超越容器，在 macOS 上使用 Kubernetes 编排 LLM

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GROWING CLOUD NATIVE TOGETHER
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Beyond Containers, Orchestrate LLMs with Kubernetes on macOS

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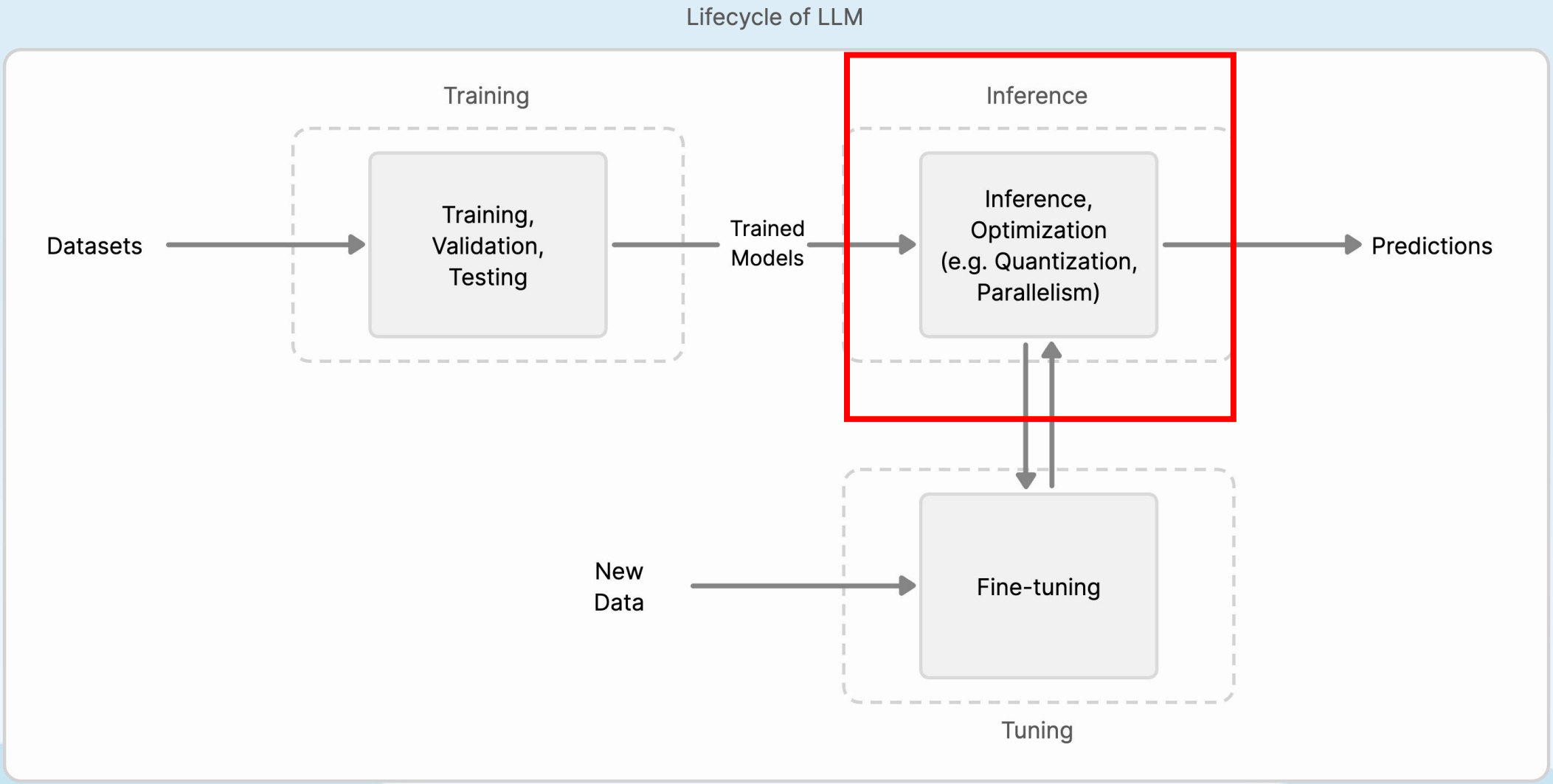
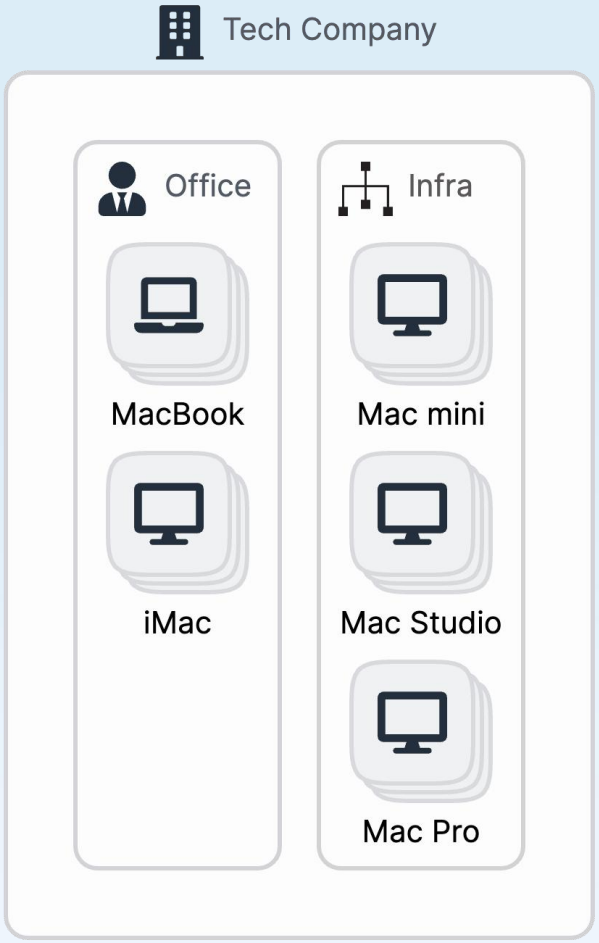
Agenda

