Summary of Cloud Computing at University of Bristol 2018 / 2019[*]

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[*]This is just a simple summary. I am not responsible for the provided content or anything which belongs to this. If there are any questions please contact me at bauerflorian13@gmail.com .

Contents

Lecture 01: Introduction

Comparison of the internet and electricity network

- starts with everyone has his own (electricity/ computationally power)
- connection between every single users grows
- ends in an all connected world with only a few big services provided by a small number of providers (computationally power goes from the device of the endusers to the cloud, electricity comes from big providers)

Normal Failure

- cloud data centre with 99.999% survival rate
- 500000 server, probability of 100% of the servers are still running after 3 years is 1%.
- **solution**: modular data centres, *servers in container boxes*

Essential Characteristics of Cloud Computing

This definition belongs to NIST's characteristics of Cloud Computing

- **On-demand self service**
- **Broad network access**
- **Ressource pooling**
- **Rapid elasticity**
- **Measured service**

A common stratification: *aaS

Everything as a Service.

- **SaaS**: *Software as a Service*, for instance: everyone
- **PaaS**: *Platform as a Service*, for instance: *Google App Engine*, *Amazon Appstream*
- **IaaS**: *Infrastructure as a Service*, for instance: *Amazon EC2*, *S3*, *Google Compute Engine*

A small number of companies providing IaaS/PaaS s services. Convergence to an oligopoly of less than five providers seems certain.

Lecture 02: Coursework

Just a few informations about the coursework and programming project. May be hopefully not important for the exam...

L03: Economics of Cloud

The basic Economics

- **Cap**ital **Ex**penditure: *Capex*
- **Op**erating **Ex**panditure: *Opex*
- Capex vs Opex: *Why buy a cow if all you need is the milk?*

A typical warehouse scale computer

- *pizzabox* in a *refrigerator* is a server rack
- multiple server racks together are a cluster
- see Figure 1

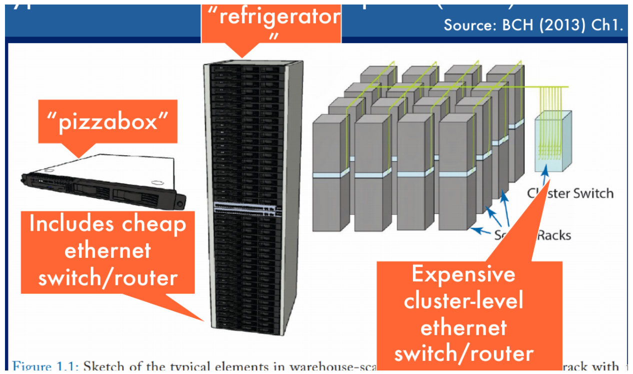

"refrigerator"
Source: BCH (2013) Ch1.
"pizzabox"
Includes cheap ethernet switch/router
Cl ster Switch
Racks
Expensive cluster-level ethernet switch/router
Figure 1.1: Sketch of the typical elements in warehouse-sca

Figure 1: WSC - Warehouse-scale Computer

Energy & Power Efficiency

- cooling cost are around 42%
- optimizing the cooling efficiency will lower the overall costs massivley

Resume

- there is a lot going on *under the hood of a WSC* (WSC = **Warehouse-scale Computer**)
- *prod>>dev*: The innovations are made by and in companies not universitys

L05: *aaS

Definiton see in the Introduction section (Everything as a Service).

Why Xaas or *aaS

- avoiding of **Undiffertiated Heavy Lifting**
- the cloud is an ideal environment providing *scale*, *low cost*, *automation via Infrastructure-as-Code*

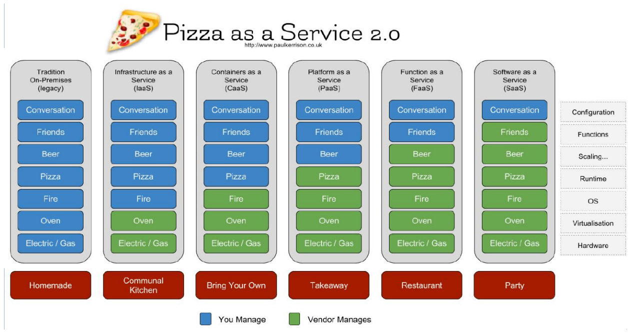


Figure 2: Pizza as a Service Example for *aaS

Structure of AWS Cloud

- **Availability Zones**: cluster of independent data centres, enables **fault isolation** and **high availability**
- **Regions**: entirely independent clouds, consists of a least two *AZ*s, interconnection on global backbone, different regions have different costings

Which Region should I choose?

