Hortonworks

Apache Hadoop YARN

Enabling next generation data applications

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Agenda

- Why YARN?
- YARN Architecture and Concepts
- Building applications on YARN
- Next Steps

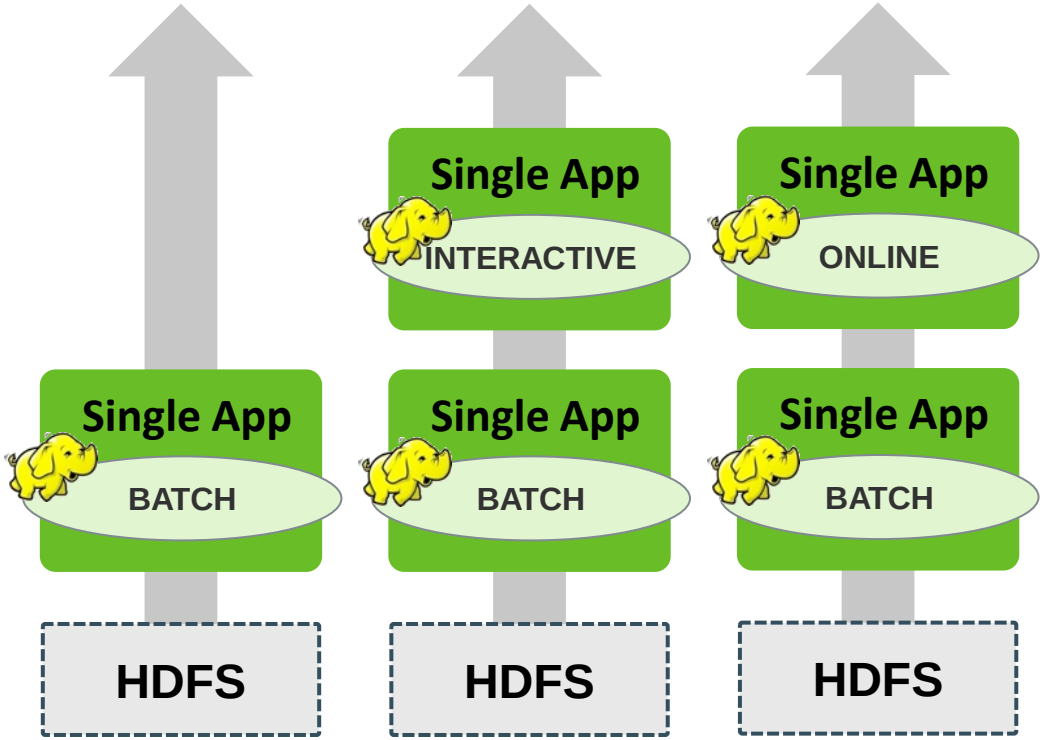
Agenda

- **Why YARN?**
- YARN Architecture and Concepts
- Building applications on YARN
- Next Steps

The 1st Generation of Hadoop: Batch

HADOOP 1.0

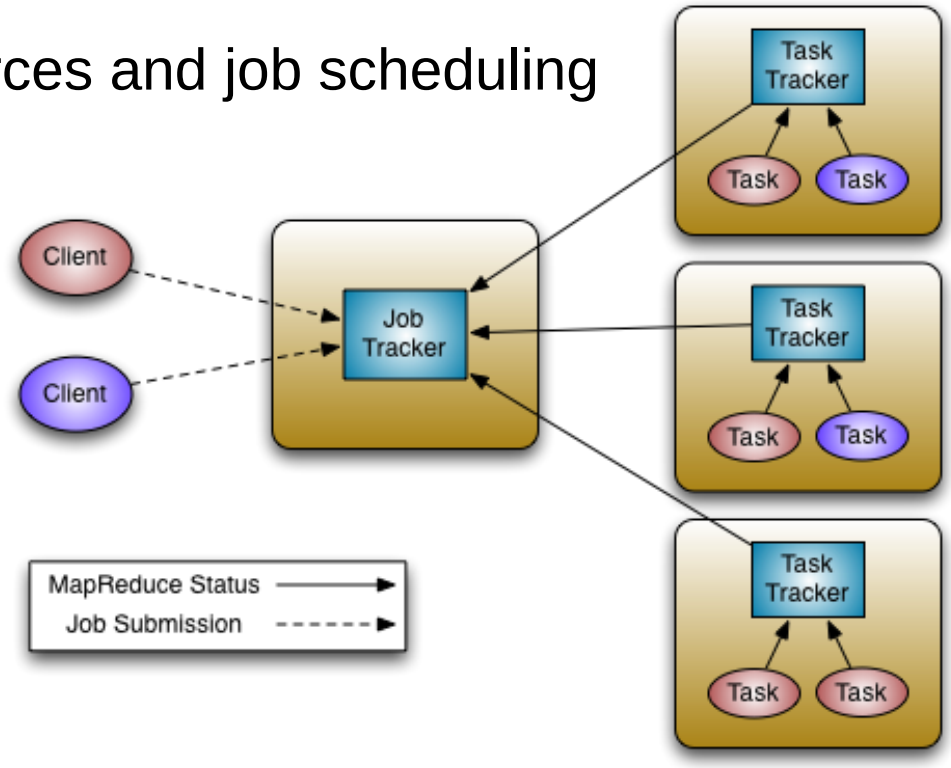
Built for Web-Scale Batch Apps



- All other usage patterns must leverage that same infrastructure
- Forces the creation of silos for managing mixed workloads

Hadoop MapReduce Classic

- **JobTracker**
  - Manages cluster resources and job scheduling
- **TaskTracker**
  - Per-node agent
  - Manage tasks



MapReduce Classic: Limitations

- **Scalability**
  - Maximum Cluster size – 4,000 nodes
  - Maximum concurrent tasks – 40,000
  - Coarse synchronization in JobTracker
- **Availability**
  - Failure kills all queued and running jobs
- **Hard partition of resources into map and reduce slots**
  - Low resource utilization
- **Lacks support for alternate paradigms and services**
  - Iterative applications implemented using MapReduce are 10x slower

