Open FinTech Forum

*AI, Blockchain & Kubernetes on Wall Street*

# Building Machine Learning Stack on Kubernetes

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THE LINUX FOUNDATION

# Agenda

- AI and ML
- Kubernetes
  - What and Why
- Deep Learning
- Leveraging K8s for ML
  - KubeFlow
  - Fabric for Deep Learning (FfDL or Fiddle)

# AI is everywhere

# AI is everywhere

IBM Watson

# AI is everywhere

# AI is everywhere

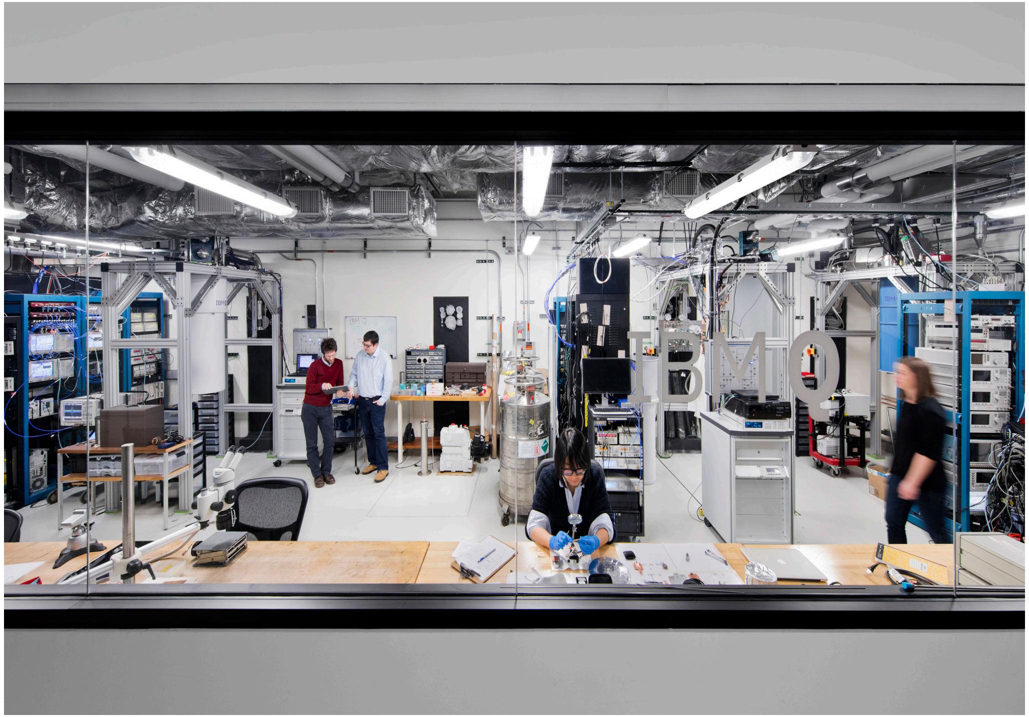
# Gartner predicts: By 2020, 85% of CIOs will pilot AI programs

- **85%**

# What’s different about **ML workloads?**

# ML Workload Characteristics

- CPU intensive
- Strength of HPC and GPUs
- High memory
- Need to scale workloads as the app grow

