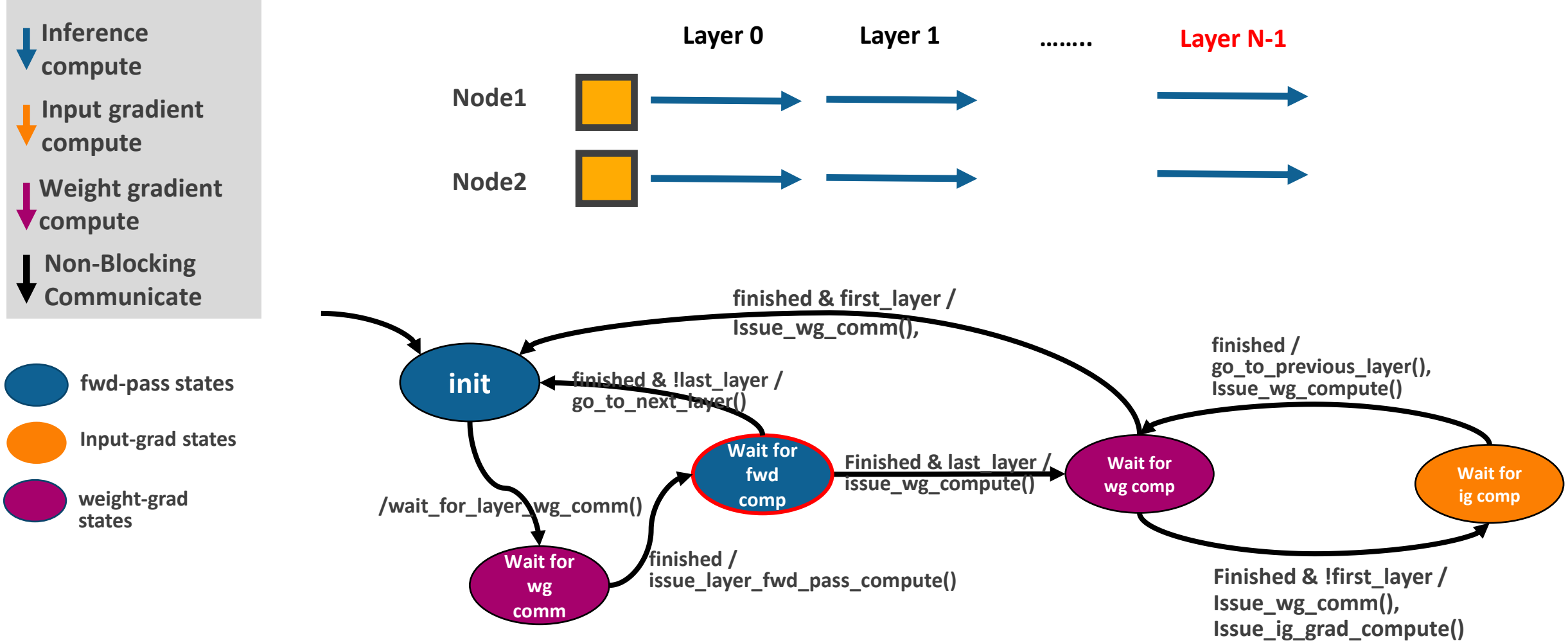

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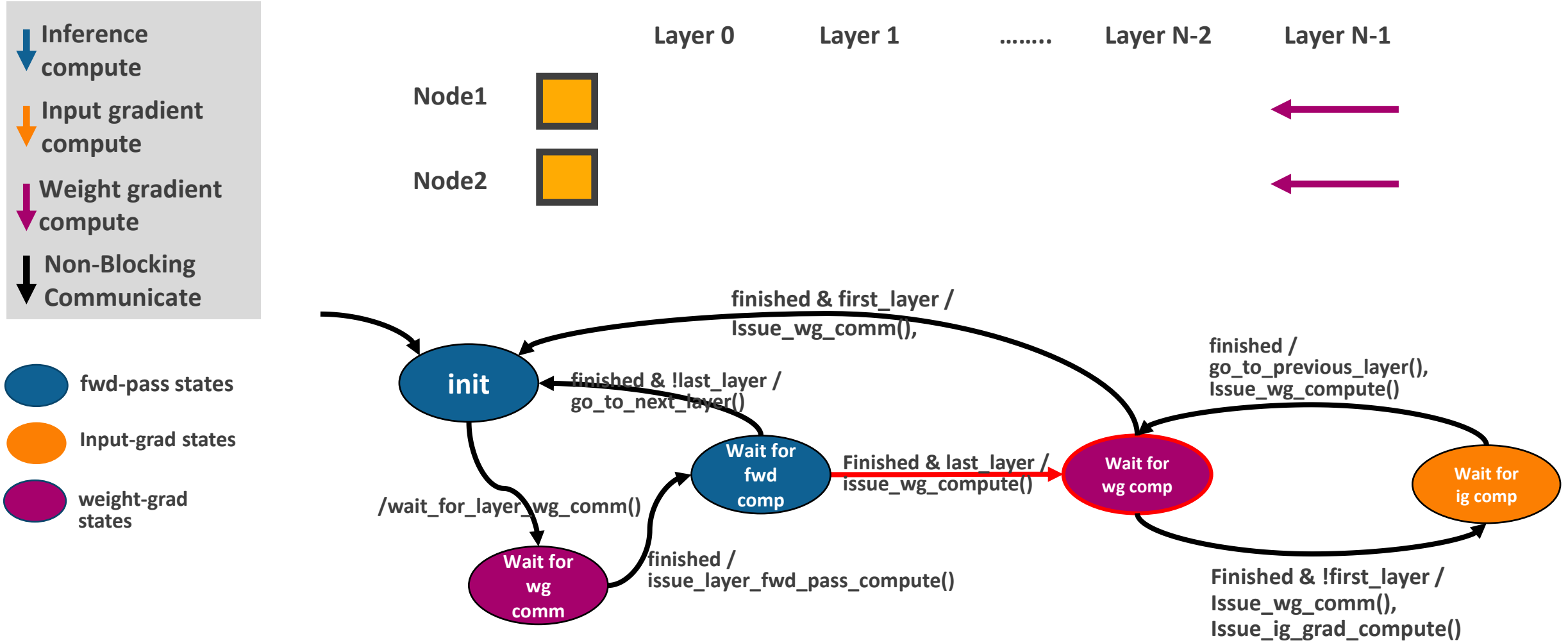

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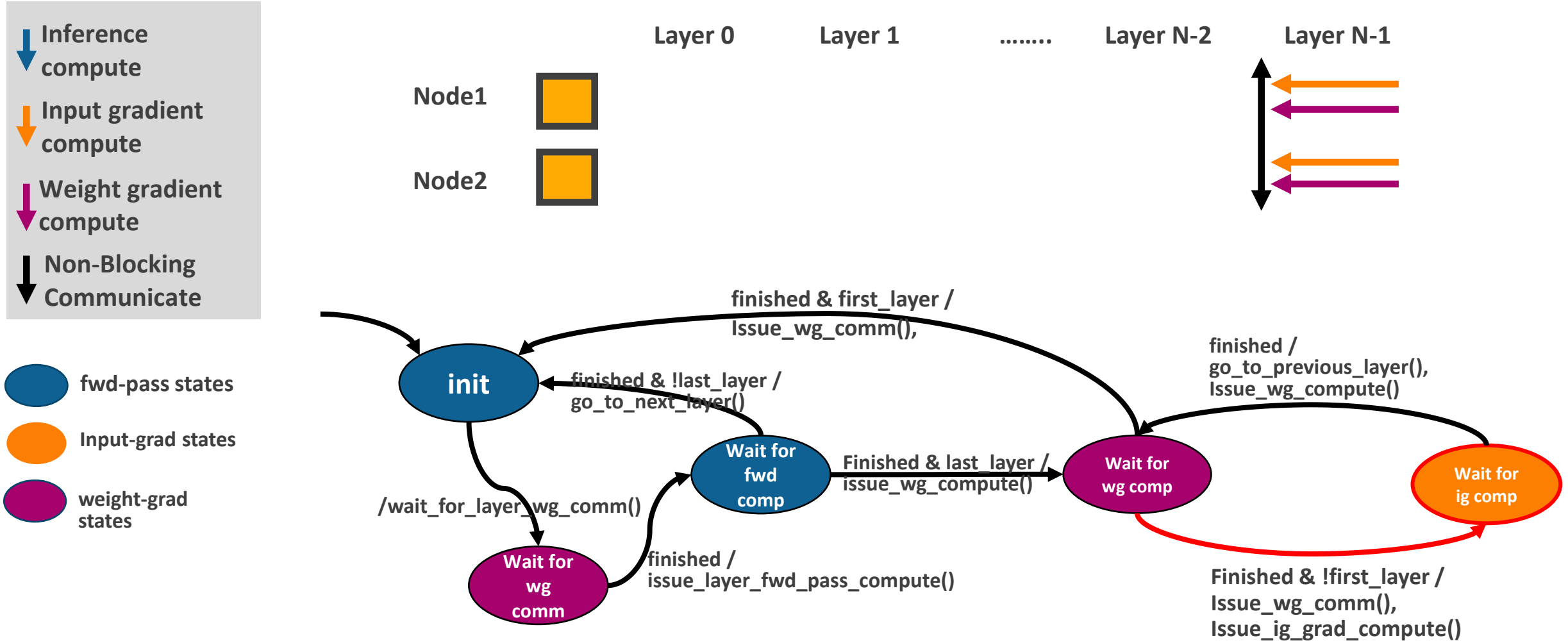

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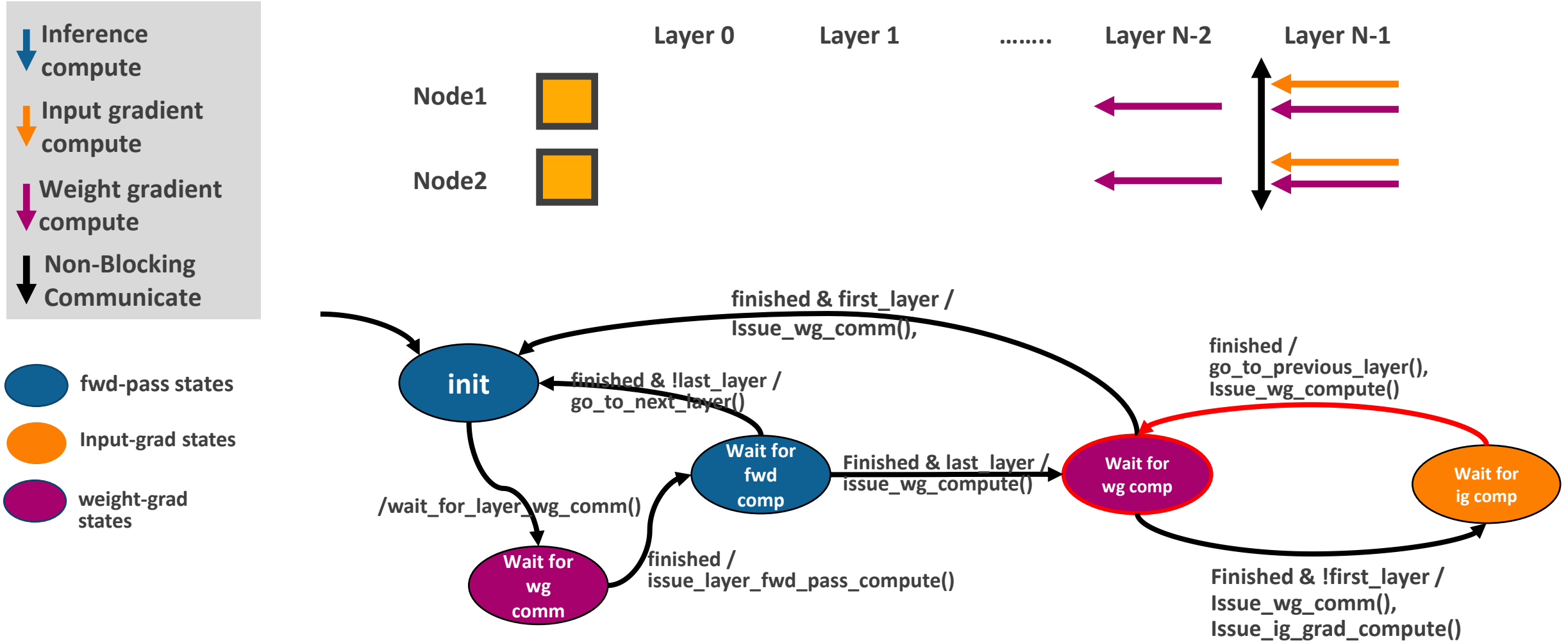

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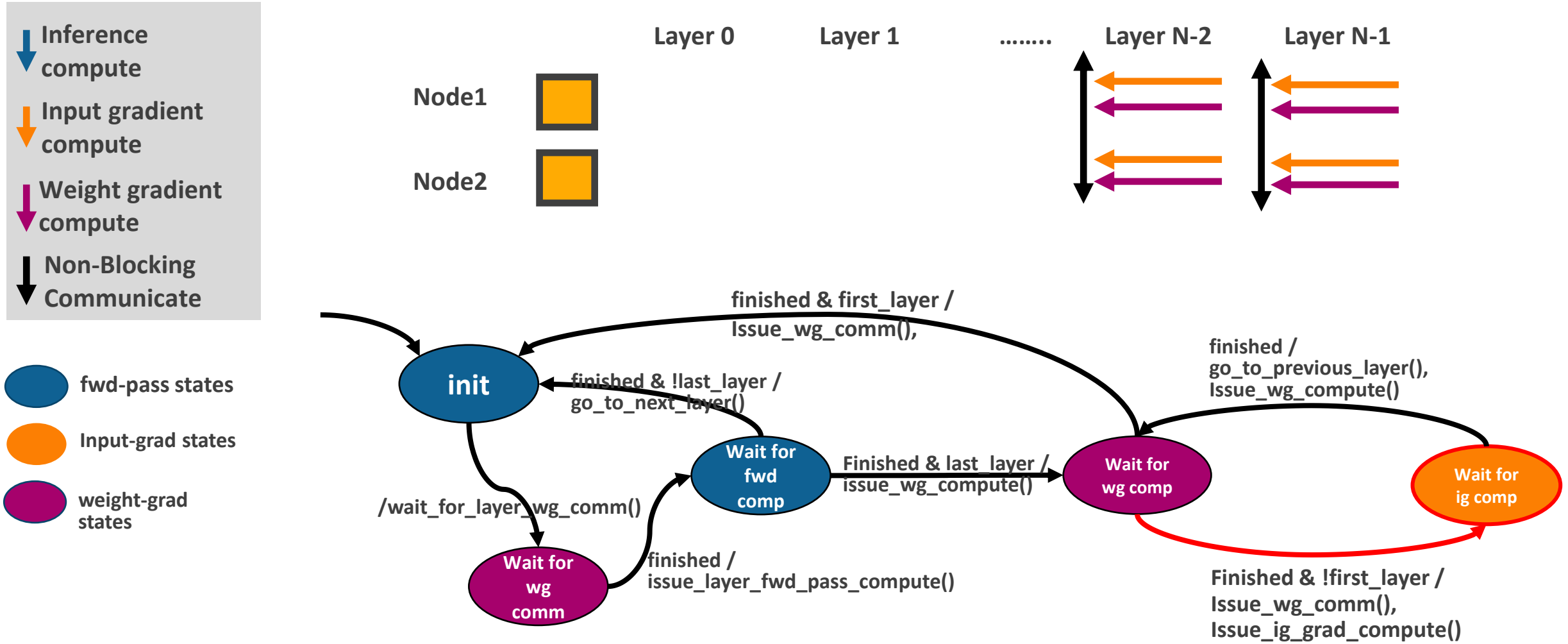

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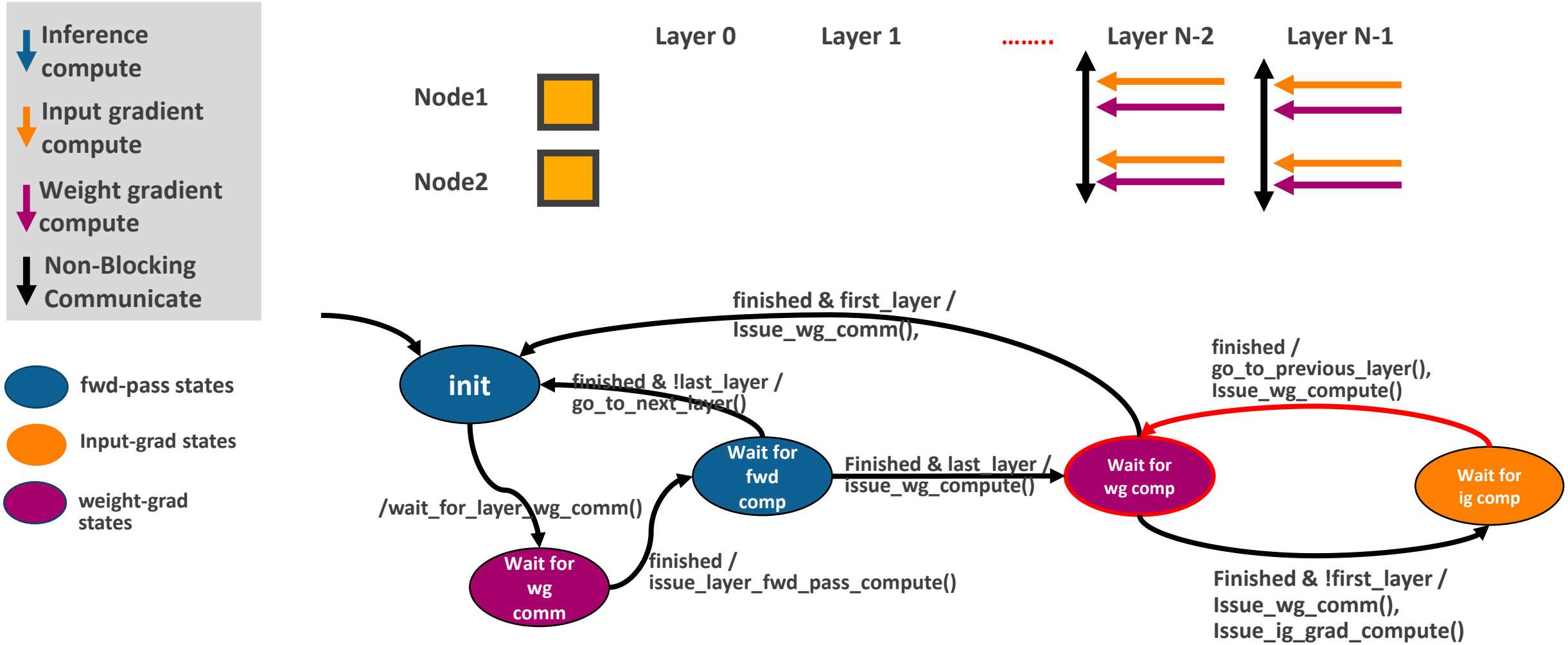

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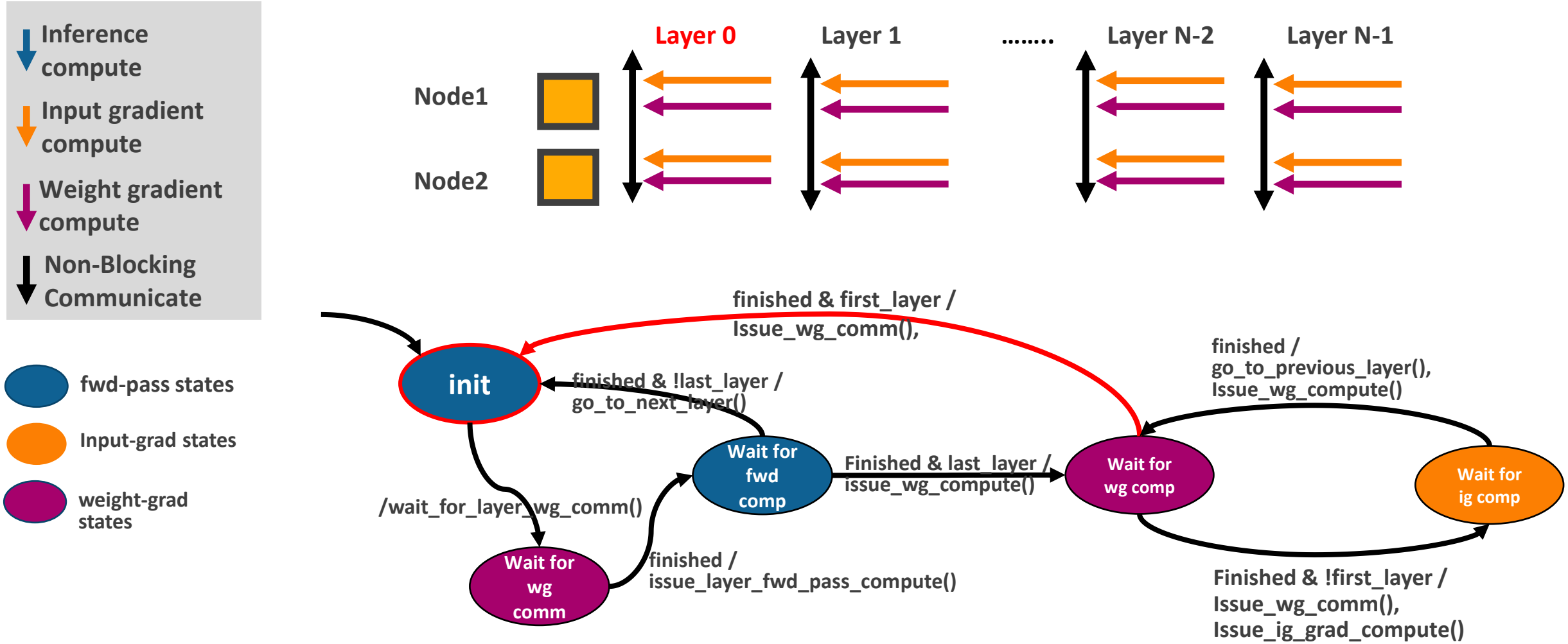

Workload Input

- Captures the static structure of the workload (training loop).

