Flink in Containerland

Deploying Apache Flink on Kubernetes

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What's this talk about?

Lessons learned based on…

- getting a Flink cluster working in Docker
- creating the Flink image for Docker Hub
- deploying Flink on Kubernetes (K8s)
- tying it all together for dA Platform 2

Why containerized Flink?

- Fits our ideal deployment model (more about this later)
- Efficient dynamic resource allocation and scaling
- Application-oriented instead of machine-oriented philosophy

Why Kubernetes?

- Principled API design
- Resource-oriented
- Disciplined about the layer of infrastructure it occupies
- Provides all the necessary parts to effectively run containerized applications at scale

Agenda

- **Part 1**: Setting the Stage
  - Background of Flink and Kubernetes
- **Part 2**: Challenges and Solutions
  - Discussion of and solutions for various challenges with containerized Flink
- **Part 3**: Conclusion
- **Part 4**: Q&A

Part 1 – Setting the Stage

Agenda (Part 1)

- ~~Introduction~~
- **Recap of Flink architecture**
- One job per cluster
- Kubernetes intro and terminology
- Flink-on-K8s example

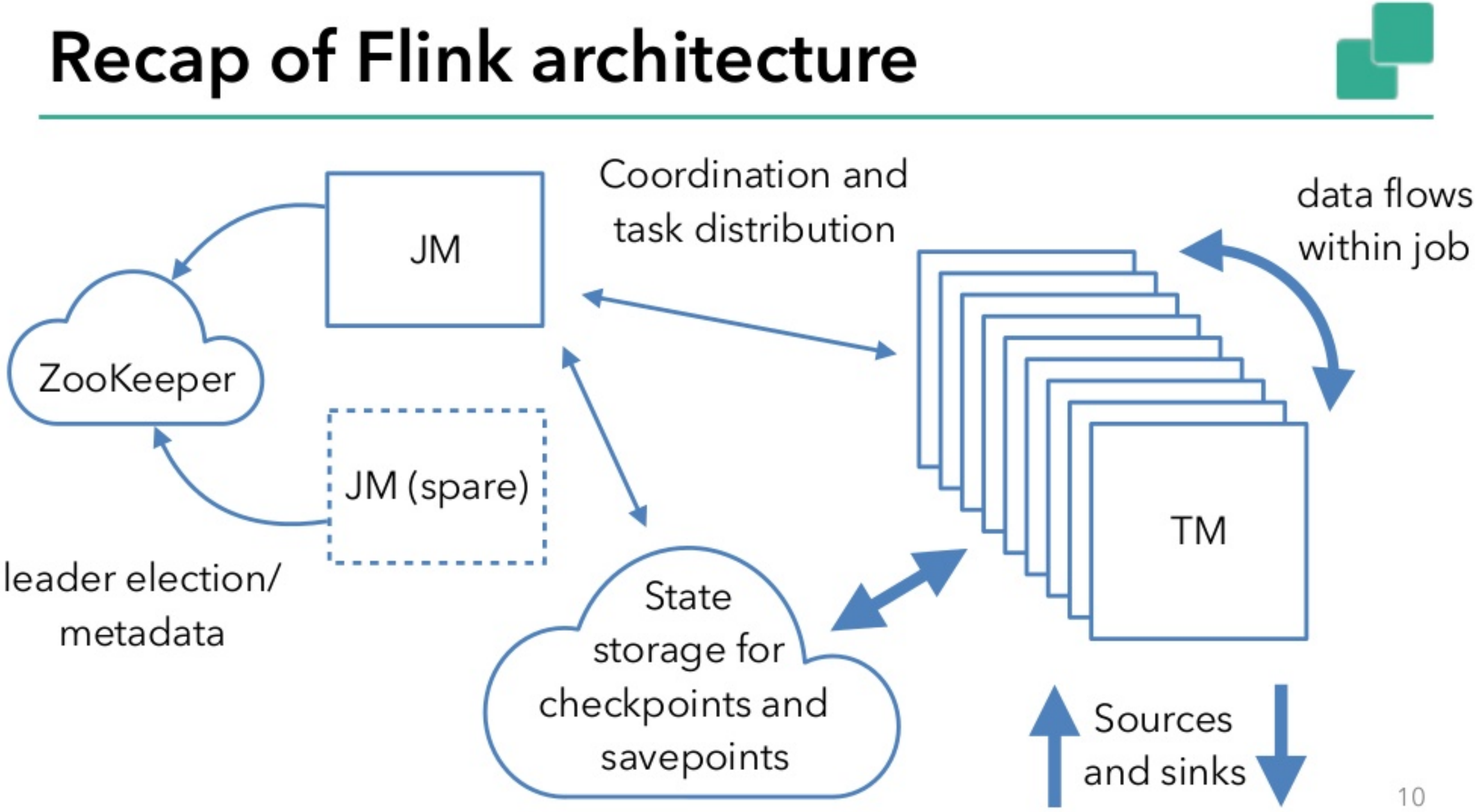
Recap of Flink architecture

- 1 active JobManager (JM)
  - central coordinator for cluster/jobs
  - orchestrates task distribution and checkpointing
  - serves UI and HTTP API

