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⛔ Visibility

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Lack of fine-grained visibility at queue pair level

Pre-race & race time!

⛔ Visibility

AI-generated images

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Lack of fine-grained visibility at queue pair level

Pre-race & race time!

⛔ Visibility

⛔ Reliability

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Lack of fine-grained visibility at queue pair level

Pre-race & race time!

⛔ Visibility

NIC/link flapping

⛔ Reliability

AI-generated images

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AI/ML Networking Challenges

Lerna Ekmekcioglu
Sr. Solutions Engineer
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Agenda

- AI workload layers
- Demands from AI networks
- Challenges in AI networks
- Key Takeaways

Time Force,

Department of Temporal Affairs

Tempus Mundi Servamus

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1

DeepSpaceExplorer LLM Model

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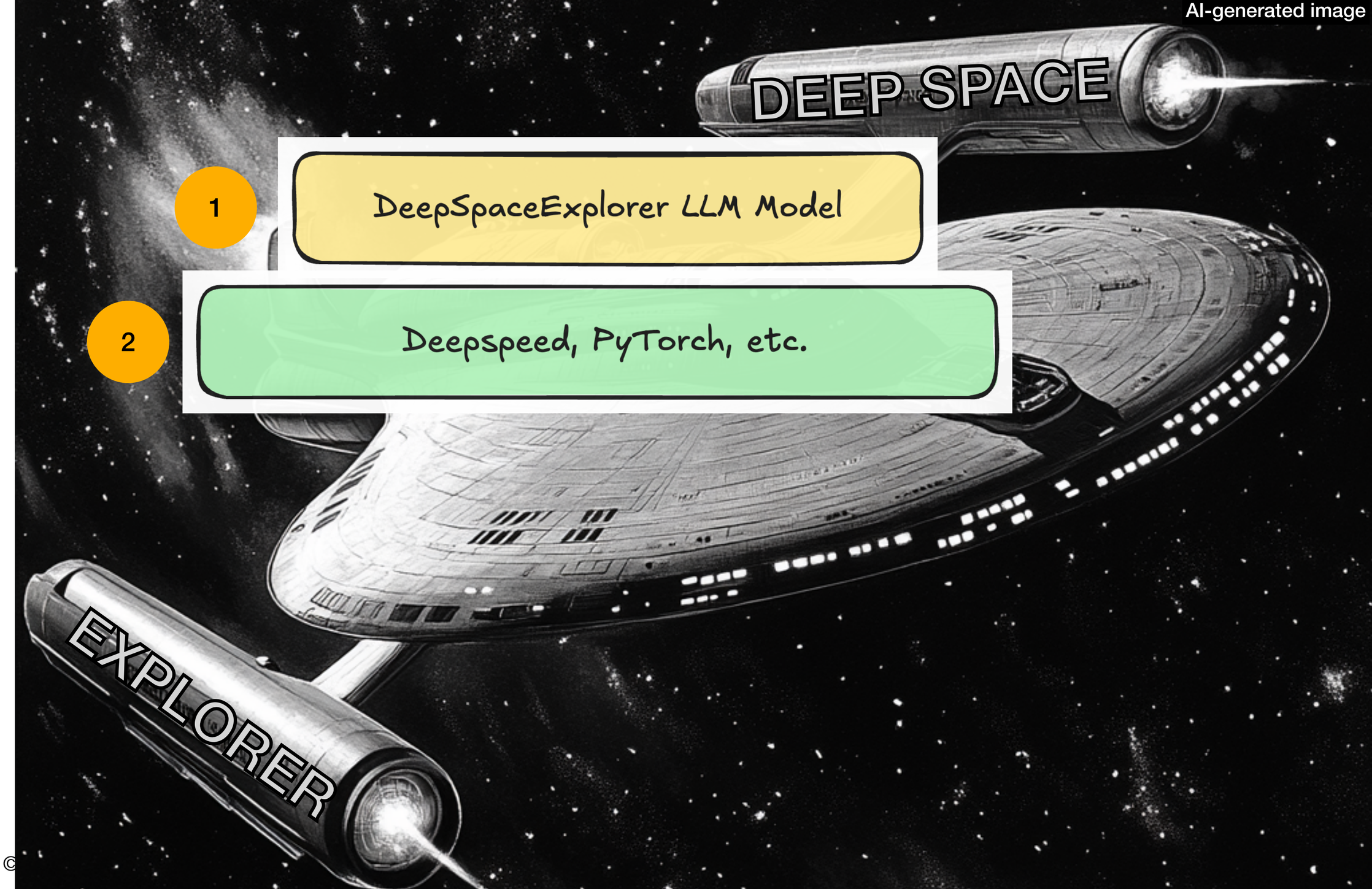

1 DeepSpaceExplorer LLM Model

2 Deepspeed, PyTorch, etc.

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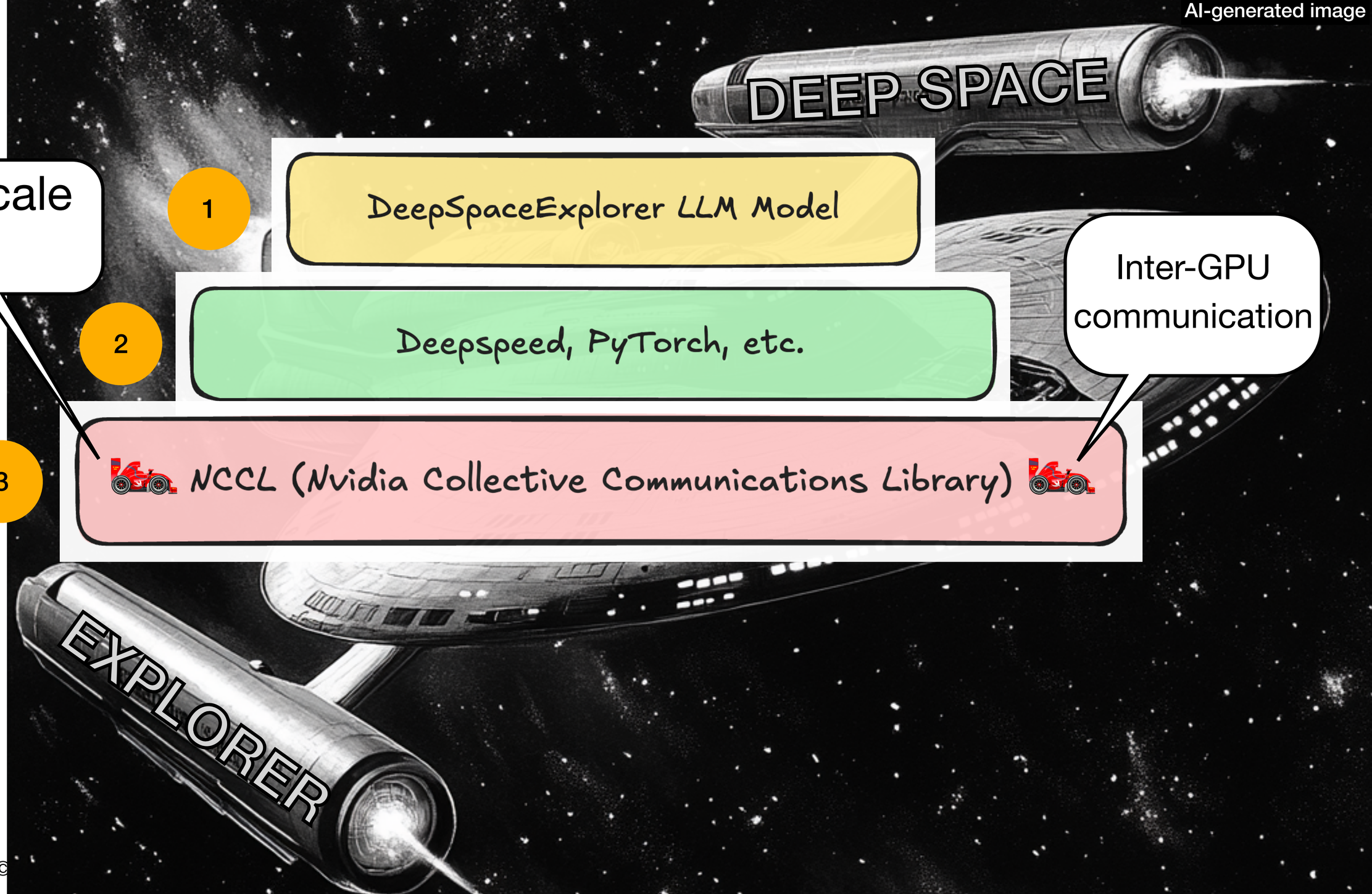

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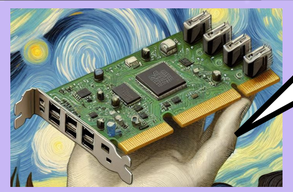
DEEP SPACE

1 DeepSpaceExplorer LLM Model

2 Deepspeed, PyTorch, etc.

3 🏎️ NCCL (Nvidia Collective Communications Library) 🏎️

4 Network Device (Infiniband or RoCE)



RDMA capable!

EXPLORER

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RDMA

Fast data transfer

Memory

🐢 OS

Memory

🐢 OS

Transporter

AI-generated image

RDMA

Fast data transfer

Memory

🐢 OS

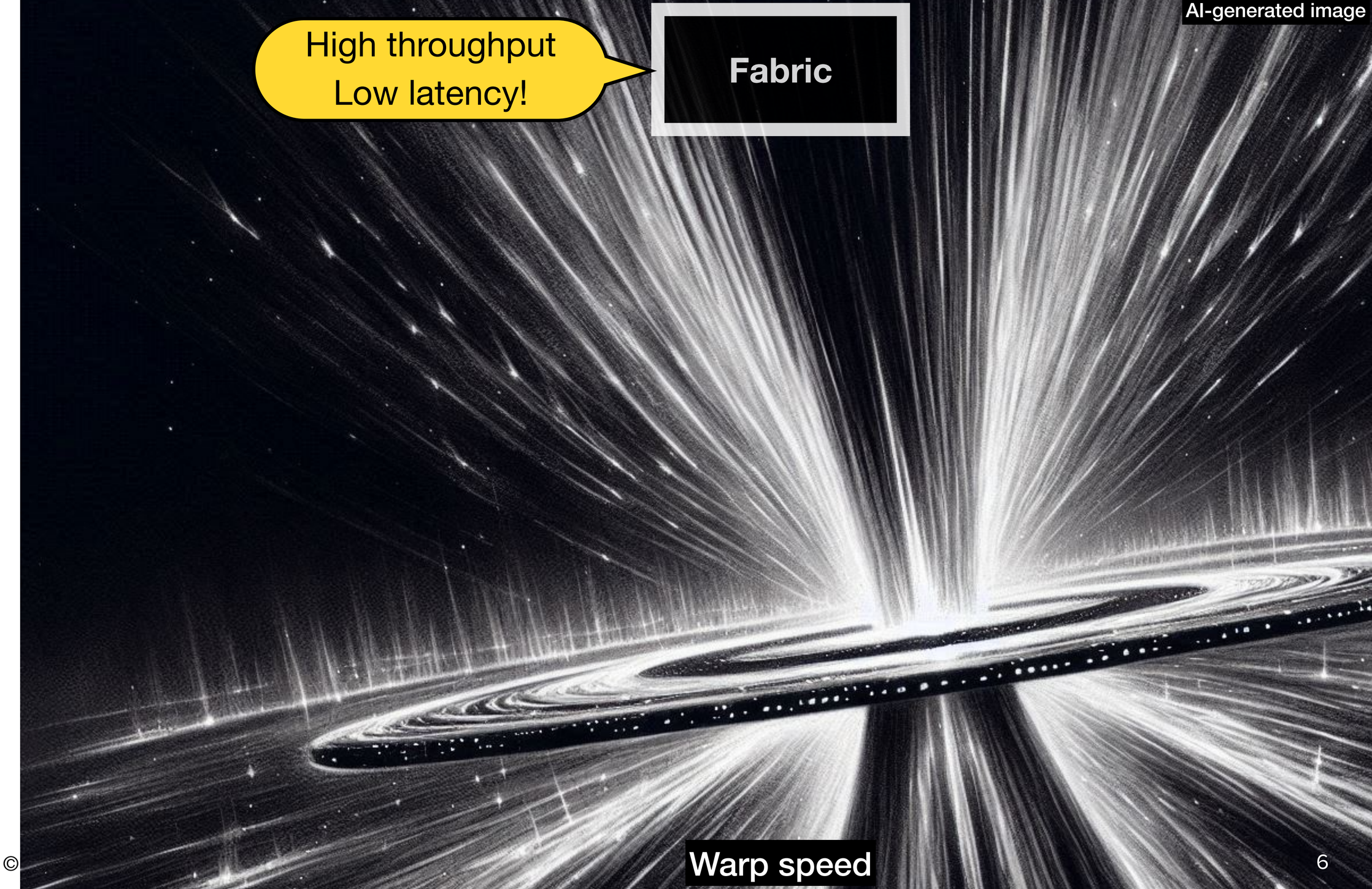
Kernel Bypass

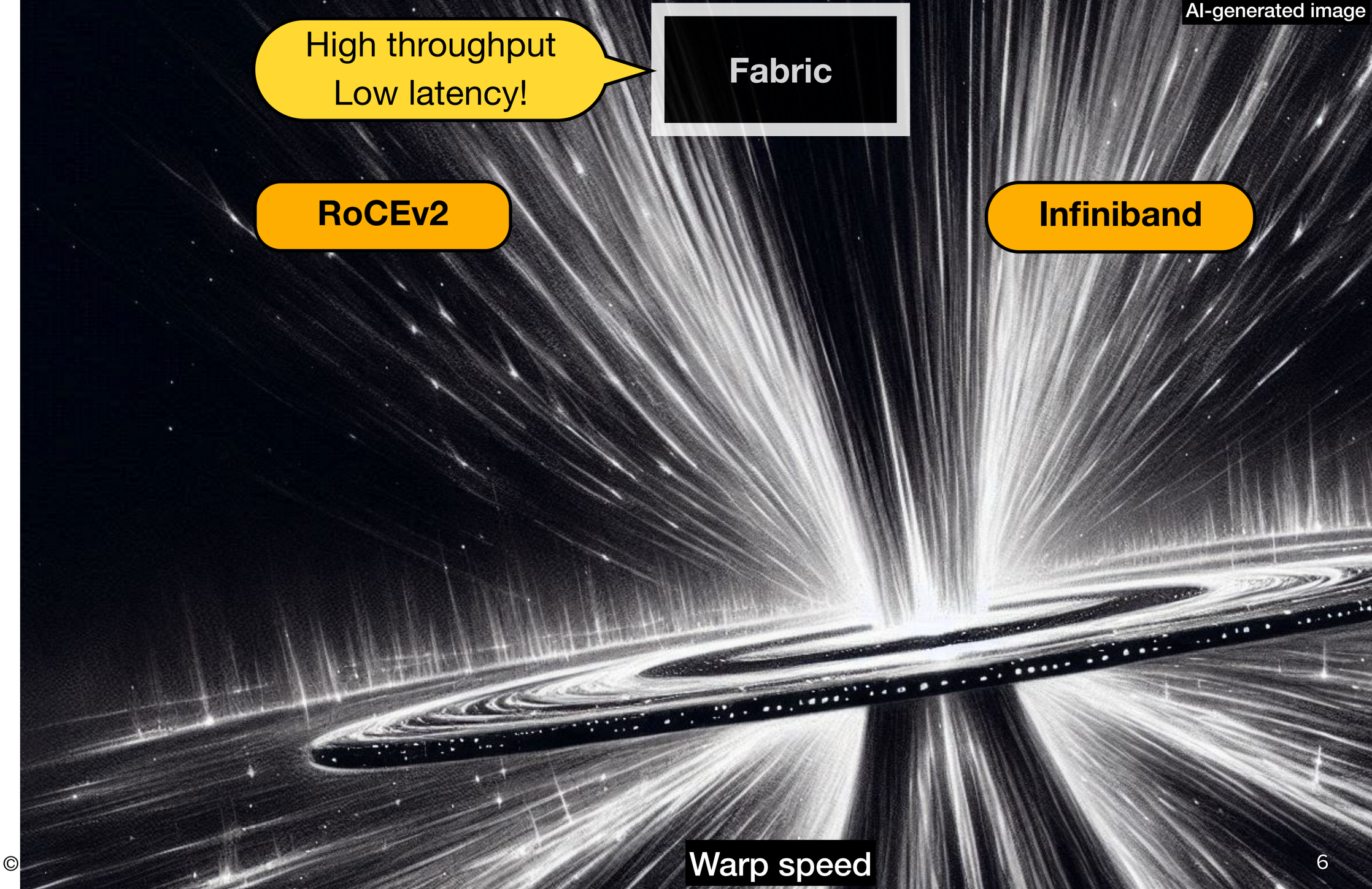
Memory

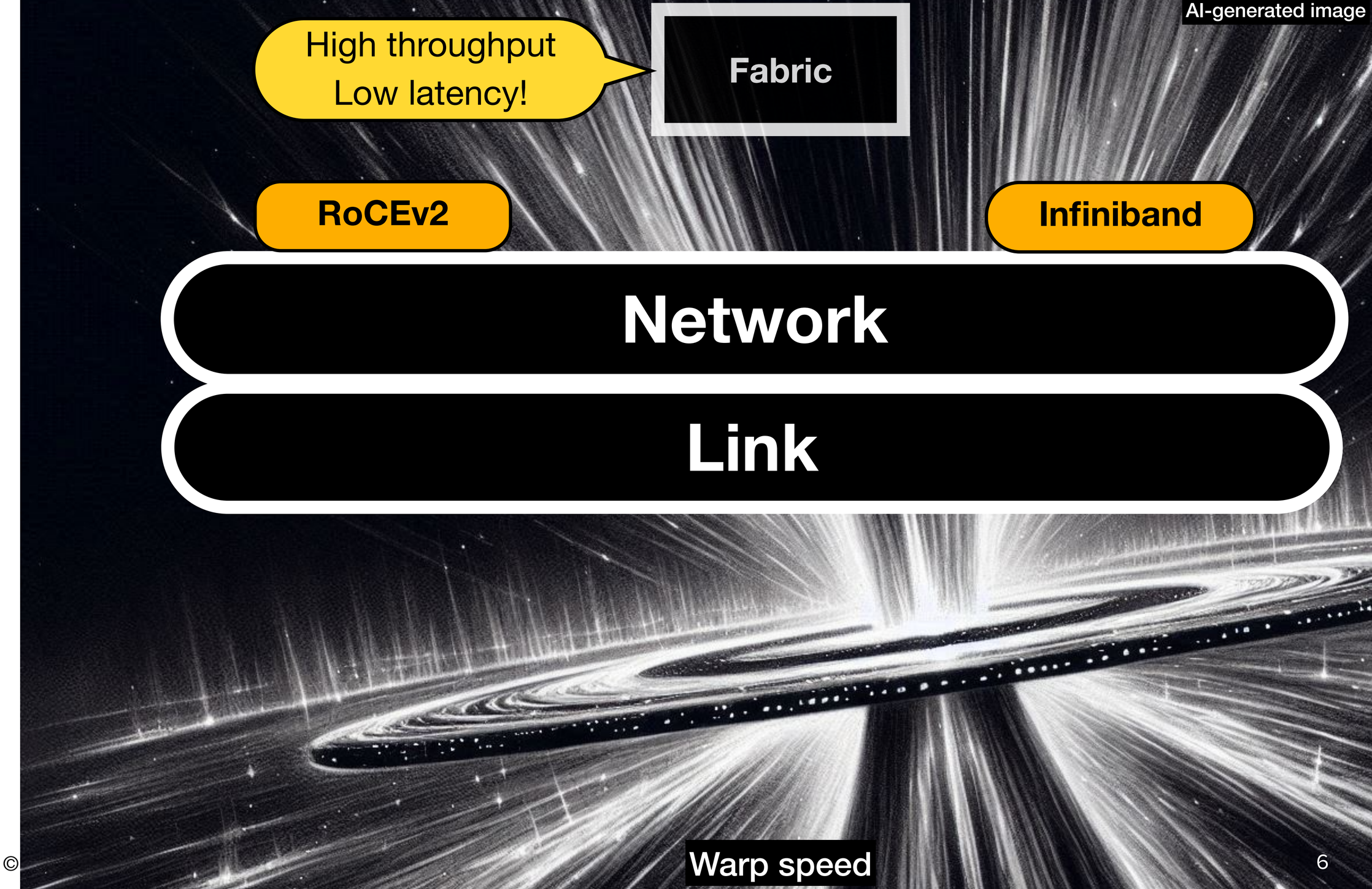
🐢 OS

Infiniband or RoCE

Transporter


High throughput
Low latency!
Fabric
AI-generated image
Warp speed


AI-generated image
High throughput
Low latency!
Fabric
RoCEv2
Infiniband
Warp speed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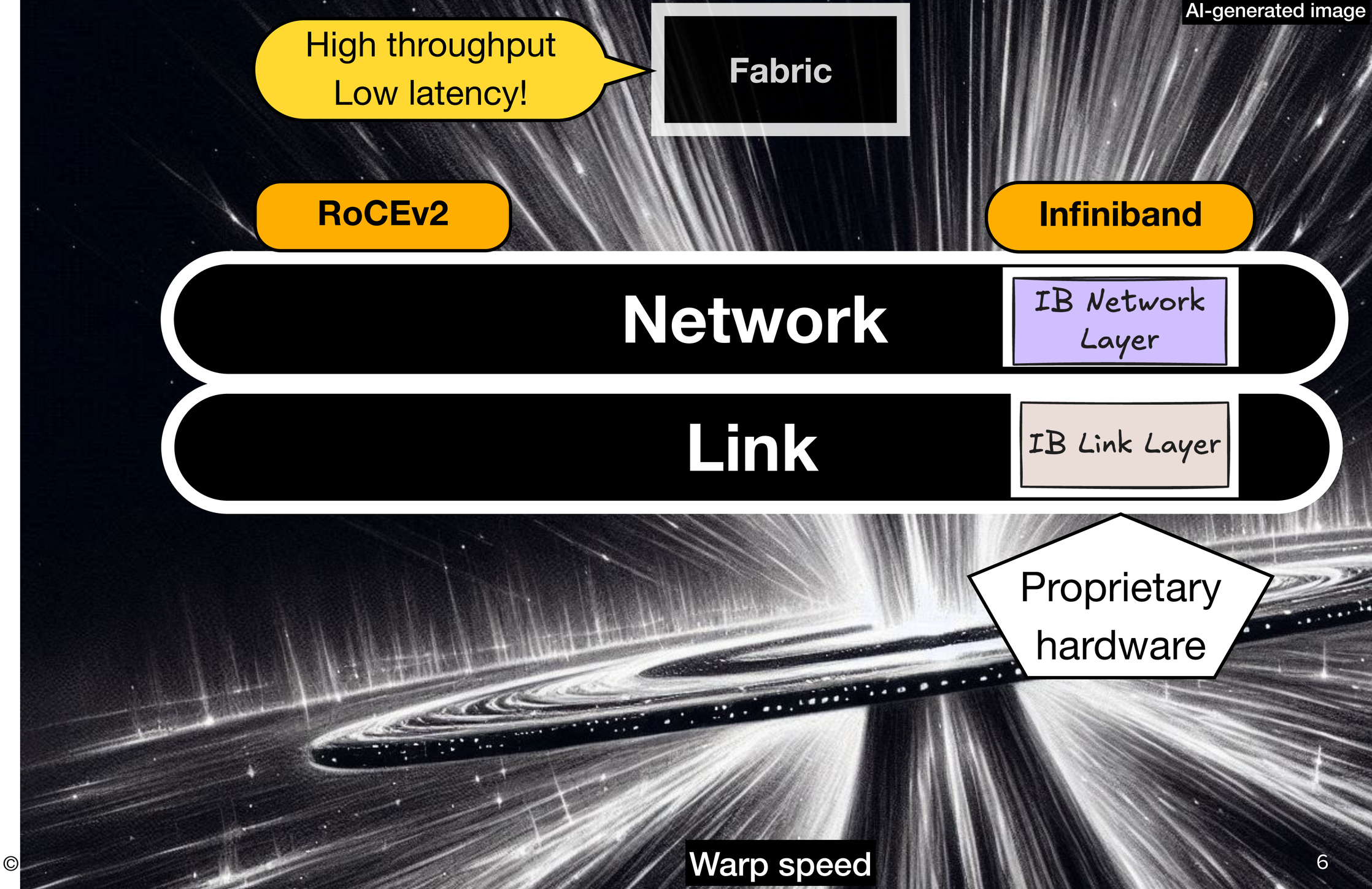
High throughput
Low latency!
Fabric
RoCEv2
Infiniband
Network
Link
Warp speed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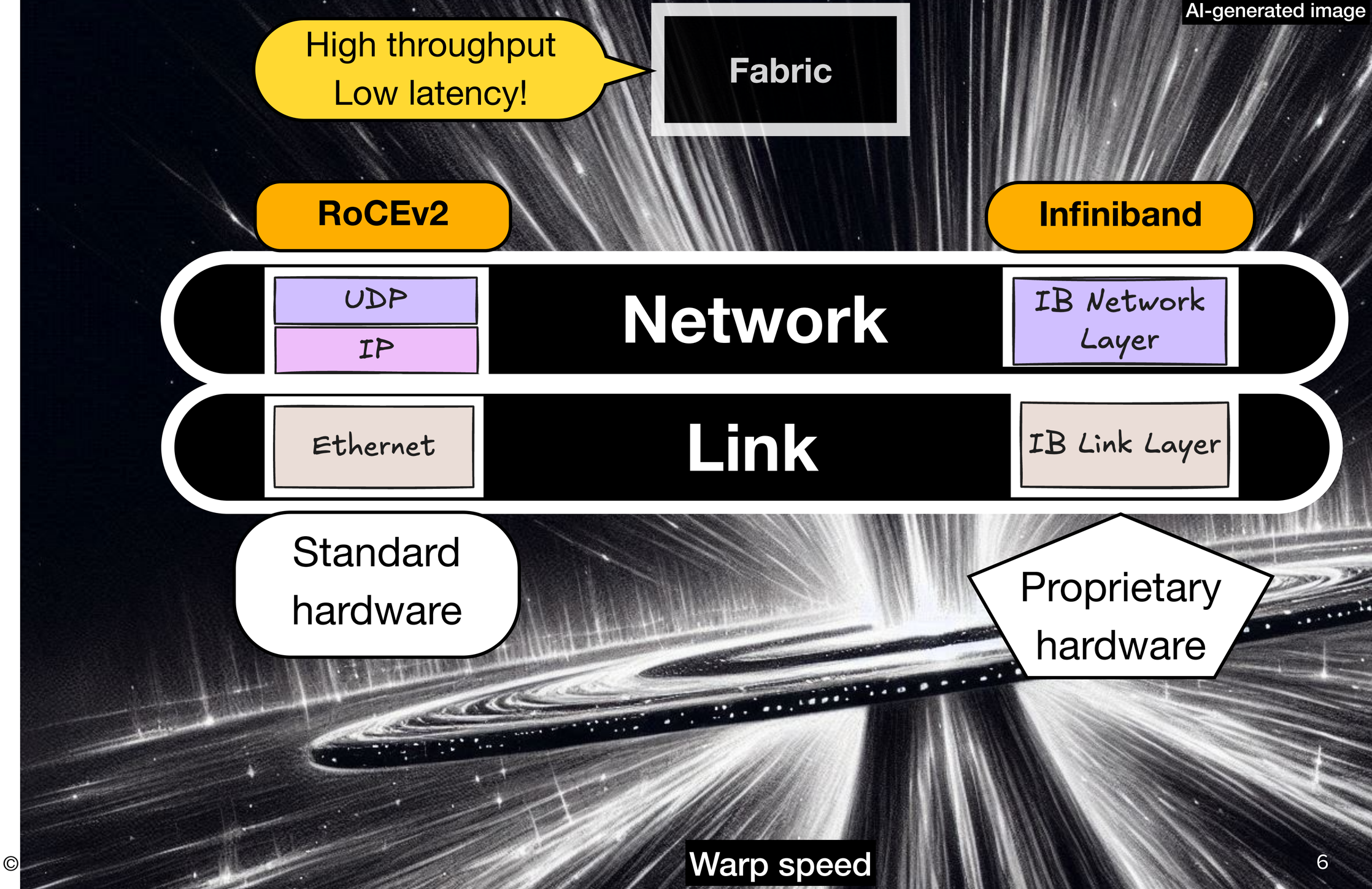
High throughput
Low latency!
Fabric
RoCEv2
Infiniband
Network
IB Network Layer
Link
IB Link Layer
Proprietary hardware
Warp speed


