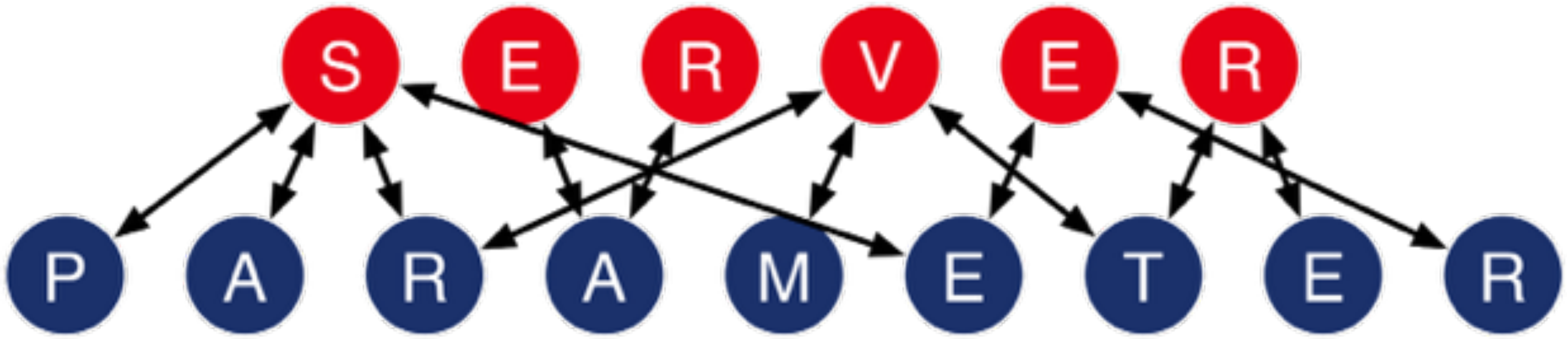
Scaling Distributed Machine Learning with the



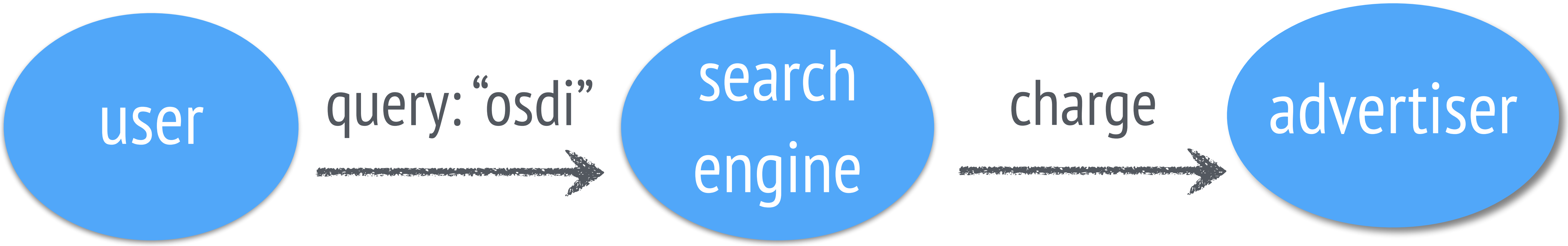
Mu Li

muli@cs.cmu.edu

CARNEGIE MELLON UNIVERSITY PITTSBURGH PENNSYLVANIA 1900

Baidu 百度

Google



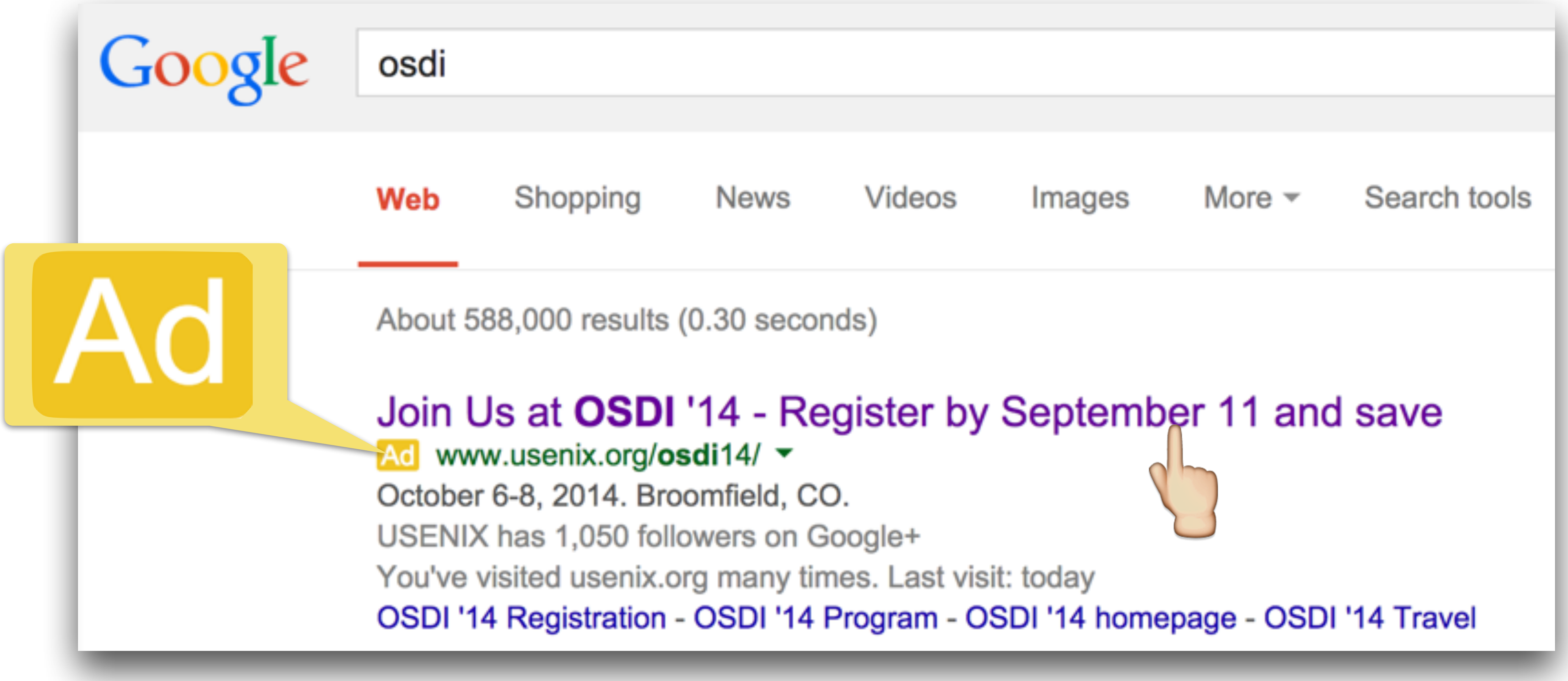
user

query: “osdi”

search engine

charge

advertiser



About 588,000 results (0.30 seconds)

Join Us at **OSDI** '14 - Register by September 11 and save

Ad www.usenix.org/**osdi**14/

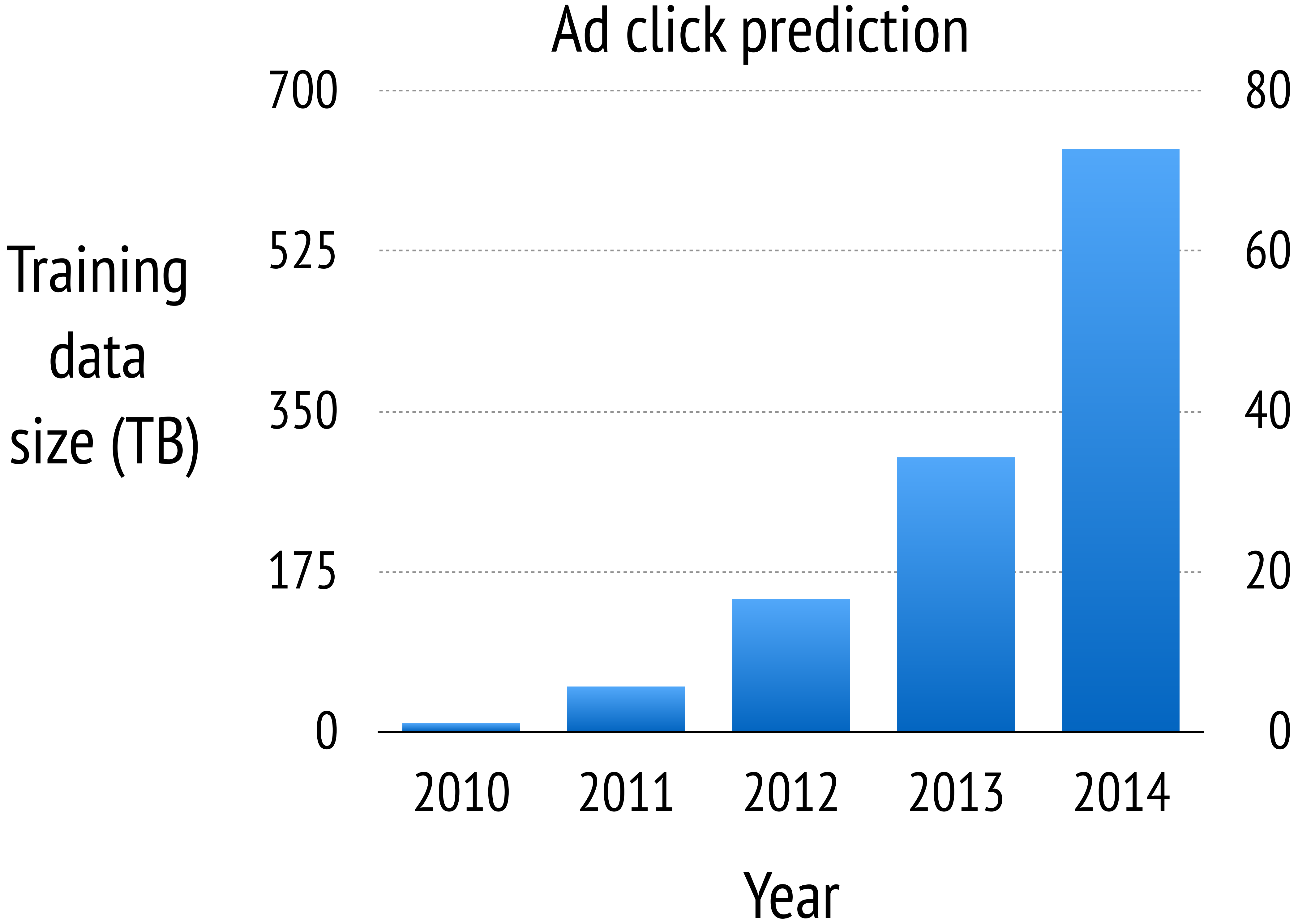
October 6-8, 2014. Broomfield, CO.

USENIX has 1,050 followers on Google+

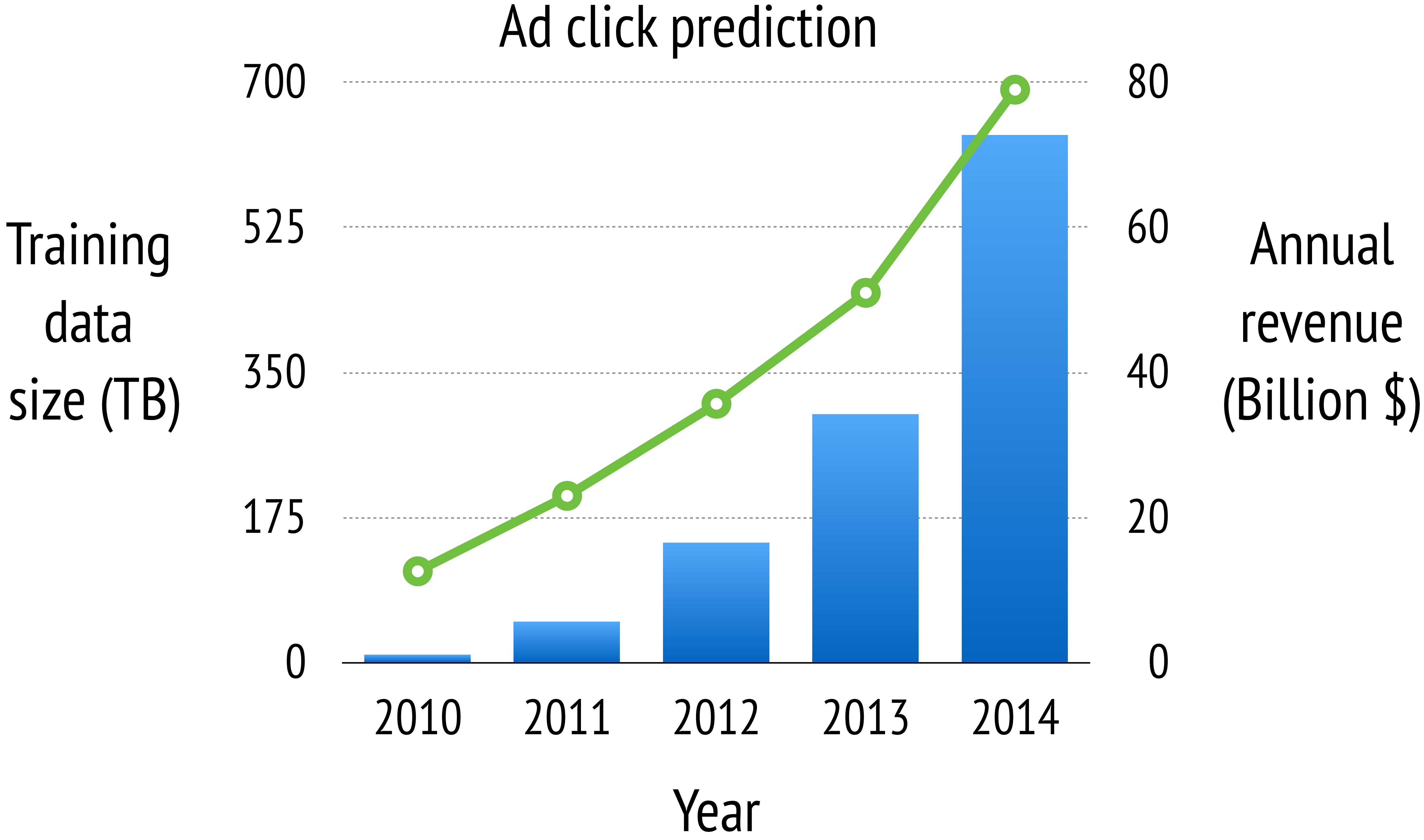
You've visited usenix.org many times. Last visit: today

