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Large Scale Data Processing

Lecture 3 – Data processing stack

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HR EXCELLENCE IN RESEARCH

Overview

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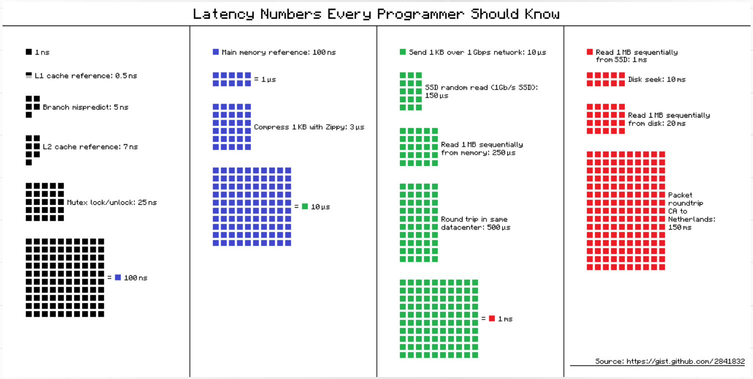
Overview

- Concepts
  - Stateless vs Stateful application
  - High Availability
  - Continuous X
  - Software Updates
- Resource orchestration platforms
  - Hadoop
  - YARN
  - Zookeeper
  - Swarm
  - Kubernetes
  - Openstack
- Useful tools
  - Helm
  - Ansible

Latency times

Concepts

https://bit.ly/34jmK47



Latency times

Concepts

- L1 cache reference =0.5 ns
- Branch mispredict = 5 ns
- L2 cache reference = 7 ns
- Mutex lock/unlock = 25 ns
- Main memory reference = 100 ns
- Compress 1K bytes with Zippy = 3,000 ns = 3 µs
- Send 2K bytes over 1 Gbps network = 20,000 ns = 20 µs
- SSD random read = 150,000 ns = 150 µs
- Read 1 MB sequentially from memory = 250,000 ns = 250 µs
- Round trip within same datacenter = 500,000 ns = 0.5 ms
- Read 1 MB sequentially from SSD = 1,000,000 ns = 1 ms
- Disk seek = 10,000,000 ns = 10 ms
- Read 1 MB sequentially from disk = 20,000,000 ns = 20 ms
- Send packet CA->Netherlands->CA = 150,000,000 ns = 150 ms

Stateless vs Stateful applications

Concepts

- How to design apps?
- How to store user sessions?
- How to store user data?

Stateless (1)

Concepts (Stateless vs Stateful application)

- Application do not persist any data in their memory
- Requests are processed one by one
- Requests are processed independently (without context of previous requests)
- No session persisted in the app memory

Stateless (2)

Concepts (Stateless vs Stateful application)

- Session can be persisted in persistence solution
  - Accessible by other replicas of app
  - For example Redis or MongoDB
  - Can be scaled and replicated separately
- There is no need of sticky session usage
- App can be easily scaled horizontally
- Development process might be more complex

Stateful (1)

Concepts (Stateless vs Stateful application)

- Application can persist data in memory
- Requests can be processed in context of previous requests
- Session is persisted in app memory

Stateful (2)

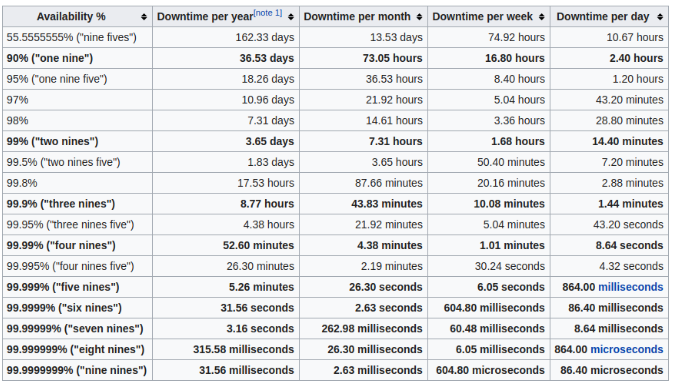
Concepts (Stateless vs Stateful application)

- We need to use sticky session
- Scaling and availability is not so trivial
- Development might be easier

High Availability

Concepts (High Availability)

- characteristic of production level systems
- should be online (available) as much as possible
- SLA (Service Level Agreement) - *"nines"*