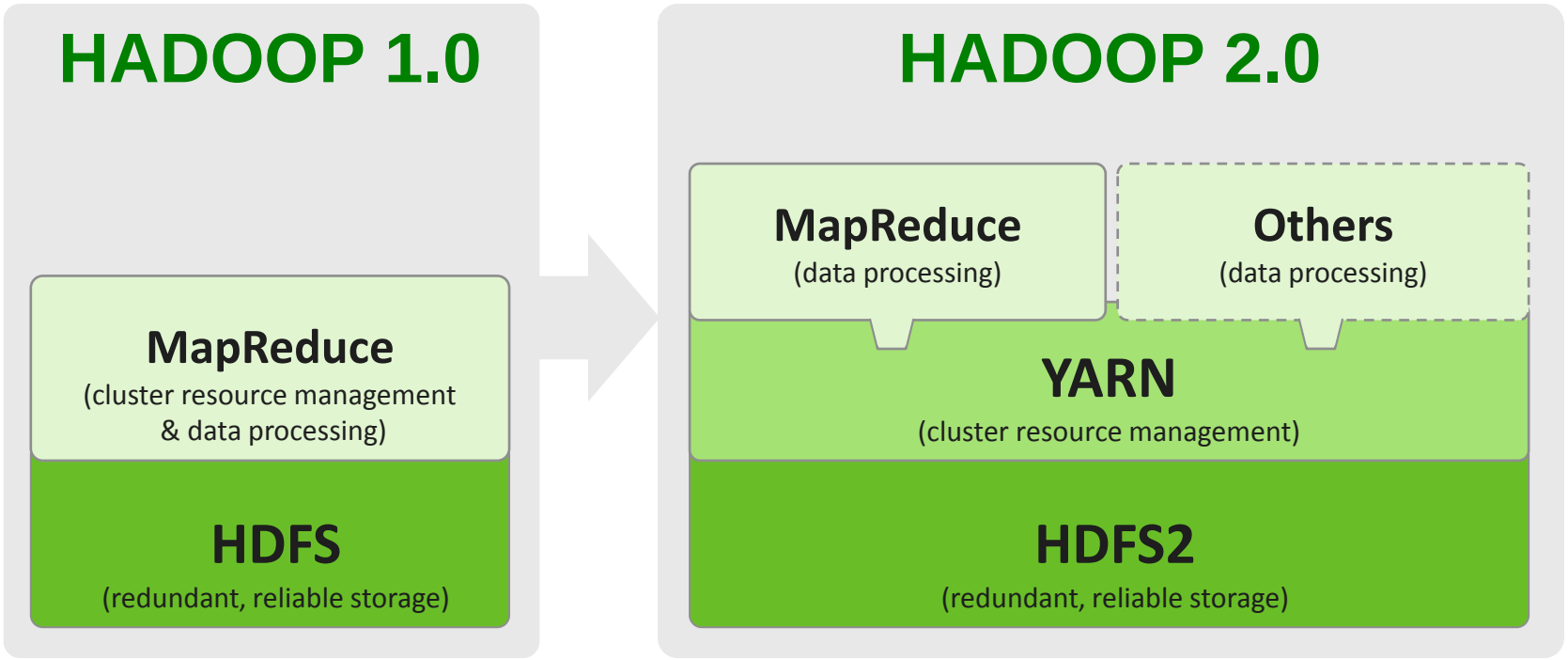
Our Vision: Hadoop as Next-Gen Platform

Single Use System

Batch Apps

Multi Purpose Platform

Batch, Interactive, Online, Streaming, …

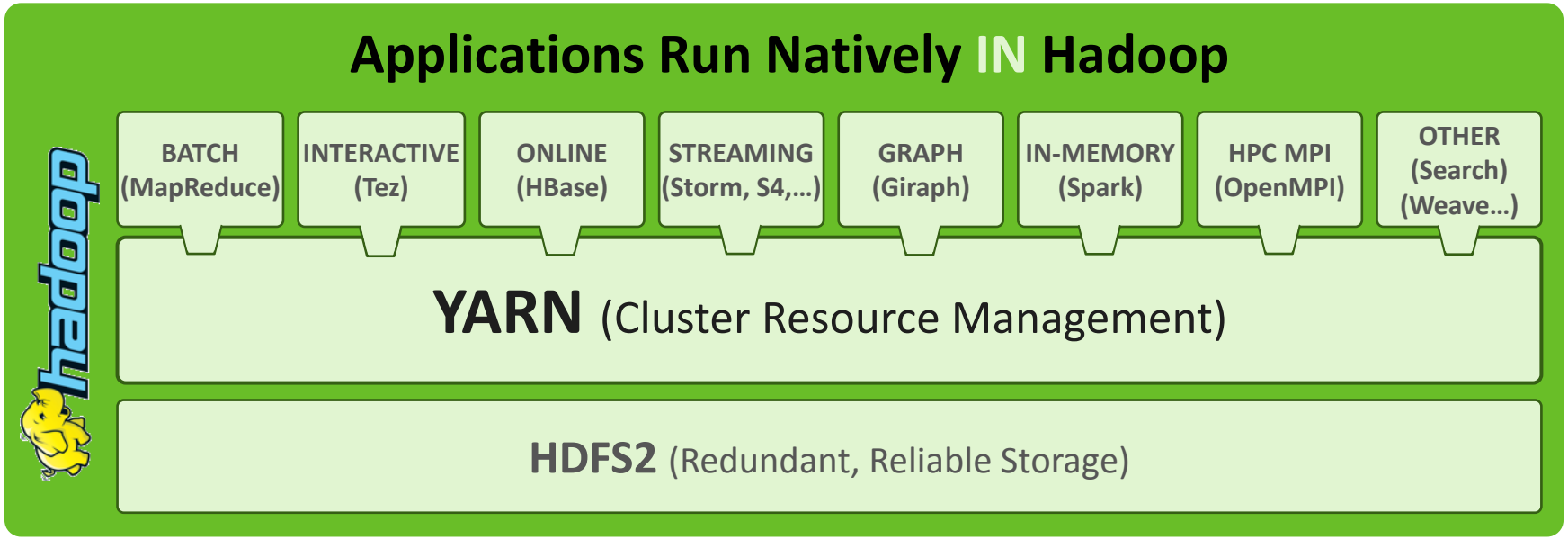


YARN: Taking Hadoop Beyond Batch

Store ALL DATA in one place…

Interact with that data in MULTIPLE WAYS

with Predictable Performance and Quality of Service



5 Key Benefits of YARN

1. **Scale**
2. **New Programming Models & Services**
3. **Improved cluster utilization**
4. **Agility**
5. **Beyond Java**

Agenda

- Why YARN
- **YARN Architecture and Concepts**
- Building applications on YARN
- Next Steps

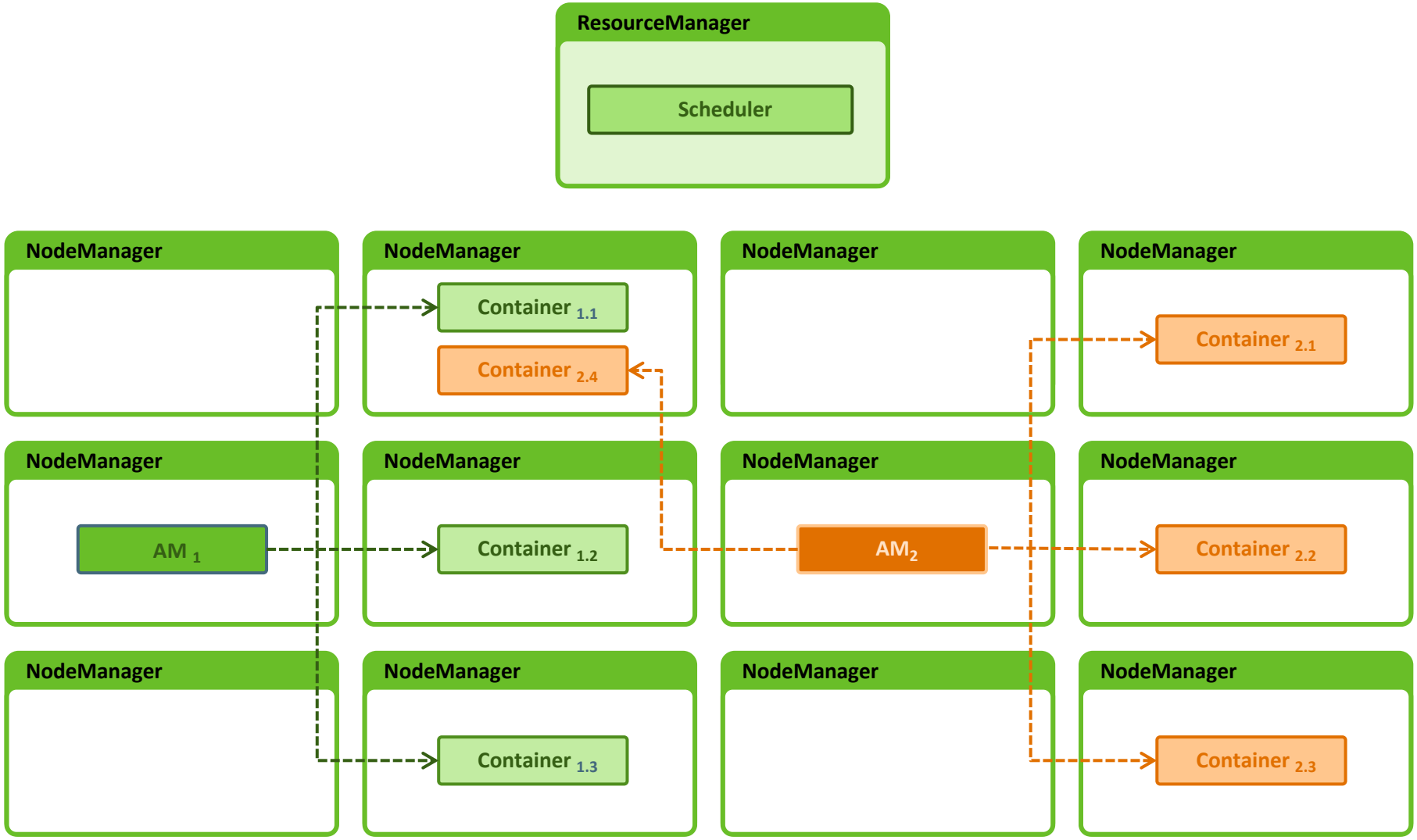
A Brief History of YARN

- **Originally conceived & architected by the team at Yahoo!**
  - Arun Murthy created the original JIRA in 2008 and led the PMC
- **The team at Hortonworks has been working on YARN for 4 years**
- **YARN based architecture running at scale at Yahoo!**
  - Deployed on 35,000 nodes for 8+ months
- **YARN applications**
  - MapReduce v2
  - Tez
  - HBase
  - Storm
  - Giraph

Concepts

- **Application**
  - Application is a job submitted to the framework
  - Example – Map Reduce Job
- **Container**
  - Basic unit of allocation
  - Fine-grained resource allocation across multiple resource types (memory, cpu, disk, network, gpu etc.)
    - container_0 = 2GB, 1CPU
    - container_1 = 1GB, 6 CPU
  - Replaces the fixed map/reduce slots

