PORTEND: A Joint Performance Model for Partitioned Early-Exiting DNNs

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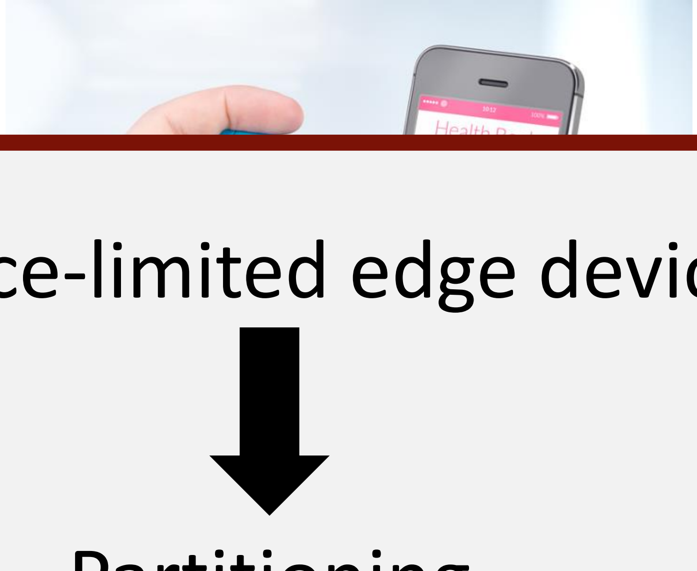
Edge and mobile applications, need fast DNN inference