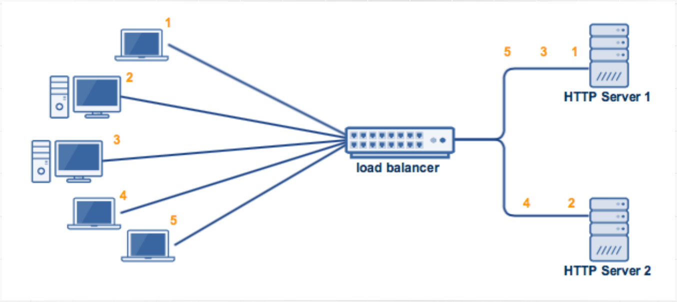
Availability %	Downtime per year[note 1]	Downtime per month	Downtime per week	Downtime per day
55.5555555% ("nine fives")	162.33 days	13.53 days	74.92 hours	10.67 hours
90% ("one nine")	**36.53 days**	**73.05 hours**	**16.80 hours**	**2.40 hours**
95% ("one nine five")	18.26 days	36.53 hours	8.40 hours	1.20 hours
97%	10.96 days	21.92 hours	5.04 hours	43.20 minutes
98%	7.31 days	14.61 hours	3.36 hours	28.80 minutes
99% ("two nines")	**3.65 days**	**7.31 hours**	**1.68 hours**	**14.40 minutes**
99.5% ("two nines five")	1.83 days	3.65 hours	50.40 minutes	7.20 minutes
99.8%	17.53 hours	87.66 minutes	20.16 minutes	2.88 minutes
99.9% ("three nines")	**8.77 hours**	**43.83 minutes**	**10.08 minutes**	**1.44 minutes**
99.95% ("three nines five")	4.38 hours	21.92 minutes	5.04 minutes	43.20 seconds
99.99% ("four nines")	**52.60 minutes**	**4.38 minutes**	**1.01 minutes**	**8.64 seconds**
99.995% ("four nines five")	26.30 minutes	2.19 minutes	30.24 seconds	4.32 seconds
99.999% ("five nines")	**5.26 minutes**	**26.30 seconds**	**6.05 seconds**	**864.00 milliseconds**
99.9999% ("six nines")	**31.56 seconds**	**2.63 seconds**	**604.80 milliseconds**	**86.40 milliseconds**
99.99999% ("seven nines")	**3.16 seconds**	**262.98 milliseconds**	**60.48 milliseconds**	**8.64 milliseconds**
99.999999% ("eight nines")	**315.58 milliseconds**	**26.30 milliseconds**	**6.05 milliseconds**	**864.00 microseconds**
99.9999999% ("nine nines")	**31.56 milliseconds**	**2.63 milliseconds**	**604.80 microseconds**	**86.40 microseconds**

HA idea

Concepts (High Availability)

How to achieve HA?

- replicate your service
- route all the traffic through a proxy / load balancer



HA in real systems

Concepts (High Availability)

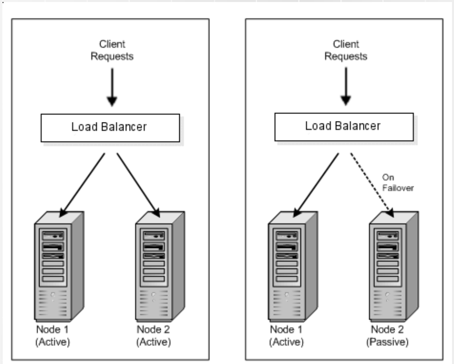
But in reality it’s not that easy:

- implementation of health checks, liveness probes,
- retry mechanisms,
- how to automatically scale services?
- choose scaling criterion, number of fallback replicas,
- ensure fast application startup,

Active-active vs active-passive

Concepts (High Availability)

- two types of HA: **active-active**, **active-passive**
- for statefull application:
  - active-active is hard to maintain $\rightarrow$ the state of all instances must be synchronized along with processing of requests,
  - active-passive requires also state synchronization (easier, only one node receives requests),
- stateless applications - both HA types are easier to apply,



Continuous X

Concepts

- How to cooperate within teams?
- What we can do to make sure our software works and has high quality
- How to find out when something was broken?
- What if two people change dependant functionalities?