AI-generated image
High throughput
Low latency!
Fabric
RoCEv2
Infiniband
UDP
IP
Network
IB Network Layer
Ethernet
Link
IB Link Layer
Standard hardware
Proprietary hardware
Warp speed

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Traditional networks

🏎️ AI networks

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AI networks

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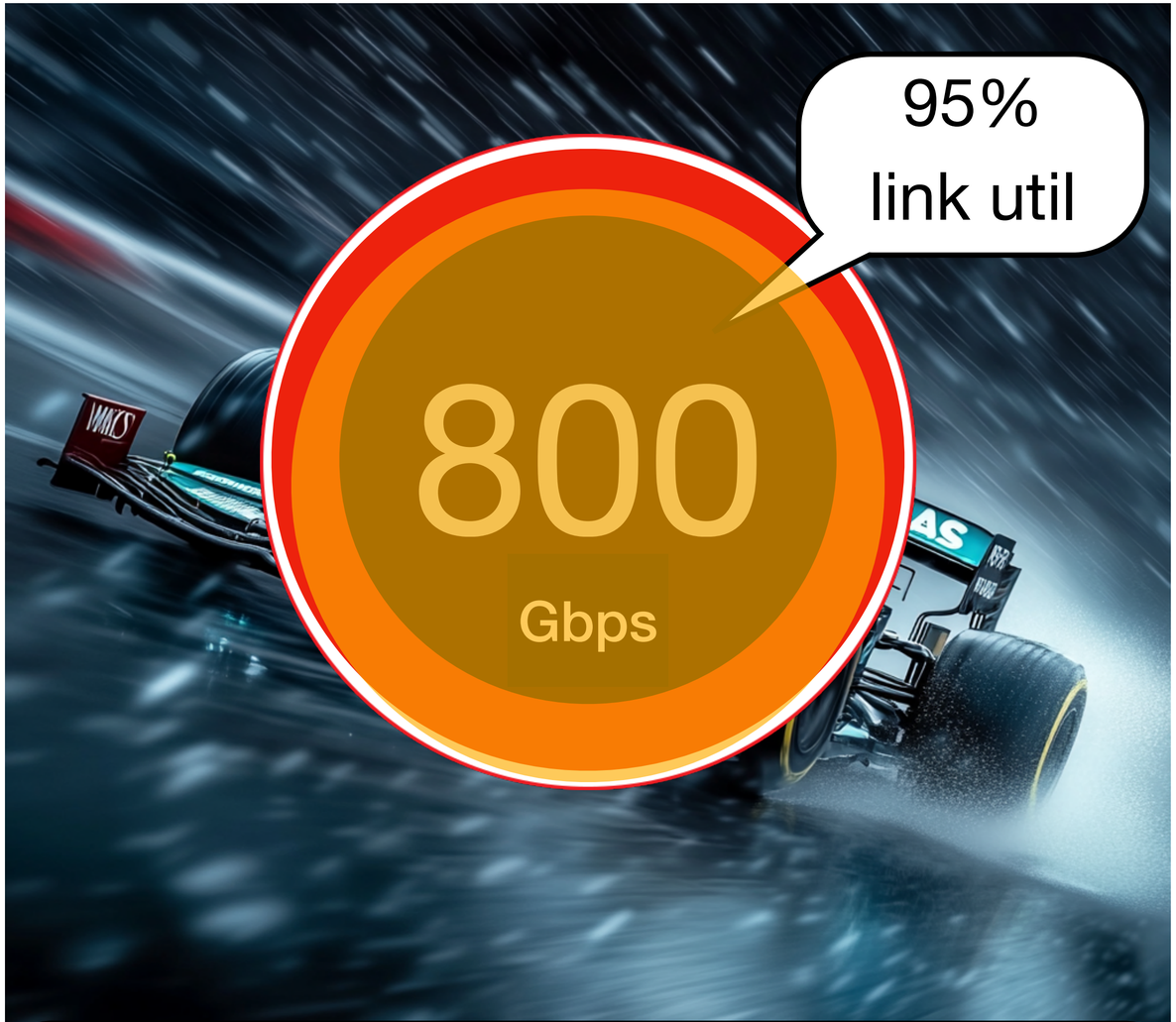
Traditional networks



AI networks

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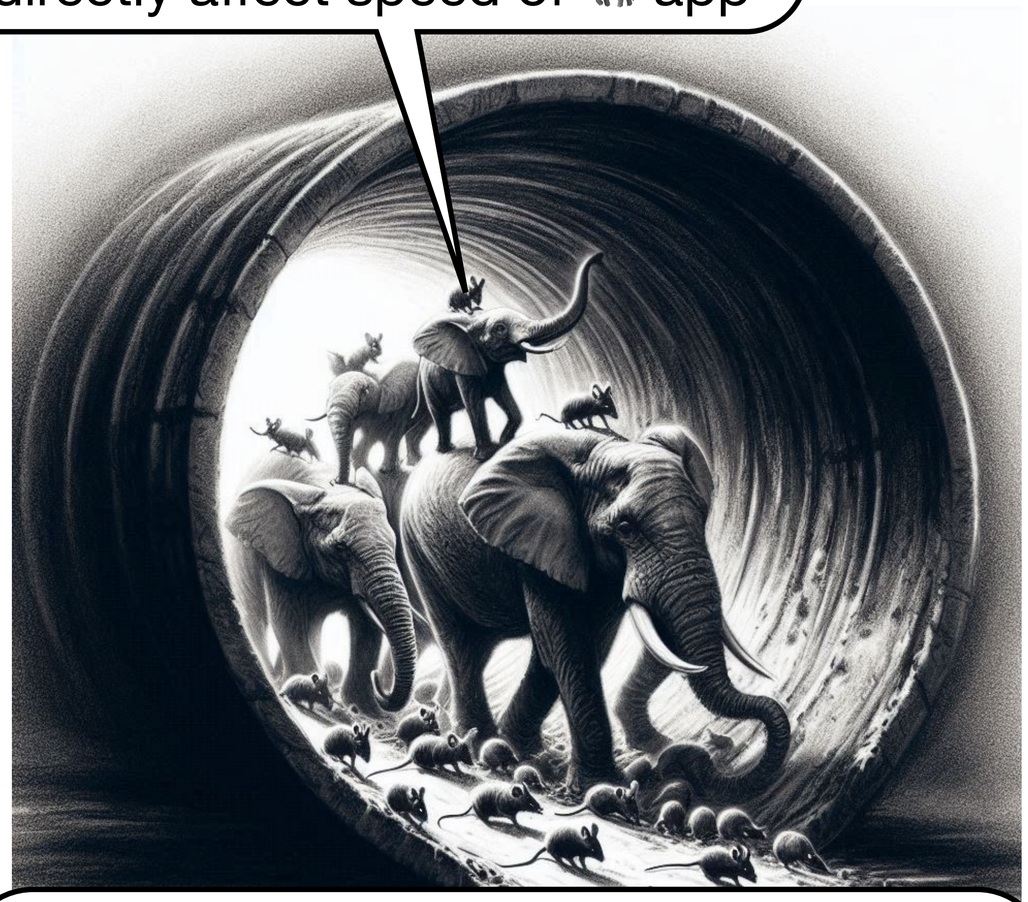
Speed of 🐭 app doesn't directly affect speed of 🐘 app



Traditional networks

🏎️ AI networks

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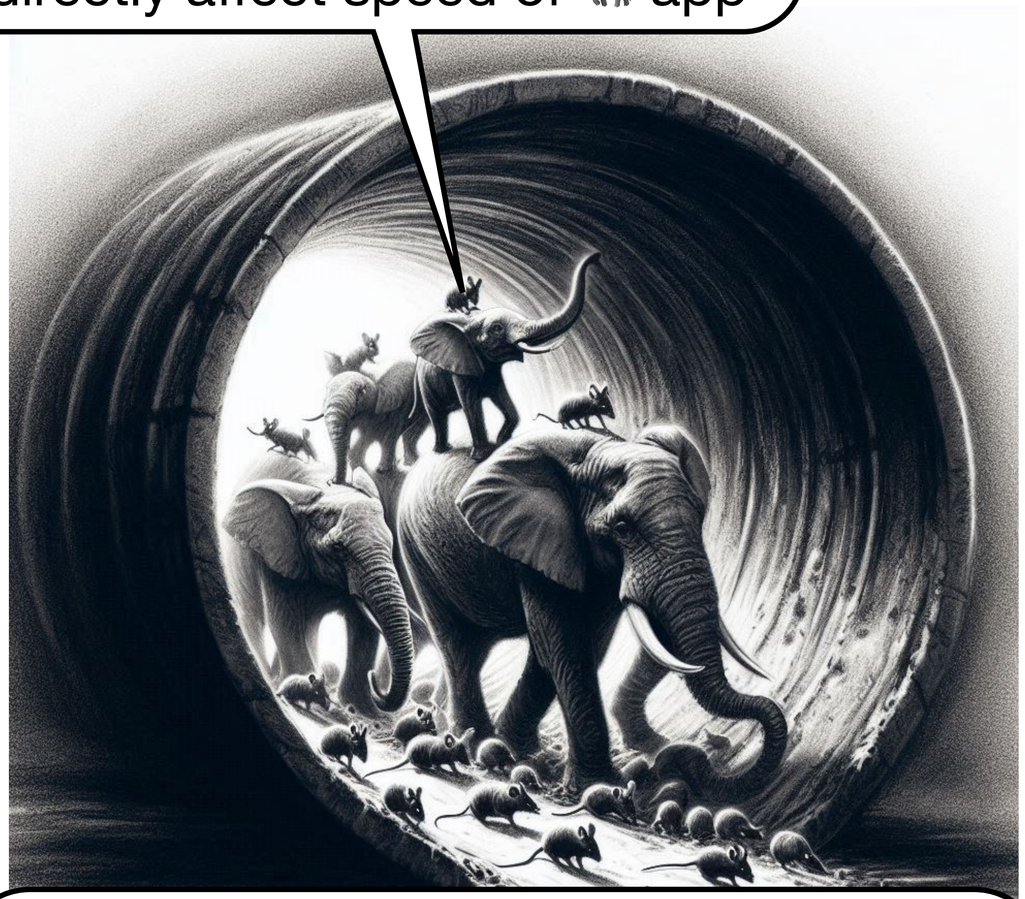
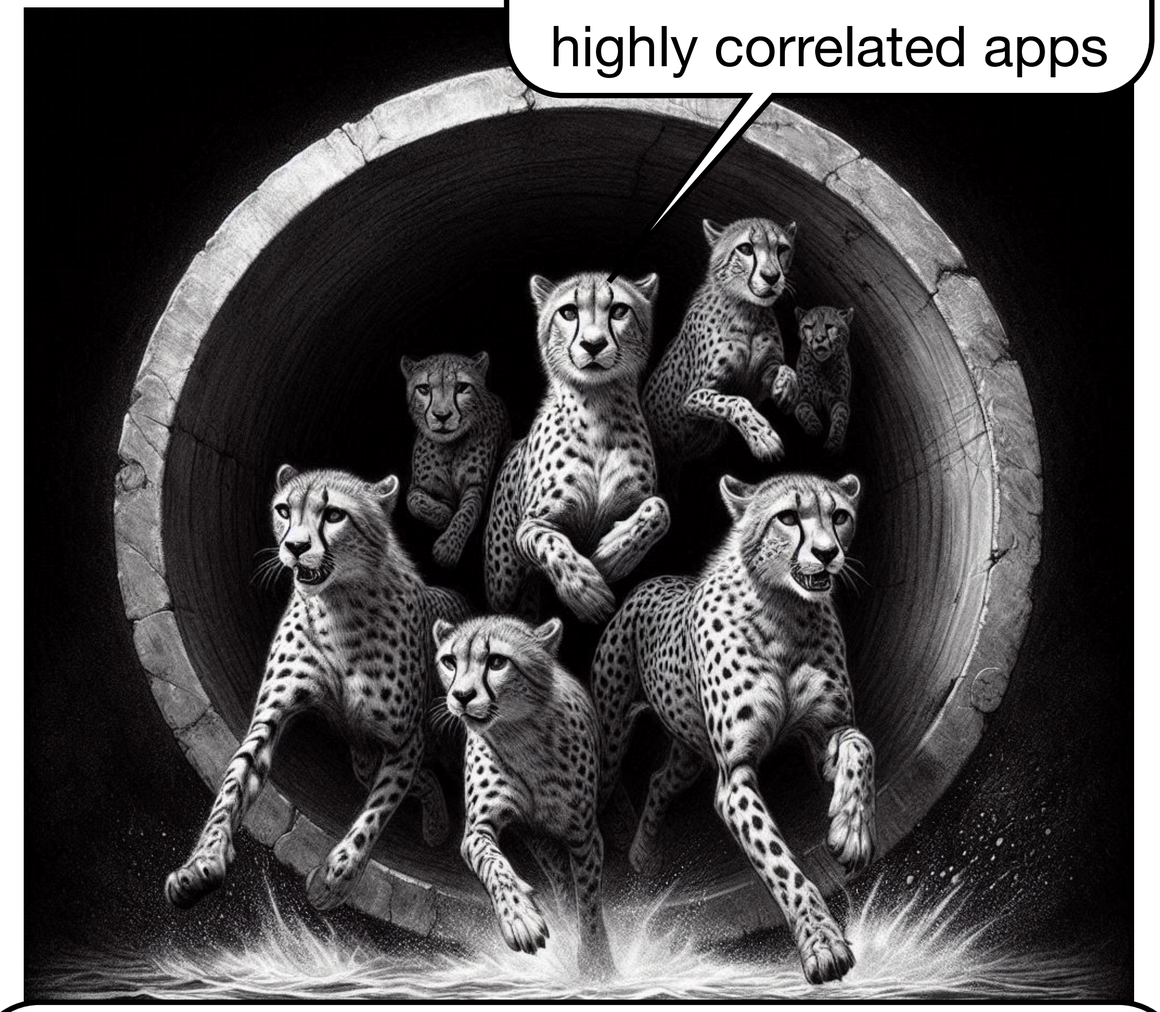
Speed of 🐭 app doesn’t directly affect speed of 🦏 app



Traditional networks

Similar highly correlated apps



🏎️ AI networks

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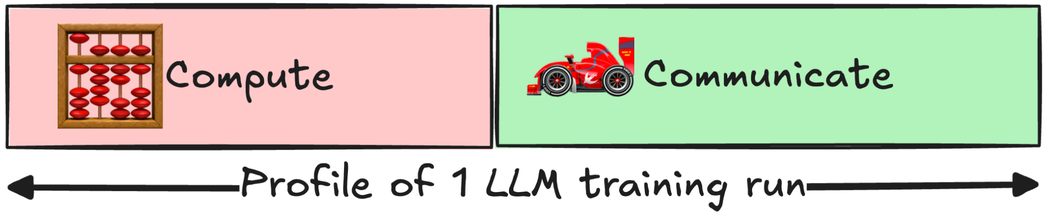
Profile of an LLM training job



Source: Nvidia

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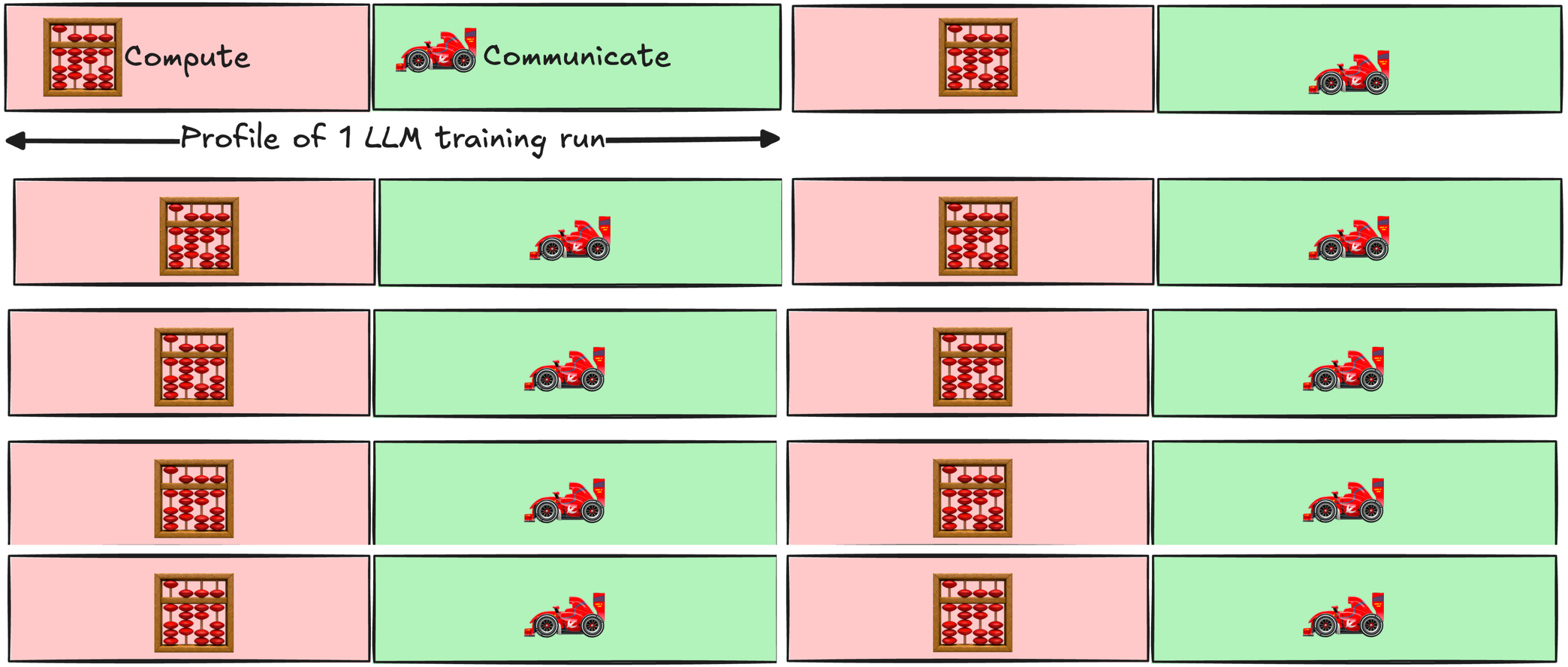
Profile of an LLM training job



Source: Nvidia

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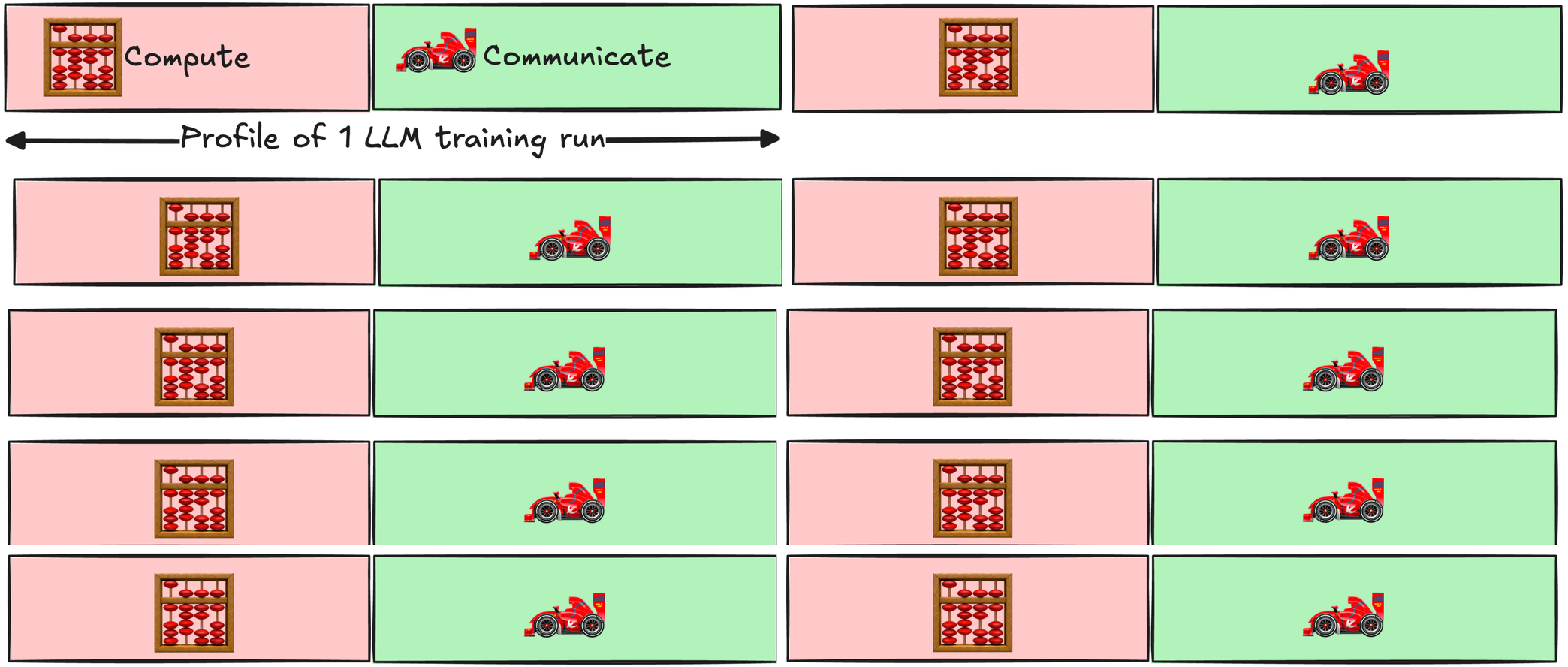

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> 30 % of total job completion time is spent on networking!