OSDI '14 Registration - OSDI '14 Program - OSDI '14 homepage - OSDI '14 Travel

Machine learning is concerned with systems that can learn from data

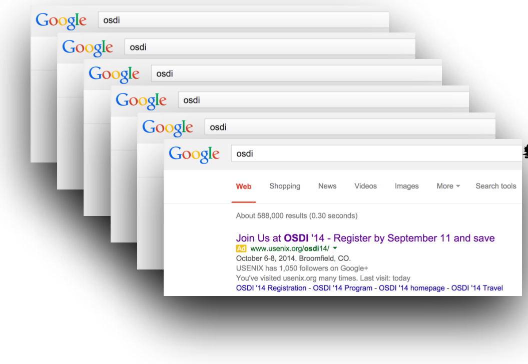


Machine learning is concerned with systems that can learn from data



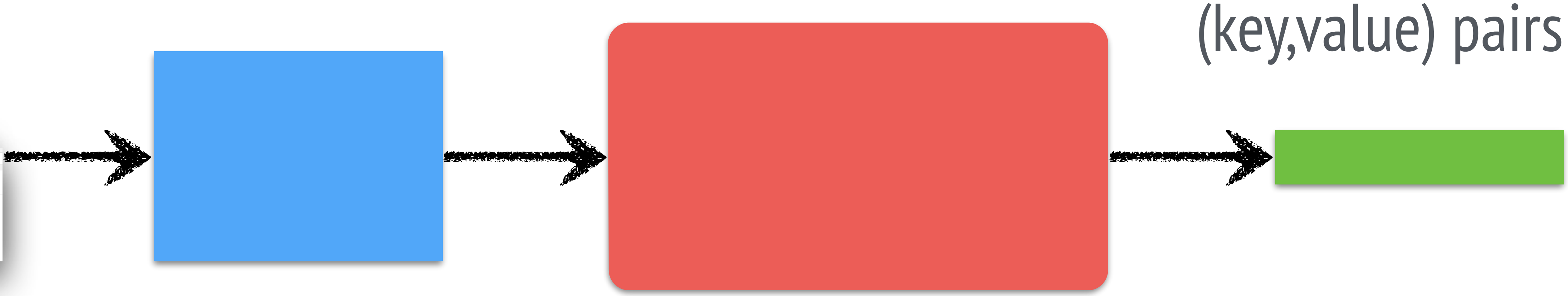
Overview of machine learning

raw data



About 588,000 results (0.30 seconds)

Join Us at **OSDI** '14 - Register by September 11 and save
Ad www.usenix.org/**osdi**14/
October 6-8, 2014. Broomfield, CO.
USENIX has 1,050 followers on Google+
You've visited usenix.org many times. Last visit: today
OSDI '14 Registration - OSDI '14 Program - OSDI '14 homepage - OSDI '14 Travel

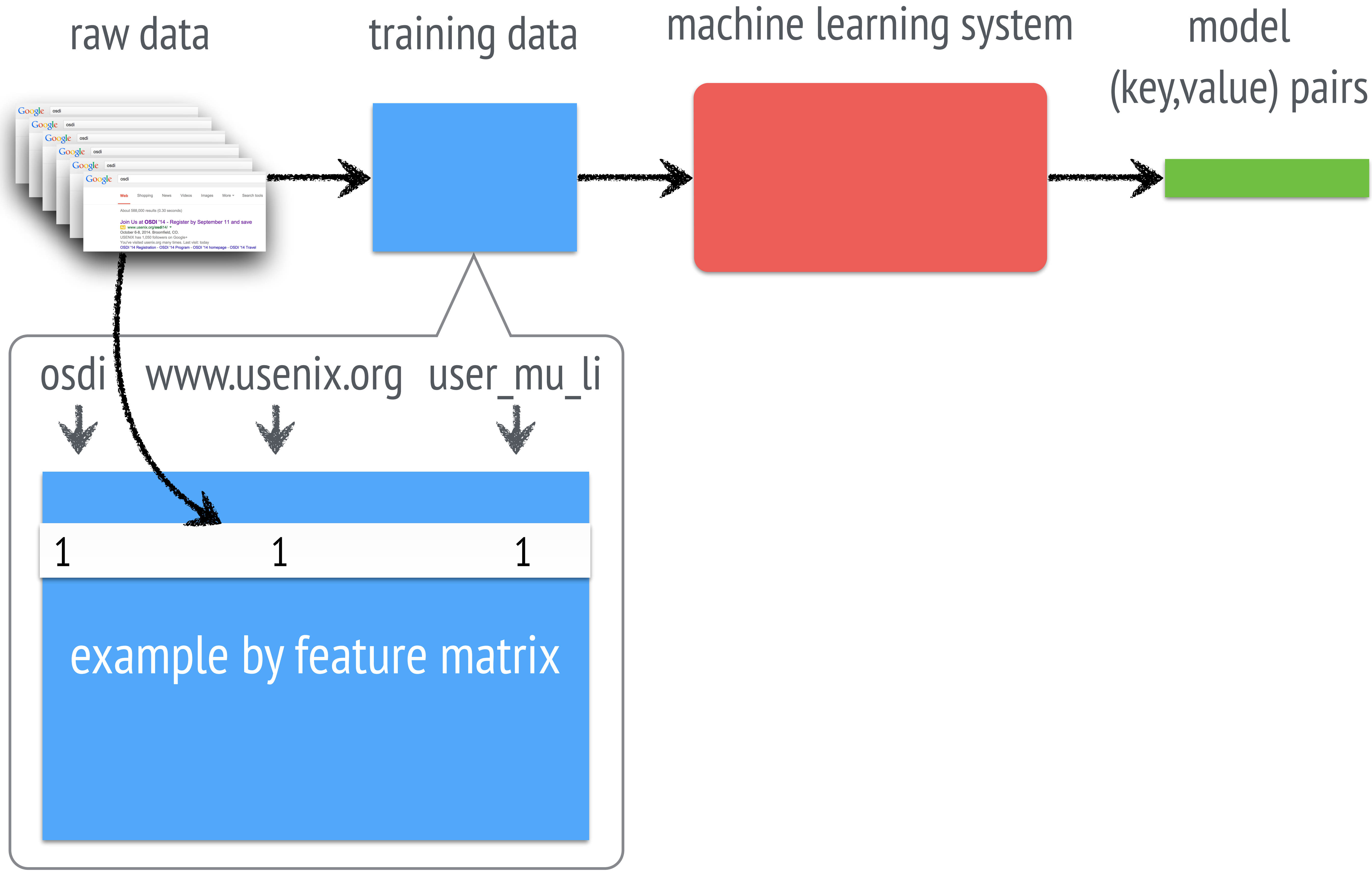


training data

machine learning system

model
(key,value) pairs

Overview of machine learning



raw data

training data

machine learning system

model

(key,value) pairs

Google osdi

Web Shopping News Videos Images More Search tools

About 588,000 results (0.30 seconds)

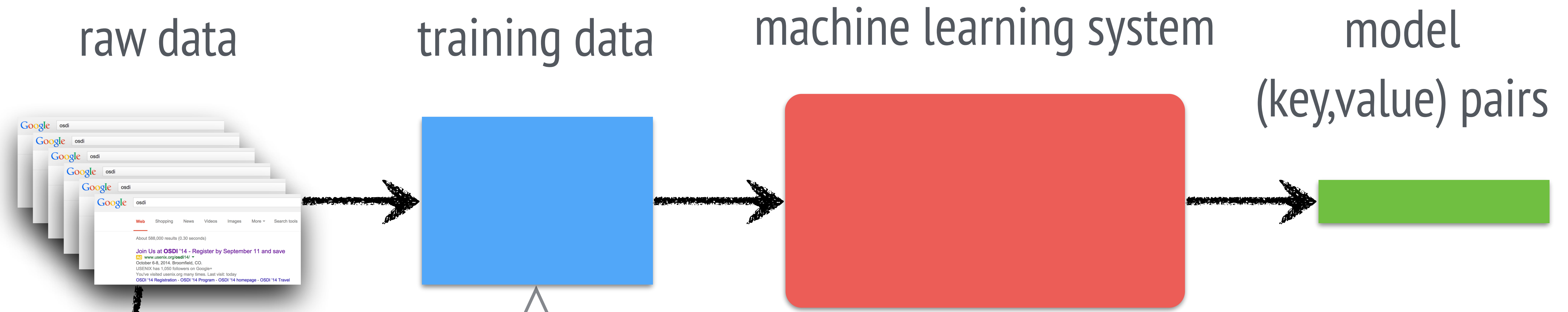
Join Us at **OSDI** '14 - Register by September 11 and save
Ad www.usenix.org/**osdi**14/
October 6-8, 2014. Broomfield, CO.
USENIX has 1,050 followers on Google+
You've visited usenix.org many times. Last visit: today
OSDI '14 Registration - OSDI '14 Program - OSDI '14 homepage - OSDI '14 Travel

osdi www.usenix.org user_mu_li

1 1 1

example by feature matrix

Overview of machine learning



About 588,000 results (0.30 seconds)

Join Us at **OSDI** '14 - Register by September 11 and save

Ad www.usenix.org/**osdi**14/

October 6-8, 2014. Broomfield, CO.

USENIX has 1,050 followers on Google+

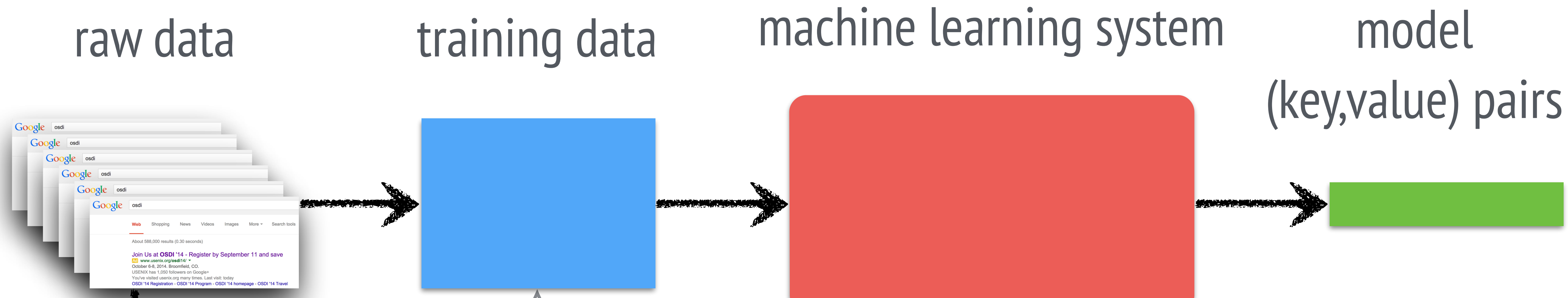
You've visited usenix.org many times. Last visit: today

OSDI '14 Registration - OSDI '14 Program - OSDI '14 homepage - OSDI '14 Travel

Scale of Industry problems

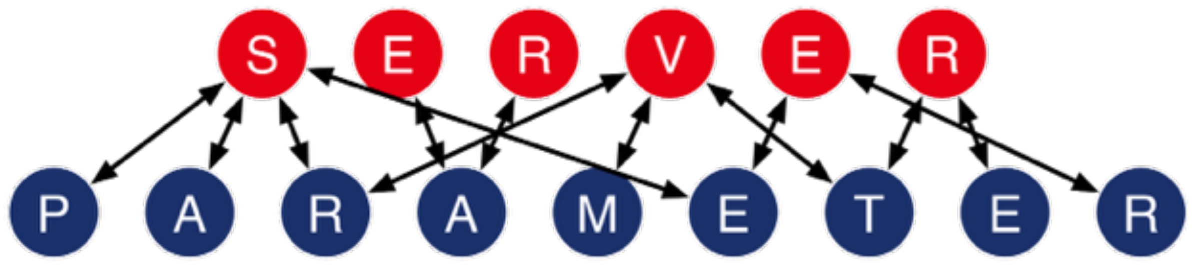
- 100 billion examples
- 10 billion features
- 1T —1P training data
- 100—1000 machines

Overview of machine learning



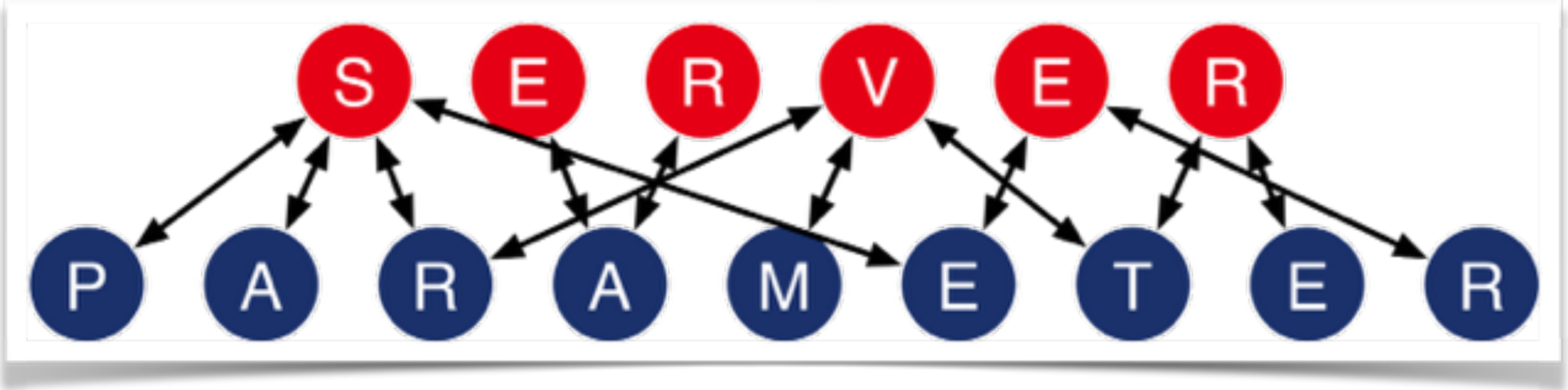
Scale of Industry problems

- 100 billion examples
- 10 billion features
- 1T – 1P training data
- 100 – 1000 machines

