Distributed Systems

Introduction

Slides Credits

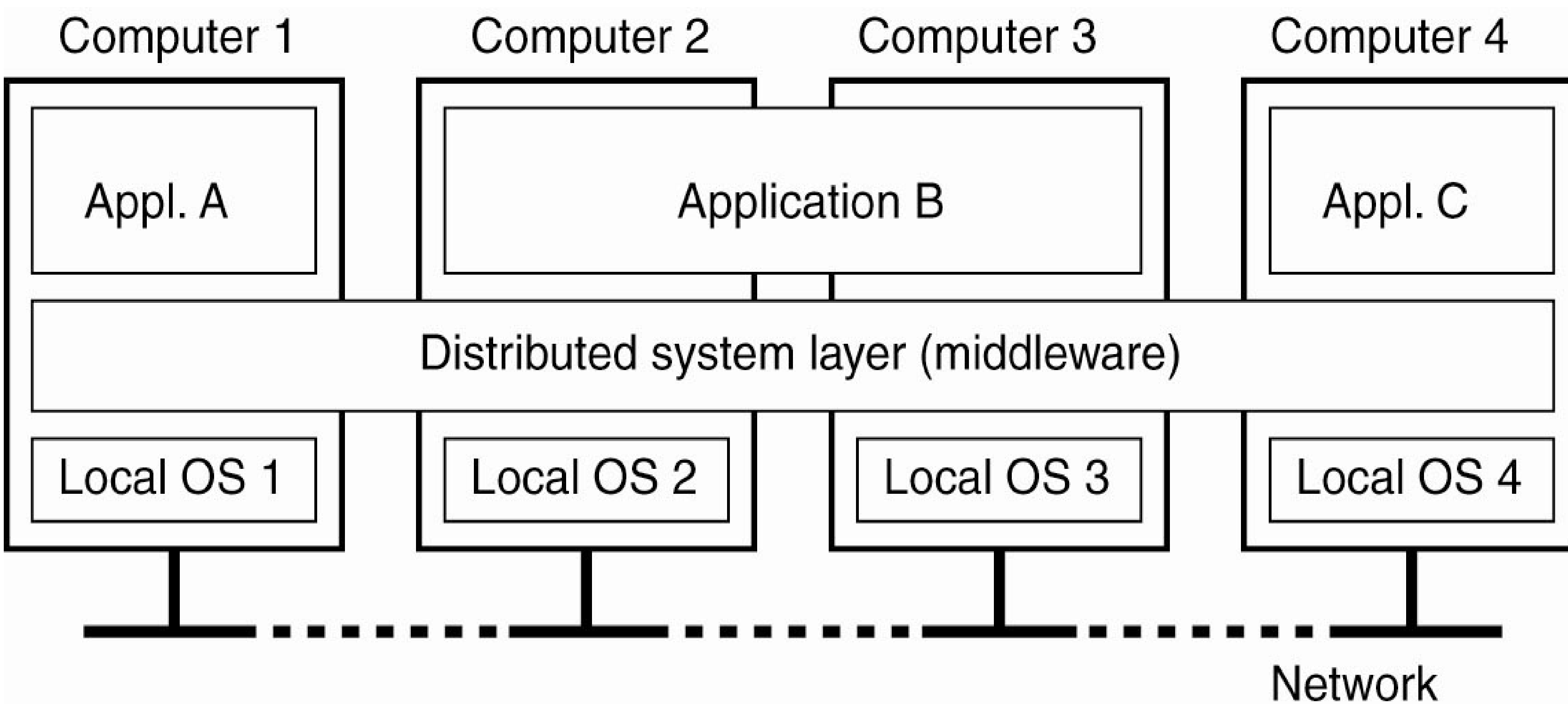
Note: Most of the course presentations are based on those developed by Andrew S. Tanenbaum and Maarten van Steen.

Definition of a Distributed System

A distributed system is:

A collection of independent computers
that appears to its users
as a single coherent system

Definition of a Distributed System



A distributed system organized as middleware.
The middleware layer extends over multiple machines, and offers each application the same interface

Goals of Distributed Systems

- Easily Connect Users/Resources
- Exhibit Distribution Transparency
- Support Openness
- Be Scalable:
  - in size
  - geographically
  - administratively

Looking at these goals helps use answer the question: “Is building a distributed system worth the effort?”

