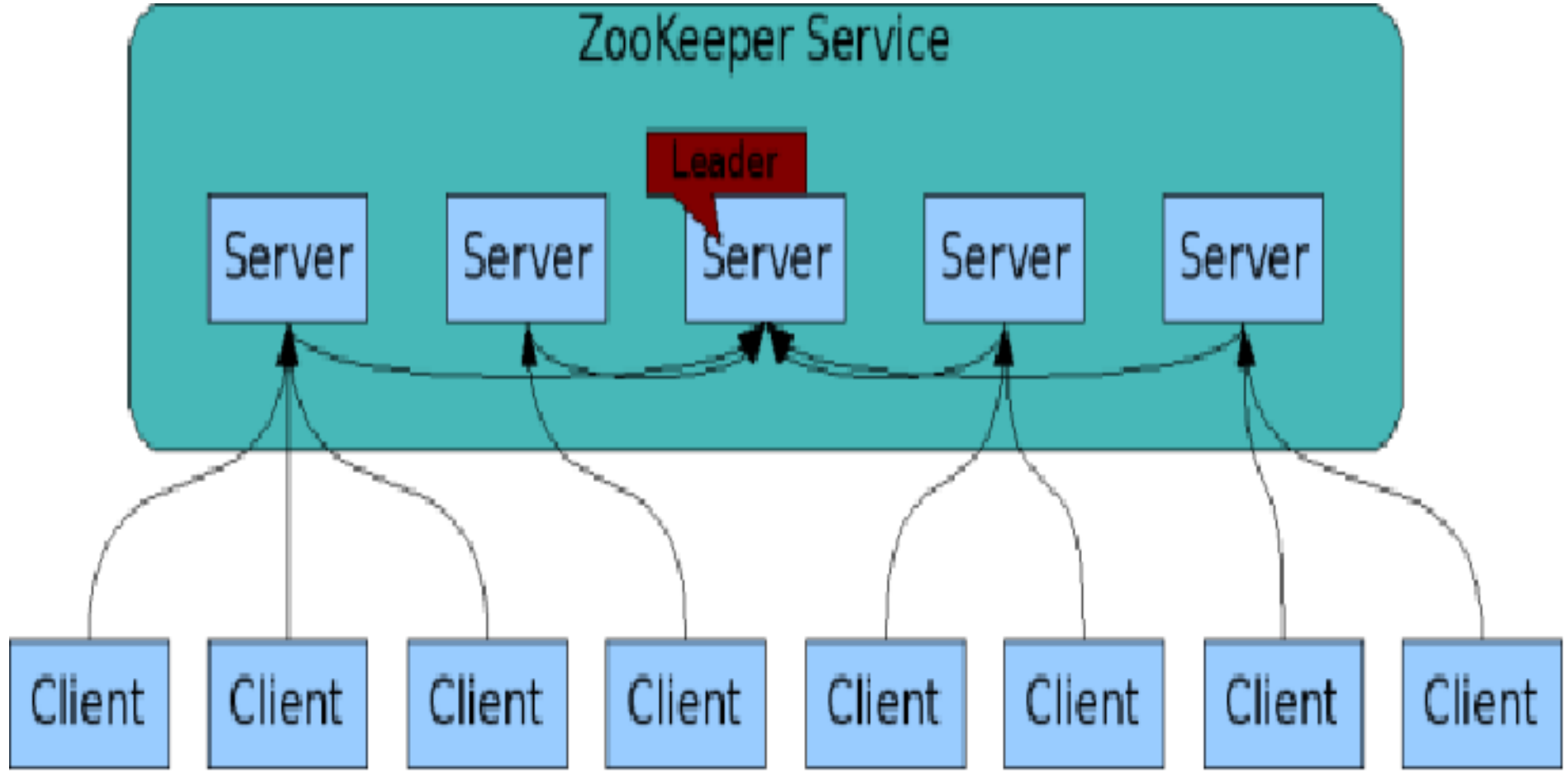