Source: AMD

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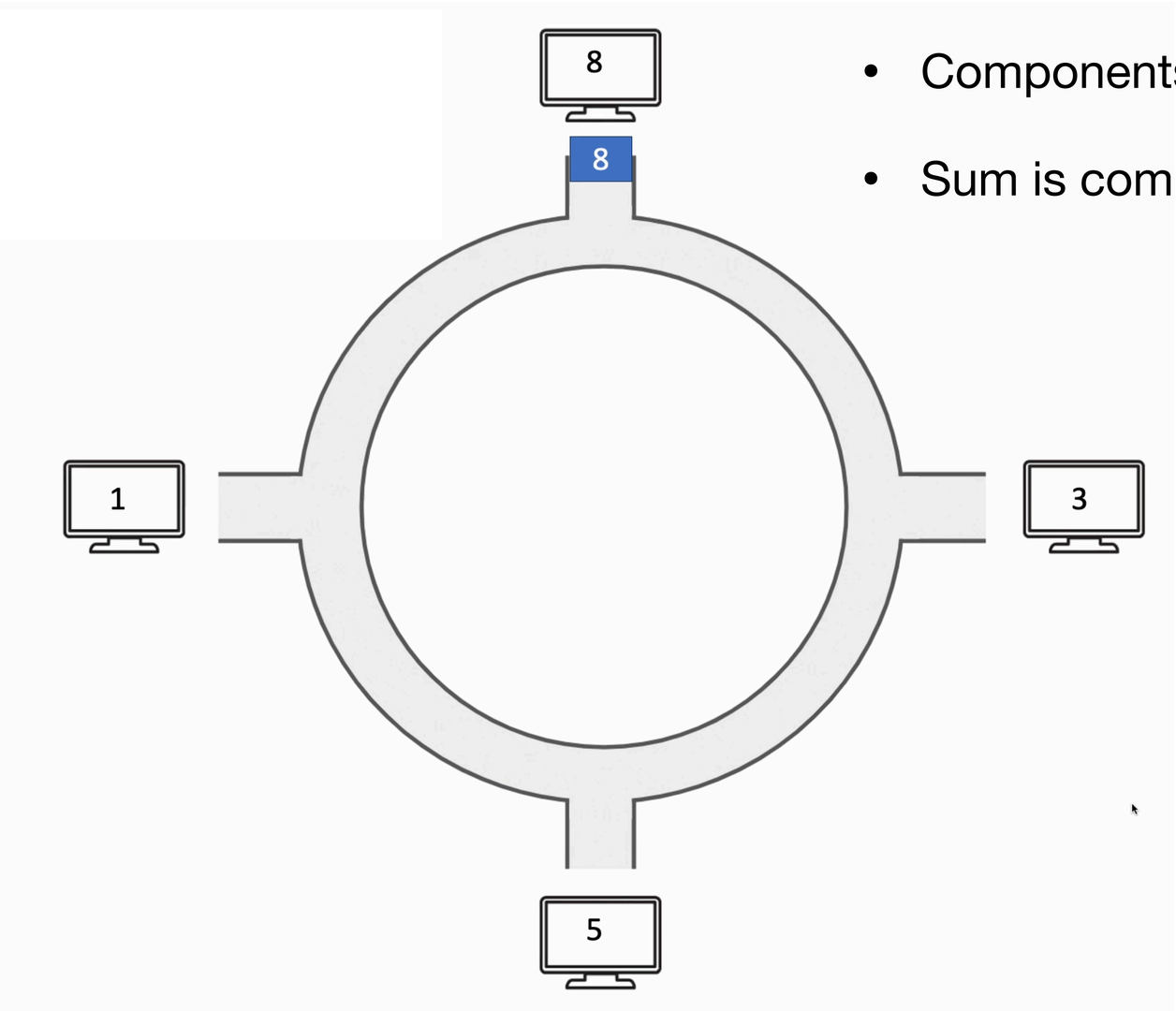
All-reduce (NCCL ring implementation)



- Components of the sum get passed around
- Sum is computed then passed around

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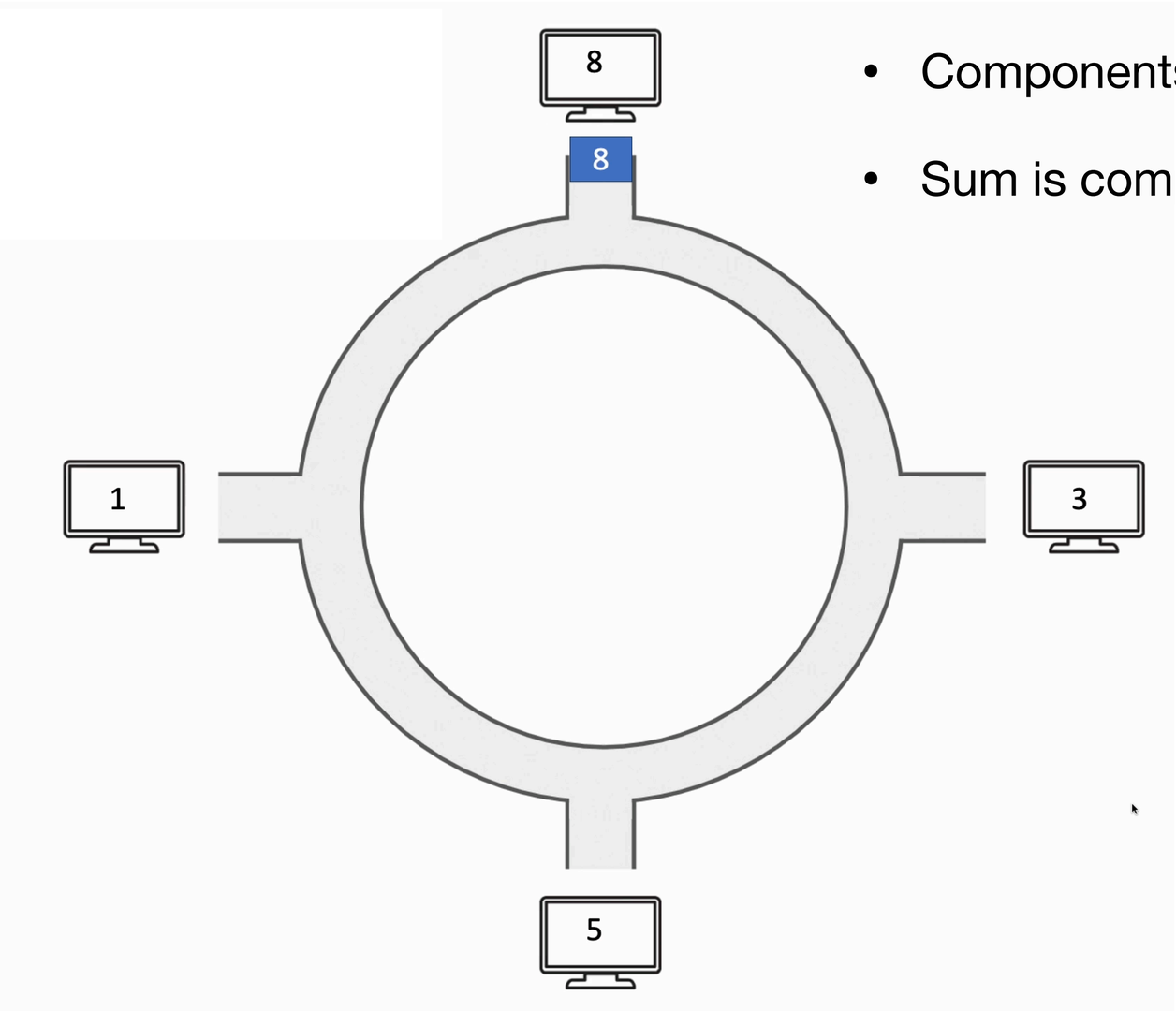
All-reduce (NCCL ring implementation)



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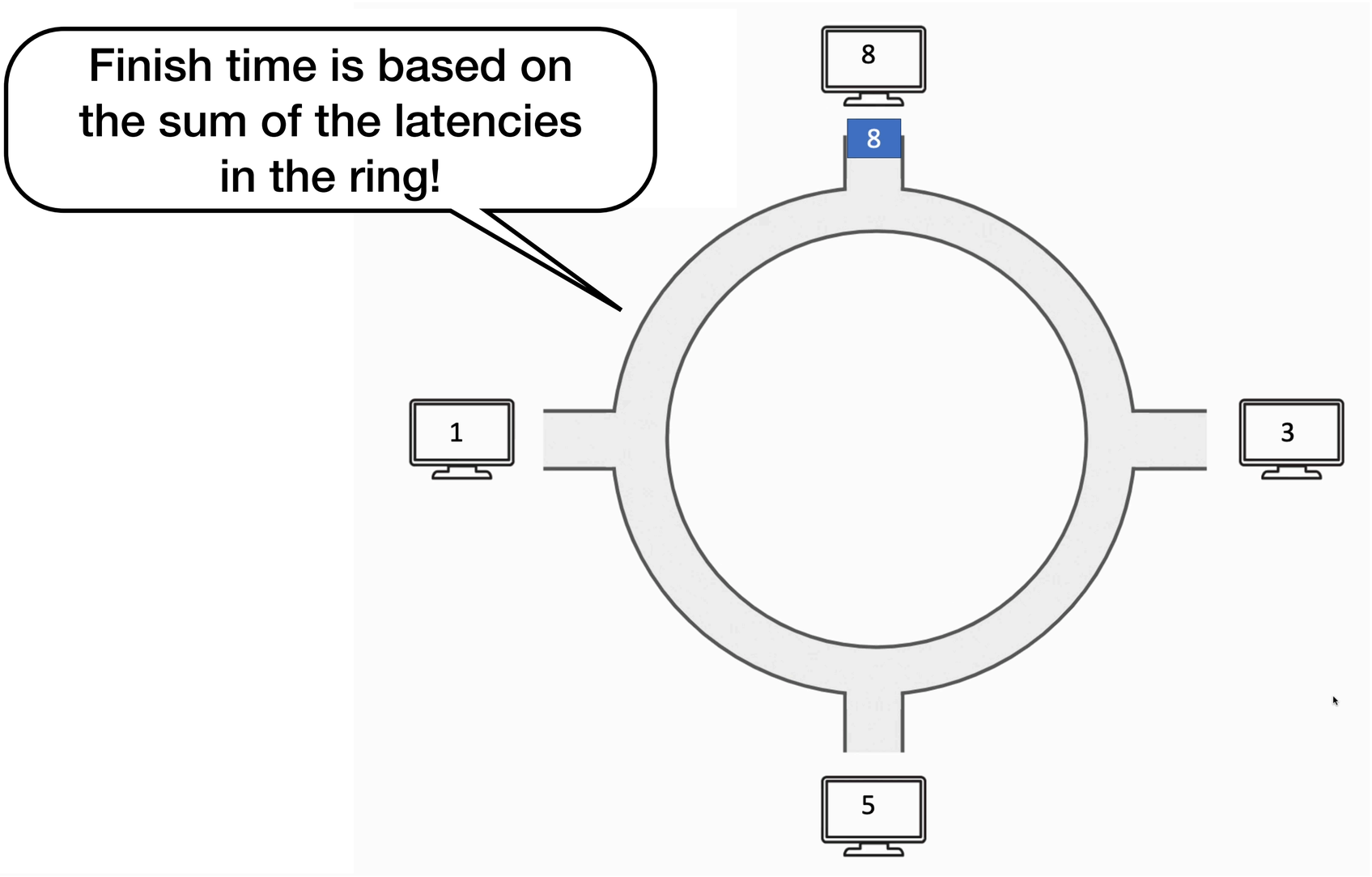

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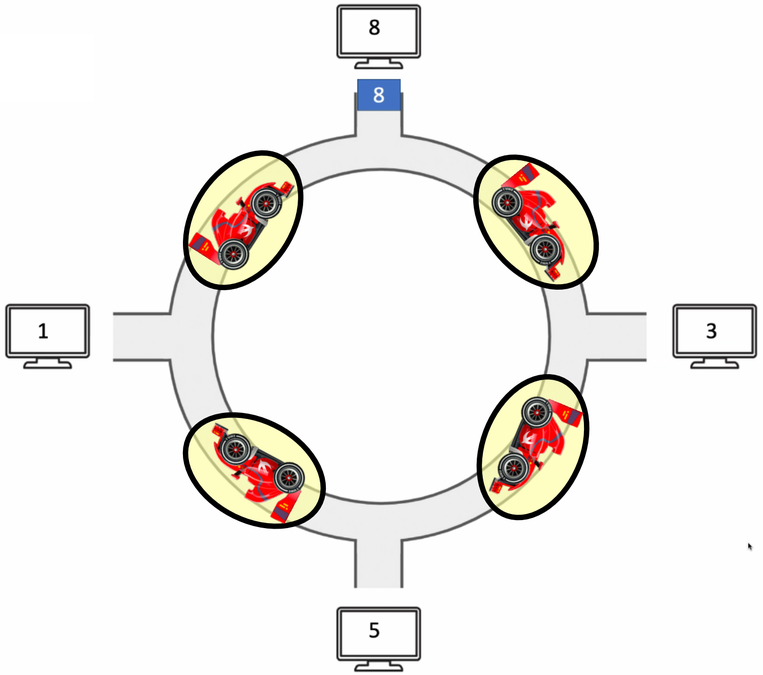
Communicate



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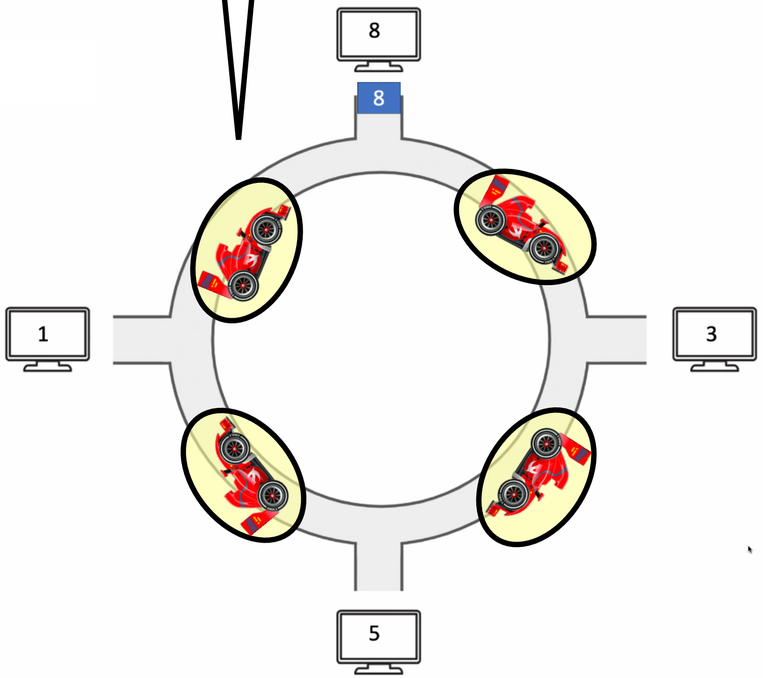
Communicate

GPU's won't proceed to next step until all synchronize partial results.



At a pit stop, pit crew is not done until all teammates are done.

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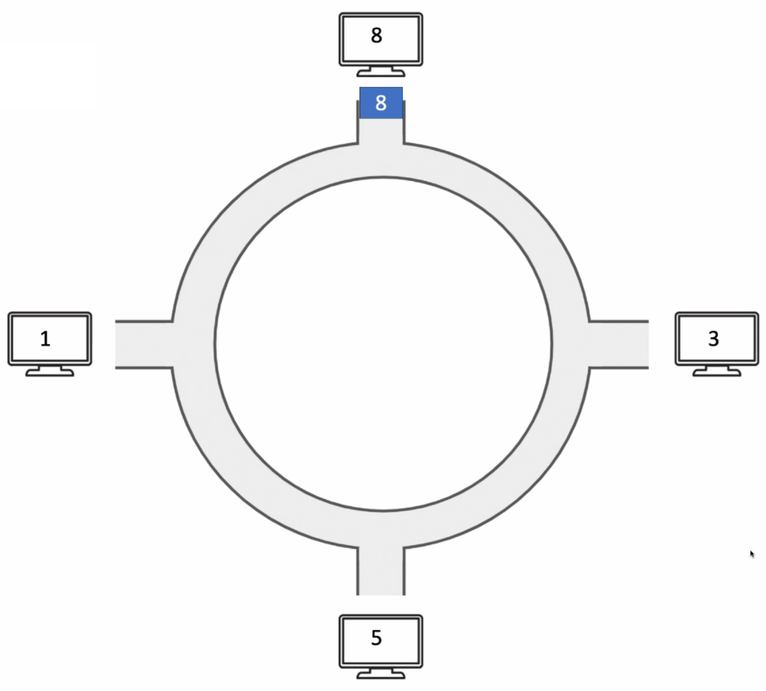

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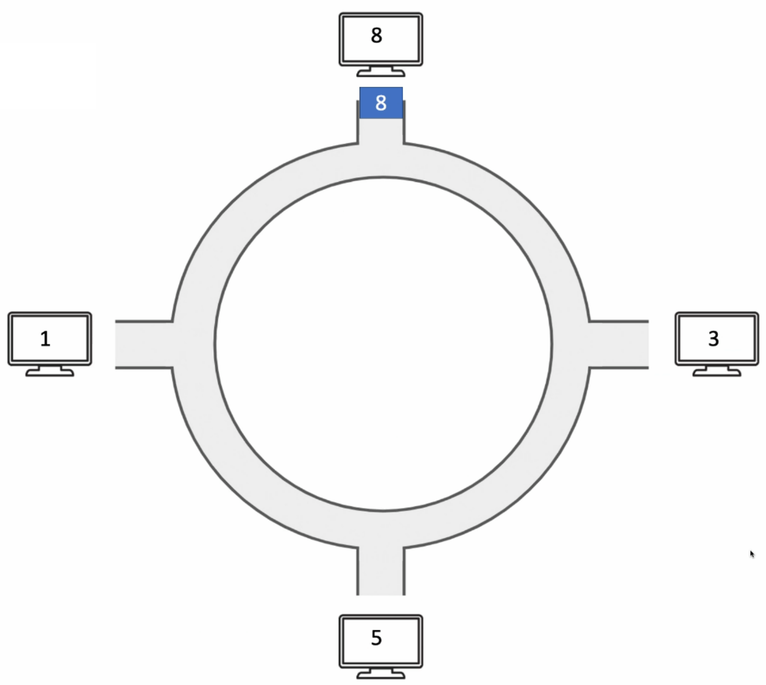

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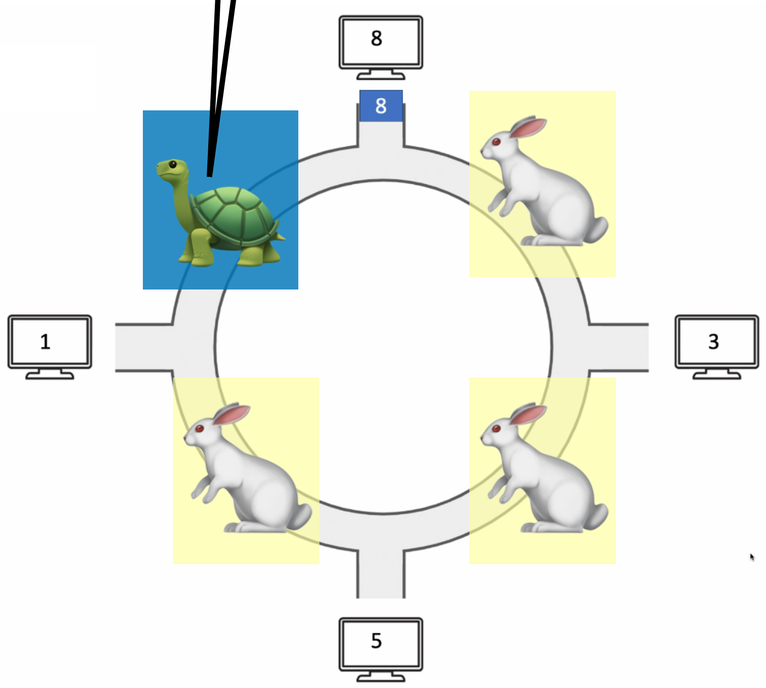
Slowest flow (or node) determines throughput.



Slowest determines speed.

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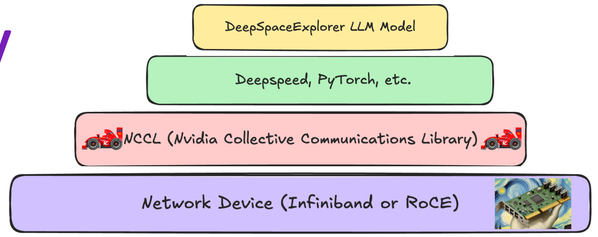
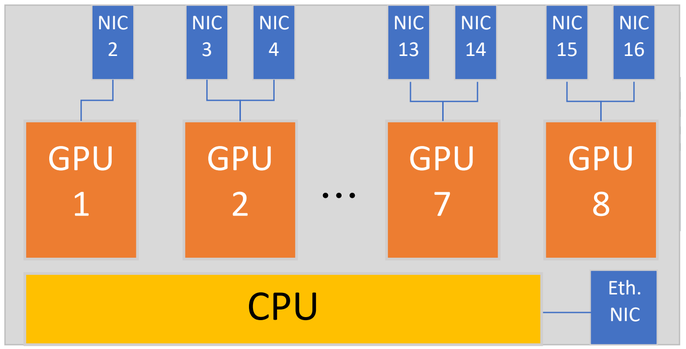
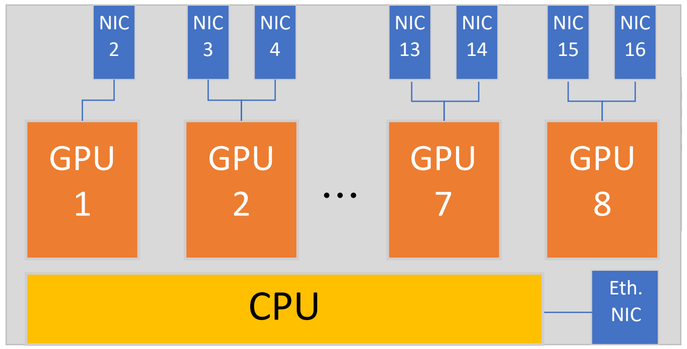
Under the hood: NCCL or other communication library







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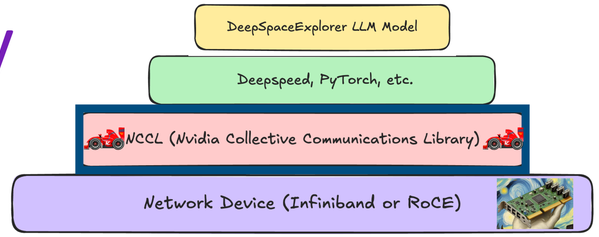
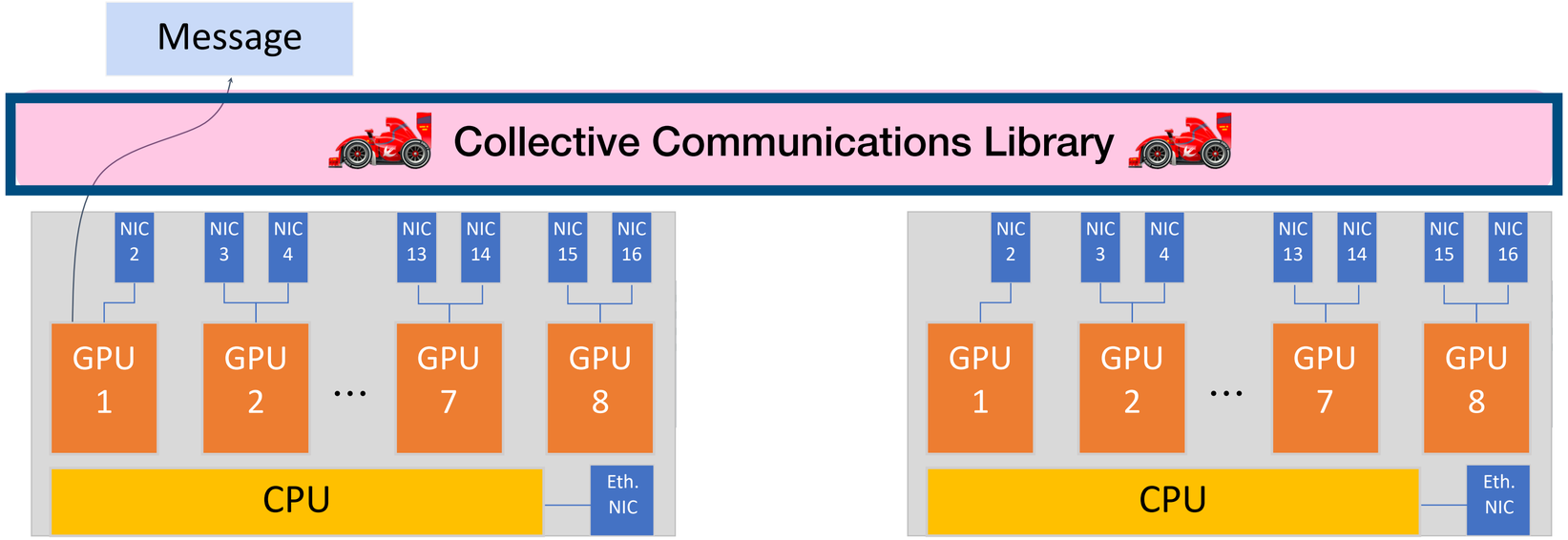
Under the hood: NCCL or other communication library





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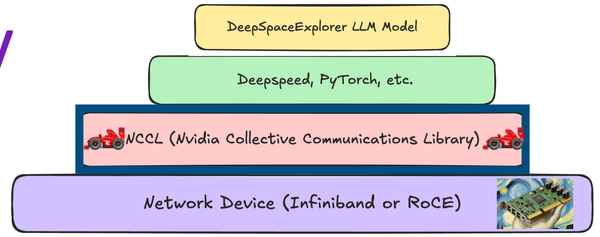

