Goals of Distributed Systems

- Transparency
- Openness
- Scalability

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Transparency

- **Transparency** is the concealment from the users and the application programmers of the fact that the processes and resources of a distributed system are physically distributed across multiple computers
- A transparent system is perceived as a whole rather than as a collection of independent components

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Types of Transparency (1)

- **Access transparency** enables local and remote resources to be accessed using identical operations
  - E.g., an API for files that uses the same operations to access both local and remote files
- **Location transparency** enables resources to be accessed without knowledge of their physical location
  - Resources are referred by location transparent logical names that contain no information about the physical location of the resource
  - E.g., URLs of Web pages are location transparent
- **Migration transparency** enables resources to be moved without affecting how they can be accessed
  - E.g., a Web page can be moved to a different location without having its URL changed
- **Relocation transparency** enables resources to move **while in use** without being noticed by users and applications
  - E.g., mobile users can continue to use their laptops while moving from place to place without being disconnected from the Internet

Types of Transparency (2)

- **Concurrency transparency** enables users and applications to access shared resources without interference between each other
  - Concurrent access to a shared resource should leave that resource in a consistent state
  - Consistency can be achieved using locks or transactions
- **Replication transparency** enables multiple instances of resources to be used to increase availability and performance without knowledge of the replicas by users
  - E.g., replicated web contents
- **Failure transparency** enables users and application programs to complete their tasks despite the failure of hardware or software components
  - E.g., email delivery

Openness

- An **open distributed system** is a system that offers services according to **published** standards that describe the syntax and semantics of those services
  - E.g., Internet is an open system as the specifications of Internet protocols are published in RFCs
- Services in distributed systems are generally specified through **interfaces***,* which are often described in an **Interface Definition Language** (IDL)
  - Interface definitions written in an IDL specify the **syntax** of the services (i.e., the names of the functions that are available, the types of the parameters, return values, and possible exceptions that can be raised)
  - **Semantics** of interfaces are specified in an informal way by means of natural language

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Benefits of Open Distributed Systems

- **Interoperability**: components written by different programmers can easily work together
- **Portability**: applications can be easily ported between different distributed systems that implement the same interfaces
- **Extensibility:** new services can be easily added and old services can be easily re-implemented

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Scalability

- A system is said to be **scalable** if it will remain effective when there is a significant increase in the number of users and the number of resources
- Scalability problems
  - **Size scalability**: as the number of users and resources increase, the system may become overloaded
  - **Geographical scalability**: as the distance between nodes increases, communication delay becomes significant

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Scaling Techniques

- **Decentralization**
  - achieves size scalability
- **Reducing communication**
  - achieves geographical scalability
- **Replication**
  - achieves size scalability and geographical scalability

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Achieving Size Scalability

- To achieve size scalability, we should eliminate performance bottlenecks, including
  - Centralized services (e.g., a single server)
  - Centralized data (e.g., a single DNS table)
  - Centralized algorithms (e.g., routing based on complete information)

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Decentralizing Services and Data

- Spreading data and services across multiple machines
- Examples
  - The Web is physically distributed across a large number of Web servers, each handling a collection of Web documents
  - The naming service of DNS is distributed across many name servers
    - The table that maps host names to IP addresses is partitioned between the name servers

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Decentralizing Algorithms

- Decentralized algorithms should be used to avoid performance bottlenecks
- Characteristics of decentralized algorithms
  - No machine has complete information about the system state
  - Machines make decisions based only on local information
  - Failure of one machine does not ruin the algorithm
  - No assumption of a global clock
    - It is impossible to get all the clocks in a distributed system exactly synchronized

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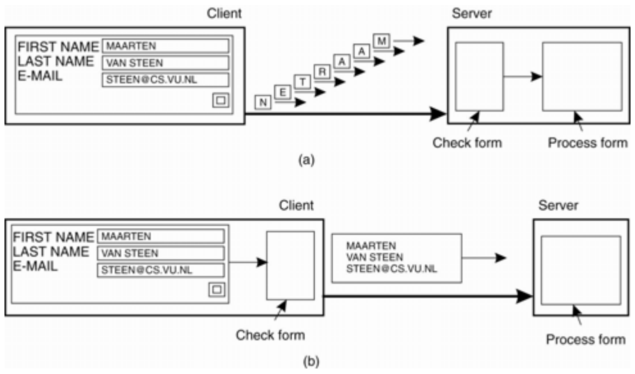
Reducing Communication

- To achieve geographical scalability, we can reduce communication by moving part of the computation from server to client



The difference between letting (a) a server or (b) a client check forms as they are being filled.

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Replication

- When a distributed system grows in size and in geographical coverage, the performance can decrease
- Replicating data and services across a distributed system can improve performance
  - Replicating services balance the load between servers
  - Placing a copy of data near a client reduces communication latency
- Replication lead to **consistency** problem – modifying one copy makes it different from other copies

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