Transparency in a Distributed System

Transparency	Description
Access	Hide differences in data representation and how a resource is accessed
Location	Hide where a resource is located
Migration	Hide that a resource may move to another location
Relocation	Hide that a resource may be moved to another location while in use
Replication	Hide that a resource is replicated
Concurrency	Hide that a resource may be shared by several competitive users
Failure	Hide the failure and recovery of a resource

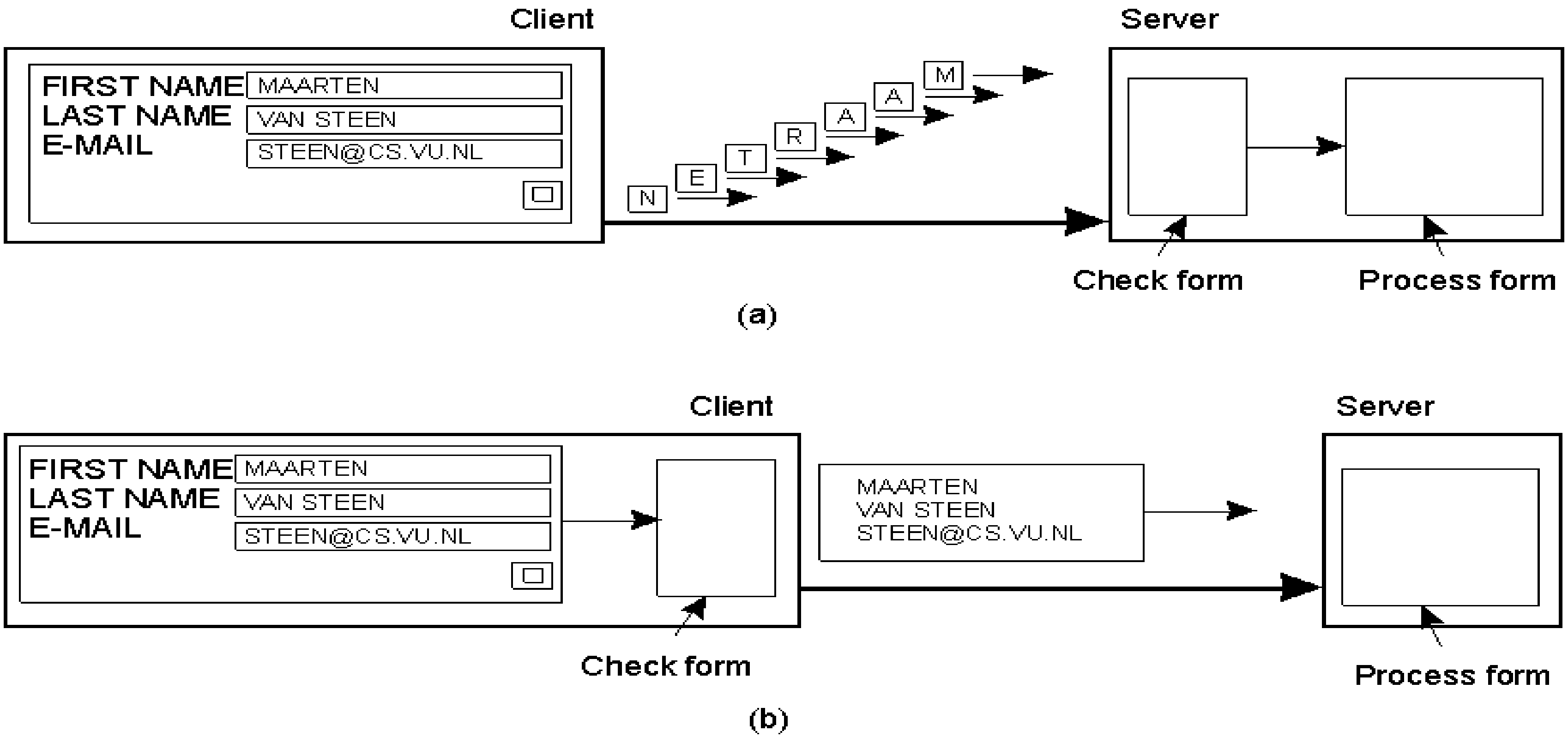
Different forms of transparency in a distributed system (ISO, 1995)

Scalability Limitations

Concept	Example
Centralized services	A single server for all users
Centralized data	A single on-line telephone book
Centralized algorithms	Doing routing based on complete information