- The Opportunity with Apple Silicon
- Kubernetes with LLMs - An Evolving Landscape
- Embracing macOS for LLM Inference
- Technical Deep Dive
- Demo: Deploying Open-Source Foundation Models
- Future Outlook
- Related links

In this talk


Lifecycle of LLM
Training
Inference
Datasets
Training,
Validation,
Testing
Trained
Models
Inference,
Optimization
(e.g. Quantization,
Parallelism)
Predictions
New
Data
Fine-tuning
Tuning

The Opportunity with Apple Silicon Cost



- GPUs are expensive and hard to buy in China (no warranty in some cases)
- Macs are free to buy and have warranty of 2 years in China!
- There are many Macs with idle GPUs in the tech company - reuse them as Kubernetes nodes

The Opportunity with Apple Silicon Performance

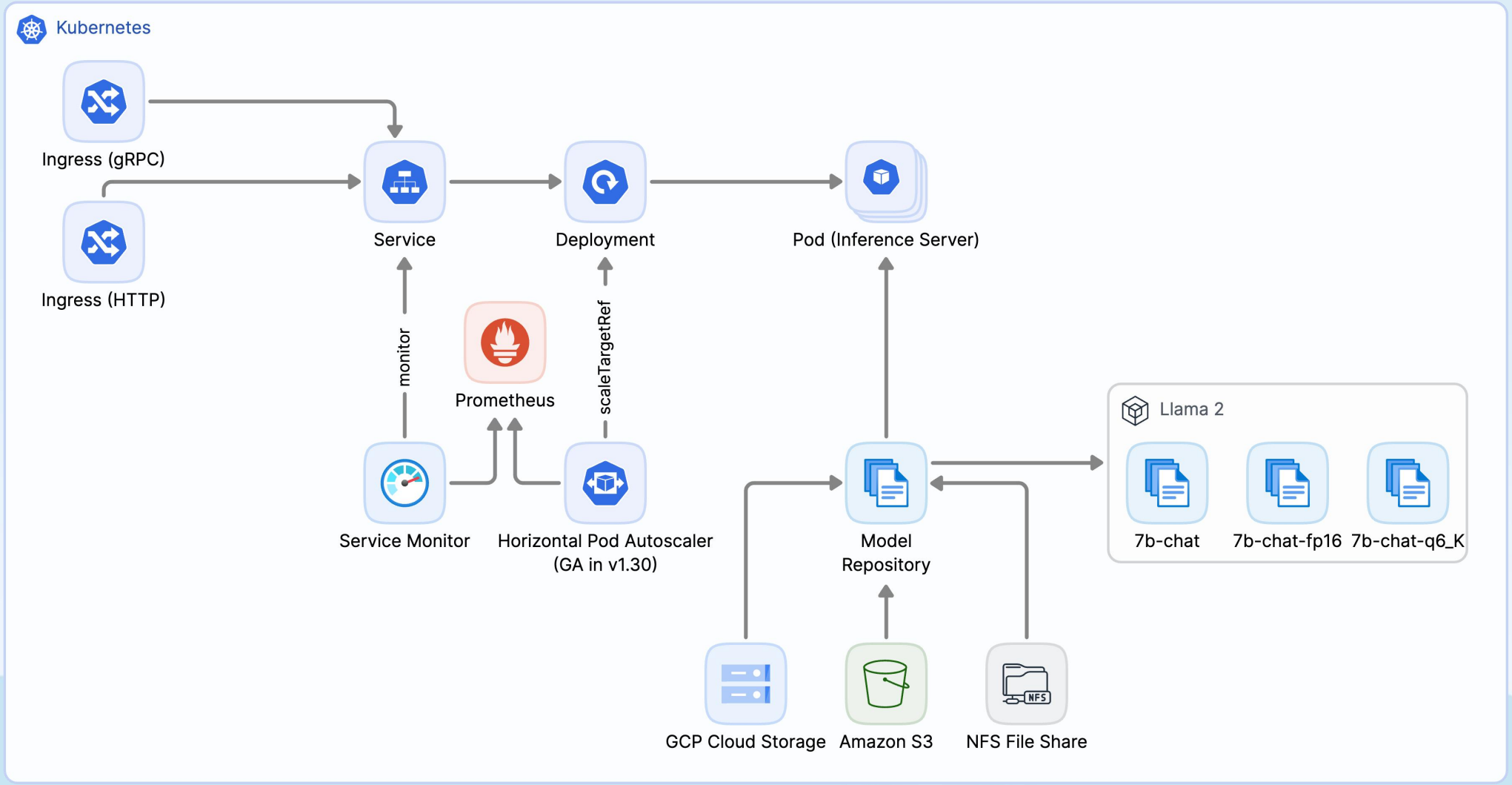
- Killer Features
  - Unified Memory Architecture (UMA)
    - Up to 192GB (~155GB can be accessed by Metal. Llama 2 7b ~ 3.8GB/13b ~ 7.4GB/70b-fp16 ~ 138GB)
    - 800GB/s of memory bandwidth
  - High performance GPU and Neural Engine
- llama.cpp on Apple Silicon
  - First-class citizen - optimized via ARM NEON, Accelerate and Metal frameworks
  - Performance
    - PP = Prompt processing (bs=512)