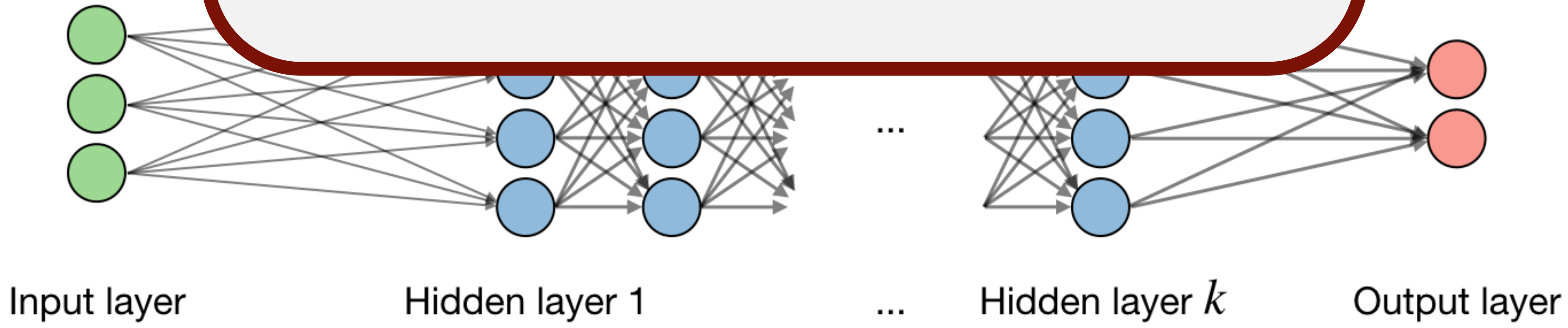


Resource-limited edge devices

↓

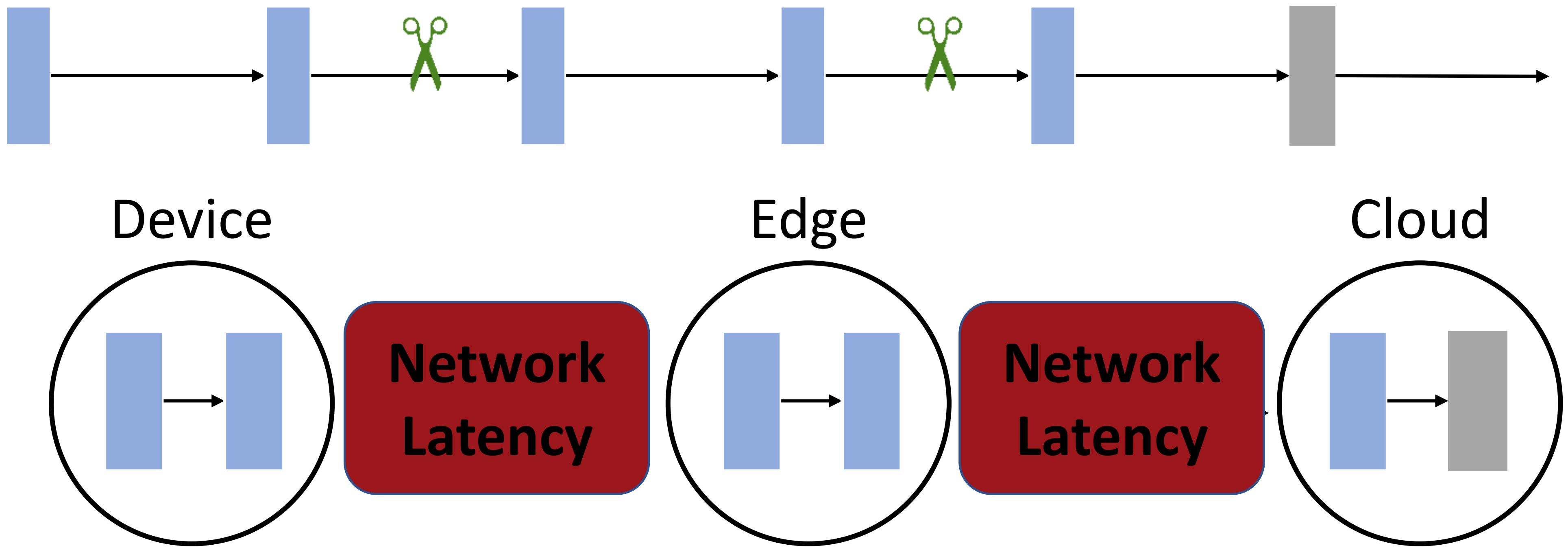
Partitioning

Early Exit



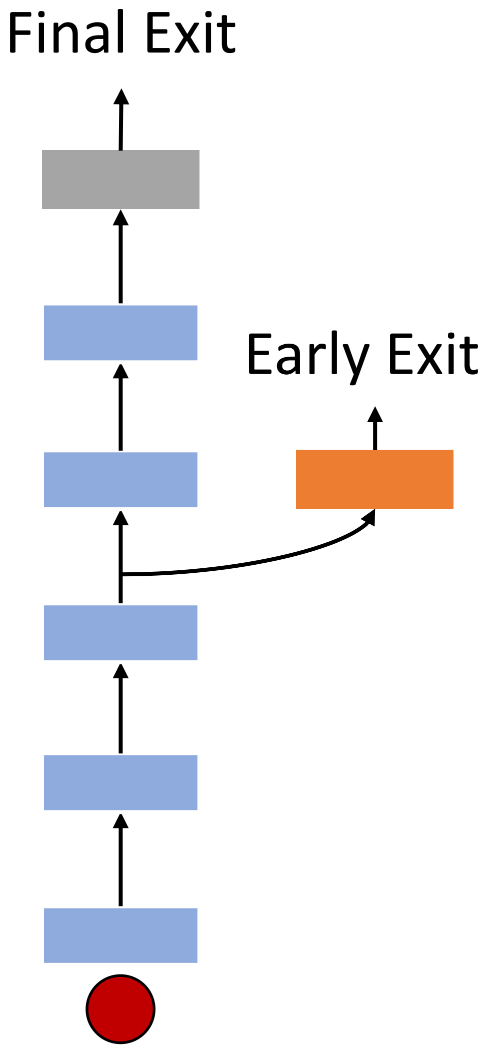
Background: Partitioning

Split pre-trained DNN across multiple servers



This approach trades-off computation time for network latency

Background: Early Exit



Add early exit branches as auxiliary classifiers

Use entropy to measure the confidence of the prediction

Entropy(output) < Threshold ⟶ Exit

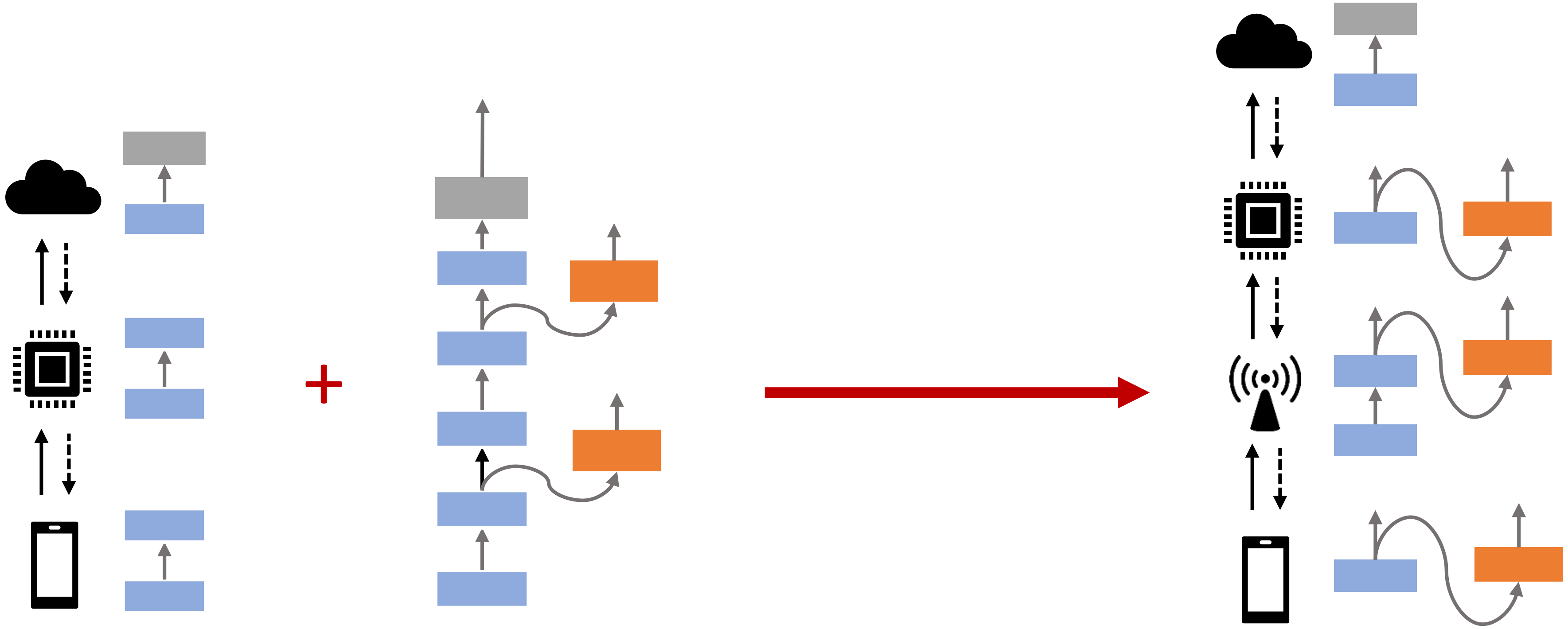
Entropy(output) > Threshold ⟶ Stay

This approach trades-off accuracy for computation latency

Combining DNN partitioning and early exit

Consider partitioning and early exit holistically

- A performance model that jointly optimizes them



Partitioning

Early Exit

Partitioning + Early Exit

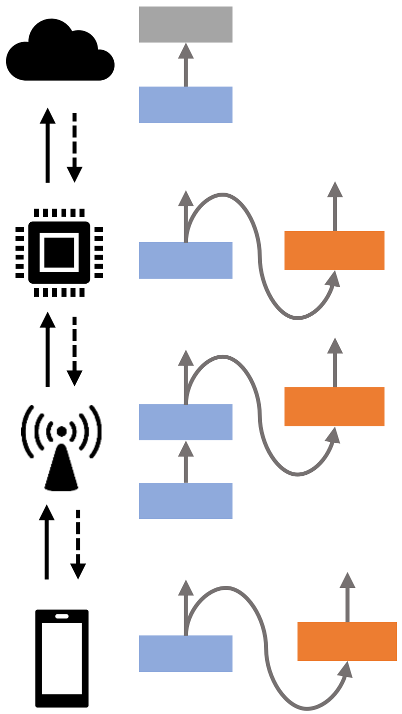
Combining DNN partitioning and early exit

1. Where to *partition* the model

   and attach the early exit branches?

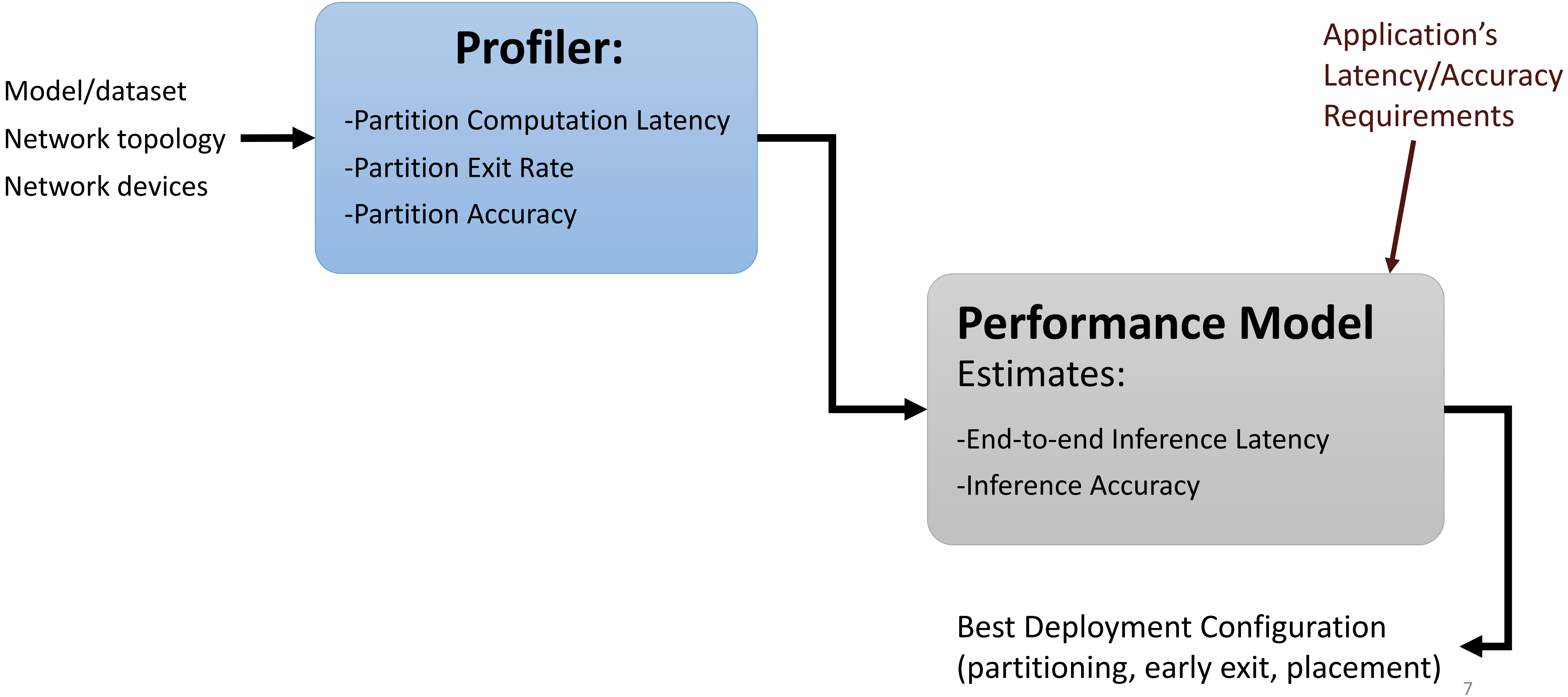
2. How to *place* these partitions on network devices?

