OST
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Distributed Systems (DSy)

Introduction

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Learning Goals

- Lecture 1
  - Distributed systems add complexity. Avoid complexity!
  - Why do we need distributed systems?
    - Scaling (if one machine is not enough)
    - Location (to move closer to the user)
    - Fault-tolerance (HW will fail eventually)
- Lecture 2
  - What is a distributed system?
  - How can it be categorized?
  - What are transparencies?

Distributed Systems Definition

Definition: A distributed system in its simplest definition is a group of computers working together as to appear as a single computer to the user

Distributed Systems Definition

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can you give me a definition of a distributed system

A distributed system is a network of independent computers that work together to achieve a common goal. In a distributed system, the computers communicate and coordinate their actions through message passing or other forms of communication, but they do not share a common memory or clock. Each computer in the system is typically responsible for its own processing and storage, and the computers may be geographically dispersed and connected through a network. The goal of a distributed system is to provide a higher level of performance, reliability, and scalability than can be achieved with a single, centralized system. Distributed systems are used in a wide variety of applications, including cloud computing, peer-to-peer file sharing, and distributed databases.

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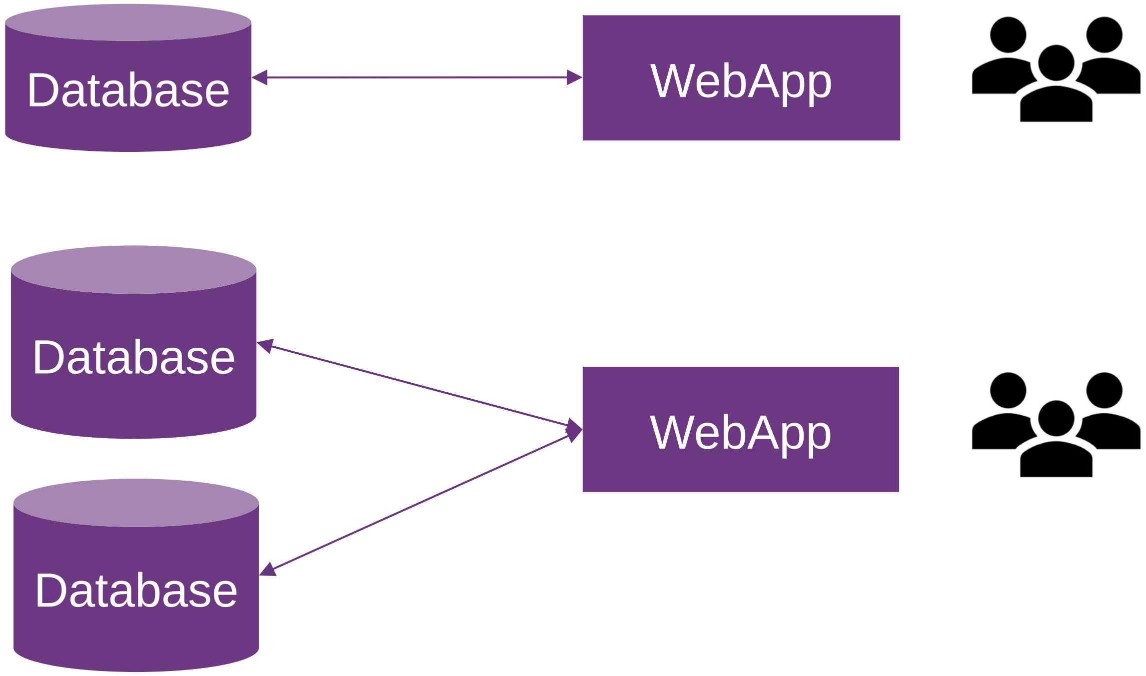
Distributed Systems Categorization

- It is useful to classify distributed systems as either tightly coupled, meaning that the processing elements, or nodes, have access to a common memory, and loosely coupled, meaning that they do not [reference]
- A homogeneous system is one in which all processors are of the same type; a heterogeneous system contains processors of different types
- Small-scale system: WebApp + database vs. large-scale with more than 2 machines

- Decentralized vs. distributed
  - Decentralized ~ distributed in the technical sense, but not owned by one actor



Distributed Systems Categorization

- Spring Term – Distributed Systems (DSy)
  - Tightly/loosely coupled
  - Heterogeneous systems
  - Small-scale systems
  - Distributed systems

  (we will also talk about blockchains in this lecture)

- Fall Term – Blockchain (BlCh)
  - Loosely coupled
  - Heterogeneous systems
  - Large-scale systems
  - Decentralized systems

  (we will also talk about distributed systems in this lecture, but DSy is highly recommended)

Distributed Systems Categorization

- Another classification
- CAP theorem - states that a distributed data store cannot simultaneously be consistent, available and partition tolerant
  - Consistency—Every node has the same consistent state
  - Availability— Every non-failing node always returns a response
  - Partition Tolerant—The system continues to be consistent even when network partitions
- With network partition - choose between consistency and availability
  - Is a system AP or CP?
- Blockchain and CAP
  - Both, if you wait for n blocks, CP, if you don’t AP
- Cassandra AP
  - But can be configured CP