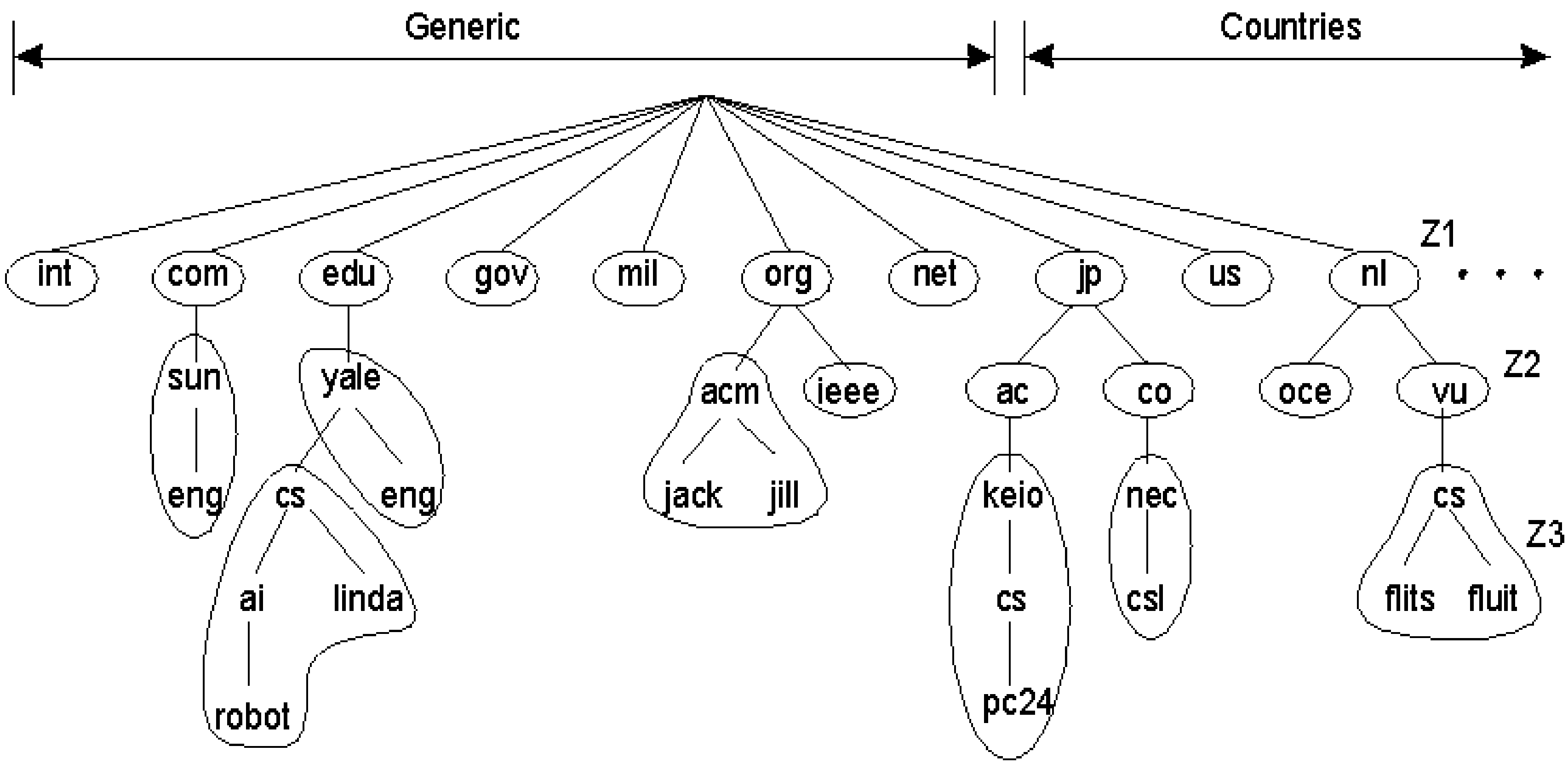
Examples of scalability limitations

Scaling Techniques (1)



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

Scaling Techniques (2)



An example of dividing the DNS name space into zones

: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.
- There is no implicit assumption that a global clock exists.