- **Data souvereignty and compilance**: where to store user data?
- **Proximity of users to data**: where are the most of my users? -¿ lowest latency
- **Services and feature availability**: services and features may vary
- **Cost effectiveness**: each region has different costs (Europe and US are the cheapest)

High Availability & Fault Tolerance

High Availability:

- minimise service downtime by using redundant components
- require components in at least two AZs
- IaaS may have HA, PaaS usually will have HA

Fault Tolerance

- ensure no service disruption by using active-active architecture
- requires service components in at least three AZs
- Iaas is unlikely to offer FT, PaaS some offers FT

AWS Storage options

- Elastic Block Storage: SSDs, Magnetic, NAS, Use: OS, Apps
- S3: durable object storage, very cheap and big
- Instance Storage: on-host storage, very fast, caching
- Elastic File Store: shared storage across AZs

IaaS vs PaaS

- IaaS mainly used by SysAdmins, PaaS mainly used by Developers
- IaaS provides e.g. *VMs*,*Storage Services*,*Networking*, PaaS provides e.g. hosted databases, *App deployment and managment env.*,*test suites*
- IaaS lower cloud costs, PaaS lower human costs

L07: Virtualisation, Containers and Container Orchestration

Virtualisation Basics

- server hardware should be hidden from the user, → user sees only guest OS in a VM and not the host OS
- Amazon offers different VMs (*AMIs*) with Linux or Windows
- VMs are created and run by the *Virtual Machine Monitor (VMM)* aka the **hypervisor**
- VMs can stopped, copied, paused and resumed, which enables **server consolidation**: compress VMs to freeup servers

Types of Virtualisation

Have a look at Figure 3

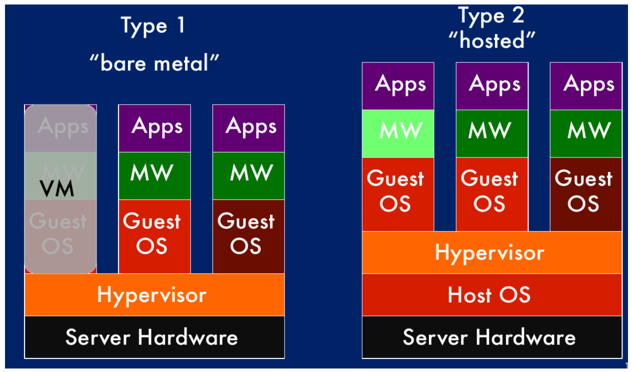


Figure 3: The two different virtualisation types

Xen is an example for Type 1 VMs.

- **Full virtualisation**: complete simulation of underlying guest machine hardware

- **Paravirtualisation**: guest OS can make Syscalls via the hypervisor's API, hypervisor does not simulate hardware

Containerisation: Docker

- package and run application in lightweight, isolated environment
- Docker runs user processes in a super-isolated execution mode
- *operating system level virtualisation* with shared kernel
- Advantage: No need to boot a whole VM
- Disadvantage: Potentially more insecure than complete virtualisation

Docker Objects

- **Images**: read only template with instructions how to create a Docker Container
- **Container**: runnable instance of an image, but ephemeral → all changes not mounted to persistend storage will be lost

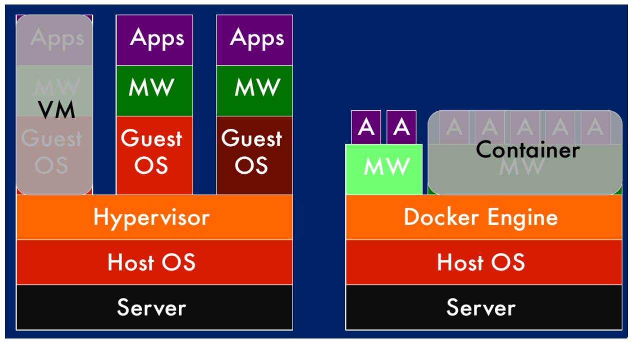


Figure 4: VMs vs Docker architecture schema

Container Orchestration: Kubernetes

Motivation

- To run containers at scale needs managment tools
- **(Horizontal) Auto-scaling on demand**
- **Fault Tolerance**
- **Manage Accessibility from the web**
- **update/rollback without downtime**