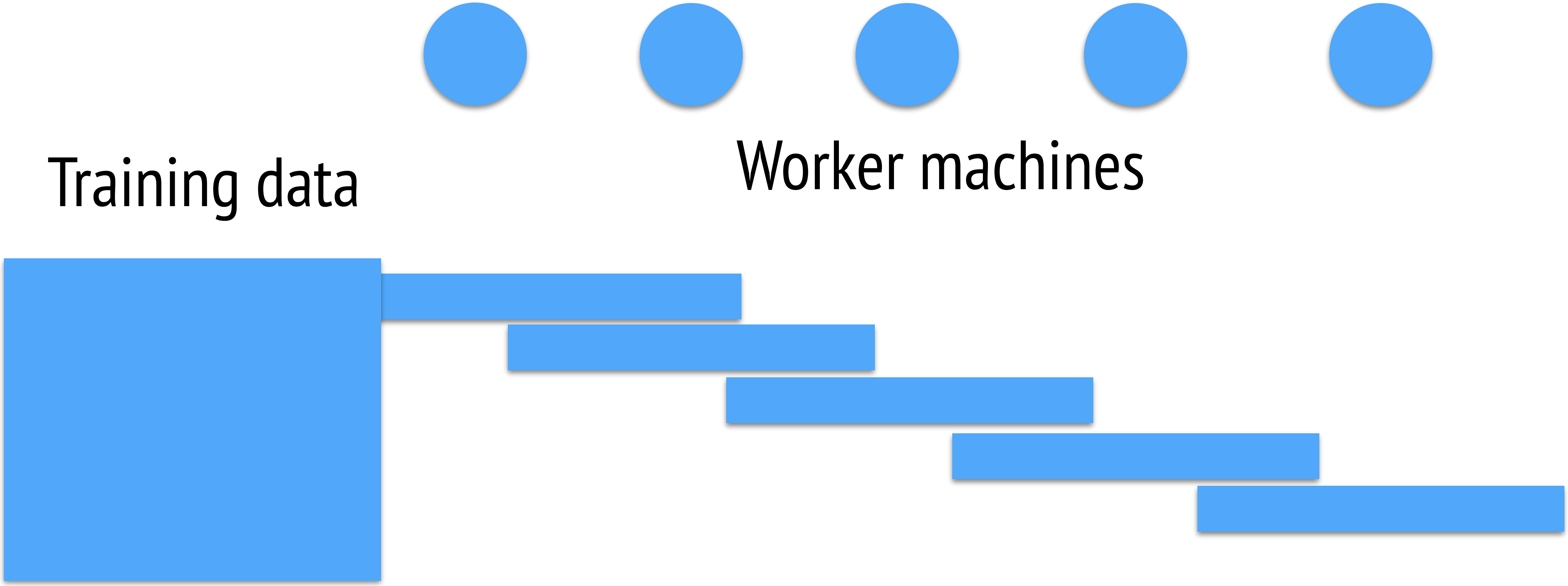


- scale to industry problems
- efficient communication
- fault tolerance
- easy to use