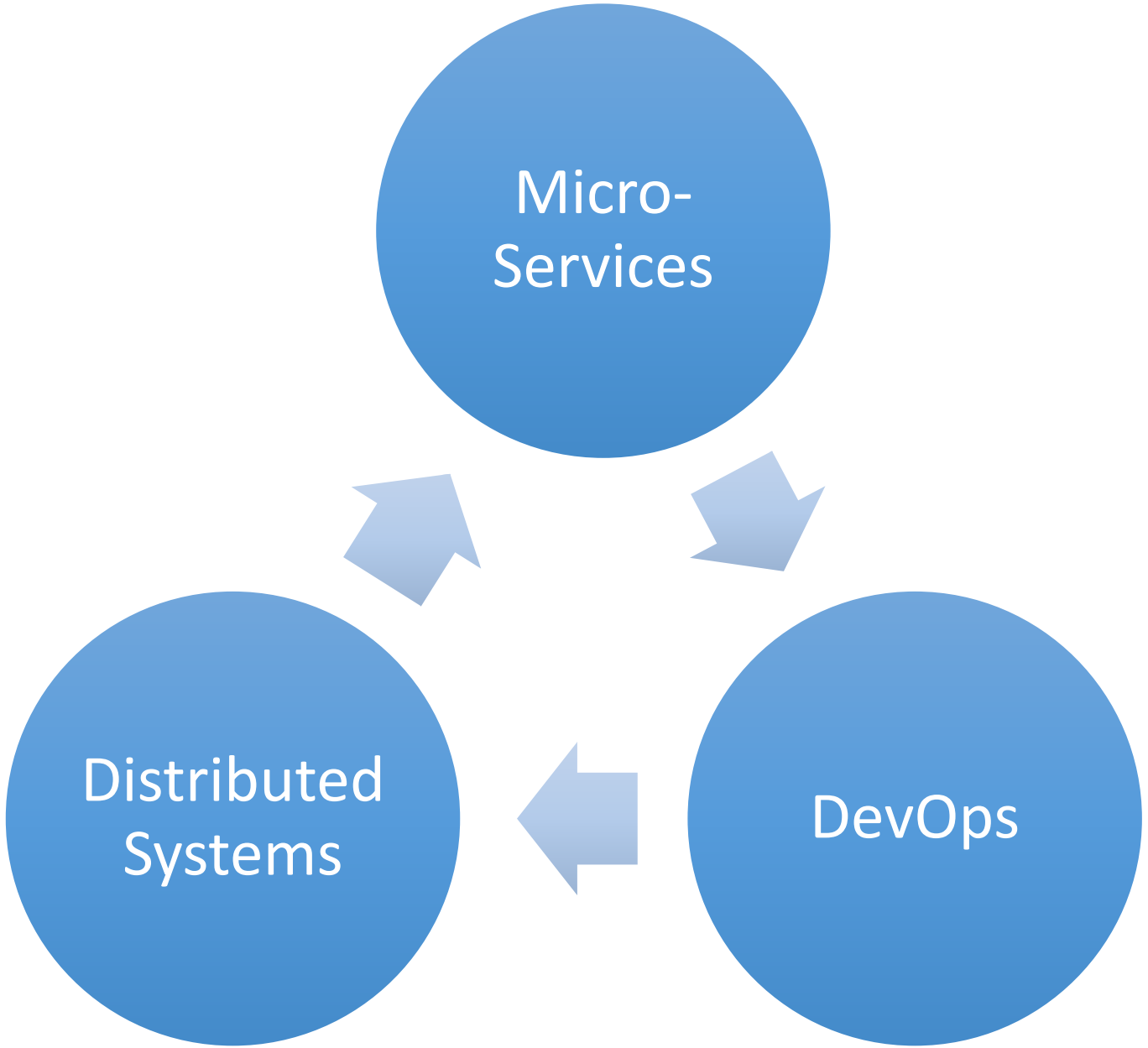
November 15th and 17th Classes