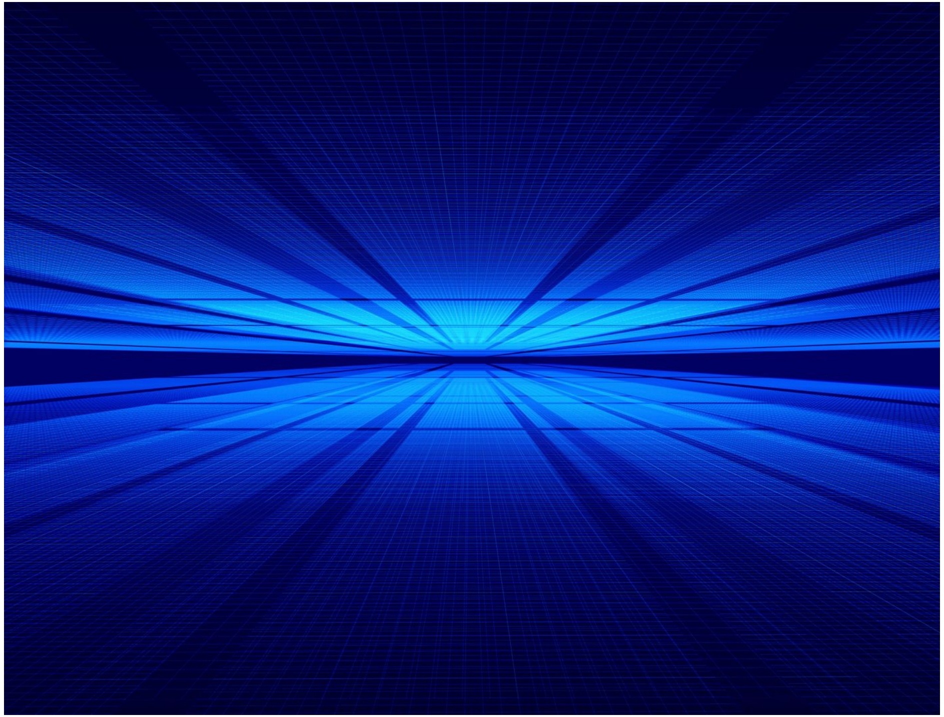


# Perception of ML Apps

- Lot of code around ML and very little code around infrastructure management, scaling, monitoring, logging, configuration management etc.
- People think that these other things are somehow being taken care of

# Reality of ML Apps

- Major burden is around running ML apps in production at scale around the things like
  - how do I deploy it
  - scale it
  - manage it
  - secure it
  - push continuous updates to it



# Watson AI workloads on IKS

IBM Watson workloads:

Proven AI workload on IBM Cloud Kubernetes Service

12 Watson services/apps represented as 800+ Kubernetes services

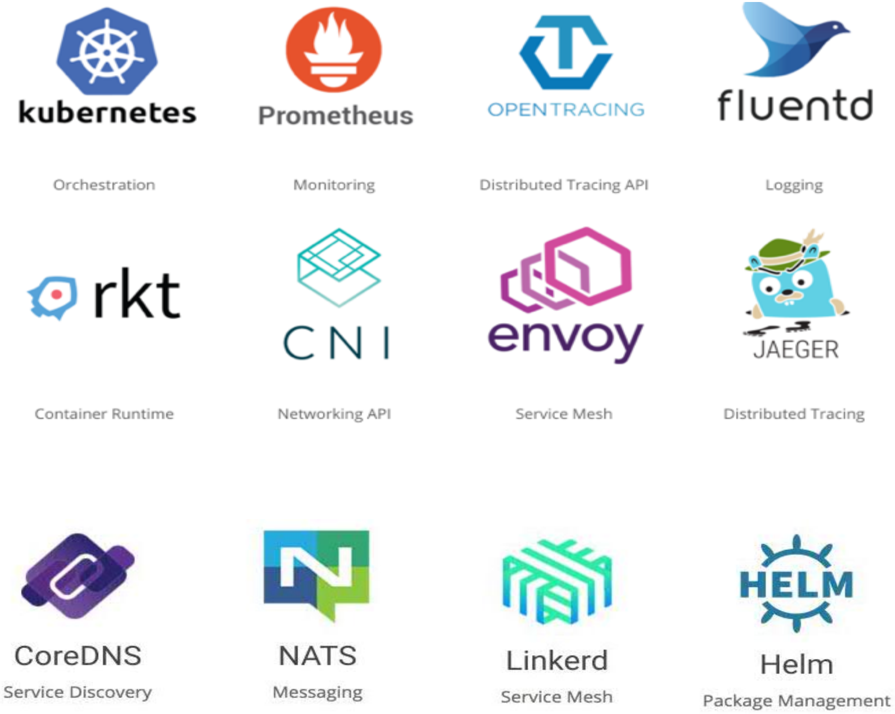
*"We no longer worry about managing the infrastructure because IBM Cloud Kubernetes Service takes care of that for us." – Watson Project Team*

One deployment example:

3000+ pods on 500+ nodes

# Kubernetes Overview

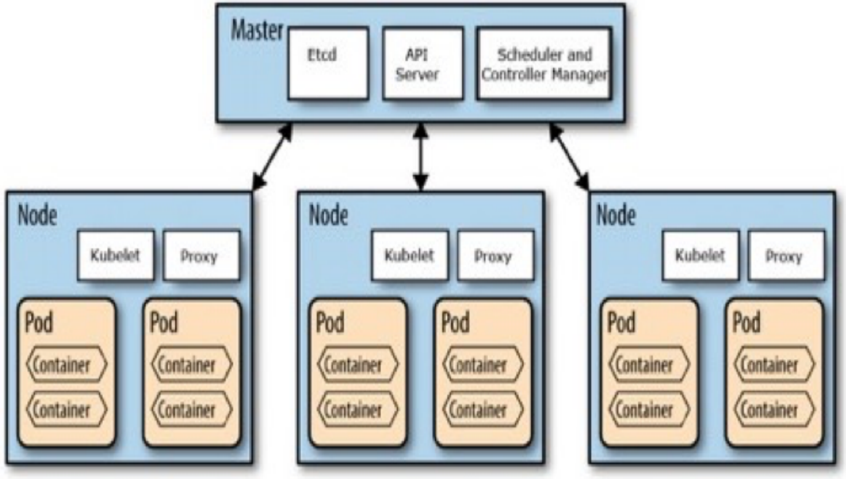
- **C**loud **N**ative **C**omputing **F**oundation project
- Enterprise level container orchestration
- Provision, manage, scale applications (containers) across a cluster
- Declarative model
  - Provide the "desired state" and Kubernetes will make it happen
- Github
  - [github.com/kubernetes/kubernetes](https://github.com/kubernetes/kubernetes)



# Kubernetes Cluster

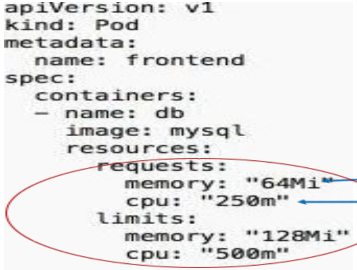
- A running Kubernetes cluster contains a cluster control plane (AKA *master*) and worker node(s), with cluster state backed by a distributed storage system(etcd). Cluster can be a single node to several nodes

- Kubernetes can run on various platforms – Laptop, VMs, Rack of bare metal servers. The effort required to set up a cluster varies from running a single command to crafting your own customized cluster



# Constrain Cluster Resources / Scheduler Optimization

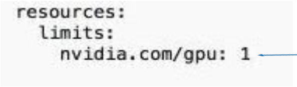
## Requests and limits



```
apiVersion: v1
kind: Pod
metadata:
  name: frontend
spec:
  containers:
  - name: db
    image: mysql
    resources:
      requests:
        memory: "64Mi"
        cpu: "250m"
      limits:
        memory: "128Mi"
        cpu: "500m"
```

64 MiB

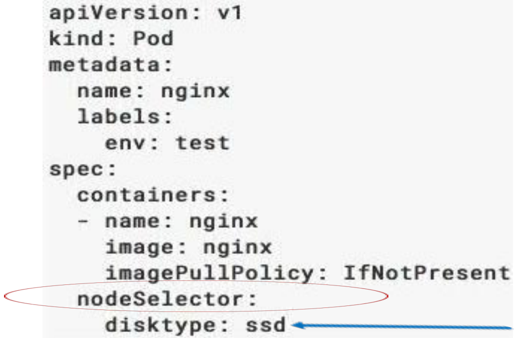
250 millicore/ millicpu



```
resources:
  limits:
    nvidia.com/gpu: 1
```

