ATP: In-network Aggregation for Multi-tenant Learning

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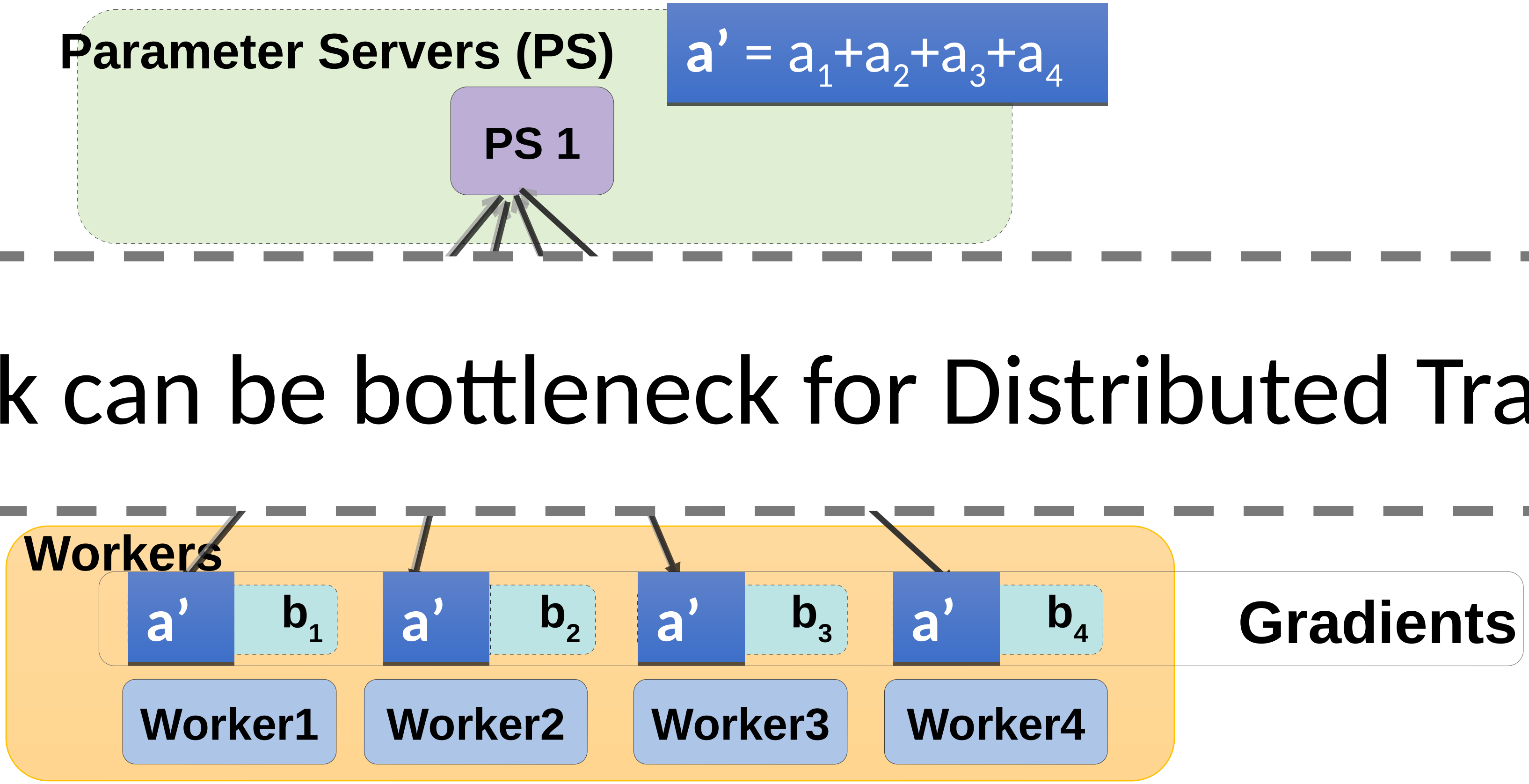
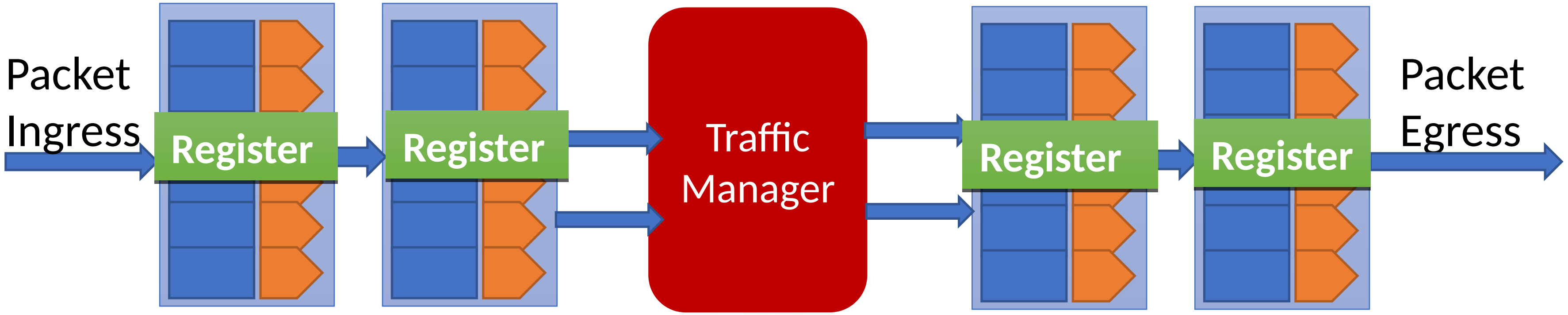
Distributed Training (PS Architecture)