Featues of Kubernetes

- **Automated scaling**
- **Self healing**
- **Horizontal scaling**
- **Service discovery and Load Balancing**
- **Automated Rollbacks/Rollouts**

Kubernetes Components

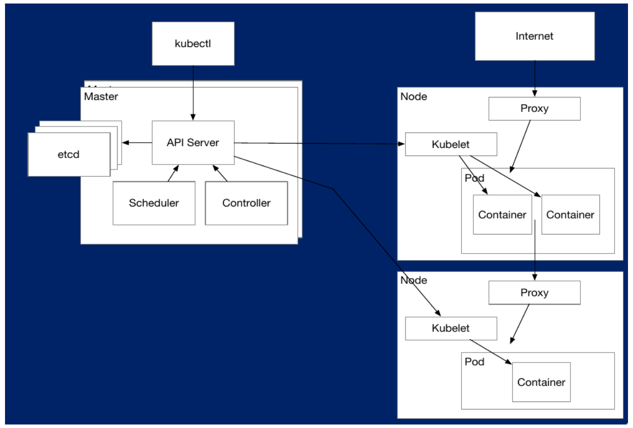


Figure 5: Components of the Kubernetes architecture

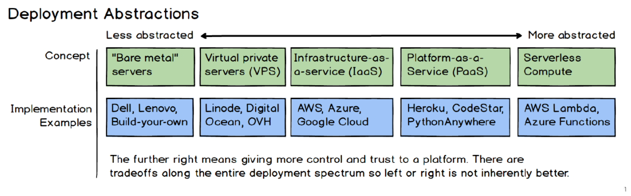
- **Master**: manages the cluster state, subcomponents: **API Server**, **Controller**, **Scheduler**, writes to *etcd*
- **Nodes**: run work in pods, **Pods** are the scheduling unit, **Kubelet** is the agent to communicates with master, **Kube-proxy** is the network agent
- **Kubeclt**: local cli to controll cluster
- **Etcd**: distributed key-value store
- **Deployments**: **Replica Sets**, balances the number of running and scheduled pods; deployments provide update to Pods or ReplicaSets
- **Services**: groupings of pods which can be referred by a name, Unique IP and DNS name; Pods in Services are load balanced

L09: Serverless

Definiton: *The essence of the serverless trend is the **absence** of the server concept during software development.*

Abstractions of App Deployment

- *More Abstraction*: more control and trust to given platform
- *Less Abstraction*:more undifferentiated heavy lifting


Deployment Abstractions
Less abstracted
More abstracted
Concept
"Bare metal" servers
Virtual private servers (VPS)
Infrastructure-as-a-service (IaaS)
Platform-as-a-Service (PaaS)
Serverless Compute
Implementation Examples
Dell, Lenovo, Build-your-own
Linode, Digital Ocean, OVH
AWS, Azure, Google Cloud
Heroku, CodeStar, PythonAnywhere
AWS Lambda, Azure Functions

The further right means giving more control and trust to a platform. There are tradeoffs along the entire deployment spectrum so left or right is not inherently better.

Figure 6: Deployment abstractions: More vs less abstraction

The four pillars of serverless

- No server managment
- Flexible Scaling
- High Availability
- Never Pay for Idle

Serverless FaaS: AWS Lambda

- Triggered by an event
- typically invoked in a few ms (warm start)
- Cold start issue: code that hasn't been used for a while takes longer to start

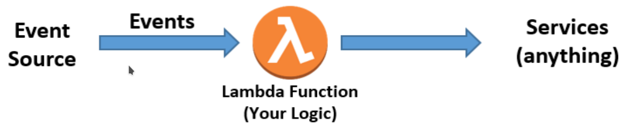


Figure 7: AWS Lambda: Event Triggers

The four stumbling blocks of serverless

- Performance Limitations
- Vendor Lock-in
- Monitoring and Debugging
- Security and Privacy

Serverless usecases

- Event-driven data processing (resize uploaded images)
- Serverless webapplication (simple 3-tier app)
- Mobile and IoT Apps (Airbnb smart home)
- Application Ecosystem (Alexa Skill)
- Event Workflow (image recognition and processing)