Industry size machine learning problems



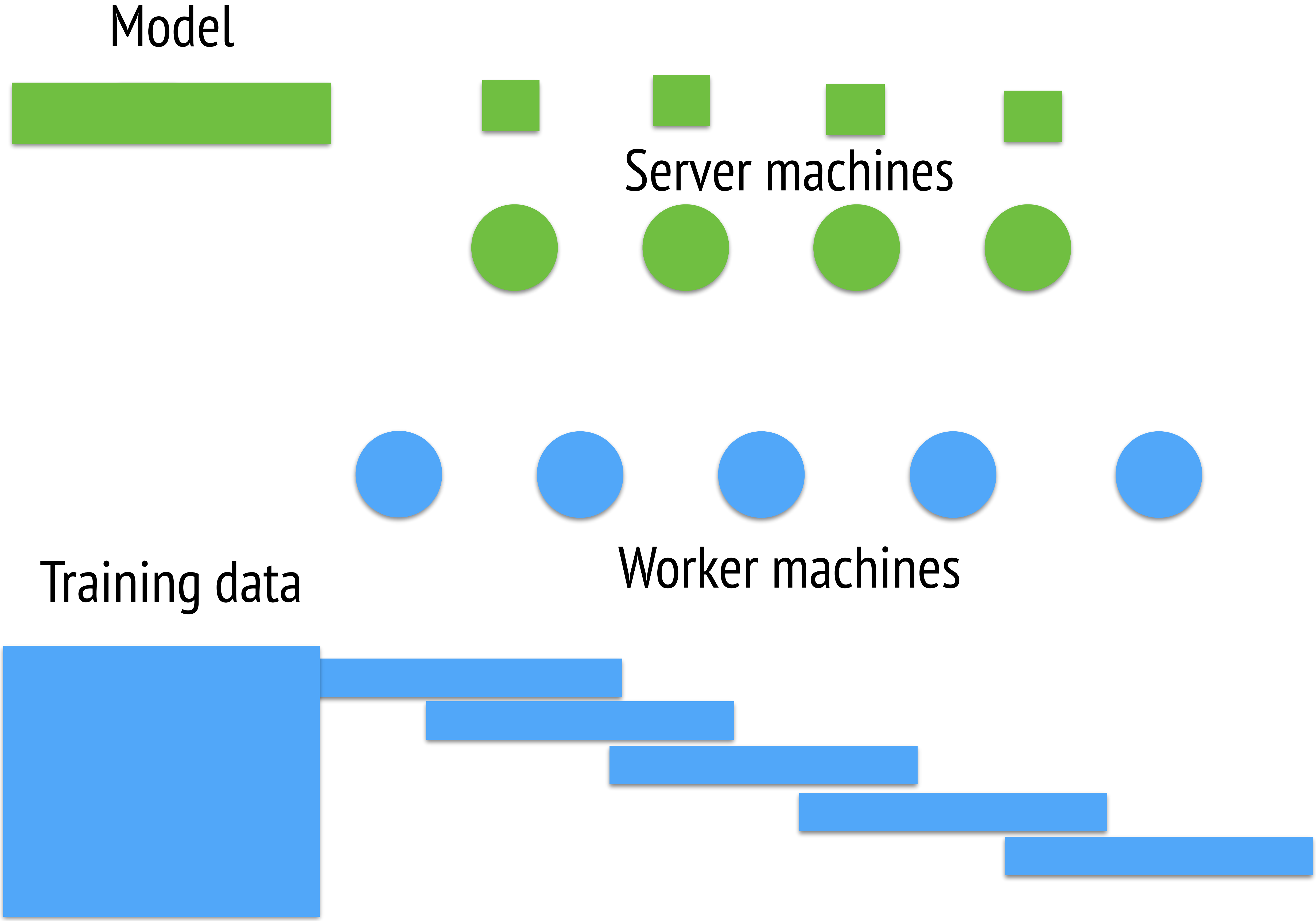
Data and model partition



Worker machines

Training data

Data and model partition



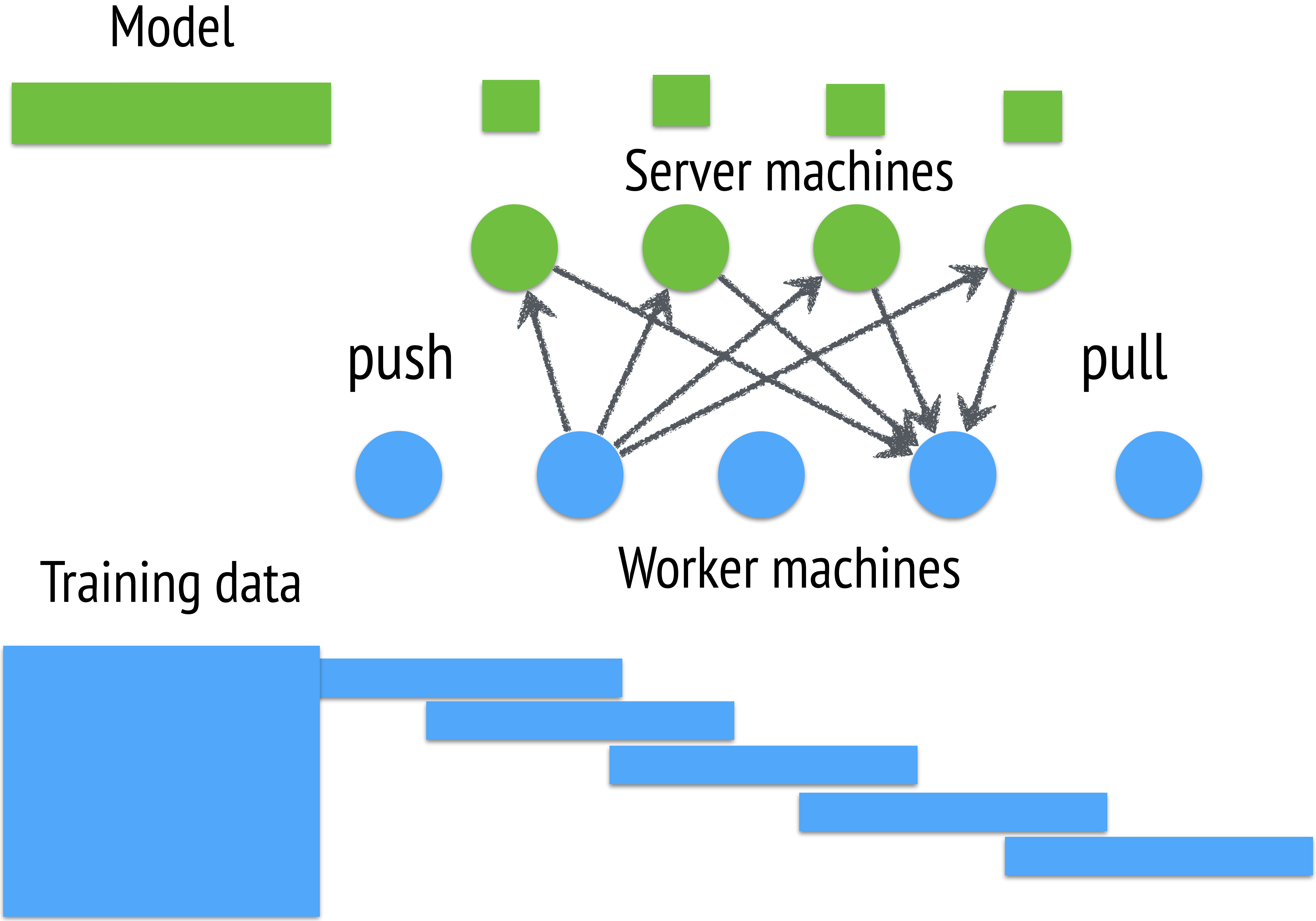
Model

Server machines

Worker machines

Training data

Data and model partition



Model

Server machines

push

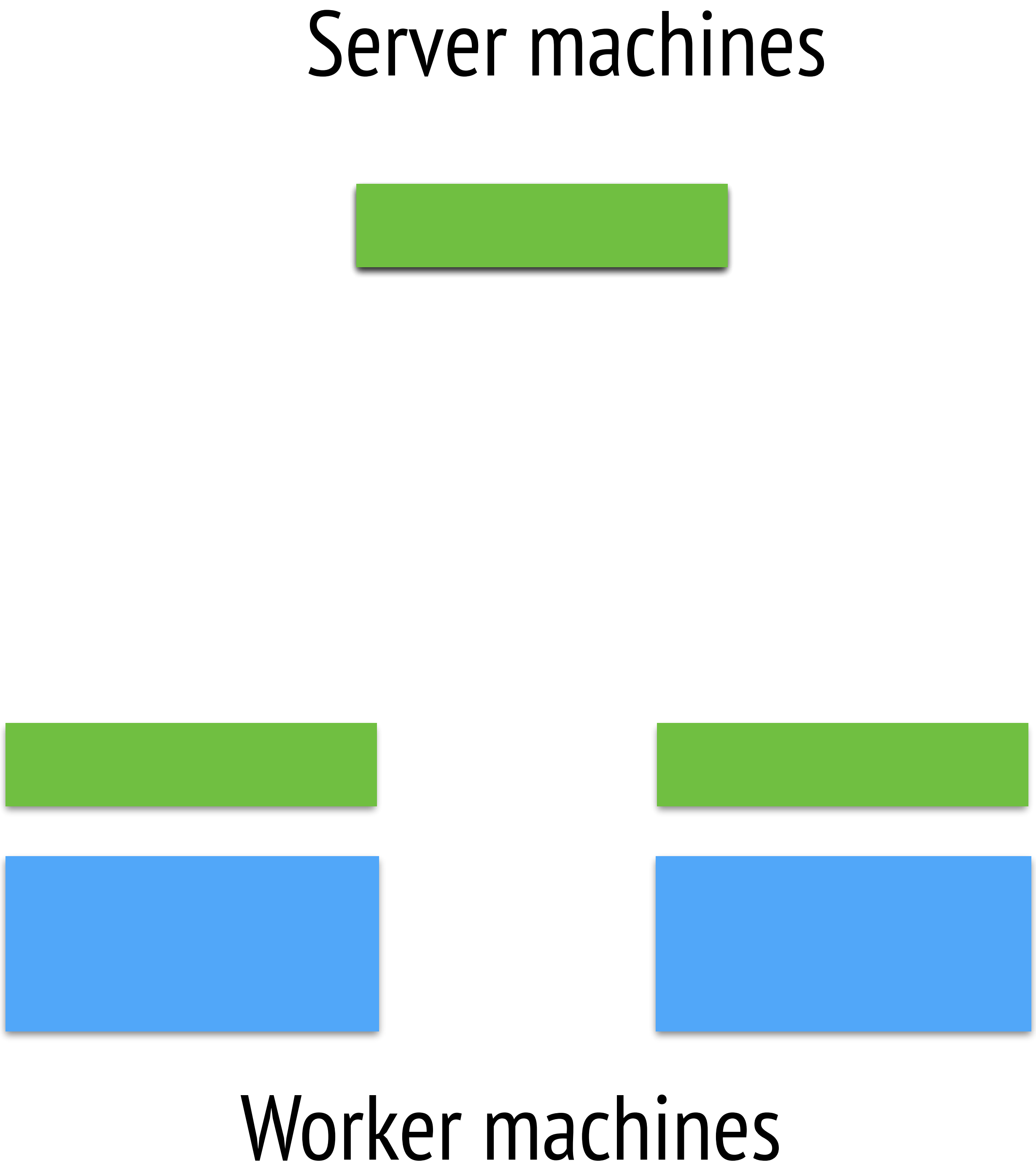
pull

Worker machines

Training data

Example: distributed gradient descent

Workers **pull** the working set of model



Server machines

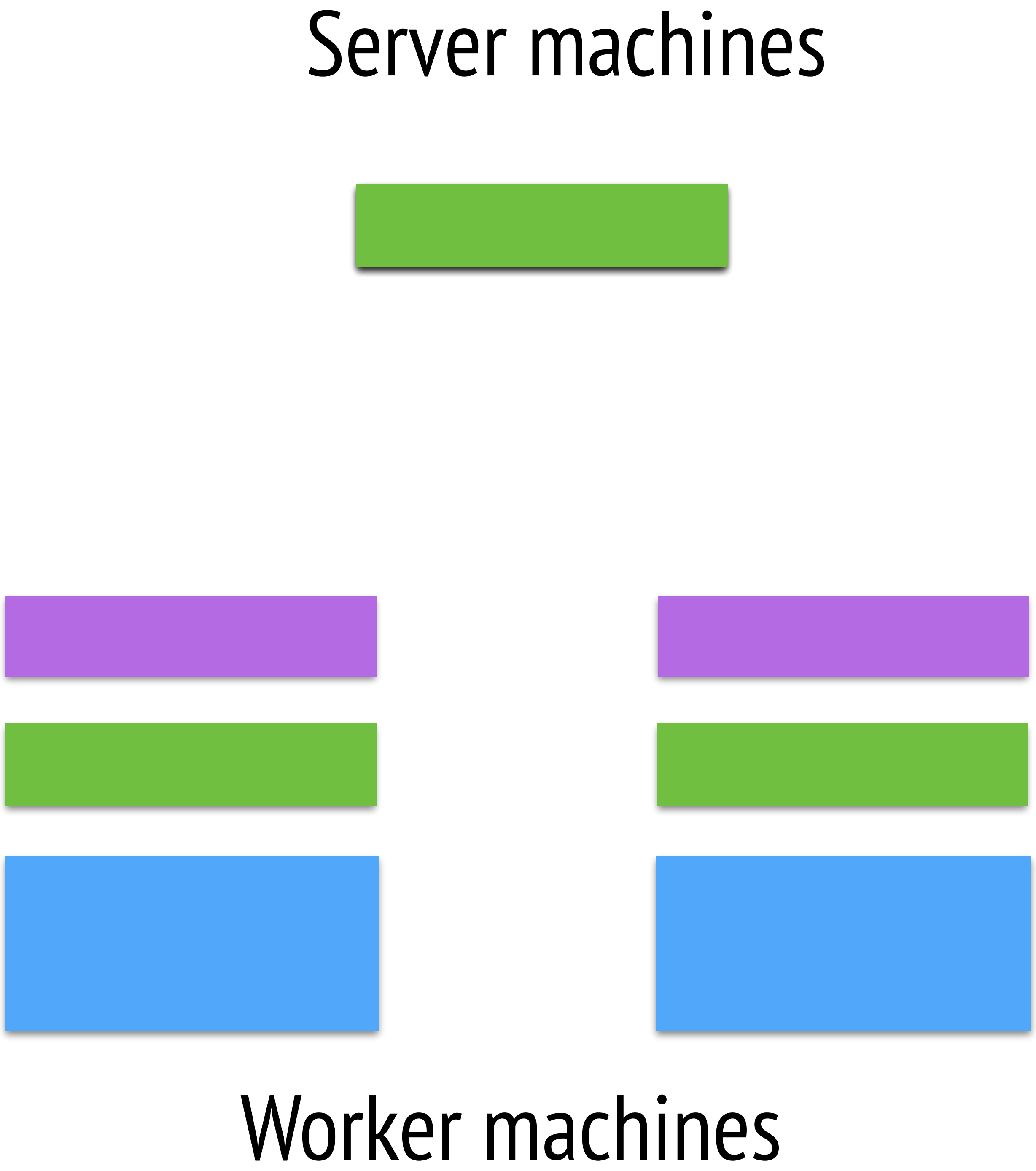
Worker machines

Example: distributed gradient descent

Workers **pull** the working set of model

Iterate until stop

- workers compute gradients

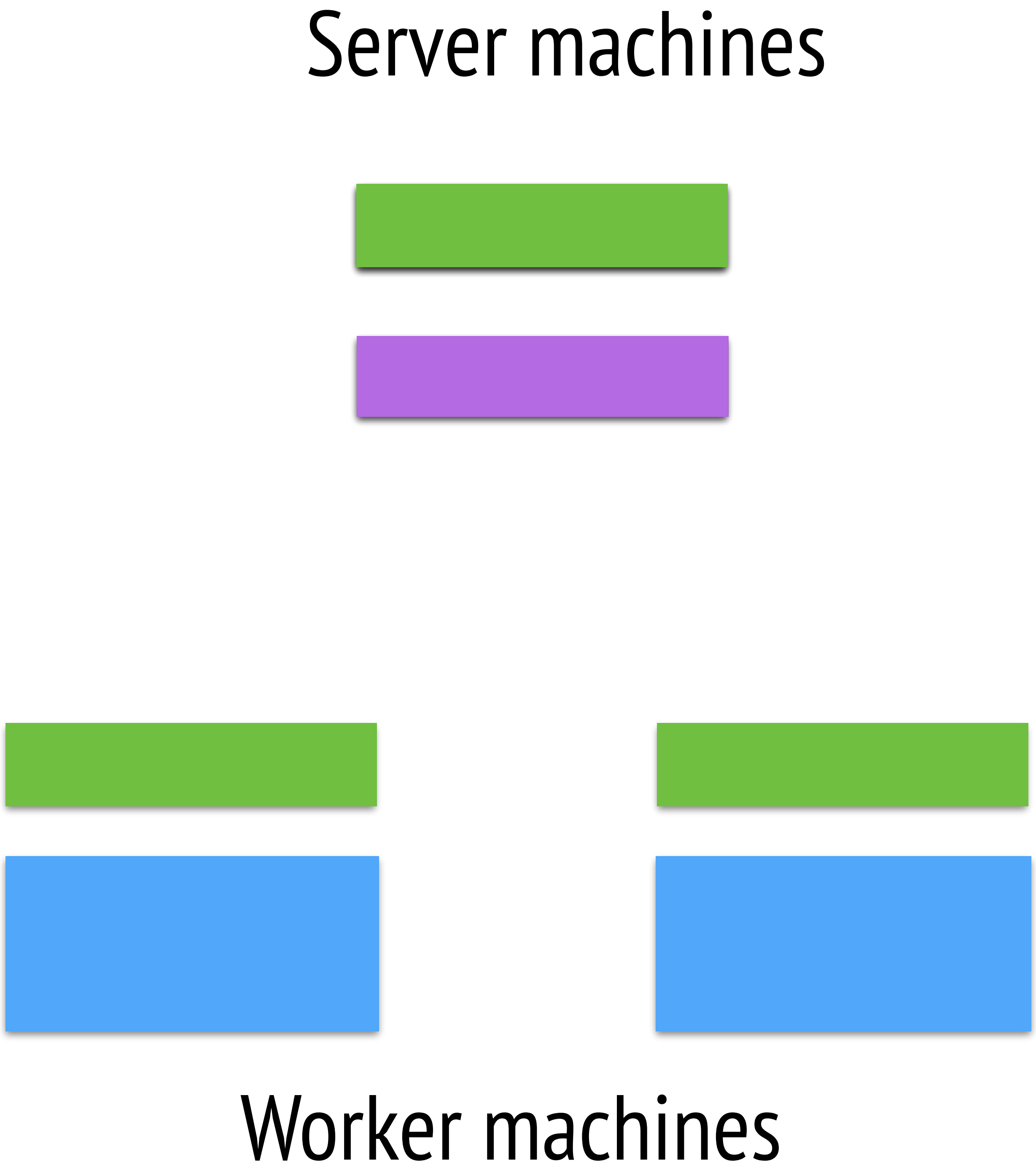


Example: distributed gradient descent

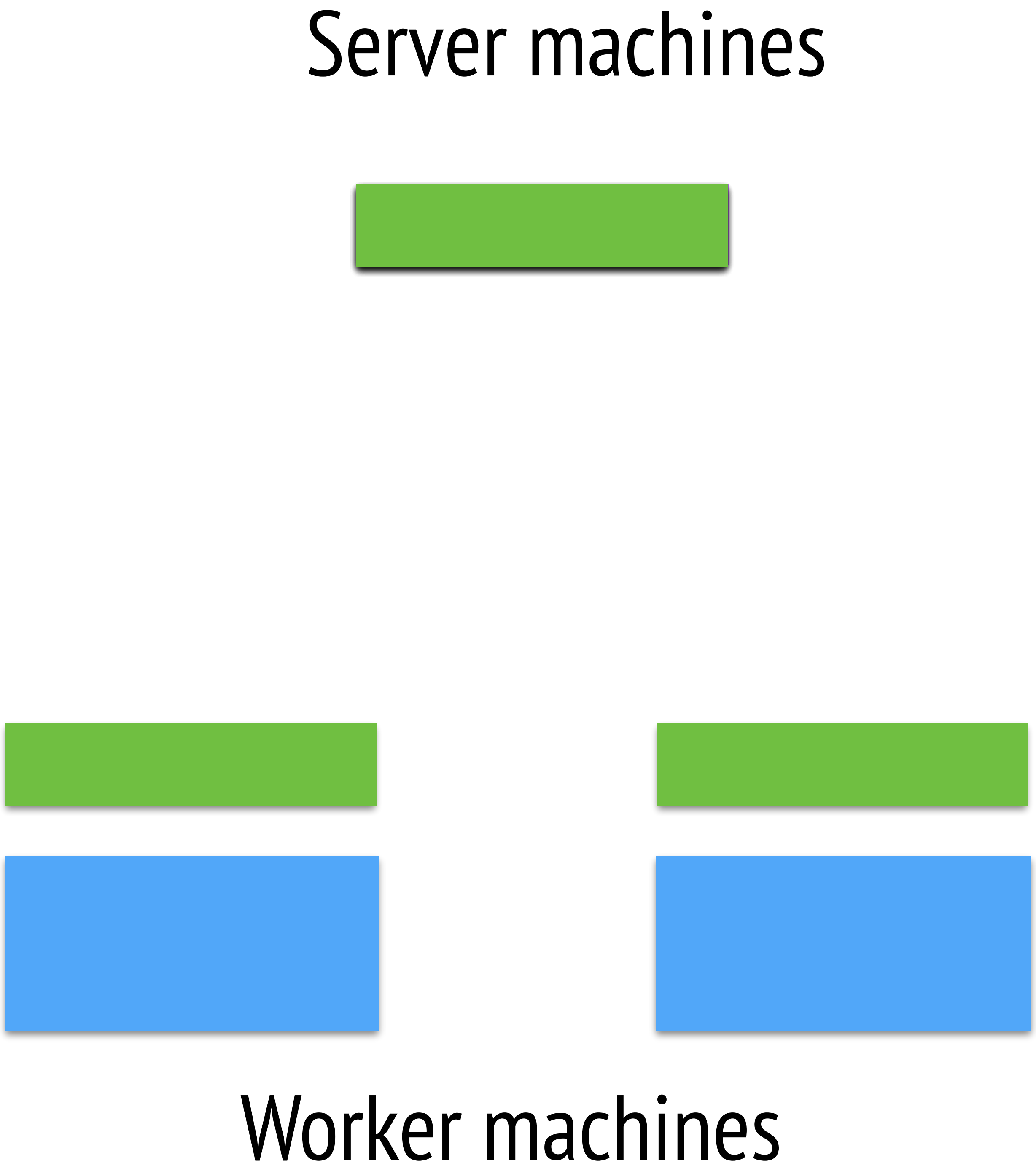
Workers **pull** the working set of model