Network can be bottleneck for Distributed Training

Trend of In-network Computation

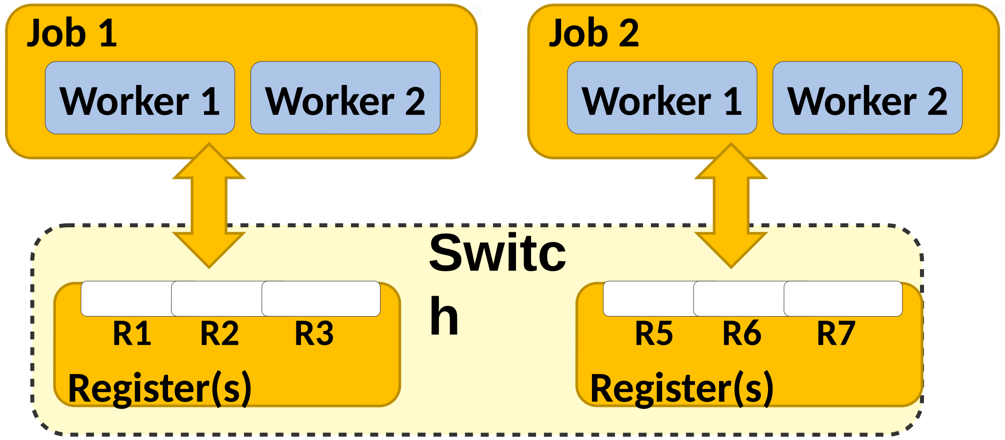
- Programmable switch offers in-transit packet processing and in-network state



- Reduce training time by moving gradient aggregation into the network

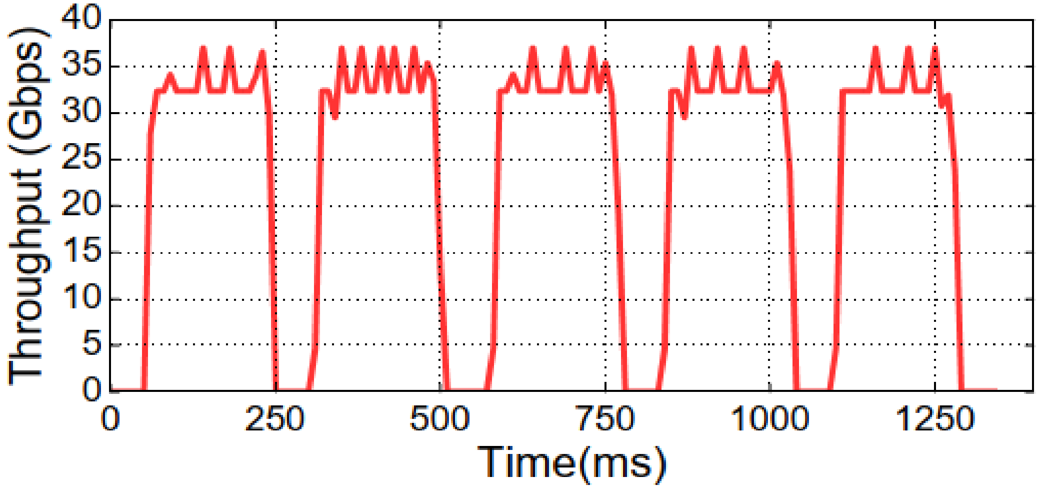
State-of-the-art In-network Aggregation

- SwitchML (Sapio et al. NSDI’21)
  - Target single-rack settings
  - Support multiple jobs by static partitioning of switch resources
- Short comings
  - Inefficiently use the switch resources
  - Does not consider multi-rack setting



BERT-Large Training Times on GPUs

Time	System	Numl
47 min	DGX SuperPOD	92 x [
67 min	DGX SuperPOD	64 x [



Key Goal

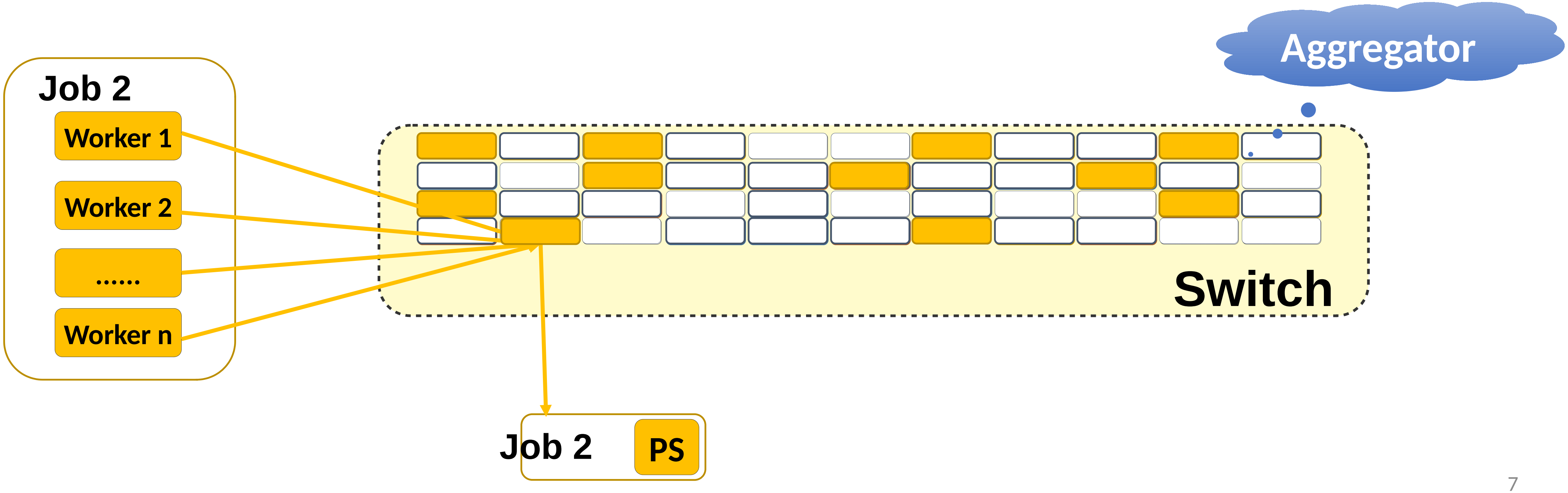
Speed up multiple DT jobs in a cluster while maximizing the benefits from in-network multi-switch aggregation