Continuous Integration (1)

Concepts (Continuous X)

Term comes from Extreme Programming by Kent Beck

- testing your code is important!,
- different kind of tests:
  - unit,
  - integration,
  - functional,
  - regression,
  - code quality,
  - security / bugs tests

Continuous Integration (2)

Concepts (Continuous X)

- manual vs automated tests,
- manual:
  - not perfect solution, but still used
  - e.g. done by testers to prepare automated tests
  - acceptance tests on client side, etc.
- automated:
  - utilize testing frameworks (e.g. in Python: unittest, pytest, flake8, in Scala: ScalaTest, Play),
  - should handle creation of proper testing environments (reproducible builds),
  - can be ran on developers machine,
  - after a developer pushes code to remote repository, the CI systems should build the code and run all tests against it (CI pipeline)

Continuous Deployment (1)

Concepts (Continuous X)

- What if continuous integration is not enough for you?
- What if you want to deploy your software as fast as possible after feature development?
- How to perform multiple deployments daily? (e.g. Facebook performs thousands of deployments per day)
- You need to be sure that your production environment is as fresh as it can be?

Continuous Deployment (2)

Concepts (Continuous X)

- Deploy your software as part of your build pipeline (to production or production-like environment)
- Create push-button deployment possibilities
- Automate as much as you can
- CI do not guarantee that your software will be deploy-able, CD does

Continuous Deployment (3)

Concepts (Continuous X)

- Create continuous integration pipeline with all its requirements
- Extend it to contain executable creation
- Create automation procedure that allows you to deploy your app/services
- Utilize appropriate updates procedure (canary etc.)
- Add deployment as part of build pipeline, or create special build for that

Automation servers

Concepts (Continuous X)

Software development automation servers

- **Jenkins**
- **GitLab CI**
- TeamCity
- **Zuul**
- Travis
- CircleCI

Software Updates

Concepts

- How to perform app updates without downtime?
- How to perform app updates to part of users
- How to make sure that app will be working correctly before full roll-out

Software Update Types

Concepts (Software Updates)

- Blue-Green
- Canary
- Rolling

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Data schema updates (1)

Concepts (Software Updates)

- What about persistence?
- You need to separate schema from app upgrades
- On schema changes, you might need to do it in multi-phases

Data schema updates (2)

Concepts (Software Updates)

Field removal:

- Schema and app requires some field
- Change schema and app to make field optional
- Make upgrade
- Shut down app version that requires that field
- Change schema and app to make field absent

Blue-green (1)

Concepts (Software Updates)

- Load-balancer of proxy in front of app
- Two same environments
  - Green - One environment currently running
  - Blue - One that is updated
- Redirect traffic from green to blue after update
- All ok - blue becomes green, green becomes blue
- Problem? - redirect traffic back

Blue-green (2)

Concepts (Software Updates)

Update procedure

- Update blue environment
- Redirect traffic from green to blue
- All OK - blue becomes green, green can be again used as blue
- Problem? - redirect traffic back

Canary (1)

Concepts (Software Updates)

- Roll-out updates only to small part of traffic
- You can roll-out only to part of your users
- At Facebook:
  - Gatekeeper
  - Roll-out using information about users
  - By age
  - By gender
  - etc.

Canary (2)

Update procedure

- Create app instance with new features
- Redirect part of traffic using some predicate to new instance
- All OK? - continue redirecting the traffic until 100% on new app
- Problem - roll-back to the old instances

Rolling (1)

Concepts (Software Updates)

- N - number of running instances before update
- During the update, at most $N + 1$ running instances
- At each step of update, replace one old version instance with new one

Rolling (2)

Concepts (Software Updates)

Update procedure

- Create new version instance
- All OK - Turn off one old version instance
- All OK - Repeat until you have only new version instances
- Problem? - Recreate old instances

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Overview

Overview

Resource orchestration platforms (Hadoop)

- framework for processing big data
- not a brand name
- open source project
- effective for analytics, sometimes operations

	Operational	**Analytical**
Latency	1 ms - 100 ms	1 min - 100 min
Concurrency	1000 - 100,000	1 - 10
Access Pattern	Writes and Reads	Reads
Queries	Selective	Unselective
Data Scope	Operational	Retrospective
End User	Customer	Data Scientist
Technology	NoSQL	MapReduce, BSP

Introduction

Resource orchestration platforms (Hadoop)

Hadoop’s core:

- HDFS
- MapReduce
- YARN
- Common

HDFS Overview

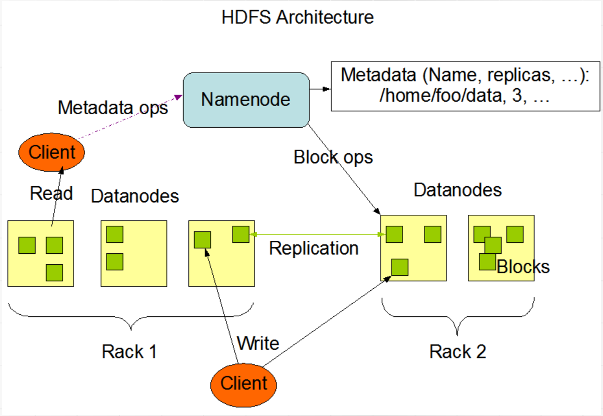
Resource orchestration platforms (Hadoop)

- Hadoop Distributed File System
- heart of Hadoop technology
- manages how data files are divided and stored across the cluster
- data is divided into blocks; each server in the cluster contains data from different blocks
- some built-in redundancy
- provides file permissions and authentication
- has a master/slave architecture

HDFS Architecture

HDFS cluster consists of:

- single NameNode - master server that manages the file system namespace and regulates access to files
- a number of DataNodes (usually one per node in the cluster) - manage storage attached to the nodes



HDFS Operations

Resource orchestration platforms (Hadoop)

The NameNode:

- executes file system namespace
- opening, closing, and renaming files and directories
- mapping of blocks to DataNodes

The DataNodes are responsible for:

- serving read and write requests from the clients
- perform block creation, deletion (NameNode instructions)

Block

- user data is stored in the files of HDFS; the file in a file system is divided into one or more segments and stored in individual data nodes
- file segments are called as blocks
- the minimum amount of data that HDFS can read or write is called a Block
- default block size is 64MB

MapReduce

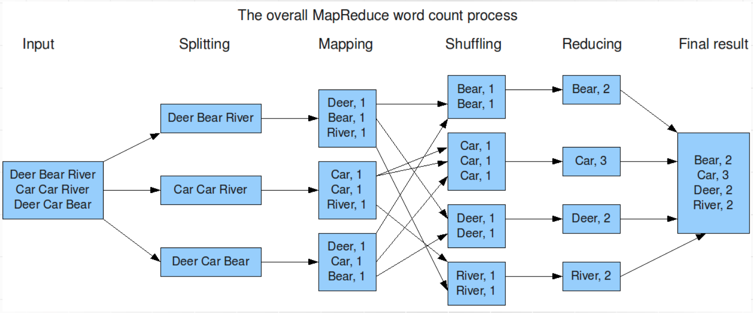
Resource orchestration platforms (Hadoop)

MapReduce - a method for parallel processing on distributed servers

Stages of MapReduce:

1. map - process the input data from HDFS; input file is passed to the mapper function line by line; creates several small chunks of data
2. shuffle - transfers the map output from Mapper to a Reducer
3. reduce - takes the output of the mapper (intermediate key-value pair); output of the reducer is the final output in HDFS; usually aggregation or summation

MapReduce example

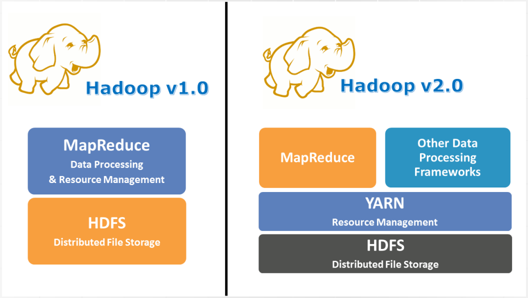


1. the input is first splitting into blocks
2. the splitted input is assined to [key,value] pair in mapper side
3. all the values are ordered in shuffling phase
4. reducer side sorting and grouping is done

Hadoop YARN

Resource orchestration platforms (YARN)

- not to be confused with Javascript’s yarn package manager
- handles processing part in Hadoop
- YARN = Yet Another Resource Negotiator
- assigns resources to each application