LLaMA 7B

	BW [GB/s]	GPU Cores	F16 PP [t/s]	F16 TG [t/s]	Q8_0 PP [t/s]	Q8_0 TG [t/s]	Q4_0 PP [t/s]	Q4_0 TG [t/s]
✅ M1 [1]	68	7			108.21	7.92	107.81	14.19
✅ M1 [1]	68	8			117.25	7.91	117.96	14.15
✅ M1 Pro [1]	200	14	262.65	12.75	235.16	21.95	232.55	35.52
✅ M1 Pro [1]	200	16	302.14	12.75	270.37	22.34	266.25	36.41
✅ M1 Max [1]	400	24	453.03	22.55	405.87	37.81	400.26	54.61
✅ M1 Max [1]	400	32	599.53	23.03	537.37	40.2	530.06	61.19
✅ M1 Ultra [1]	800	48	875.81	33.92	783.45	55.69	772.24	74.93
✅ M1 Ultra [1]	800	64	1168.8	37.01	1042.95	59.87	1030.04	83.73
✅ M2 [2]	100	8			147.27	12.18	145.91	21.7
✅ M2 [2]	100	10	201.34	6.72	181.4	12.21	179.57	21.91
✅ M2 Pro [2]	200	16	312.65	12.47	288.46	22.7	294.24	37.87