Recap of Flink architecture

- 1 or more TaskManagers (TM)
  - execute user code
  - configured with address of JM

Recap of Flink architecture



Agenda (Part 1)

- ~~Introduction~~
- ~~Recap of Flink architecture~~
- **One job per cluster**
- Kubernetes intro and terminology
- Flink-on-K8s example

One job per cluster

- Evolving job deployment philosophy
- Tie cluster lifecycle to job lifecycle
- Ideally, the job is first-class
  - think about running a job on a platform like Kubernetes, not a running Flink cluster first then submitting the job

One job per cluster

- Early versions of Flink heavily inspired by Hadoop
  - have a cluster comprised of nodes having different roles (JM, TMs)
- FLIP-6, ongoing project to improve and modernize this aspect of Flink

Agenda (Part 1)

- ~~Introduction~~
- ~~Recap of Flink architecture~~
- ~~One job per cluster~~
- **Kubernetes intro and terminology**
- Flink-on-K8s example

Kubernetes intro and terminology

- Resource-oriented with declarative configuration
  - Tell K8s about what should exist, and a background process asynchronously makes it happen
- “3 replicas of this container should be kept running, only on nodes with this label”
- “a load balancer should exist, listening on port 443, backed by containers with this label”

Kubernetes intro and terminology

- Various kinds of resources, very extensible (add your own resources and "controllers" that handle them)
- Some core types:
  - **Pod** (one or more containers running on a node)
  - **Deployment** (keep 0 or more pods running, specified by a template)
  - **Service** (a hostname-accessible network service that listens on one or more ports and proxies to pods that match given labels)
  - **ConfigMap** (data that can be rendered as files or env vars)

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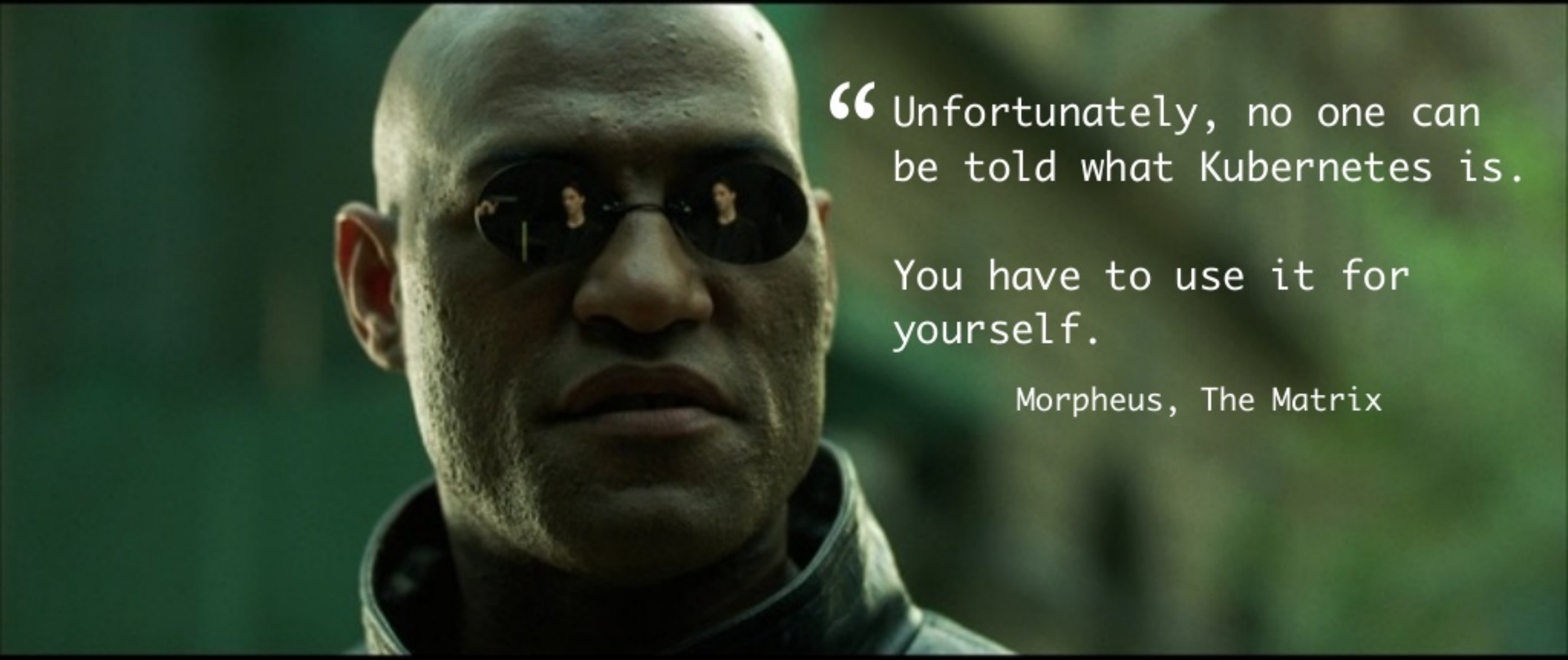
- **Flink-on-K8s example**