- Calculate the inference latency and accuracy
- Objective: minimizing latency/maximizing accuracy



Partitioning + Early Exit

PORTEND



Model/dataset

Network topology

Network devices

Profiler:

-Partition Computation Latency

-Partition Exit Rate

-Partition Accuracy

Application’s
Latency/Accuracy
Requirements

Performance Model

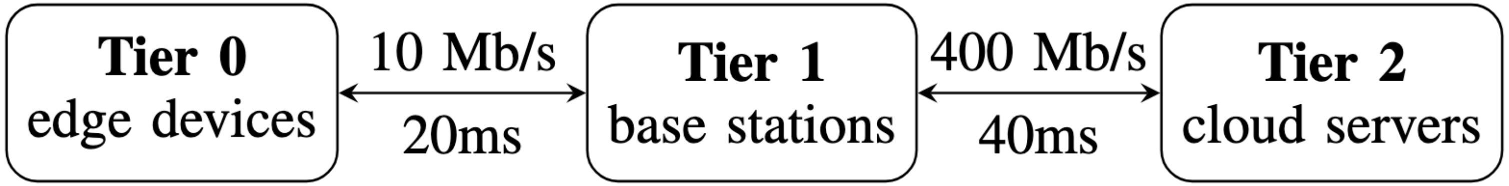
Estimates:

-End-to-end Inference Latency

-Inference Accuracy

Best Deployment Configuration
(partitioning, early exit, placement)

Experimental Setup



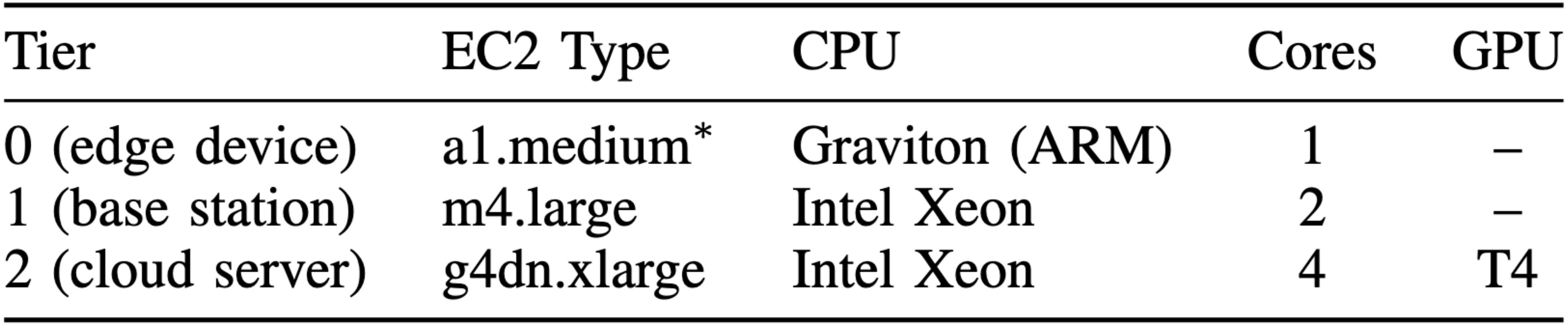
Tier 0 edge devices

10 Mb/s 20ms

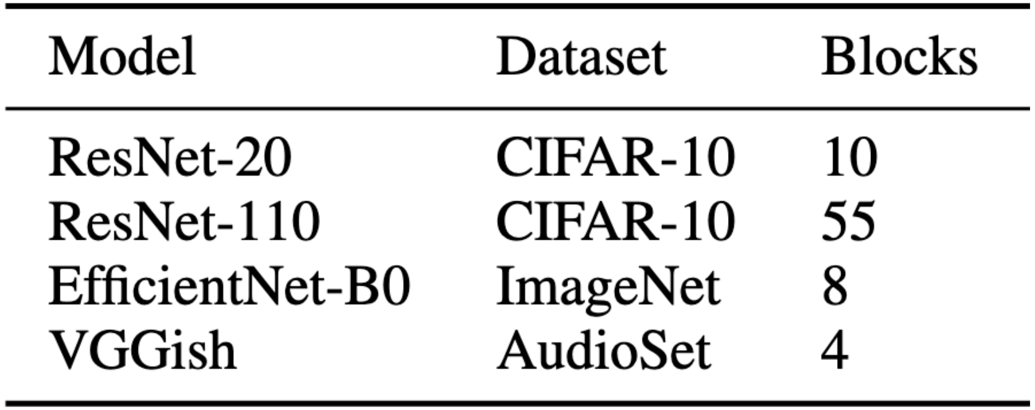
Tier 1 base stations

400 Mb/s 40ms

Tier 2 cloud servers

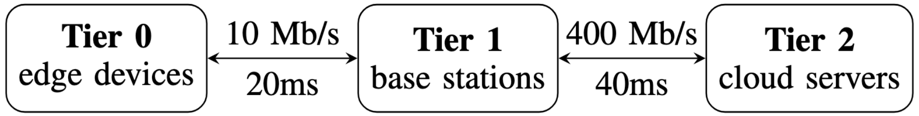


Tier	EC2 Type	CPU	Cores	GPU
0 (edge device)	a1.medium*	Graviton (ARM)	1	–
1 (base station)	m4.large	Intel Xeon	2	–
2 (cloud server)	g4dn.xlarge	Intel Xeon	4	T4



Model	Dataset	Blocks
ResNet-20	CIFAR-10	10
ResNet-110	CIFAR-10	55
EfficientNet-B0	ImageNet	8
VGGish	AudioSet	4