L11: Scalable Systems

The Scale Cube

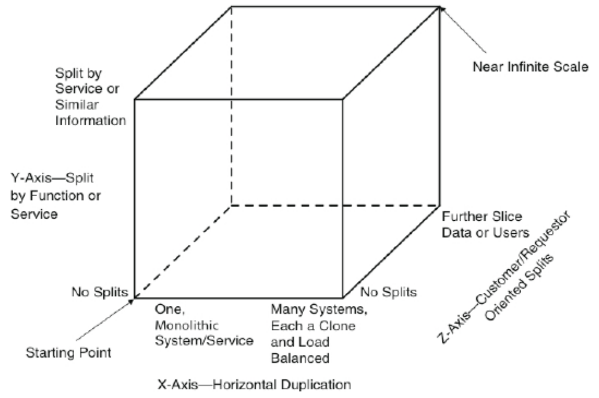

Near Infinite Scale
Split by Service or Similar Information
Y-Axis—Split by Function or Service
Further Slice Data or Users
No Splits
No Splits
Starting Point
One, Monolithic System/Service
Many Systems, Each a Clone and Load Balanced
X-Axis—Horizontal Duplication
Z-Axis—Customer/Requestor Oriented Splits

Figure 8: The Scale Cube

- x-axis: **Horizontal Duplication**, unbiased cloning of services and data
- y-axis: **split by function or service**:refers to isolation (making different services)
- z-axis: **partitioning the domain of incoming requests**:data-partitioning, split relevant to client (example: All customers from A-F are together processed, all customers from G-M, etc)

Software architectures

- set of structures needed to reason about the system
- might be implicit

Architectural Components and Patterns for scalable systems

- **Decoupled Components**: allows independent scalability of components; mechanisms to decouple:
  - load balancers
  - message queues
  - message topics
  - service registry
- **Load Balancers**: distributing requests, hiding the server from client access, manage availability (HA),session affinity/sticky sessions
- **Session affinity/sticky sessions**:cookies managed by load balancer(duration based), cookies managed by application cookie
- **LB Algorithms**:(Weighted) Round Robin, Least connections
- **Message Topics**:messages are immeditaley pushed to subscribers, decouple producers and subscribers, concurrent processing
- **Message Queues**: Asynchronous: queue it now but run it later; seperates application logic; introduces latency
- **Service Registries**: resolve addresses for names, Leader voting (*Byzantine Generel*)
- **Automation**: autoscaler as sclaing can not be done manually (Metrics are CPU, RAM, Memory)
- Architectural Patterns: Service oriented architectures; APIs are cloud requirement

L13: MapReduce and GFS/HDFS

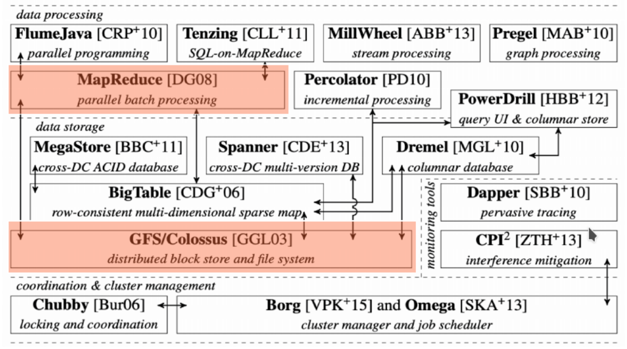

data processing
FlumeJava [CRP+10] parallel programming
Tenzing [CLL+11] SQL-on-MapReduce
MillWheel [ABB+13] stream processing
Pregel [MAB+10] graph processing
MapReduce [DG08] parallel batch processing
Percolator [PD10] incremental processing
PowerDrill [HBB+12] query UI & columnar store
data storage
MegaStore [BBC+11] cross-DC ACID database
Spanner [CDE+13] cross-DC multi-version DB
Dremel [MGL+10] columnar database
BigTable [CDG+06] row-consistent multi-dimensional sparse map
GFS/Colossus [GGL03] distributed block store and file system
monitoring tools
Dapper [SBB+10] pervasive tracing
CPI2 [ZTH+13] interference mitigation
coordination & cluster management
Chubby [Bur06] locking and coordination
Borg [VPK+15] and Omega [SKA+13] cluster manager and job scheduler