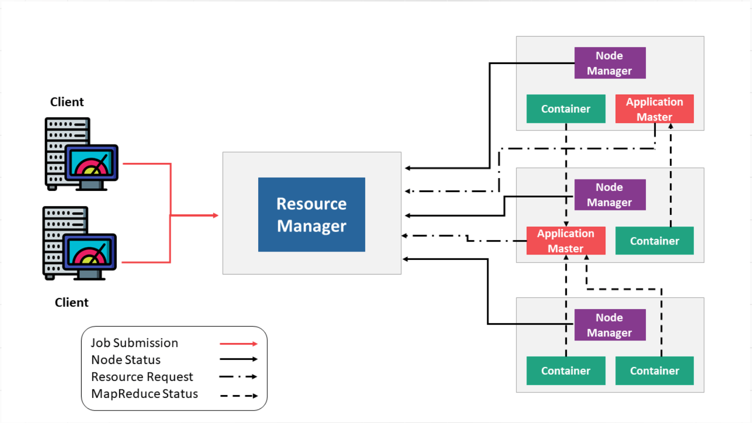
YARN components

Resource orchestration platforms (YARN)

- **Resource Manager**
  - communicates with the client;
  - tracks resources on the cluster;
  - coordinates node manager by assigning job according to requirement;
  - allocates memory in form of containers;
- **Node Manager**
  - monitoring of running app;
  - offers resources (memory and CPUs) as resource container;
  - every datanode $\rightarrow$ one node manager;
  - containers run tasks (including Application Masters);
- **Application Master**
  - every job is initialized by Application manager;
  - manages the global assignment of compute resources to applications (e.g. memory, CPU, disk, network, etc.)

YARN diagram

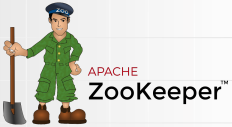
Resource orchestration platforms (YARN)



Zookeeper

Resource orchestration platforms (Zookeeper)

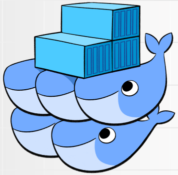
- not a resource orchestration tool
- often used along with Hadoop, HBase, Hive, Kafka etc.
- centralized service for:
  - maintaining configuration information,
  - naming,
  - providing distributed synchronization,
  - providing group services.



Docker Swarm

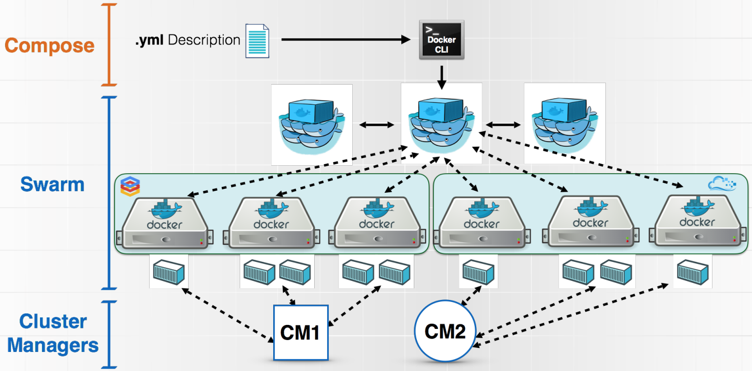
Resource orchestration platforms (Swarm)

- container orchestration system created by Docker;
- allows to distribute Docker containers across multiple nodes;
- introduces *stacks* and services;
- resource reservations and limits;
- container scaling;
- rolling updates;
- does not provide advanced networking (overlay);
- very basic compared to Kubernetes;



Docker Swarm

Resource orchestration platforms (Swarm)



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Kubernetes

Resource orchestration platforms (Kubernetes)

- Google
- Based on huge experience on handling distributed environments
- Open-source
- huge community

Kubernetes

Resource orchestration platforms (Kubernetes)

- Not so easy to deploy
- Many dependant services
- K3S
  - a simpler and easier in deployment and management
  - use SQLite, for big traffic might be a bottleneck
- For local development
  - Minikube
  - microk8s

Architecture

Resource orchestration platforms (Kubernetes)

Kubernetes has two types of nodes (each running multiple microservices):

- master (control plane) nodes:
  - API server,
  - Scheduler,
  - Controller Manager,
  - ETCD,
- worker nodes:
  - Kubelet,
  - Kube-proxy,
  - *Container runtime**

Master nodes components (1)

Resource orchestration platforms (Kubernetes)

https://kubernetes.io/docs/concepts/overview/components/

- API server (*kube-apiserver*):
  - exposes the Kubernetes API,
  - front end for the control plane,
  - designed to scale horizontally (via load balancers),
- Scheduler (*kube-scheduler*):
  - watches newly created pods that have no node assigned,
  - selects a node for them to run on,
  - individual and collective resource requirements, hardware/software/policy constraints, affinity and anti-affinity specifications, data locality, inter-workload interference and deadlines,