Training loop

Workload-specific metadata

DLRM_HybridParallel.txt

```
HYBRID_DLRM 4
8
Embedding       -1  300     ALLTOALL    98304   300     ALLTOALL    98304   300     NONE        0       98
MLP_Bottom_0    -1  1280    NONE        0       794     NONE        0       896     ALLREDUCE   13312   13
MLP_Bottom_1    -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
MLP_Bottom_2    -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
MLP_Bottom_3    -1  800     NONE        0       1280    NONE        0       800     ALLREDUCE   16384   16
MLP_Top_0       -1  6400    NONE        0       6400    NONE        0       4480    ALLREDUCE   1064960 1065
MLP_Top_1       -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
MLP_Top_2       -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
```

Workload Input

- Captures the static structure of the workload (training loop).

# of layers

DLRM_HybridParallel.txt

```
HYBRID_DLRM 4
8
Embedding       -1  300     ALLTOALL    98304   300     ALLTOALL    98304   300     NONE        0       98
MLP_Bottom_0    -1  1280    NONE        0       794     NONE        0       896     ALLREDUCE   13312   13
MLP_Bottom_1    -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
MLP_Bottom_2    -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
MLP_Bottom_3    -1  800     NONE        0       1280    NONE        0       800     ALLREDUCE   16384   16
MLP_Top_0       -1  6400    NONE        0       6400    NONE        0       4480    ALLREDUCE   1064960 1065
MLP_Top_1       -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
MLP_Top_2       -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
```

Workload Input

- Captures the static structure of the workload (training loop).

Layer description

DLRM_HybridParallel.txt

```
HYBRID_DLRM 4
8
Embedding       -1  300     ALLTOALL    98304   300     ALLTOALL    98304   300     NONE        0       98
MLP_Bottom_0    -1  1280    NONE        0       794     NONE        0       896     ALLREDUCE   13312   13
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MLP_Top_1       -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
MLP_Top_2       -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
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Workload Input

- Captures the static structure of the workload (training loop).

Layer name

DLRM_HybridParallel.txt

```
HYBRID_DLRM 4
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Embedding       -1  300     ALLTOALL    98304   300     ALLTOALL    98304   300     NONE        0       98
MLP_Bottom_0    -1  1280    NONE        0       794     NONE        0       896     ALLREDUCE   13312   13
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MLP_Top_2       -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
```

Workload Input

- Captures the static structure of the workload (training loop).

Fwd-pass compute

Fwd-pass comm type

Fwd-pass comm size

DLRM_HybridParallel.txt

```
HYBRID_DLRM 4
8
Embedding       -1  300     ALLTOALL    98304   300     ALLTOALL    98304   300     NONE        0       98
MLP_Bottom_0    -1  1280    NONE        0       794     NONE        0       896     ALLREDUCE   13312   13
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MLP_Top_2       -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
```

Workload Input

- Captures the static structure of the workload (training loop).

Input-grad compute

Input-grad comm type

Input-grad comm size

DLRM_HybridParallel.txt

```
HYBRID_DLRM 4
8
Embedding       -1  300     ALLTOALL    98304   300     ALLTOALL    98304   300     NONE        0       98
MLP_Bottom_0    -1  1280    NONE        0       794     NONE        0       896     ALLREDUCE   13312   13
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MLP_Top_1       -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
MLP_Top_2       -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
```

Workload Input

- Captures the static structure of the workload (training loop).

Weight-grad compute

Weight-grad comm type

Weight-grad comm size

DLRM_HybridParallel.txt

```
HYBRID_DLRM 4
8
Embedding       -1  300     ALLTOALL    98304   300     ALLTOALL    98304   300     NONE        0       98
MLP_Bottom_0    -1  1280    NONE        0       794     NONE        0       896     ALLREDUCE   13312   13
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MLP_Top_2       -1  2560    NONE        0       2560    NONE        0       1792    ALLREDUCE   524288  524
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Workload Input