Iterate until stop

- workers compute gradients
- workers **push** gradients

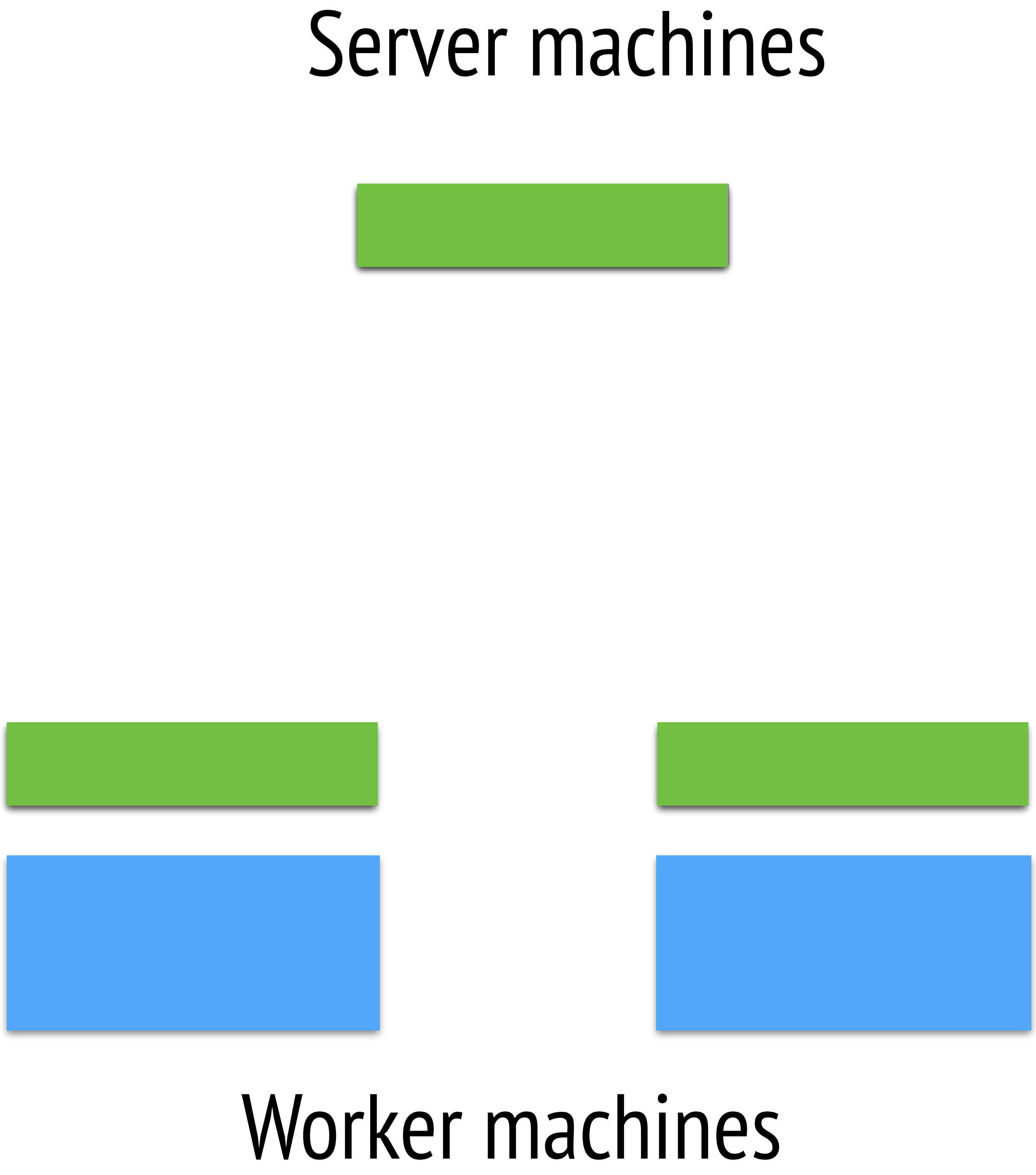


Example: distributed gradient descent



```
Workers pull the working set of model
Iterate until stop
    workers compute gradients
    workers push gradients
    update model
```

Example: distributed gradient descent



Server machines

Worker machines

Workers **pull** the working set of model

Iterate until stop

workers compute gradients

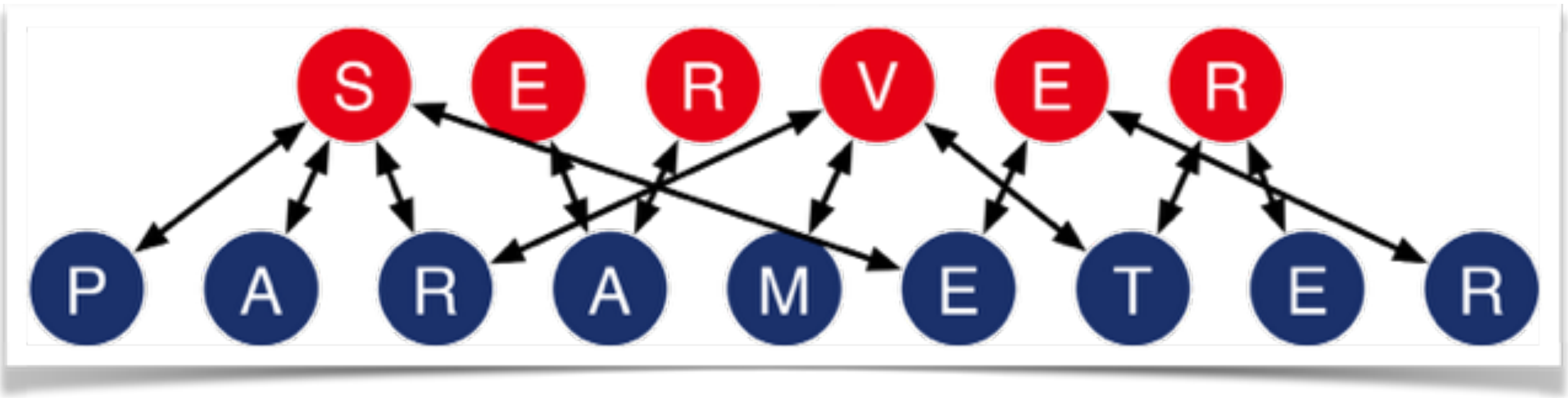
workers **push** gradients

update model

workers **pull** updated model

Industry size machine learning problems ✓

Efficient communication

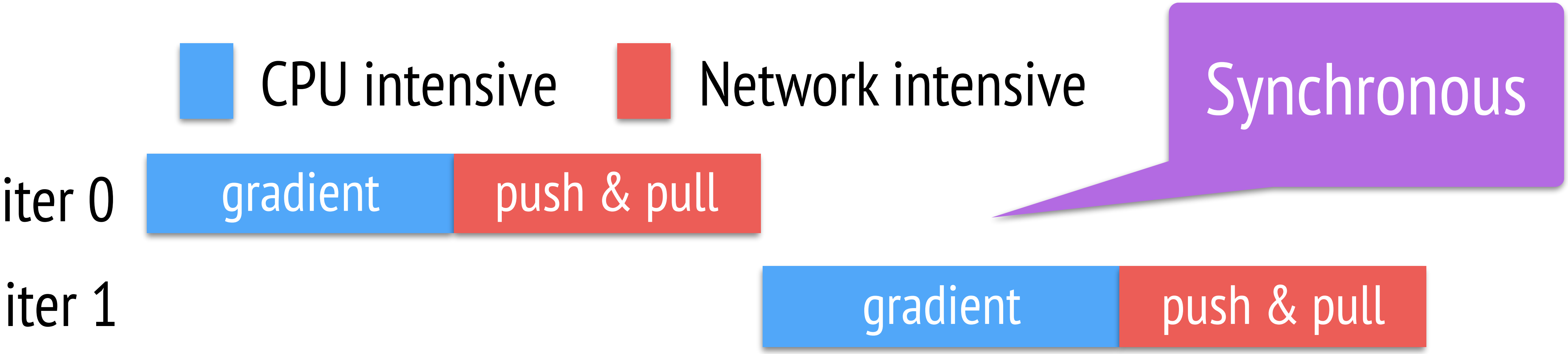


Challenges for data synchronization

- Massive communication traffic
  - frequent access to the shared model
- Expensive global barriers
  - between iterations

Task

- a push / pull / user defined function (an iteration)
- "execute-after-finished" dependency