Schedule pod to a node per this GPU constraint

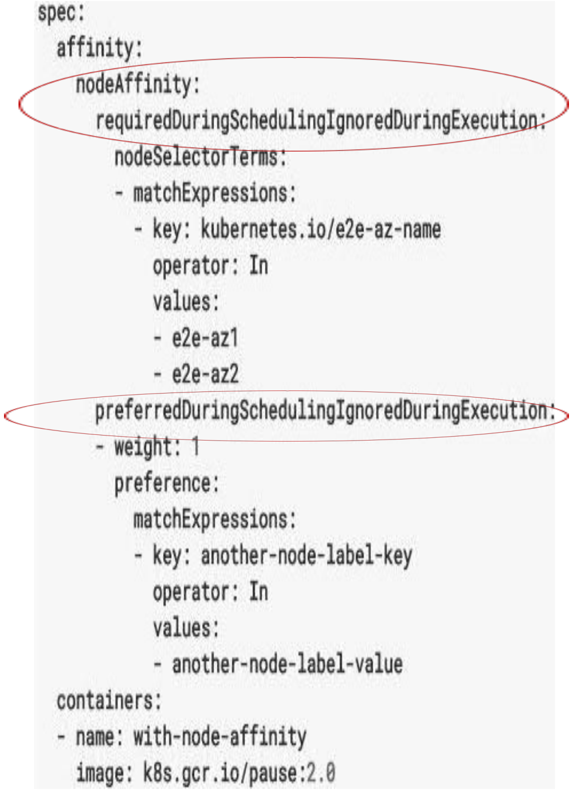
## Node Selector



```
apiVersion: v1
kind: Pod
metadata:
  name: nginx
  labels:
    env: test
spec:
  containers:
  - name: nginx
    image: nginx
    imagePullPolicy: IfNotPresent
  nodeSelector:
    disktype: ssd
```

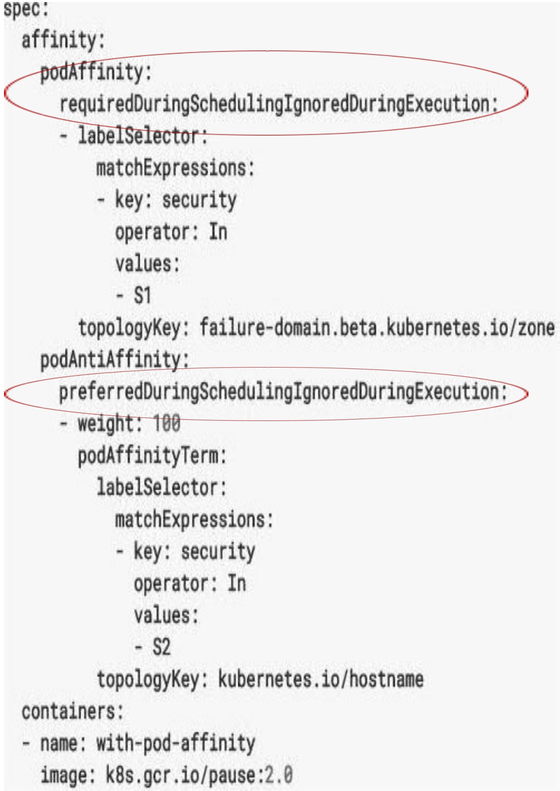
Node label

## Node Affinity



```
spec:
  affinity:
    nodeAffinity:
      requiredDuringSchedulingIgnoredDuringExecution:
        nodeSelectorTerms:
        - matchExpressions:
          - key: kubernetes.io/e2e-az-name
            operator: In
            values:
            - e2e-az1
            - e2e-az2
      preferredDuringSchedulingIgnoredDuringExecution:
      - weight: 1
        preference:
          matchExpressions:
          - key: another-node-label-key
            operator: In
            values:
            - another-node-label-value
  containers:
  - name: with-node-affinity
    image: k8s.gcr.io/pause:2.0
```

## Pod Affinity



```
spec:
  affinity:
    podAffinity:
      requiredDuringSchedulingIgnoredDuringExecution:
      - labelSelector:
          matchExpressions:
          - key: security
            operator: In
            values:
            - S1
        topologyKey: failure-domain.beta.kubernetes.io/zone
    podAntiAffinity:
      preferredDuringSchedulingIgnoredDuringExecution:
      - weight: 100
        podAffinityTerm:
          labelSelector:
            matchExpressions:
            - key: security
              operator: In
              values:
              - S2
          topologyKey: kubernetes.io/hostname
  containers:
  - name: with-pod-affinity
    image: k8s.gcr.io/pause:2.0
```