✅ M2 Pro [2]	200	19	384.38	13.06	344.5	23.01	341.19	38.86
✅ M2 Max [2]	400	30	600.46	24.16	540.15	39.97	537.6	60.99
✅ M2 Max [2]	400	38	755.67	24.65	677.91	41.83	671.31	65.95
✅ M2 Ultra [2]	800	60	1128.59	39.86	1003.16	62.14	1013.81	88.64
✅ M2 Ultra [2]	800	76	1401.85	41.02	1248.59	66.64	1238.48	94.27
🟥 M3 [3]	100	8						
🟨 M3 [3]	100	10			187.52	12.27	186.75	21.34
🟨 M3 Pro [3]	150	14			272.11	17.44	269.49	30.65
✅ M3 Pro [3]	150	18	357.45	9.89	344.66	17.53	341.67	30.74
✅ M3 Max [3]	300	30	589.41	19.54	566.4	34.3	567.59	56.58
✅ M3 Max [3]	400	40	779.17	25.09	757.64	42.75	759.7	66.31
🟥 M3 Ultra	800	60						
🟥 M3 Ultra	800	80						

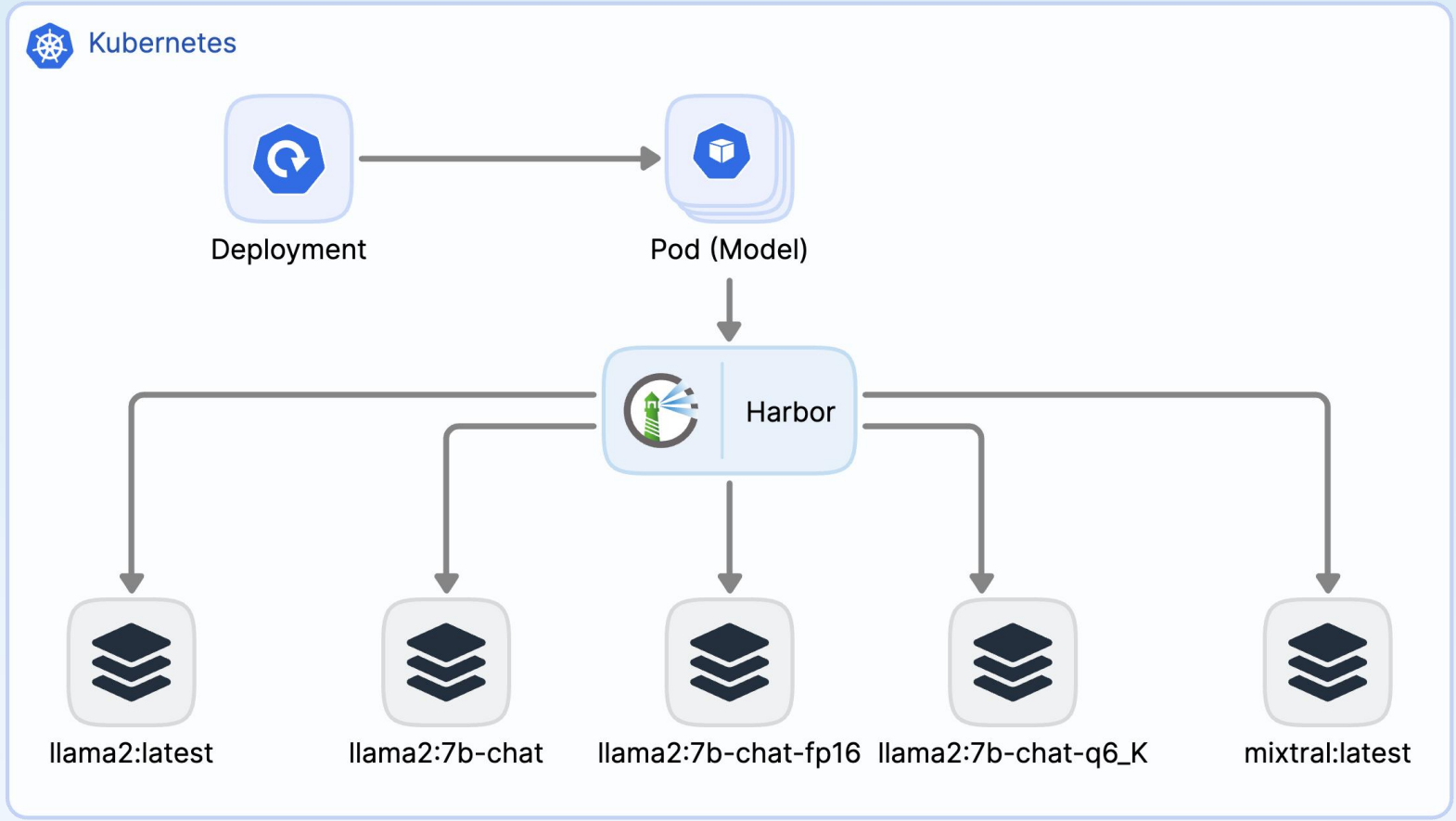
Kubernetes & LLMs - An Evolving Landscape