YARN Architecture



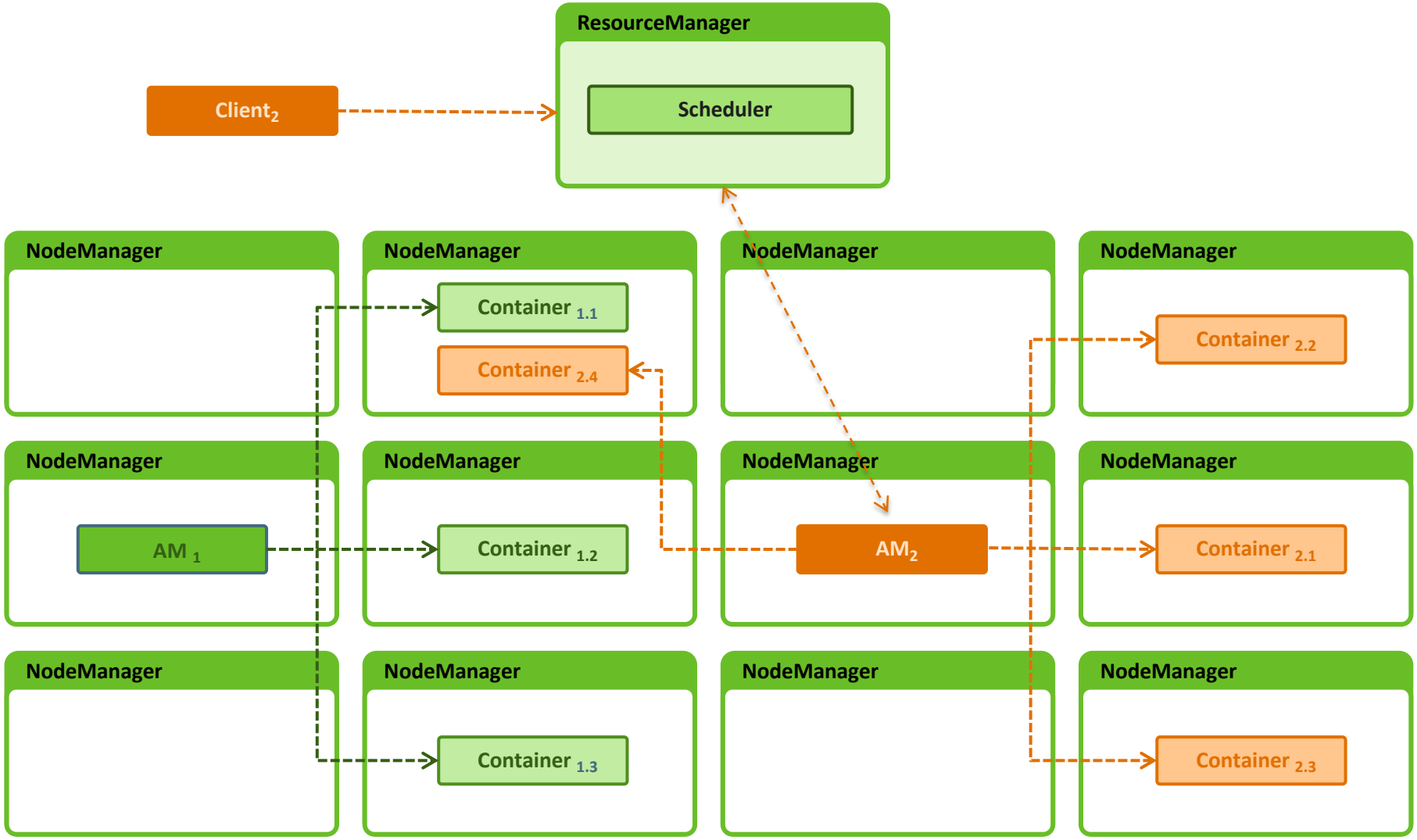
Architecture

- **Resource Manager**
  - Global resource scheduler
  - Hierarchical queues
- **Node Manager**
  - Per-machine agent
  - Manages the life-cycle of container
  - Container resource monitoring
- **Application Master**
  - Per-application
  - Manages application scheduling and task execution
  - E.g. MapReduce Application Master

Design Concepts

- **Split up the two major functions of JobTracker**
  - Cluster resource management
  - Application life-cycle management
- **MapReduce becomes user-land library**

YARN Architecture - Walkthrough



Review - Benefits of YARN

1. **Scale**
2. **New Programming Models & Services**
3. **Improved cluster utilization**
4. **Agility**
5. **Beyond Java**

Agenda

- Why YARN
- YARN Architecture and Concepts
- **Building applications on YARN**
- Next Steps

YARN Applications

- **Data processing applications and services**
  - Online Serving – HOYA (HBase on YARN)
  - Real-time event processing – Storm, S4, other commercial platforms
  - Tez – Generic framework to run a complex DAG
  - MPI: OpenMPI, MPICH2
  - Master-Worker
  - Machine Learning: Spark
  - Graph processing: Giraph
  - Enabled by allowing the use of paradigm-specific application master

Run all on the same Hadoop cluster!

YARN – Implementing Applications

- **What APIs do I need to use?**
  - Only three *protocols*
    - Client to ResourceManager
      - Application submission
    - ApplicationMaster to ResourceManager
      - Container allocation
    - ApplicationMaster to NodeManager
      - Container launch
  - Use client libraries for all 3 actions
    - Module yarn-client
    - Provides both synchronous and asynchronous libraries
    - Use 3rd party like Weave
      - http://continuuity.github.io/weave/

YARN – Implementing Applications

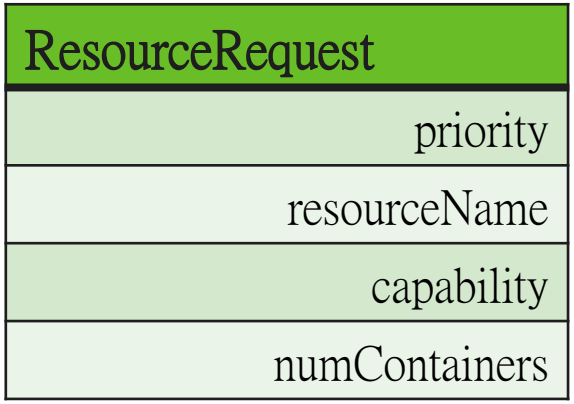
- **What do I need to do?**
  - Write a submission Client
  - Write an ApplicationMaster (well copy-paste)
    - *DistributedShell is the new WordCount*
  - Get containers, run whatever you want!

YARN – Implementing Applications

- **What else do I need to *know*?**
  - Resource Allocation & Usage
    - ResourceRequest
    - Container
    - ContainerLaunchContext
    - LocalResource
  - ApplicationMaster
    - ApplicationId
    - ApplicationAttemptId
    - ApplicationSubmissionContext

YARN – Resource Allocation & Usage

- ResourceRequest
  - Fine-grained resource *ask* to the ResourceManager
  - Ask for a specific amount of resources (memory, cpu etc.) on a specific machine or rack
  - Use special value of * for resource name for *any* machine



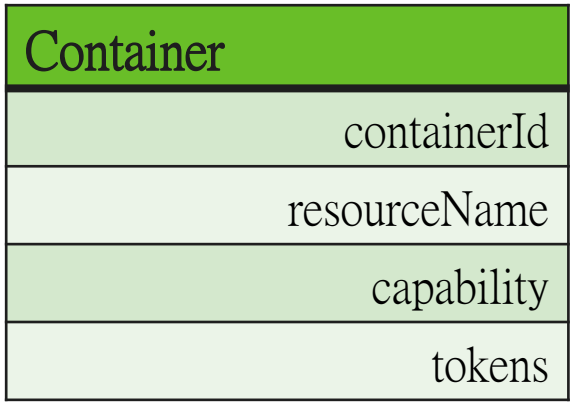
YARN – Resource Allocation & Usage

- ResourceRequest

priority	capability	resourceName	numContainers
0	<2gb, 1 core>	host01	1
		rack0	1
		*	1
1	<4gb, 1 core>	*	1

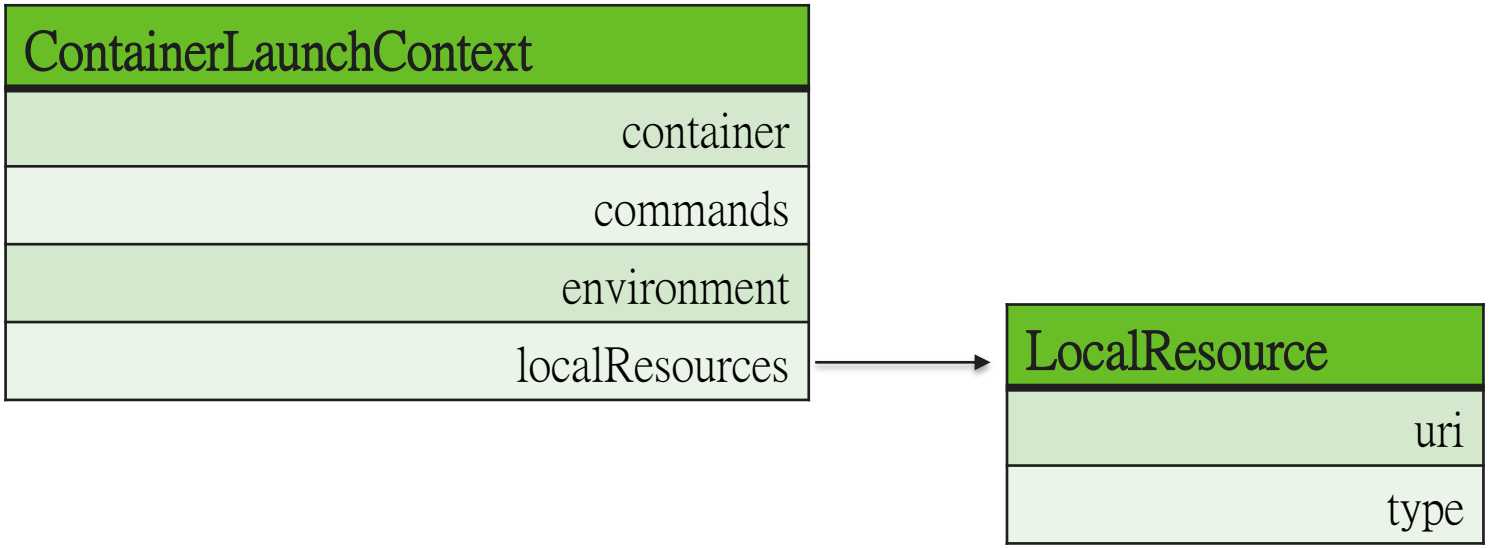
YARN – Resource Allocation & Usage

- Container
  - The basic unit of allocation in YARN
  - The *result* of the ResourceRequest provided by ResourceManager to the ApplicationMaster
  - A *specific amount of resources* (cpu, memory etc.) on a *specific machine*



YARN – Resource Allocation & Usage

- ContainerLaunchContext
  - The context provided by ApplicationMaster to NodeManager to launch the Container
  - *Complete specification for a process*
  - LocalResource used to specify container binary and dependencies
    - NodeManager responsible for downloading from shared namespace (typically HDFS)