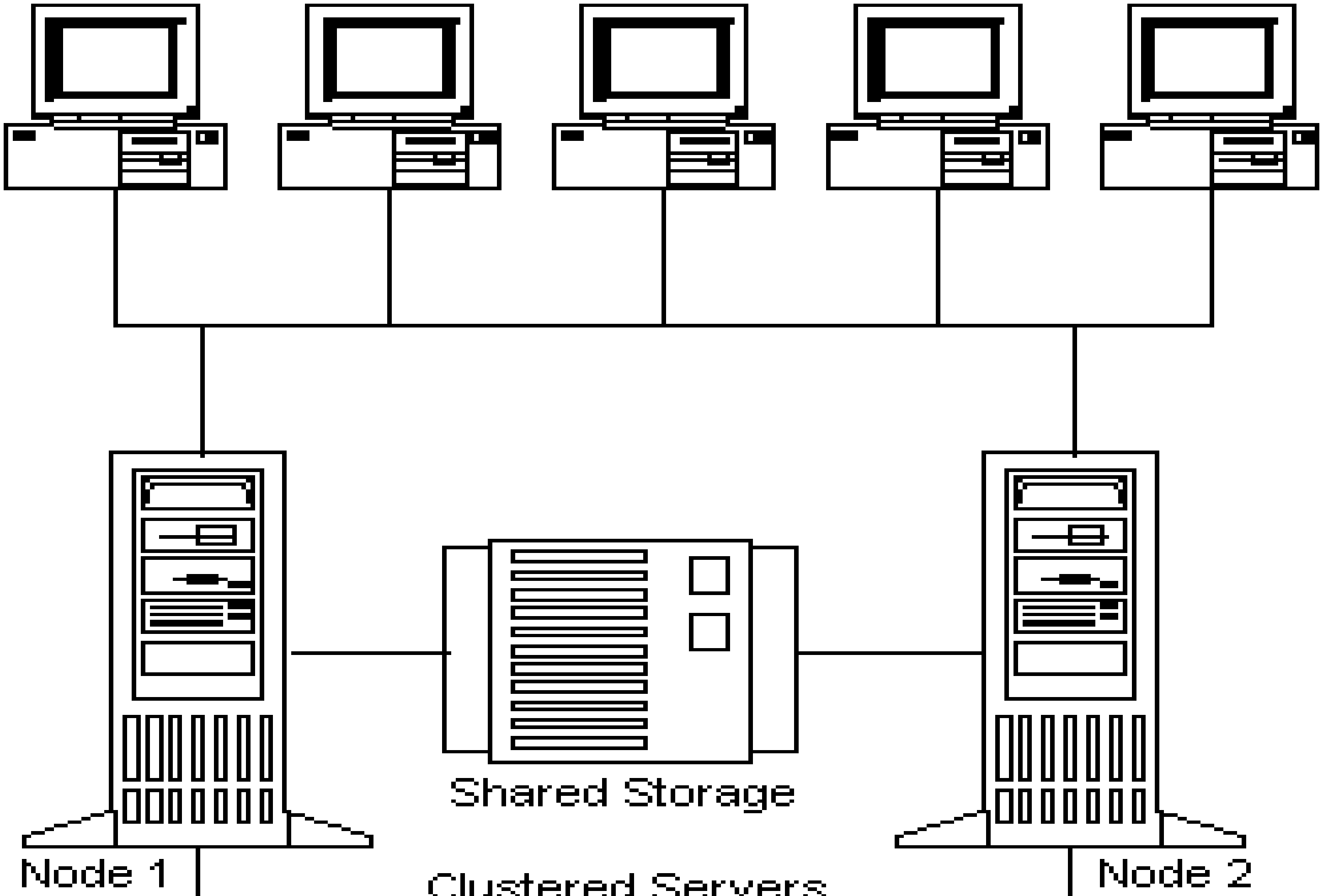
Pitfalls when Developing Distributed Systems

- The network is reliable
- The network is secure
- The network is homogeneous
- The topology does not change
- Latency is zero
- Bandwidth is infinite
- Transport cost is zero
- There is one administrator

Types of Distributed Systems

- Distributed Computing Systems
  - High Performance Computing (HPC)
- Distributed Information Systems
  - Transaction Processing Systems (TPS)
  - Enterprise Application Integration (EAI)
- Distributed Pervasive Systems
  - Ubiquitous Systems