# What is Deep Learning?

- python programs executed via:
  - notebooks
  - scripts
- tend to deal with a lot of data
- tend to run for long periods of time
- tend to require a lot of setup, esp. with gpus

# Why ??

- Deep learning on containers
- Deep learning on kubernetes
- Deep learning on cloud

# How??

- Floydhub
- Kubeflow
- FfDL

# Kubeflow

- Developed by Google and contributions from others
- Training and Inferencing
- Expects the user to have knowledge of kubernetes
- umbrella project for other DL related projects as well

# Floydhub

- Focused on training
- Abstracts the notion of underlying infrastructure
- cli and jupyter lab support

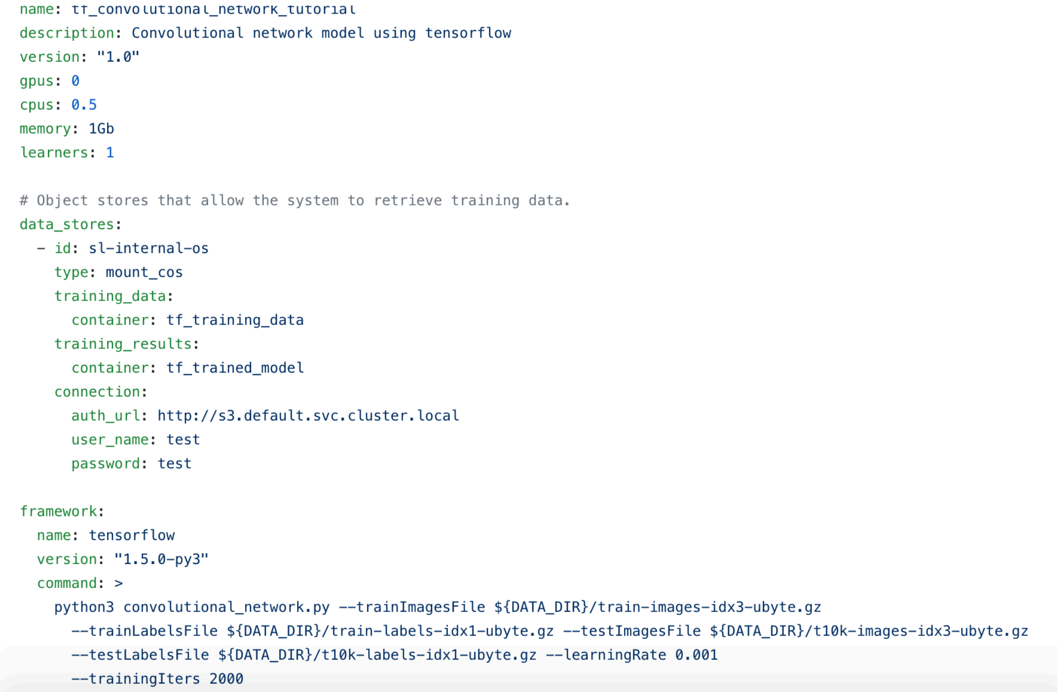
# FfDI

- Developed by IBM
- Abstracts the notion of underlying infrastructure
- cli UI and notebooks

# FfDI

- run a training
  - ffdl train <manifest file location> <model definition zip | model definition directory>