Master nodes components (2)

Resource orchestration platforms (Kubernetes)

`https://kubernetes.io/docs/concepts/overview/components/`

- CM (*kube-controller-manager*) – runs controllers:
  - Node Controller – Responsible for noticing and responding when nodes go down.
  - Replication Controller – Responsible for maintaining the correct number of pods for every replication controller object in the system.
  - Endpoints Controller – Populates the Endpoints object (that is, joins Services & Pods).
  - Service Account & Token Controllers – Create default accounts and API access tokens for new namespaces,
- ETCD:
  - consistent and highly-available key value store,
  - used as Kubernetes' backing store for all cluster data,
  - can be run in standalone or cluster mode,

Worker nodes components

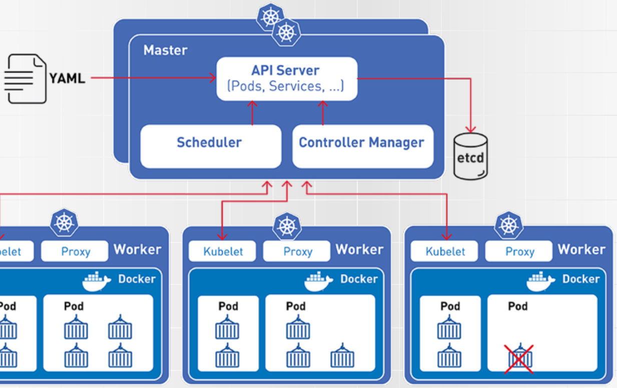
Resource orchestration platforms (Kubernetes)

`https://kubernetes.io/docs/concepts/overview/components/`

- kubelet:
  - daemon running on each worker node,
  - makes sure that containers are running in a pod,
  - manages only containers created by Kubernetes,
- kube-proxy:
  - network proxy running on each worker node,
  - maintains network rules on nodes (ingress / egress),
  - utilizes OS packet filtering layer (if available)
- Container runtime – supported ones:
  - Docker, containerd,
  - cri-o, rktlet,
  - any implementation of the Kubernetes CRI (Container Runtime Interface).

Architecture diagram

Resource orchestration platforms (Kubernetes)



Kubernetes objects

Resource orchestration platforms (Kubernetes)

kubernetes defines multiple objects that an application can make use of:

- deployment
- service
- daemonset
- statefulset
- configmap
- secret
- persistentvolume(claim)

Kubernetes manifests

Resource orchestration platforms (Kubernetes)

Kubernetes object are created using YAML manifests:

```
---
apiVersion: apps/v1
kind: Deployment
metadata:
  name: nginx-deployment
spec:
  selector:
    matchLabels:
      app: nginx
  replicas: 1
  template:
    metadata:
      labels:
        app: nginx
    spec:
      volumes:
        - name: nginx-sample-page
          configMap:
            name: nginx-sample-page
      containers:
      - name: nginx
        image: nginx:latest
        ports:
          - containerPort: 80
        volumeMounts:
          - name: nginx-sample-page
            mountPath: /usr/share/nginx/html/index.html
            subPath: index.html
```

Kubernetes management

- most cluster actions are performed using `kubectl`,
- it allows to manage the cluster, as well as deploy application manifests,
- alternatively, for deployment you can use `helm` (we'll discuss it later),

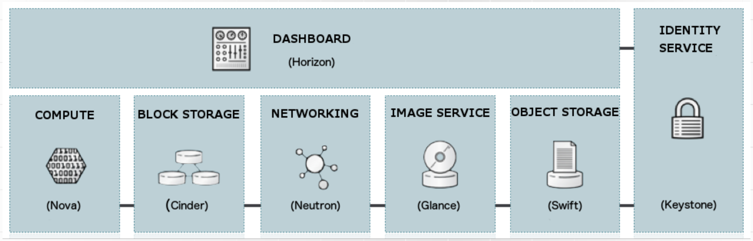
Openstack

Resource orchestration platforms (Openstack)

- most popular open source virtual machine orchestration platform;
- operates on VMs instead on containers;
- microservice based architecture;
- multiple specialized services;