Benefits of Multiple Partitions - ResNet-110



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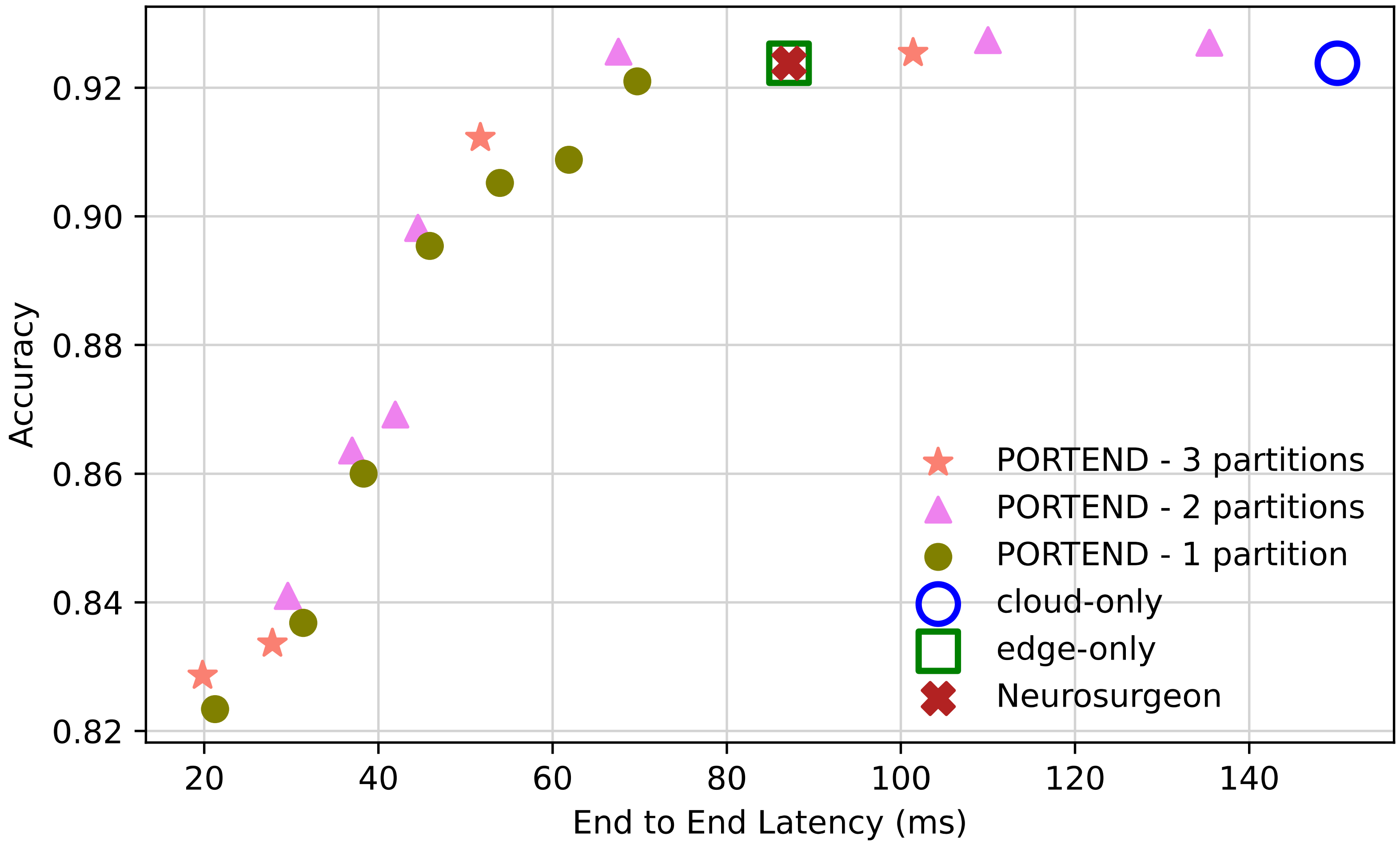
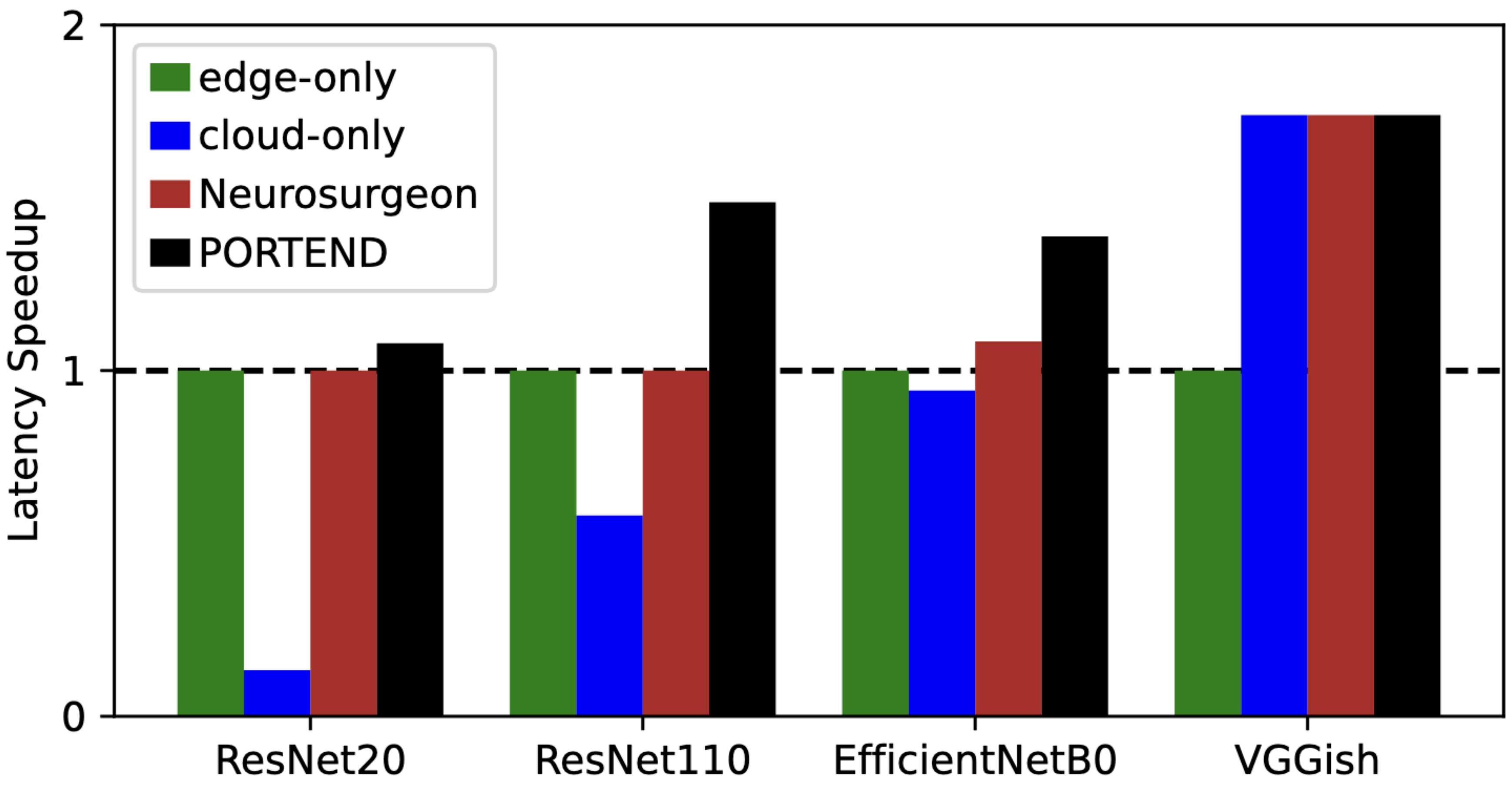
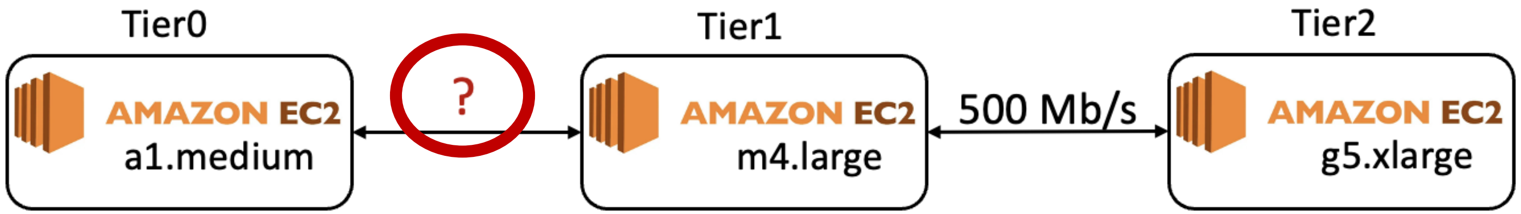


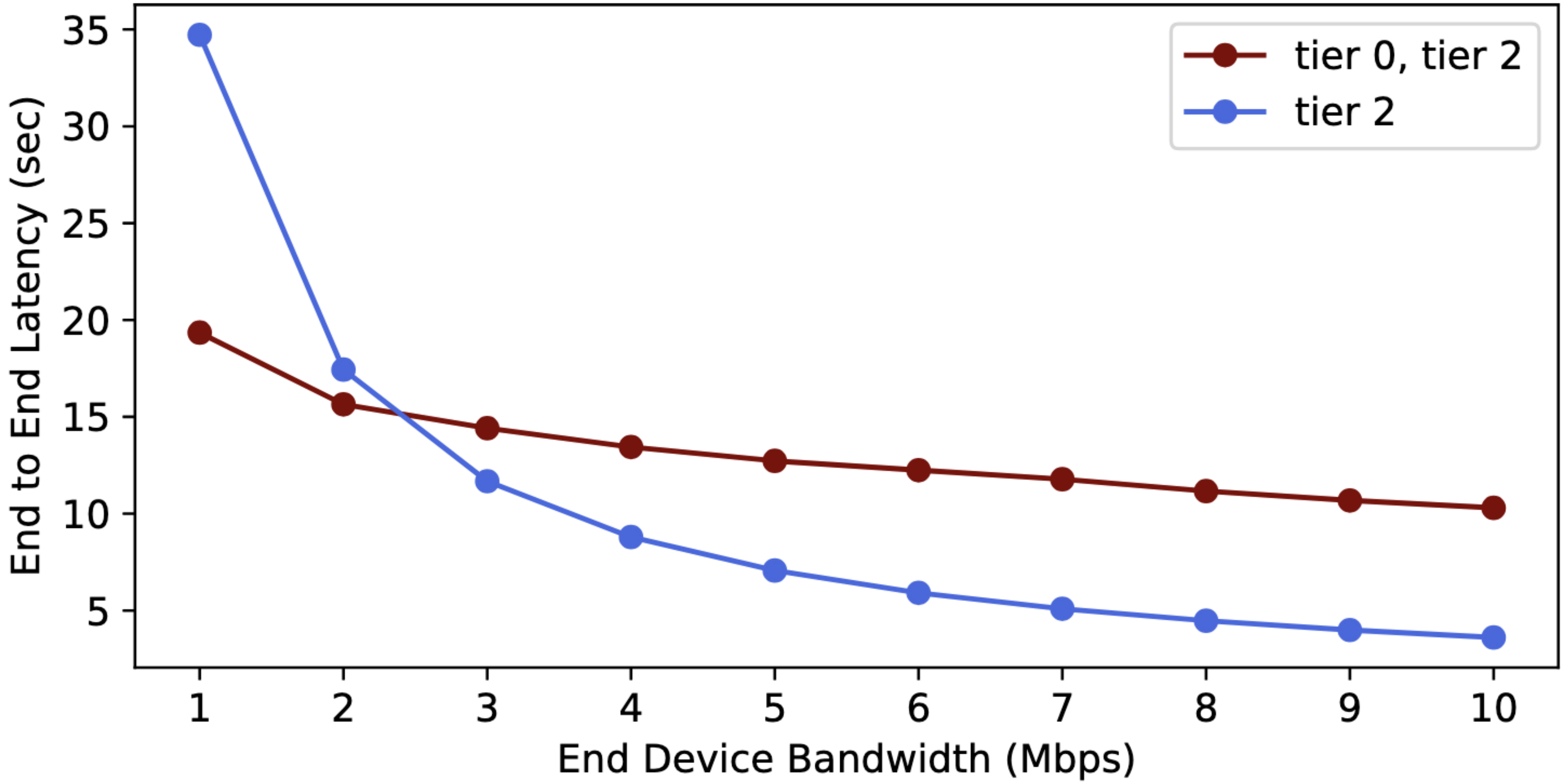
PORTEND Latency Speed-up



Exploring Hypothetical Scenarios

Reducing Bandwidth – EfficientNetB7





Conclusions & Future Work:

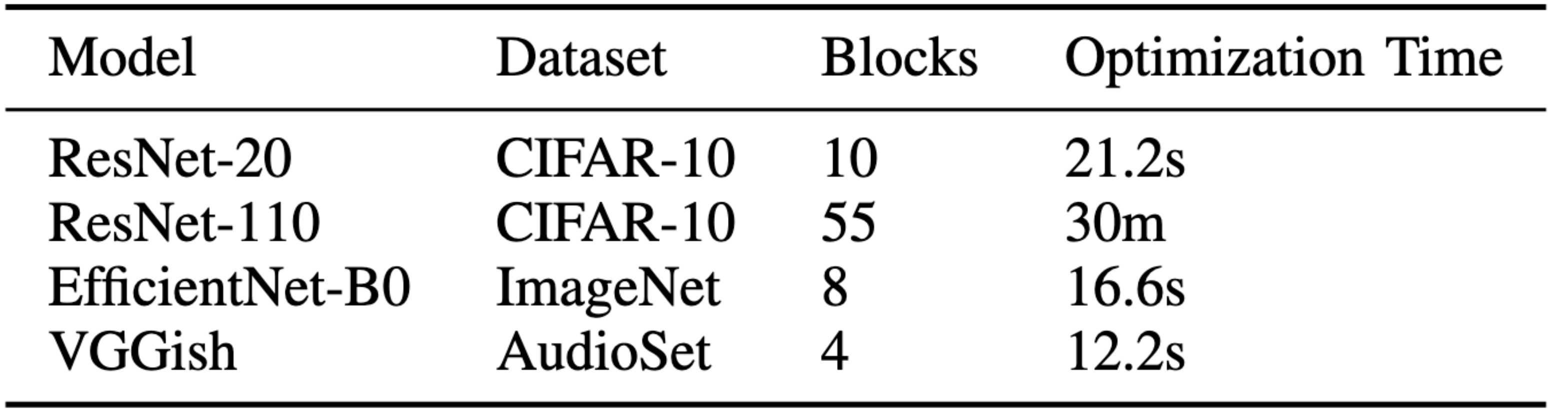
1. Considering multiple partitions with early exits improves the latency-accuracy trade-off.
2. Considering flexible placement is necessary.
3. Future work:
   1. Model compression and quantization
   2. Dynamic scheduling environment

Thank you!

Questions?

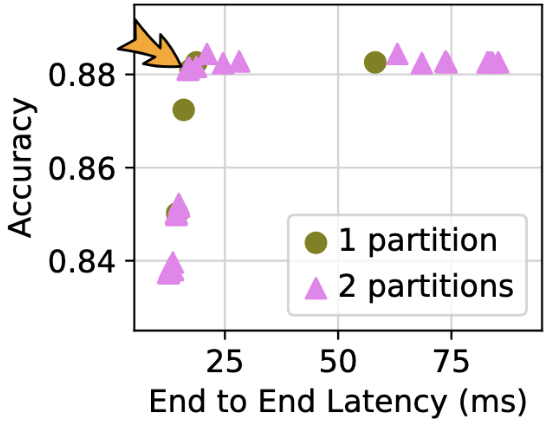
Experimental Setup

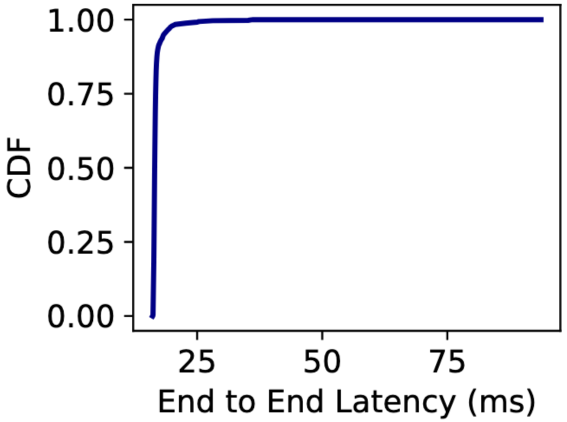
Image and Audio Classification Models

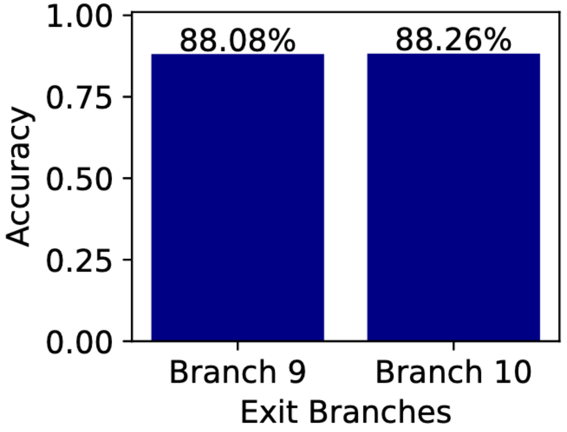


Model	Dataset	Blocks	Optimization Time
ResNet-20	CIFAR-10	10	21.2s
ResNet-110	CIFAR-10	55	30m
EfficientNet-B0	ImageNet	8	16.6s
VGGish	AudioSet	4	12.2s

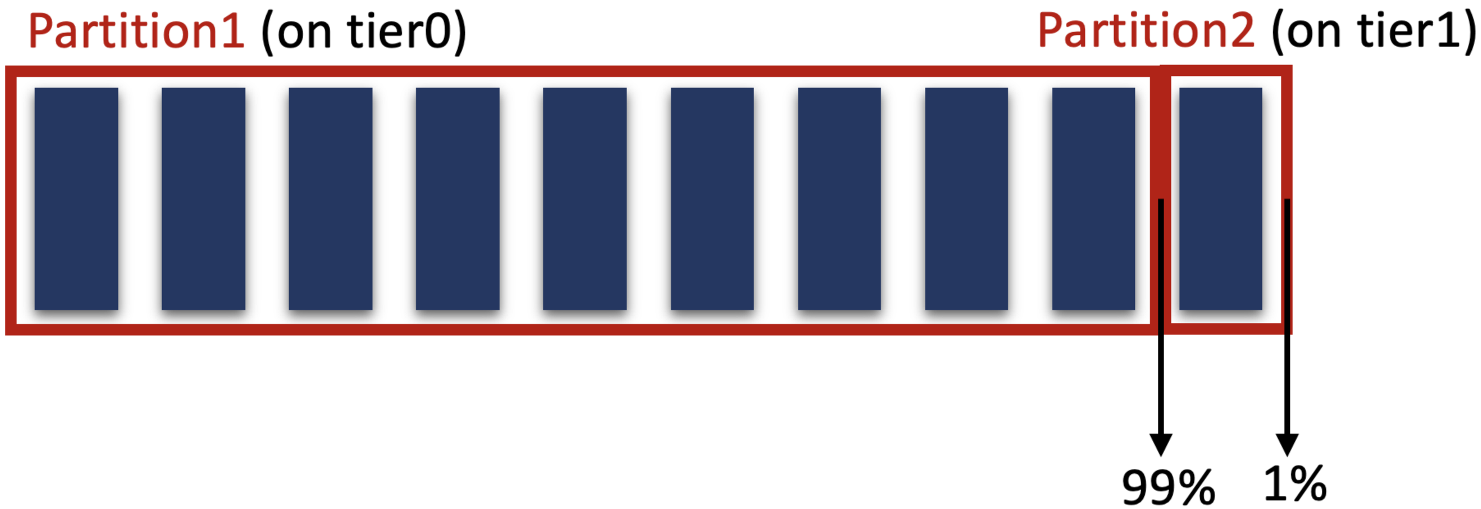
Finding Optimal Configurations- ResNet20







Model	Tiers [blocks]	Threshold	Exit rates
ResNet-20	0 [1–9] , 1 [10]	0.7	99% , 1%