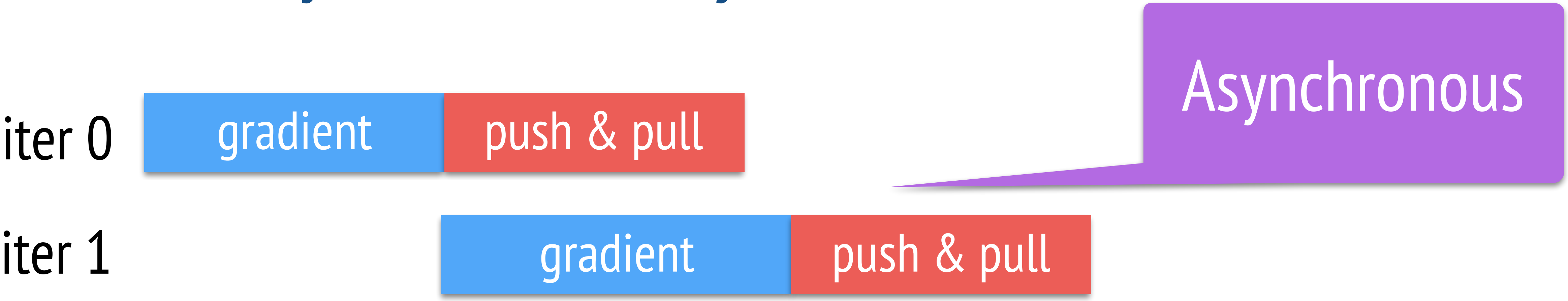
🟦 CPU intensive 🟥 Network intensive

Synchronous

iter 0 gradient push & pull

iter 1 gradient push & pull

- executed asynchronously



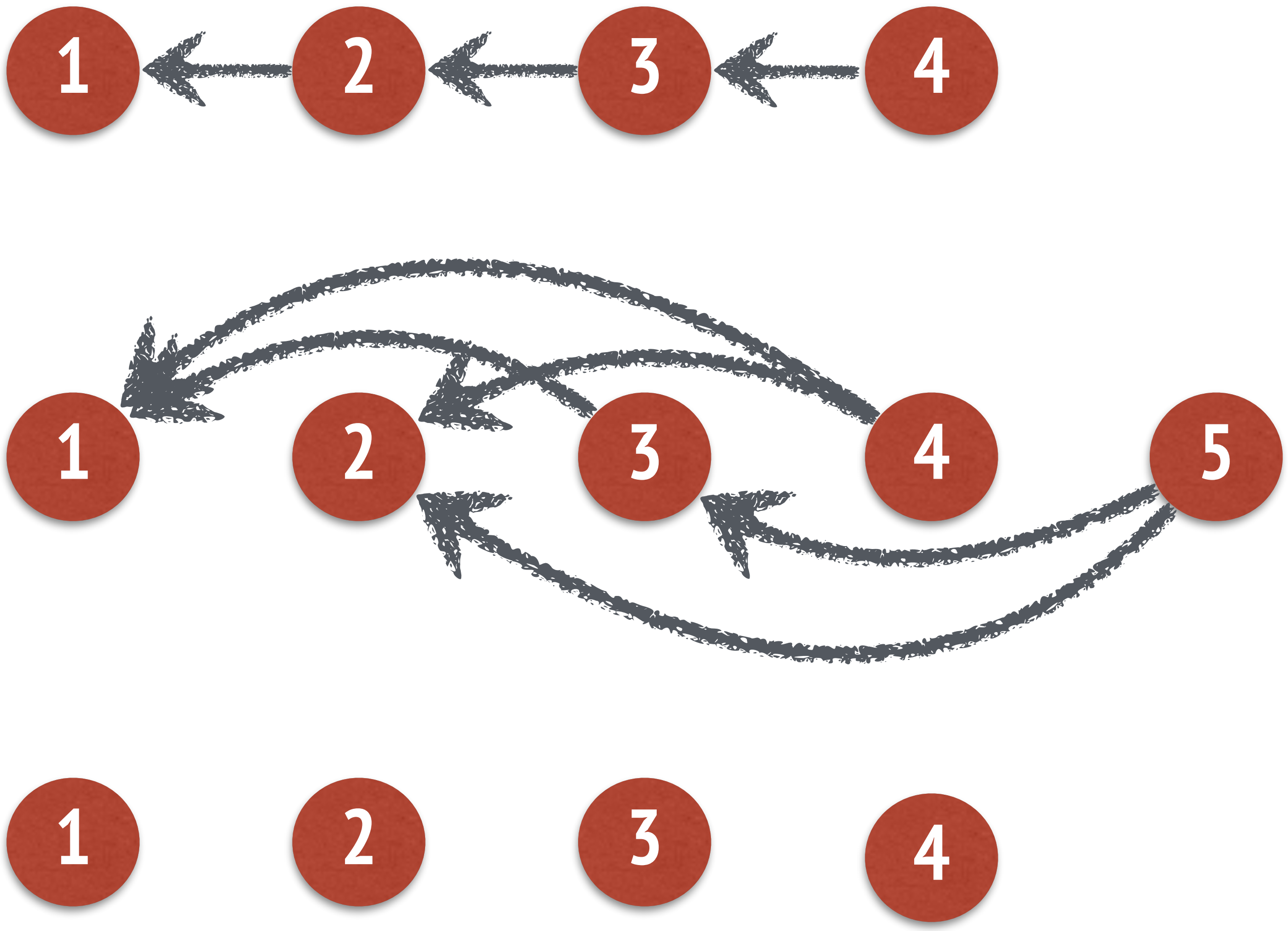
Asynchronous

iter 0 gradient push & pull

iter 1 gradient push & pull

Flexible consistency

- Trade-off between algorithm efficiency and system performance

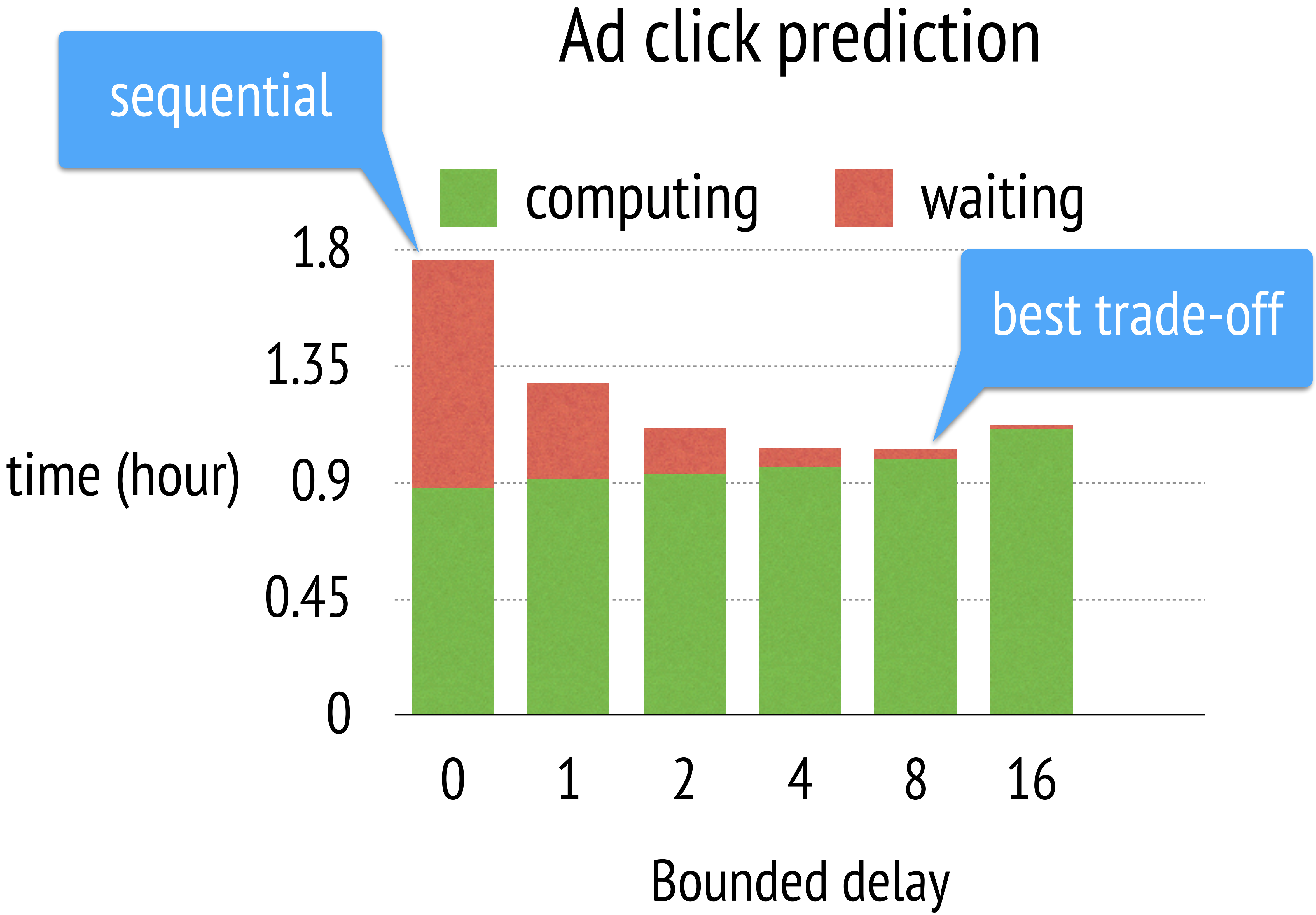


Sequential

1-bounded delay

Eventual

Results for bounded delay



sequential

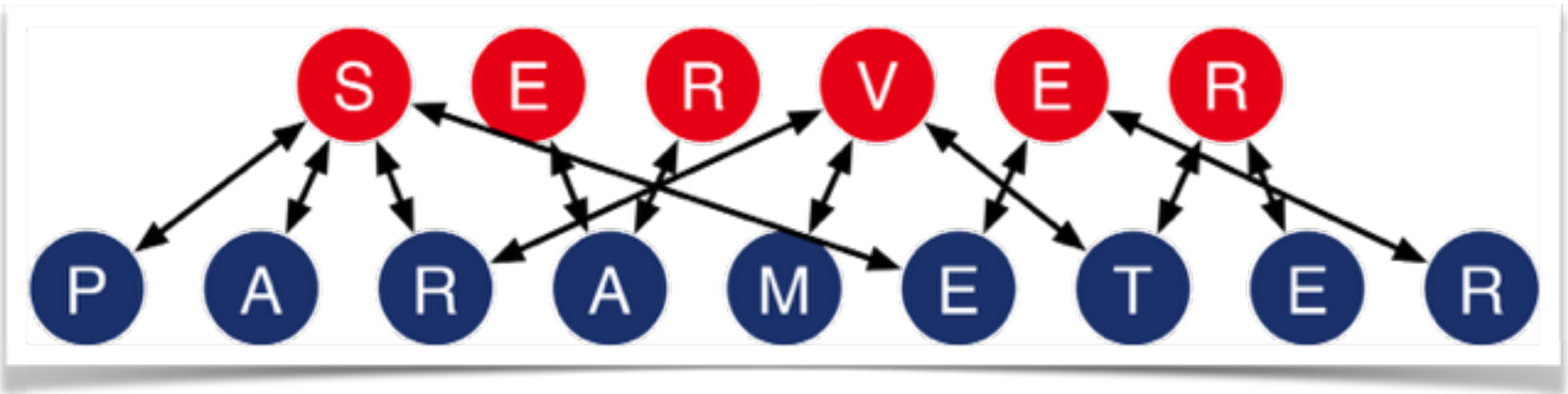
best trade-off

User-defined filters

- Selectively communicate (key, value) pairs
- E.g., the KKT filter
  - send pairs if they are likely to affect the model
  - >95% keys are filtered in the ad click prediction task

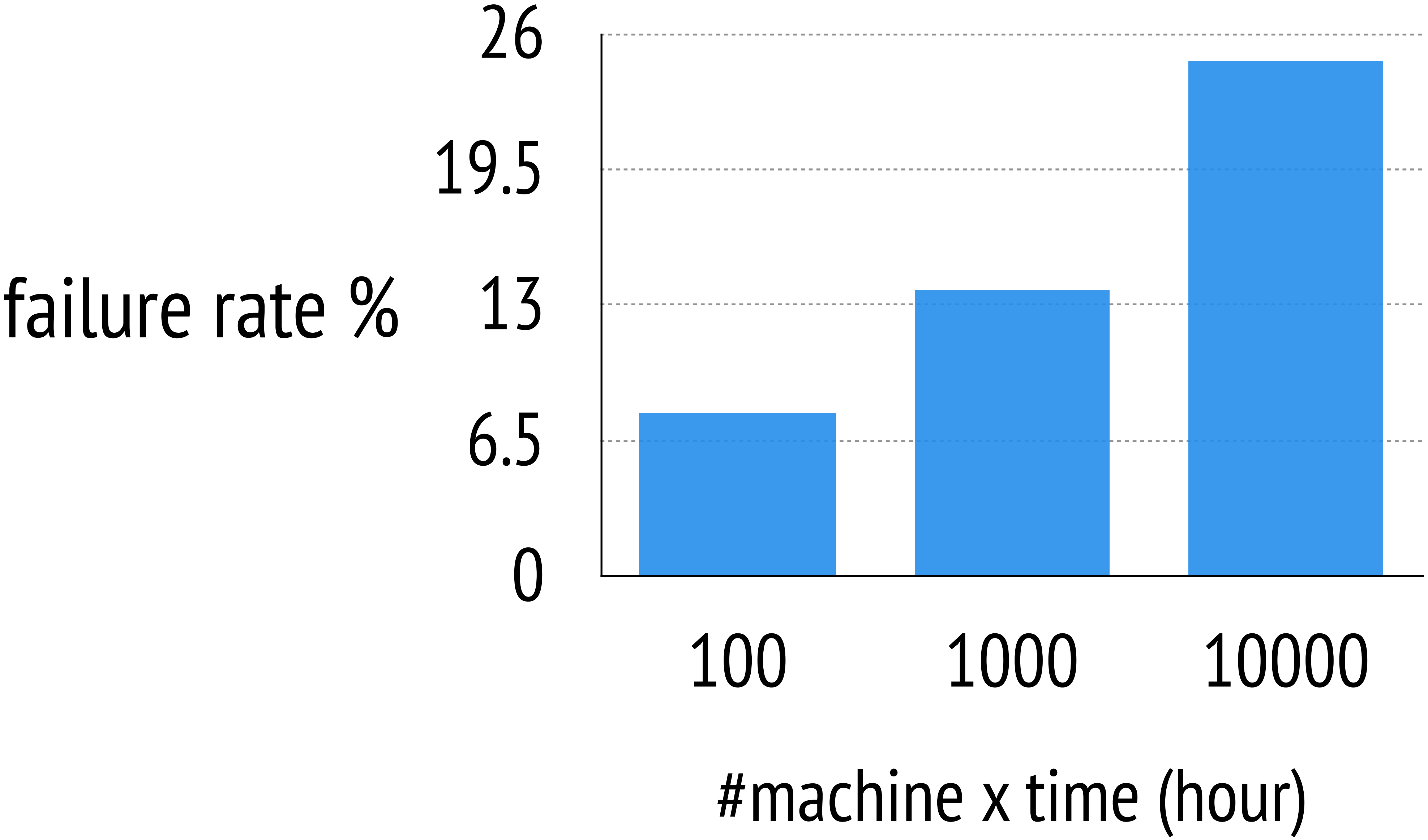
Industry size machine learning problems ✓

Efficient communication ✓



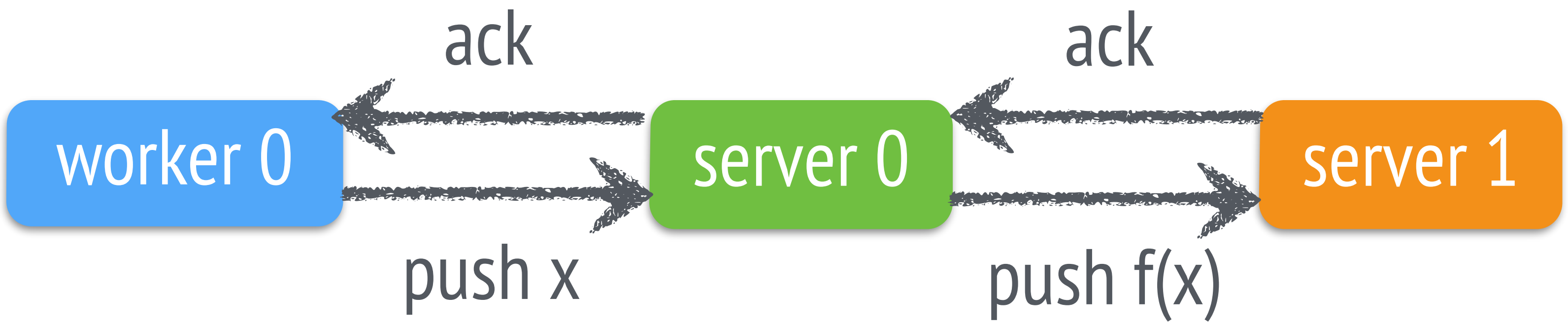
Fault tolerance

Machine learning job logs in a three-month period:

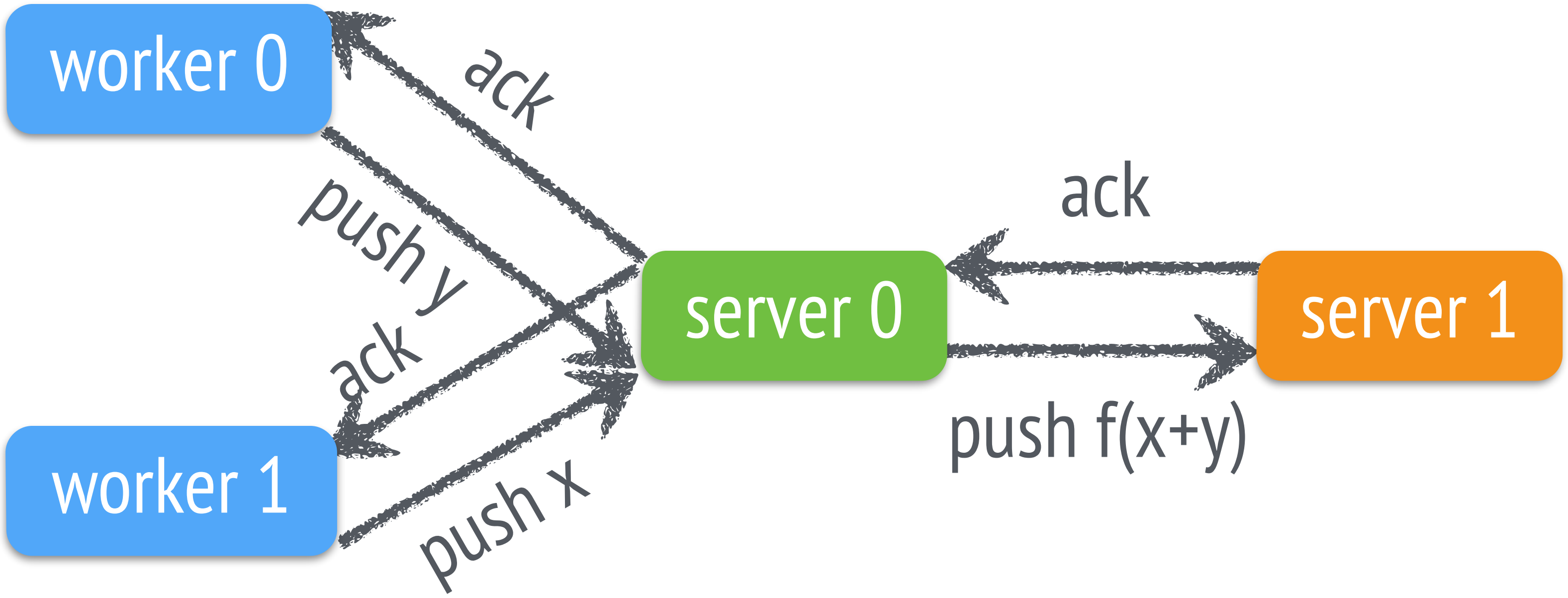


Fault tolerance

- Model is partitioned by consistent hashing
- Default replication: Chain replication (consistent, safe)

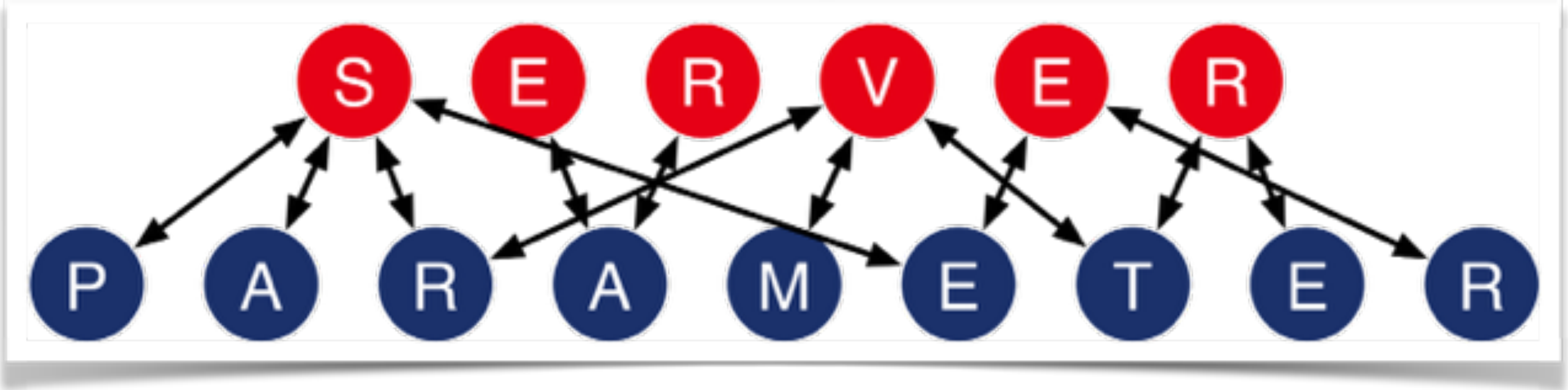


- Option: Aggregation reduces backup traffic (algo specific)