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Parameter-update latency

DLRM_HybridParallel.txt

```
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Embedding       -1  300     ALLTOALL    98304   300     ALLTOALL    98304   300     NONE        0       98
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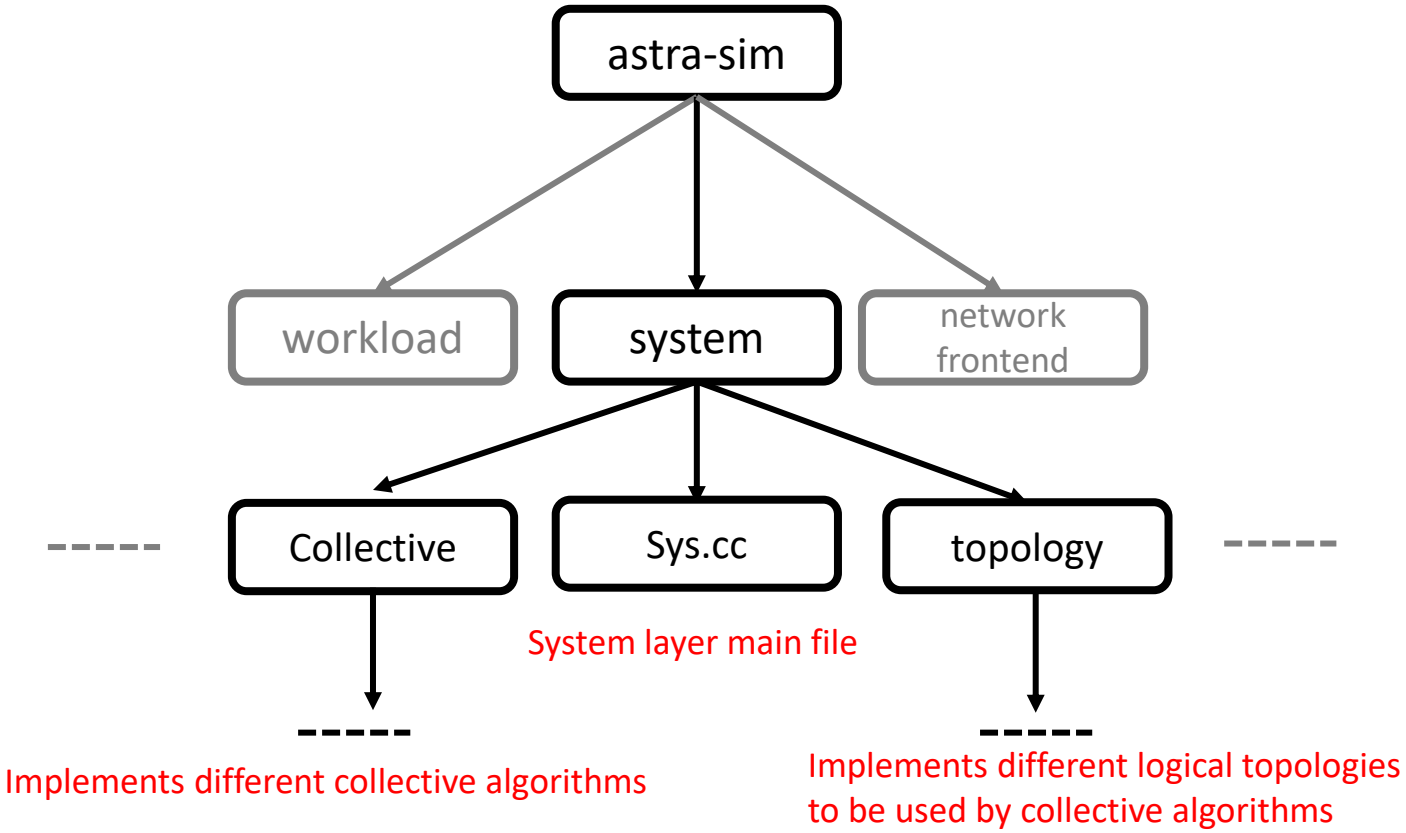
System Layer

System Layer Collective Implementation

- Code Structure

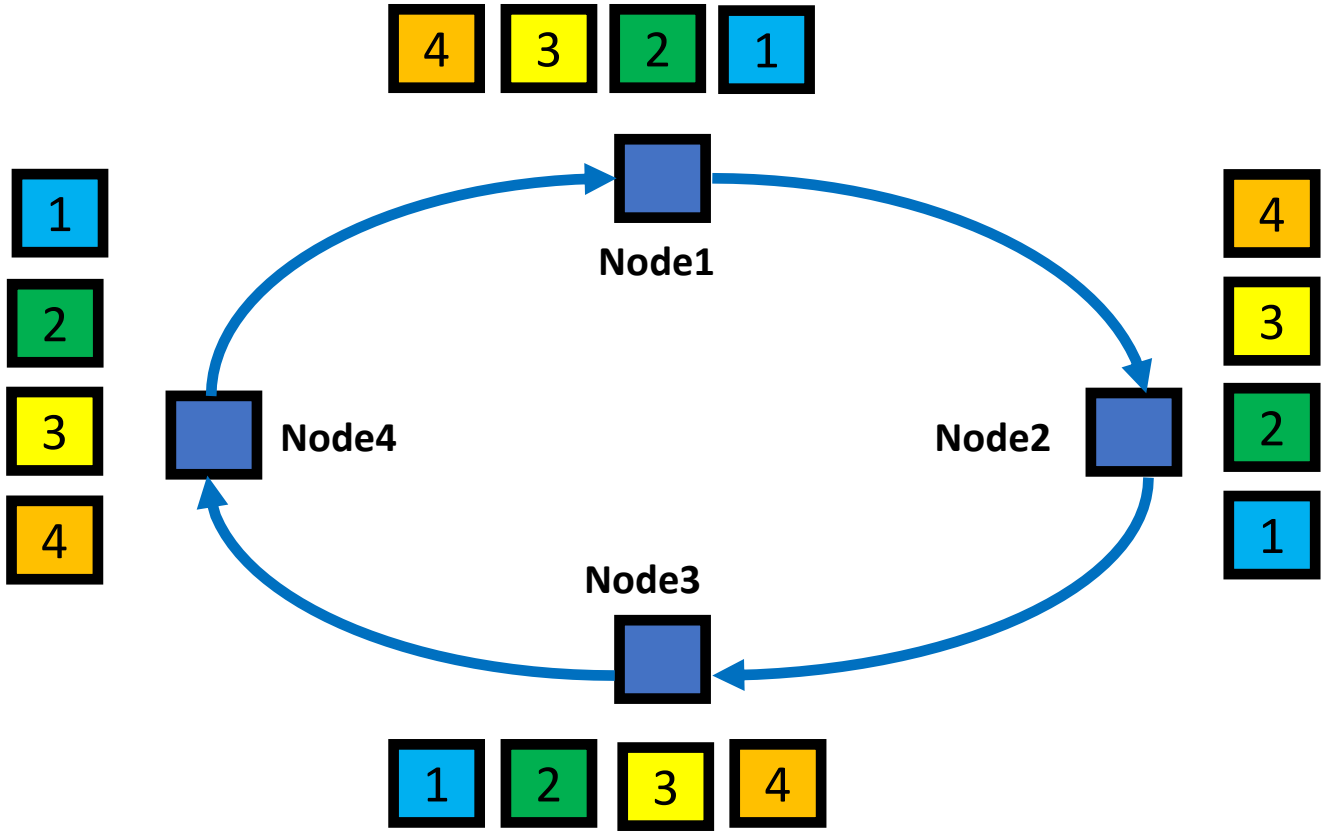


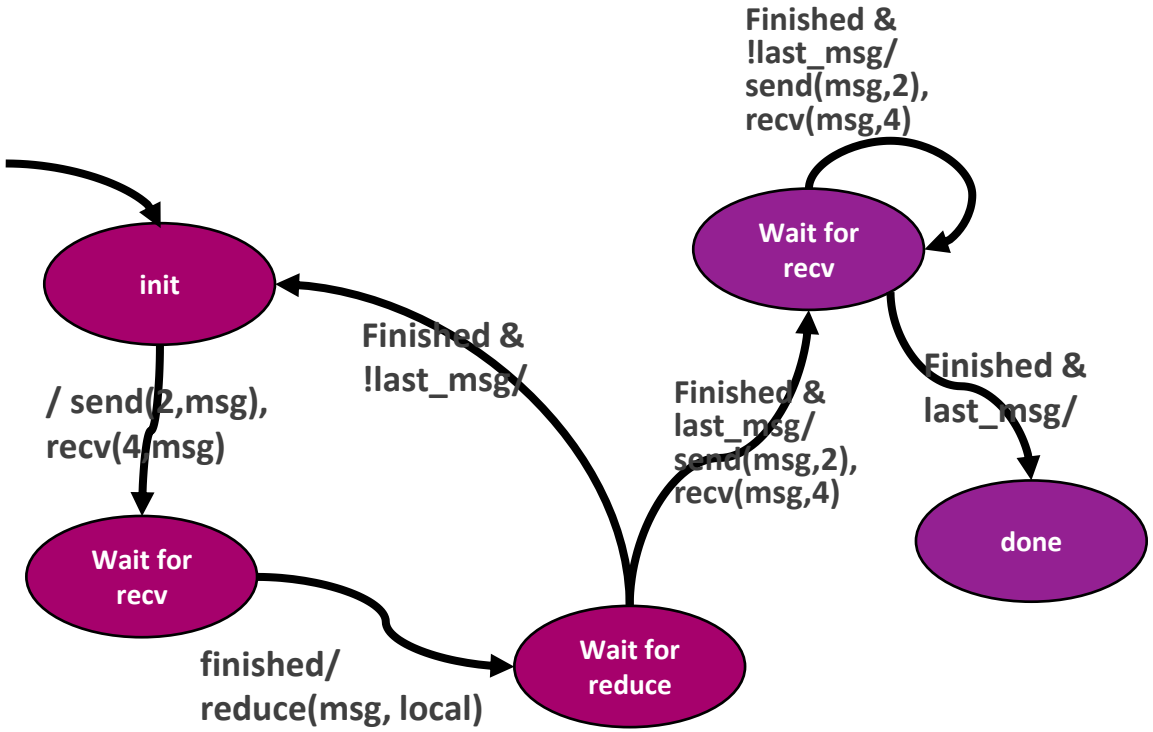
System Layer Collective Implementation

- Each collective algorithm works based on a logical topology.
- Logical topologies are implemented in “system/topology/*” and instantiated in sys.cc.
- Collective algorithms are implemented in “system/topology/*” and instantiated in sys.cc.
- Collective algorithms can be implemented using **state machines**.

System Layer Collective Implementation

- Collective algorithms can be implemented using **state machines**.





Node1 FSM

System Layer Collective Implementation

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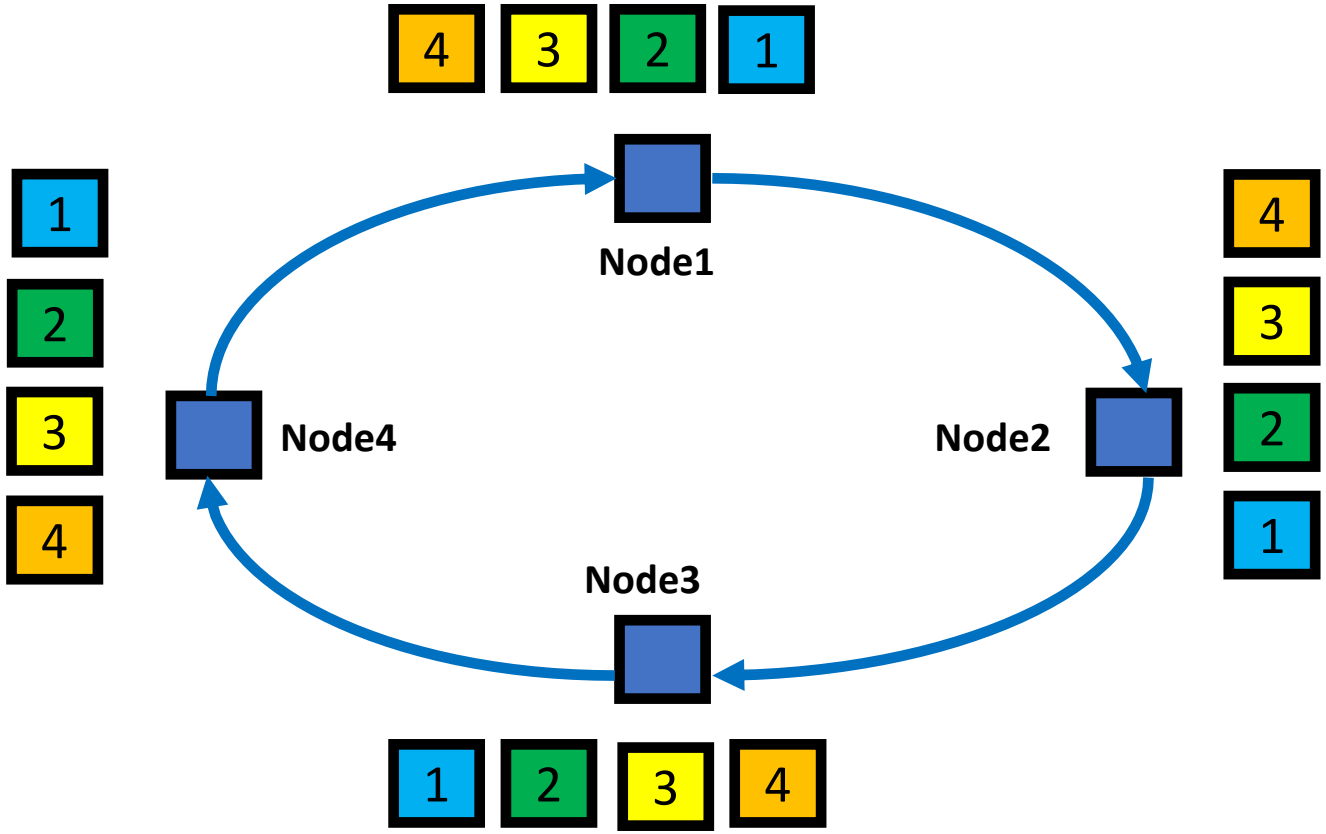

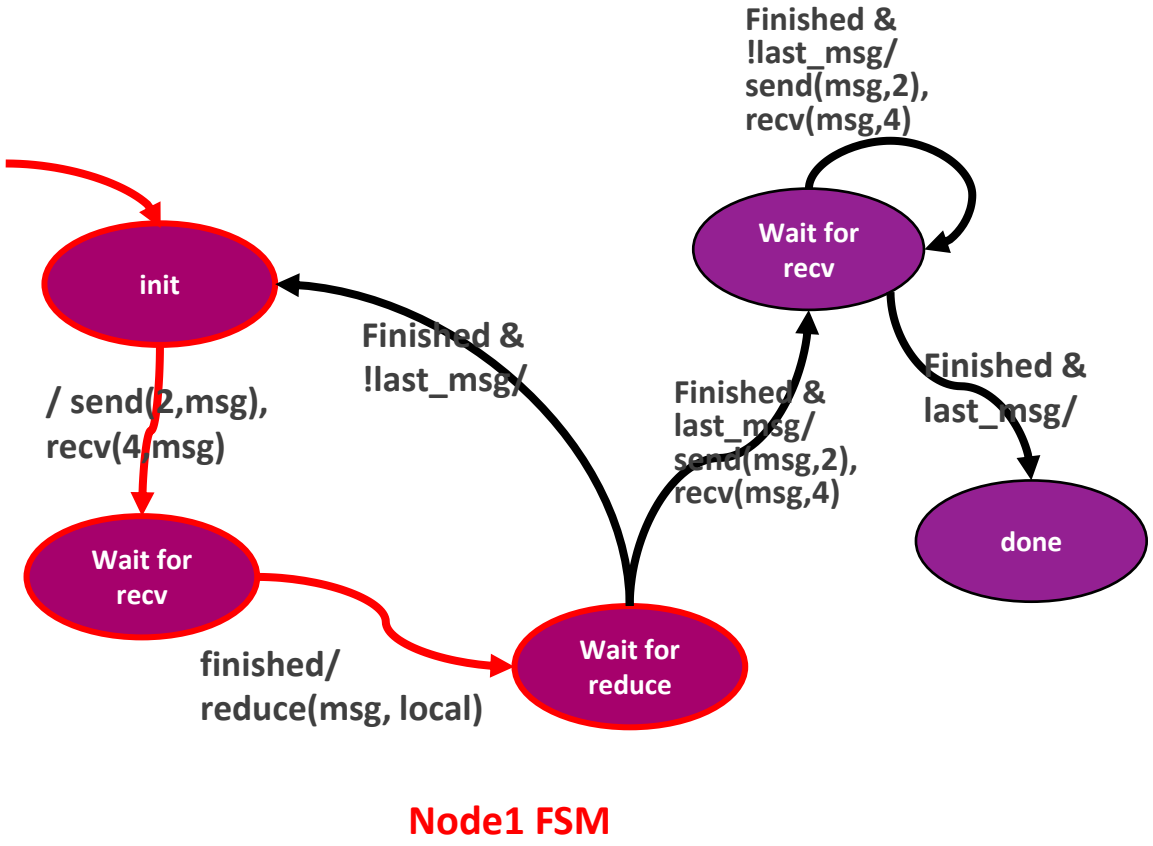

System Layer Collective Implementation

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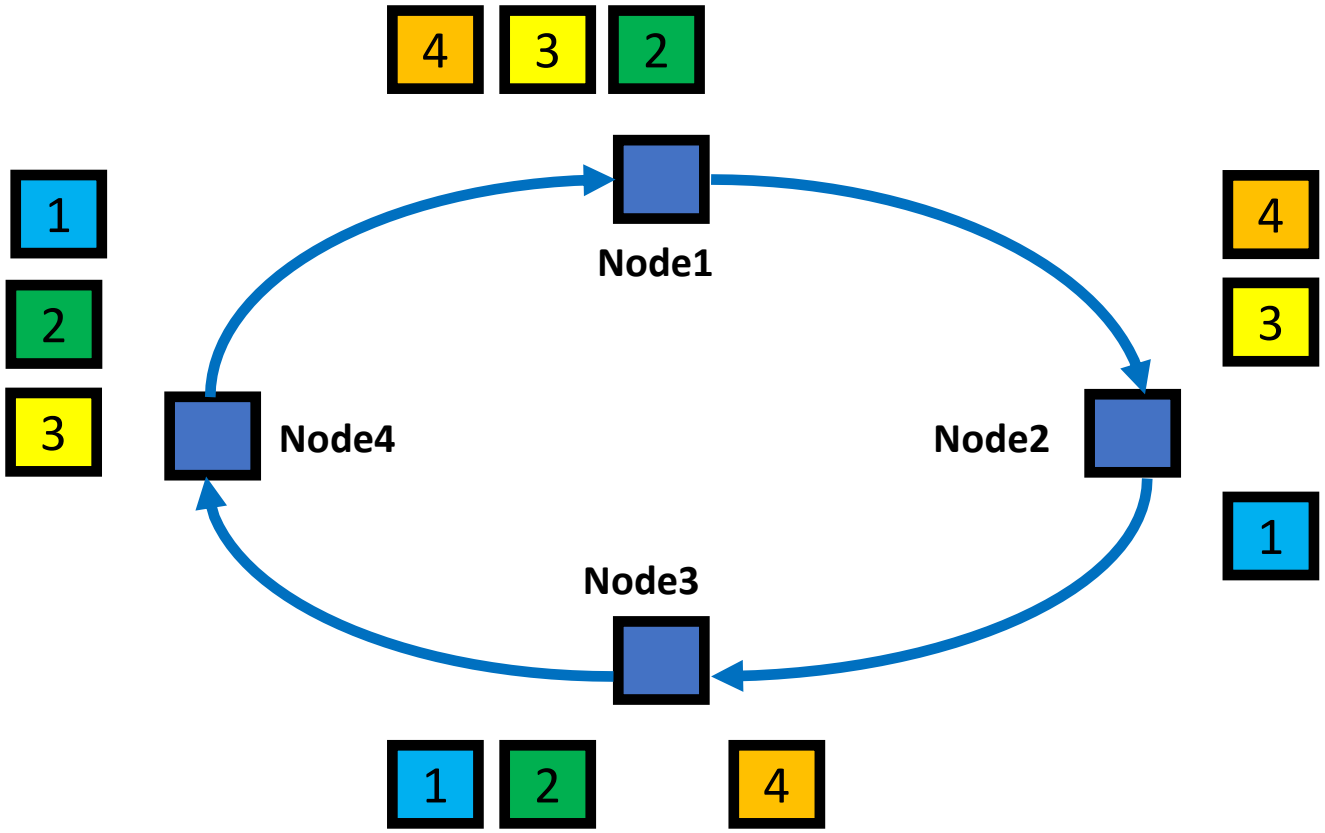