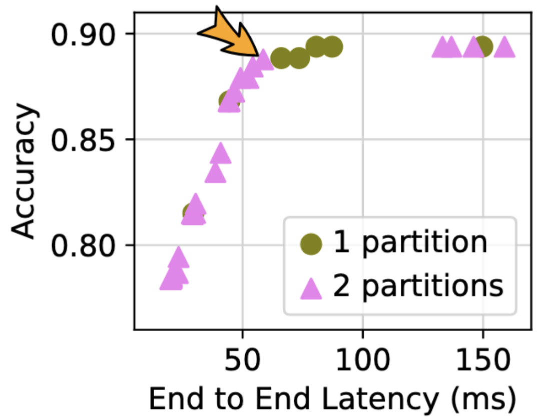
Partition1 (on tier0)

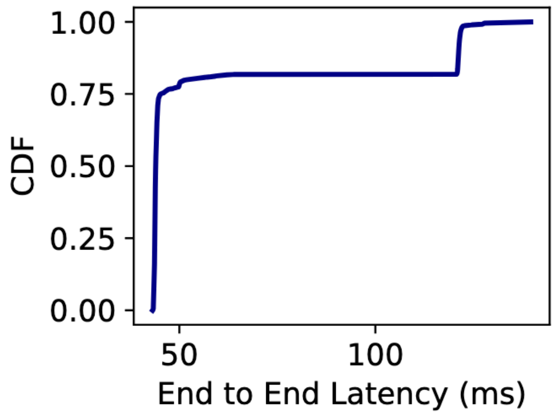
Partition2 (on tier1)

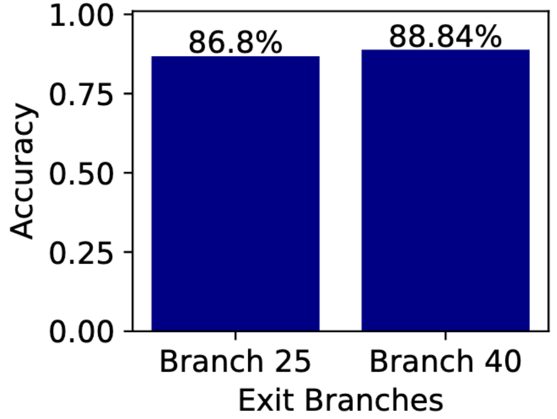
99%

1%

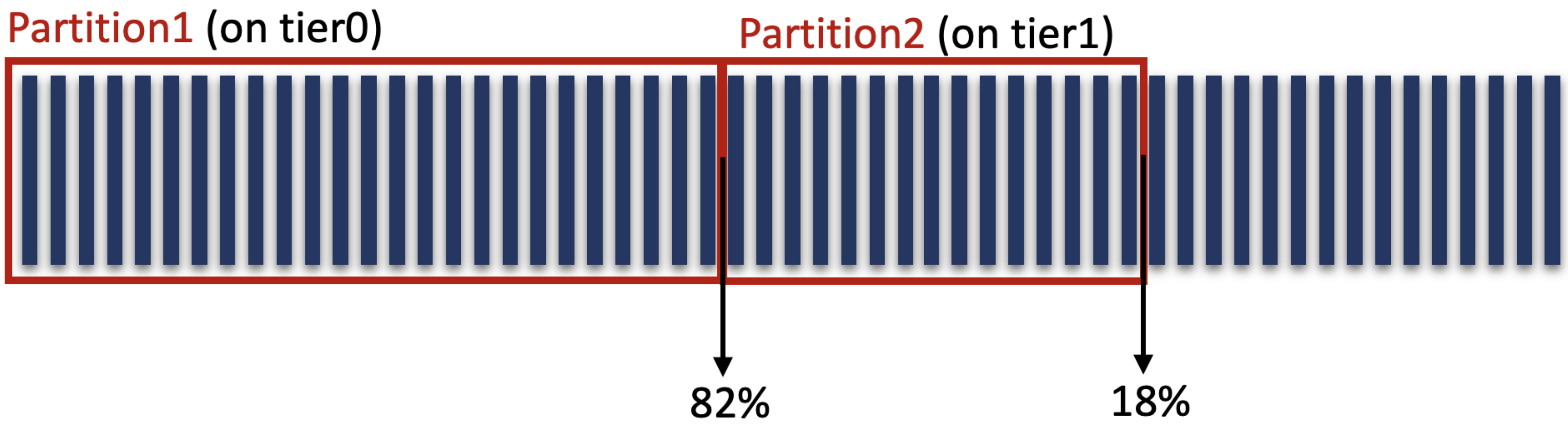
Finding Optimal Configurations- ResNet110







Model	Tiers [blocks]	Threshold	Exit rates
ResNet-110	0 [1–25] , 1 [26–40]	0.1	82% , 18%



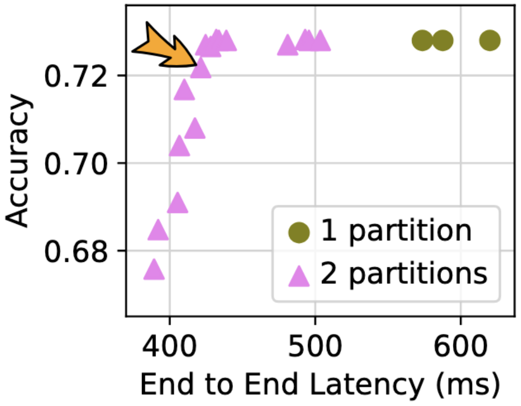
Partition1 (on tier0)

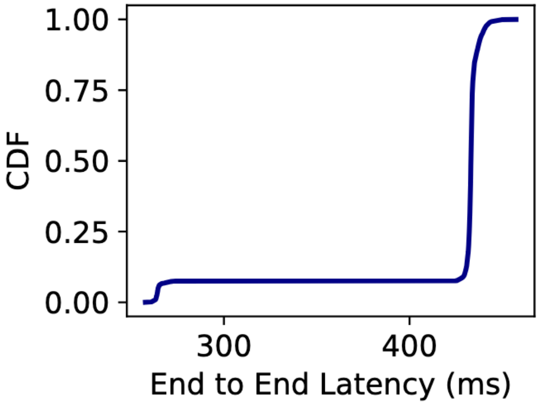
Partition2 (on tier1)

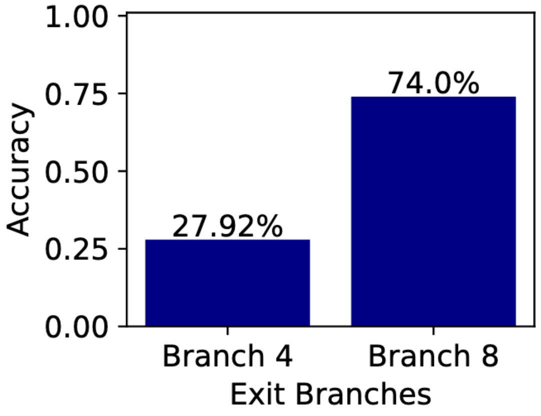
82%

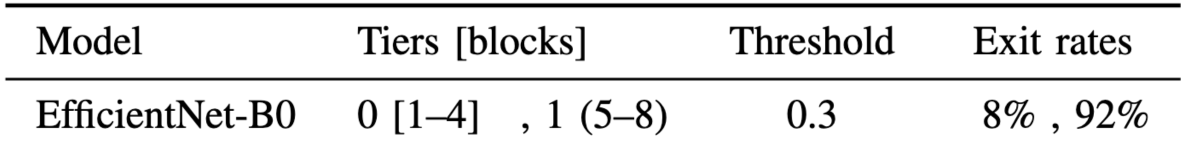
18%

Finding Optimal Configurations- EfficientNetB0

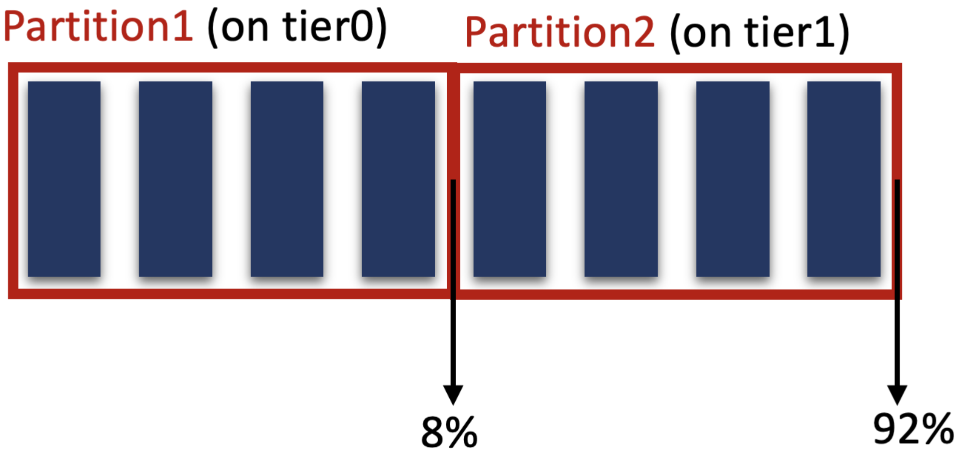








Model	Tiers [blocks]	Threshold	Exit rates
EfficientNet-B0	0 [1–4] , 1 (5–8)	0.3	8% , 92%