- A typical LLM inference service deployed in Kubernetes



Embracing macOS for LLM Inference

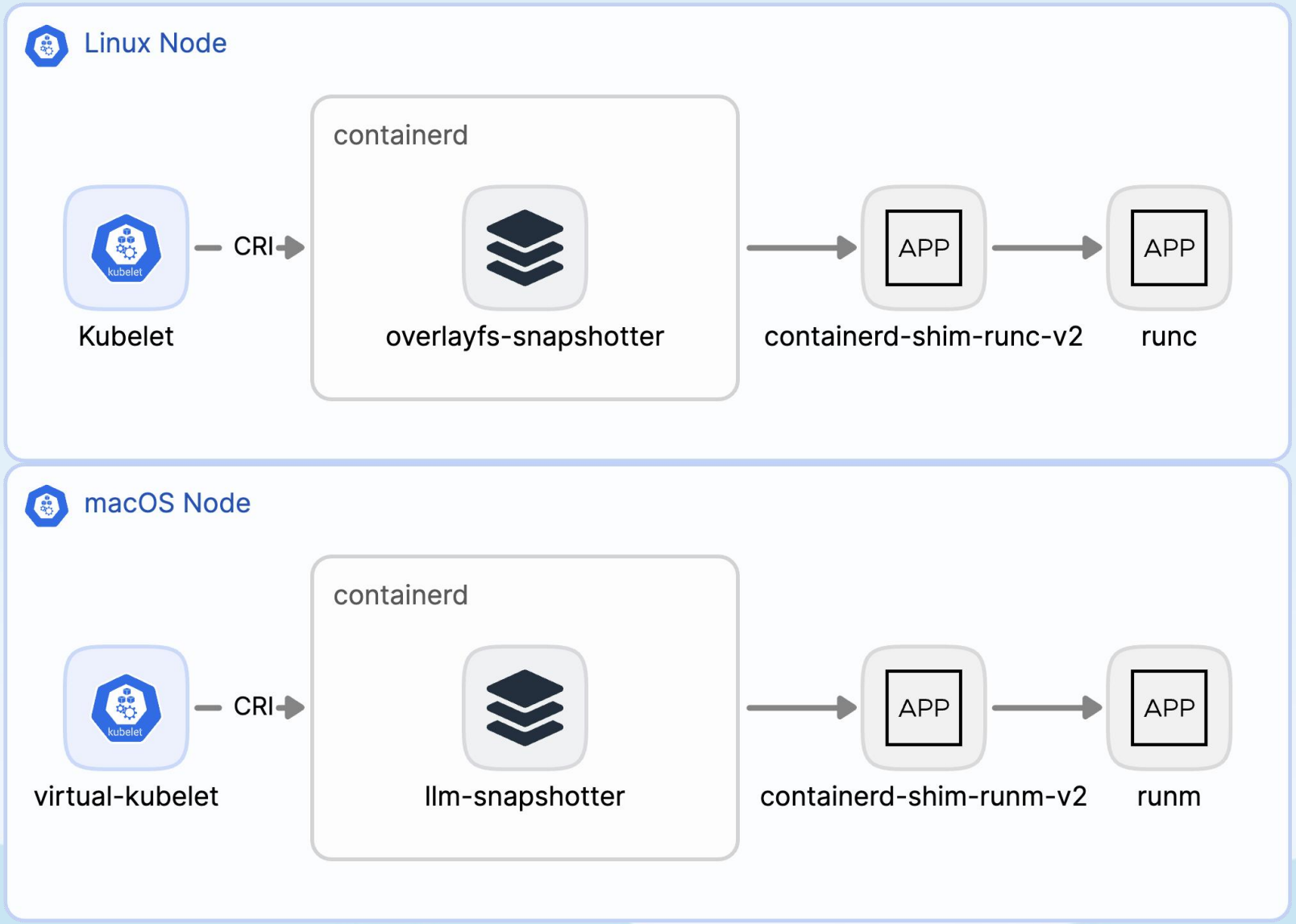
- Distribute LLMs by OCI image format
  - Get multiple benefits (layering, hashing, Auth & RBAC, retrial mechanism, etc)
  - No cloud native stack on macOS (Every container starts with a OCI image)
  - Proven by Ollama on local LLM