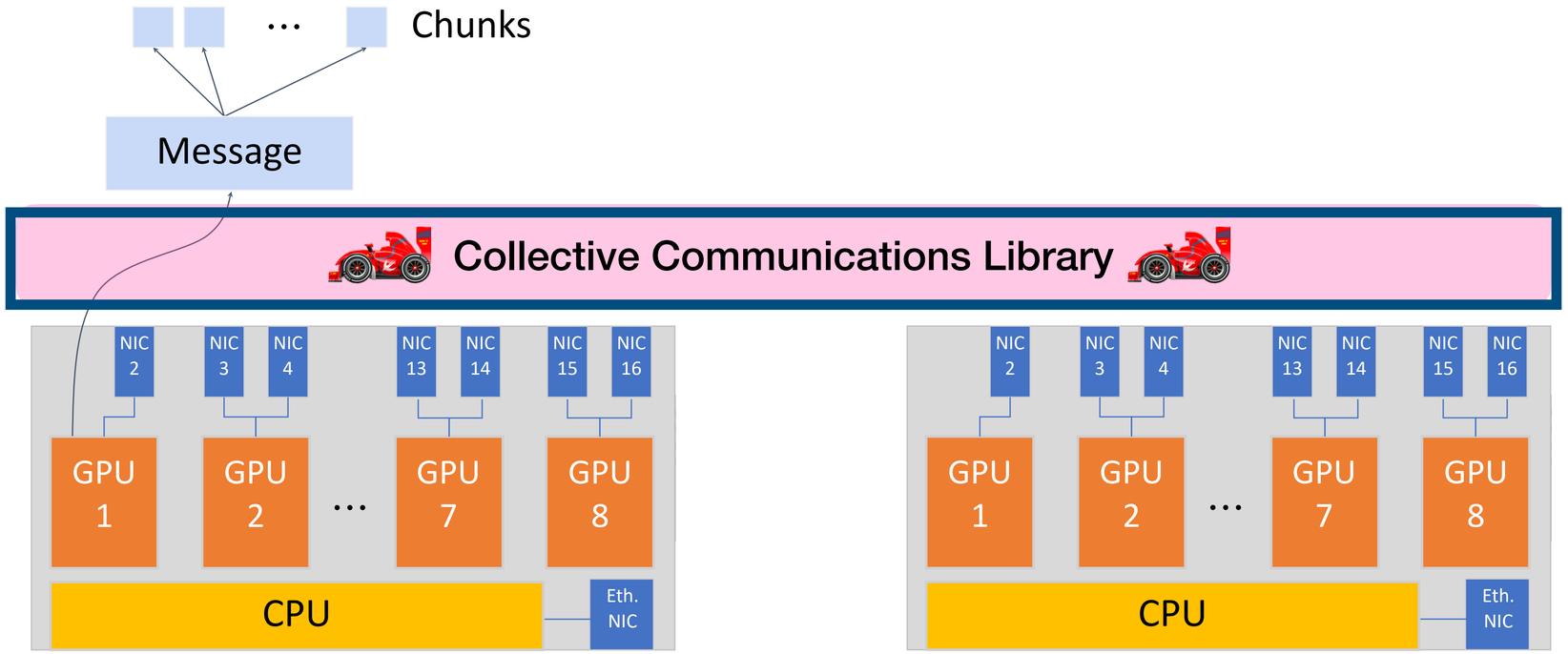

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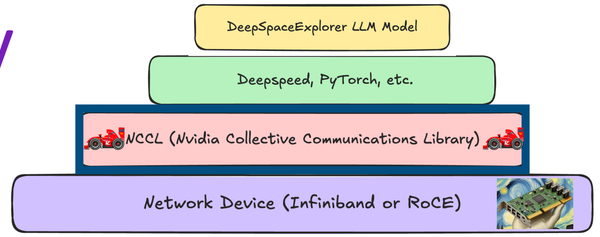

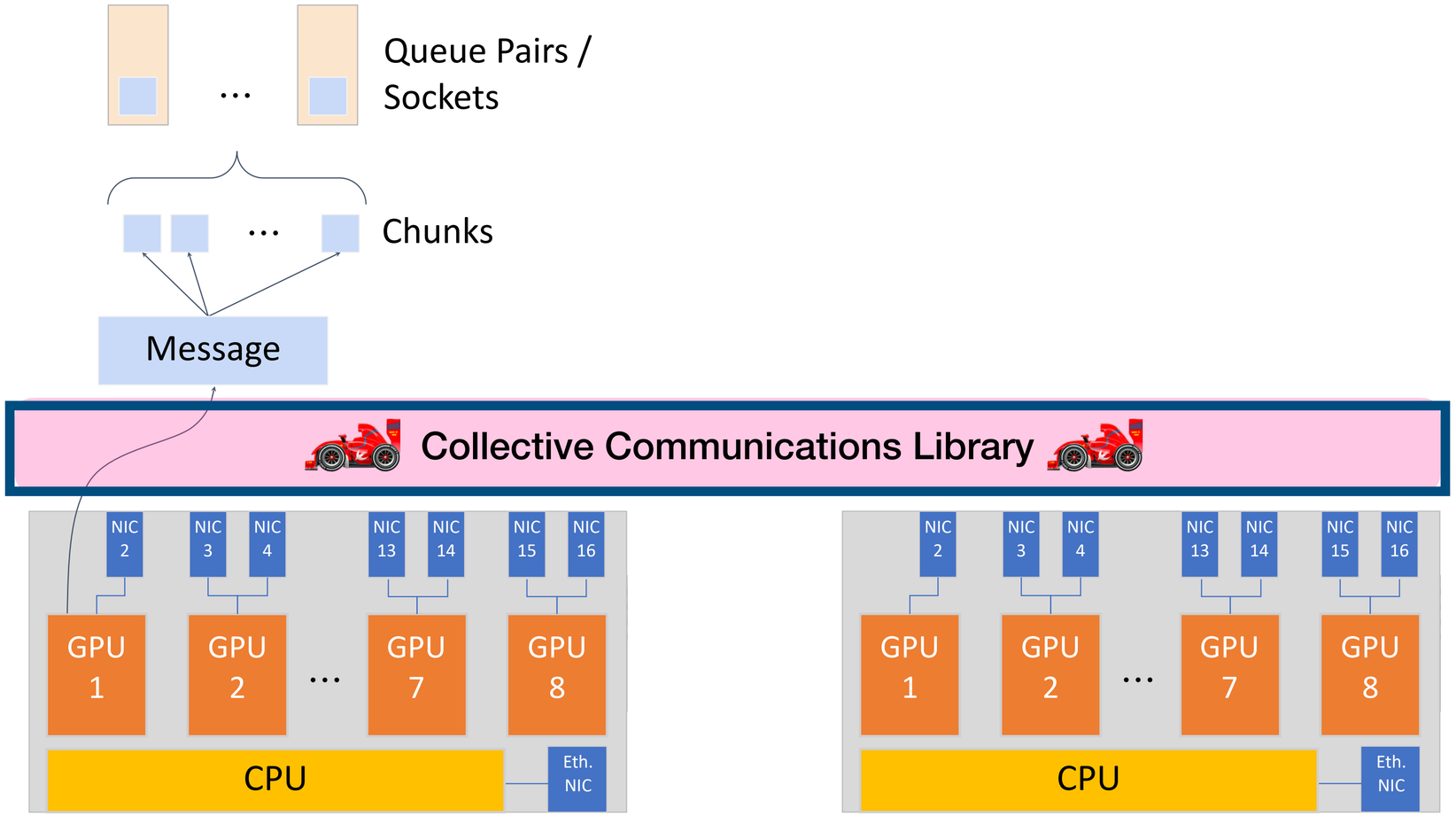

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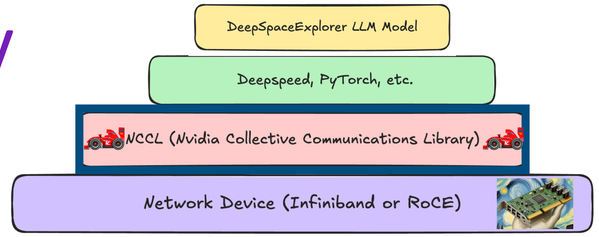

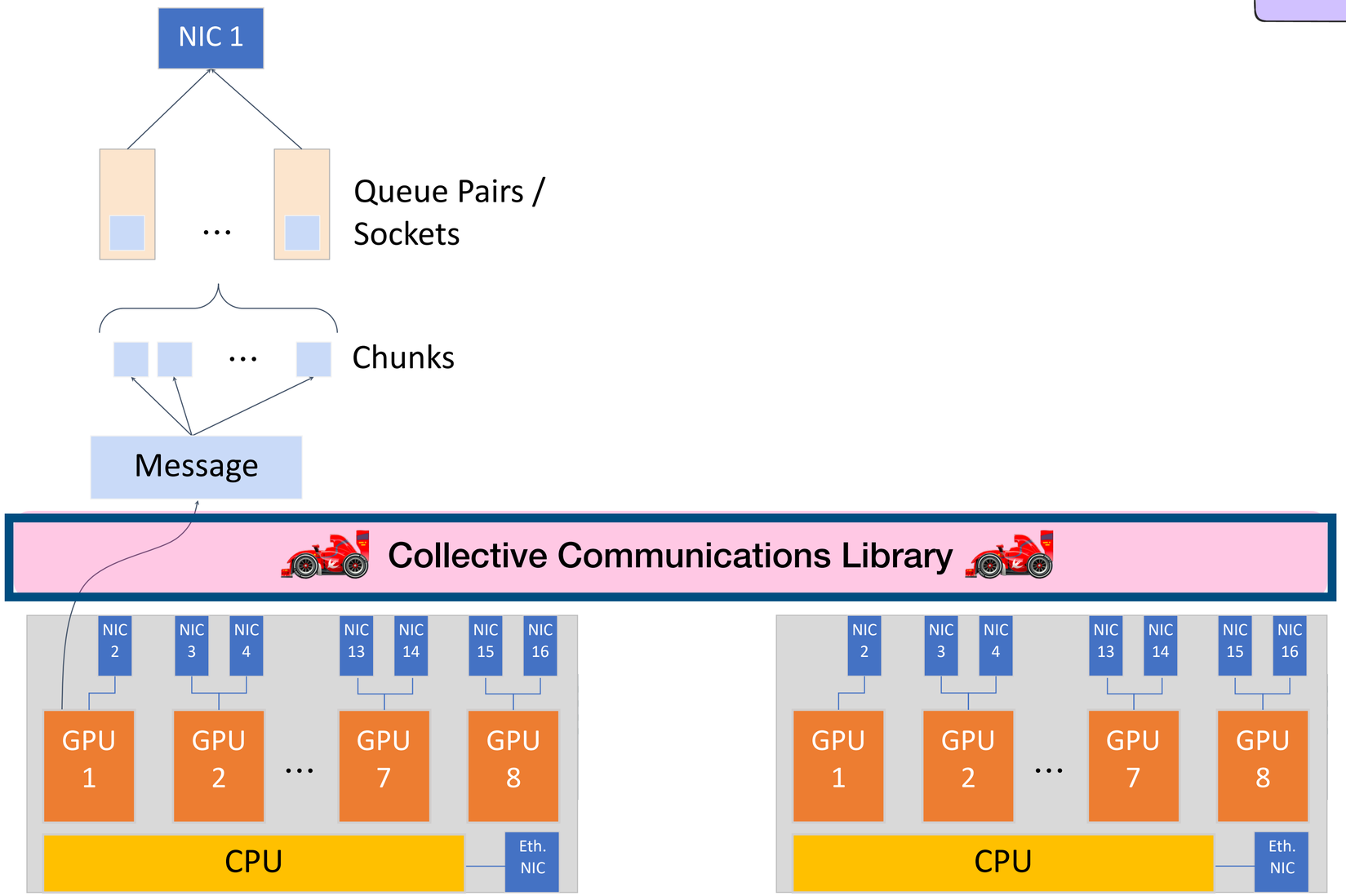

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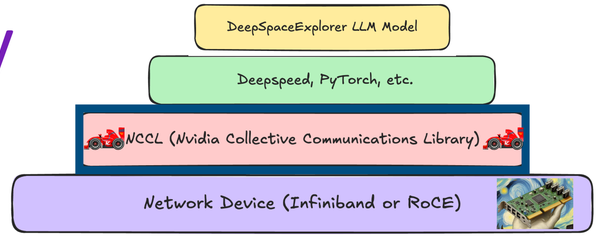

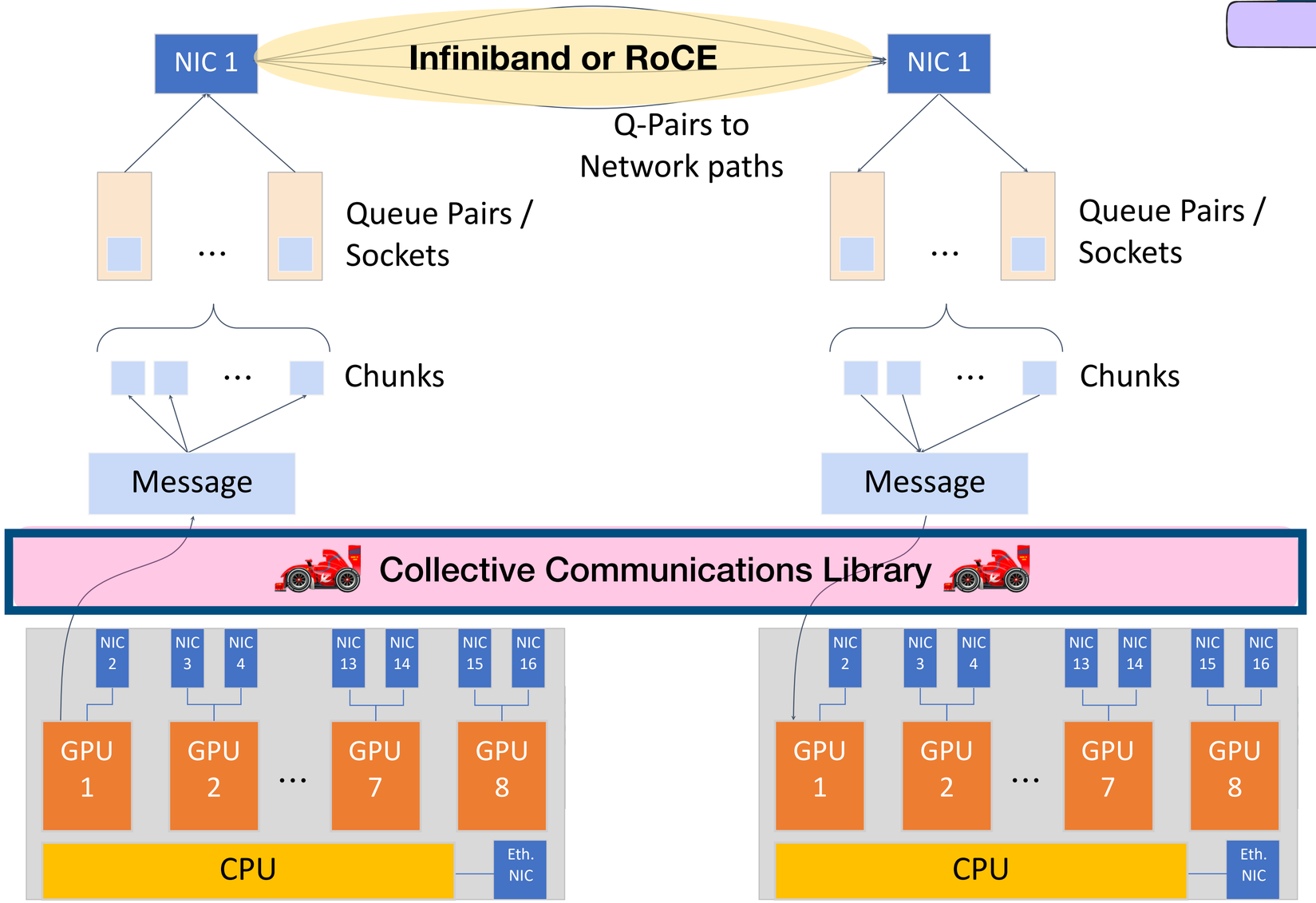

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The Interconnection Fabric: A Fat-tree Network (or Rail-Optimized Topology)

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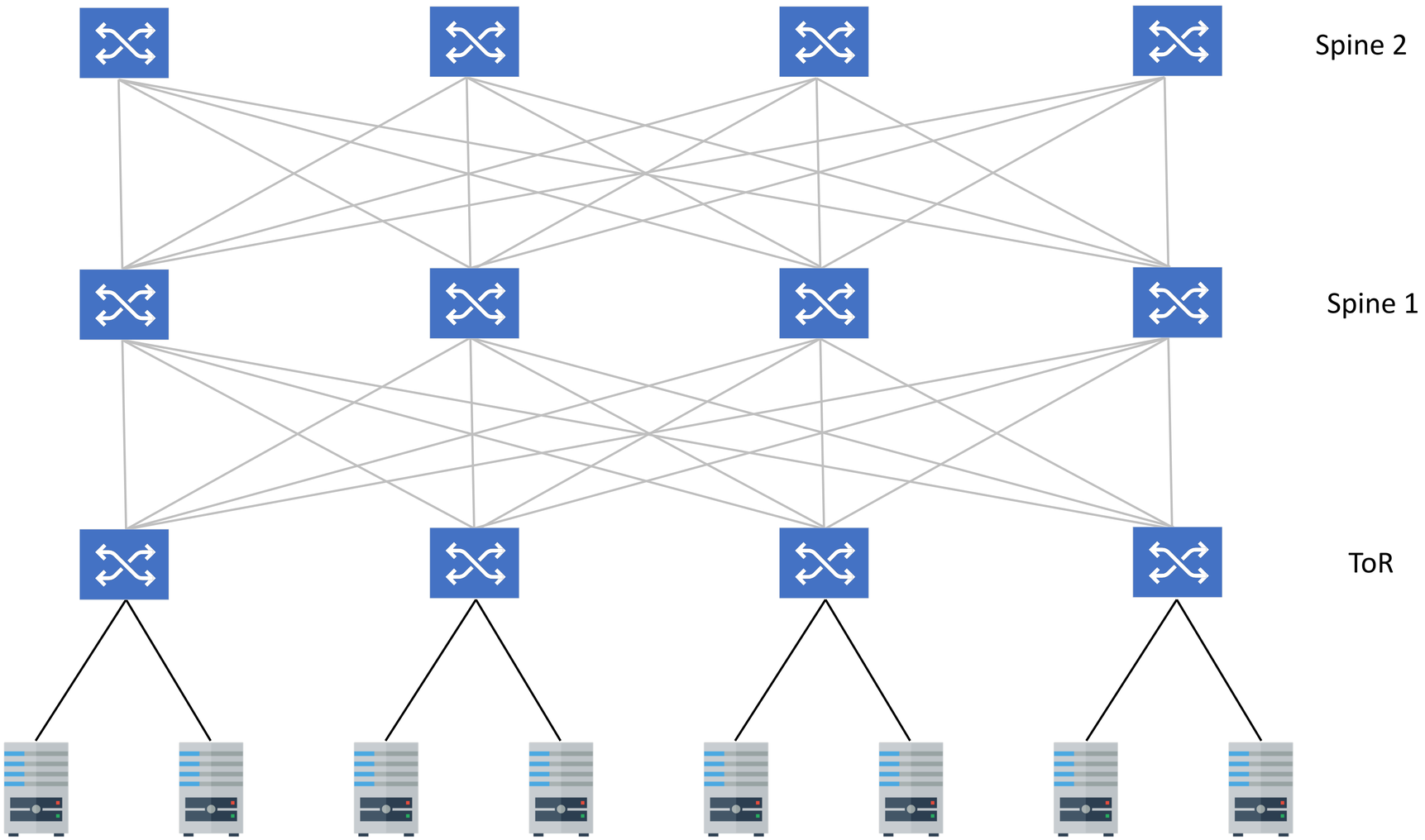
The Interconnection Fabric: A Fat-tree Network (or Rail-Optimized Topology)



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3. Challenges in AI networks
4. Key Takeaways

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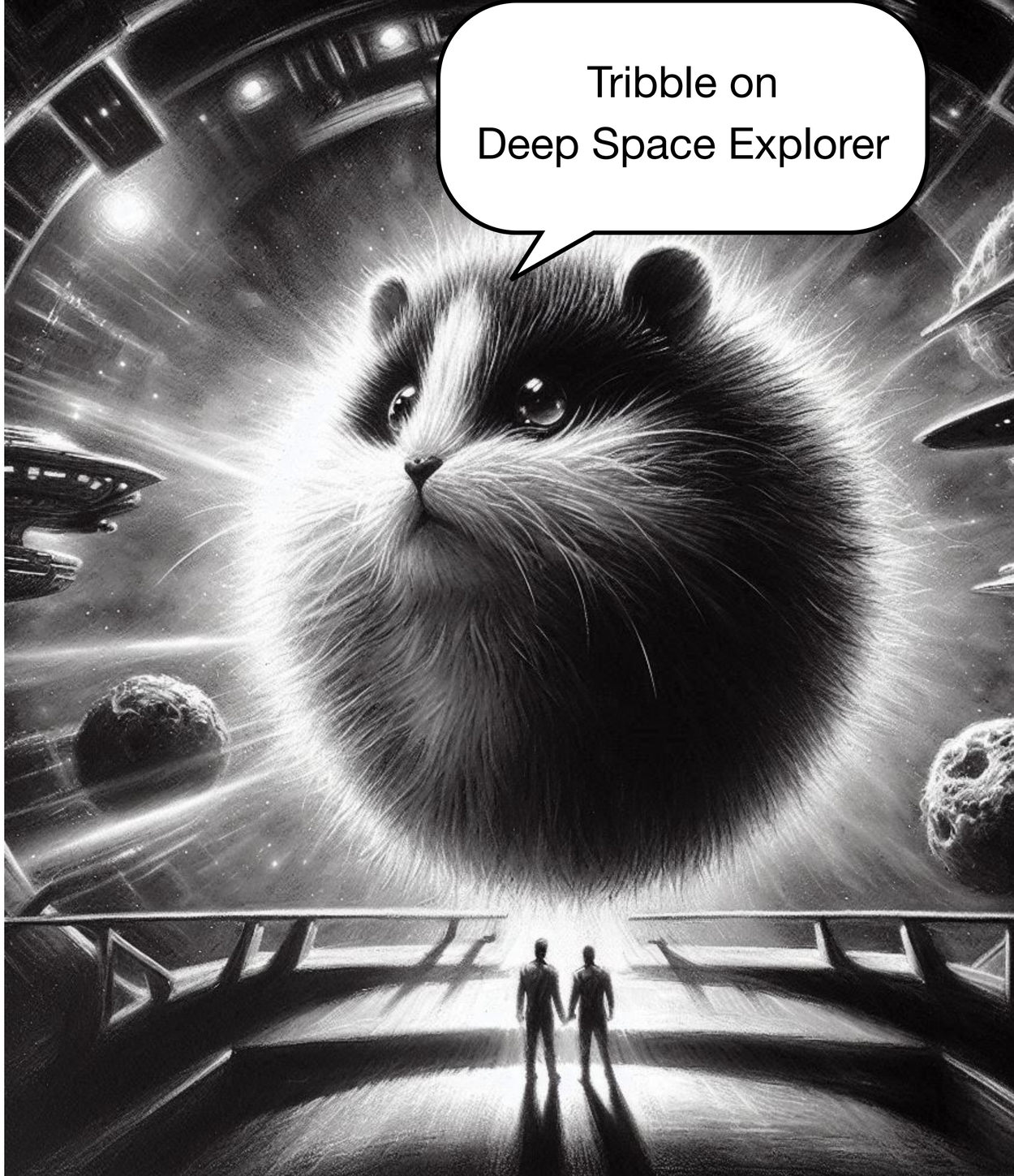

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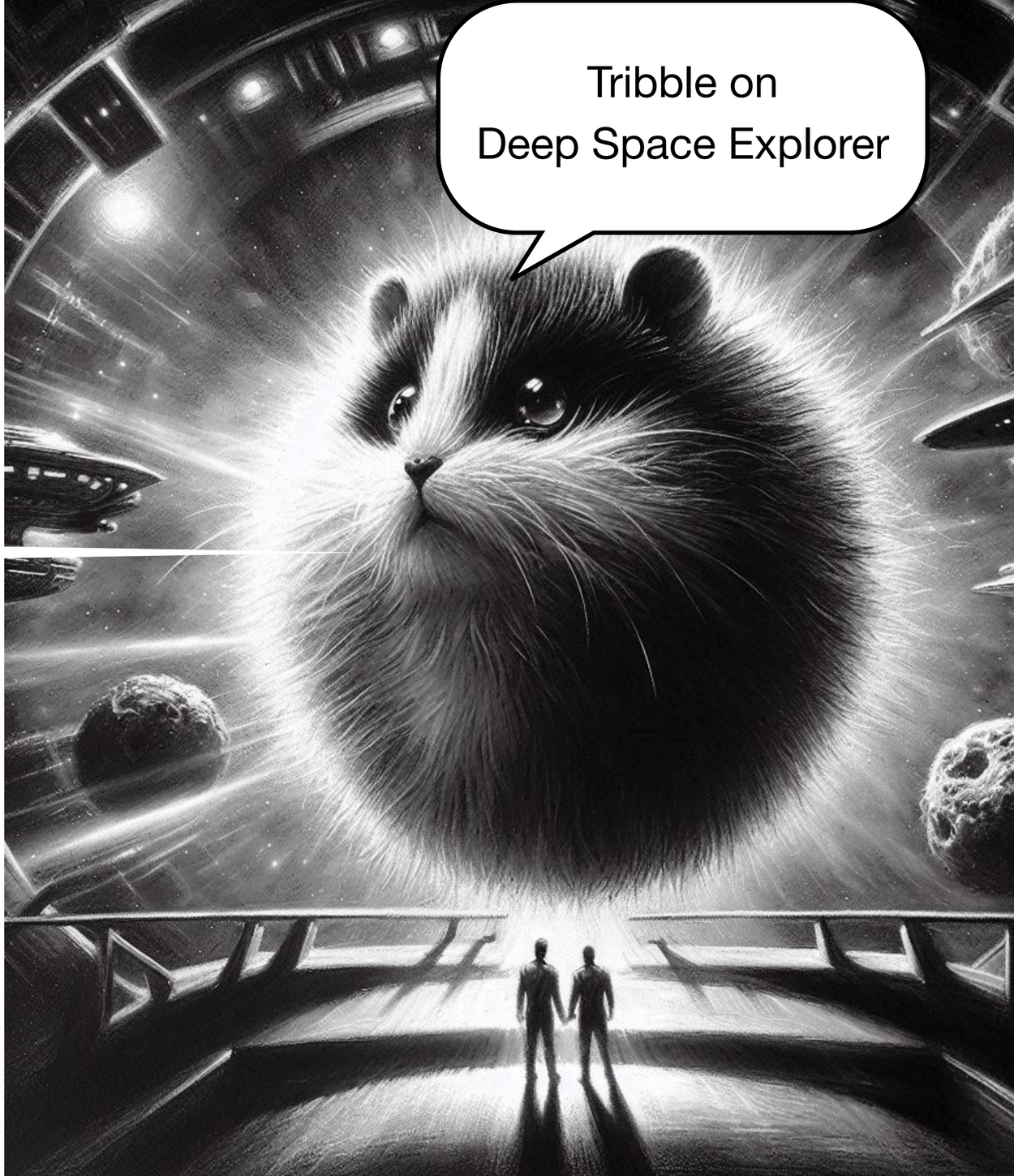