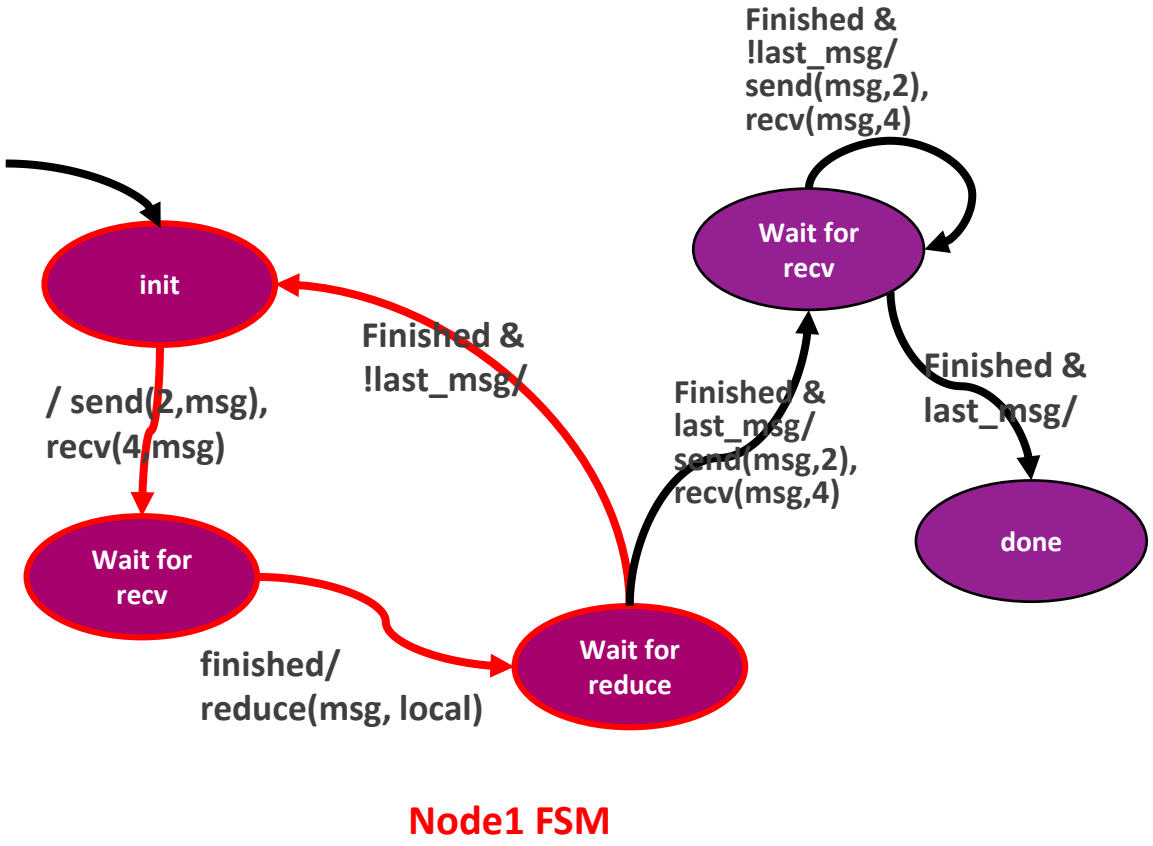

System Layer Collective Implementation

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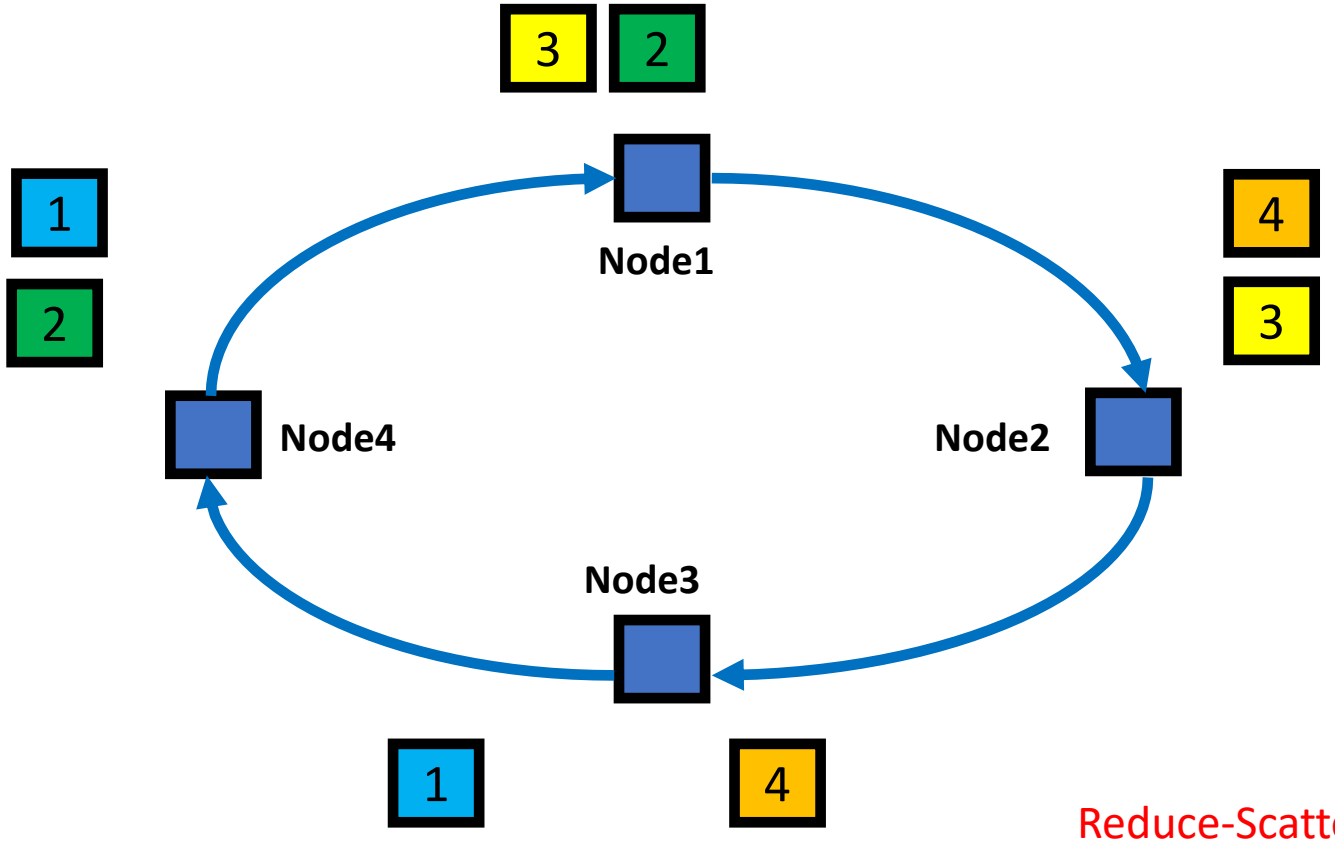

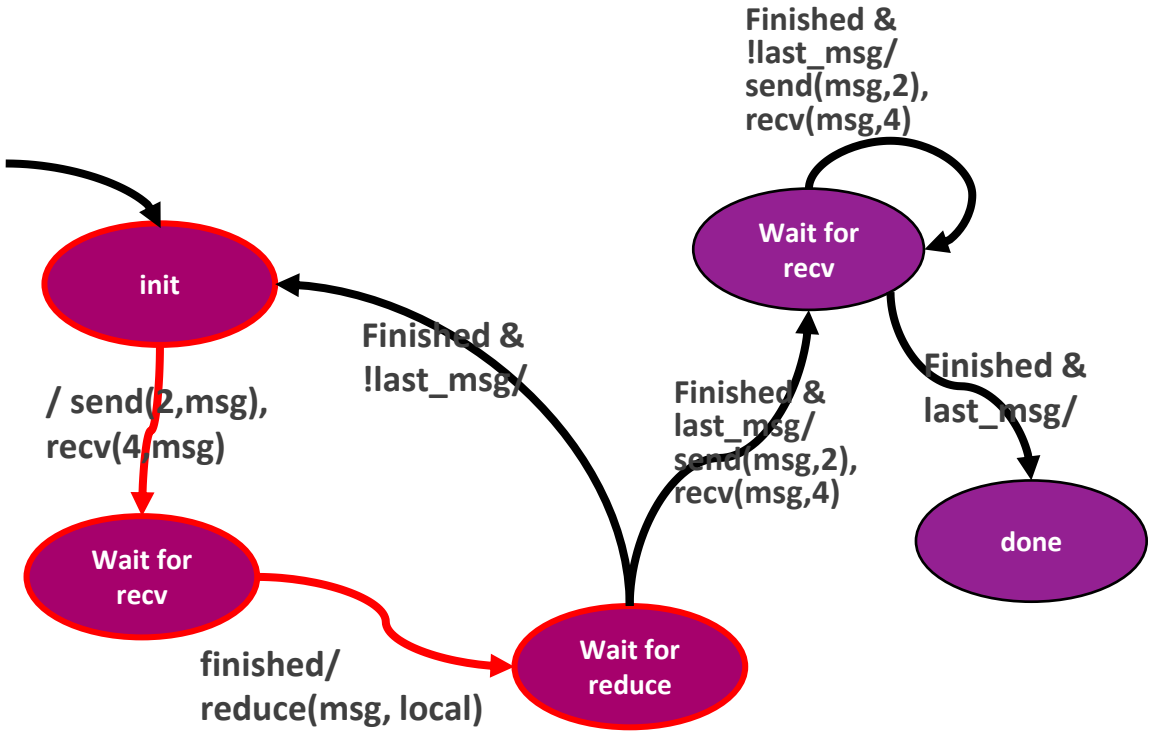

Node1 FSM

Reduce-Scatter done!

System Layer Collective Implementation

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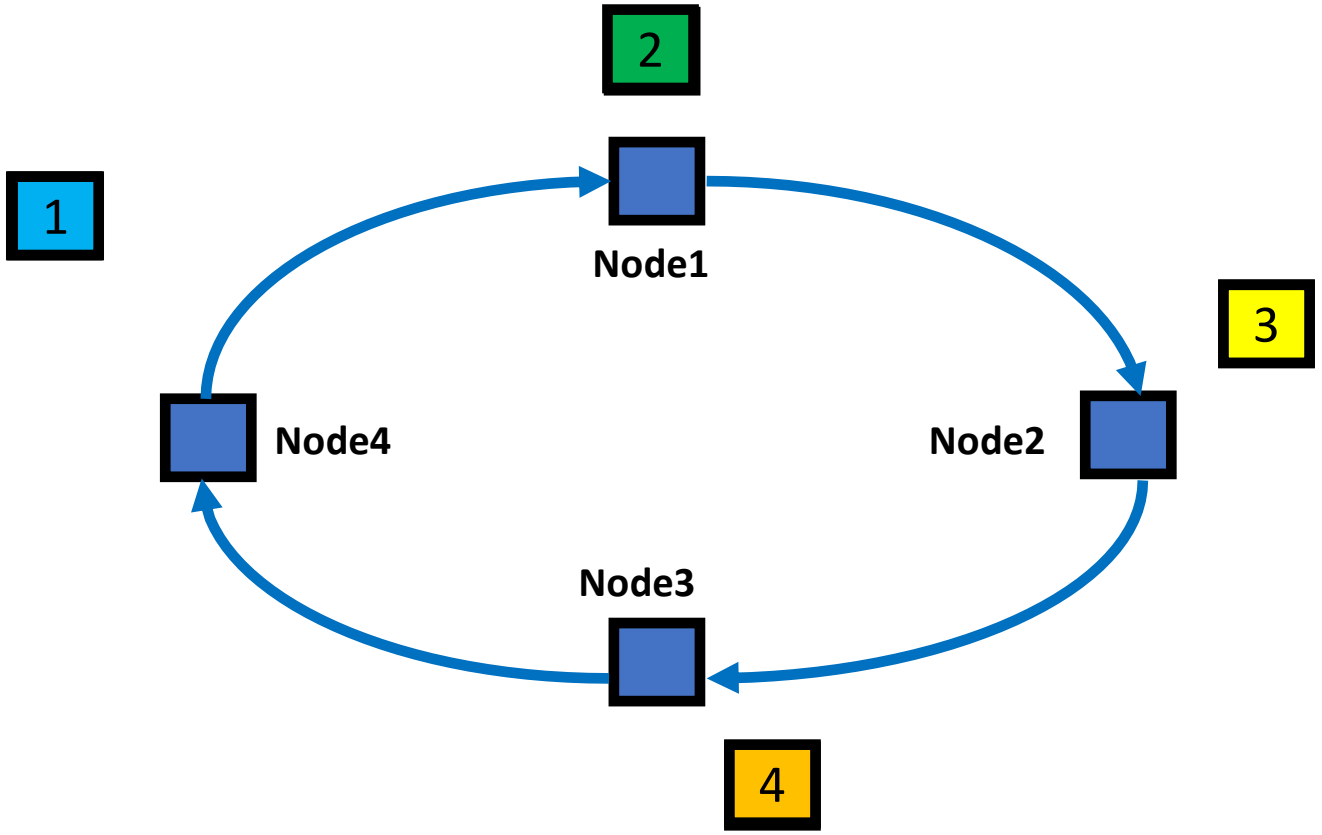

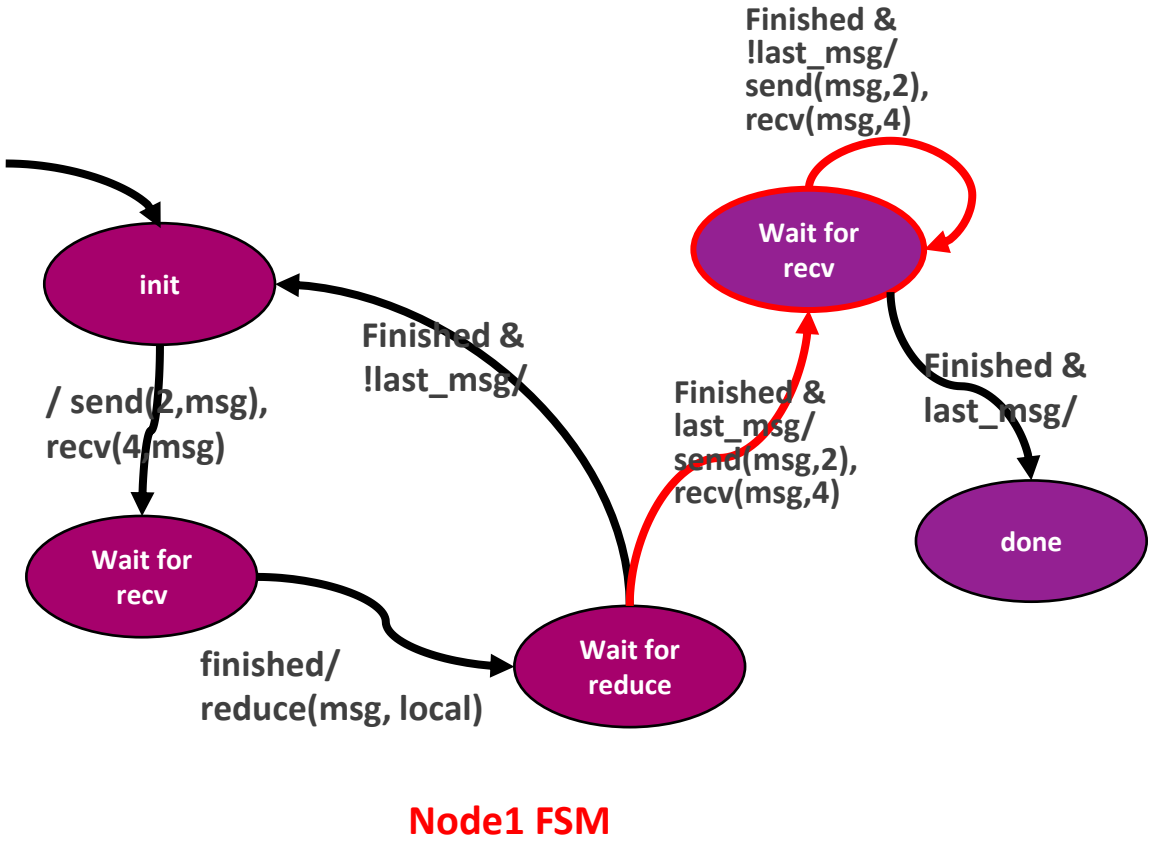

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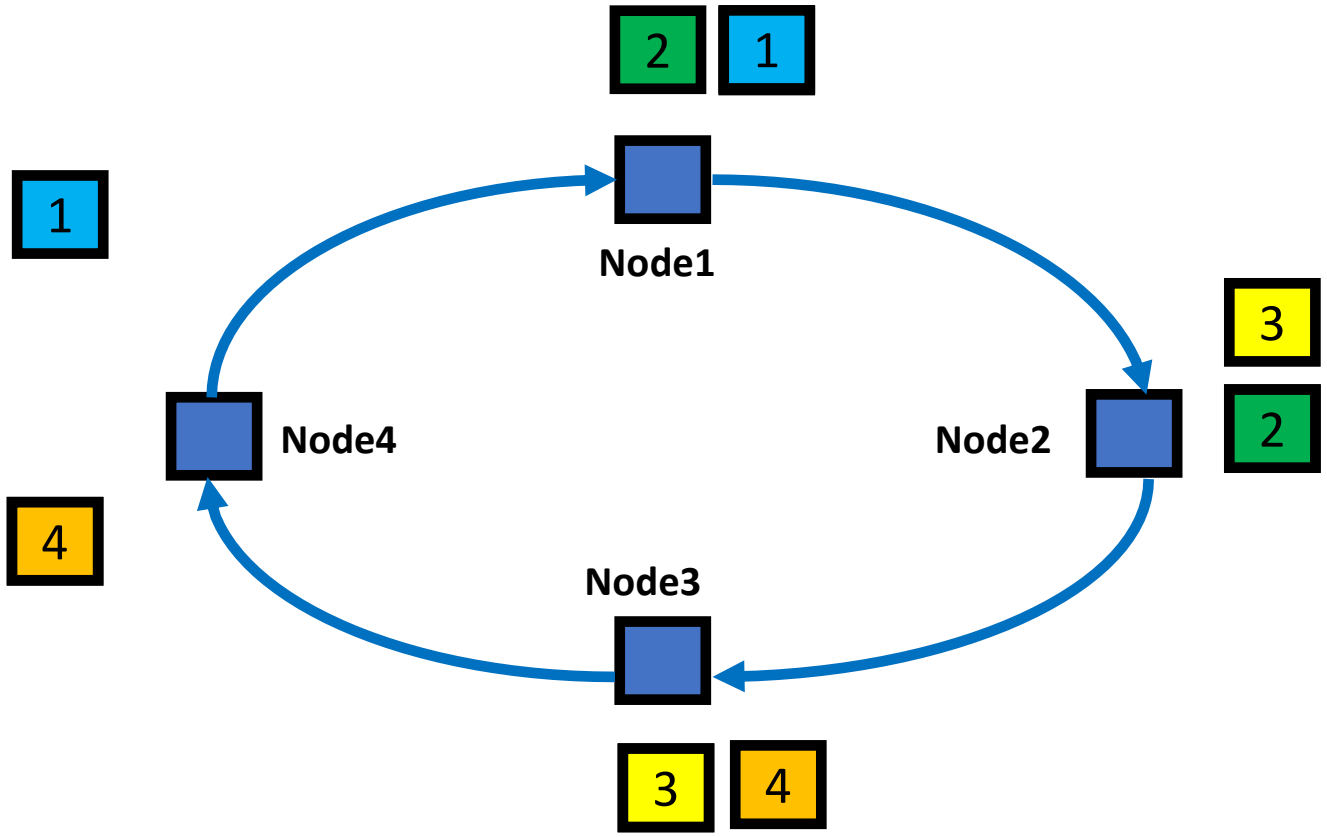

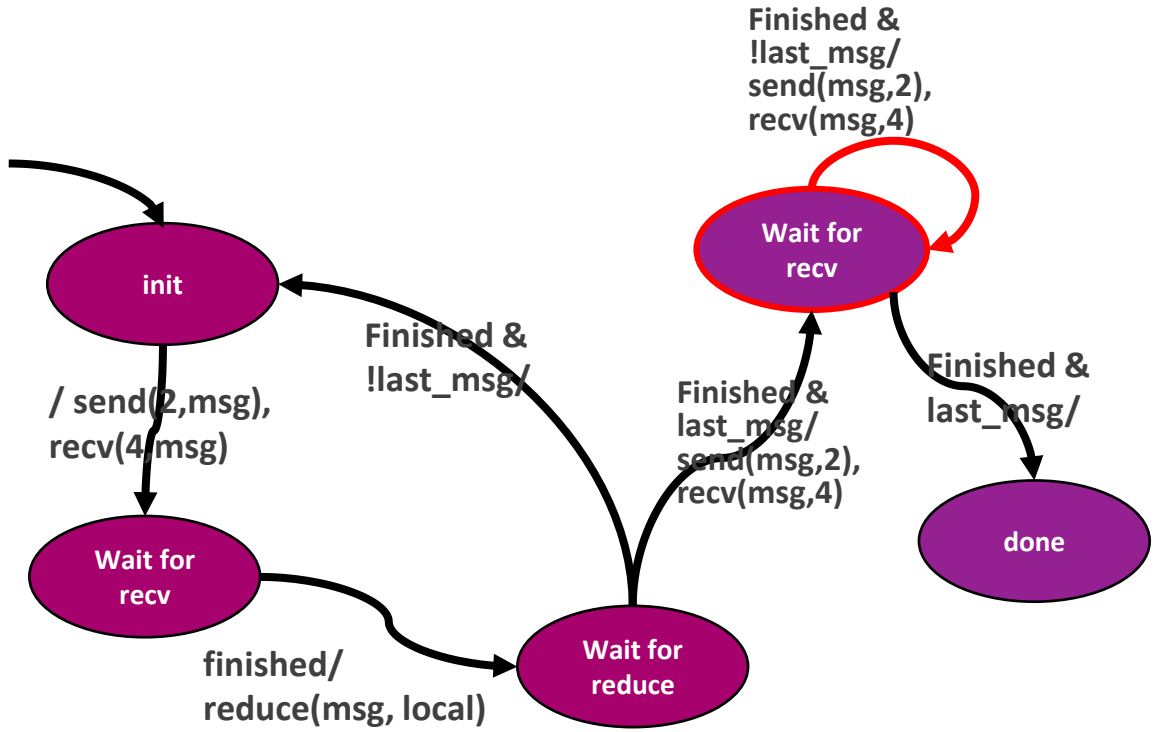

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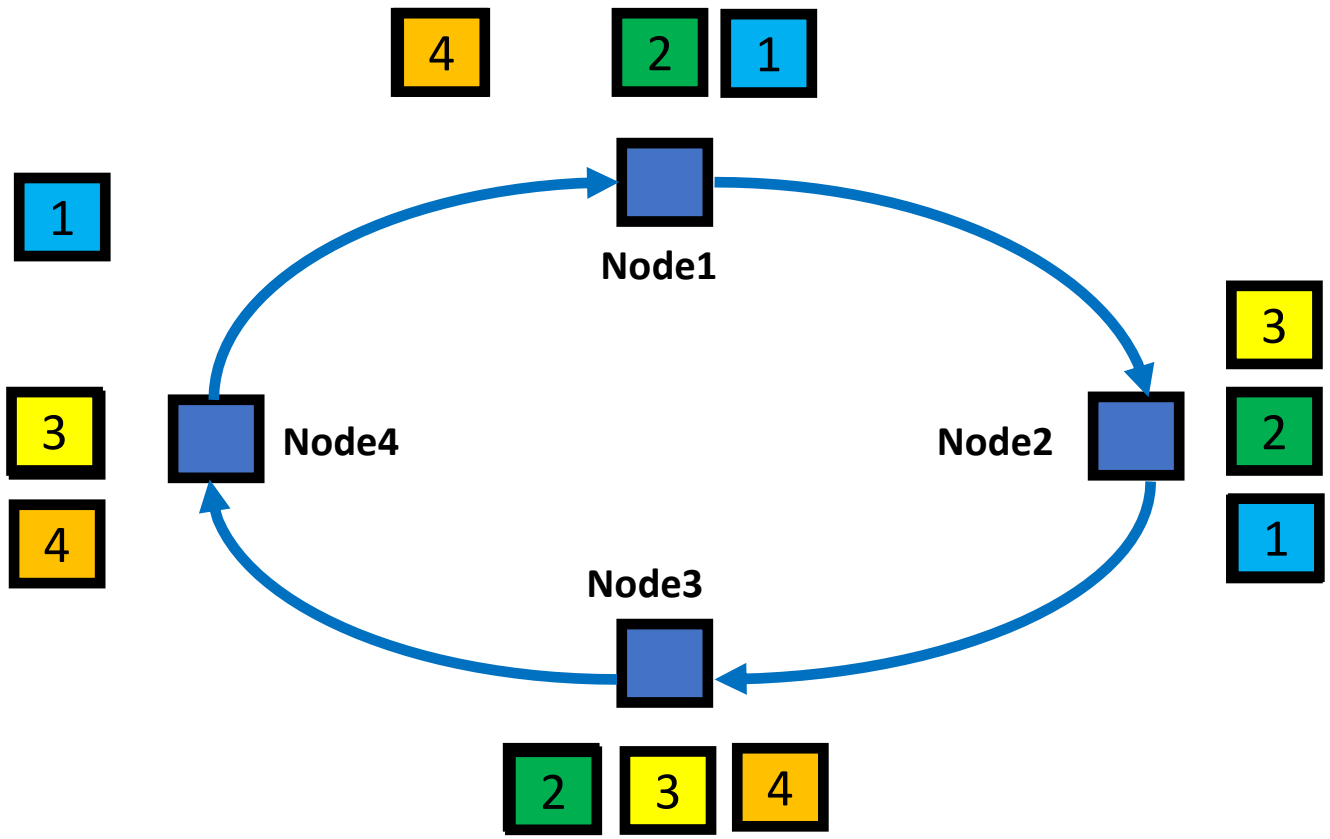

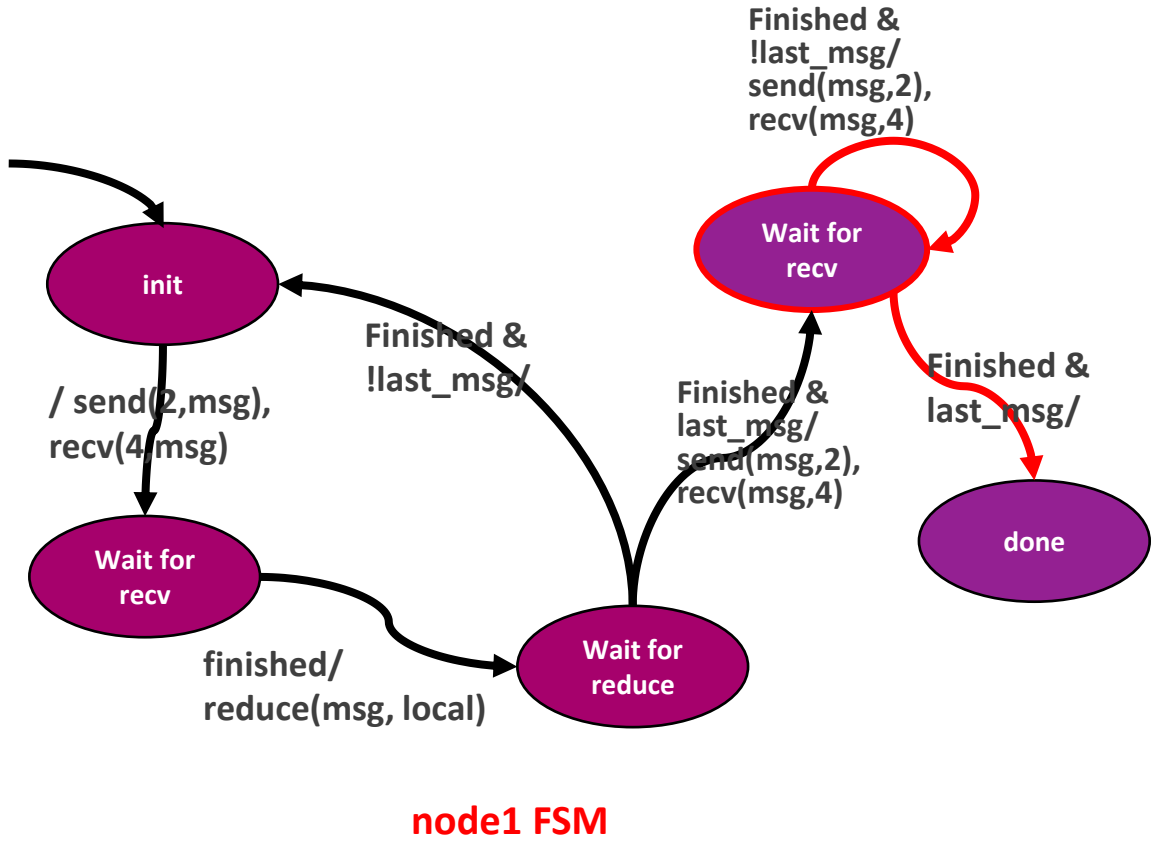

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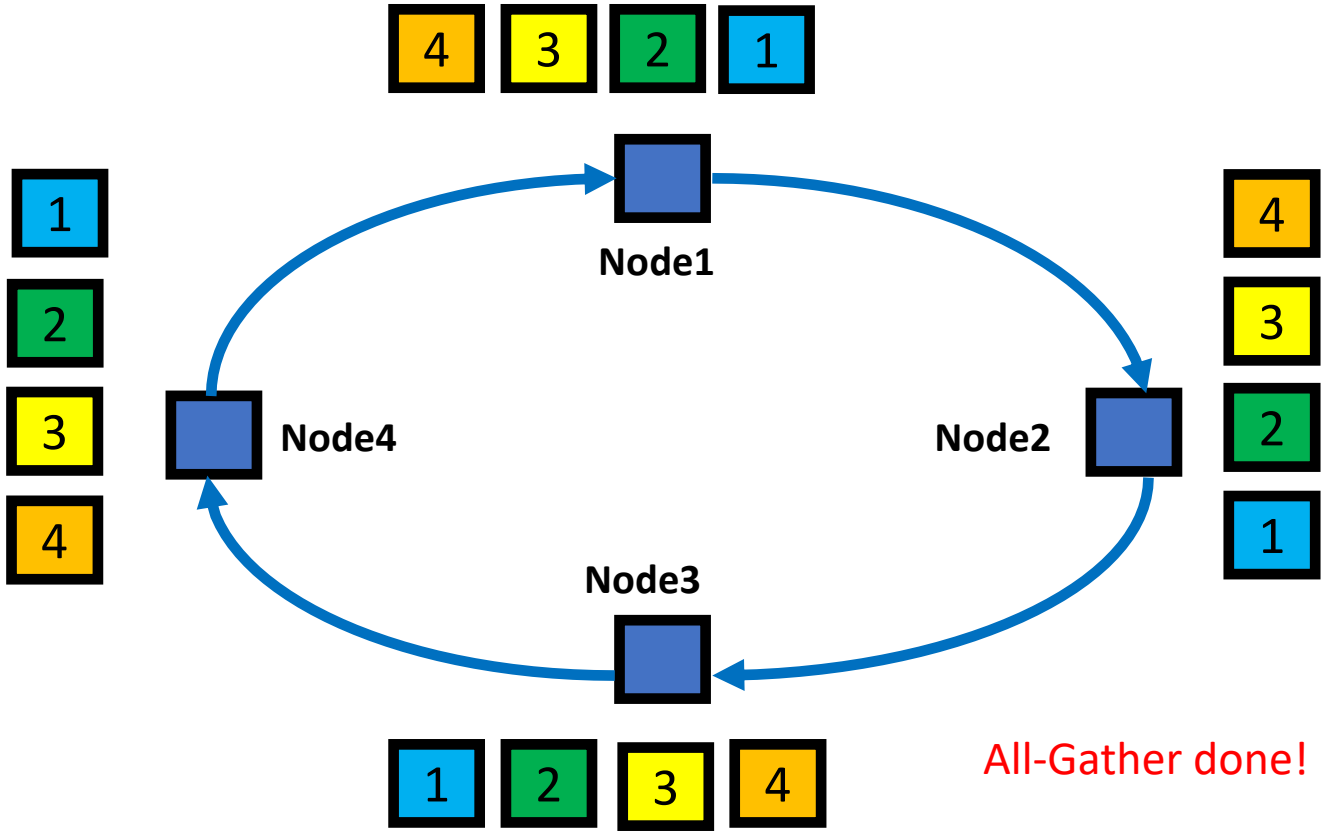
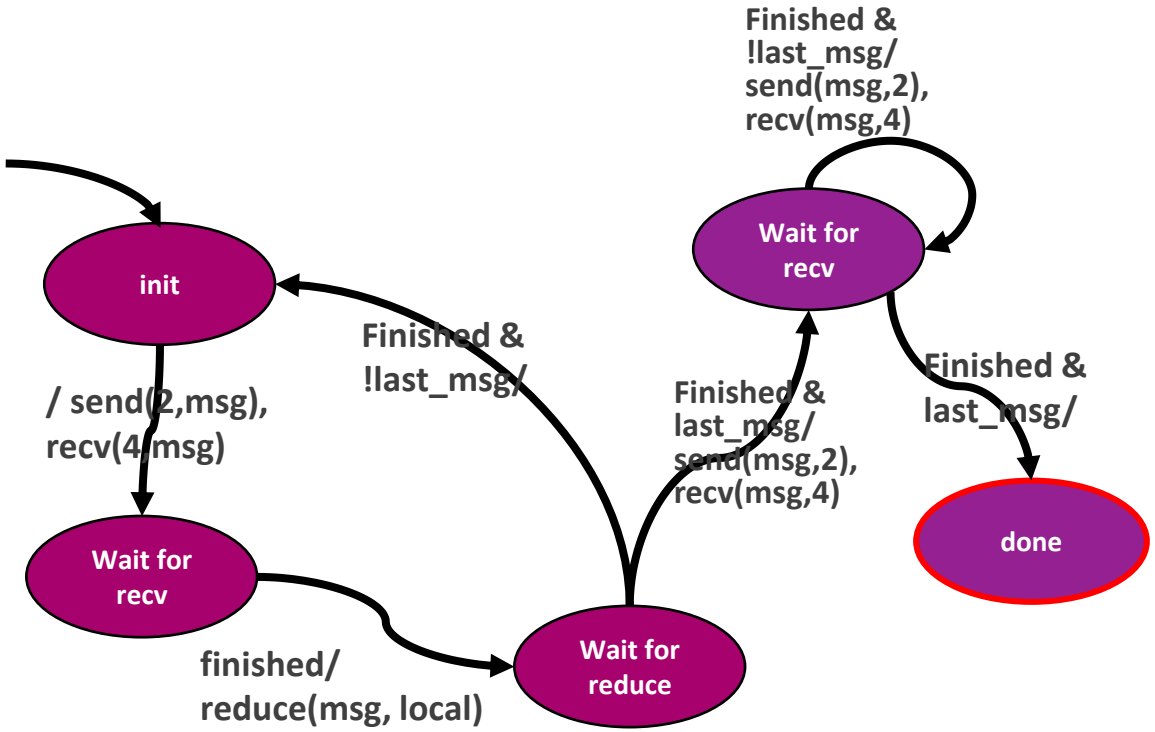


All-Gather done!



node1 FSM

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- A collective is broken into multiple chunks and inserted into the first queue.
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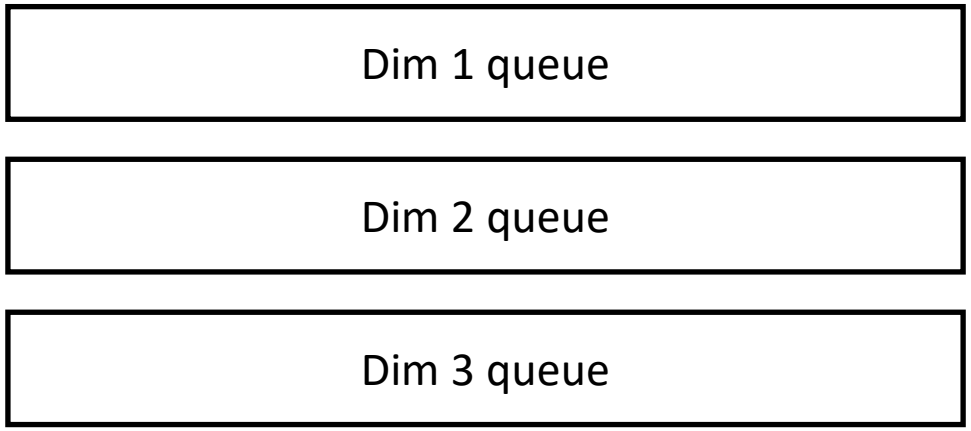

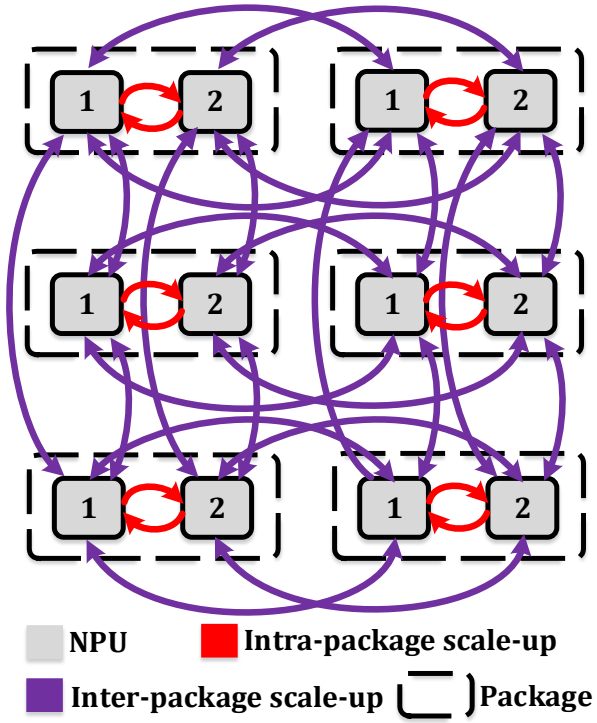

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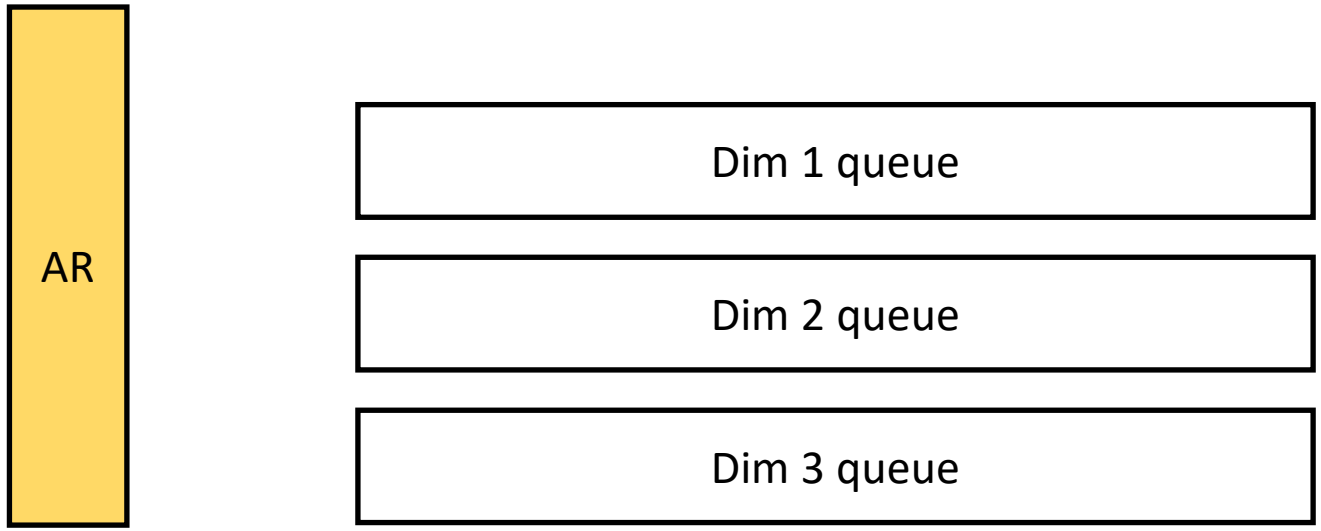