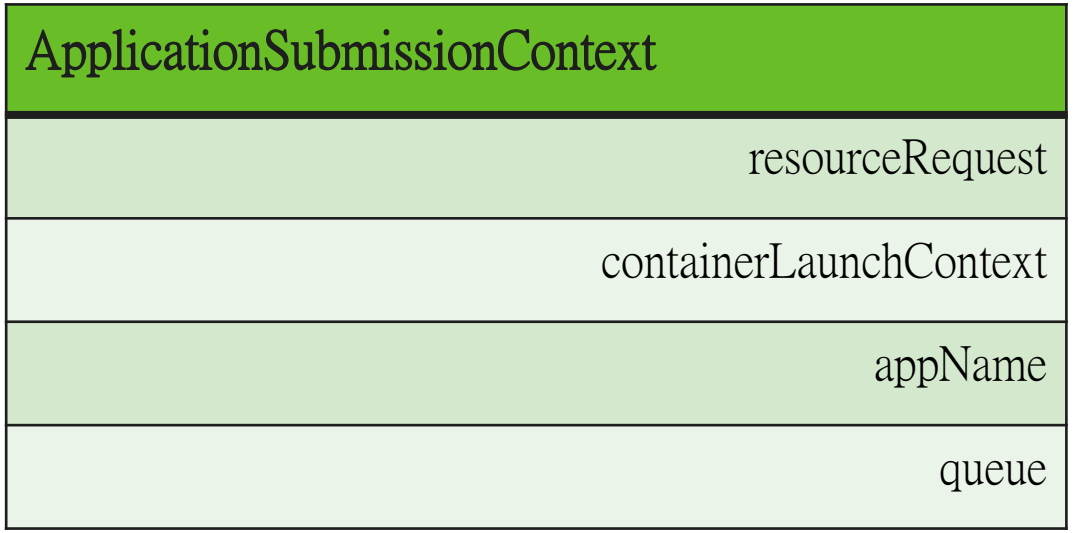


YARN - ApplicationMaster

- **ApplicationMaster**
  - Per-application controller aka *container_0*
  - Parent for all containers of the application
    - ApplicationMaster negotiates all it's containers from ResourceManager
  - ApplicationMaster container is child of ResourceManager
    - Think *init* process in Unix
    - RM restarts the ApplicationMaster *attempt* if required (unique ApplicationAttemptId)
  - Code for application is submitted along with Application itself

YARN - ApplicationMaster

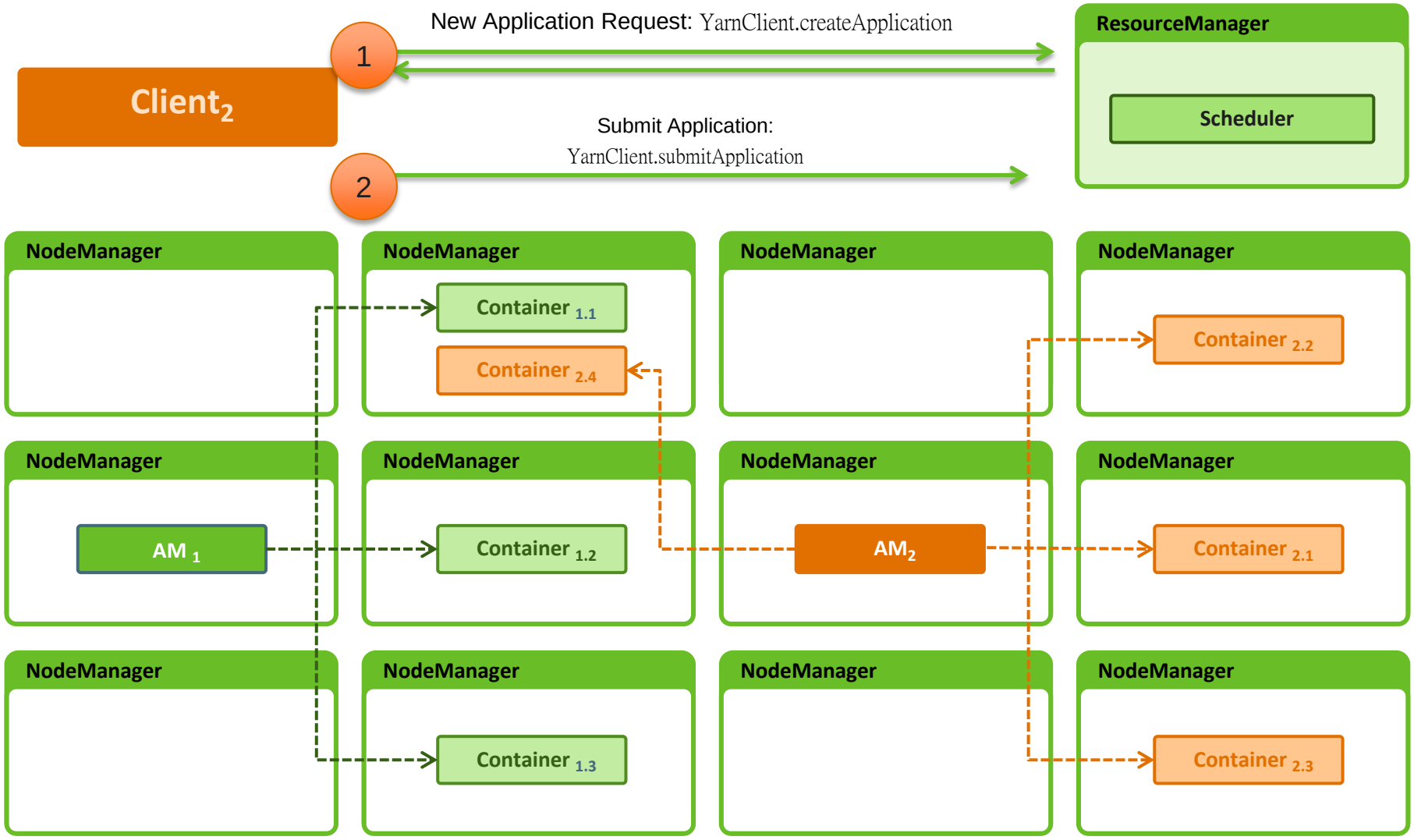
- **ApplicationMaster**
  - ApplicationSubmissionContext is the complete specification of the ApplicationMaster, provided by Client
  - ResourceManager responsible for *allocating* and *launching* ApplicationMaster container



YARN Application API - Overview

- hadoop-yarn-client **module**
- YarnClient **is submission client api**
- **Both synchronous & asynchronous APIs for resource allocation and container start/stop**
- **Synchronous API**
  - AMRMClient
  - AMNMClient
- **Asynchronous API**
  - AMRMClientAsync
  - AMNMClientAsync

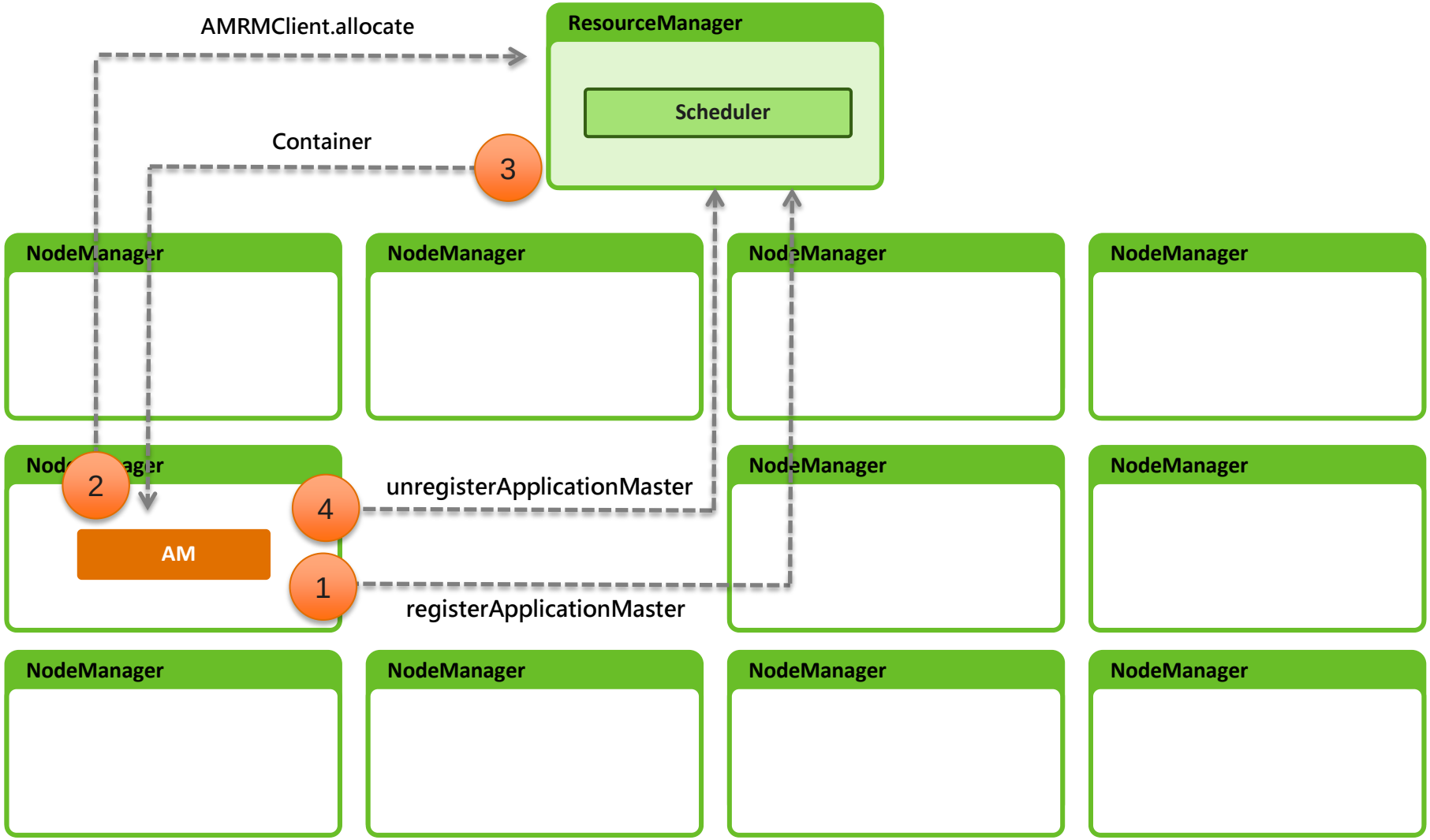
YARN Application API – The Client



YARN Application API – The Client

- **YarnClient**
  - createApplication to create application
  - submitApplication to start application
    - Application developer needs to provide ApplicationSubmissionContext
  - APIs to get other information from ResourceManager
    - getAllQueues
    - getApplications
    - getNodeReports
  - APIs to manipulate submitted application e.g. killApplication