- Anuj Bhandar will be the guest lecturer on November 15th
  - DevSecOps: Security in Microservices
- November 17th will be a TA help session
- Suresh and Marlon will be at Supercomputing 2016
- Here is where we were last week: http://sciencegateways.org/gateways2016/
- Final Presentations will be December 1st, 6th, and 8th



Microservice clients use Zookeeper primitives to build higher level services.

Any questions about Project Milestone 3?


Micro-
Services
DevOps
Distributed
Systems

Messaging in Distributed Systems

Examining messaging in distributed systems though Advanced Message Queuing Protocol (AMQP) and RabbitMQ overviews

Questions

- Who has used AMQP messaging systems like RabbitMQ previously?
- Has anyone used other messaging systems
  - Apache Kafka
  - ZeroMQ
  - JMS
  - XMPP…
- Why did no team choose a messaging approach for inter-service communication?

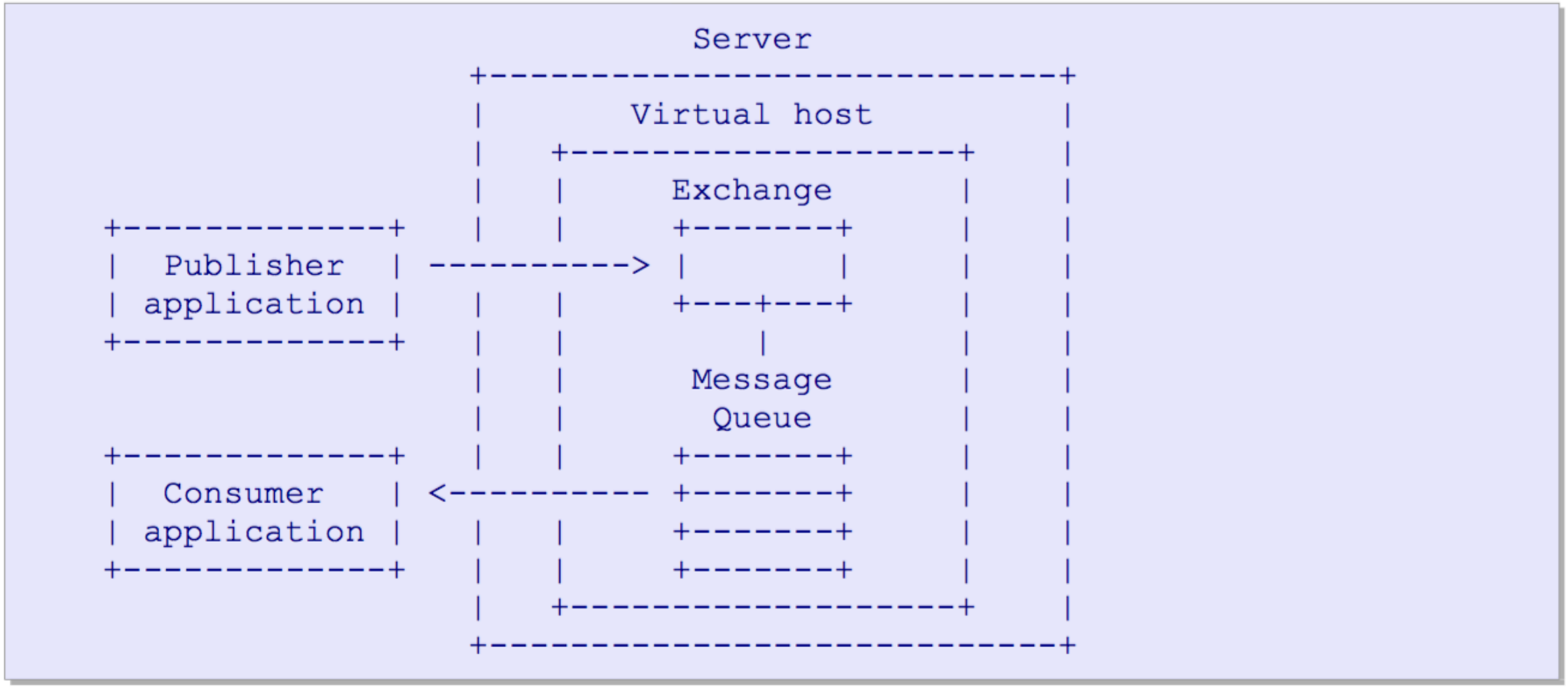
AMQP: Network Protocol and Architecture, Not An API

- Many Implementations
  - RabbitMQ, Apache ActiveMQ, Apache Qpid, SwiftMQ, ...
- I'll focus on Version 0-9-1 and RabbitMQ
- Note as we go similarities and differences with Zookeeper
  - Similar philosophy: provide "primitive" operations that can be combined to support more complicated scenarios.
- This is not an AMQP tutorial

Value of Messaging Queuing Systems, Generally

- They are queues for messages....
- Even if you are doing point-to-point routing, messaging systems remove the need for publishers and consumers to know each other's addresses.
  - Publishers and consumers just need to know how to connect to the message broker.
  - The network locations and specific instances of the publishers and consumers can change over time.
  - Logical instances persist
- Synchronous and asynchronous messages natively supported.
- Multiplex multiple channels of communication over a single TCP/IP connection

Basic Concepts



An AMQP Server (or Broker)

Two main parts

- Exchange
- Message Queue
- Exchanges can interact with multiple message queues

Exchange

- Accepts producer messages
- Sends to 0 or more Message Queues using routing keys

Message Queue

- Routes messages to different consumers depending on arbitrary criteria
- Buffers messages when consumers are not able to accept them fast enough.

Producers and Consumers

- Producers only interact with Exchanges
- Consumers interact with Message Queues
- Consumers aren’t passive
  - Can create and destroy message queues
- The same application can act as both a publisher and a consumer
  - You can implement Request-Response with AMQP
  - Except the publisher doesn’t block
- Ex: your application may want an ACK or NACK when it publishes
  - This is a reply queue

Message Queue Properties and Examples

- Basic queue properties:
  - Private or shared
  - Durable or temporary
  - Client-named or server- named, etc.
- Combine these to make all kinds of queues, such as
- **Store-and-forward queue**: holds messages and distributes these between consumers on a round-robin basis.
  - Durable and shared between multiple consumers.
- **Private reply queue**: holds messages and forwards these to a single consumer.
  - Reply queues are typically temporary, server-named, and private to one consumer.
- **Private subscription queue**: holds messages collected from various "subscribed" sources, and forwards these to a single consumer.
  - Temporary, server-named, and private

Consumers and Message Queues

- AMQP Consumers can create their own queues and bind them to Exchanges
  - This has an interesting implication
- Queues can have more than one attached consumer
- AMQP queues are FIFO
  - AMQP allows only one consumer per queue to receive the message.
  - Use round-robin delivery if > 1 attached consumer.
- If you need > 1 consumer to receive a message, you can give each consumer their own queue.
  - Each Queue can attach to the same Exchange, or you can use topic matching.
- Compare this to Zab and atomic broadcast protocols, generally.
  - AMQP makes some simplifications