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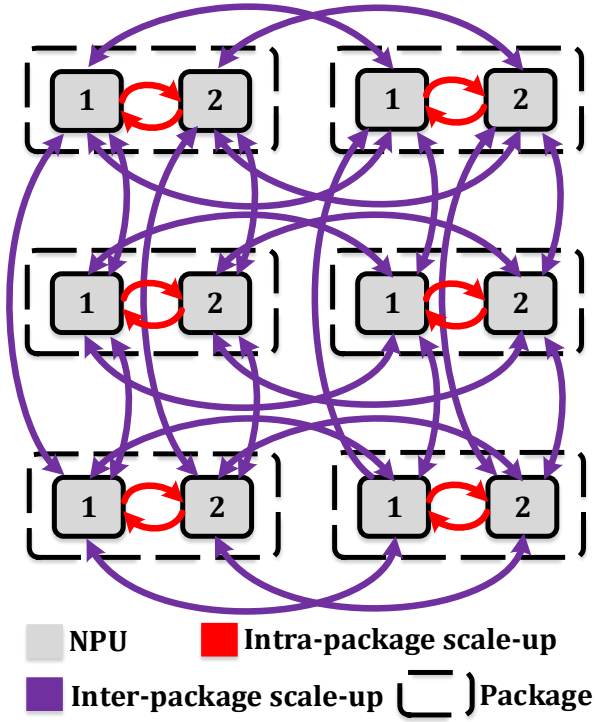

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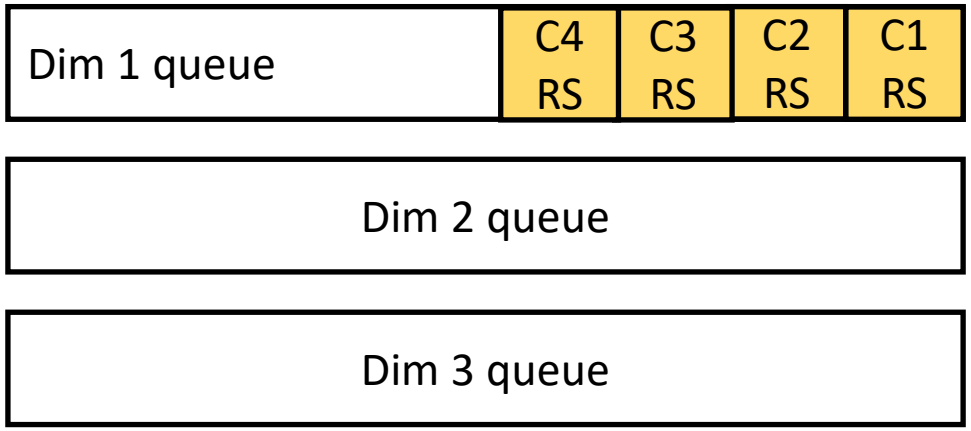

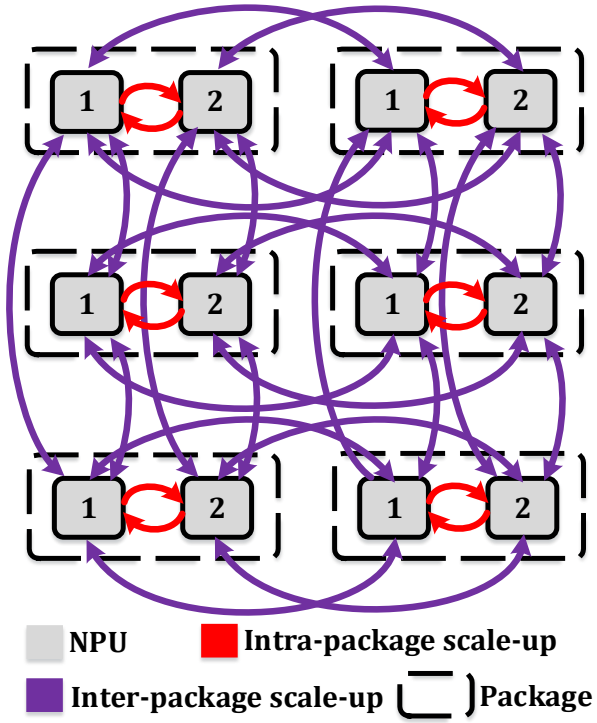

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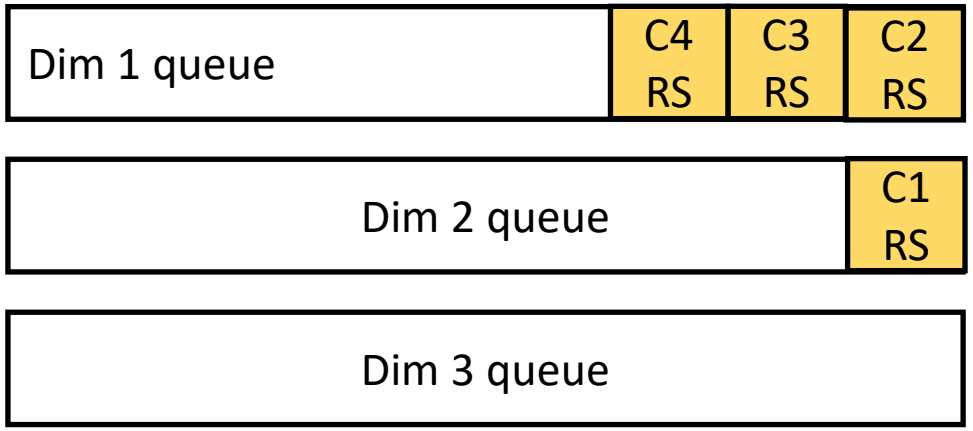

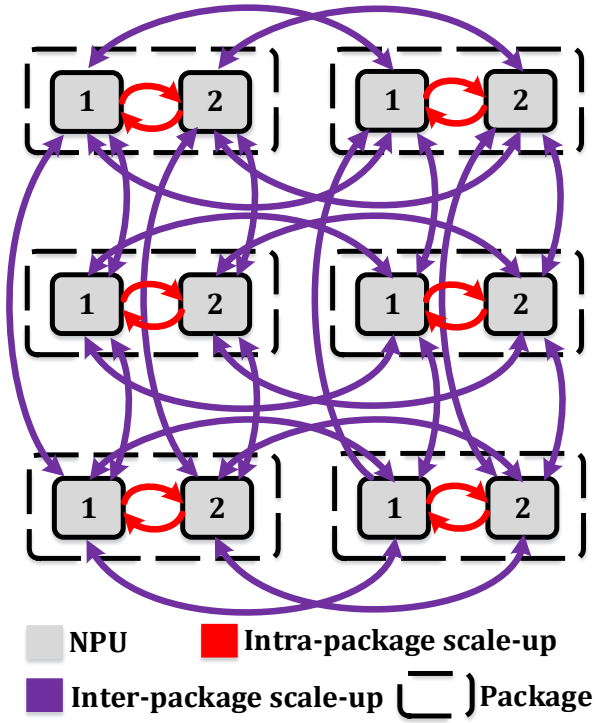

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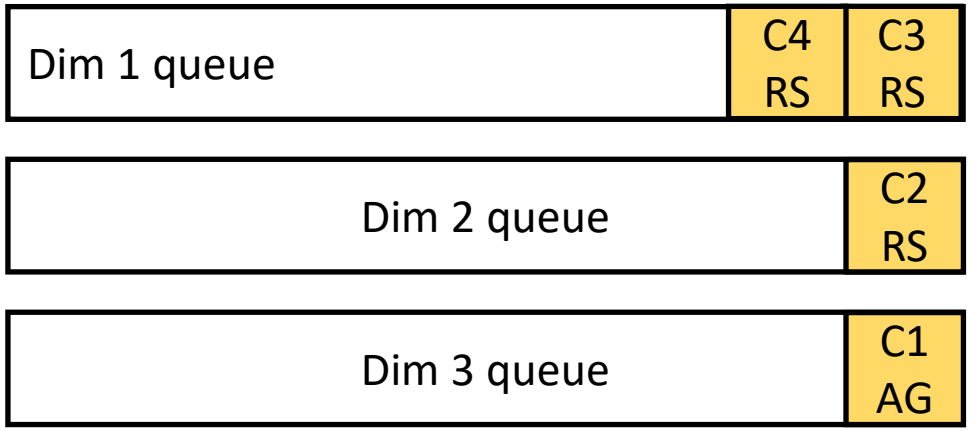

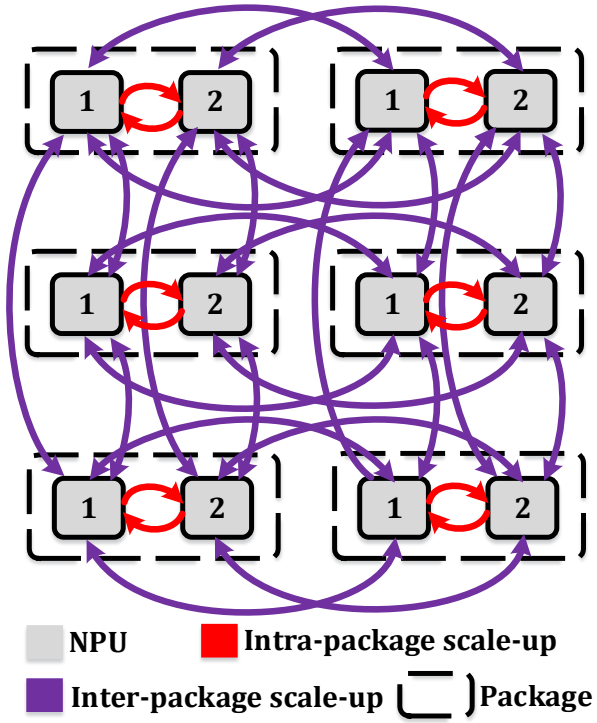

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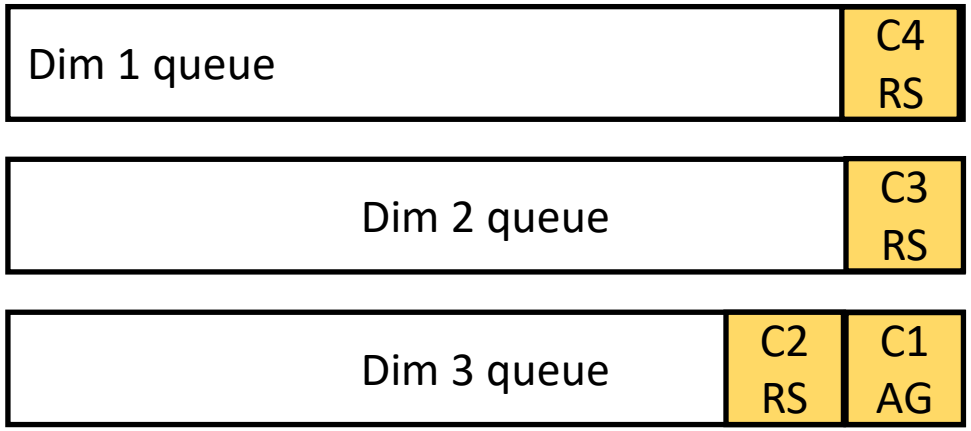

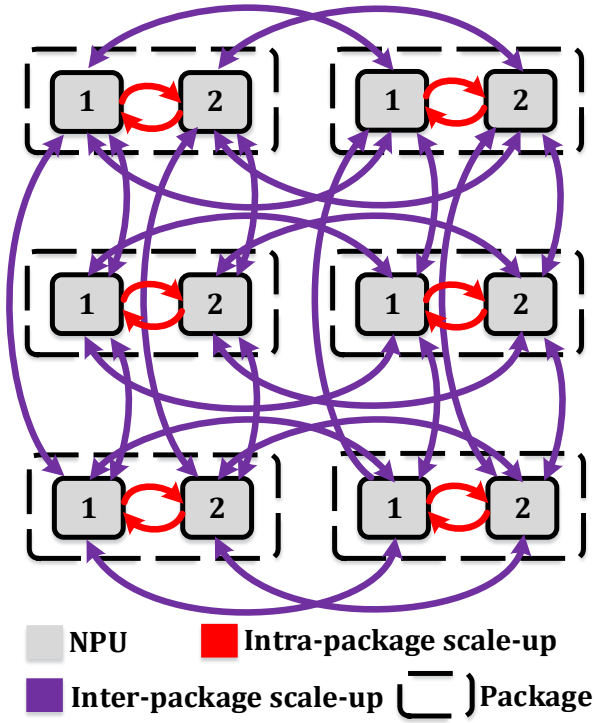

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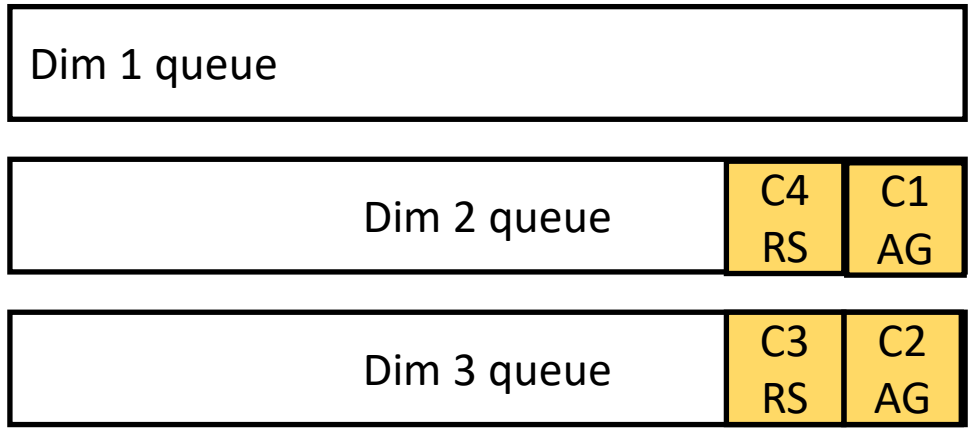

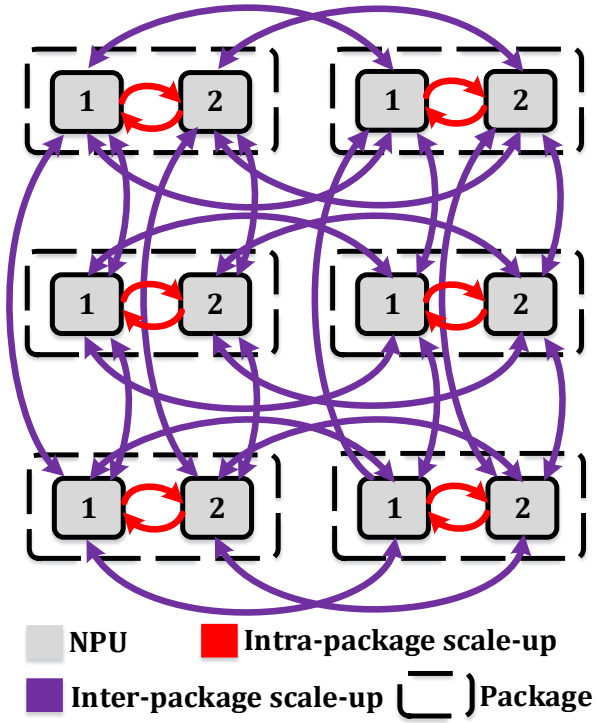

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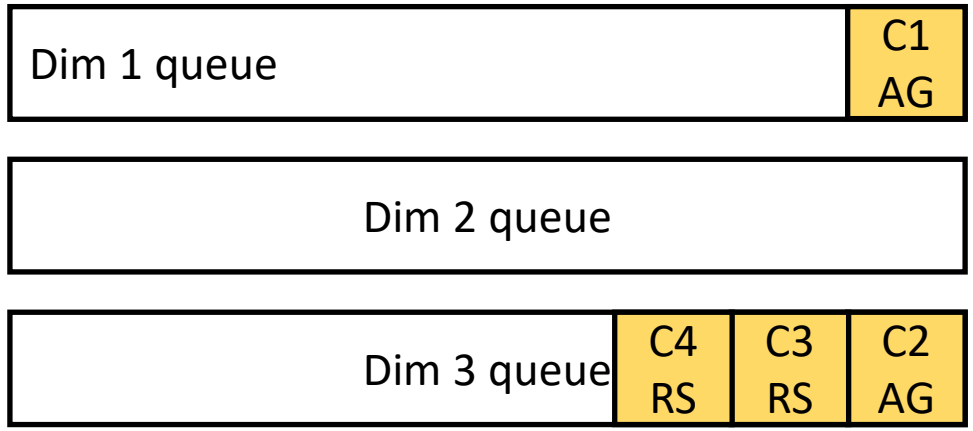

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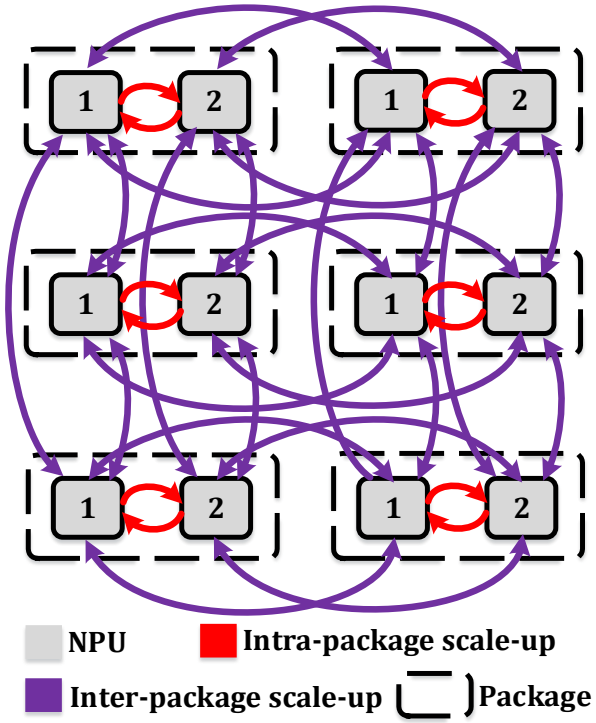

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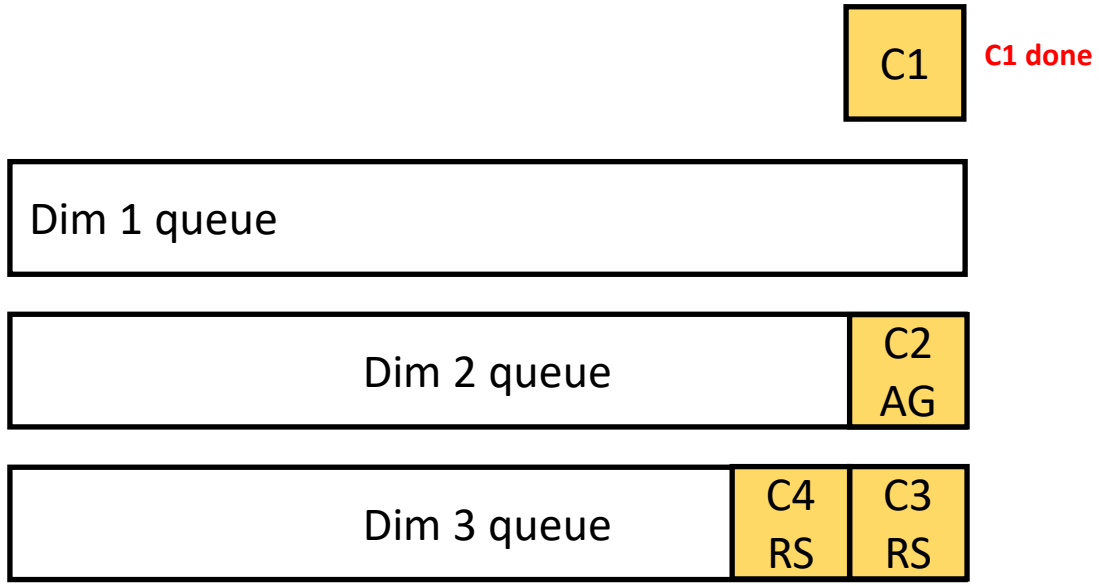

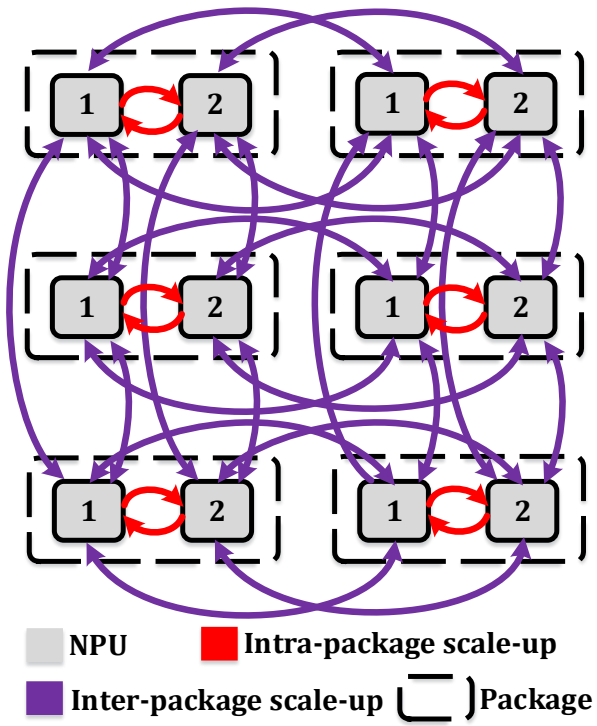

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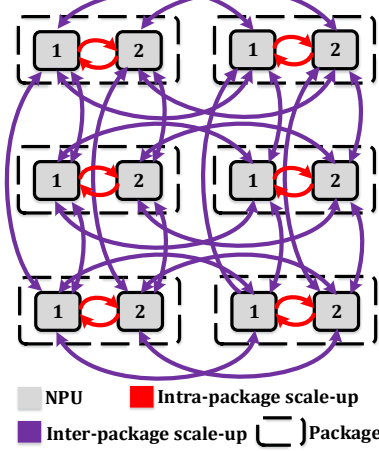
System Input

Collective Policy for

sample_torus_sys.txt