Outline

- Multi-tenant
- Multi-rack
- Additional challenges
  - Reliability
  - Congestion control
  - Improve floating point computation
- Evaluation

Multi-tenant: dynamic allocation

- Objective: maximize switch resource utilization
- Key idea: dynamic allocation in per-packet level
  - Randomly hash gradient packets to whole memory



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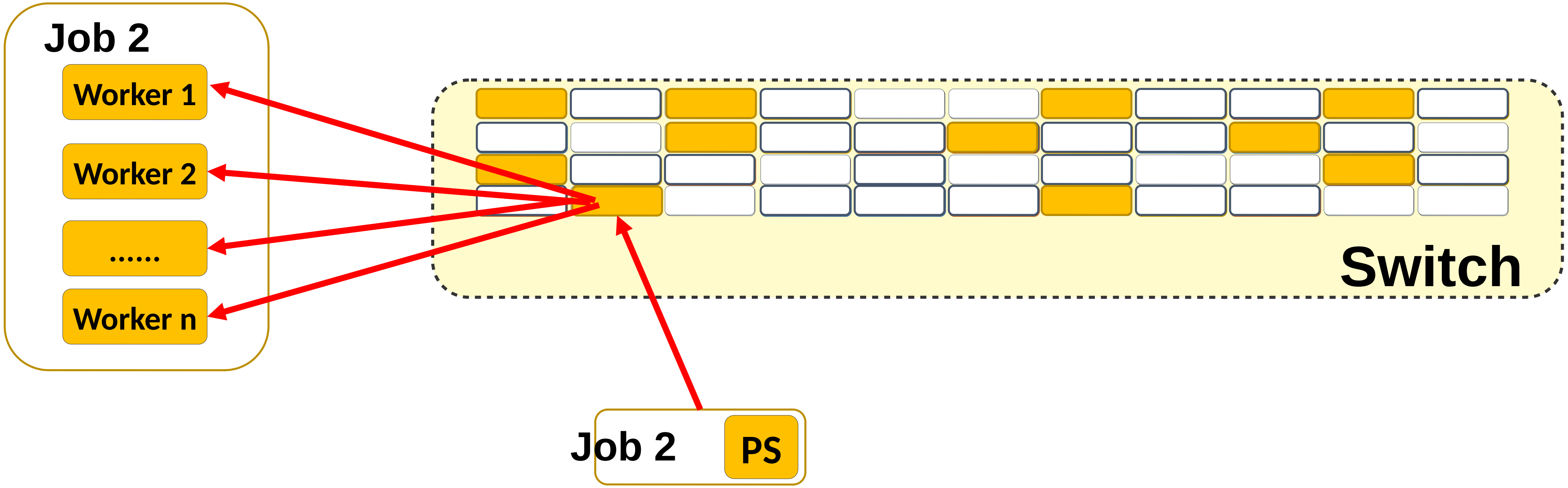
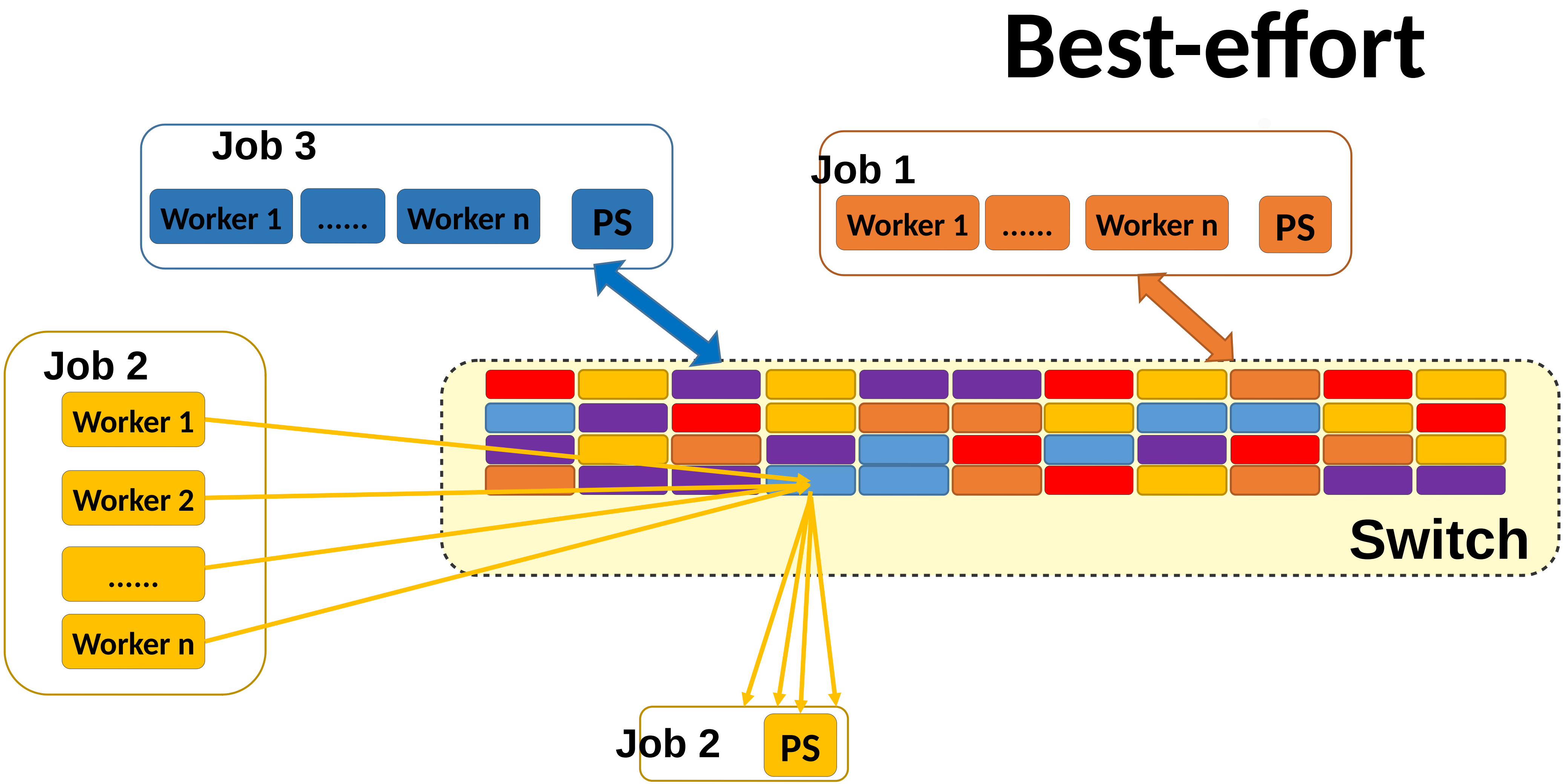