The Exchange

- Receives messages
- Inspects a message header, body, and properties
- Routes messages to appropriate message queues
- Routing usually done with **routing keys** in the message payload
  - For point-to-point messages, the routing key is the name of the message queue
  - For pub-sub routing, the routing key is the name of the topic
    - Topics can be hierarchical

Publish-Subscribe Patterns

- Useful for many-to-many messaging
- In microservice-based systems, several different types of components may want to receive the same message
  - But take different actions
  - Ex: you can always add a logger service
- You can always do this with explicitly named routing keys.
- You may also want to use hierarchical (name space) key names and pattern matching.
  - gateway.jobs.jobtype.gromacs
  - gateway.jobs.jobtype.*

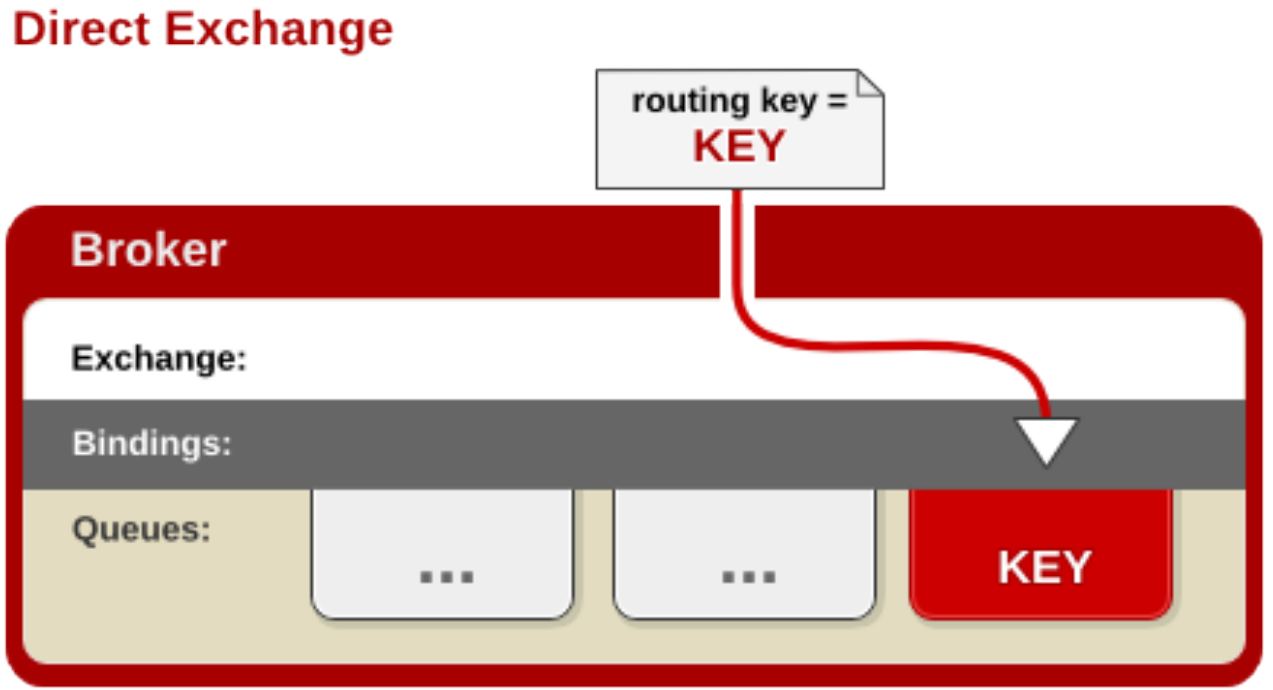
The Message Payload

- Read the specification for more details.
- In general AMQP follows the head-body format
- The message body payload is binary
- AMQP assumes the content is handled by consumers
  - The message body is opaque to the AMQP server.
- You could serialize your content with JSON or Thrift and deserialize it to directly send objects.