```
scheduling-policy: LIFO
endpoint-delay: 1
active-chunks-per-dimension: 1
preferred-dataset-splits: 4
boost-mode: 0
all-reduce-implementation: ring_ring_ring
all-gather-implementation: ring_ring_ring
reduce-scatter-implementation: ring_ring_ring
all-to-all-implementation: ring_ring_ring
collective-optimization: localBWAware
```



System Input

Constant delay before NPU sending a message

sample_torus_sys.txt

```
scheduling-policy: LIFO
endpoint-delay: 1
active-chunks-per-dimension: 1
preferred-dataset-splits: 4
boost-mode: 0
all-reduce-implementation: ring_ring_ring
all-gather-implementation: ring_ring_ring
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collective-optimization: localBWAware
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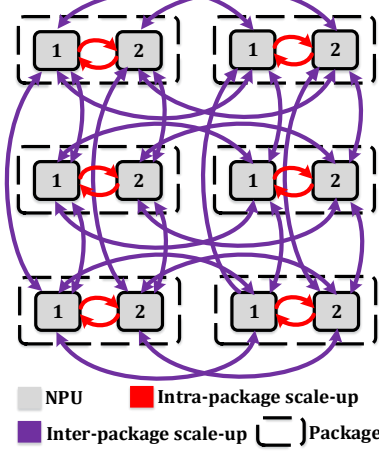

System Input

Max running chunks per each physical network dimension

sample_torus_sys.txt

```
scheduling-policy: LIFO
endpoint-delay: 1
active-chunks-per-dimension: 1
preferred-dataset-splits: 4
boost-mode: 0
all-reduce-implementation: ring_ring_ring
all-gather-implementation: ring_ring_ring
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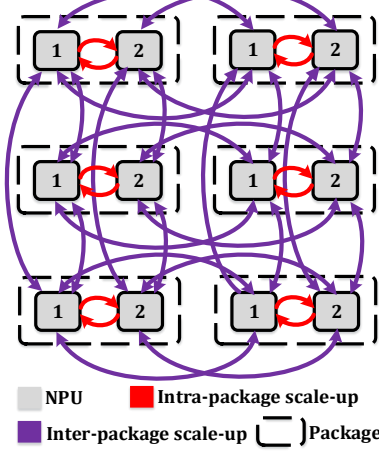

System Input

of chunks to split each collective into

sample_torus_sys.txt

```
scheduling-policy: LIFO
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active-chunks-per-dimension: 1
preferred-dataset-splits: 4
boost-mode: 0
all-reduce-implementation: ring_ring_ring
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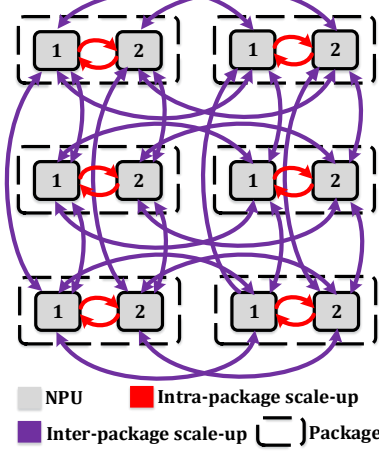
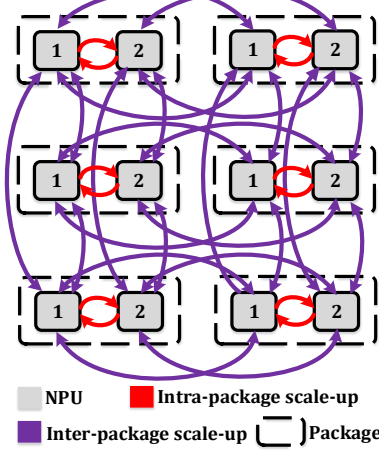


System Input



Speed-up the simulation

sample_torus_sys.txt

```
scheduling-policy: LIFO
endpoint-delay: 1
active-chunks-per-dimension: 1
preferred-dataset-splits: 4
boost-mode: 0
all-reduce-implementation: ring_ring_ring
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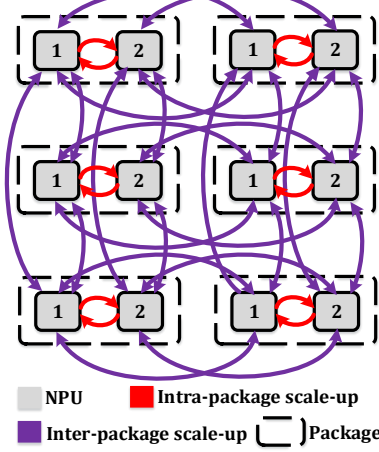
System Input



Hierarchical collective algorithm implementation

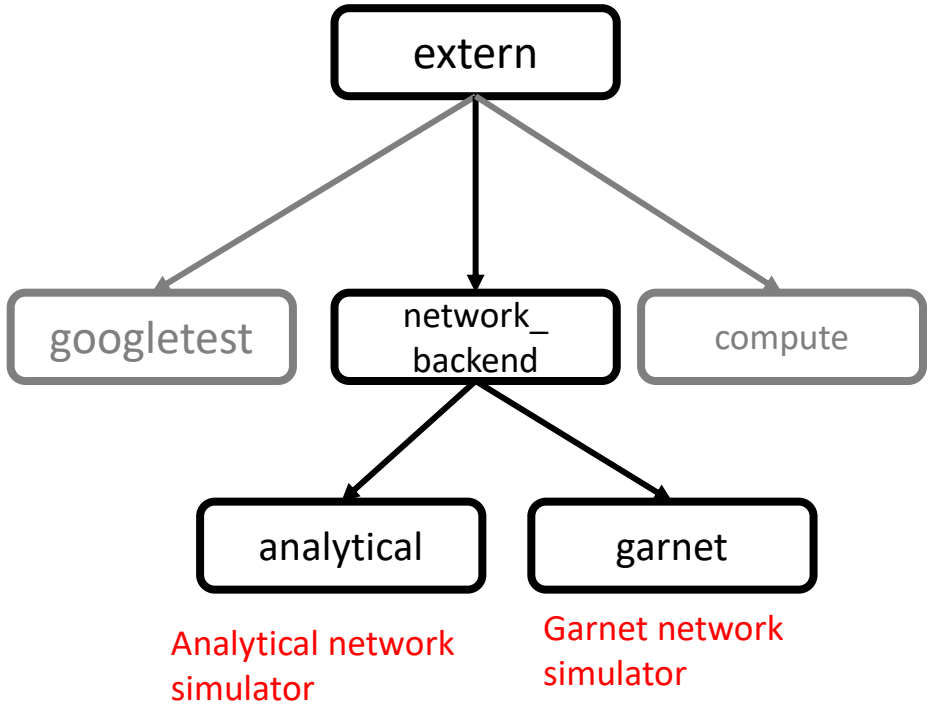
sample_torus_sys.txt

```
scheduling-policy: LIFO
endpoint-delay: 1
active-chunks-per-dimension: 1
preferred-dataset-splits: 4
boost-mode: 0
all-reduce-implementation: ring_ring_ring
all-gather-implementation: ring_ring_ring
reduce-scatter-implementation: ring_ring_ring
all-to-all-implementation: ring_ring_ring
collective-optimization: localBWAware
```

Network Layer

Network Layer Structure

- Network backends are maintained separately and are imported as **submodule**.



Simulation Control Flow

- The main file is implemented inside network layer.
- Network layer creates corresponding System and NetworkAPI instances.
- Each system layer instance **internally** creates its workload layer instance.

Where do instantiations happen?
Analytical backend: analytical/src/main.cc
Garnet backend: garnet/gem5_astra/src/mem/ruby/network/garnet2.0/NetworkInterface.cc

Network Layer

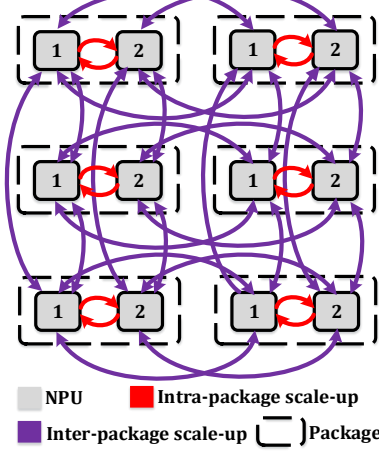
```
void main(){
        ⋮
Instantiate NetworkAPI[];
Instantiate System[];
        ⋮
for(auto &s:system){
    s->workload.fire();
}
process_all_events();
return;
}
```

Garnet vs. Analytical

- Regular topologies + topology-aware collectives make traffic patterns to be congestionless (in most cases), enabling analytical backend to calculate latencies fast and accurately.

Analytical	Garnet
Supports hierarchical topologies	Supports switch-based and torus-based topologies
Each level in hierarchy can be switch, ring, FC	Supports credit-based flow control
Uses simple link latency, BW analytical model to get latency.	Performs packetization, flow control, congestion modeling, etc.
Fast	Slow for large systems & big models
Accurate when comm patterns are congestionless.	Accurate in all scenarios.

Network Input



Garnet network input

sample_torus.txt

```
num-npus: 12
num-packages: 6
package-rows: 3
topology: Torus3D
local-rings: 2
vertical-rings: 1
horizontal-rings: 1
flit-width: 2048
local-packet-size: 4096
package-packet-size: 4096
tile-link-width: 256
package-link-width: 256
vcs-per-vnet: 50
routing-algorithm: Ring_XY
router-latency: 1
local-link-latency: 90
package-link-latency: 200
buffers-per-vc: 5000
local-link-efficiency: 1.0
package-link-efficiency: 1.0
```

Analytical network input

sample_Torus3D.json

```
{
  "topology-name": "Hierarchical",
  "topologies-per-dim": ["Ring", "Ring", "Ring"],
  "dimension-type": ["N", "N", "N"],
  "dimensions-count": 3,
  "units-count": [2, 2, 3],
  "links-count": [2, 2, 2],
  "link-latency": [10, 100, 100],
  "link-bandwidth": [32, 16, 16],
  "nic-latency": [0, 0, 0],
  "router-latency": [0, 0, 0],
  "hbm-latency": [500, 500, 500],
  "hbm-bandwidth": [370, 370, 370],
  "hbm-scale": [0, 0, 0]
}
```

ASTRA-SIM Run Script

A Sample Run Script

run_DLRM_analytical.sh

```
#! /bin/bash -v

# Absolue path to this script
SCRIPT_DIR=$(dirname "$(realpath $0)")

# Absolute paths to useful directories
BINARY="${SCRIPT_DIR:?}"/../build/astra_analytical/build/AnalyticalAstra/bin/AnalyticalAstra
NETWORK="${SCRIPT_DIR:?}"/../inputs/network/analytical/sample_Torus3D.json
SYSTEM="${SCRIPT_DIR:?}"/../inputs/system/sample_torus_sys.txt
WORKLOAD="${SCRIPT_DIR:?}"/../inputs/workload/DLRM_HybridParallel.txt
STATS="${SCRIPT_DIR:?}"/results/run_DLRM_analytical

rm -rf "${STATS}"
mkdir "${STATS}"