Distributed Systems Categorization

- More Classifications
- Classification based on architecture
  - Client-server, peer-to-peer (P2P), or hybrid, or even more [link]
  - Software architecture [link]
- Classification based on communication model
  - Synchronous or asynchronous
- Classification: degree of transparency, fault tolerance, scalability, consistency (strong, eventual, and causal), data replication, data partitioning, heterogeneity

- No single universally applicable categorization of distributed systems

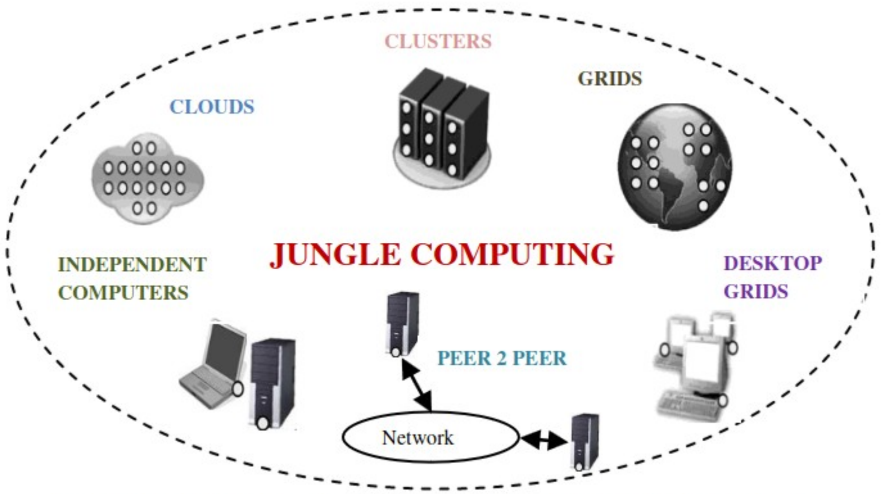


Figure 6.1: The jungle computing - a diverse collection of computing

[source]

Distributed Systems Categorization

"Controlled" Distributed Systems

- 1 responsible organization
- Low churn
- Examples:
  - Amazon DynamoDB
  - Client/server
- "Secure environment"
- High availability
- Can be homogeneous / heterogeneous

"Fully" Decentralized Systems

- N responsible organizations
- High churn
- Examples:
  - BitTorrent
  - Blockchain
- "Hostile environment"
- Unpredictable availability
- Is heterogeneous

Distributed Systems Categorization

“Controlled” Distributed Systems

- Mechanisms that work well:
  - Consistent hashing (DynamoDB, Cassandra)
  - Master nodes, central coordinator
- Network is under control or client/server → no NAT issues

“Fully” Decentralized Systems

- Mechanisms that work well:
  - Consistent hashing (DHTs)
  - Flooding/broadcasting - Bitcoin
- NAT and direct connectivity huge problem

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Distributed Systems Categorization

"Controlled" Distributed Systems

- Consistency
  - Leader election (Zookeeper/Zab, Paxos, Raft)
- Replication principles
  - More replicas: higher availability, higher reliability, higher performance, better scalability, but: requires maintaining consistency in replicas
- Transparency principles apply

"Fully" Decentralized Systems

- Consistency
  - Weak consistency: DHTs
  - Nakamoto consensus (aka proof of work, [link])
  - Proof of stake – Leader election, PBFT protocols
    Is Bitcoin eventually consistent?
    - Some argue no, some argue it has even stronger guarantees [link]
- Replication principles apply to fully decentralized systems as well
- Transparency principles apply

Transparency in distributed systems

- Distributed system should hide its distributed nature
  - Location transparency – users should not be aware of the physical location
  - Access transparency - users should access resources in a single, uniform way
  - Migration, relocation transparency – users should not be aware, that resource have moved
  - Replication transparency – users should not be aware about replicas, it should appear as a single resource

- Concurrent transparency – users should not be aware of other users
- Failure transparency – users should be aware of recovery mechanisms
- Security transparency – users should be minimally aware of security mechanisms
- More/other transparencies here, here, here
  - Depends on the context

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Fallacies of Distributed Computing

- 8 fallacies to consider

  1) The network is reliable
     - Submarine cables
  2) Latency is zero
     - Ping to Australia is ~300ms, ping via Starlink in Ukraine adds 77ms
  3) Bandwidth is infinite
     - What is faster? Send a bike courier with an 8TB disk, that arrives 10h later, or send the data with a 1Gibt/s link? 8 * 1000 * 8 / (10 * 60 * 60) = 1.7Gbit/s
  4) The network is secure
     - Assume someone is listening. Don’t send sensitive data over the network
  5) Topology doesn't change
     - Ping to Australia, request can take different route than reply
  6) There is one administrator
     - Sometimes your route goes from one company to another rival company (UPC, Init7)
  7) Transport cost is zero
     - Someone build and maintains the network
  8) The network is homogeneous
     - From fiber to WiFi to cable, server, desktop, mobile