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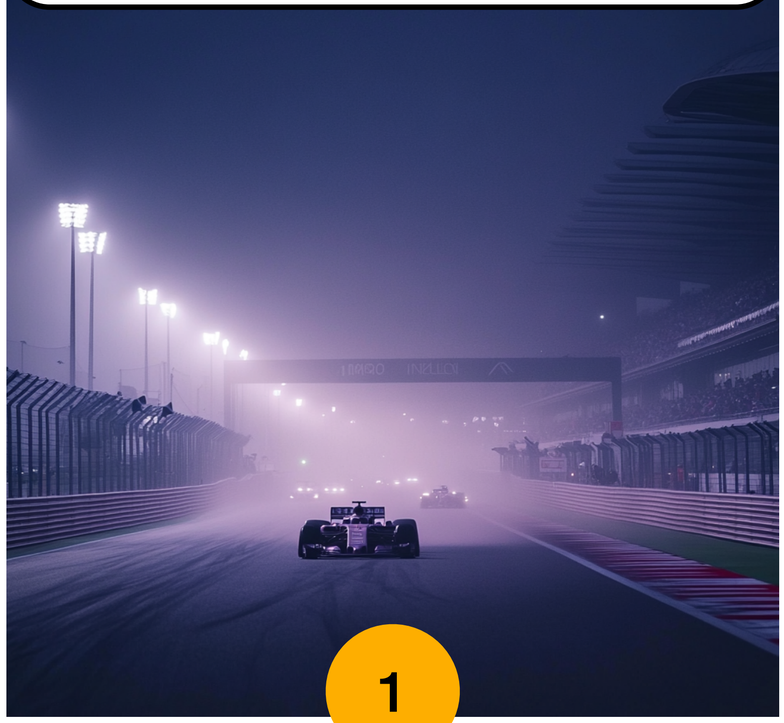
Networking challenges of AI/ML workloads

⛔ Visibility



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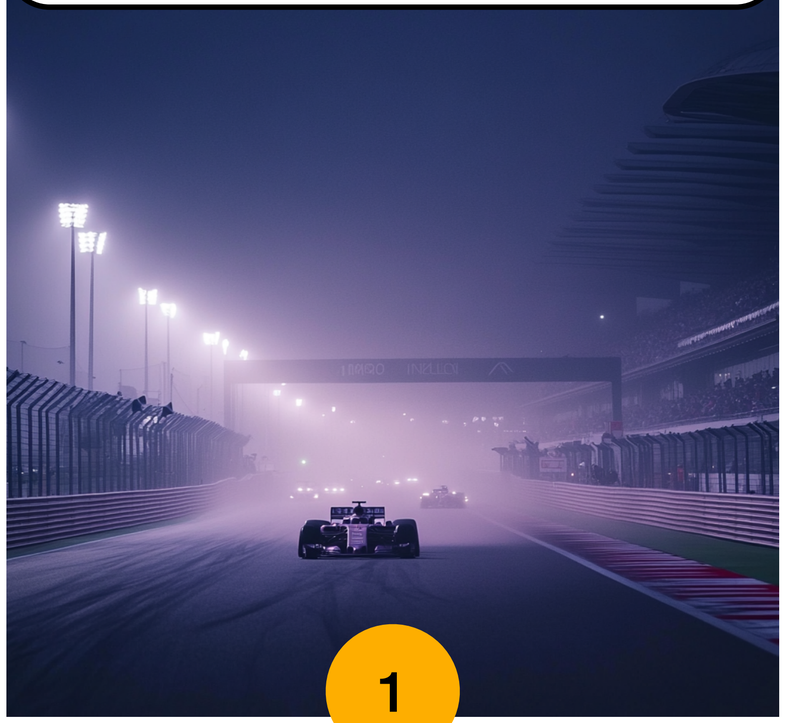
Networking challenges of AI/ML workloads

⛔ Visibility



1

⛔ Reliability

2

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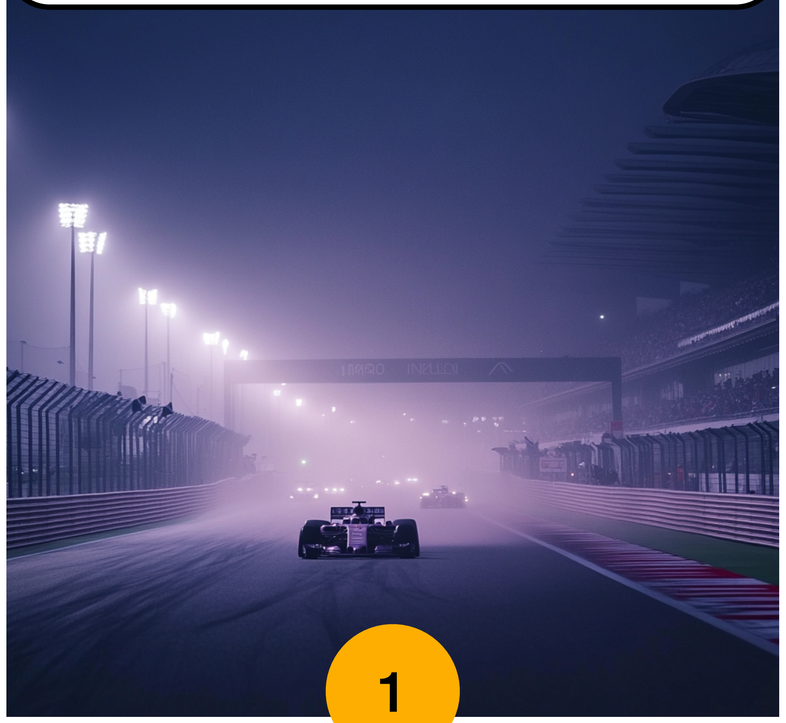
Networking challenges of AI/ML workloads

⛔ Visibility

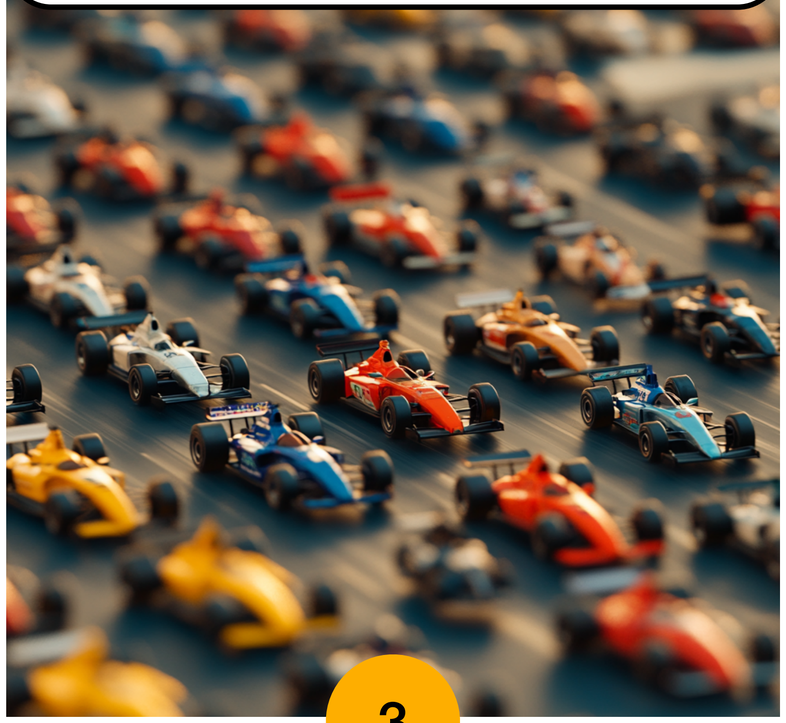


1

⛔ Reliability

2

⛔ Performance



3

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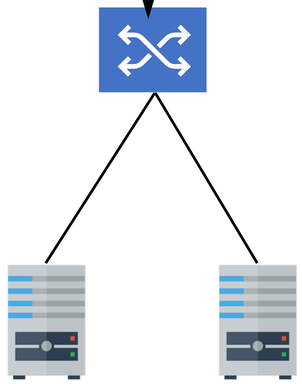
1 Lack of visibility

🚨Alert

😤

The ToR has
3 down uplinks
since 6 months ago
but we are not sure why!



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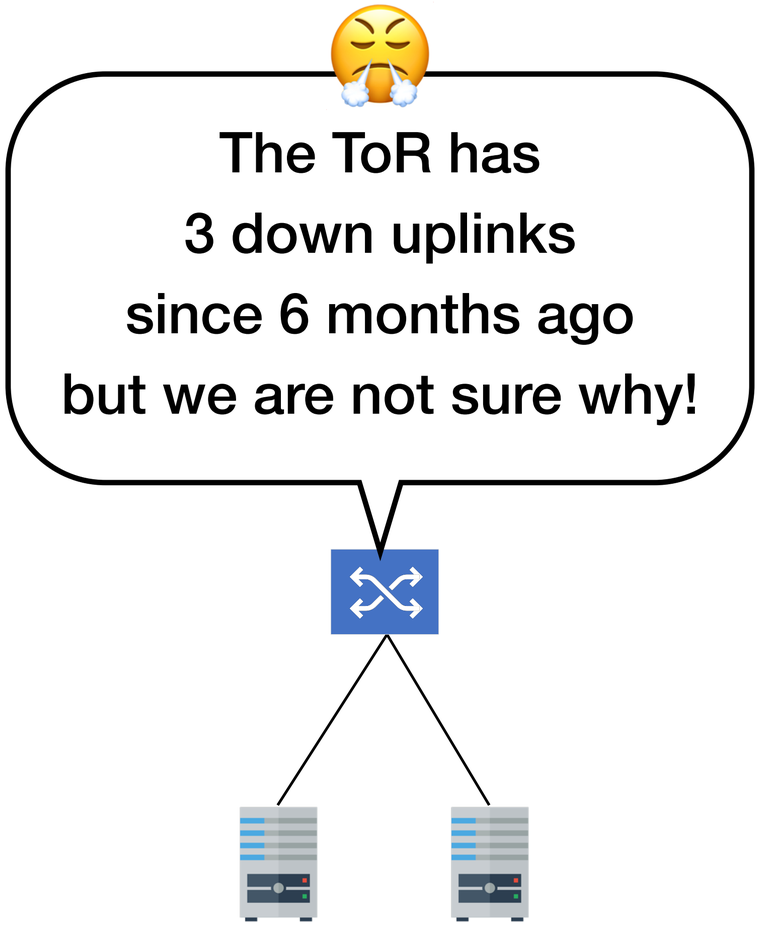
🚨Alert



Why?

- Aggregate level metrics
- No fine grained instrumentation
- No visibility down to the queue pair level

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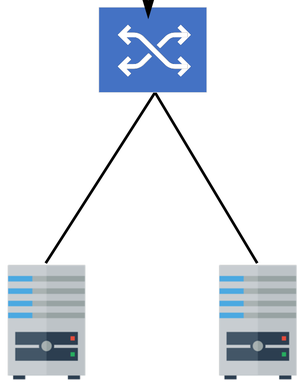

Why?

- Aggregate level metrics
- No fine grained instrumentation
- No visibility down to the queue pair level

- Unable to identify root cause to resolve issues quickly.
- Not only at fleet level but at workload level

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Visibility

Huygens clock synchronization

- Software based
- High precision at scale 🎯

https://www.usenix.org/conference/nsdi18/presentation/geng

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Huygens clock synchronization

- Software based
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Measures
one way delays

https://www.usenix.org/conference/nsdi18/presentation/geng

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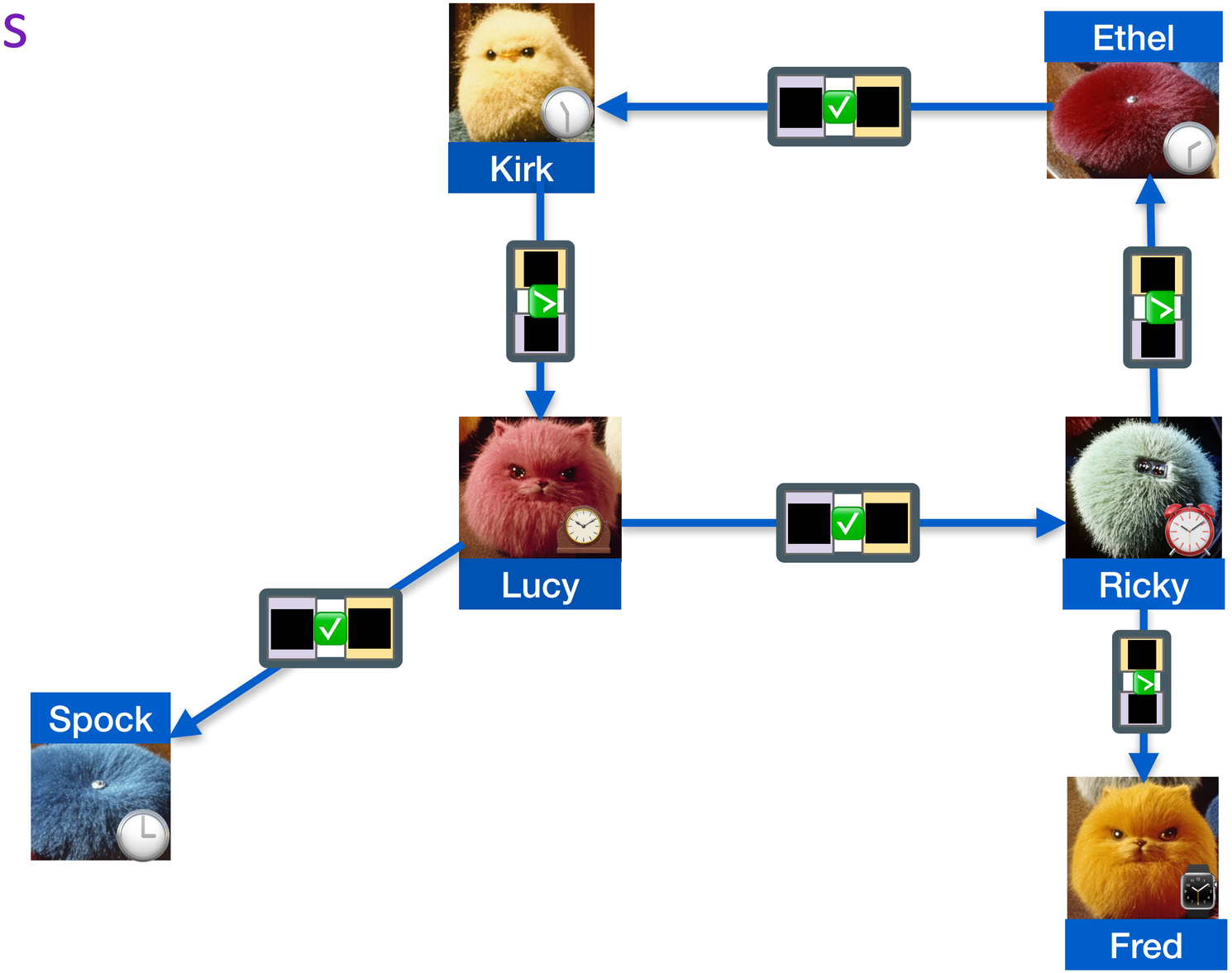
Huygens



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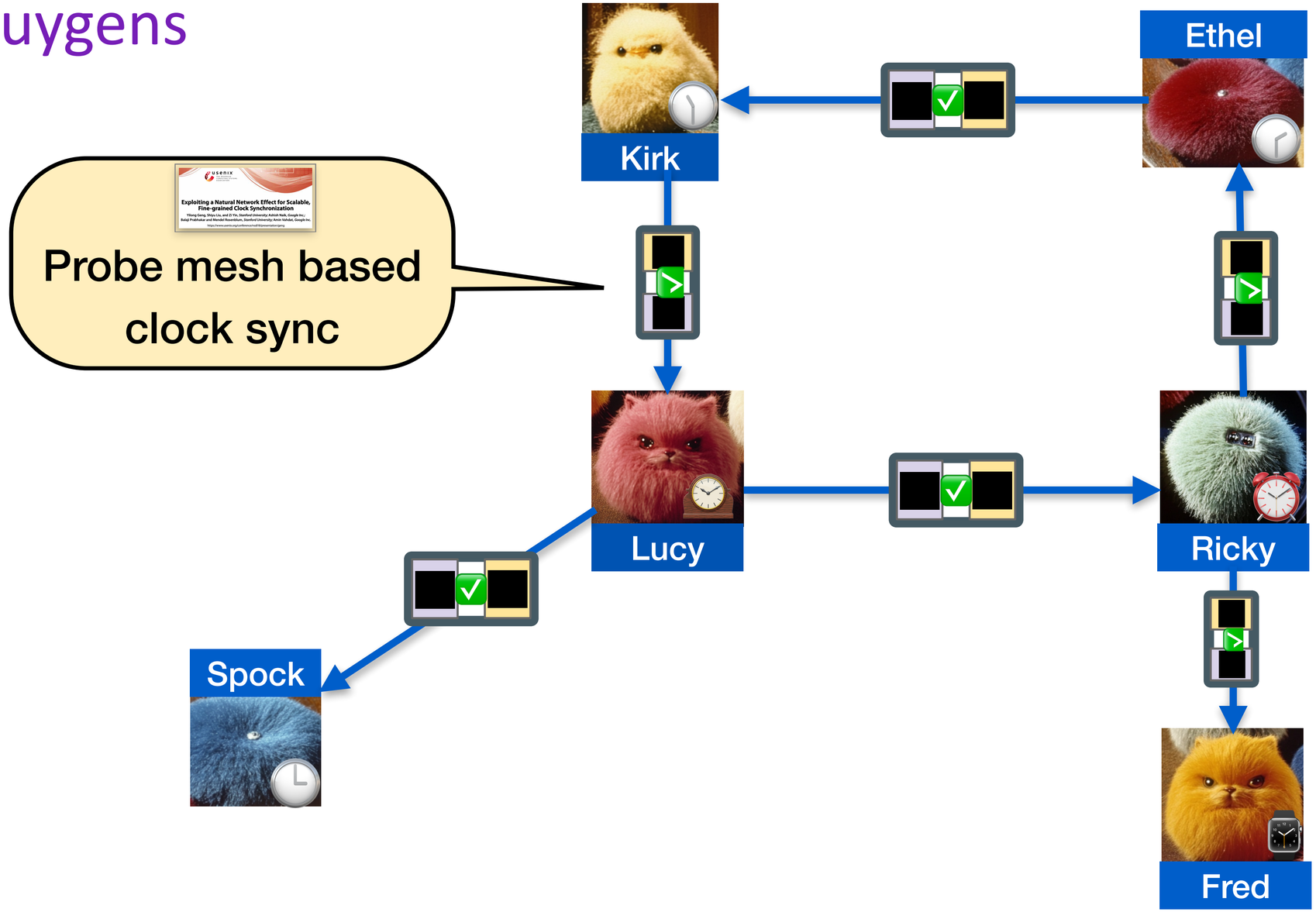
Huygens



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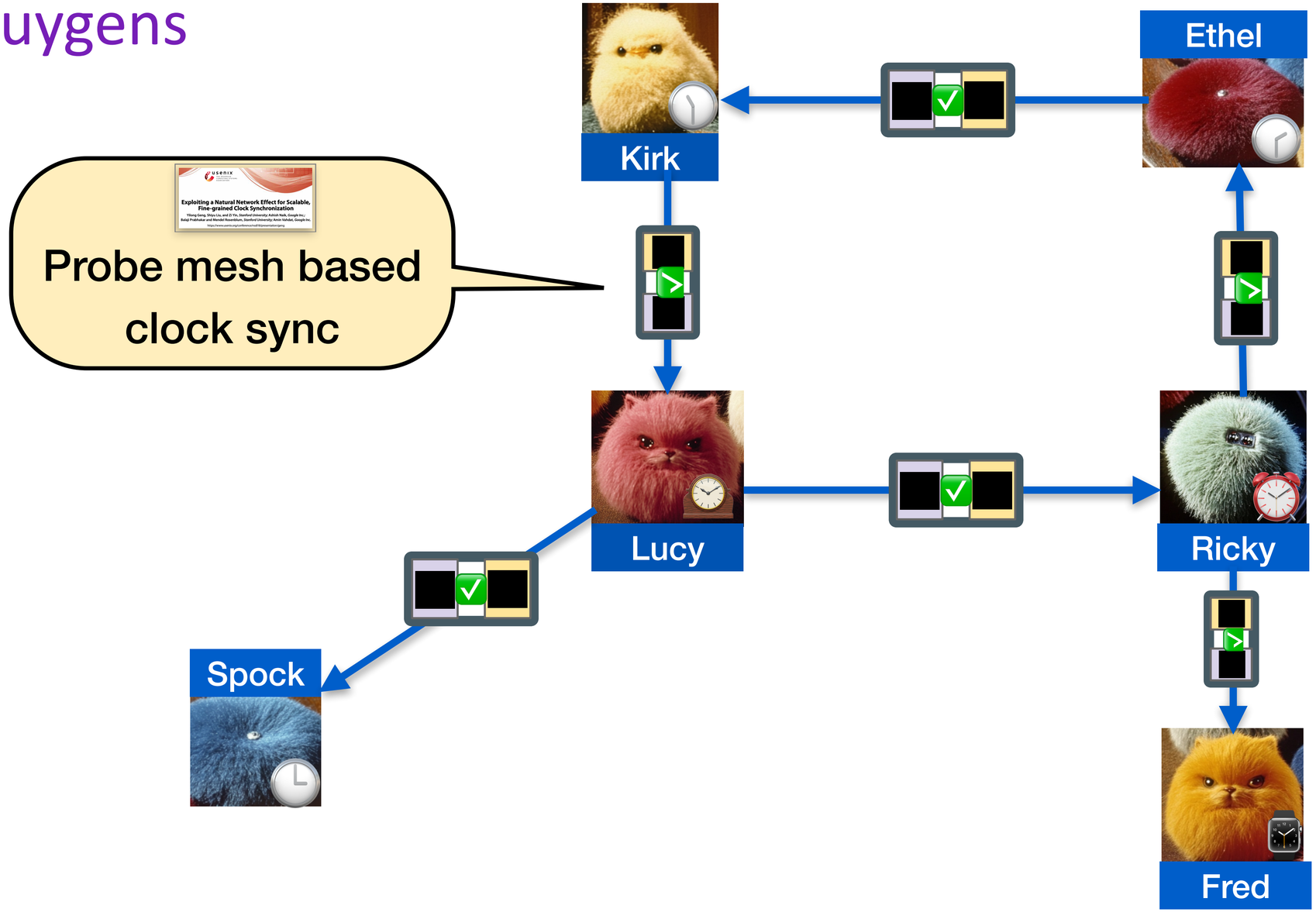
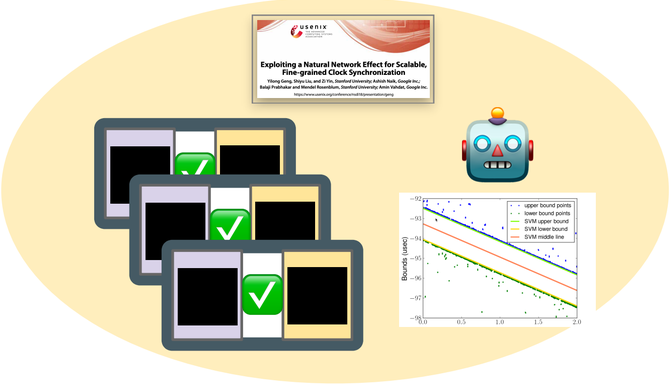
Huygens





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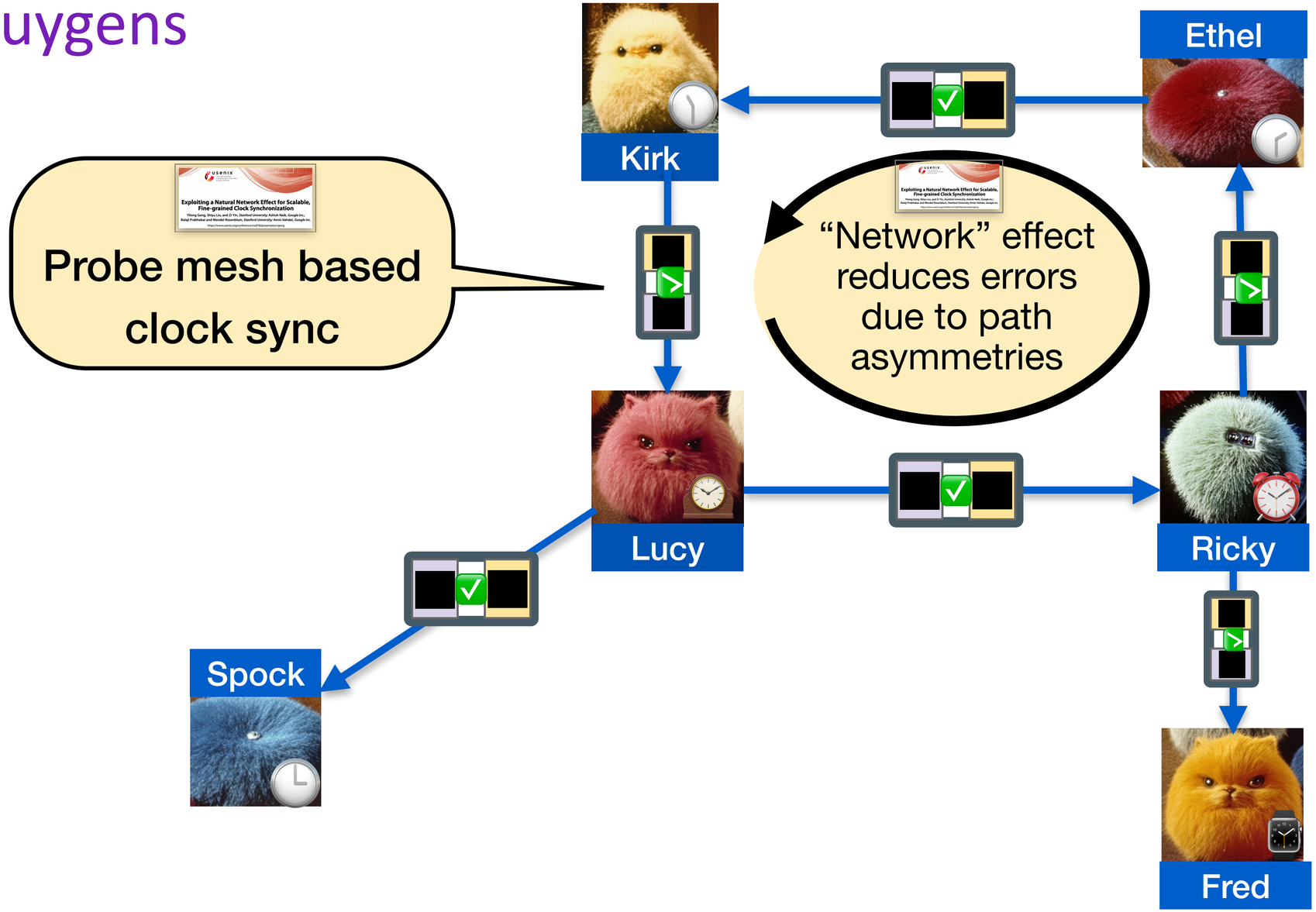
Huygens