"${BINARY}" \
--network-configuration="${NETWORK}" \
--system-configuration="${SYSTEM}" \
--workload-configuration="${WORKLOAD}" \
--path="${STATS}/" \
--run-name="sample_DLRM" \
--num-passes=2 \
--total-stat-rows=1 \
--stat-row=0
```

A Sample Run Script

run_DLRM_analytical.sh

```
#! /bin/bash -v

# Absolue path to this script
SCRIPT_DIR=$(dirname "$(realpath $0)")

# Absolute paths to useful directories
BINARY="${SCRIPT_DIR:?}"/../build/astra_analytical/build/AnalyticalAstra/bin/AnalyticalAstra
NETWORK="${SCRIPT_DIR:?}"/../inputs/network/analytical/sample_Torus3D.json
SYSTEM="${SCRIPT_DIR:?}"/../inputs/system/sample_torus_sys.txt
WORKLOAD="${SCRIPT_DIR:?}"/../inputs/workload/DLRM_HybridParallel.txt
STATS="${SCRIPT_DIR:?}"/results/run_DLRM_analytical

rm -rf "${STATS}"
mkdir "${STATS}"

"${BINARY}" \
--network-configuration="${NETWORK}" \
--system-configuration="${SYSTEM}" \
--workload-configuration="${WORKLOAD}" \
--path="${STATS}/" \
--run-name="sample_DLRM" \
--num-passes=2 \
--total-stat-rows=1 \
--stat-row=0
```

Runtime parameters

ASTRA-SIM Reports

Overall Results

- Endtoend.csv.

Layer name

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1			fwd compute	wg compute	ig compute	fwd exposed	wg exposed c	ig exposed cc	fwd total com	wg total com	ig total comn	workload fini	total comp	total exposed comm	
2	conv1	sample_Resnet	26.006	64.582	0	0	17.364	0	0	17.366	0	4875.201	2164.9	2710.301	
3	layer_64_1_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	4.796	0	4875.201			
4	layer_64_1_c	sample_Resnet	6.912	14.976	6.912	0	0	0	0	27.08	0	4875.201			
5	layer_64_1_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	47.906	0	4875.201			
6	layer_64_1_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	13.648	0	4875.201			
7	layer_64_2_c	sample_Resnet	7.296	19.968	6.912	0	0	0	0	10.166	0	4875.201			
8	layer_64_2_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	20.102	0	4875.201			
9	layer_64_2_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	22.048	0	4875.201			
10	layer_64_3_c	sample_Resnet	7.296	19.968	6.912	0	0	0	0	30.082	0	4875.201			
11	layer_64_3_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	11.334	0	4875.201			
12	layer_64_3_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	7.526	0	4875.201			
13	layer_128_1_	sample_Resnet	5.184	12.288	5.184	0	0	0	0	36.03	0	4875.201			
14	layer_128_1_	sample_Resnet	7.296	19.968	7.04	0	0	0	0	9.08	0	4875.201			
15	layer_128_1_	sample_Resnet	12.96	13.312	11.68	0	0	0	0	28.13	0	4875.201			
16	layer_128_1_	sample_Resnet	4.672	10.24	5.184	0	0	0	0	13.272	0	4875.201			
17	layer_128_2_	sample_Resnet	5.184	8.192	4.672	0	0	0	0	30.868	0	4875.201			
18	layer_128_2_	sample_Resnet	12.96	13.312	11.68	0	0	0	0	33.952	0	4875.201			
19	layer_128_2_	sample_Resnet	4.672	10.24	5.184	0	0	0	0	101.056	0	4875.201			

Overall Results

- Endtoend.csv.

Run name

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1			fwd compute	wg compute	ig compute	fwd exposed	wg exposed c	ig exposed cc	fwd total com	wg total com	ig total comn	workload fini	total comp	total exposed comm	
2	conv1	sample_Resnet	26.006	64.582	0	0	17.364	0	0	17.366	0	4875.201	2164.9	2710.301	
3	layer_64_1_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	4.796	0	4875.201			
4	layer_64_1_c	sample_Resnet	6.912	14.976	6.912	0	0	0	0	27.08	0	4875.201			
5	layer_64_1_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	47.906	0	4875.201			
6	layer_64_1_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	13.648	0	4875.201			
7	layer_64_2_c	sample_Resnet	7.296	19.968	6.912	0	0	0	0	10.166	0	4875.201			
8	layer_64_2_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	20.102	0	4875.201			
9	layer_64_2_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	22.048	0	4875.201			
10	layer_64_3_c	sample_Resnet	7.296	19.968	6.912	0	0	0	0	30.082	0	4875.201			
11	layer_64_3_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	11.334	0	4875.201			
12	layer_64_3_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	7.526	0	4875.201			
13	layer_128_1_	sample_Resnet	5.184	12.288	5.184	0	0	0	0	36.03	0	4875.201			
14	layer_128_1_	sample_Resnet	7.296	19.968	7.04	0	0	0	0	9.08	0	4875.201			
15	layer_128_1_	sample_Resnet	12.96	13.312	11.68	0	0	0	0	28.13	0	4875.201			
16	layer_128_1_	sample_Resnet	4.672	10.24	5.184	0	0	0	0	13.272	0	4875.201			
17	layer_128_2_	sample_Resnet	5.184	8.192	4.672	0	0	0	0	30.868	0	4875.201			
18	layer_128_2_	sample_Resnet	12.96	13.312	11.68	0	0	0	0	33.952	0	4875.201			
19	layer_128_2_	sample_Resnet	4.672	10.24	5.184	0	0	0	0	101.056	0	4875.201			

Overall Results

- Endtoend.csv.

Compute times (us)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1			fwd compute	wg compute	ig compute	fwd exposed	wg exposed c	ig exposed cc	fwd total com	wg total com	ig total comn	workload fini	total comp	total exposed comm	
2	conv1	sample_Resnet	26.006	64.582	0	0	17.364	0	0	17.366	0	4875.201	2164.9	2710.301	
3	layer_64_1_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	4.796	0	4875.201			
4	layer_64_1_c	sample_Resnet	6.912	14.976	6.912	0	0	0	0	27.08	0	4875.201			
5	layer_64_1_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	47.906	0	4875.201			
6	layer_64_1_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	13.648	0	4875.201			
7	layer_64_2_c	sample_Resnet	7.296	19.968	6.912	0	0	0	0	10.166	0	4875.201			
8	layer_64_2_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	20.102	0	4875.201			
9	layer_64_2_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	22.048	0	4875.201			
10	layer_64_3_c	sample_Resnet	7.296	19.968	6.912	0	0	0	0	30.082	0	4875.201			
11	layer_64_3_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	11.334	0	4875.201			
12	layer_64_3_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	7.526	0	4875.201			
13	layer_128_1_	sample_Resnet	5.184	12.288	5.184	0	0	0	0	36.03	0	4875.201			
14	layer_128_1_	sample_Resnet	7.296	19.968	7.04	0	0	0	0	9.08	0	4875.201			
15	layer_128_1_	sample_Resnet	12.96	13.312	11.68	0	0	0	0	28.13	0	4875.201			
16	layer_128_1_	sample_Resnet	4.672	10.24	5.184	0	0	0	0	13.272	0	4875.201			
17	layer_128_2_	sample_Resnet	5.184	8.192	4.672	0	0	0	0	30.868	0	4875.201			
18	layer_128_2_	sample_Resnet	12.96	13.312	11.68	0	0	0	0	33.952	0	4875.201			
19	layer_128_2_	sample_Resnet	4.672	10.24	5.184	0	0	0	0	101.056	0	4875.201			

Overall Results

- Endtoend.csv.

Raw communication times (us)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1			fwd compute	wg compute	ig compute	fwd exposed	wg exposed c	ig exposed cc	fwd total com	wg total com	ig total comn	workload fini	total comp	total exposed comm	
2	conv1	sample_Resnet	26.006	64.582	0	0	17.364	0	0	17.366	0	4875.201	2164.9	2710.301	
3	layer_64_1_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	4.796	0	4875.201			
4	layer_64_1_c	sample_Resnet	6.912	14.976	6.912	0	0	0	0	27.08	0	4875.201			
5	layer_64_1_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	47.906	0	4875.201			
6	layer_64_1_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	13.648	0	4875.201			
7	layer_64_2_c	sample_Resnet	7.296	19.968	6.912	0	0	0	0	10.166	0	4875.201			
8	layer_64_2_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	20.102	0	4875.201			
9	layer_64_2_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	22.048	0	4875.201			
10	layer_64_3_c	sample_Resnet	7.296	19.968	6.912	0	0	0	0	30.082	0	4875.201			
11	layer_64_3_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	11.334	0	4875.201			
12	layer_64_3_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	7.526	0	4875.201			
13	layer_128_1_	sample_Resnet	5.184	12.288	5.184	0	0	0	0	36.03	0	4875.201			
14	layer_128_1_	sample_Resnet	7.296	19.968	7.04	0	0	0	0	9.08	0	4875.201			
15	layer_128_1_	sample_Resnet	12.96	13.312	11.68	0	0	0	0	28.13	0	4875.201			
16	layer_128_1_	sample_Resnet	4.672	10.24	5.184	0	0	0	0	13.272	0	4875.201			
17	layer_128_2_	sample_Resnet	5.184	8.192	4.672	0	0	0	0	30.868	0	4875.201			
18	layer_128_2_	sample_Resnet	12.96	13.312	11.68	0	0	0	0	33.952	0	4875.201			
19	layer_128_2_	sample_Resnet	4.672	10.24	5.184	0	0	0	0	101.056	0	4875.201			

Overall Results

- Endtoend.csv.

Exposed communication times (us)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1			fwd compute	wg compute	ig compute	fwd exposed	wg exposed c	ig exposed cc	fwd total com	wg total com	ig total comn	workload fini	total comp	total exposed comm	
2	conv1	sample_Resnet	26.006	64.582	0	0	17.364	0	0	17.366	0	4875.201	2164.9	2710.301	
3	layer_64_1_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	4.796	0	4875.201			
4	layer_64_1_c	sample_Resnet	6.912	14.976	6.912	0	0	0	0	27.08	0	4875.201			
5	layer_64_1_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	47.906	0	4875.201			
6	layer_64_1_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	13.648	0	4875.201			
7	layer_64_2_c	sample_Resnet	7.296	19.968	6.912	0	0	0	0	10.166	0	4875.201			
8	layer_64_2_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	20.102	0	4875.201			
9	layer_64_2_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	22.048	0	4875.201			
10	layer_64_3_c	sample_Resnet	7.296	19.968	6.912	0	0	0	0	30.082	0	4875.201			
11	layer_64_3_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	11.334	0	4875.201			
12	layer_64_3_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	7.526	0	4875.201			
13	layer_128_1_	sample_Resnet	5.184	12.288	5.184	0	0	0	0	36.03	0	4875.201			
14	layer_128_1_	sample_Resnet	7.296	19.968	7.04	0	0	0	0	9.08	0	4875.201			
15	layer_128_1_	sample_Resnet	12.96	13.312	11.68	0	0	0	0	28.13	0	4875.201			
16	layer_128_1_	sample_Resnet	4.672	10.24	5.184	0	0	0	0	13.272	0	4875.201			
17	layer_128_2_	sample_Resnet	5.184	8.192	4.672	0	0	0	0	30.868	0	4875.201			
18	layer_128_2_	sample_Resnet	12.96	13.312	11.68	0	0	0	0	33.952	0	4875.201			
19	layer_128_2_	sample_Resnet	4.672	10.24	5.184	0	0	0	0	101.056	0	4875.201			

Overall Results

- Endtoend.csv.

Total compute & exposed communication times across all layers (us)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1			fwd compute	wg compute	ig compute	fwd exposed	wg exposed c	ig exposed cc	fwd total con	wg total com	ig total comn	workload fini	total comp	total exposed comm	
2	conv1	sample_Resnet	26.006	64.582	0	0	17.364	0	0	17.366	0	4875.201	2164.9	2710.301	
3	layer_64_1_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	4.796	0	4875.201			
4	layer_64_1_c	sample_Resnet	6.912	14.976	6.912	0	0	0	0	27.08	0	4875.201			
5	layer_64_1_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	47.906	0	4875.201			
6	layer_64_1_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	13.648	0	4875.201			
7	layer_64_2_c	sample_Resnet	7.296	19.968	6.912	0	0	0	0	10.166	0	4875.201			
8	layer_64_2_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	20.102	0	4875.201			
9	layer_64_2_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	22.048	0	4875.201			
10	layer_64_3_c	sample_Resnet	7.296	19.968	6.912	0	0	0	0	30.082	0	4875.201			
11	layer_64_3_c	sample_Resnet	21.888	28.288	20.736	0	0	0	0	11.334	0	4875.201			
12	layer_64_3_c	sample_Resnet	6.912	14.976	7.296	0	0	0	0	7.526	0	4875.201			
13	layer_128_1_	sample_Resnet	5.184	12.288	5.184	0	0	0	0	36.03	0	4875.201			
14	layer_128_1_	sample_Resnet	7.296	19.968	7.04	0	0	0	0	9.08	0	4875.201			
15	layer_128_1_	sample_Resnet	12.96	13.312	11.68	0	0	0	0	28.13	0	4875.201			
16	layer_128_1_	sample_Resnet	4.672	10.24	5.184	0	0	0	0	13.272	0	4875.201			
17	layer_128_2_	sample_Resnet	5.184	8.192	4.672	0	0	0	0	30.868	0	4875.201			
18	layer_128_2_	sample_Resnet	12.96	13.312	11.68	0	0	0	0	33.952	0	4875.201			
19	layer_128_2_	sample_Resnet	4.672	10.24	5.184	0	0	0	0	101.056	0	4875.201			

Overall Results

- Detailed.csv.

Average chunk queueing delay per each collective phase (us)

	A	B	C	D	E	F	G	H	I	J	K	L	M
1			queuing d	queuing delay phase 1	queuing delay phase 2	queuing delay phase 3	queuing delay phase 4	queuing delay phase 5	network delay phase 1	network delay phase 2	network delay phase 3	network delay phase 4	network delay phase 5
2	conv1	sample_Resnet	0	1.8795	0.5455	0	0.137	2.3575	0.035	0.018	0.005	0.018	0.035
3	layer_64_1_	sample_Resnet	0	0.453	0.03925	0	0.02725	0.2425	0.06	0.03	0.008	0.03	0.06
4	layer_64_1_	sample_Resnet	0	2.9225	2.3655	0	0.065	7.1915	0.015	0.008	0.002	0.008	0.015
5	layer_64_1_	sample_Resnet	0	6.8005	2.5125	1.2645	3.2625	6.7425	0.135	0.068	0.017	0.068	0.135
6	layer_64_1_	sample_Resnet	0	2.013	0.412	0	0.227	2.536	0.06	0.03	0.008	0.03	0.06
7	layer_64_2_	sample_Resnet	0	2.889	0.03925	0	0.02725	0.2425	0.06	0.03	0.008	0.03	0.06
8	layer_64_2_	sample_Resnet	0	5.9785	0.08275	0	0.07075	0.5485	0.135	0.068	0.017	0.068	0.135
9	layer_64_2_	sample_Resnet	0	1.901	2.947	0	0.227	4.313	0.06	0.03	0.008	0.03	0.06
10	layer_64_3_	sample_Resnet	0	5.669	1.306	0	0.227	5.954	0.06	0.03	0.008	0.03	0.06
11	layer_64_3_	sample_Resnet	0	1.5945	0.08275	0	0.07075	0.5485	0.135	0.068	0.017	0.068	0.135
12	layer_64_3_	sample_Resnet	0	0.383	0.409	0	0.227	1.108	0.06	0.03	0.008	0.03	0.06
13	layer_128_1	sample_Resnet	0	6.6015	0.4635	0	0.262	3.0585	0.477	0.239	0.06	0.239	0.477
14	layer_128_1	sample_Resnet	0	1.176	0.07225	0	0.06325	0.4915	0.12	0.06	0.015	0.06	0.12
15	layer_128_1	sample_Resnet	0	2.9015	0.31	0	0.2935	2.2045	0.537	0.269	0.068	0.269	0.537
16	layer_128_1	sample_Resnet	0	1.4375	0.14125	0	0.12925	0.9775	0.239	0.12	0.03	0.12	0.239
17	layer_128_2	sample_Resnet	0	1.3395	2.3275	0	0.905	4.1295	0.239	0.12	0.03	0.12	0.239
18	layer_128_2	sample_Resnet	0	2.9285	0.37	0	0.487	3.393	0.537	0.269	0.068	0.269	0.537
19	layer_128_2	sample_Resnet	0	6.5115	0.8545	0.8115	8.02825	20.68175	0.239	0.12	0.03	0.12	0.239
20	layer_128_3	sample_Resnet	0	4.6365	0.42475	0.01275	0.549	16.7855	0.239	0.12	0.03	0.12	0.239

Overall Results

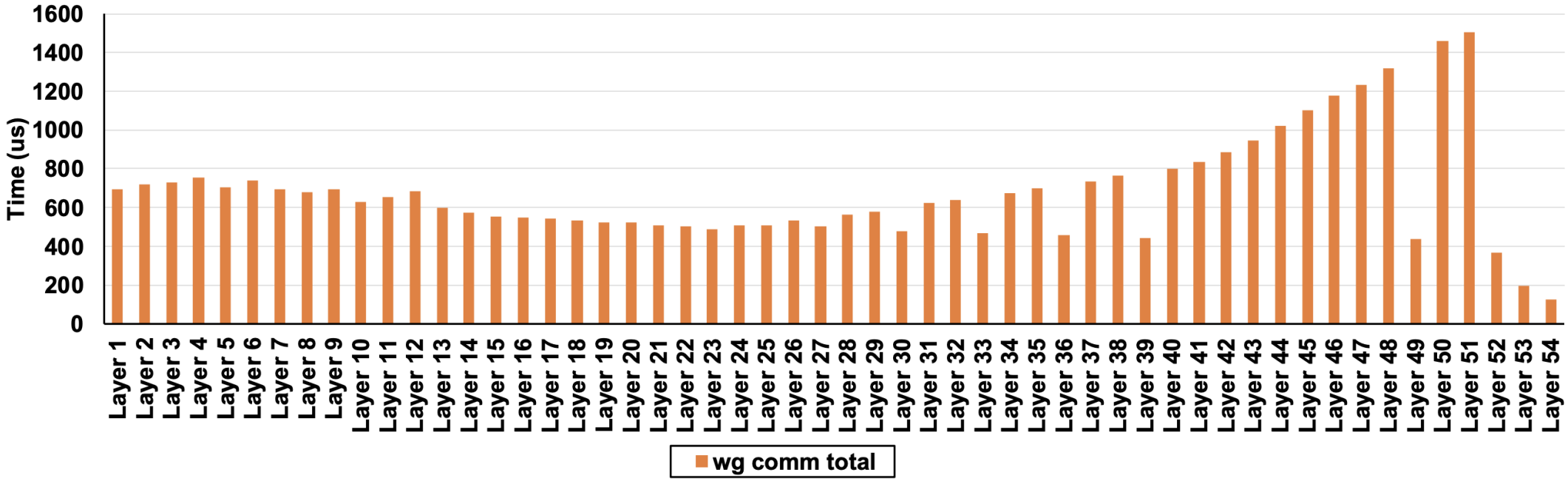
- Detailed.csv.

Average message latency per each collective phase (us)

	A	B	C	D	E	F	G	H	I	J	K	L	M
1			queuing d	queuing delay phase 1	queuing delay phase 2	queuing delay phase 3	queuing delay phase 4	queuing delay phase 5	network delay phase 1	network delay phase 2	network delay phase 3	network delay phase 4	network delay phase 5
2	conv1	sample_Resnet	0	1.8795	0.5455	0	0.137	2.3575	0.035	0.018	0.005	0.018	0.035
3	layer_64_1_	sample_Resnet	0	0.453	0.03925	0	0.02725	0.2425	0.06	0.03	0.008	0.03	0.06
4	layer_64_1_	sample_Resnet	0	2.9225	2.3655	0	0.065	7.1915	0.015	0.008	0.002	0.008	0.015
5	layer_64_1_	sample_Resnet	0	6.8005	2.5125	1.2645	3.2625	6.7425	0.135	0.068	0.017	0.068	0.135
6	layer_64_1_	sample_Resnet	0	2.013	0.412	0	0.227	2.536	0.06	0.03	0.008	0.03	0.06
7	layer_64_2_	sample_Resnet	0	2.889	0.03925	0	0.02725	0.2425	0.06	0.03	0.008	0.03	0.06
8	layer_64_2_	sample_Resnet	0	5.9785	0.08275	0	0.07075	0.5485	0.135	0.068	0.017	0.068	0.135
9	layer_64_2_	sample_Resnet	0	1.901	2.947	0	0.227	4.313	0.06	0.03	0.008	0.03	0.06
10	layer_64_3_	sample_Resnet	0	5.669	1.306	0	0.227	5.954	0.06	0.03	0.008	0.03	0.06
11	layer_64_3_	sample_Resnet	0	1.5945	0.08275	0	0.07075	0.5485	0.135	0.068	0.017	0.068	0.135
12	layer_64_3_	sample_Resnet	0	0.383	0.409	0	0.227	1.108	0.06	0.03	0.008	0.03	0.06
13	layer_128_1	sample_Resnet	0	6.6015	0.4635	0	0.262	3.0585	0.477	0.239	0.06	0.239	0.477
14	layer_128_1	sample_Resnet	0	1.176	0.07225	0	0.06325	0.4915	0.12	0.06	0.015	0.06	0.12
15	layer_128_1	sample_Resnet	0	2.9015	0.31	0	0.2935	2.2045	0.537	0.269	0.068	0.269	0.537
16	layer_128_1	sample_Resnet	0	1.4375	0.14125	0	0.12925	0.9775	0.239	0.12	0.03	0.12	0.239
17	layer_128_2	sample_Resnet	0	1.3395	2.3275	0	0.905	4.1295	0.239	0.12	0.03	0.12	0.239
18	layer_128_2	sample_Resnet	0	2.9285	0.37	0	0.487	3.393	0.537	0.269	0.068	0.269	0.537
19	layer_128_2	sample_Resnet	0	6.5115	0.8545	0.8115	8.02825	20.68175	0.239	0.12	0.03	0.12	0.239
20	layer_128_3	sample_Resnet	0	4.6365	0.42475	0.01275	0.549	16.7855	0.239	0.12	0.03	0.12	0.239

ResNet-50 Layer-Wise Raw Comm Latency

- A Torus 3D with total of 32 (2X4X4) nodes is used.
- Data parallel approach is used.
- Raw latency depends on the comm size plus the priority of each layer comm (queuing delay).

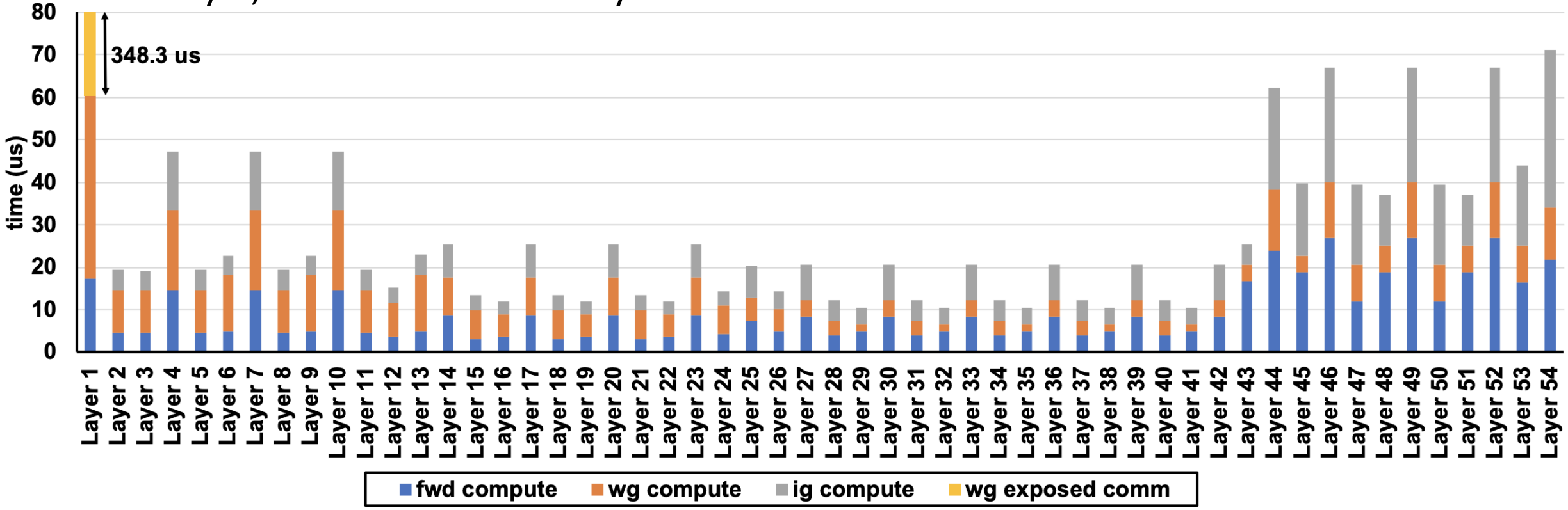


ResNet-50 Layer-Wise Compute vs. Exposed Comm Latency

- Exposed comm latency is observed for the first layer.

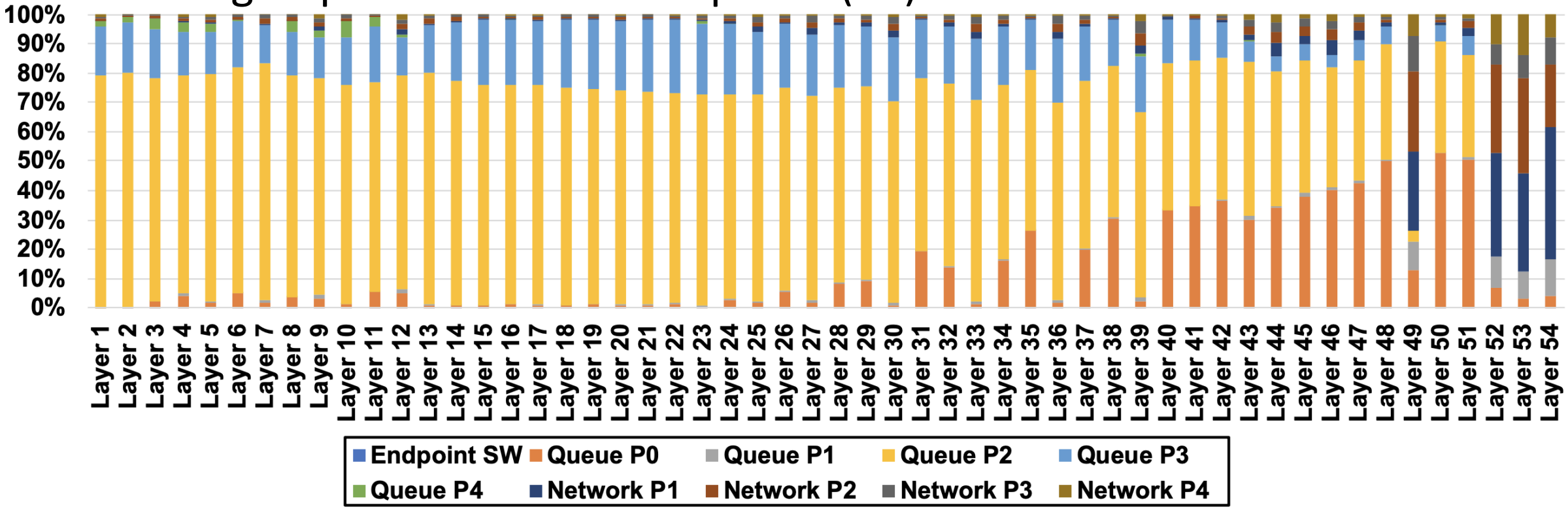
because by the time we reach other layers except that.

first layer, their comm is already finished.



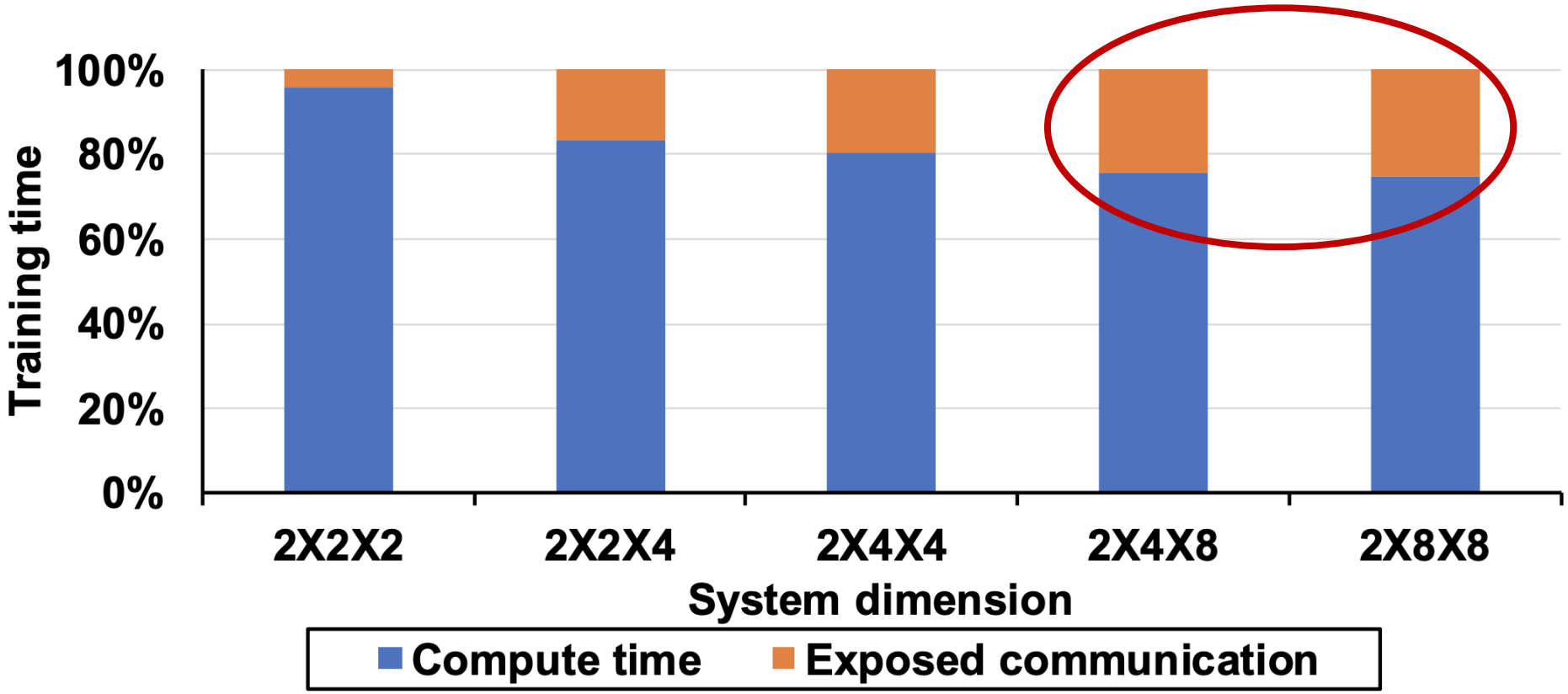
ResNet-50 Layer-Wise detailed latency

- Queue P2 is becoming the dominant factor due to very high speed of P1 (within package) that results most of the chunks get queued for the next phase (P2).



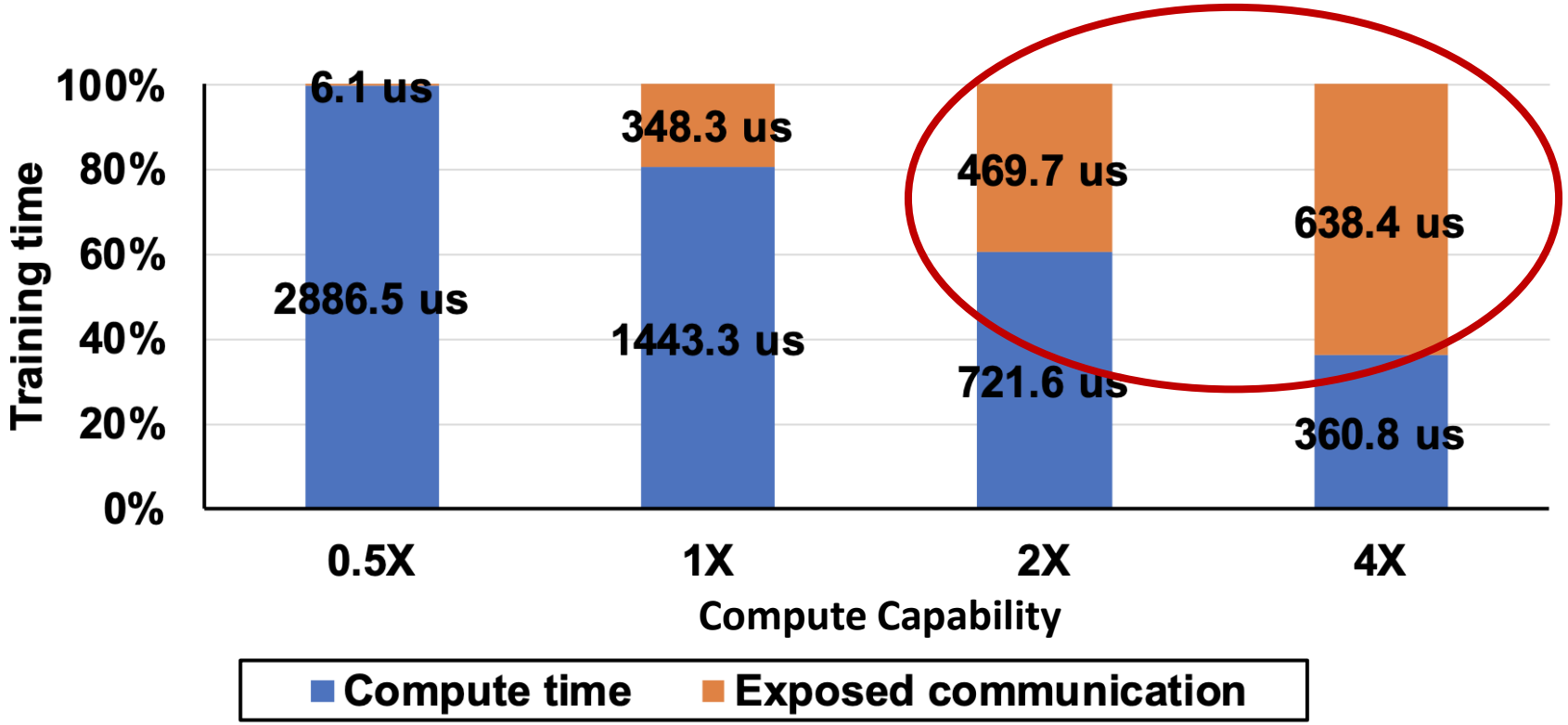
Effect of # of nodes on the Ratio of Total Compute vs Total Exposed Comm for ResNet-50

- A Torus 3D with total of 8, 16, 32, 64, 128 nodes are used.



Effect of Enhanced Compute Time per Node on the Ratio of Total Compute vs Total Exposed Comm for ResNet-50

- A Torus 3D with total of 32 nodes (2X4X4) is used.



Workload Generator

Workload Generator

- Should receive the GEMM operations (M, N, K dimensions) and the parallelization strategy as input.
- It uses SCALE-SIM simulator to find the compute times.
- Please see astra-sim/scripts/workload_generator/README.md.

Sample script to call workload generator