Industry size machine learning problems ✓

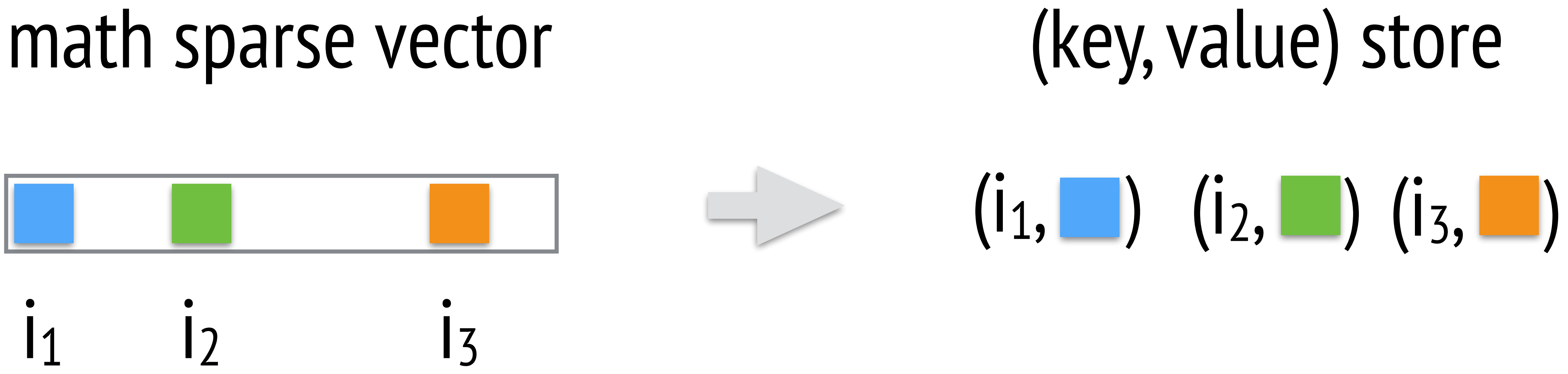
Efficient communication ✓



Fault tolerance ✓

Easy to use

(Key, value) vectors for the shared parameters



math sparse vector

(key, value) store

i_1 i_2 i_3

(i_1, 🟦) (i_2, 🟩) (i_3, 🟧)

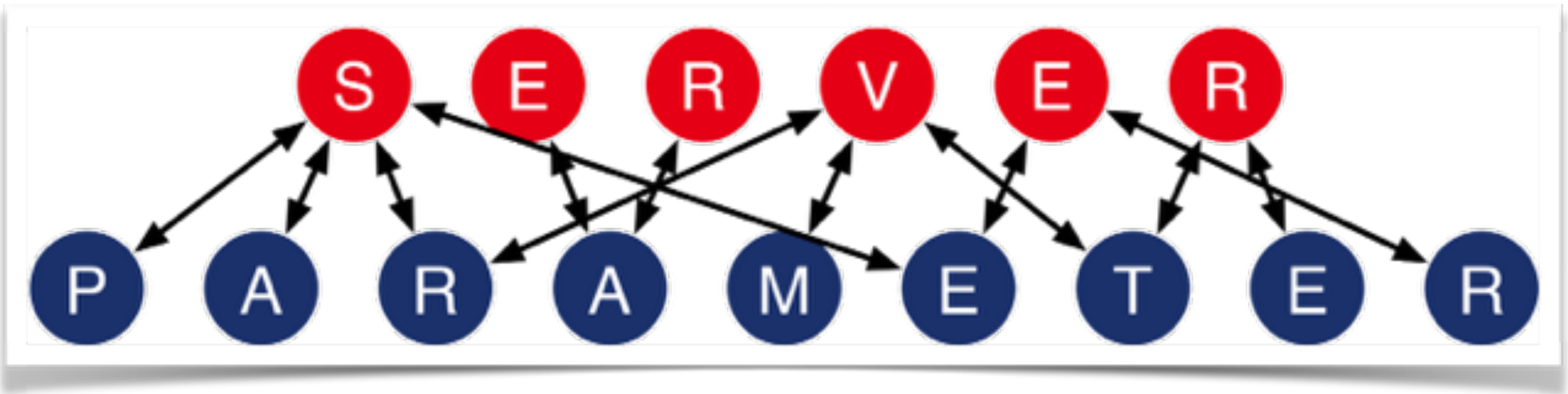
- Good for programmers: Matches mental model
- Good for system: Expose optimizations based upon structure of data

Example: computing gradient

gradient = data^T × (− label × 1 / (1 + exp (label × data × model))

Industry size machine learning problems ✓

Efficient communication ✓



Fault tolerance ✓

Easy to use ✓

Evaluation

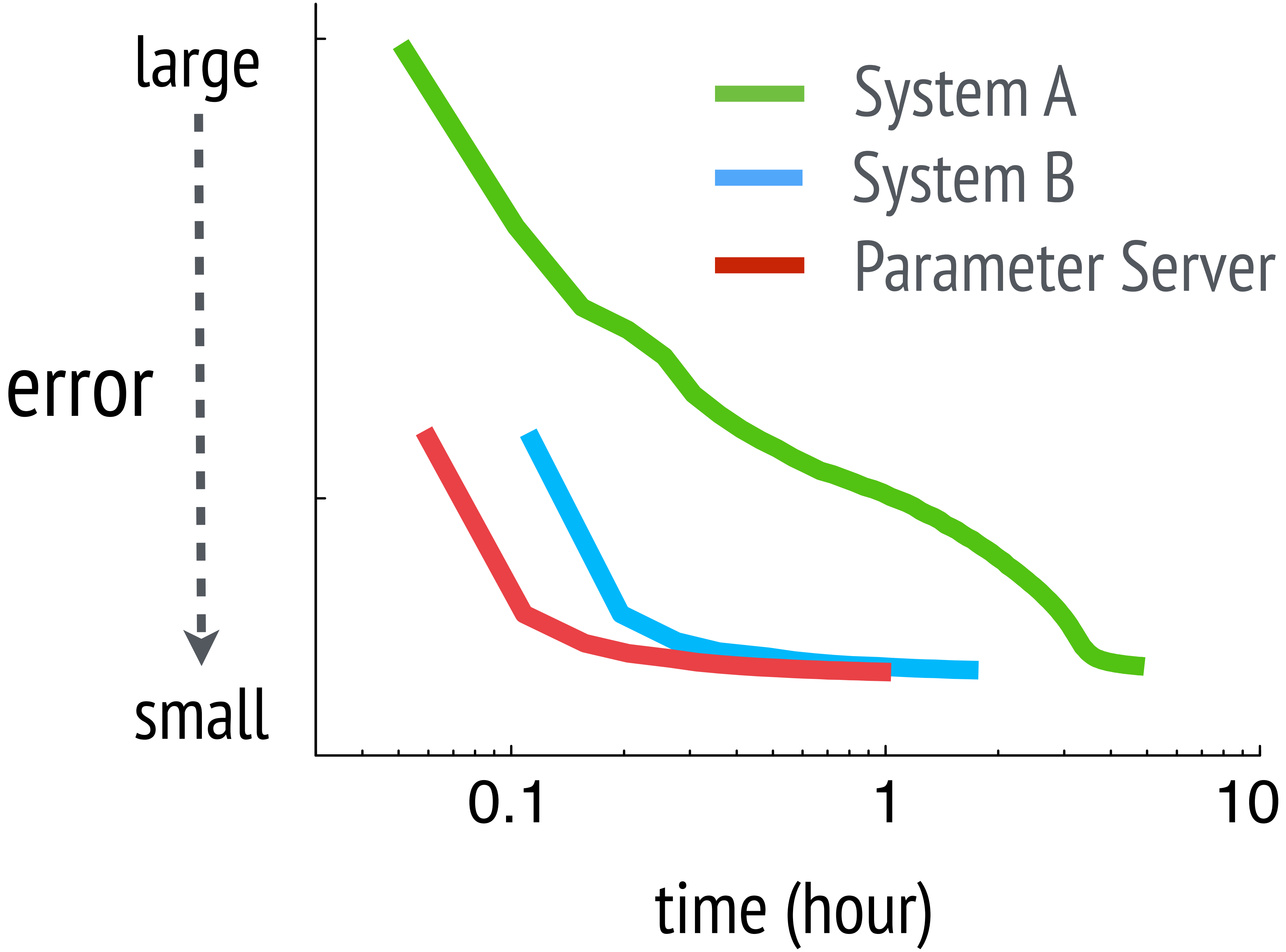
Sparse Logistic Regression

- Predict ads will be clicked or not
- Baseline: two systems in production

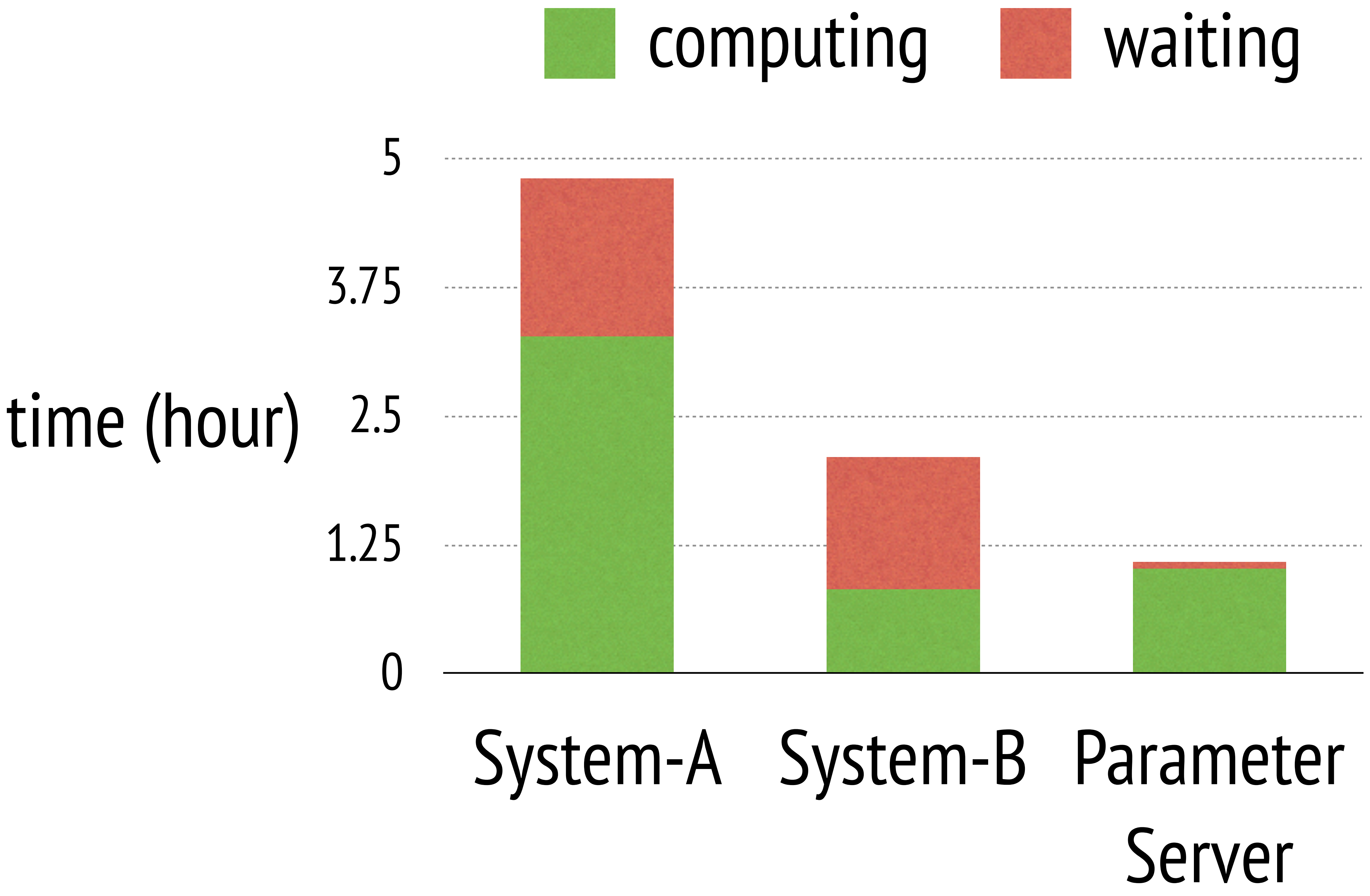
	Method	Consistency	LOC
System-A	L-BFGS	Sequential	10K
System-B	Block PG	Sequential	30K
Parameter Server	Block PG	Bounded Delay + KKT	300

- 636T real ads data
  - 170 billions of examples, 65 billions of features
- 1,000 machines with 16,000 cores