Challenge 1: Heavy Contention



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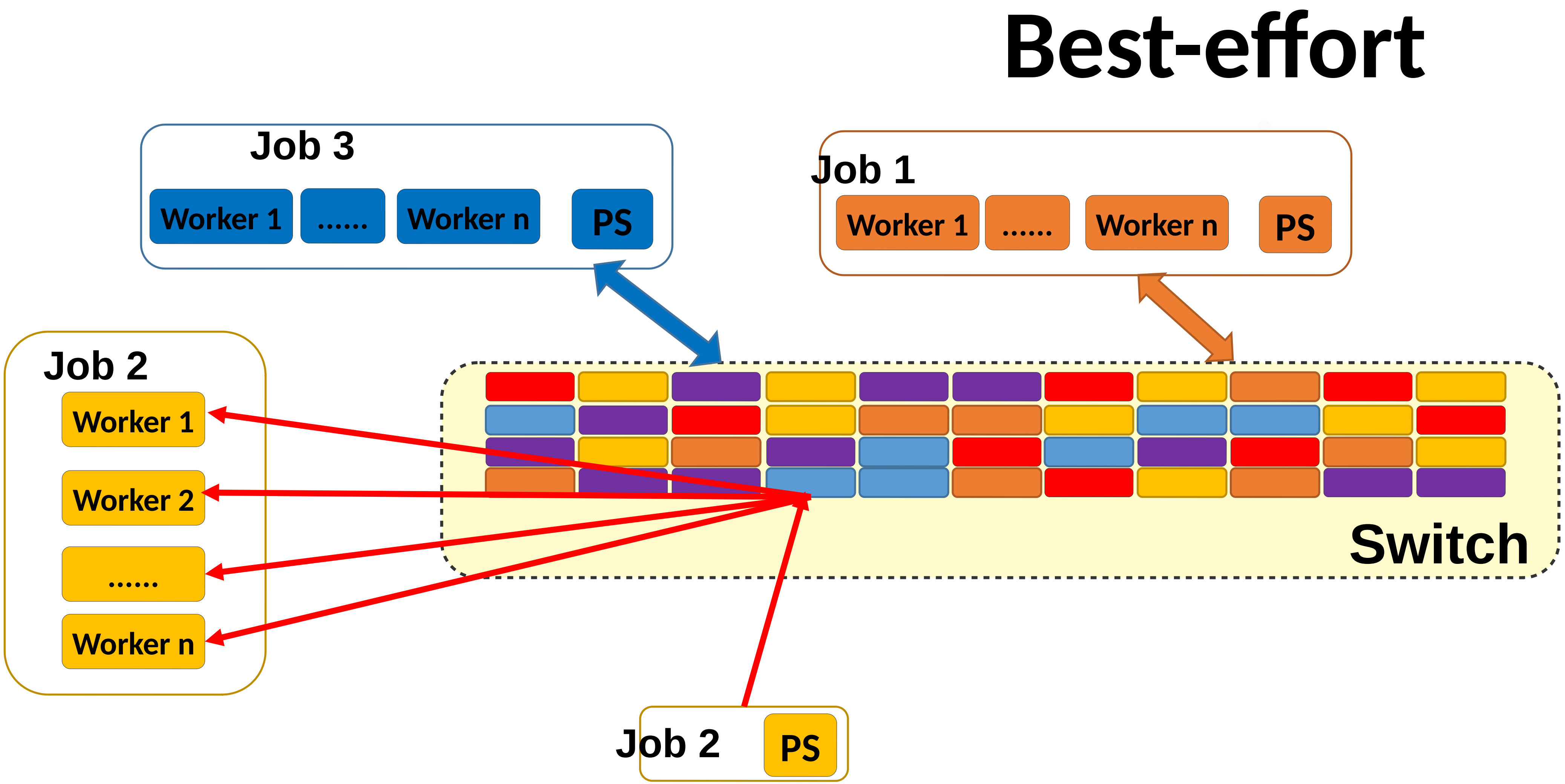
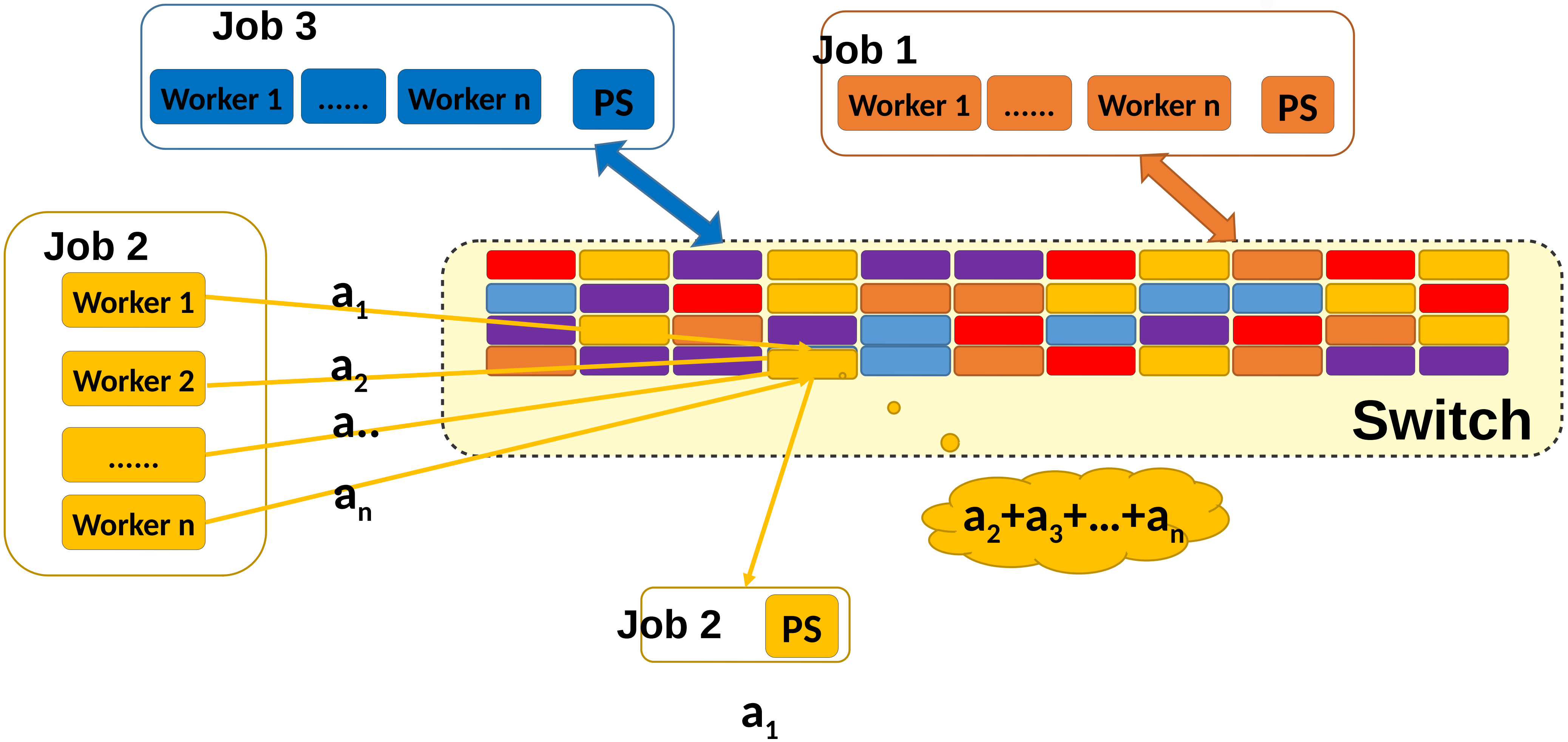