Technical Deep Dive

- Linux Node vs macOS Node
- LLM Image and New LLM SnapShotter
- runm - A Lightweight Inference Solution Derived from ggerganov/llama.cpp
- A specific network

Linux Node vs macOS Node



LLM Image and New LLM SnapShotter - 1

- OCI artifacts as LLM image

harbor.mthreads.com/llm/tinyllama:latest

Layers

"mediaType": "application/vnd.ollama.image.model",
"digest": "sha256:2af3b81862c6be03c769683af18efdadb2c33f60ff32ab6f83e42c043d6c7816",
"size": 637699456

"mediaType": "application/vnd.ollama.image.template",
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"size": 31

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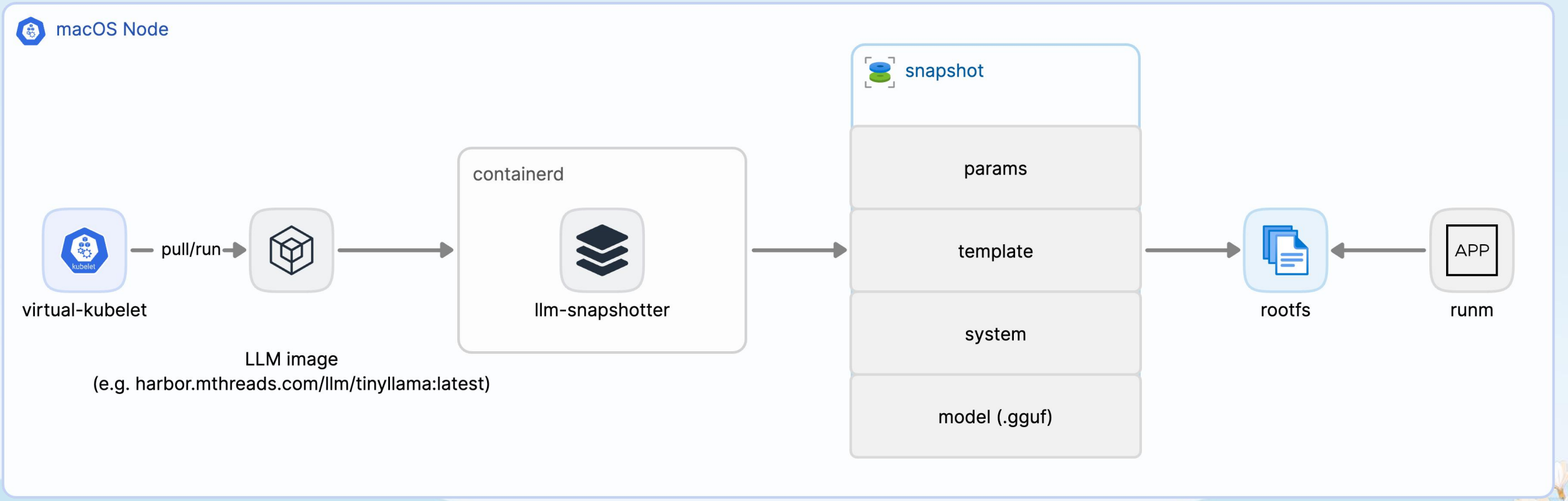
"size": 98