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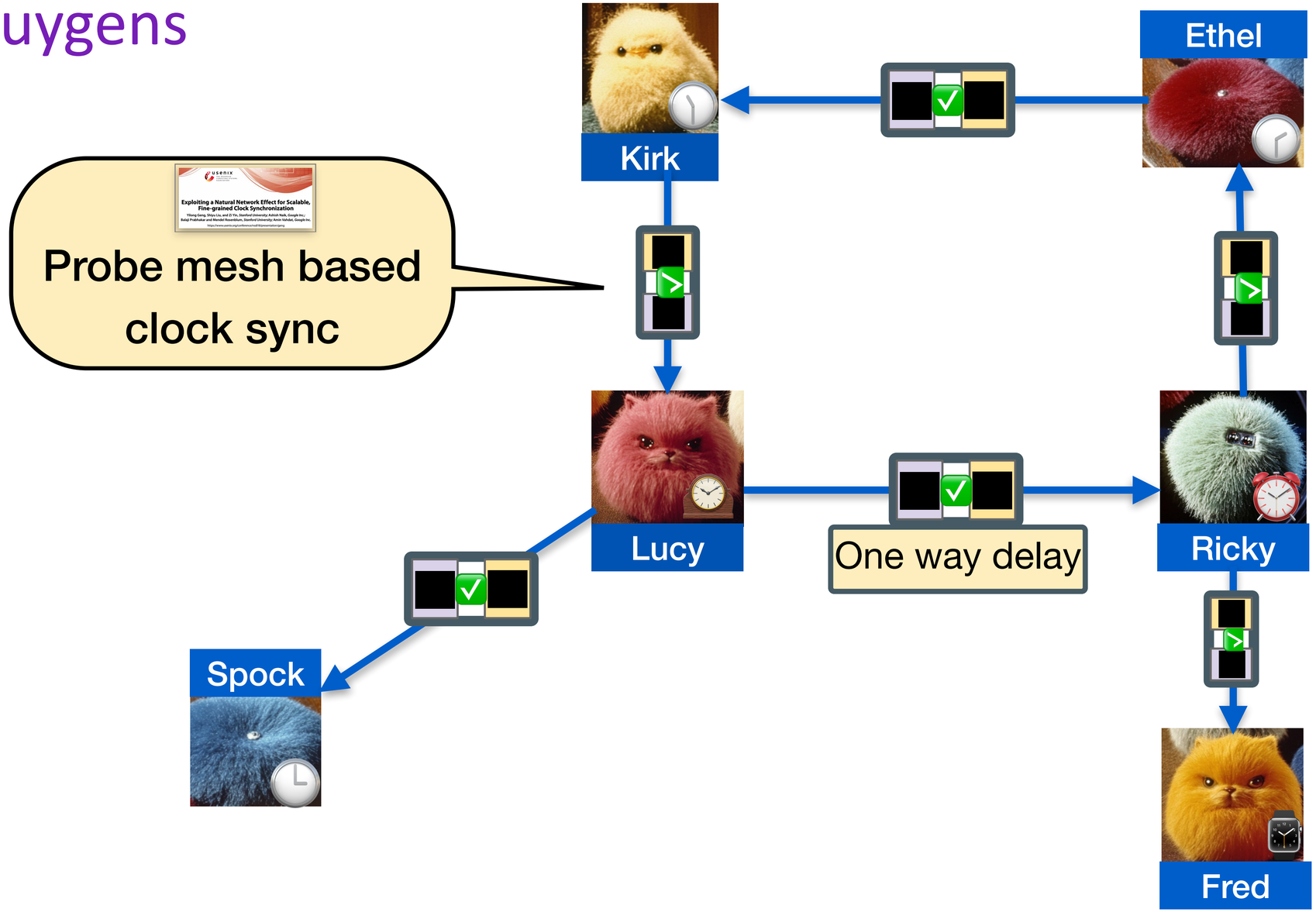
Huygens



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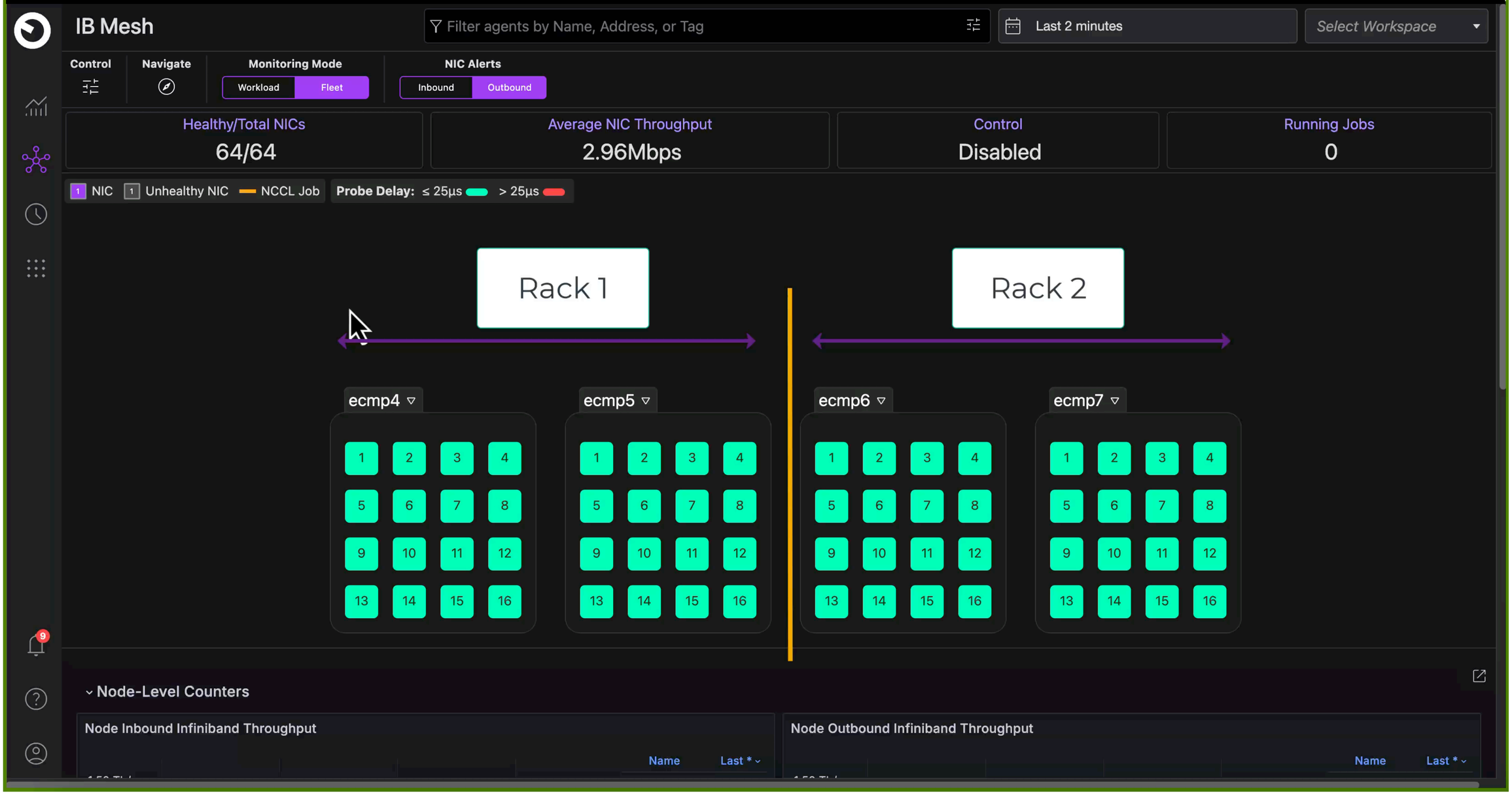
Visibility demo



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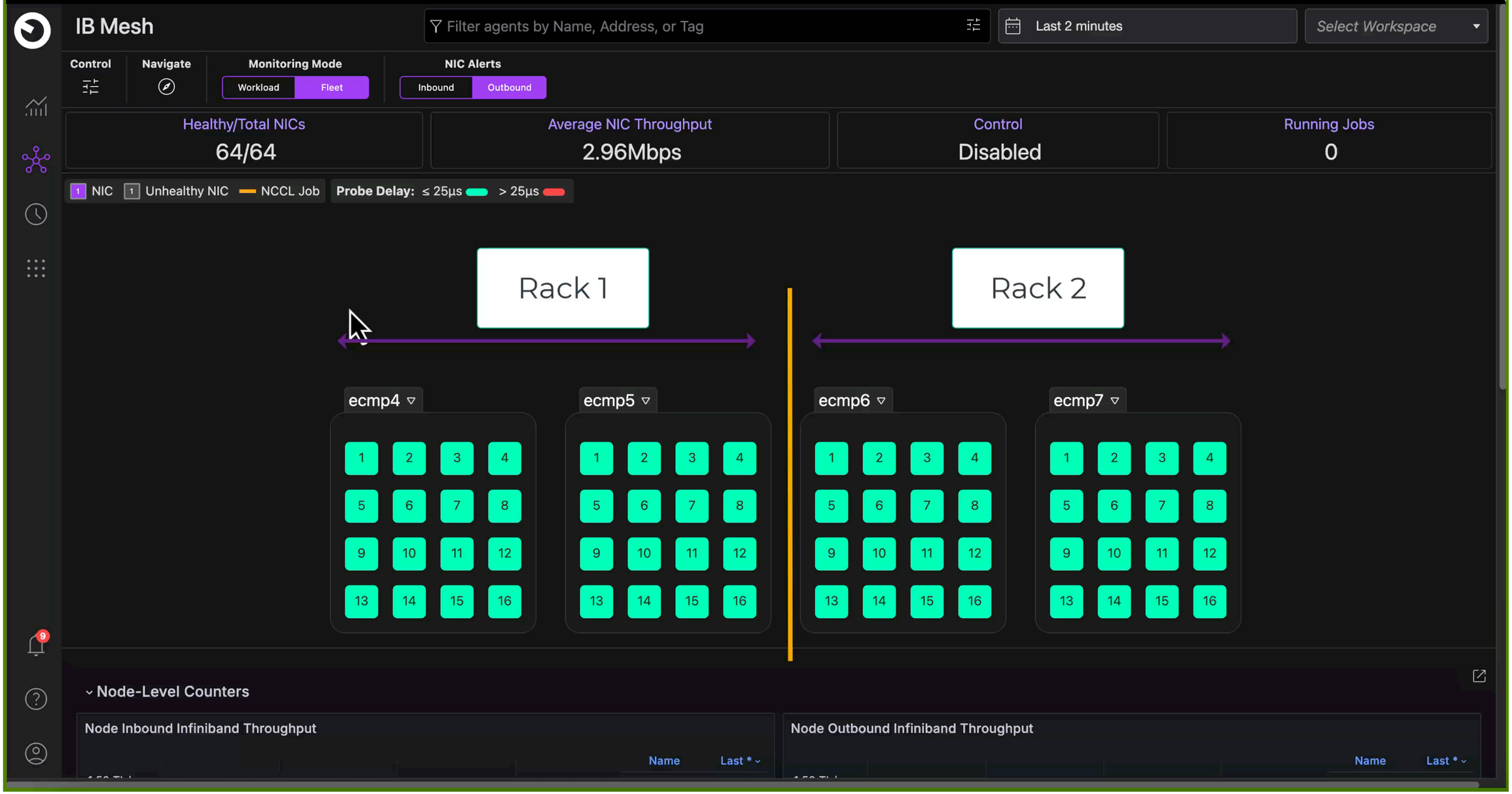

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2 Lack of reliability

🚨 Alert

😤

Link flapped 10 times!
Send technicians
to swap cables!

AI-generated image

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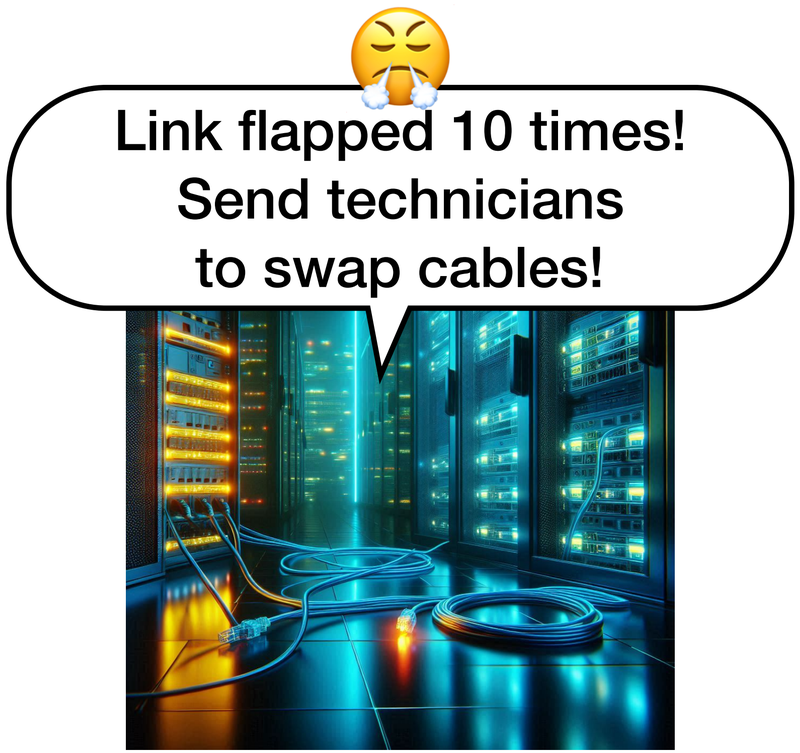
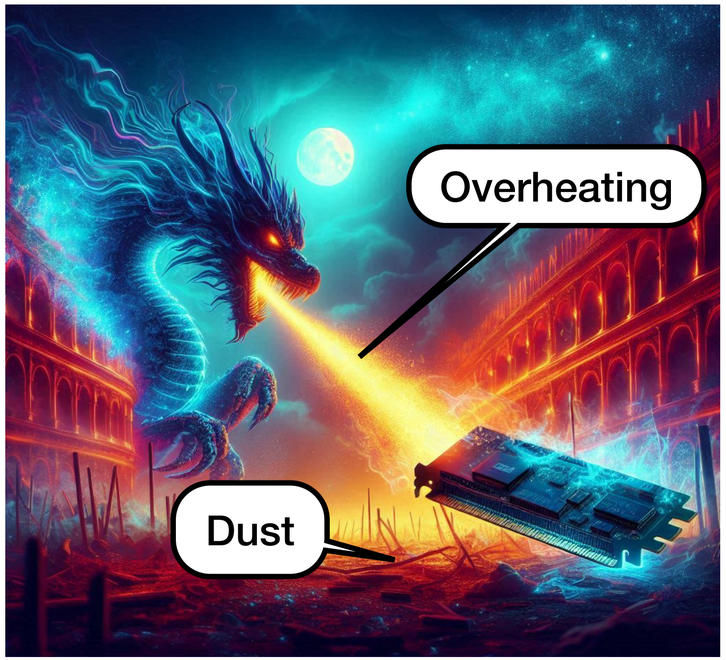
2 Lack of reliability

🚨 Alert



Why?

🔥 Common in large clusters



Source: semianalysis

AI-generated image

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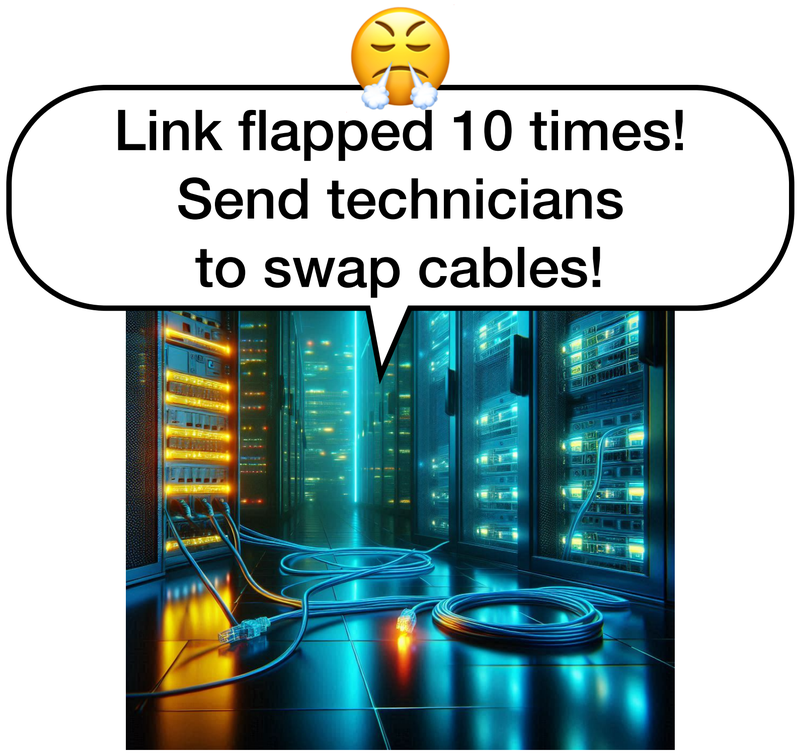

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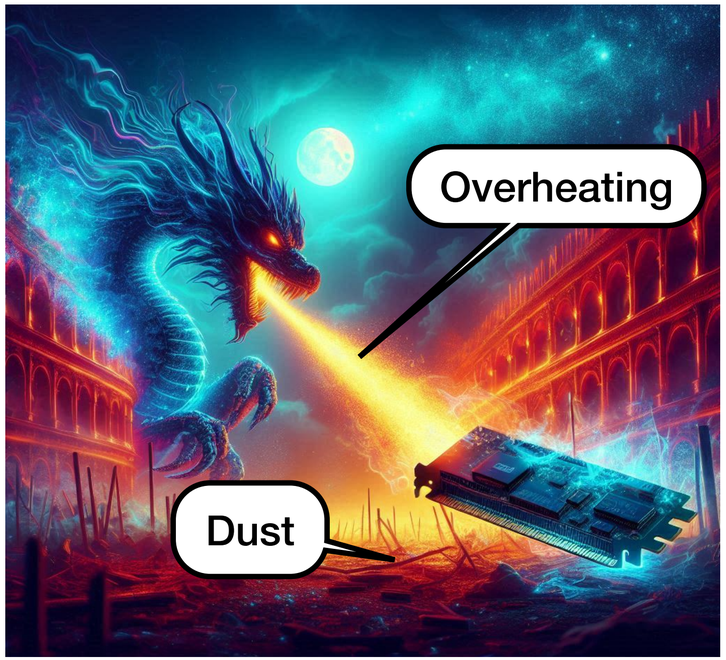

Source: semianalysis

So what?

- Job crashes
- Forces to restart from previous checkpoint.
- Lost ⌛ 💰

AI-generated image

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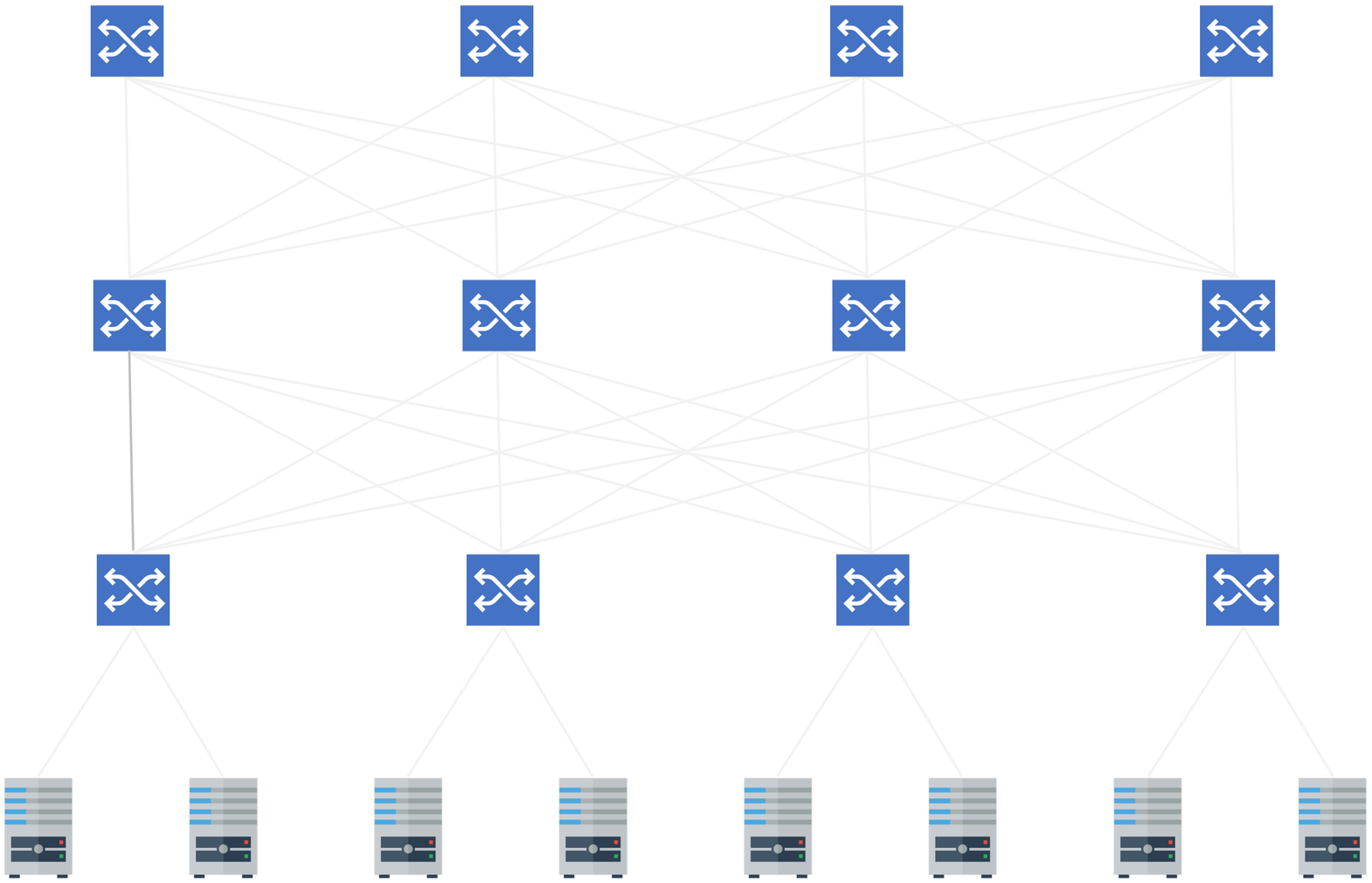
Link/NIC Flapping



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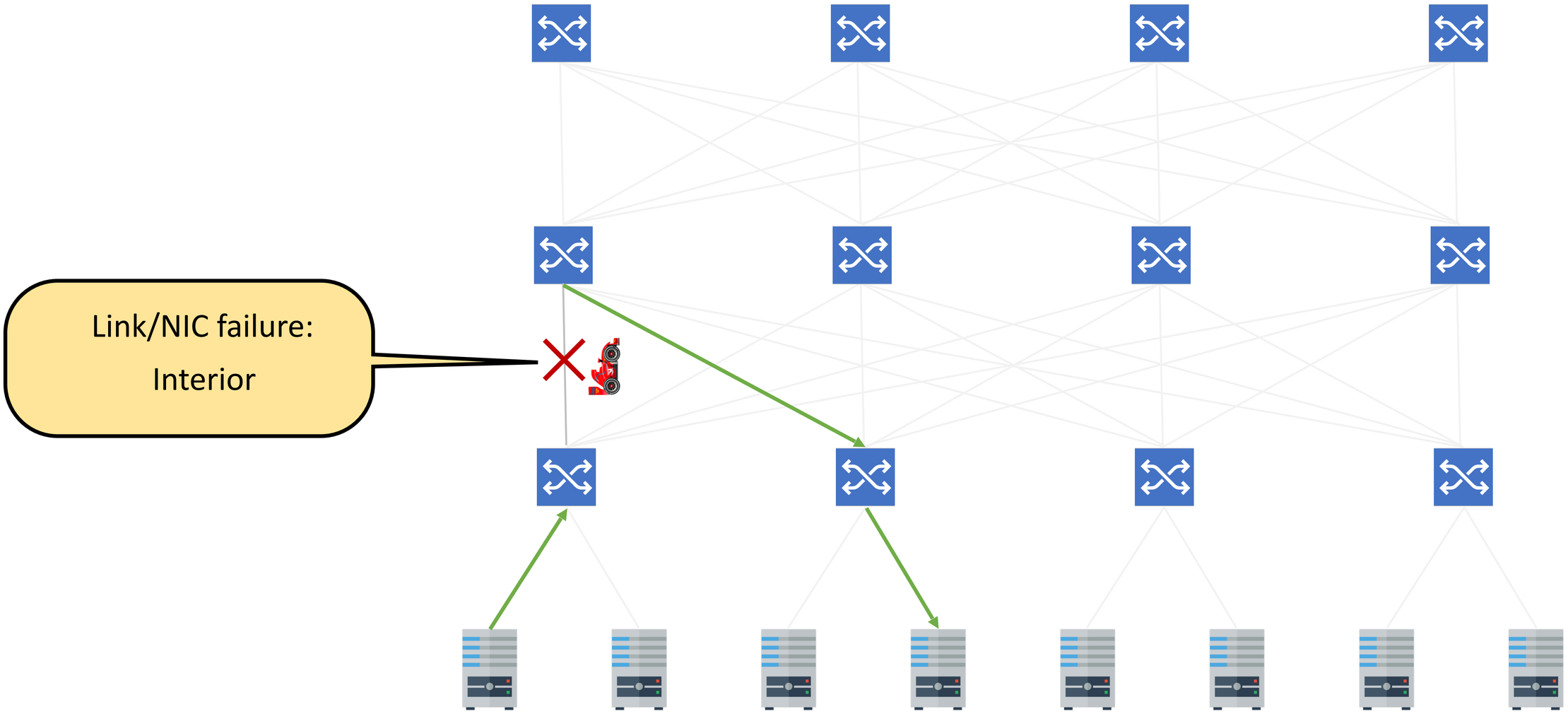