Challenge 2: Incomplete Aggregation



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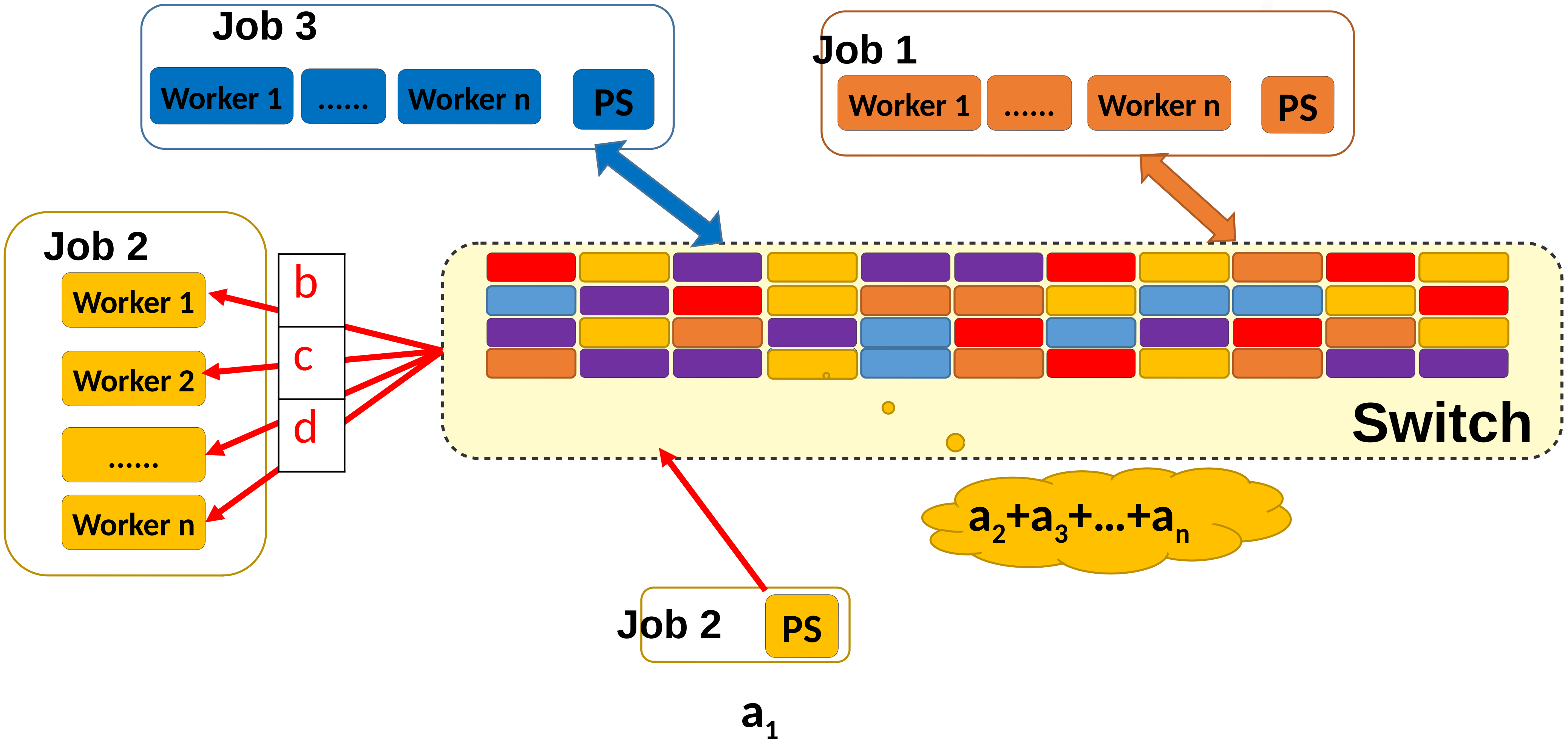