YARN Application API – Resource Allocation



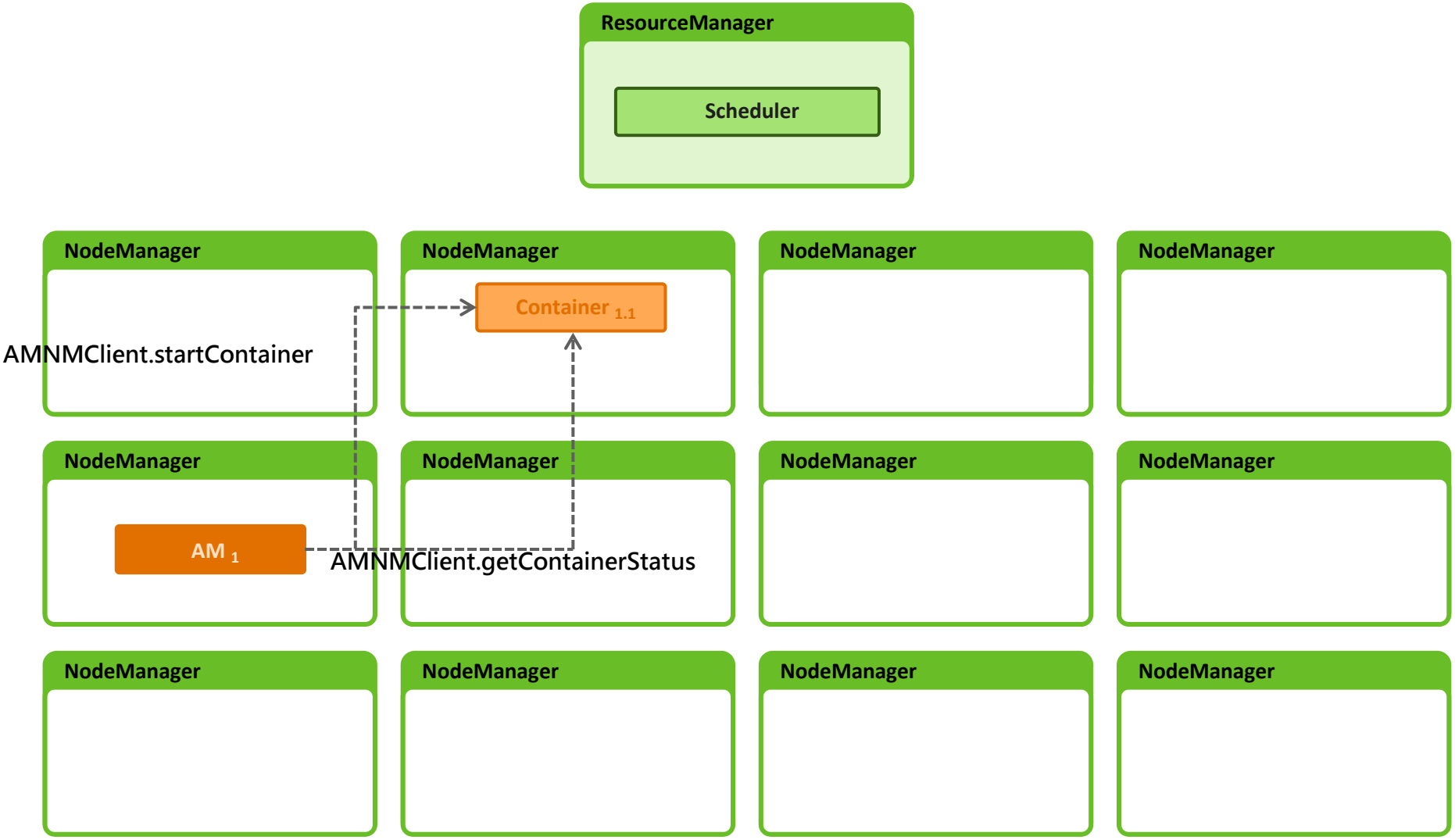
YARN Application API – Resource Allocation

- **AMRMClient - Synchronous API for ApplicationMaster to interact with ResourceManager**
  - Prologue / epilogue – registerApplicationMaster / unregisterApplicationMaster
  - Resource negotiation with ResourceManager
    - Internal book-keeping - addContainerRequest / removeContainerRequest releaseAssignedContainer
    - Main API – allocate
  - Helper APIs for cluster information
    - getAvailableResources
    - getClusterNodeCount

YARN Application API – Resource Allocation

- **AMRMClientAsync - Asynchronous API for ApplicationMaster**
  - Extension of AMRMClient to provide asynchronous
  - Callbacks make it easier to build mental model of interaction with ResourceManager for the application developer
    - onContainersAllocated
    - onContainersCompleted
    - onNodesUpdated
    - onError
    - onShutdownRequest

YARN Application API – Using Resources



YARN Application API – Using Resources

- **AMNMClient - Synchronous API for ApplicationMaster to launch / stop containers at NodeManager**
  - Simple (trivial) APIs
    - startContainer
    - stopContainer
    - getContainerStatus

YARN Application API – Using Resources

- **AMNMClient - Asynchronous API for ApplicationMaster to launch / stop containers at NodeManager**
  - Simple (trivial) APIs
    - startContainerAsync
    - stopContainerAsync
    - getContainerStatusAsync
  - CallbackHandler to make it easier to build mental model of interaction with NodeManager for the application developer
    - onContainerStarted
    - onContainerStopped
    - onStartContainerError
    - onContainerStatusReceived

YARN Application API - Development

- **Un-Managed Mode for ApplicationMaster**
  - Run ApplicationMaster on development machine rather than in-cluster
    - No submission client
  - hadoop-yarn-applications-unmanaged-am-launcher
  - Easier to step through debugger, browse logs etc.

```
$ bin/hadoop jar hadoop-yarn-applications-unmanaged-am-launcher.jar \
    Client \
    – jar my-application-master.jar \
    – cmd ‘java MyApplicationMaster <args>’
```

Sample YARN Application – DistributedShell

- **Overview**
  - YARN application to run *n* copies for a Shell command
  - Simplest example of a YARN application – get *n* containers and run a specific Unix command

```
$ bin/hadoop jar hadoop-yarn-applications-distributedshell.jar \
      org.apache.hadoop.yarn.applications.distributedshell.Client \
       – shell_command  '/bin/date'  \
       – num_containers <n>
```

Code: *https://github.com/hortonworks/simple-yarn-app*

Sample YARN Application – DistributedShell

- **Code Overview**
  - User submits application to ResourceManager via org.apache.hadoop.yarn.applications.distributedshell.Client
    - Client provides ApplicationSubmissionContext to the ResourceManager
  - It is responsibility of org.apache.hadoop.yarn.applications.distributedshell.ApplicationMaster to negotiate *n* containers
    - ApplicationMaster launches containers with the user-specified *command* as ContainerLaunchContext.commands

Sample YARN Application – DistributedShell

- **Client – Code Walkthrough**
  - hadoop-yarn-client module
  - Steps:
    - YarnClient.createApplication
    - Specify ApplicationSubmissionContext, in particular, ContainerLaunchContext with commands, and other key pieces such as resource capability for ApplicationMaster container and queue, appName, appType etc.
    - YarnClient.submitApplication

```
1.  // Create yarnClient
2.  YarnClient yarnClient = YarnClient.createYarnClient();
3.  yarnClient.init(new Configuration());
4.  yarnClient.start();
5.
6.  // Create application via yarnClient
7.  YarnClientApplication app = yarnClient.createApplication();
8.
```

Sample YARN Application – DistributedShell

- **Client – Code Walkthrough**

```
9.  // Set up the container launch context for the application master
10. ContainerLaunchContext amContainer =
11.     Records.newRecord(ContainerLaunchContext.class);
12. List<String> command = new List<String>();
13. commands.add("$JAVA_HOME/bin/java");
14. commands.add("-Xmx256M");
15. commands.add(
16.     "org.apache.hadoop.yarn.applications.distributedshell.ApplicationMaster");
17. commands.add("--container_memory 1024”    );
18. commands.add("--container_cores 1”  );
19. commands.add("--num_containers 3");
20. amContainer.setCommands(commands);
21.
22. // Set up resource type requirements for ApplicationMaster
23. Resource capability = Records.newRecord(Resource.class);
24. capability.setMemory(256);
25. capability.setVirtualCores(2);
26.
```