- manifest file



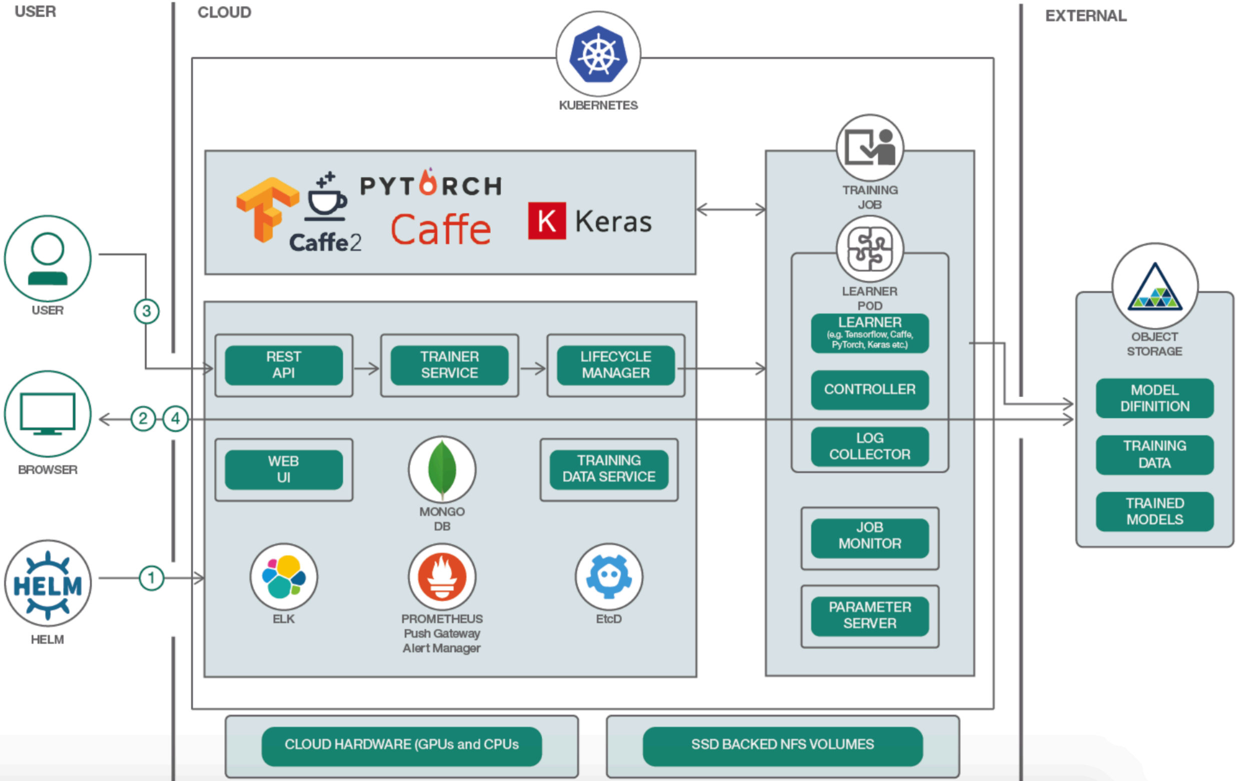
```
name: tf_convolutional_network_tutorial
description: Convolutional network model using tensorflow
version: "1.0"
gpus: 0
cpus: 0.5
memory: 1Gb
learners: 1

# Object stores that allow the system to retrieve training data.
data_stores:
  - id: sl-internal-os
    type: mount_cos
    training_data:
      container: tf_training_data
    training_results:
      container: tf_trained_model
    connection:
      auth_url: http://s3.default.svc.cluster.local
      user_name: test
      password: test

framework:
  name: tensorflow
  version: "1.5.0-py3"
  command: >
    python3 convolutional_network.py --trainImagesFile ${DATA_DIR}/train-images-idx3-ubyte.gz
      --trainLabelsFile ${DATA_DIR}/train-labels-idx1-ubyte.gz --testImagesFile ${DATA_DIR}/t10k-images-idx3-ubyte.gz
      --testLabelsFile ${DATA_DIR}/t10k-labels-idx1-ubyte.gz --learningRate 0.001
      --trainingIters 2000
```

# Behind the scenes

## FfDL: Architecture



USER

CLOUD

EXTERNAL

KUBERNETES

PYTORCH

Caffe2

Caffe

Keras

TRAINING JOB

LEARNER POD

LEARNER (e.g. Tensorflow, Caffe, PyTorch, Keras etc.)