Message Exchange Patterns

Direct Exchange

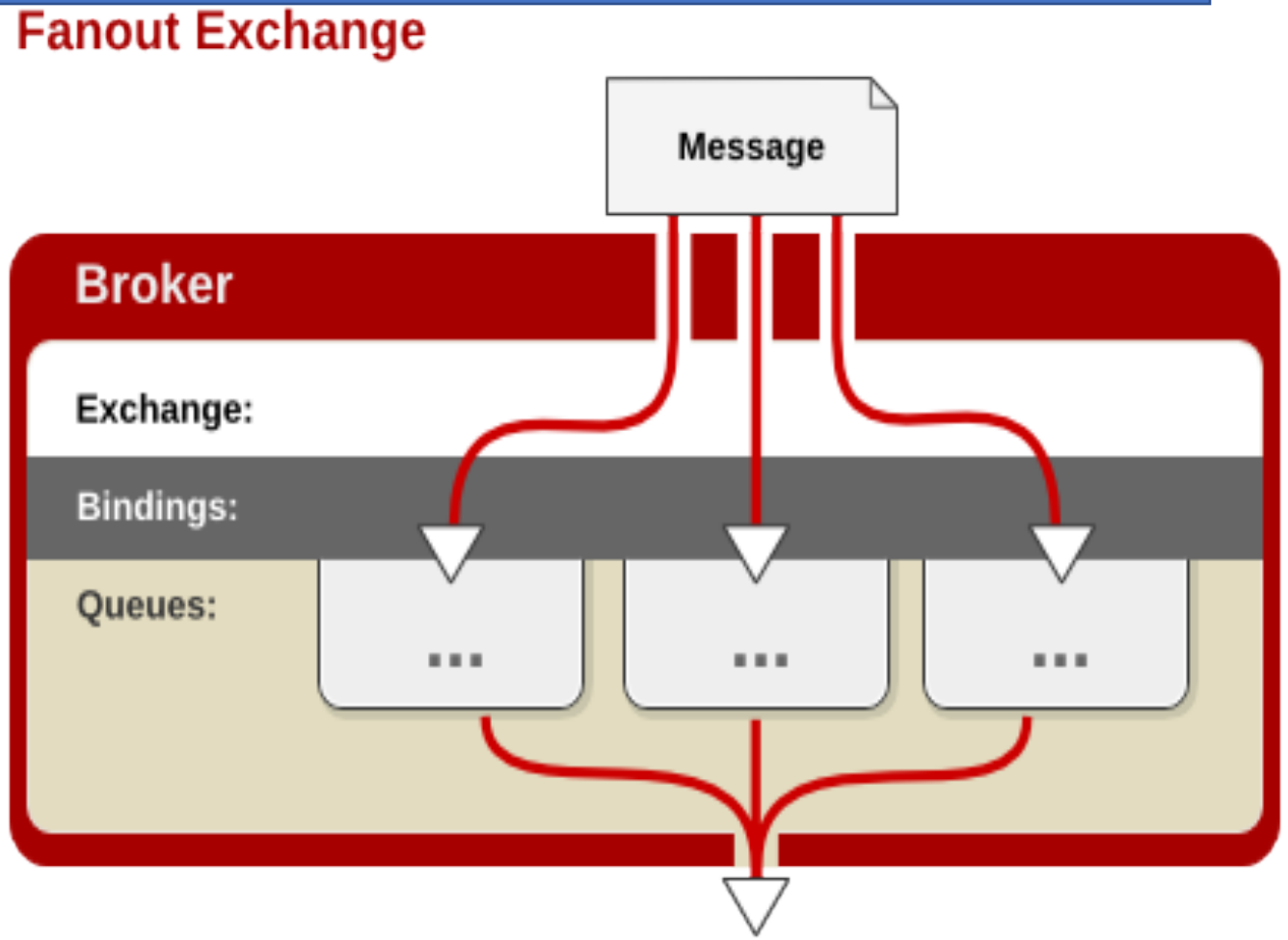
- A publisher sends a message to an exchange with a specific routing key.
- The exchange routes this to the message queue bound to the routing key.
- One or more consumers receive messages if listening to the queue.
- Default: round-robin queuing to deliver to multiple subscribers of same queue




```
Queue.Declare queue=app.svc01
Basic.Consume queue=app.svc01
Basic.Publish routing-
key=app.svc01
```