Flink-on-K8s example

- JobManager **Deployment**
  - maintain 1 replica of Flink container running as a JobManager
  - apply a label like “flink-jobmanager”
- JobManager **Service**
  - make JobManager accessible by a hostname & port
  - select pods with label “flink-jobmanager”

Flink-on-K8s example

- TaskManager **Deployment**
  - maintain *n* replica of Flink container running as a TaskManager
- Flink config **ConfigMap**
  - Materialize necessary config into files (i.e. `flink-conf.yaml`; perhaps `core-site.xml`)

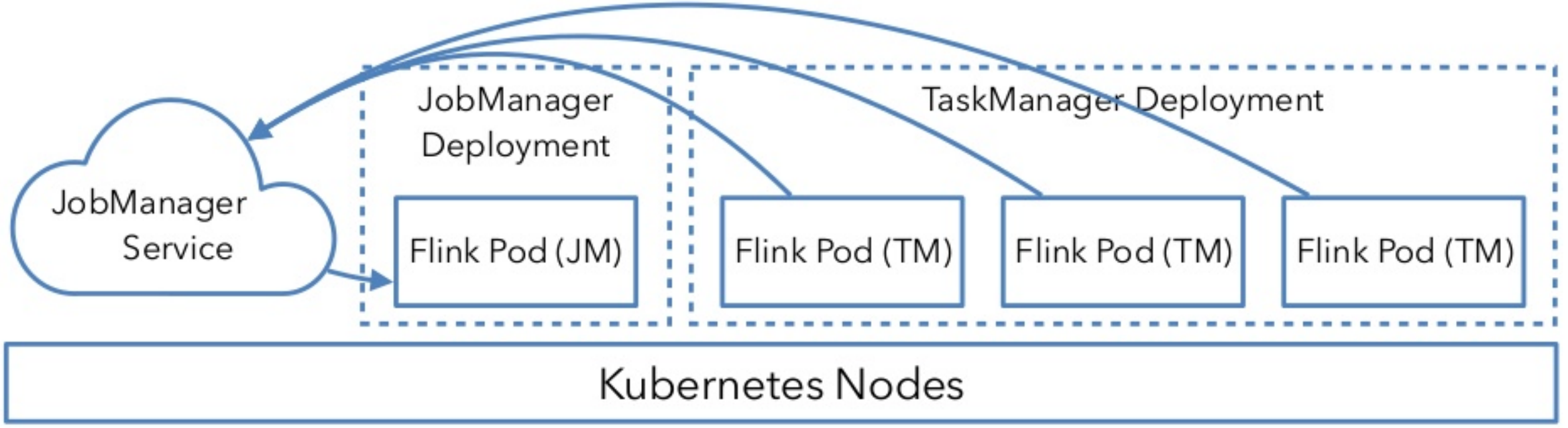

“ Unfortunately, no one can be told what Kubernetes is.
You have to use it for yourself.
Morpheus, The Matrix

Flink-on-K8s example

Service exposes predictable hostname and load balances connections across matching pods

Deployment ensures desired # of pods remain running and applies upgrade strategy

ConfigMap including contents of `flink-conf.yaml` mounted as volume in each pod at `/etc/flink`



Part 2 – Challenges and Solutions

Agenda (Part 2)

- **JobManager RPC**
- Port configuration
- “HA mode”
- Extra libraries, logging, other config
- Queryable state
- TLS/on-the-wire encryption
- Resource allocation

JobManager RPC

- Networking is the source of most challenges with Flink-on-Kubernetes
  - 5 of 7 sections in Part 2 are networking-related
- If you run a simple deployment on Kubernetes as I described above… it just doesn't work (or rather it doesn't "just work")