```
# For data-parallel
$ python3 gen_astrasim_workload_input.py \
  --datatype_size=2 \
  --mnk=mnk_inputs/example.csv \
  --num_npus=16 \
  --num_packages=2 \
  --output_file=../../inputs/workload/example_DATA.txt \
  --parallel=DATA \
  --run_name=example \
  --scalesim_config=../../extern/compute/SCALE-Sim/configs/google.cfg \
  --scalesim_path=../../extern/compute/SCALE-Sim
```

Sample MNK input file

	A	B	C	D	E
1	Layer	m	n	k	
2	MLP_Bottom	1024	128	512	
3	MLP_Bottom	1024	512	512	
4	MLP_Bottom	1024	512	512	
5	MLP_Bottom	1024	512	16	
6	MLP_Top_0	1024	1024	512	
7	MLP_Top_1	1024	512	512	
8	MLP_Top_2	1024	512	512	
9					

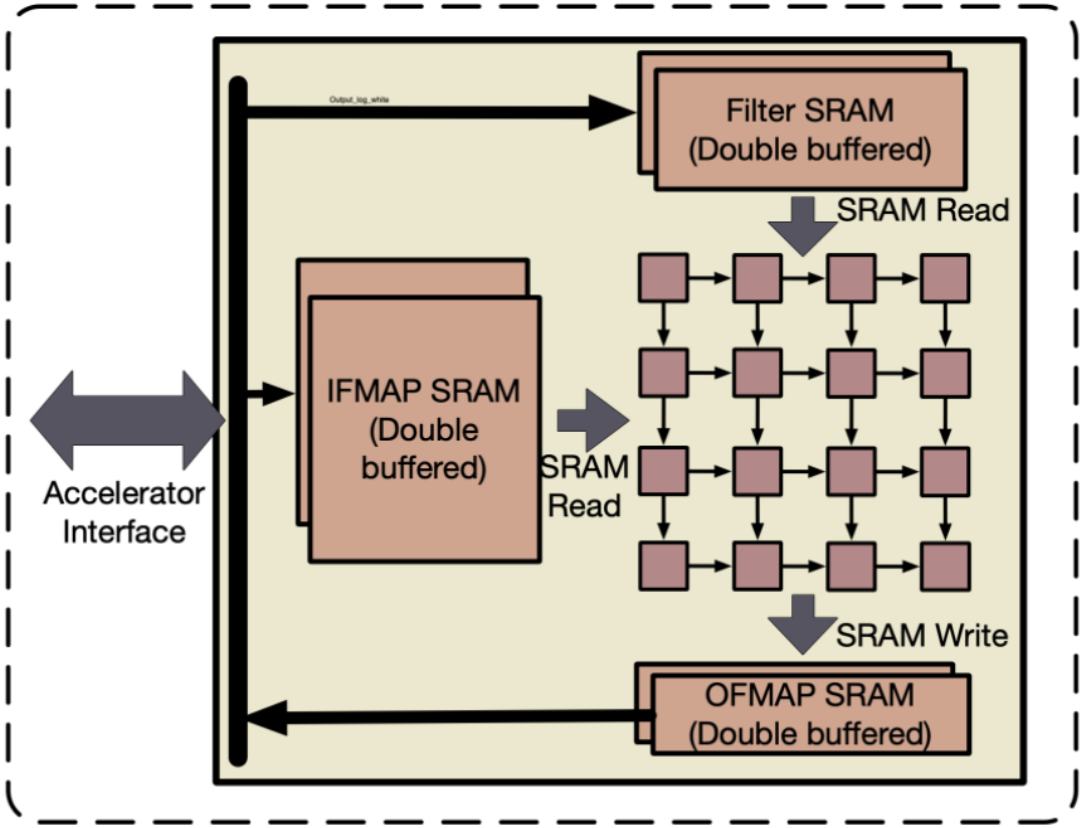
SCALE-SIM

- https://github.com/scalesim-project/scale-sim-v2

Parameter	Value
Array Height	32
Array Width	32
IFMAP SRAM Size	1024
Filter SRAM Size	1024
OFRAM SRAM Size	128
Dataflow	WS

Config file with architecture specs

Topology.csv



SCALE SIM

Cycle and IF BW

Traces
SRAM Read/Write
DRAM Read/Write

Thank you!