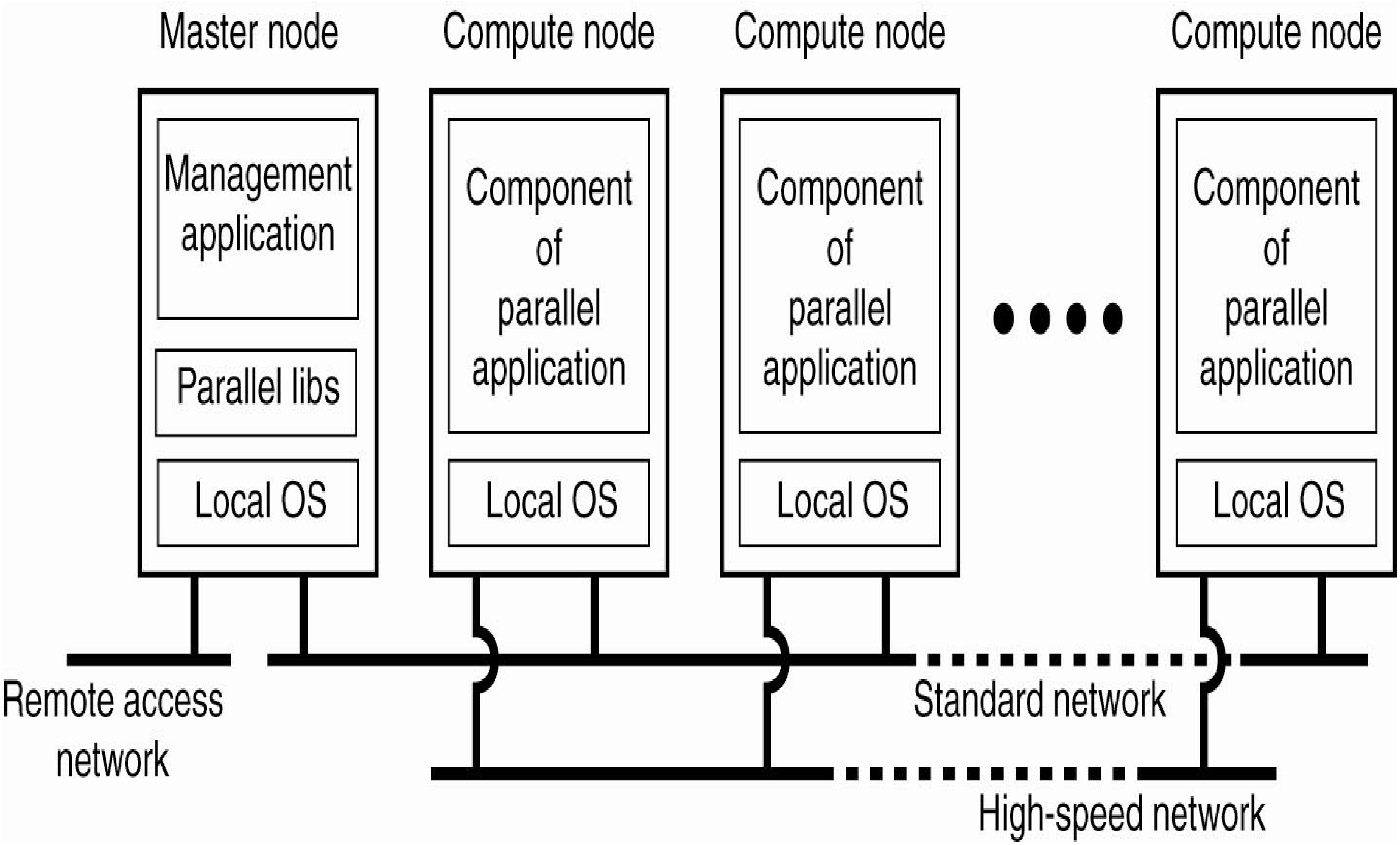
Clustered Systems Architecture



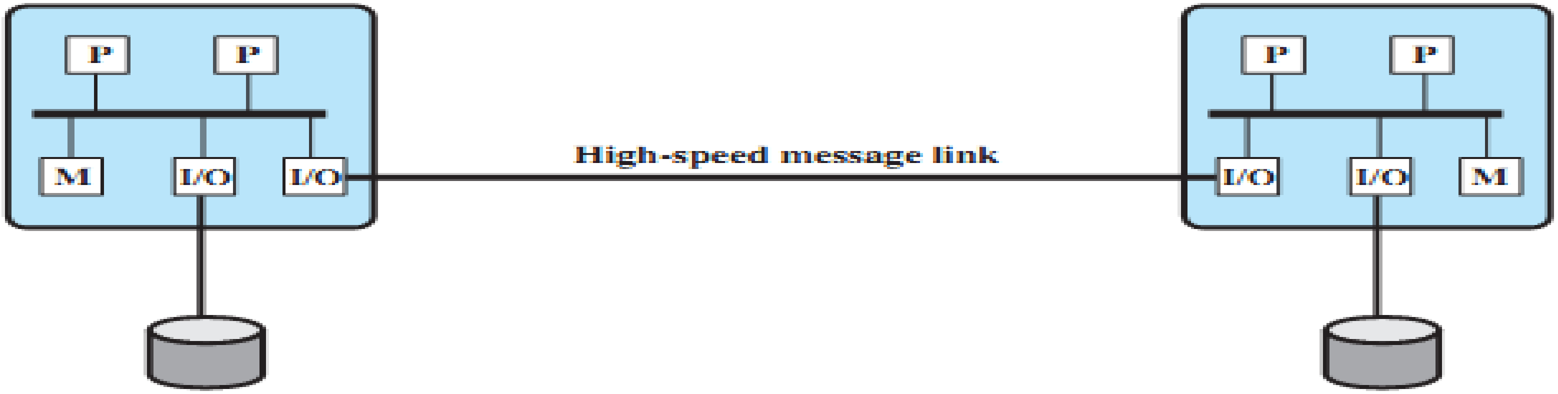
Cluster Computing Systems

- Collection of similar workstations/PCs, closely connected by means of a high-speed LAN:
  - Each node runs the same OS.
  - Homogeneous environment
  - Can serve as a supercomputer
  - Excellent for parallel programming
- Examples: Linux-based Beowulf clusters, MOSIX (from Hebrew University).