Figure 9: The Google Technology Stack

MapReduce: Basics

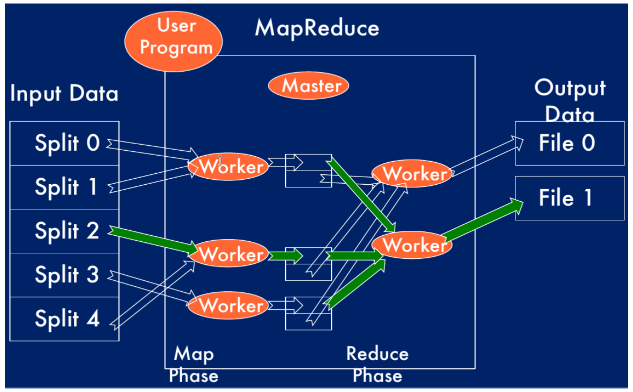


Figure 10: The MapReduce Technology

- we have some input data
- *Map phase*: master process assigns worker processes their part of the data, the data is than processed
- *Reduce phase*: other worker processes collect the processed data and reduce them

AS the master pings the worker and a failure would be noticed really fast. This can now be handled by assigning other processes the task of the failed process.

GFS - Google File System

GFS Objects

- TODO

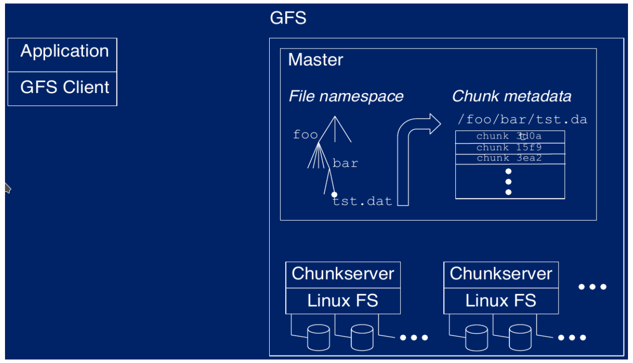


Figure 11: The GFS Architecture

TODO

L14: CAP, Paxos, BGP

CAP Theorem

A good cloud might seek to achieve these three things, but it is only able to select two of them. And as partition tolerance is mandatory for cloud applications we can only choose one of the other two.

- **C**onsistency
- **A**vailability
- **P**artition Tolerance

Paxos Approach

- **Paxos** is an approach to ensuring agreement of a series of asynchronous operations in distributed systems.
- achieve consensus, and ensure agreed actions can not be forgotten anymore
- dspite system messages being duplicate, lost, etc
- Paxos assumes messages are not deliberately malicious (BGP does)

Three paxos rules

- Proposers: learn already accepted values
- Acceptors: let proposers know already accepted values, accept or reject proposals, reach consensus on chosing a particular proposal/value
- Learners: become aware of the chosen proposal/value and action it

Types of Consistency

- **Strong Consistency**: after an update completes, every access will return the same updated value
- **Weak Consistency**: after an update completes, accesses are not guaranteed to return the updated value
- **Eventual Consistency**: eventually all access return the updated value (e.g. updates propagate in a lazy fashion)

Byzantine Generals Problem

Byzantine Faults

- **Byzantine Fault**: different symptoms to different observers

- **Byzantine Failure**: loss of a system service due to Byzantine Fault

Theoretical Problem

- there are a number of generals, each of them with one vote
- some of the generals are traitors and try to foil the other ones, by sending different votes to different generals (instead of the same vote to different generals)
- Key results of BG paper: BG can achieve consensus when $n \geq 3m + 1$ with n loyal generals and m traitors; To do so they must engange in $m + 1$ rounds of message passing
- **Oral Message algorithm**: solves the problem but preventing BFs is very expensive in term of more bandwith and redundancy

L15: The Hadoop Ecosystem

Important Components

- **Pig**: platform for batchmode analysis and large datasets, *Pig Latin* is compiled to use MapReduce
- **Hive**: datawarehouse-software, allows big queries over distributed storage via SQL
- **YARN**: cluster resource managment and job scheduling, middleware layer between HDFS and various application listed here
- **Mahout**: scalable MachineLearning platform, runs on Hadoop/Spark
- **Hoyal/HBase**: HBase is non-relational distributed database (NoSQL), similar to *Google BigTable*
- **Storm**: a distributed real-time stream-processing system
- **Giraph**: graph database, running MapReduce to process graphs
- **Spark**: analytics engine/framework for largescale dataprocessing that runs on YARN