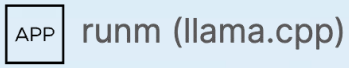
LLM Image and New LLM SnapShotter - 2

- Store LLM image locally as snapshot
- Create rootFS for runm



runm - A Lightweight Inference Solution Derived from ggerganov/llama.cpp

- Derived from ggerganov/llama.cpp
- Provide OpenAI API Compatibility



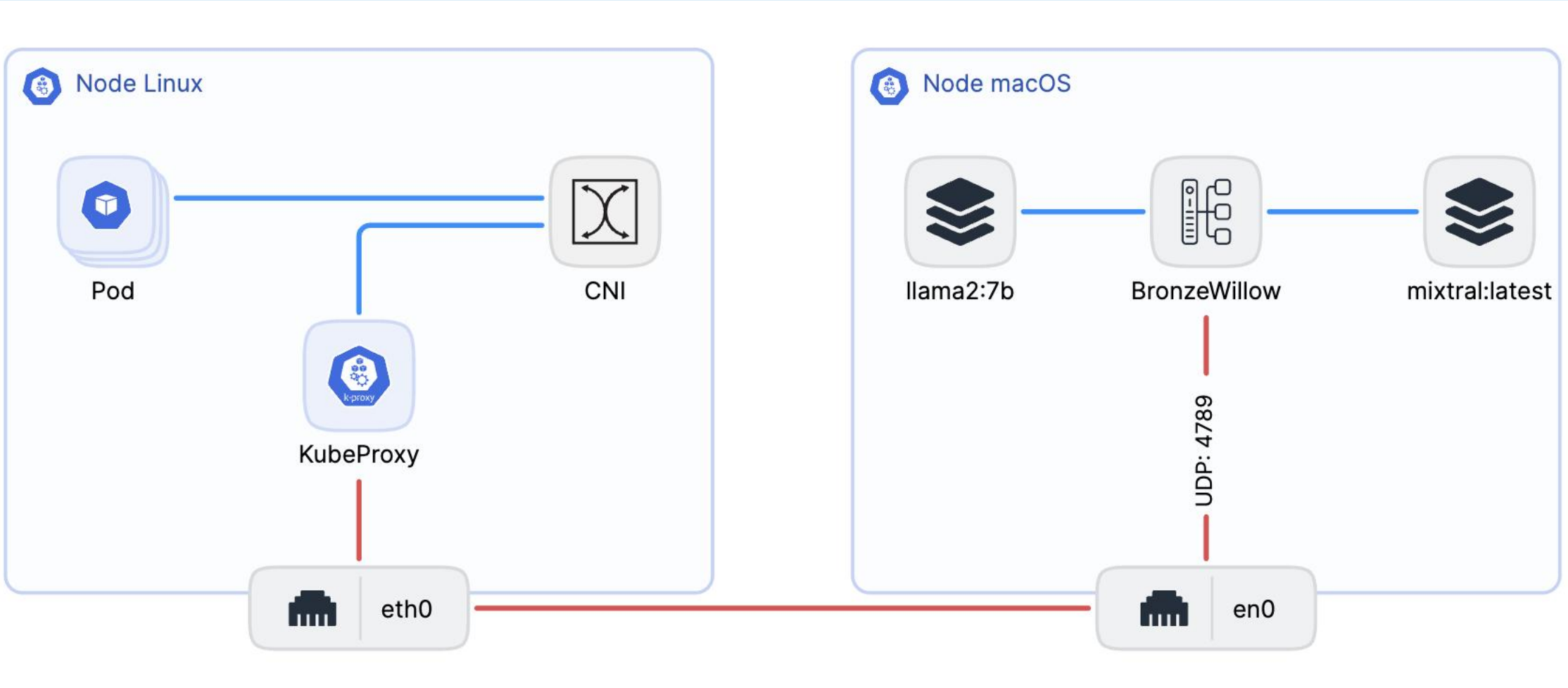
otool -L runm

```
/usr/lib/libresolv.9.dylib (compatibility version 1.0.0, current version 1.0.0)
/System/Library/Frameworks/CoreFoundation.framework/Versions/A/CoreFoundation (compatibility version 150.0.0, current version 2420.0.0)
/usr/lib/libc++.1.dylib (compatibility version 1.0.0, current version 1700.255.0)
/System/Library/Frameworks/Foundation.framework/Versions/C/Foundation (compatibility version 300.0.0, current version 2420.0.0)
/System/Library/Frameworks/CoreGraphics.framework/Versions/A/CoreGraphics (compatibility version 64.0.0, current version 1774.4.3)
/System/Library/Frameworks/Metal.framework/Versions/A/Metal (compatibility version 1.0.0, current version 343.14.0)
/usr/lib/libobjc.A.dylib (compatibility version 1.0.0, current version 228.0.0)
/System/Library/Frameworks/Security.framework/Versions/A/Security (compatibility version 1.0.0, current version 61123.100.169)
/usr/lib/libSystem.B.dylib (compatibility version 1.0.0, current version 1345.100.2)
```