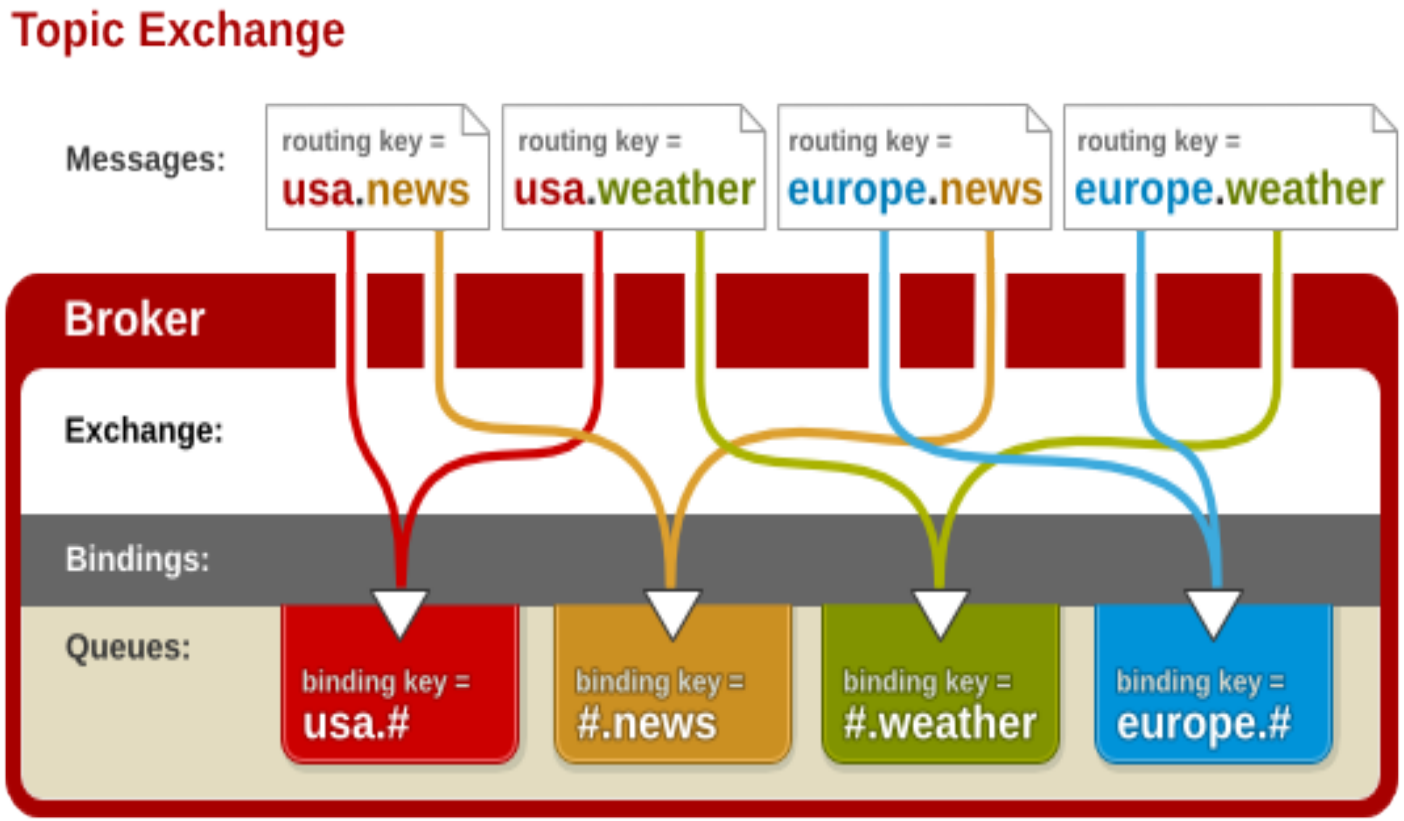
Fanout Exchange

- Message Queue binds to an Exchange with no argument
- Publisher sends a message to the Exchange
- The Exchange sends the message to the Message Queue
- All consumers listening to all Message Queues associated with an Exchange get the message



Topic Exchange

- Message Queues bind using *routing patterns* instead of routing keys.
- A Publisher sends a message with a routing key.
- Exchange will route to all Message Queues that match the routing key's pattern



More Examples

RabbitMQ Tutorial

- Has several nice examples of classic message exchange patterns.
- https://www.rabbitmq.com/getstarted.html

What It Omits

- Many publishers
- Absolute and partial event ordering are hard problems

Some Useful Capabilities of Messaging Systems for Microservices

Overarching Requirement: It should support your system's distributed state machine

Let's brainstorm some

Useful Capabilities: My List (1/2)

- Supports both push and pull messaging
- Deliver messages in order
- Successfully delivered messages are delivered exactly once
  - Multiple recipients OK
- Deliver messages to one or more listeners based on pre-defined topics.
- Store messages persistently
  - There are no active recipients.
  - All recipients are busy
- Determine if critical messages were delivered correctly

Useful Capabilities: My List (2/2)

- Redeliver messages that weren't correctly received
  - Corrupted messages, no recipients, etc
  - Recipient can change
- Redeliver messages on request
  - Helps clients resynch their states
- Allow other components to inspect message delivery metadata.
  - Supports elasticity, fault tolerance
- Priority messaging?
- Qualities of Service
  - Security, fault tolerance

Which Messaging Software to Choose?