Sample YARN Application – DistributedShell

- **Client – Code Walkthrough**

```
27.  // Finally, set-up ApplicationSubmissionContext for the application
28.  ApplicationSubmissionContext appContext =
29.      app.getApplicationSubmissionContext();
30.  appContext.setQueue("my-queue");          // queue
31.  appContext.setAMContainerSpec(amContainer);
32.  appContext.setResource(capability);
33.  appContext.setApplicationName("my-app");          // application name
34.  appContext.setApplicationType("  DISTRIBUTED_SHELL");   // application type
35.
36.  // Submit application
37.  yarnClient.submitApplication(appContext);
```

Sample YARN Application – DistributedShell

- **ApplicationMaster – Code Walkthrough**
  - Again, hadoop-yarn-client module
  - Steps:
    - AMRMClient.registerApplication
    - Negotiate containers from ResourceManager by providing ContainerRequest to AMRMClient.addContainerRequest
    - Take the resultant Container returned via subsequent call to AMRMClient.allocate, build ContainerLaunchContext with Container and commands, then launch them using AMNMClient.launchContainer
      - Use LocalResources to specify software/configuration dependencies for each worker container
    - Wait till done… AllocateResponse.getCompletedContainersStatuses from subsequent calls to AMRMClient.allocate
    - AMRMClient.unregisterApplication

Sample YARN Application – DistributedShell

- **ApplicationMaster – Code Walkthrough**

```
1.        // Initialize clients to ResourceManager and NodeManagers
2.      Configuration conf = new Configuration();
3.
4.      AMRMClient rmClient = AMRMClientAsync.createAMRMClient();
5.      rmClient.init(conf);
6.      rmClient.start();
7.
8.      NMClient nmClient = NMClient.createNMClient();
9.      nmClientAsync.init(conf);
10.     nmClientAsync.start();
11.
12.     // Register with ResourceManager
13.     rmClient.registerApplicationMaster("", 0, "");
```

Sample YARN Application – DistributedShell

- **ApplicationMaster – Code Walkthrough**

```
15.  // Priority for worker containers - priorities are intra-application
16.  Priority priority = Records.newRecord(Priority.class);
17.  priority.setPriority(0);
18.
19.  // Resource requirements for worker containers
20.  Resource capability = Records.newRecord(Resource.class);
21.  capability.setMemory(128);
22.  capability.setVirtualCores(1);
23.
24.  // Make container requests to ResourceManager
25.  for (int i = 0; i < n; ++i) {
26.    ContainerRequest containerAsk = new ContainerRequest(capability, null, null, priority);
27.    rmClient.addContainerRequest(containerAsk);
28.  }
```

Sample YARN Application – DistributedShell

- **ApplicationMaster – Code Walkthrough**

```
30.  // Obtain allocated containers and launch
31.  int allocatedContainers = 0;
32.  while (allocatedContainers < n) {
33.    AllocateResponse response = rmClient.allocate(0);
34.    for (Container container : response.getAllocatedContainers()) {
35.      ++allocatedContainers;
36.
37.      // Launch container by create ContainerLaunchContext
38.      ContainerLaunchContext ctx = Records.newRecord(ContainerLaunchContext.class);
39.      ctx.setCommands(Collections.singletonList("/bin/date"));
40.      nmClient.startContainer(container, ctx);
41.    }
42.    Thread.sleep(100);
43.  }
```

Setup requirements for worker containers

Make resource requests to ResourceManager

Sample YARN Application – DistributedShell

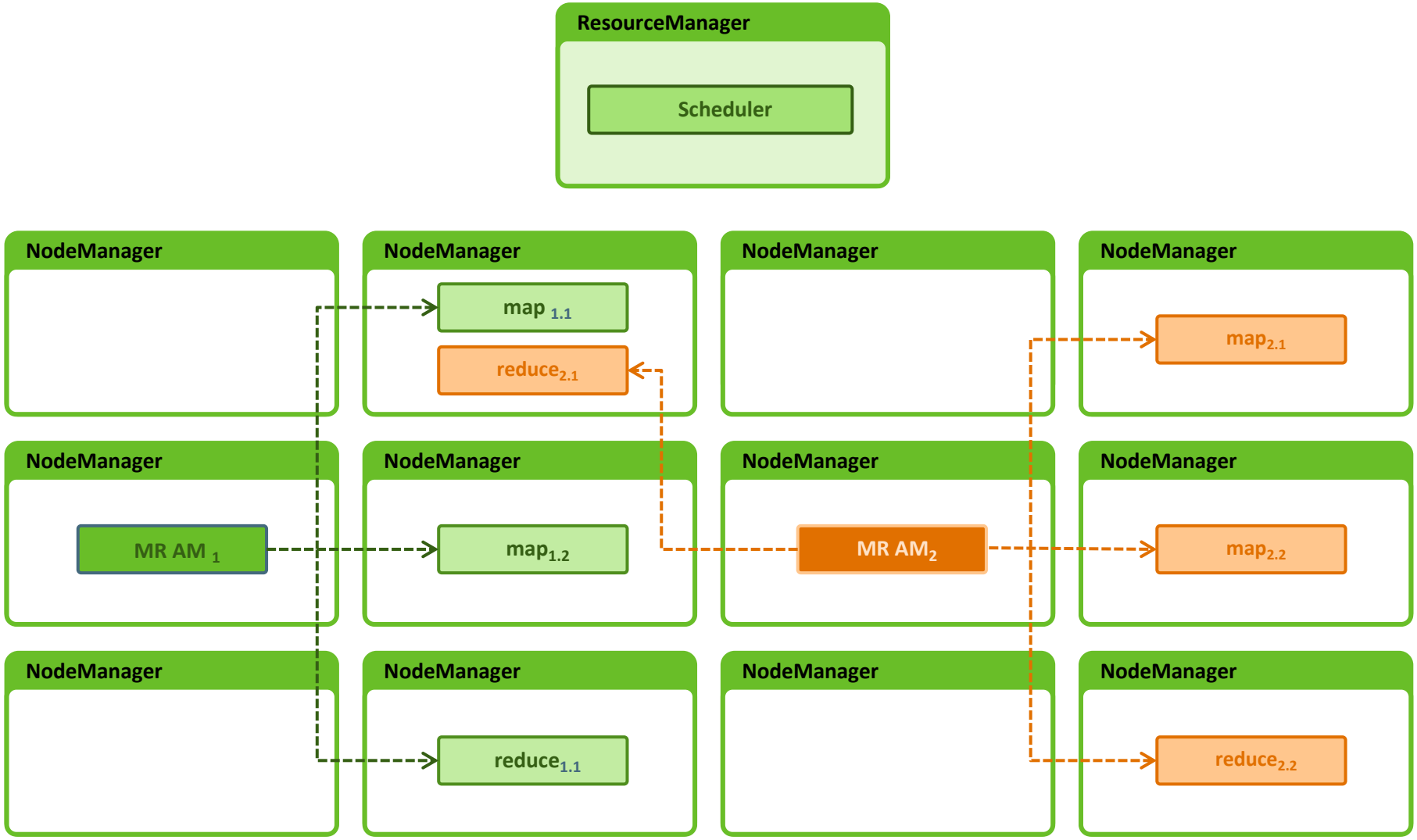
- **ApplicationMaster – Code Walkthrough**

```
4   // Now wait for containers to complete
4   int completedContainers = 0;
4   while (completedContainers < n) {
4     AllocateResponse response = rmClient.allocate(completedContainers/n);
4     for (ContainerStatus status : response.getCompletedContainersStatuses()) {
5       if (status.getExitStatus() == 0) {
5         ++completedContainers;
5       }
5     }
4     Thread.sleep(100);
5   }
5
5   // Un-register with ResourceManager
5   rmClient.unregisterApplicationMaster(SUCCEEDED, "", "");
```

Apache Hadoop MapReduce on YARN

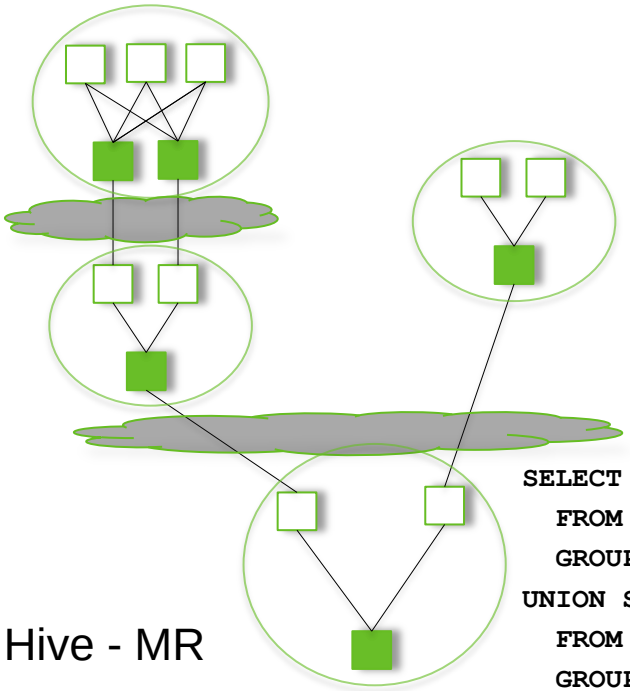
- **Original use-case**
- **Most complex application to build**
  - Data-locality
  - Fault tolerance
  - ApplicationMaster recovery: Check point to HDFS
  - Intra-application Priorities: Maps v/s Reduces
    - Needed complex feedback mechanism from ResourceManager
  - Security
  - Isolation
- **Binary compatible with Apache Hadoop 1.x**