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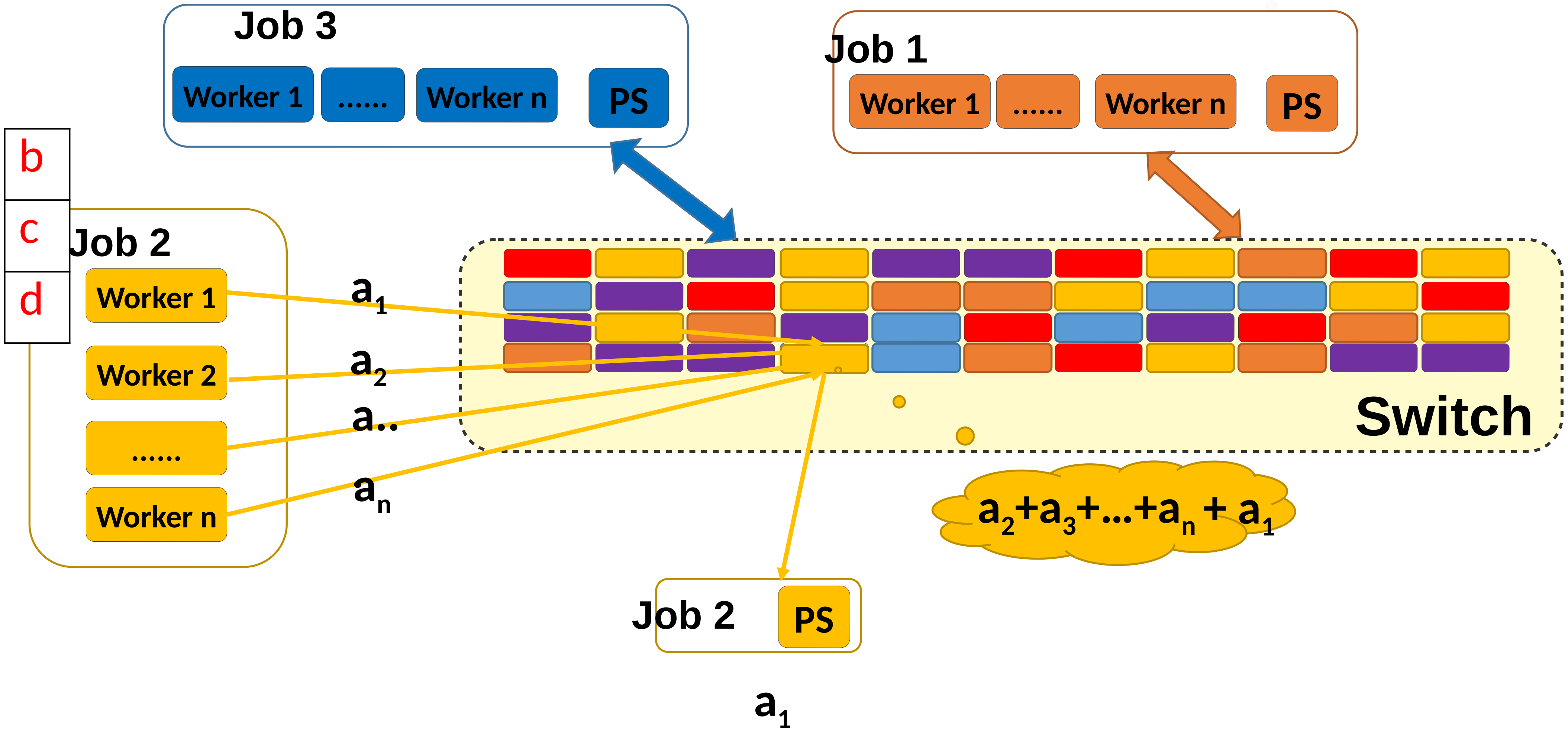
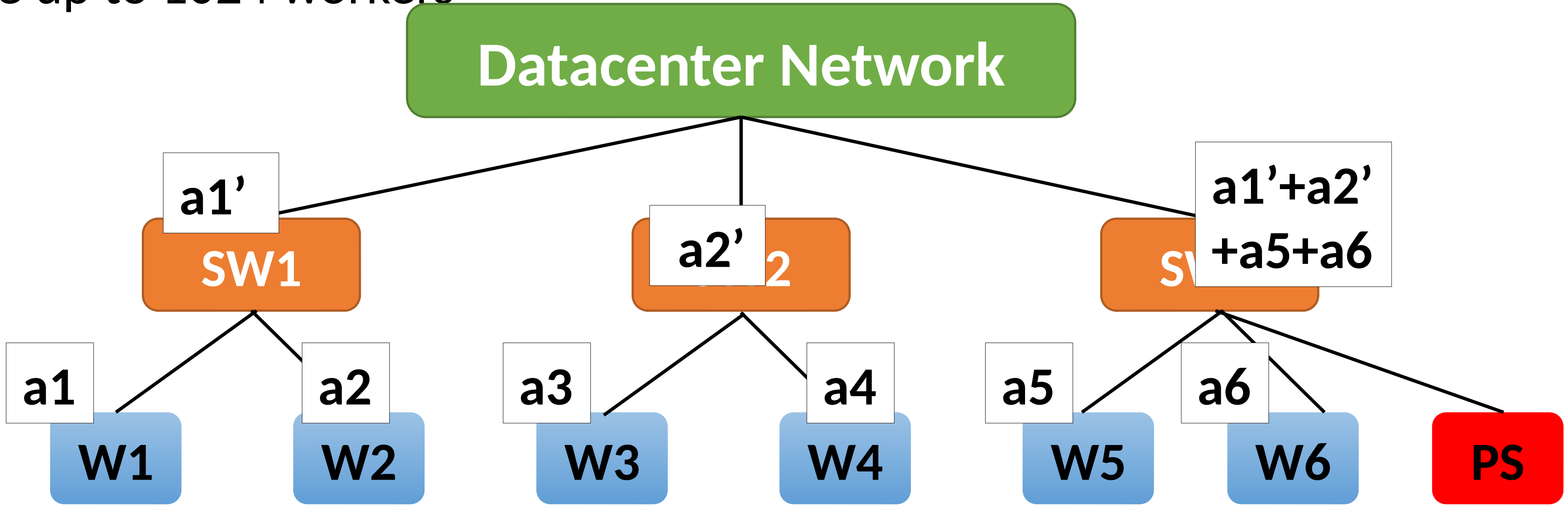


Inter-Rack Aggregation

- Aggregation at every layer of network topology
  - Nondeterministic routing, i.e., ECMP
- Support two-level aggregation at ToR switches
  - Workers and PS(es) locate in different racks
  - Scale up to 1024 workers



Additional Challenges

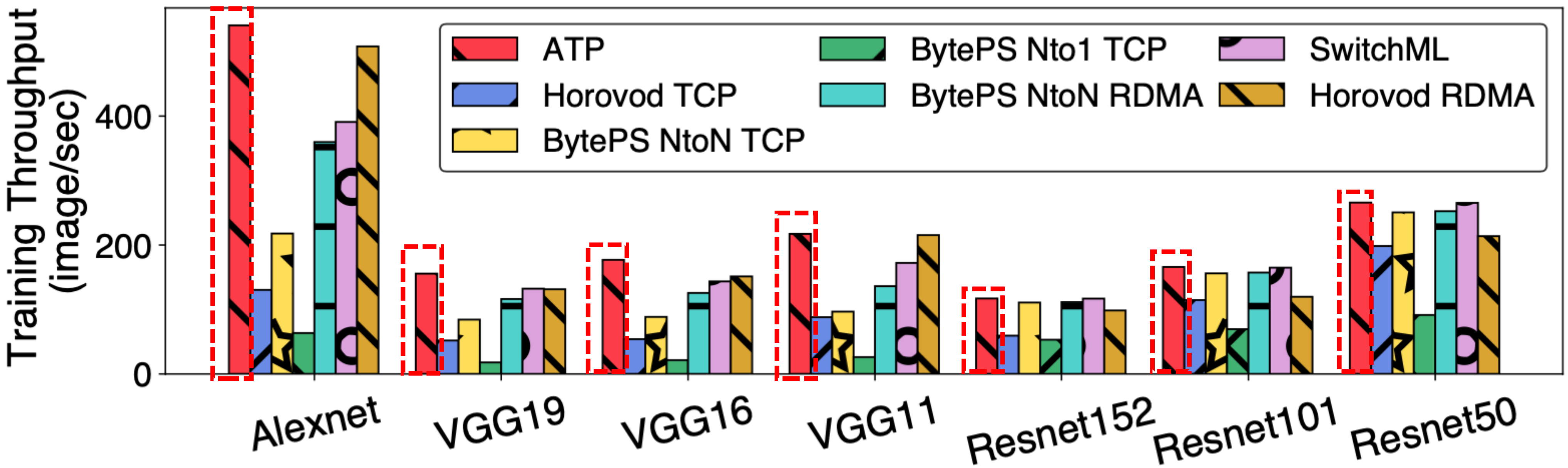
- Rethink reliability
  - Recovery from packet loss
  - Ensure exact once aggregation
  - Memory leak: aggregators are reserved forever, but not used
- Rethink congestion control
  - N flows merged into one flow communication
  - Drop congestion signal, i.e., ECN
- Improve the floating point computation
  - Convert gradients to 32-bit integer at workers by a scaling factor
  - Aggregation overflow at switch