CONTROLLER

LOG COLLECTOR

JOB MONITOR

PARAMETER SERVER

USER

BROWSER

HELM

3

2

4

1

REST API

TRAINER SERVICE

LIFECYCLE MANAGER

WEB UI

MONGO DB

TRAINING DATA SERVICE

ELK

PROMETHEUS Push Gateway Alert Manager

EtcD

OBJECT STORAGE

MODEL DIFINITION

TRAINING DATA

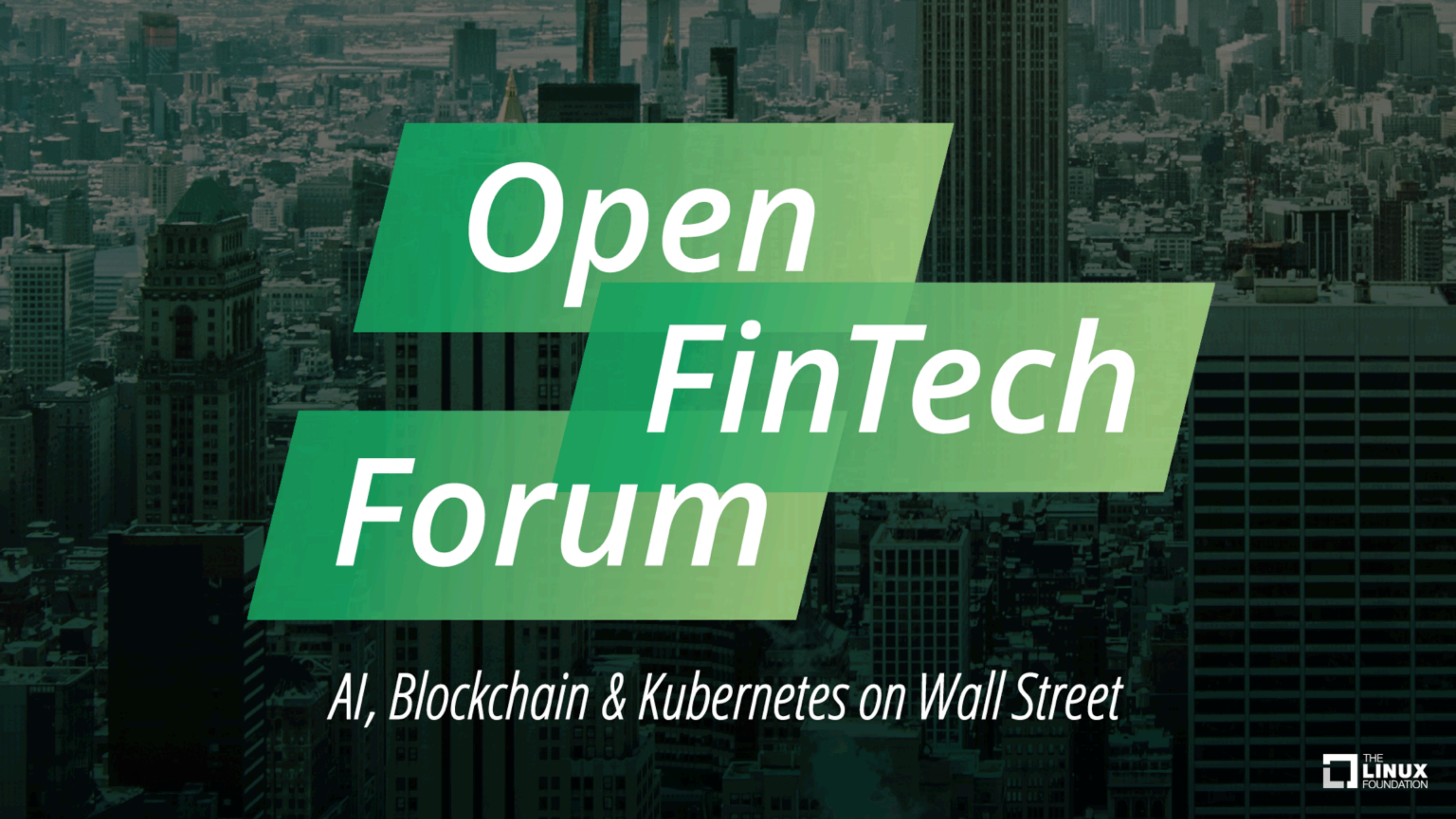
TRAINED MODELS

CLOUD HARDWARE (GPUs and CPUs

SSD BACKED NFS VOLUMES

# Lessons learnt

- What we did right
- What we did wrong
- Roadmap



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