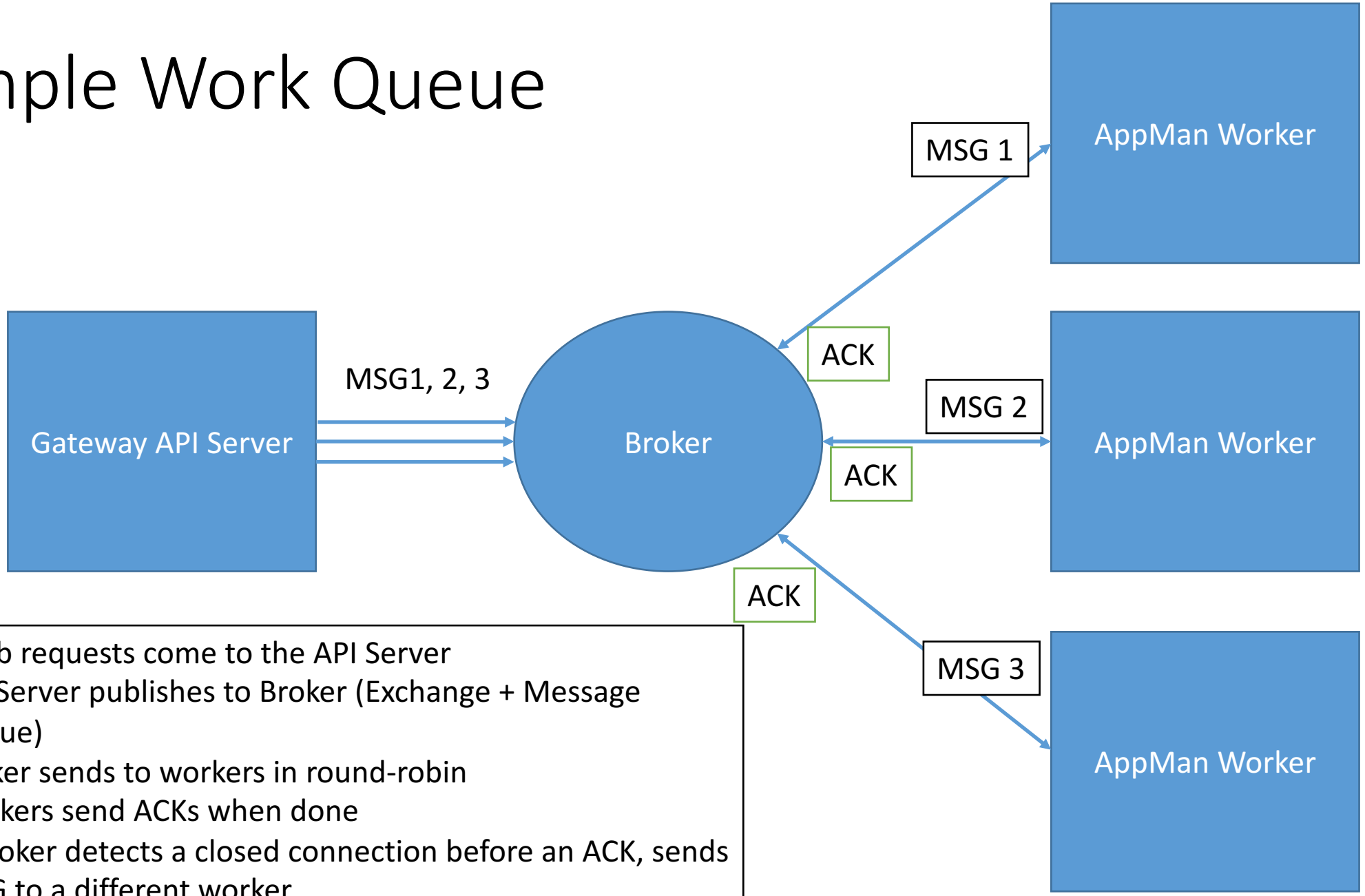
- AMQP does not cover all the capabilities listed above.
  - It can be extended to cover these in many cases
- AMQP messaging system implementations are not necessarily cloud-ready
  - They have to be configured as highly available services.
    - Primary + failover
  - No fancy leader elections, etc as used in Zookeeper + Zab
  - Have scaling limitations, although these may not matter at our scales.
- Other messaging systems (Kafka, HedWig) are alternatives

Some Applications

Simple Work Queue

- Queue up work to be done.
- Publisher: pushes a request for work into the queue
  - Queue should be a simple Direct Exchange
- Message Queue should implement “only deliver message once to once consumer”.
  - Round-robin scheduling.
  - RabbitMQ does this out of the box
- Consumer: Sends an ACK after completing the task
- If a Queue-Client closes before an ACK, resend message to a new consumer.
  - RabbitMQ detects these types of failures.

Simple Work Queue



- 3 Job requests come to the API Server
- API Server publishes to Broker (Exchange + Message Queue)
- Broker sends to workers in round-robin
- Workers send ACKs when done
- If Broker detects a closed connection before an ACK, sends MSG to a different worker