ATP Implementation and Evaluation

- Implementation
  - Replace the networking stack of BytePS at the end host
  - Use P4 to implement the in-network aggregation service at Barefoot Tofino switch

- Evaluation
  - **Setup:** 9 servers, each with one GPU, one 100G NIC
  - **Baseline:** (BytePS + TCP, BytePS+ RDMA) x (Nto1, NtoN), SwitchML, Horovod+RDMA, Horovod+TCP
  - **Metrics:** Training Throughput, Time-to-Accuracy
  - **Workloads:** AlexNet, VGG11, VGG16, VGG19, ResNet50, ResNet101, and ResNet152

Single Job Performance



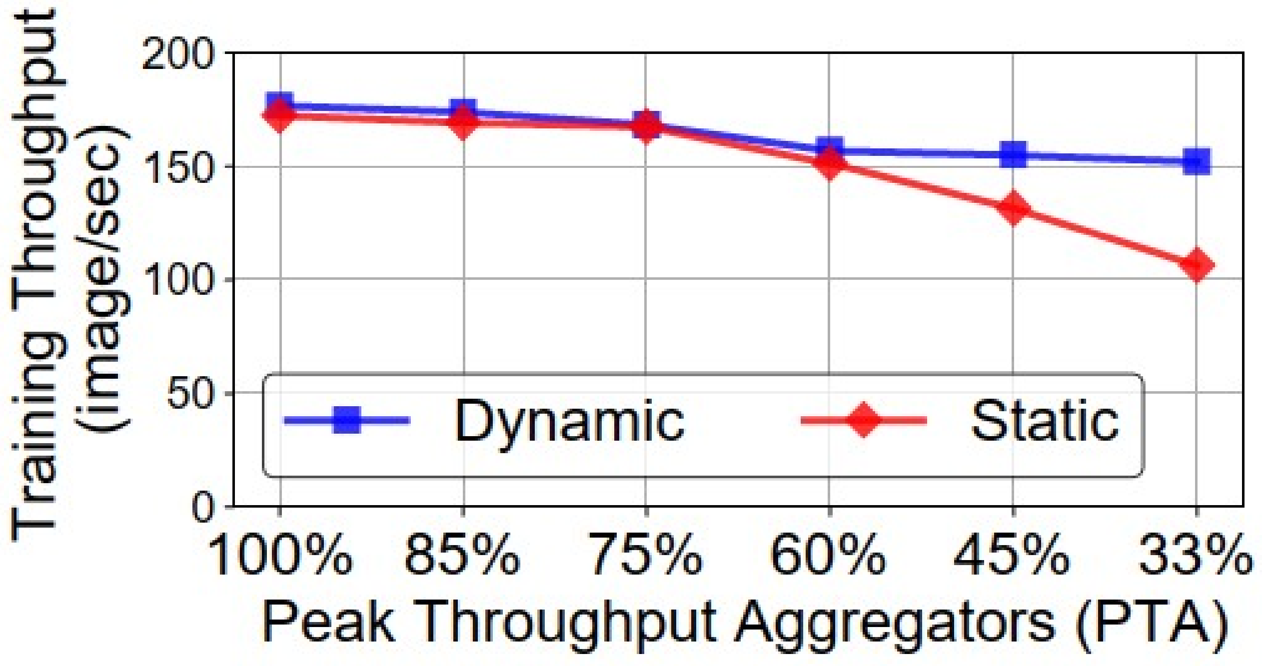
ATP is comparable to, and outperforms the state-of-the-art approaches.
ATP gets larger performance gains on network-intensive workloads (VGG) than the computation-intensive workloads (ResNet).

Multiple Jobs: dynamic (ATP) vs static

- 3 VGG16 Jobs
- Static approach evenly distributes

More evaluations about **packet loss**
congestion control in various scena

achieve the peak aggregation throughput



When switch memory is sufficient, ATP's dynamic ≈ static
When switch memory is insufficient, ATP's dynamic > static

Summary

- A network service that supports best-effort, dynamic in-network aggregation aimed at multi-rack, multi-tenant

- Co-design end-host and switch logic
  - Reliability
  - Congestion control
  - Dealing with floating point

Opensource: https://github.com/in-ATP/ATP

Thank You!

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