JobManager RPC

- Most visible issue: use of Akka for Flink CLI RPC (including job submission)
  - Akka requires that the “name” (hostname or IP) used to address the JM matches the name the JM itself is configured with
  - If connecting from outside the K8s environment, such via port-forwarding or over a load balancer, messages are silently dropped

JobManager RPC

- JM running in pod `my-flink-cluster-jobmanager-3063995c2t0`
- JM Service `my-flink-cluster-jobmanager`, listening on Flink RPC, blob server, and UI ports
- JM/TMs configured with `jobmanager.rpc.address: my-flink-cluster-jobmanager`
- TMs work fine, as they talk to the JM with the same name as it sees itself (i.e. the name of the Service)
- But if you forward the JM RPC port locally or access it via a proxy…

JobManager RPC

From my laptop, having forwarded port 6123 to a running cluster on K8s:

```
$ flink run -m localhost:6123 examples/batch/WordCount.jar
Cluster configuration: Standalone cluster with JobManager at localhost/127.0.0.1:6123
Using address localhost:6123 to connect to JobManager.
    .    .    .
Submitting job with JobID: ff86d06802fc69554ee0a5f726204db5. Waiting for job
completion.
```

… which hangs until a timeout. In the JobManager's log:

```
2017-09-08 09:42:26,082 ERROR akka.remote.EndpointWriter
[] - dropping message [class akka.actor.ActorSelectionMessage] for non-local recipient
[Actor[akka.tcp://flink@localhost:6123/]] arriving at [akka.tcp://flink@localhost:
6123] inbound addresses are [akka.tcp://flink@my-flink-cluster-jobmanager:6123]
```

JobManager RPC

- One solution is to submit the job from within the K8s environment
  - e.g. run a pod that contains your job jar, use the Flink CLI to submit
- Another solution is to use the HTTP API (or the UI)
  - Not subject to "addressability" problems
  - Cons: hard to secure, not well specified

Agenda (Part 2)

- ~~JobManager RPC~~
- **Port configuration**
- "HA mode"
- Extra libraries, logging, other config
- Queryable state
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Port configuration

- Flink chooses arbitrary ports for some services (i.e. blob server, queryable state)
- Must specify these in Flink config and JobManager service
  - `blob.server.port: 6124`
  - `query.server.port: 6125`

Agenda (Part 2)

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"HA mode"

- A misnomer—**always use HA mode in production, even with 1 JobManager**
  - JM stores critical state in ZooKeeper that allows it to recover if the JM dies
- On K8s and other resource managers, should only need to run a single JobManager as the manager will re-launch it upon failure

"HA mode"

- If you do run >1 JM, accessing the UI becomes difficult
  - If you expose both JMs in a Service, but your request routes to the non-leader, will be redirected to internal hostname of leader
  - One solution seen on the mailing list, have non-leader fail "readiness probe", so doesn't receive traffic
- *Possible improvement to Flink*: proxy non-leader requests to leader

Agenda (Part 2)

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Extra libraries, logging, other config

- For code dependencies, easiest to build a “fat jar” that includes them
- Notable exceptions are state backend, logging, and metrics dependencies, for example…
  - S3 state storage requires extra AWS, Hadoop jars
  - SLF4J and Graylog’s GELF appender require additional jars

Extra libraries, logging, other config

- For these, easiest to build your own Flink image
  - See https://github.com/docker-flink/docker-flink to see how the public image is built
- Alternatively, an advanced solution is to build an image containing your jars and use Kubernetes' "init-containers" feature to load them in before Flink starts

Agenda (Part 2)

- ~~JobManager RPC~~
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- **Queryable state**
- TLS/on-the-wire encryption
- Resource allocation

Queryable state

- Currently somewhat tricky
- Only works out-of-the-box if all TMs are addressable and routable
  - For most setups, this means you must be in the same K8s environment
- Also suffer from Akka addressability issue
- *Possible improvement to Flink*: enable TMs to proxy queries to the correct TM, à la Cassandra
  - Then, create another Service in front of all TMs listening on the query server port

Queryable state

- A more cumbersome solution that would work today is to create a service yourself that runs in the same K8s environment and proxies requests
- This has some added advantages, such as…
  - horizontal scalability
  - an opportunity for caching
  - a way to maintain partial availability while the underlying Flink job is down, e.g. during upgrades

Agenda (Part 2)

- ~~JobManager RPC~~
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- **TLS/on-the-wire encryption**
- Resource allocation