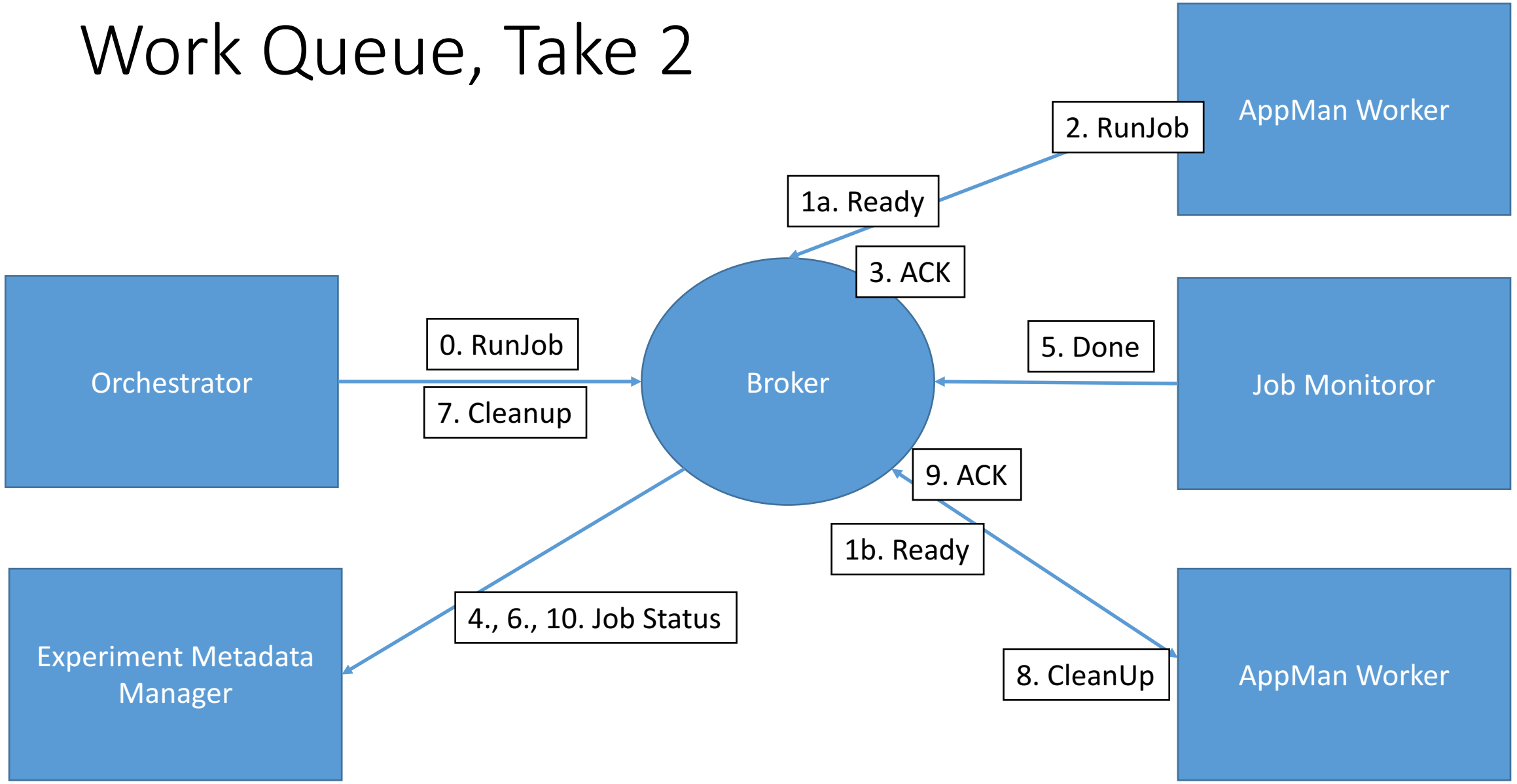
What Could Possibly Go Wrong?

- Jobs take a long time to finish, so ACKs may not come for hours.
  - Durable connections needed between Consumers and Message Queues
  - Alternatively, the ACK could come from a different process
- Jobs may actually get launched on the external supercomputer, so you don’t want to launch twice just because of a missing ACK
- Clients have to implement their own queues
  - Could get another work request while doing work.

Work Queue, Take Two

- Orchestrator pushes work into a queue.
- Have workers request work when they are not busy.
  - RabbitMQ supports this as “prefetchCount”
  - Use round-robin but don’t send work to busy workers with outstanding ACKs.
  - Workers do not receive work requests when they are busy.
- Worker sends ACK after successfully submitting the job.
  - This only means the job has been submitted
  - Worker can take more work
- A separate process handles the state changes on the supercomputer
  - Publishes ”queued”, “executing”, ”completed” or “failed” messages
- When job is done, Orchestrator creates a “cleanup” job
- Any worker available can take this.

Work Queue, Take 2



What Could Possibly Go Wrong?

- A Worker may not be able to submit the job
  - Remote supercomputer is unreachable, for example
  - We need a NACK
- The Orchestrator and Experiment Metadata components are also consumers.
  - Should send ACKs to make sure messages are delivered.
- Orchestrator and Experiment Metadata Manager may also die and get replaced.
  - Unlike AppMan workers, Orchestrator and EMM may need a leader-follower implementation
- Broker crashes
  - RabbitMQ provides some durability for restarting
  - Possible to lose cached messages that haven’t gone to persistent storage

What Else Could Go Wrong?

- Lots of things.
- How do you debug unexpected errors?
  - Logs
- A logger like LogStash should be one of your consumers
- No one-to-one messages any more.
- Everything has at least 2 subscribers
  - Your log service
  - The main target
- Or you could use Fanout

Summary

- Message systems provide an abstract system for routing communications between distributed entities.
  - You don’t need to know the physical addresses
- Support multiple messaging patterns out of the box.
  - You don’t have to implement them.
- Queues are a powerful concept within distributed systems.
  - Entities can save messages in order and deliver/accept them at a desirable rate.
  - Queues are a “primitive” (foundational) concept that you can use to build more sophisticated systems.