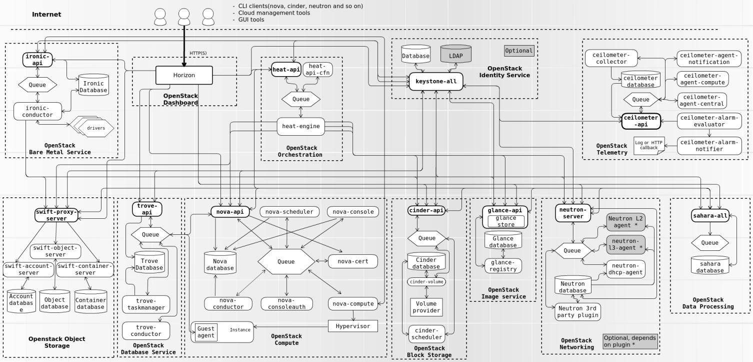
Architecture (1)

Resource orchestration platforms (Openstack)



Architecture (2)

Resource orchestration platforms (Openstack)



Services

Resource orchestration platforms (Openstack)

- **NOVA** (Compute)
- ZUN (Containers)
- **QINLING** (Functions)
- **IRONIC** (Bare Metal Provisioning)
- **CYBORG** (Hardware accelerators)
- SWIFT (Object store)
- **CINDER** (Block Storage)
- MANILA (Shared filesystems)
- **NEUTRON** (Networking)
- OCTAVIA (Load balancer)
- DESIGNATE (DNS)
- **KEYSTONE** (Identity)
- **PLACEMENT** (Placement)
- **GLANCE** (Image)
- HEAT (Orchestration)
- **MISTRAL** (Workflow)
- AODH (Alarming)
- **MAGNUM** (Container Orchestration Engine Provisioning)
- **SAHARA** (Big Data Processing Framework Provisioning)
- TROVE (Database as a Service)
- **MASAKARI** (Instances High Availability Service)
- MURANO (Application Catalog)
- **EC2API** (EC2 API proxy)
- HORIZON (Dashboard)
- and many more...

Overview

- Concepts
  - Stateless vs Stateful application
  - High Availability
  - Continuous X
  - Software Updates
- Resource orchestration platforms
  - Hadoop
  - YARN
  - Zookeeper
  - Swarm
  - Kubernetes
  - Openstack
- Useful tools
  - Helm
  - Ansible

Helm

Useful tools

- How to manage Kubernates deployments?
- There are not variables in Kubernates manifests
- What to do if we want to rollback to previous version

Helm

Useful tools

- Package manager for K8S
- OpenSource, maintained by Google, Microsoft, Bitnami, ...
- Many ready to use charts in official repository
- Possibility to use variables during deployment
- Charts can have dependencies

Helm

Useful tools

- Easily find packages
- Easily create new packages
- Can operate on any K8S cluster
- Query the cluster to see installed packages
- Update, delete, rollback and check history of installed charts

Helm

Useful tools

- Basically it templates K8S manifests (Go templates)
- Thanks to that, it is independent from resources that you want to create
- Create resource YAML, utilize {{ }} to inject variables
- Variables can be provided as a file or during the deployment

Helm

Useful tools

Helm v2

- requires Tiler
  - server-side (on cluster) component
  - manages packages
- 2-way strategic merge path
- releases names are global
- release name is optional, if not provided will be generated

Helm v3

- no Tiler
- 3-way strategic merge path
- releases names are in namespaces
- release name is required
- library charts

Directory structure

Useful tools (Helm)

```
wordpress/
  Chart.yaml          # A YAML file containing information
                      #  about the chart
  LICENSE             # OPTIONAL: A plain text file containing
                      #  the license for the chart
  README.md           # OPTIONAL: A human-readable README file
  values.yaml         # The default configuration values
                      #  for this chart
  values.schema.json  # OPTIONAL: A JSON Schema for imposing
                      #  a structure on the values.yaml file
  charts/             # A directory containing any charts upon
                      #  which this chart depends.
  crds/               # Custom Resource Definitions
  templates/          # A directory of templates that,
                      #  when combined with values, will
                      #  generate valid Kubernetes manifest files.
  templates/NOTES.txt # OPTIONAL: A plain text file containing
                      #  short usage notes
```

Example template

Useful tools (Helm)

```yaml
apiVersion: v1
kind: ConfigMap
metadata:
  name: {{ .Release.Name }}-configmap
data:
  myvalue: "Hello World"
```