Apache Hadoop MapReduce on YARN



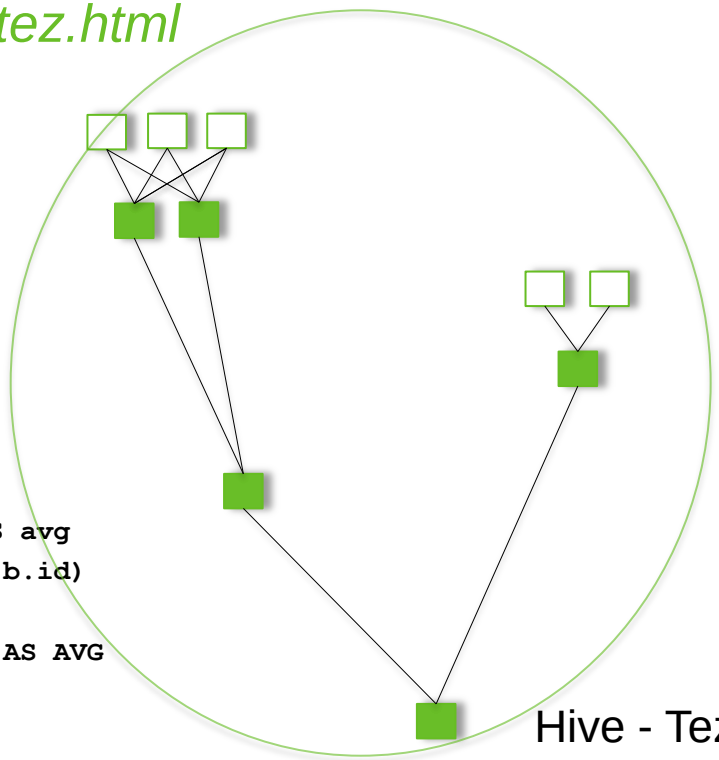
Apache Tez on YARN

- **Replaces MapReduce as primitive for Pig, Hive, Cascading etc.**
  - Smaller latency for interactive queries
  - Higher throughput for batch queries
  - *http://incubator.apache.org/projects/tez.html*



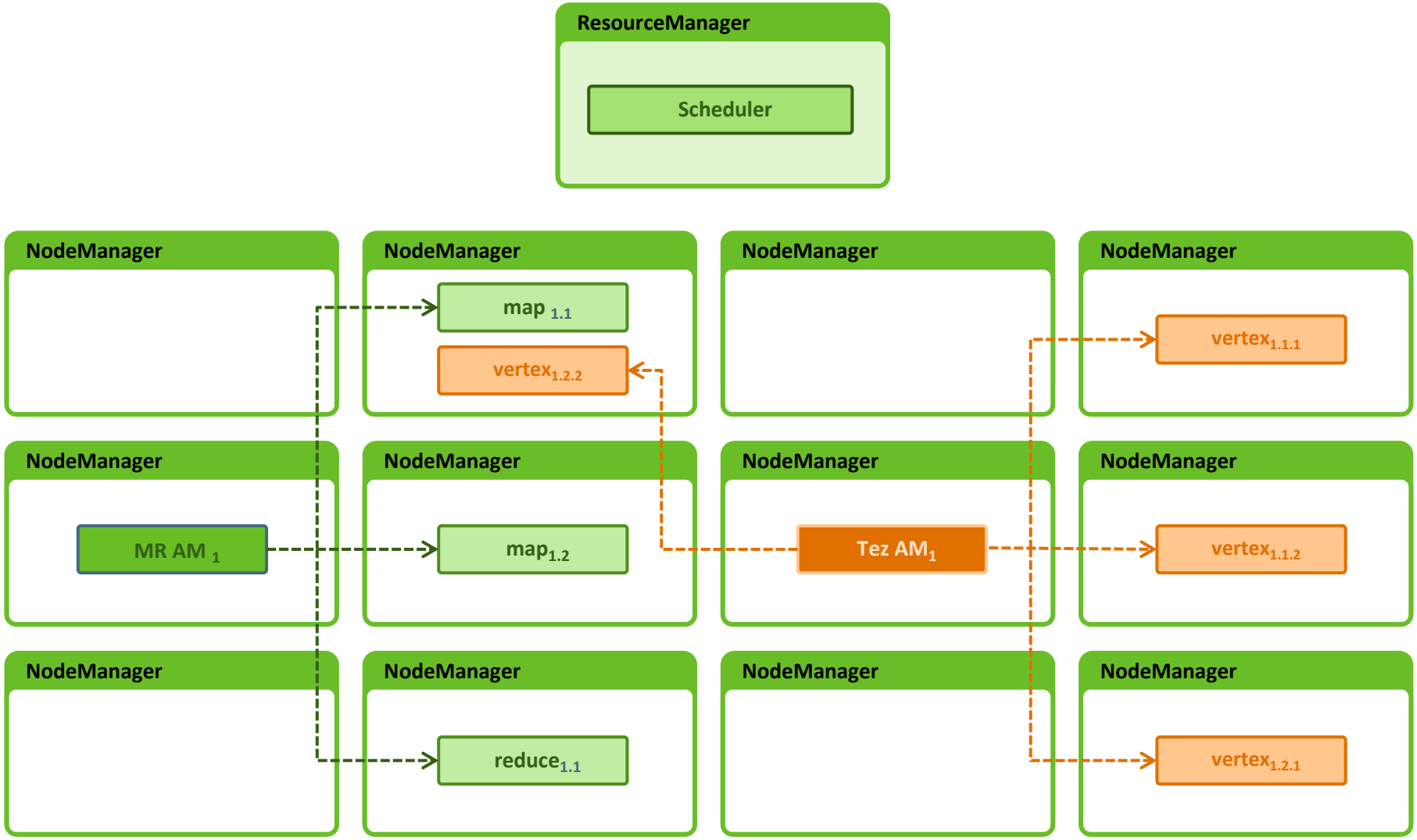
Hive - MR

```
SELECT a.x, AVERAGE(b.y) AS avg
  FROM a JOIN b ON (a.id = b.id)
  GROUP BY a
UNION SELECT x, AVERAGE(y) AS AVG
  FROM c
  GROUP BY x
ORDER BY AVG;
```



Hive - Tez

Apache Tez on YARN

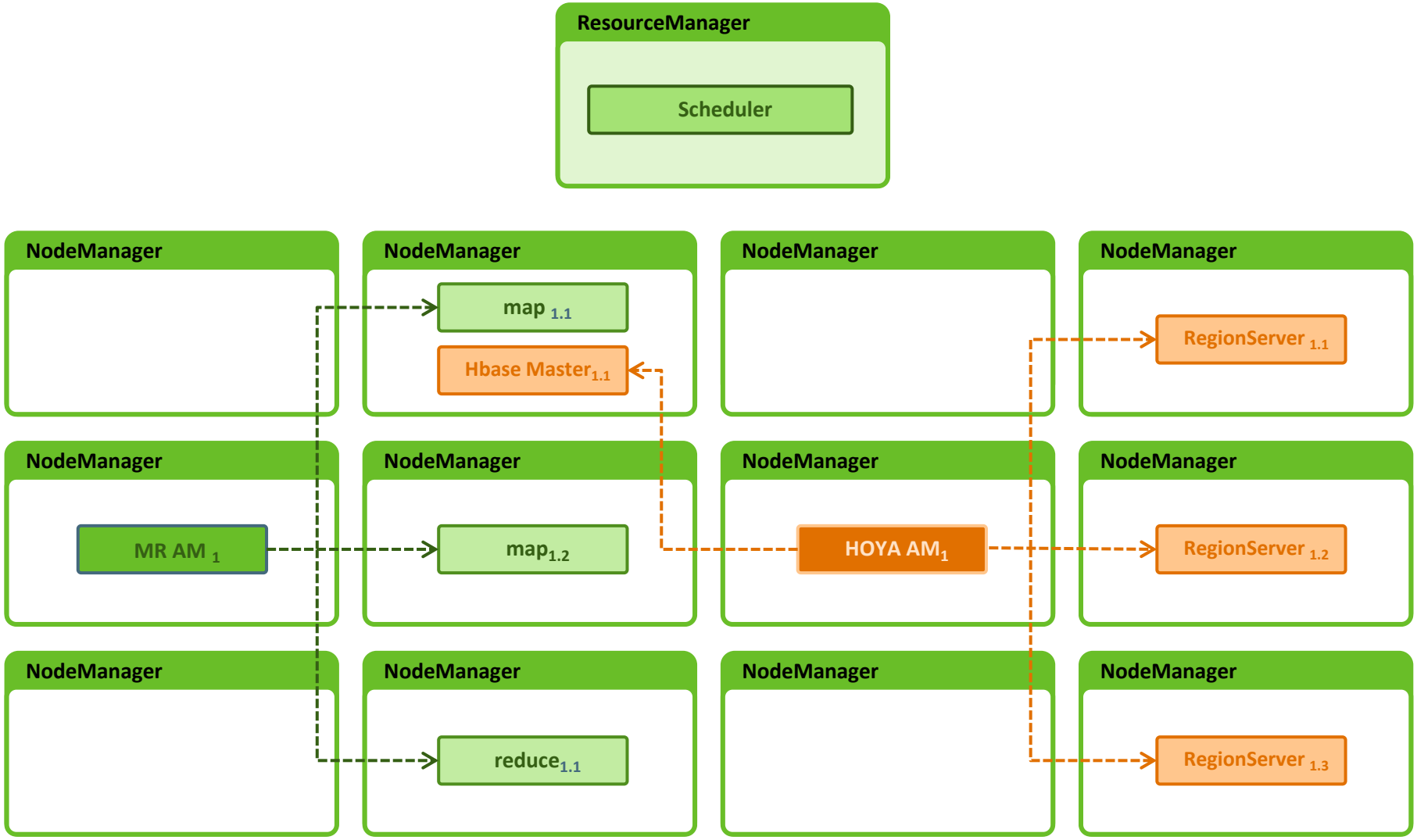


HOYA - Apache HBase on YARN

- **Hoya – Apache HBase becomes *user-level* application**
- **Use cases**
  - Small HBase cluster in large YARN cluster
  - Dynamic HBase clusters
  - Transient/intermittent clusters for workflows
- **APIs to create, start, stop & delete HBase clusters**
- **Flex cluster size: increase/decrease size with load**
- **Recover from Region Server loss with new container.**