Partition1 (on tier0)

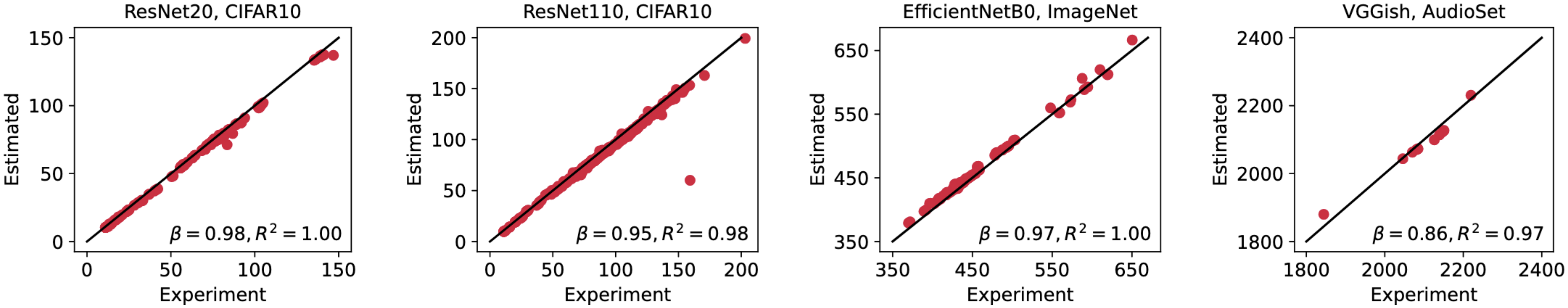
Partition2 (on tier1)

8%

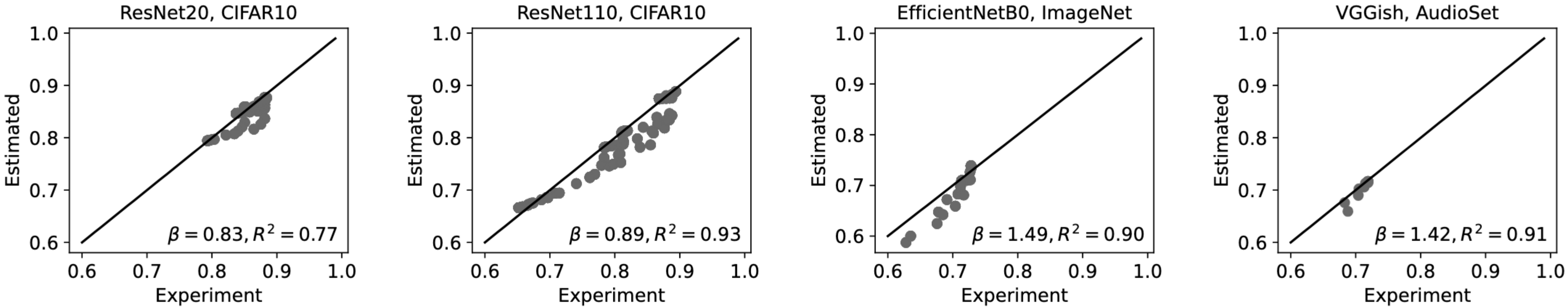
92%

Validity of the Performance Model

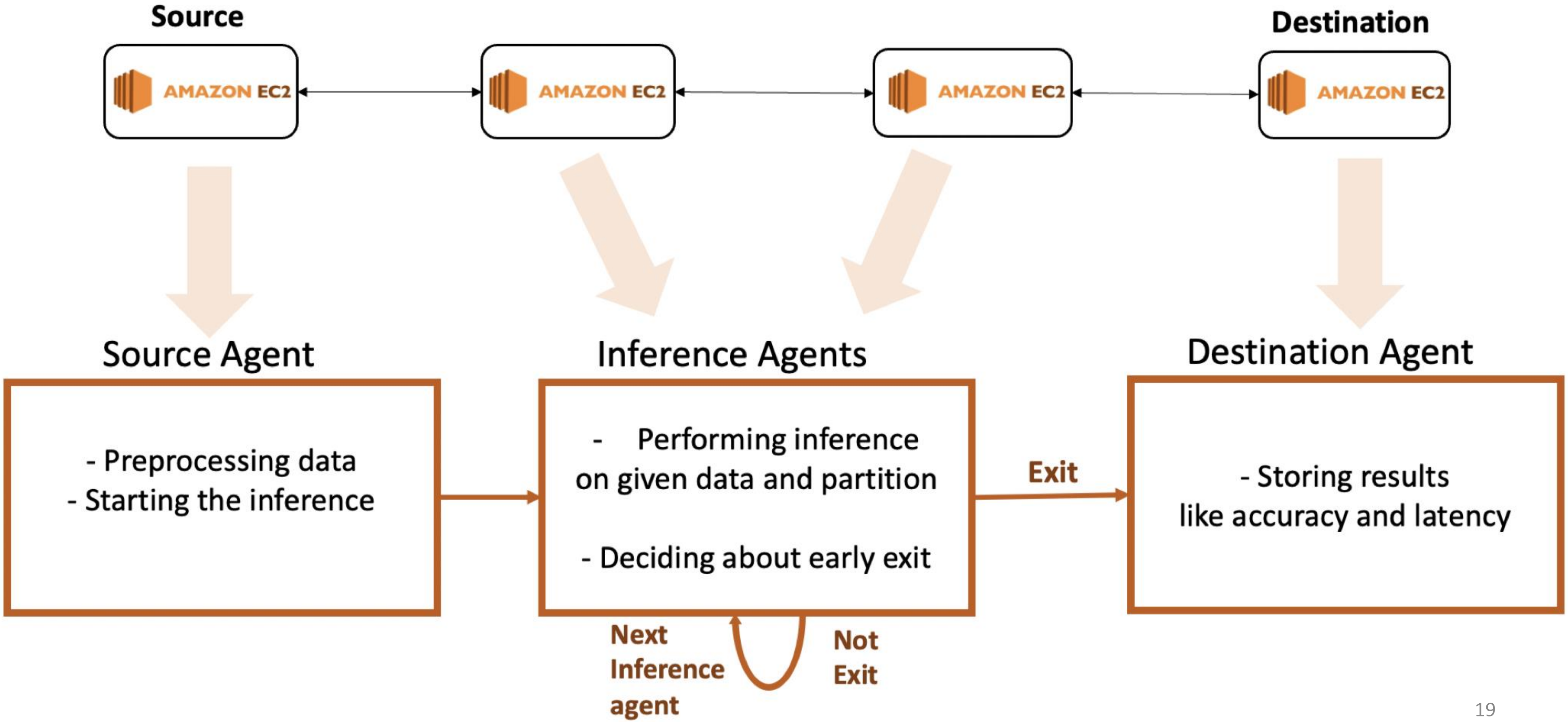
End-to-End Inference Latency



Inference Accuracy



Experimental Setup



Source Agent

- Preprocessing data
- Starting the inference

Inference Agents

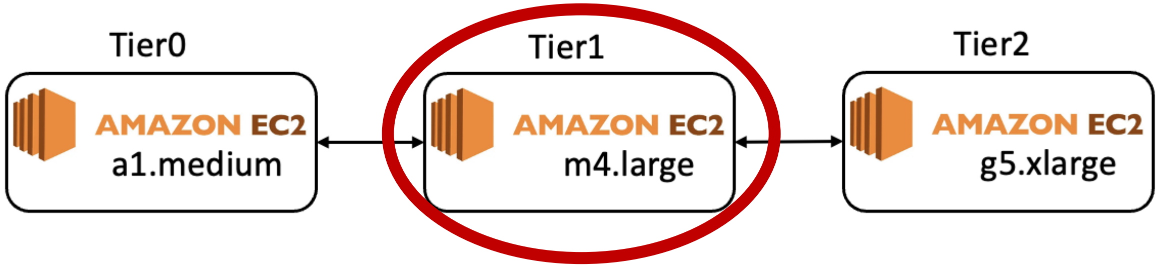
- Performing inference on given data and partition
- Deciding about early exit