Network - Overview

- A Specific CNI
  - A CNI, a VTEP, a L7 proxy with userspace network stack
- No privilege needed
- Using overlay network VXLAN/GENEVE
  - Supported by the most CNIs: Cilium, Calico, Antrea, .etc.
- Built in Rust
- Named BronzeWillow

Network - Traffic



Demo: Deploying Open-Source Foundation Models

- Create a Kubernetes Cluster (v1.30 with Antrea CNI)
- Join the macOS Node to the Cluster
    - Start the llm-containerd, llm-kubelet and BronzeWillow on macOS Node
- Create a tinyllama Deployment with 2 replicas
- Create a Service of the Deployment
- Create a Pod with *mods* (an AI CLI tool) built in
- Use *mods* with tinyllama Service

~/demo (-zsh)

```
(base) ➜ demo
```

~/demo (-zsh)

```
(base) ➜ demo
```

k9s (k9s)

```
Context: kubernetes-admin@kubernetes
Cluster: kubernetes
User:    kubernetes-admin
K9s Rev: v0.32.4
K8s Rev: v1.30.0
CPU:     n/a
MEM:     n/a
```

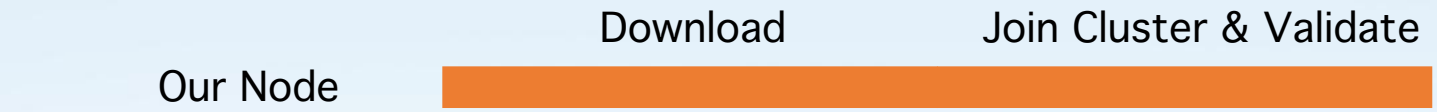
<c> Cordon <u> Uncordon
<y> YAML
<r> Drain
<?> Help

Demo 视频请查看：

https://www.bilibili.com/video/BV1YE421L7nz

Nodes(all)[2]

NAME↑	STATUS	ROLE	TAINTS	VERSION	PODS	AGE
k8s-node-control-plane	Ready	control-plane	1	v1.30.0	9	24h
k8s-node-worker-1	Ready	worker	0	v1.30.0	2	24h



This is just the start...

Download a Model Implement a service Build Image Distribute Image

Linux Node

Loop

Our Node

Maintenance is the real problem.

Future Outlook

- Built-in support of RAG and langchain composition
- Resource quota management of macOS

- Train model on KUAE and distribute models on

Related links

- https://github.com/containerd/containerd
- https://github.com/virtual-kubelet/virtual-kubelet
- https://github.com/ggerganov/llama.cpp
- https://github.com/jmorganca/ollama
- https://github.com/antrea-io/antrea
- https://github.com/charmbracelet/mods
- https://www.mthreads.com/product/KUAE
- https://kccnceu2024.sched.com/event/1YeMp
- https://kccnceu2024.sched.com/event/1YeMh
- https://www.bretfisher.com/kubernetes-vs-docker/
- https://github.com/yeahdongcn/kcd-shanghai-2024

Thanks.