Example template

Useful tools (Helm)

```
apiVersion: v1
kind: ConfigMap
metadata:
  name: {{ .Release.Name }}-configmap
data:
  myvalue: "Hello World"
  drink: {{ .Values.favoriteDrink }}
```

```
helm install --set favoriteDrink=monsterek ./mychart
```

Helm

Useful tools

- How to check if your template will work?
- dry-run will render template to STD
- you need to check it manually
- rendered template can be not accepted by kubernetes

Introduction

Useful tools (Ansible)

- open source automation tool,
- machine provision,
- configuration management,
- application deployment,
- YAML-based declarative language,
- agentless (uses SSH / Powershell),

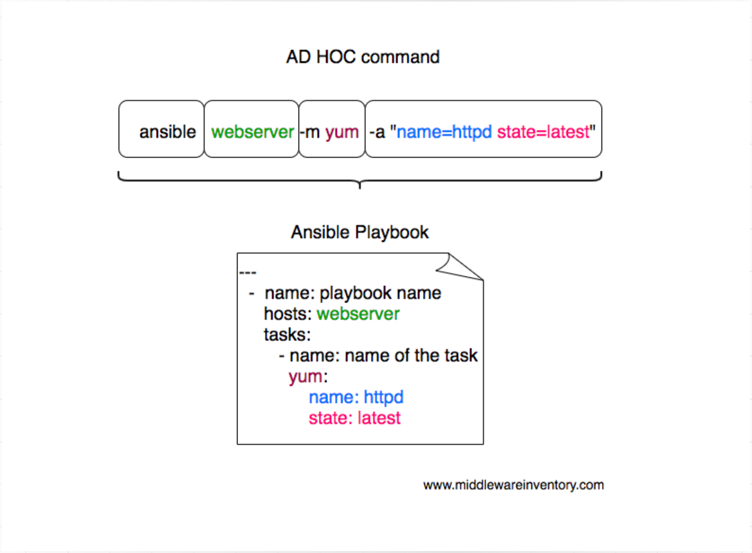
Characteristics

Useful tools (Ansible)

- simple & minimalistic (YAML-based language & Jinja templates),
- consistency (of created enviroments),
- security (no dedicated agent, SSH used for connections),
- reliability (**idempotent** playbooks),

Command vs playbook

Useful tools (Ansible)



```
---
 -  name: playbook name
    hosts: webserver
    tasks:
      - name: name of the task
        yum:
            name: httpd
            state: latest
```

Example playbook

Useful tools (Ansible)

```yaml
---
- name: Install nginx
  hosts: all
  become: true

  tasks:
  - name: Add epel-release repo
    yum:
      name: epel-release
      state: present

  - name: Install nginx
    yum:
      name: nginx
      state: present

  - name: Insert Index Page
    template:
      src: index.html
      dest: /usr/share/nginx/html/index.html

  - name: Start NGiNX
    service:
      name: nginx
      state: started
```

Concepts (1)

Useful tools (Ansible)

- playbooks:
  - define steps to build environments,
  - can be divided into multiple files (readability, reusability),
  - roles, vars, group_vars etc.
- modules:
  - define actual actions executed by Ansible,
  - examples given on previous slide,
  - standalone,
  - can be written in most scripting languages (Python, Bash, Perl, Ruby etc.),
  - should follow **idempotent** rule,

Concepts (2)

Useful tools (Ansible)

- inventory file:
  - description of nodes that can be accessed by Ansible,
  - INI or YAML format,
  - IP addresses or hostnames,
  - when necessary SSH keys and users can be provided,
  - nodes can be assigned to groups,

Inventory file example

Useful tools (Ansible)

```
# Consolidation of all groups
[hosts:children]
web-servers
offsite
onsite
backup-servers

[web-servers]
server1 ansible_host=192.168.0.1 ansible_port=1600
server2 ansible_host=192.168.0.2 ansible_port=1800

[offsite]
server3 ansible_host=10.160.40.1 ansible_port=22 ansible_user=root
192.168.6.1

# You can make groups of groups
[offsite:children]
backup-servers

[onsite]
server5 ansible_host=10.150.70.1 ansible_ssh_pass=password

[backup-servers]
foo.example.com
```

Wrocław University of Science and Technology

Large Scale Data Processing

Lecture 3 – Data processing stack

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