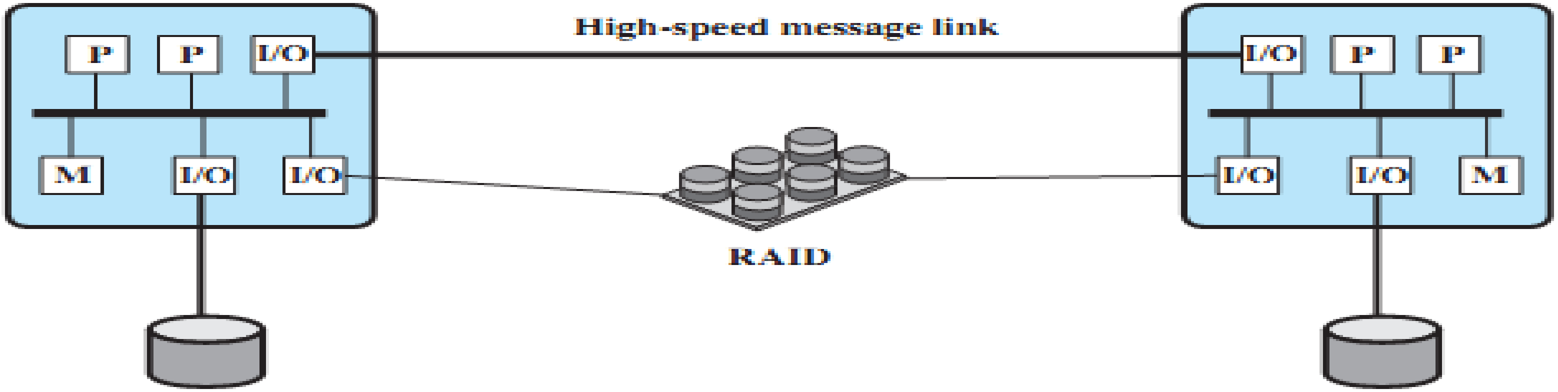
Architecture for Cluster Computing System



Cluster Configurations



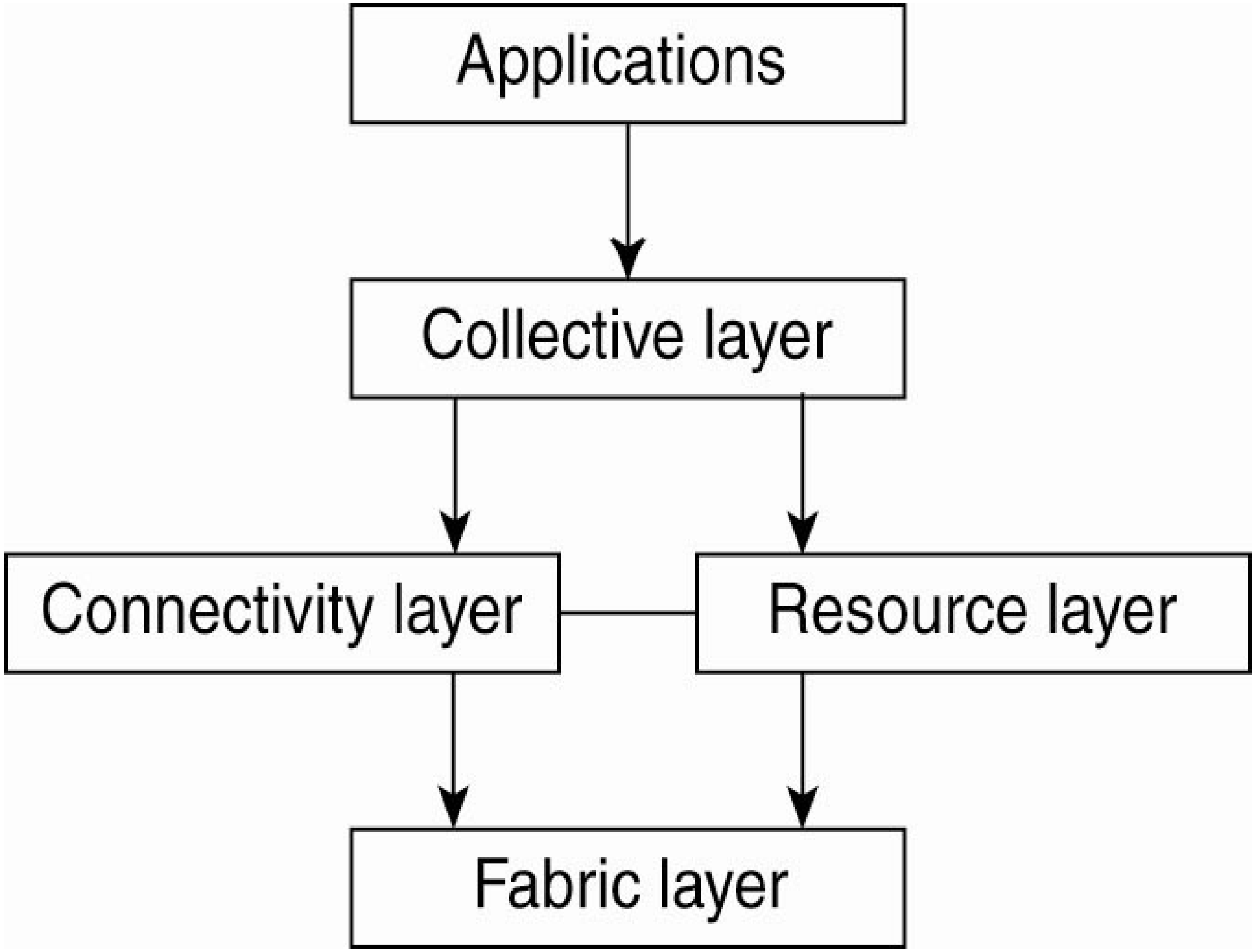
(a) Standby server with no shared disk



Grid Computing Systems

- Collection of computer resources, usually owned by multiple parties and in multiple locations, connected together such that users can share access to their combined power:
  - Can easily span a wide-area network
  - Heterogeneous environment
  - Crosses administrative/geographic boundaries
  - Supports Virtual Organizations (VOs)
- – Examples: EGEE - Enabling Grids for E-SciencE (Europe), Open Science Grid (USA).