Code: *https://github.com/hortonworks/hoya*

HOYA - Apache HBase on YARN



HOYA - Highlights

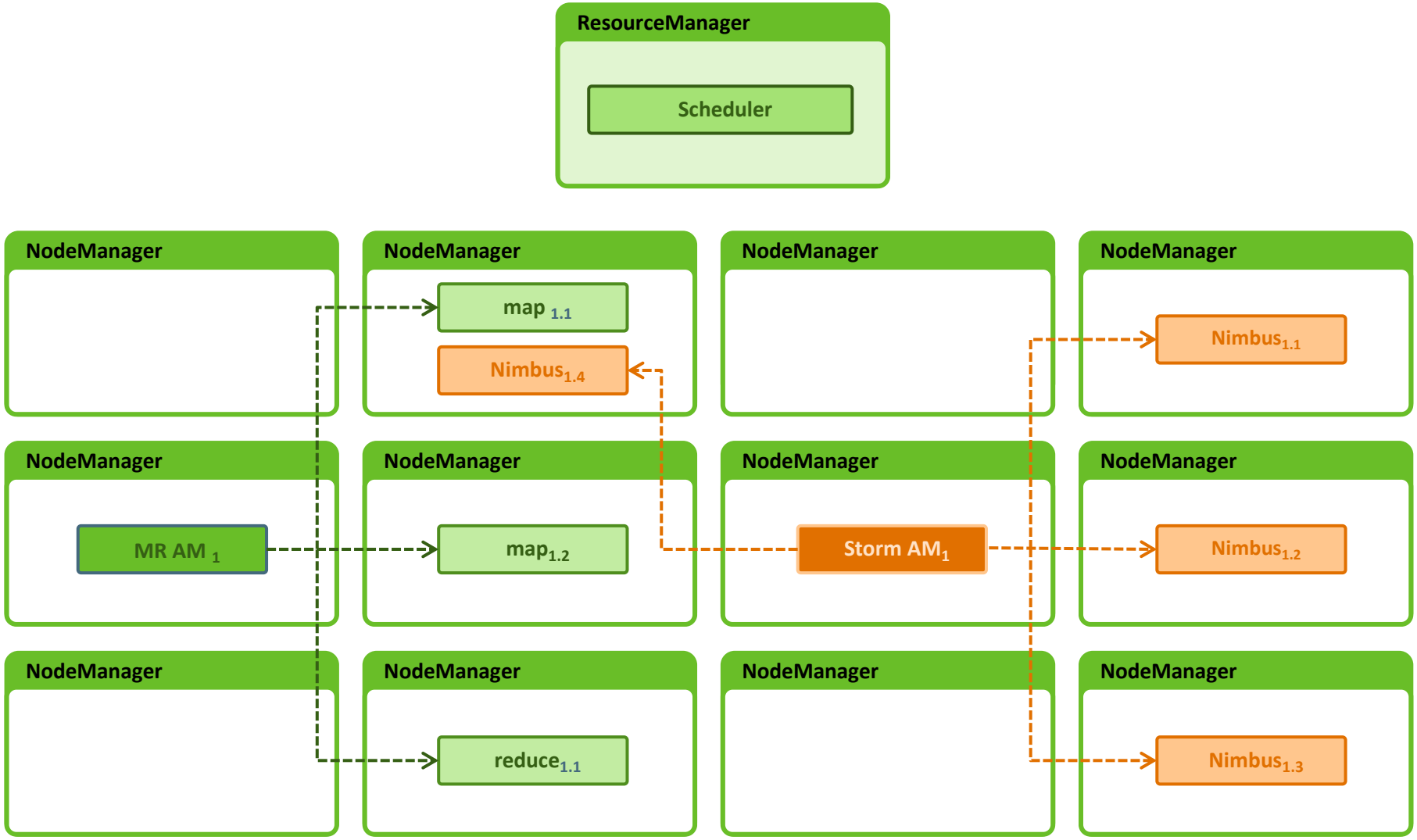
- **Cluster specification stored as JSON in HDFS**
- **Config directory cached - dynamically patched before pushing up as local resources for Master & RegionServers**
- **HBase tar file stored in HDFS -clusters can use the same/different HBase versions**
- **Handling of cluster flexing is the same code as unplanned container loss.**
- **No Hoya code on RegionServers: client and AM only**

Storm on YARN

- **Ability to deploy multiple Storm clusters on YARN for real-time event processing**
- **Yahoo – Primary contributor**
  - 200+ nodes in production
- **Ability to recover from faulty nodes**
  - Get new containers
- **Auto-scale for load balancing**
  - Get new containers as load increases
  - Release containers as load decreases

Code: *https://github.com/yahoo/storm-yarn*

Storm on YARN



General Architectural Considerations

- **Fault Tolerance**
  - Checkpoint
- **Security**
- **Always-On services**
- **Scheduler features**
  - Whitelist resources
  - Blacklist resources
  - Labels for machines
    - License management

Agenda

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- Building applications on YARN
- **Next Steps**

HDP 2.0 Community Preview & YARN Certification Program

Goal: Accelerate # of certified YARN-based solutions

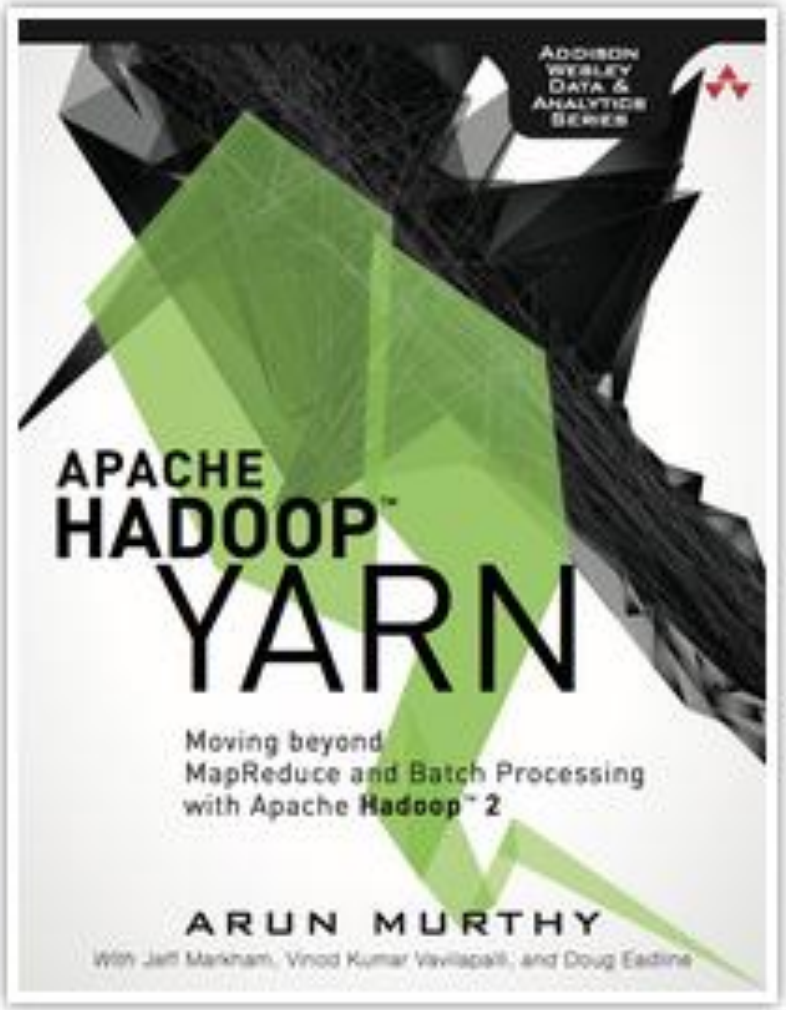
- **HDP 2.0 Community Preview**
  - Contains latest community Beta of Apache Hadoop 2.0 & YARN
  - Delivered as easy to use Sandbox VM, as well as RPMs and Tarballs
  - Enables YARN Cert Program

    Community & commercial ecosystem to test and certify new and existing YARN-based apps

- **YARN Certification Program**
  - More than 14 partners in program at launch
    - *Splunk**
    - *Elastic Search**
    - *Altiscale**
    - *Concurrent**
    - *Microsoft*
    - *Platfora*
    - *Tableau*
    - *(IBM) DataStage*
    - *Informatica*
    - *Karmasphere*
    - *and others*

* Already certified

What Next?



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http://hortonworks.com/hadoop/yarn