Hadoop Versions

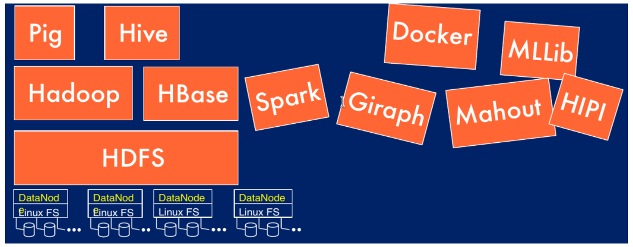


Figure 12: The architecture of Hadoop 1.0

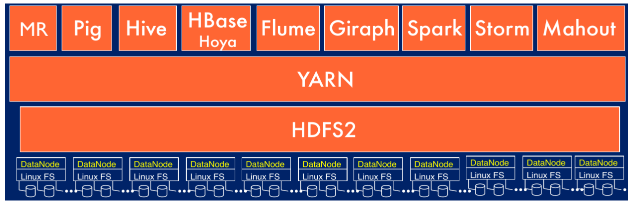


Figure 13: The architecture of Hadoop 2.0

Hive

TODO

Pig

TODO

L16: Spark and In-Memory Methods

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L17: NoSQL Databases

Main classes of NoSQL databases

- **KeyValue DBs**: e.g. DynamoDB, Redis
- **Document DBs**: e.g. CouchDB, MongoDB
- **Column-Family DBs**: e.g. Cassandra, HBase
- **Graph DBs**: e.g. Giraph

ACID & CRUD

- **ACID**: offered by RDBMSs, **A**tomacity **C**onsistency **I**solation **D**urablility
- **CRUD**: often CRUD is enough, **C**reate, **R**ead, **U**pdate, **D**elete

If you only want CRUD and do not care about the lack of ACID, you can choose NoSQL DBs instead of RDBMSs (which where engineered to run on a single server, which is hard to scale)

KeyValue DBs

- very simple, schemaless
- often very fast
- DBs have different constraints (ACID, object limit size, etc)

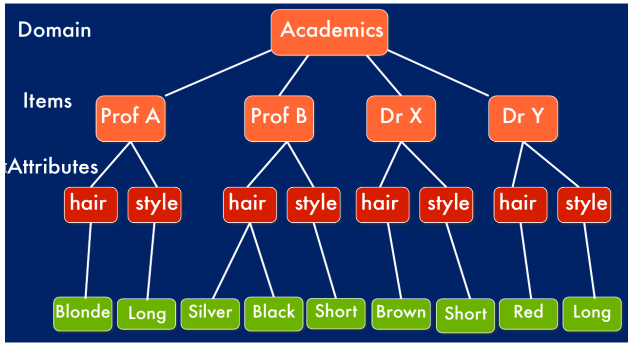

Figure 14: Example of a KeyValue DB: Amazon Simple DB

Document DBs

- manage more complex data structures than KV datastores
- do not require you to define common structure for all datasets (like KV stores)
- a *document* is a structured object, most commonly used are *XML* and *JSON*

Column-Family DBs & Columnar DBs

- for *big data*, so *VLDB* (Very Large Database)
- frequently used columns can be grouped together
- *families* are like relational tables, inividual columns are more like key-value pairs

Choices

- **Relational**:
  - *good for*: when layout of data is known in before, but exact queries are not
  - *less good for*: when data is highly variable or deeply hierarchical
- **Key Value**:
  - *good for*: data largely independant, horizontal scaling, CRUD
  - *less good for*: perform non trivial queries
- **Document**:
  - *good for*: highly variable data, storing redundant data is not a problem
  - *less good for*: when data needs to be normalized
- **Column-family**:
  - *good for*: Big Data, data compression, have an idea how the queries will look like
  - *less good for*: when you don't know how data will be quiered
- **Graph**:
  - *good for*: applications with *networks of relationships*
  - *less good for*: large scale situations where partitioning across nodes is necessary

⇒ *polyglot persistence model*: Use more databases, each playing a different role

L18: Graph Databases

L19: NewSQL & Event Stream Processing

L20: Cloud Security

L21: DevOp

Todo...

Possible exam Questions