Architecture for Grid Computing Systems



Cloud Computing Systems (1)

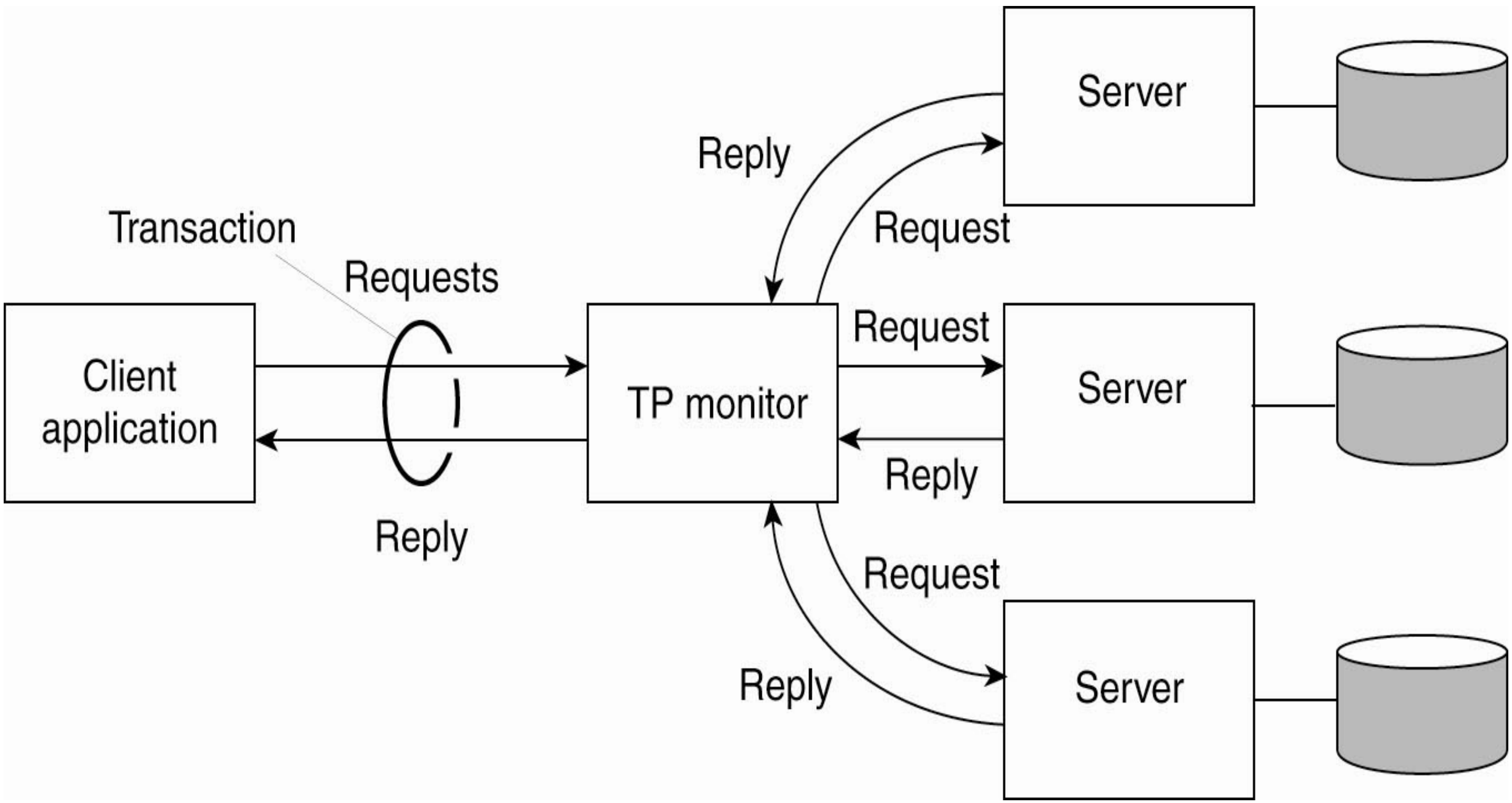
- Collection of computer resources, usually owned by a single entity, connected together such that users can lease access to a share of their combined power:
  - Location independence: the user can access the desired service from anywhere in the world, using any device with any (supported) system.
  - Cost-effectiveness: the whole infrastructure is owned by the provider and requires no capital outlay by the user.
  - Reliability: enhanced by way of multiple redundant sites, though outages can occur, leaving users unable to remedy the situation.