TLS/on-the-wire encryption

- Also a bit tricky, as Pods inherently don't have predictable hostnames or IPs
- One solution: generate a trustStore/keyStore when launching cluster
  - Which contain a single key pair and certificate that all JMs/TMs in the cluster use and verify against
  - Essentially symmetric encryption in the "convenient" wrapper of TLS
  - *I haven't actually tried this*

TLS/on-the-wire encryption

- Another possibility: use an overlay network in Kubernetes that magically does on-the-wire encryption
  - Encryption supported in some fashion by some overlay networks
  - Whether or not this is acceptable to you depends on your requirements
  - *I haven't actually tried this*

Agenda (Part 2)

- ~~JobManager RPC~~
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- **Resource allocation**

Resource allocation

- How many slots should each TM have?
  - >1 slot per TM can save some overhead
  - But fewer slots/TM could theoretically reduce time to recovery (restoring from checkpoint)
  - *But* more machines means a higher chance of some failure

Resource allocation

- How much CPU/RAM should each TM get?
  - Ideally, each slot should have one CPU
  - Within a slot, processing is serial, so >1 CPU/slot shouldn't matter much
  - RAM/slot ratio is application-dependent; 1GB is a decent minimum to start with

Resource allocation

- Check out Robert Metzger's talk about Flink operations to some deeper discussion and insight about this
  - *Keep It Going – How to Reliably and Efficiently Operate Apache Flink*
- Available on the FlinkForward YouTube channel before the end of the day

Part 3 – Conclusion

Conclusion

- Containerization/resource management platforms have a bright future
- Flink well-positioned, but has plenty of room for improvement

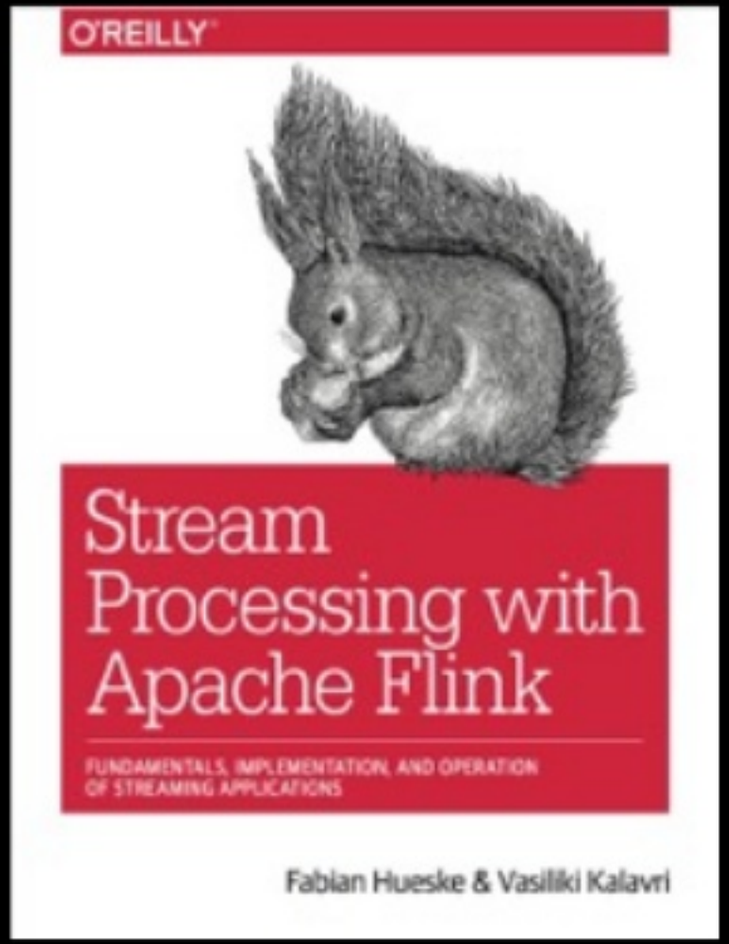
Conclusion

- My most-wanted Flink improvement vis-à-vis Flink-on-K8s
  - Establish a *specified* HTTP API for all management and monitoring functions
  - Rewrite the CLI to use this API exclusively
  - Provide health-check endpoints for JobManagers *and* TaskManagers that can be used for Liveness/ ReadinessChecks

See Also

- FLINK-6369 - Better support for overlay networks
  - for discussion about the networking-/overlay network-related issues discussed in this presentation
- The Flink User mailing list
  - plenty of posts about the topics I covered today
- FLIP-6 - Flink Deployment and Process Model
  - ongoing work to improve how Flink interacts with resource managers, notably Mesos and YARN


That's all Folks!



Thank you!

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Part 3 – Q & A