Destination Agent

- Storing results like accuracy and latency

Exploring Hypothetical Scenarios

Increasing Compute Power – EfficientNetB7



Tier0

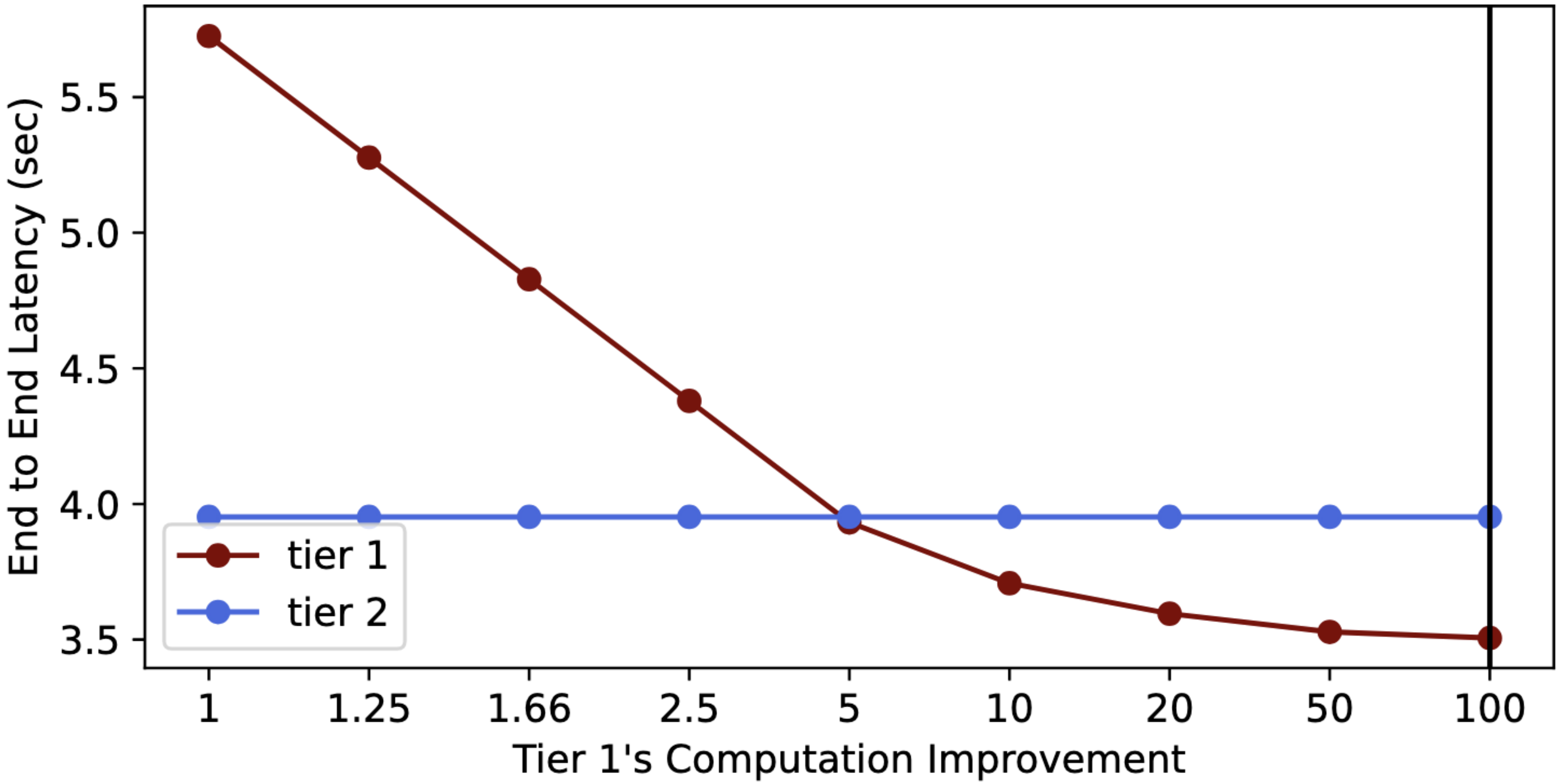
AMAZON EC2
a1.medium

Tier1

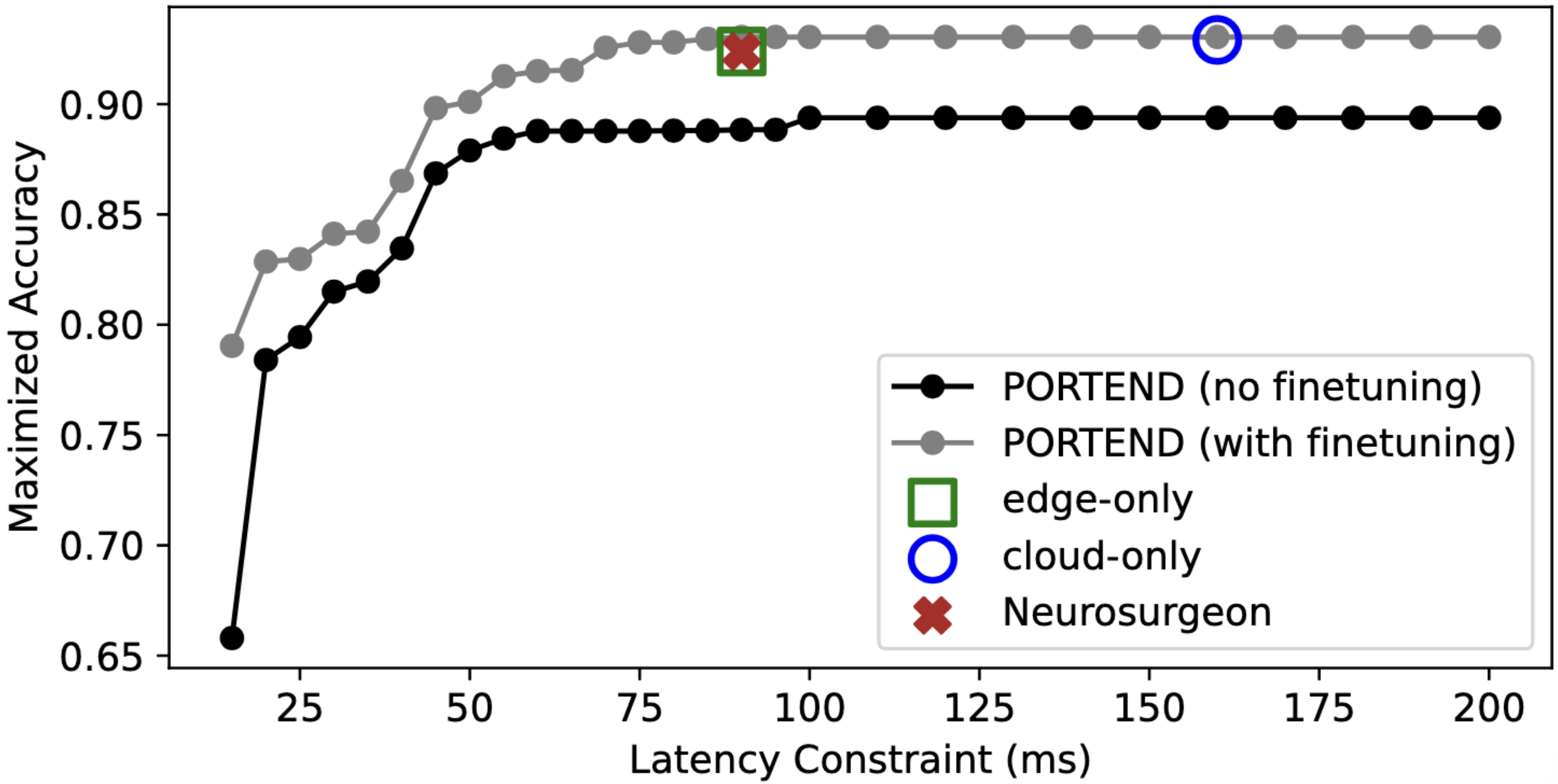
AMAZON EC2
m4.large

Tier2

AMAZON EC2
g5.xlarge



Effect of Fine-Tuning on final models


Maximized Accuracy
Latency Constraint (ms)
PORTEND (no finetuning)
PORTEND (with finetuning)
edge-only
cloud-only
Neurosurgeon