Progress

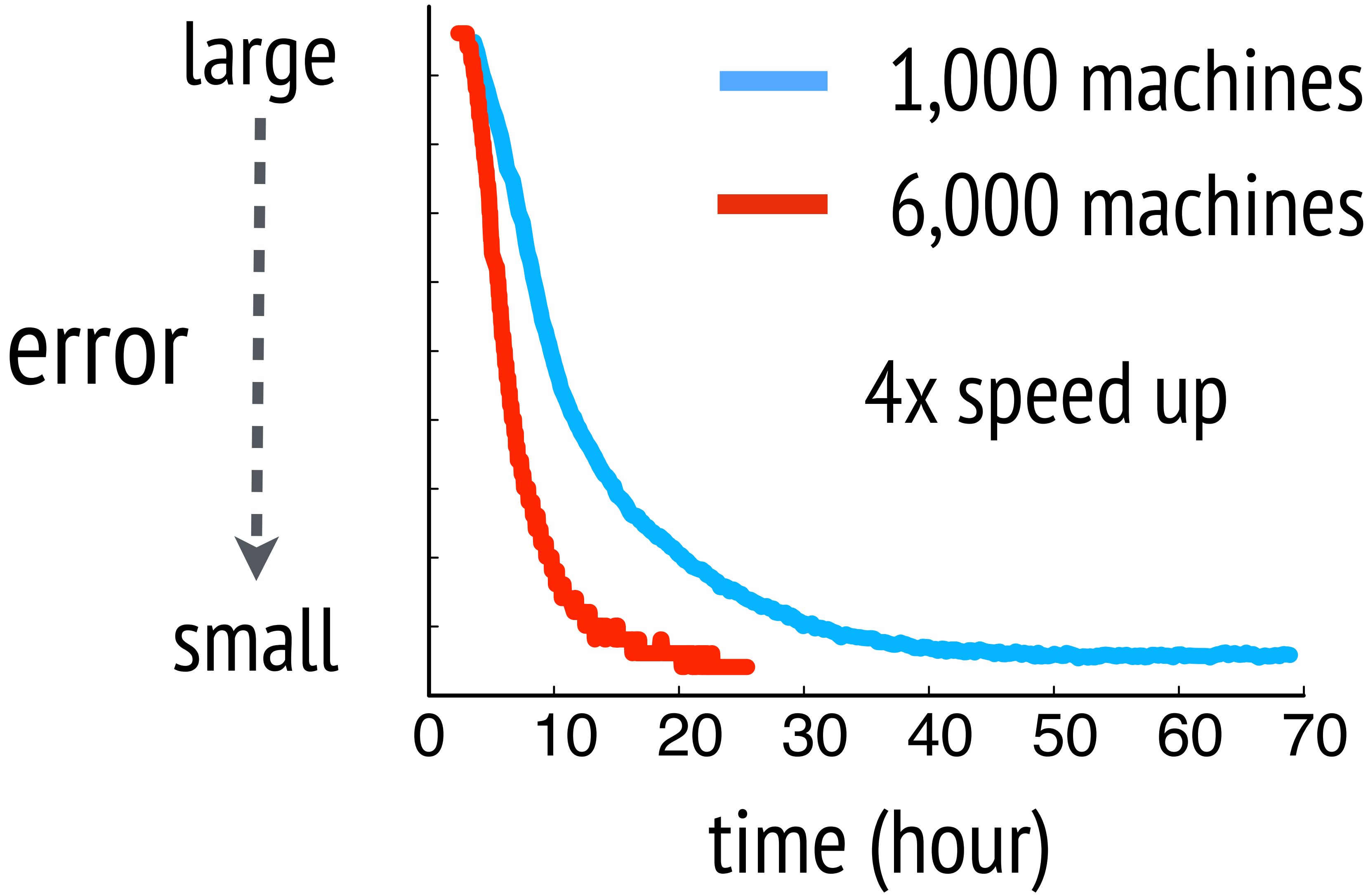

large
error
small
System A
System B
Parameter Server
0.1
1
10
time (hour)

Time decomposition



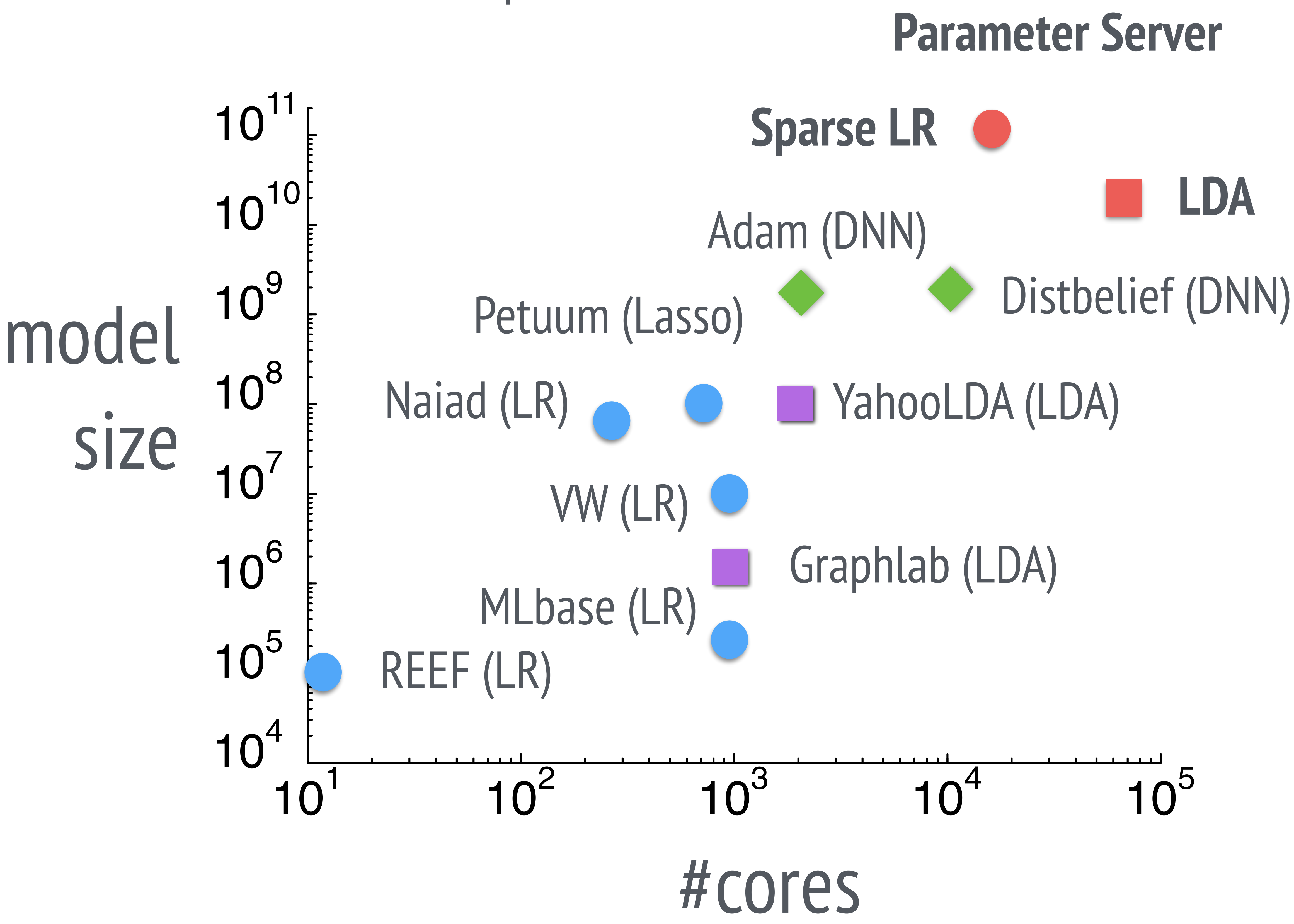
Topic Modeling (“LDA”)

- Gradient descent with eventual consistency
- 5B users’ click logs, Group users into 1,000 groups based on URLs they clicked



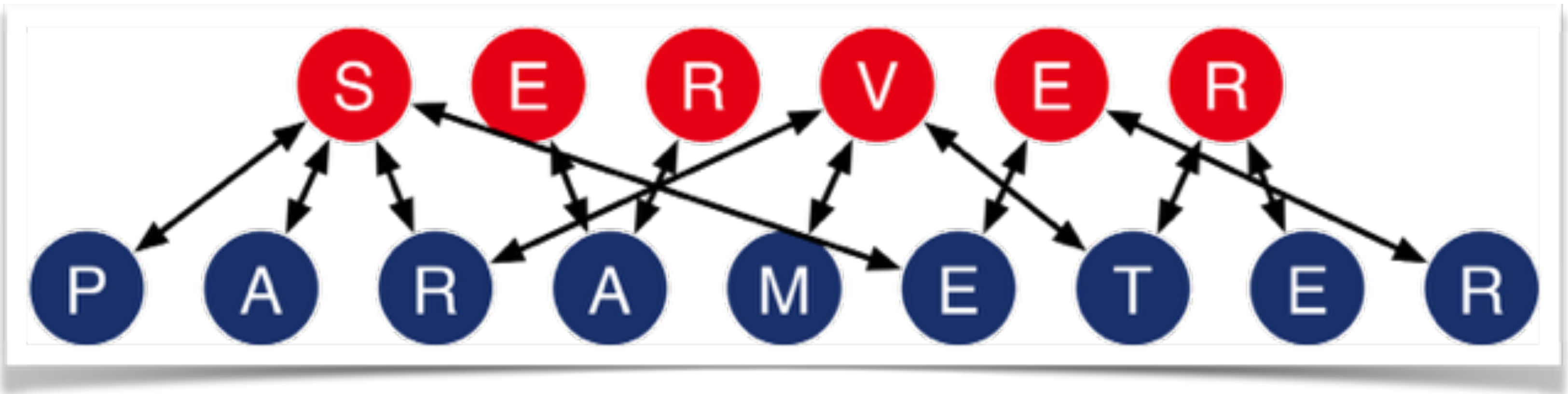
Largest experiments of related systems

Data were collected on April'14



Industry size machine learning problems ✓

Efficient communication ✓



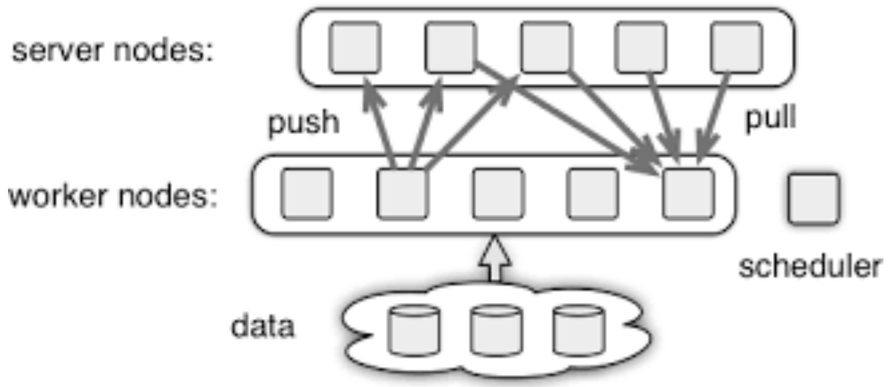
Fault tolerance ✓

Easy to use ✓

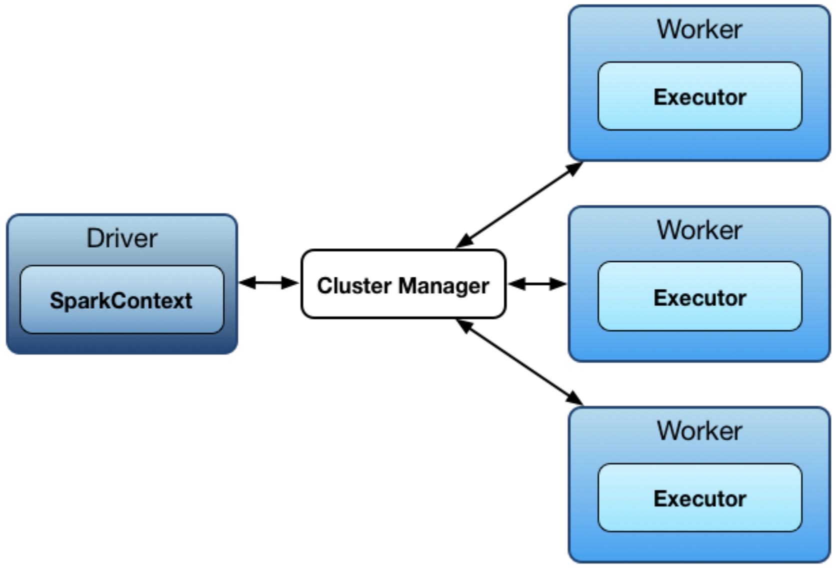
Evaluation ✓

Insights

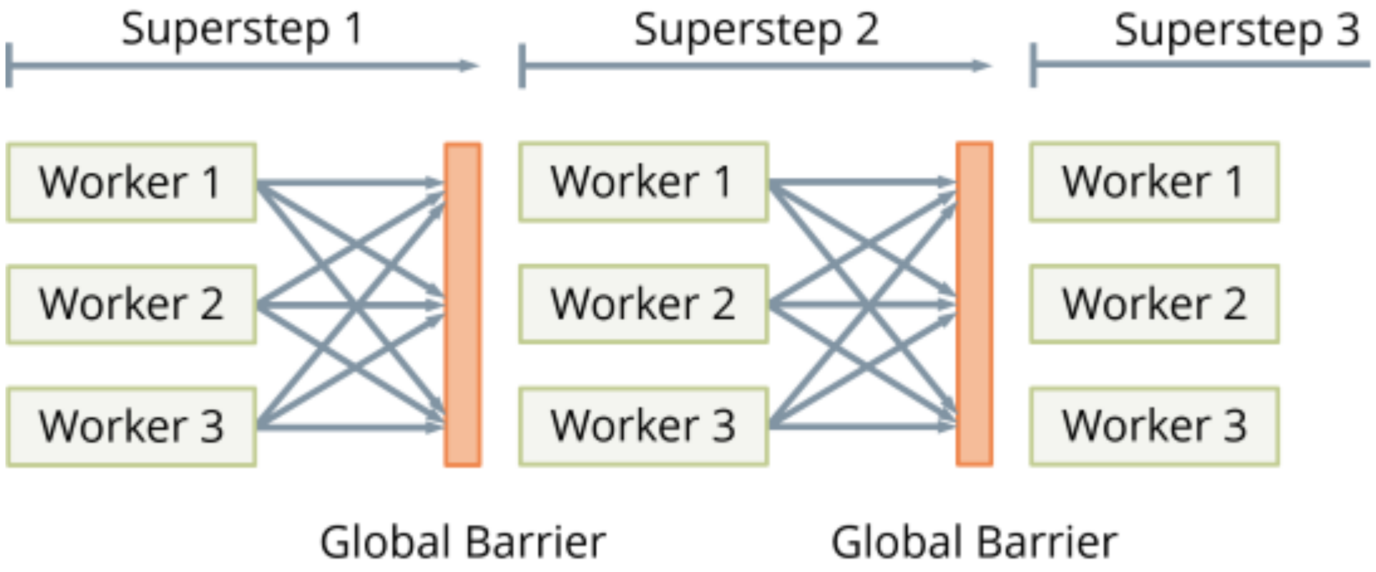
- The whole system is customized for machine learning, except the scheduler.



- Fault tolerance: checkpoint
- Spark, graph processing and parameter server



Spark



Graph processing