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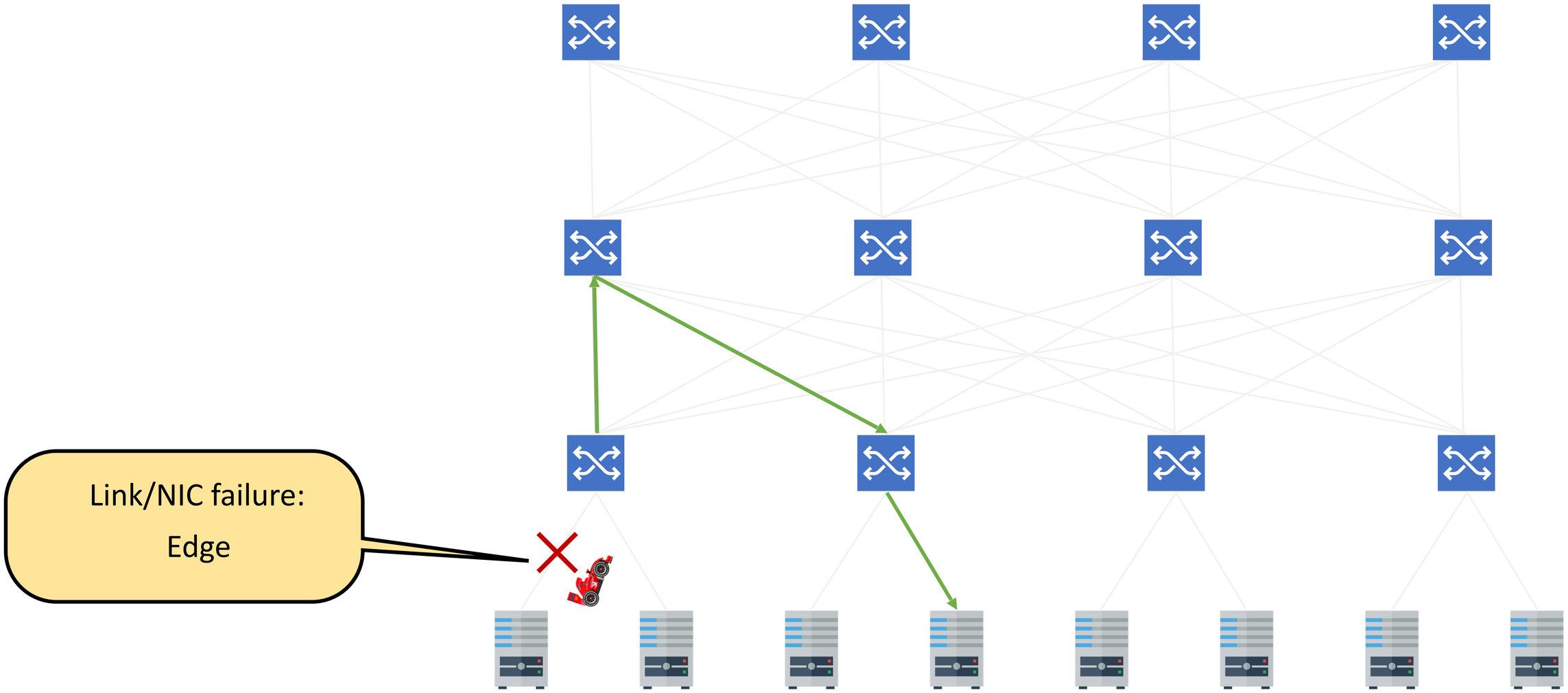

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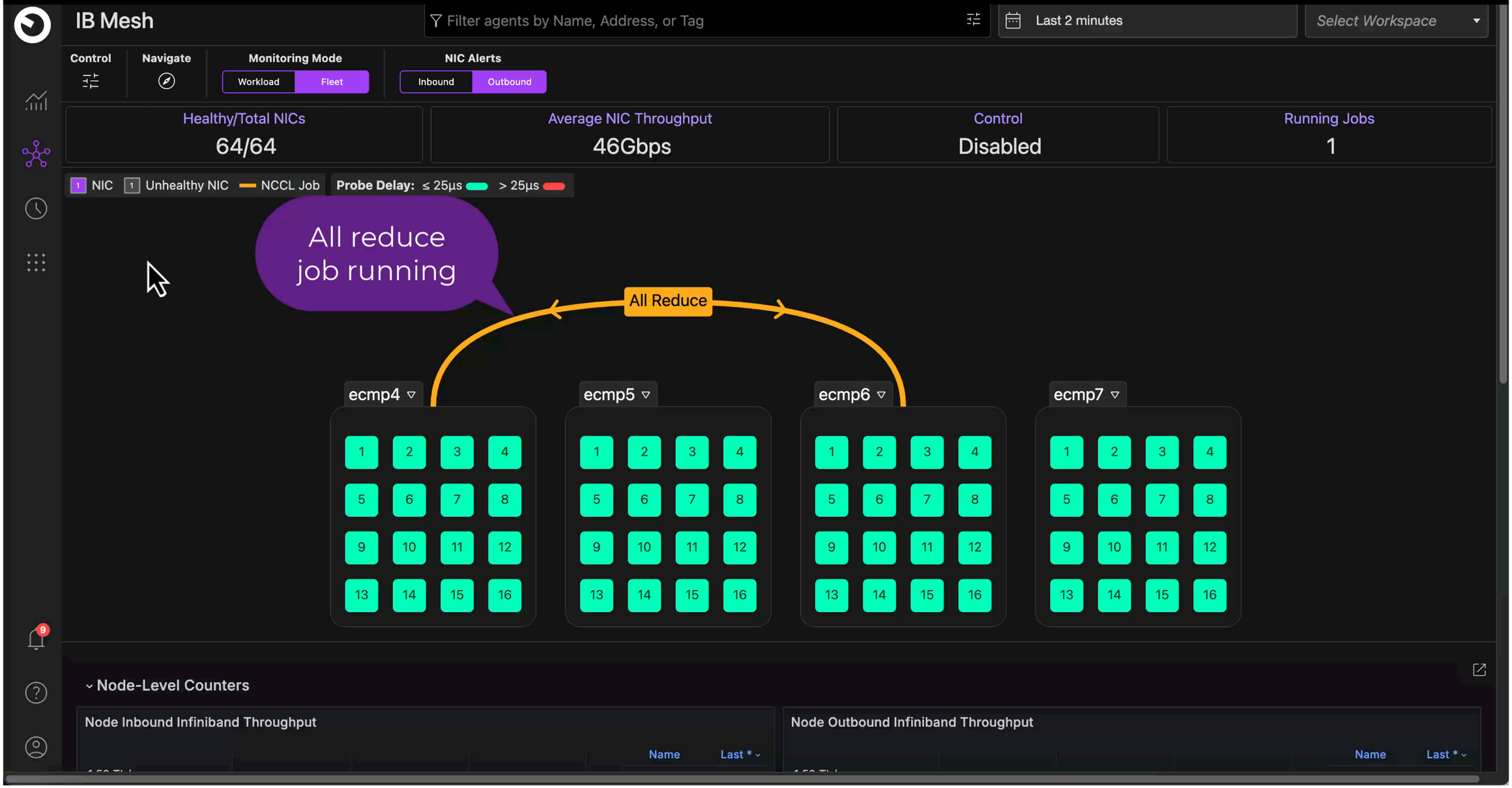
NIC flapping demo



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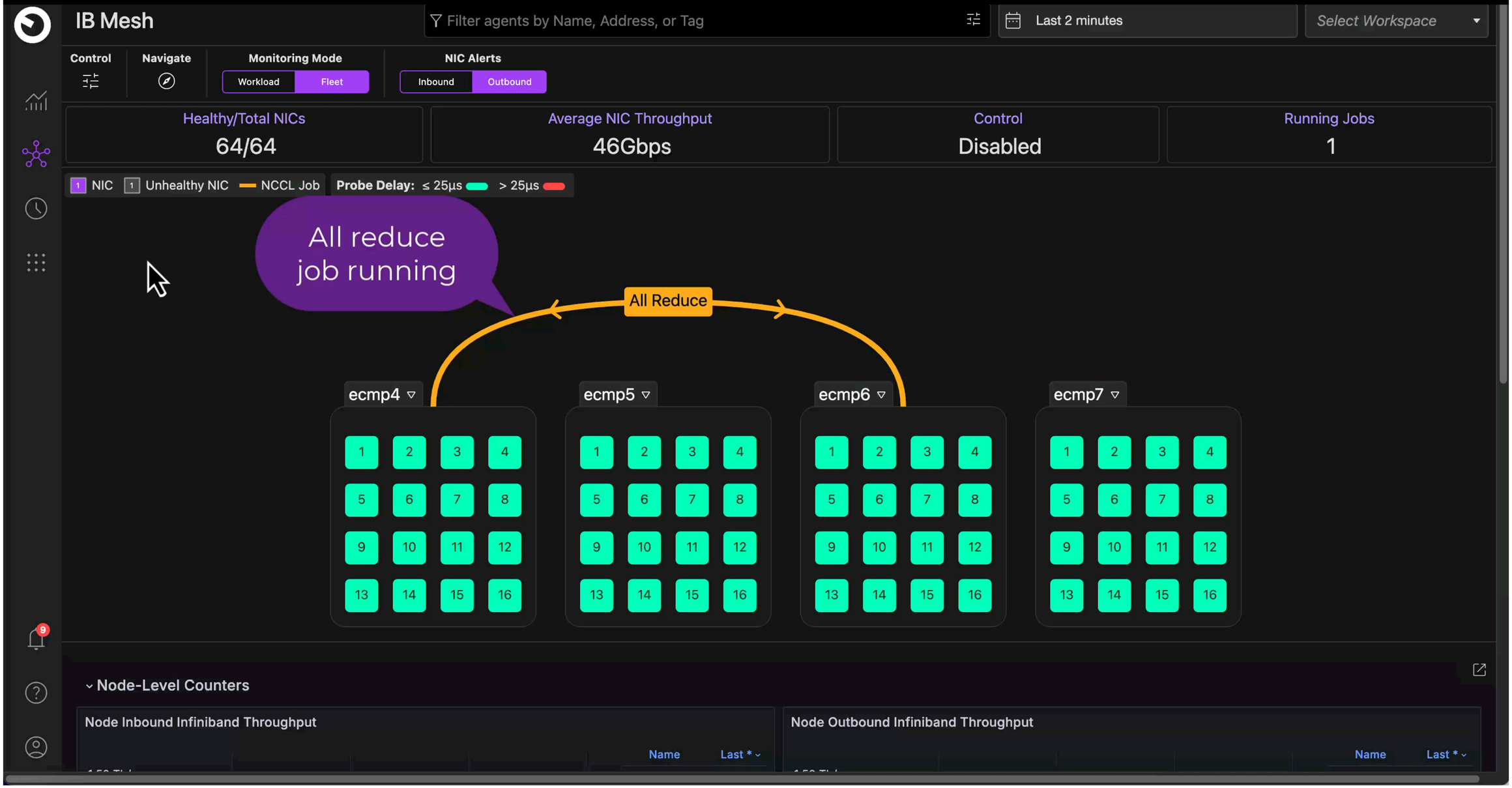

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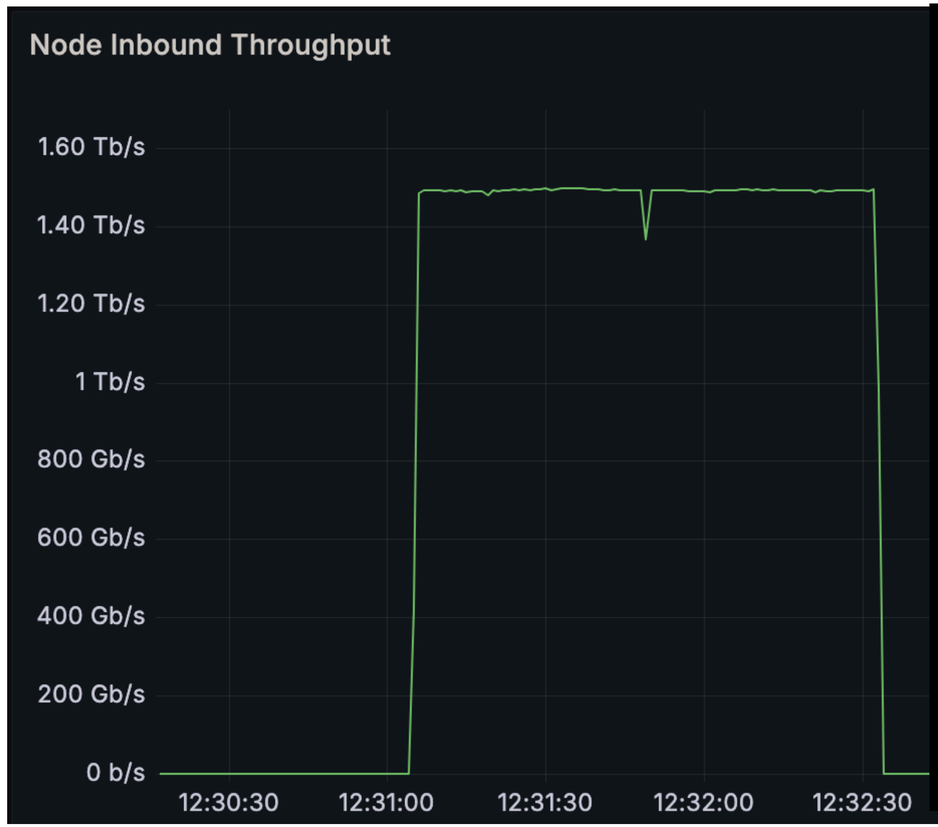
Resilience to NIC Flaps in Oracle Cloud



Run 1: No Failure

Run 2: NIC Failure
(What happens today)

Run 3: A solution
NIC Failure + Auto recovery

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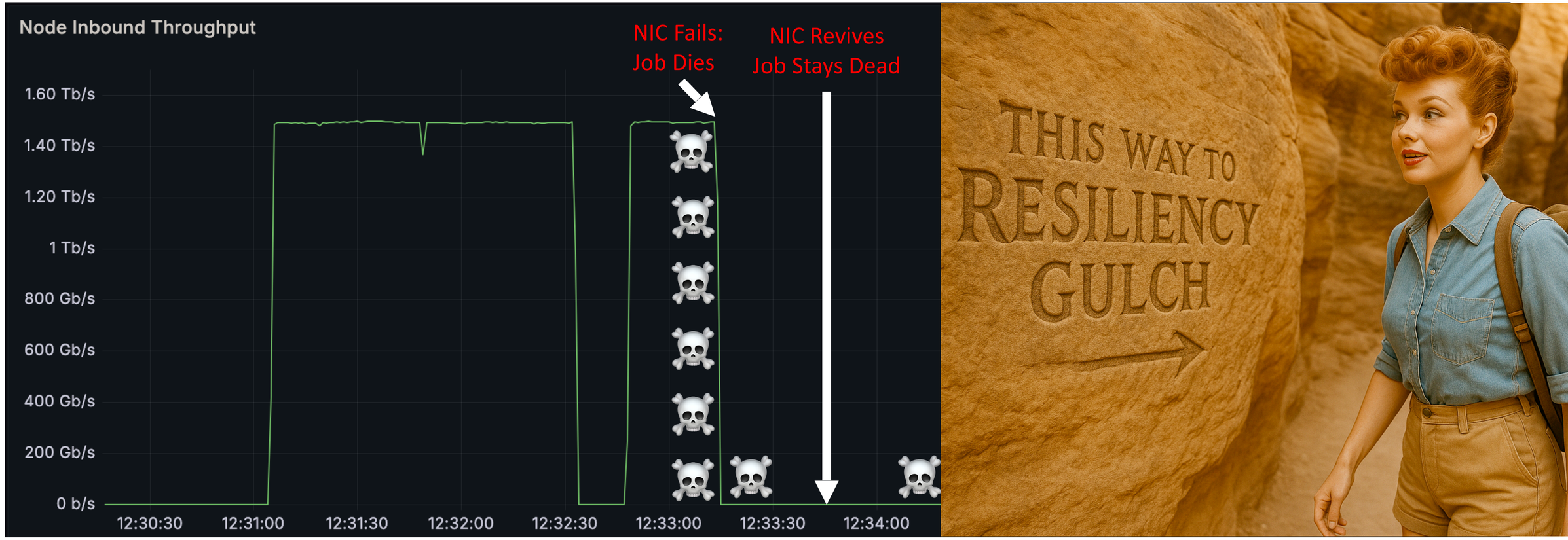
Resilience to NIC Flaps in Oracle Cloud



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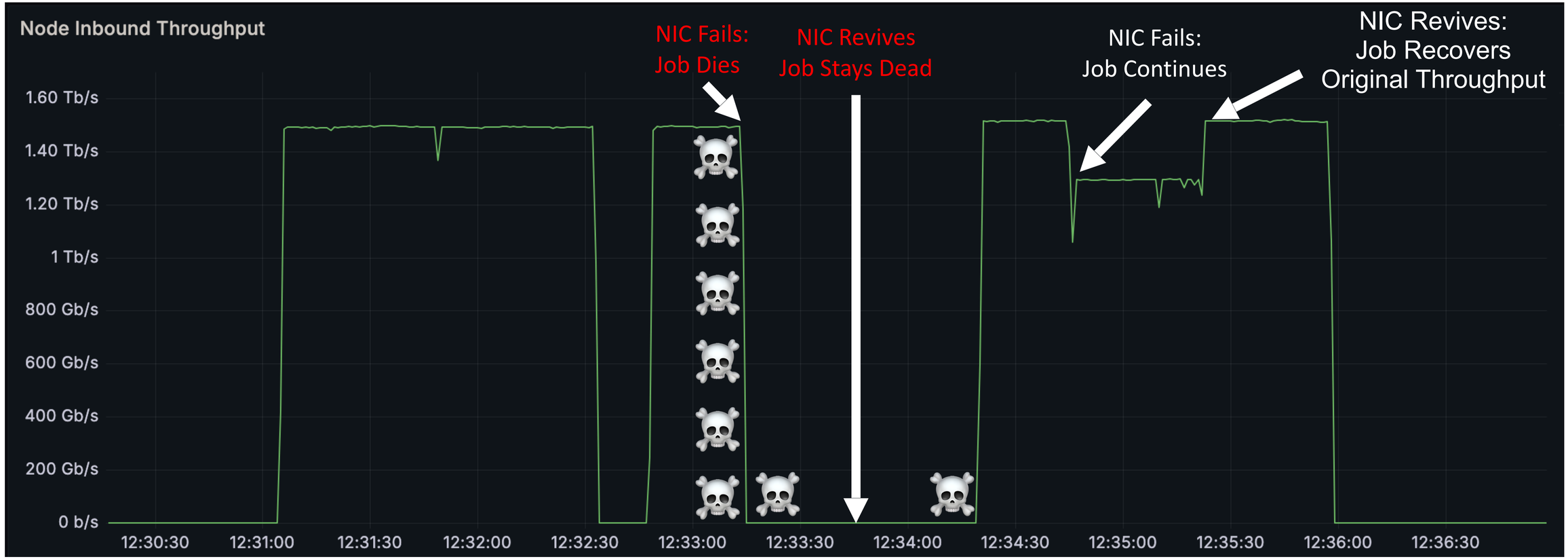

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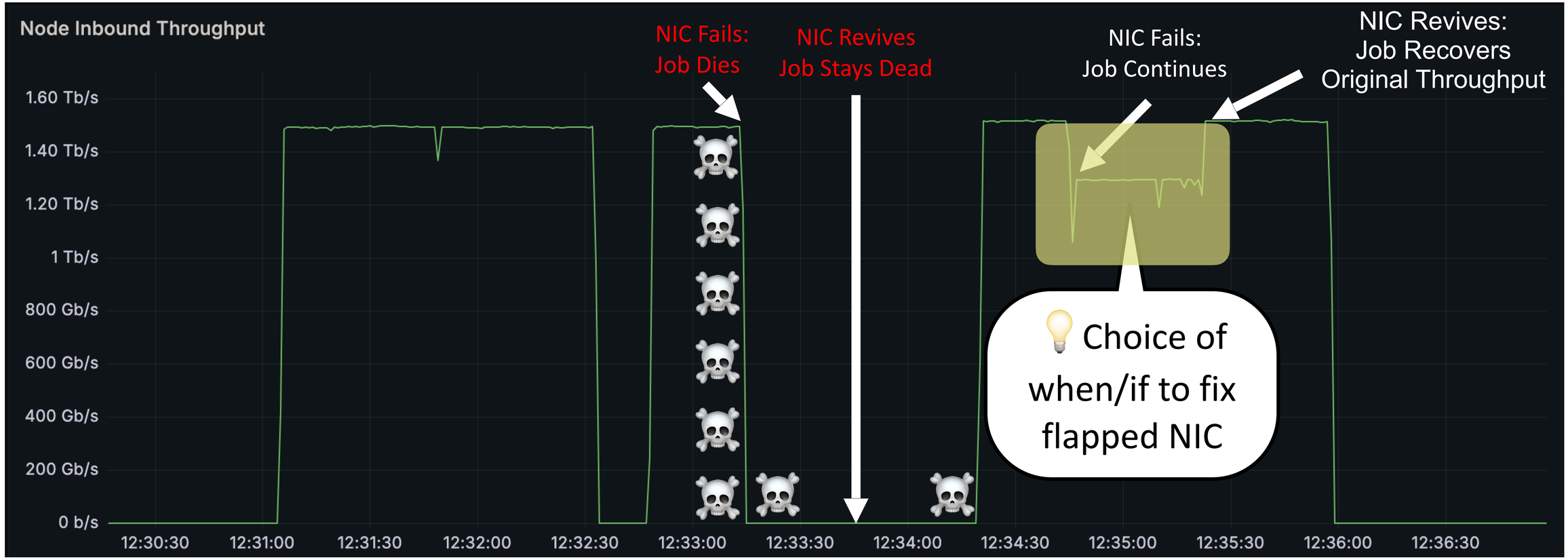

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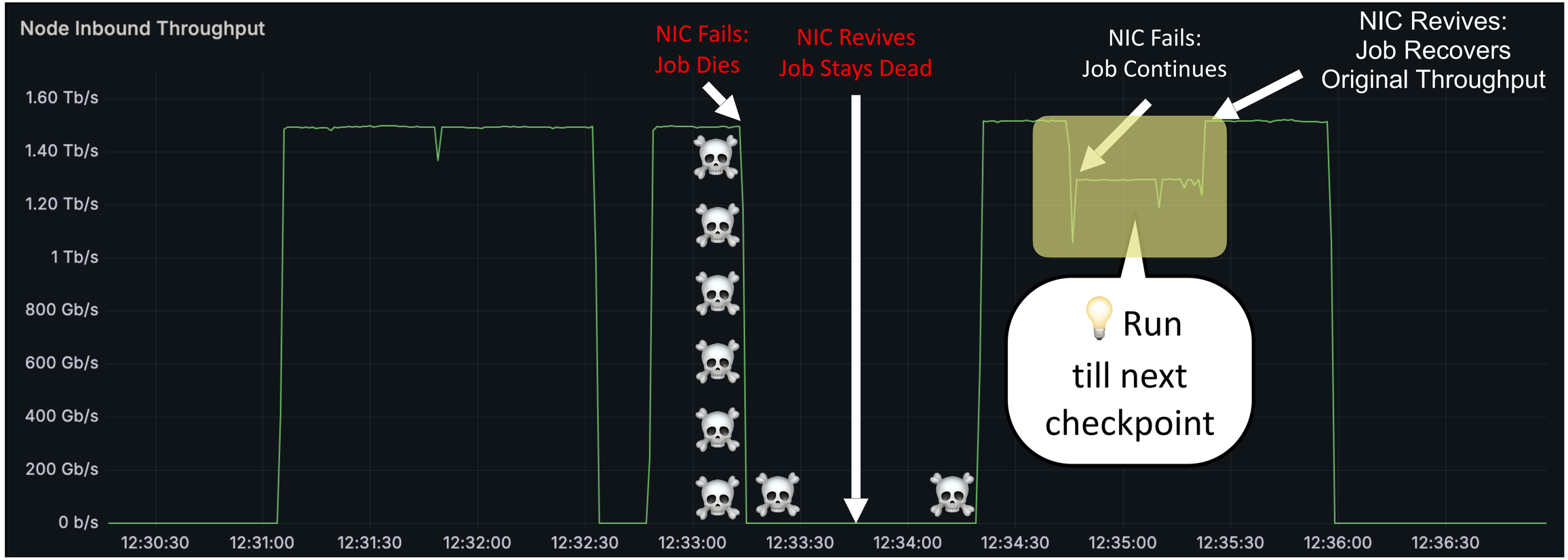

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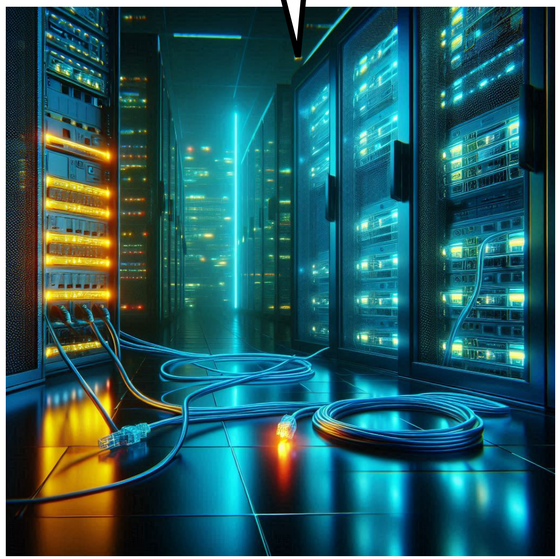
3 Lack of predictable performance

🚨 **Alert**

😤

The app is slow!



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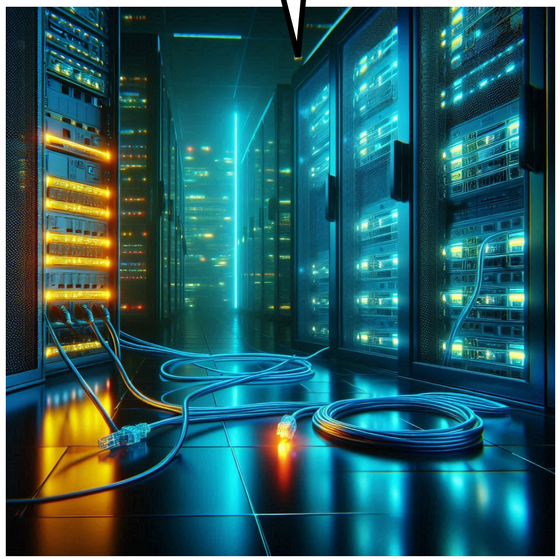
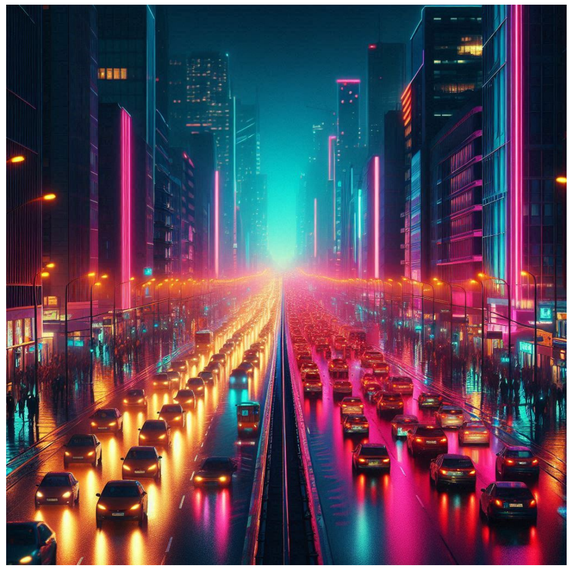


Why?

Flows contending for bandwidth



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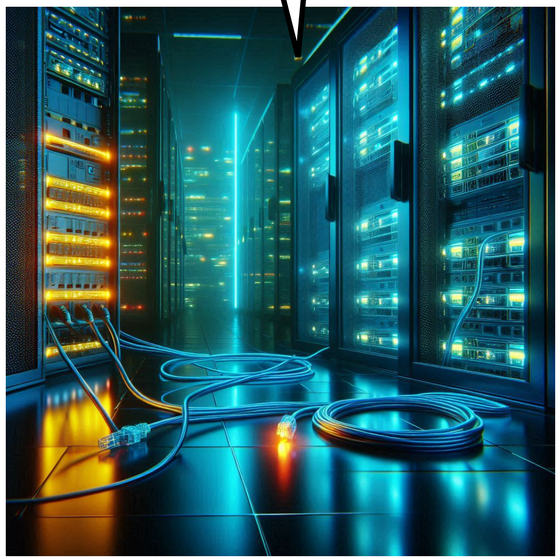

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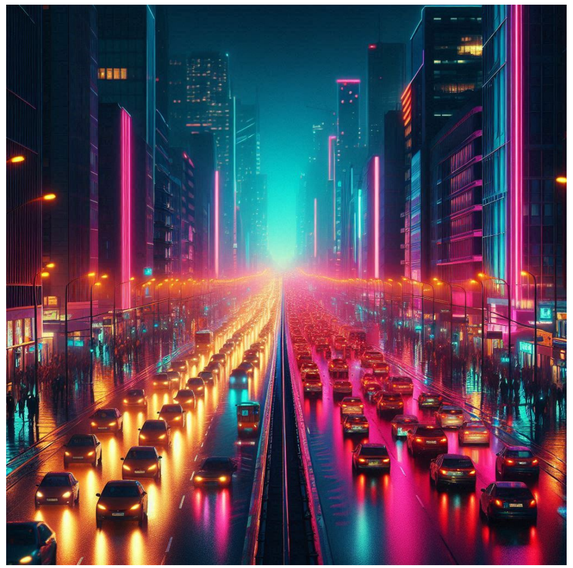

So what?

Low throughput, high latency

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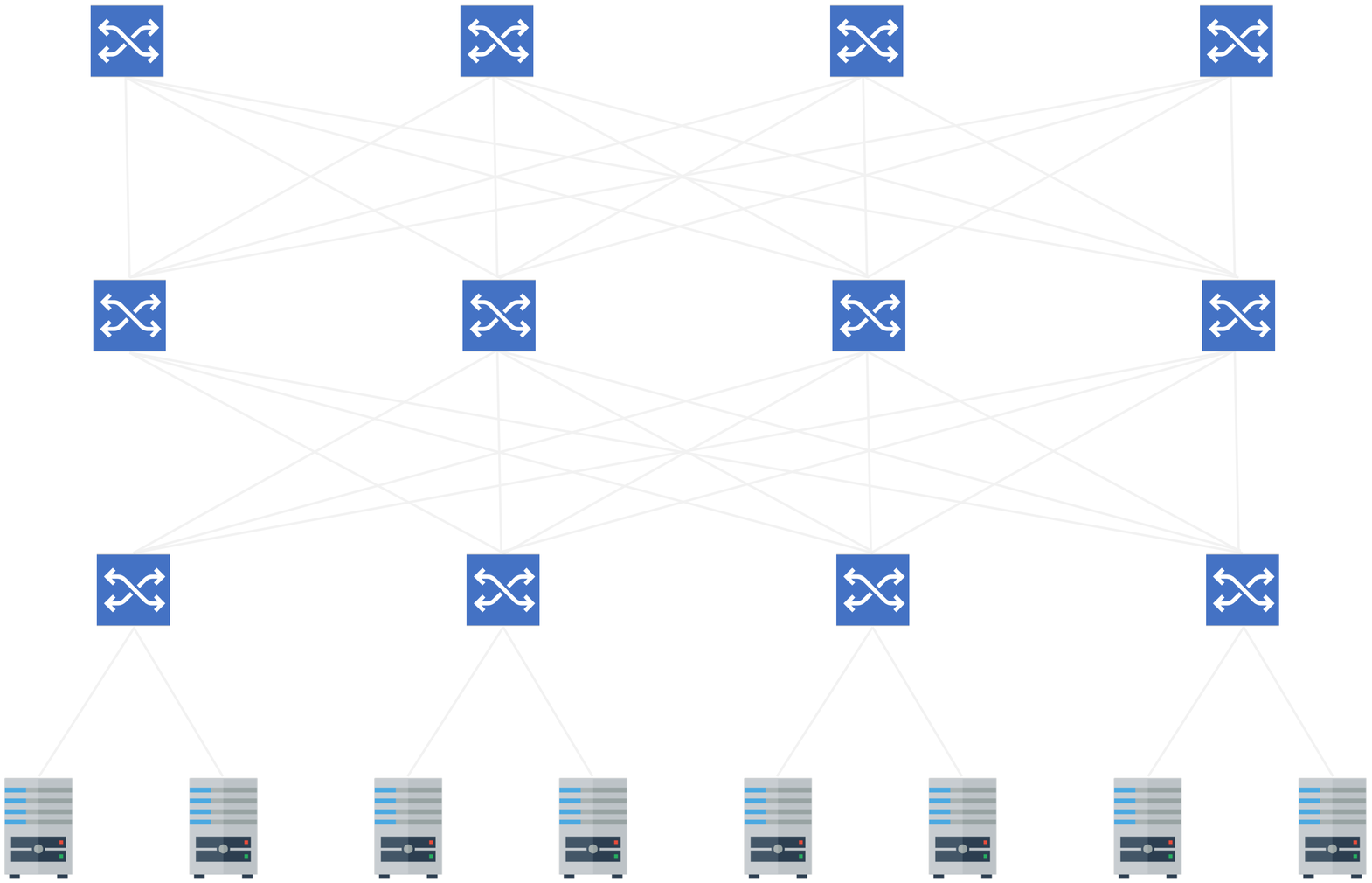
Fabric Contention

Contention



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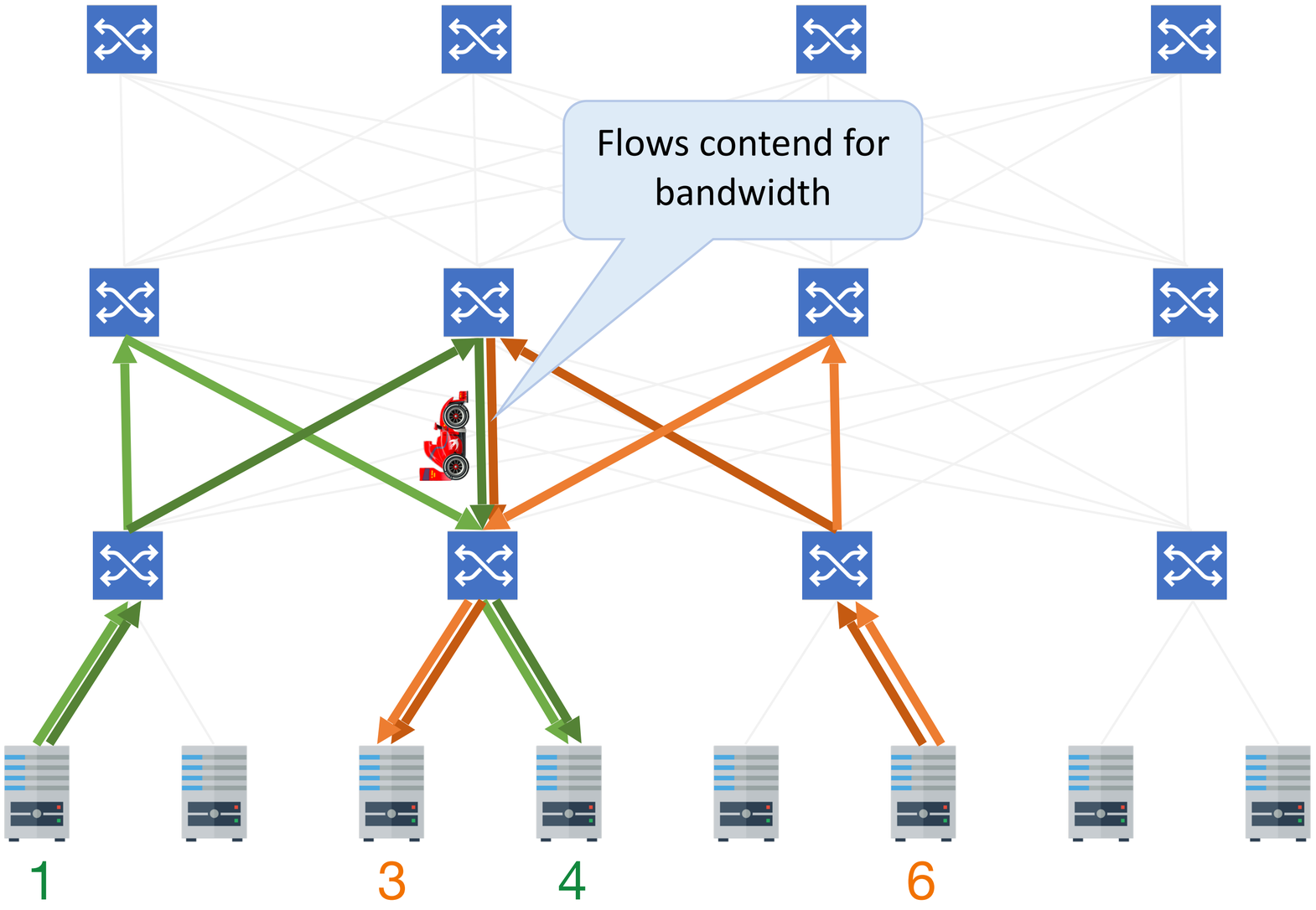
Fabric Contention

Contention

- Queue pairs collide contending for bandwidth
- Senders are not aware which paths are used vs which are free to use



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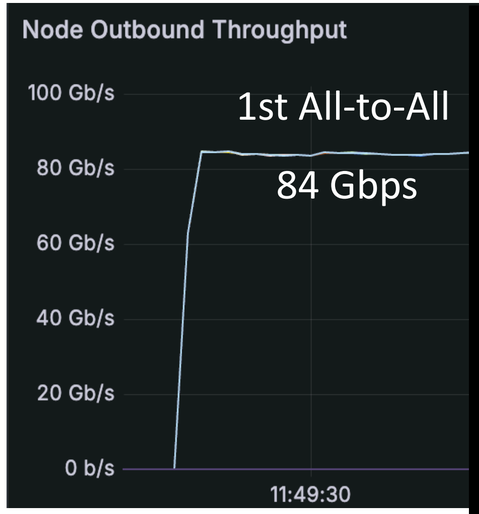
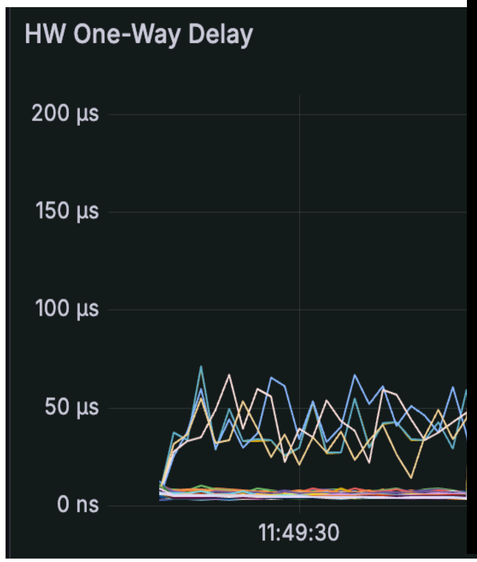
Detecting and eliminating contention on ECMP Test Bed

Throughput



One-way Delays



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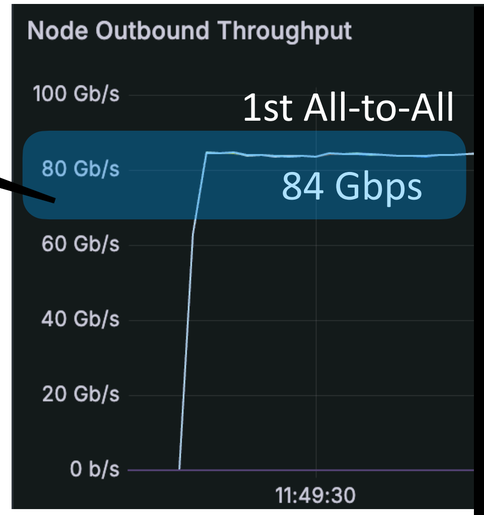
Detecting and eliminating contention on ECMP Test Bed

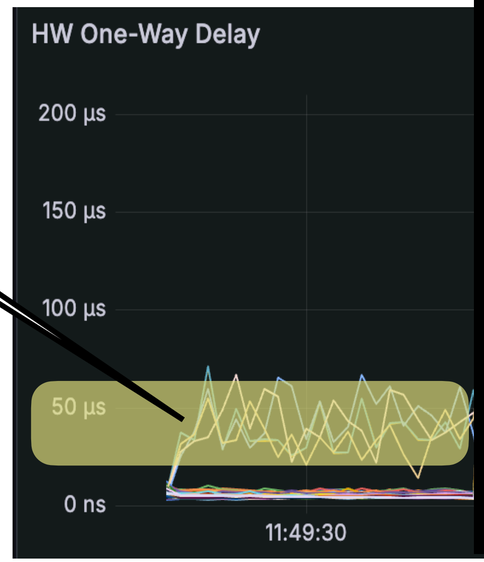
⬇️ Lower Throughput!

Throughput



🐢 Queue pairs with high one way delays!

One-way Delays



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Detecting and eliminating contention on ECMP Test Bed

⬇️ Lower Throughput!

Throughput

🕵🏽‍♂️ Contention!

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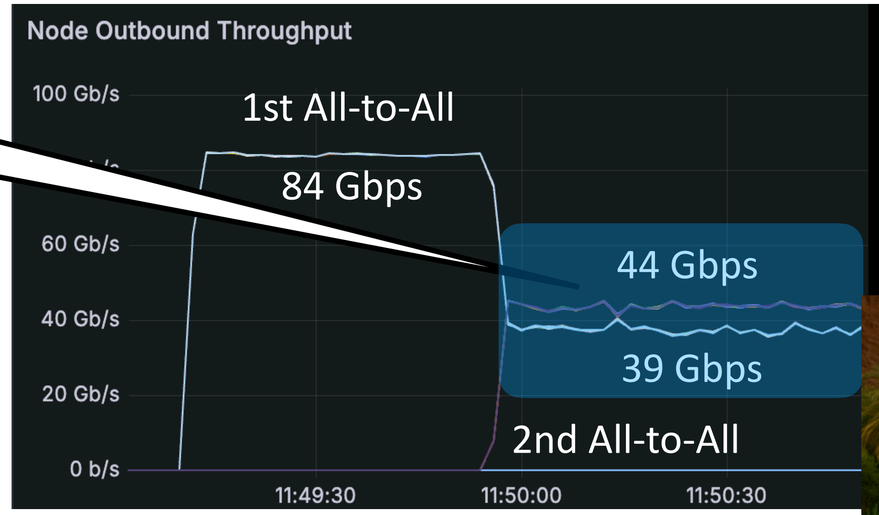
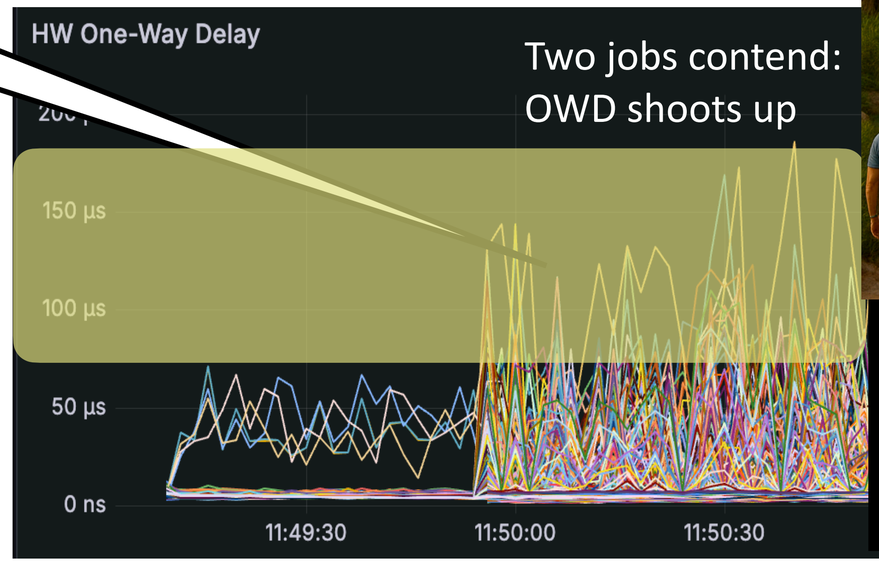
One-way Delays





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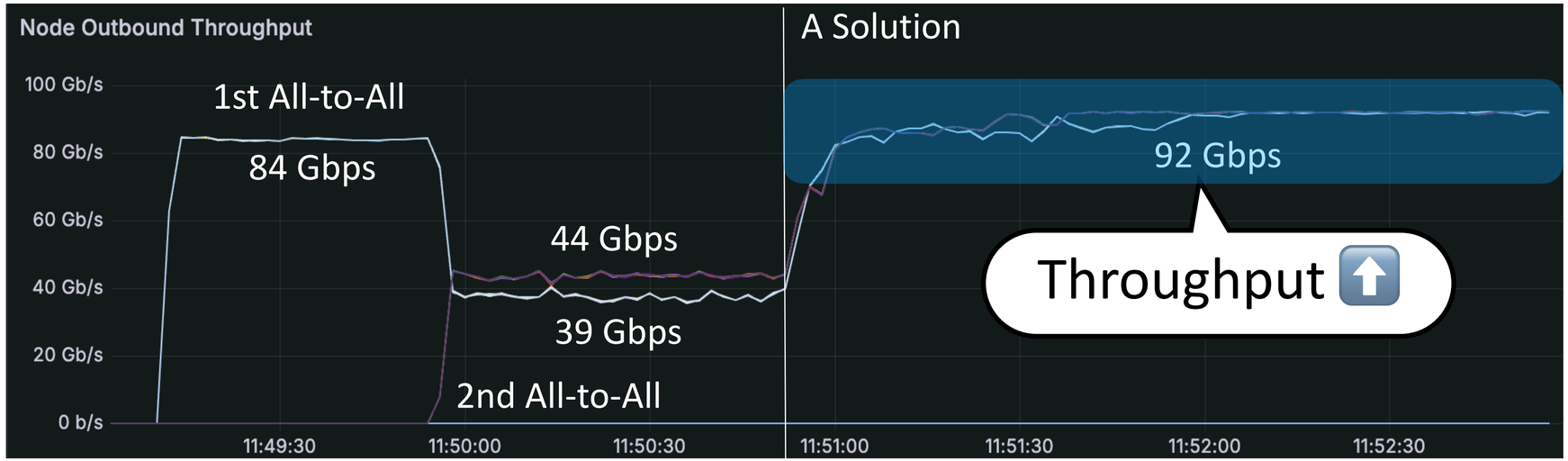

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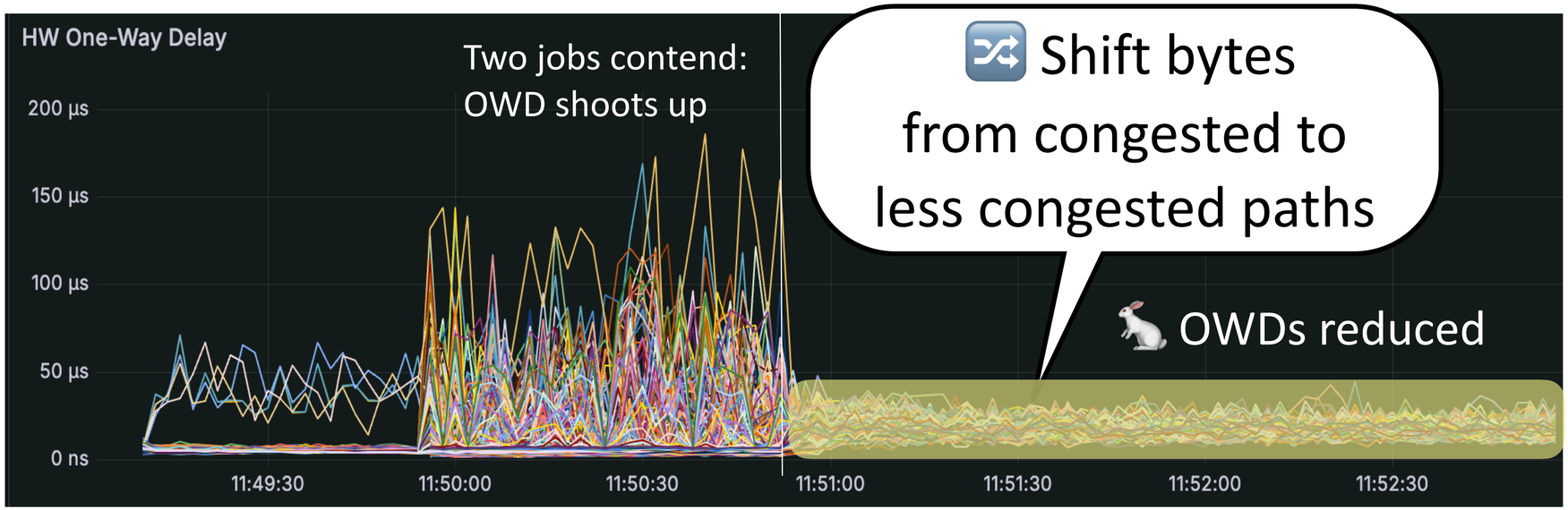

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Key Takeaways

🔎 Fine-grained visibility into queue pairs speeds up diagnosis.

Visibility

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🔎 Fine-grained visibility into queue pairs speeds up diagnosis.

Visibility

Checkpoint to recover from crashes due to NIC/link flapping.

Reliability

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Key Takeaways

🔎 Fine-grained visibility into queue pairs speeds up diagnosis.

Visibility

Checkpoint to recover from crashes due to NIC/link flapping.

Reliability

💨 Delays in slow queue pairs reduce overall job throughput.

Performance

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🏎️🔥 🏁 One **Unified** Circuit, Many Cars 🚗 🏎️ 🚚, Mixed Parts!

- Training 🏎️, inference 🚗 and now storage 🚚 workloads converging on one network.

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- Training 🏎️, inference 🚗 and now storage 🚚 workloads converging on one network.

Ah yes…I see…

less partitioned, and

more UNIFIED AI networks

in your future!

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The Road Ahead

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The Road Ahead

🔥 Efficiency > Speed + Scale

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The Road Ahead

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👋🏽 Bye Monolithic Infra,

🙋🏽‍♀️ Hello Heterogenous Envs

Cross-vendor, mixed generation GPUs, NIC speeds!

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🧠 Smart Cars 🏎️

👁️ Visibility, 💪🏽 reliability, and 💨 performance

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Thank You

Huygens Paper
& Slides

🖖🏽 lerna@clockwork.io

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