Cloud Computing Systems (2)

- Scalability: user needs can be tailored to available resources as demand dictates – cost benefit is obvious.
- Security: low risk of data loss thanks to centralization, though problems with control over sensitive data need to be solved.
- Readily consumable: the user usually does not need to do much deployment or customization, as the provided services are easy to adopt and ready-to-use.

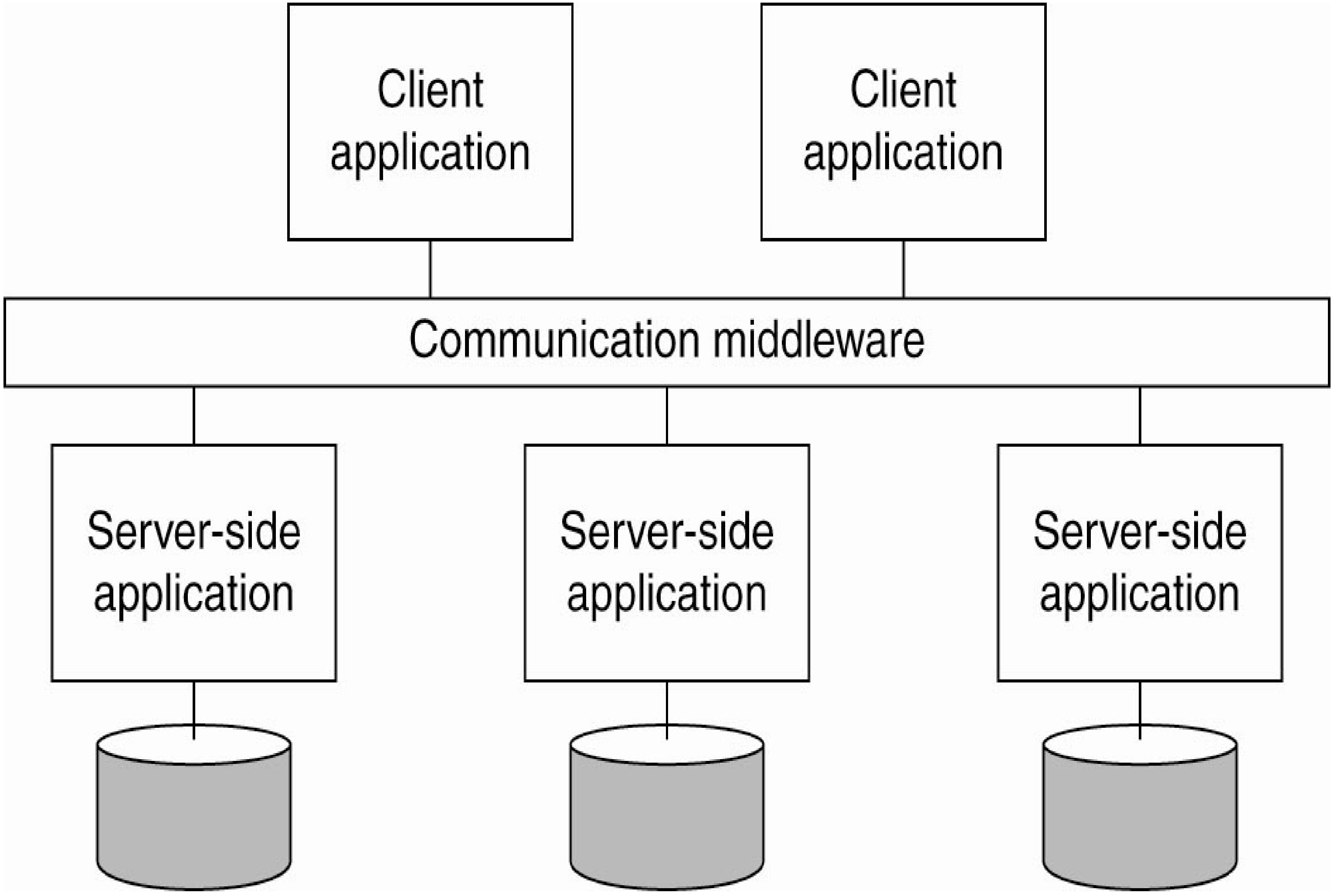
* Examples: Amazon EC2 (Elastic Compute Cloud), Google App Engine, IBM Enterprise Data Center, MS Windows Azure, SUN Cloud Computing.

Transaction Processing Systems (TPS)



The role of a TP monitor in distributed systems

Enterprise Application Integration



Communication Middleware Models/Paradigm

- Distributed File Systems
- Remote Procedure Call (RPC)
- Distributed Objects (RMI)
- Distributed Documents

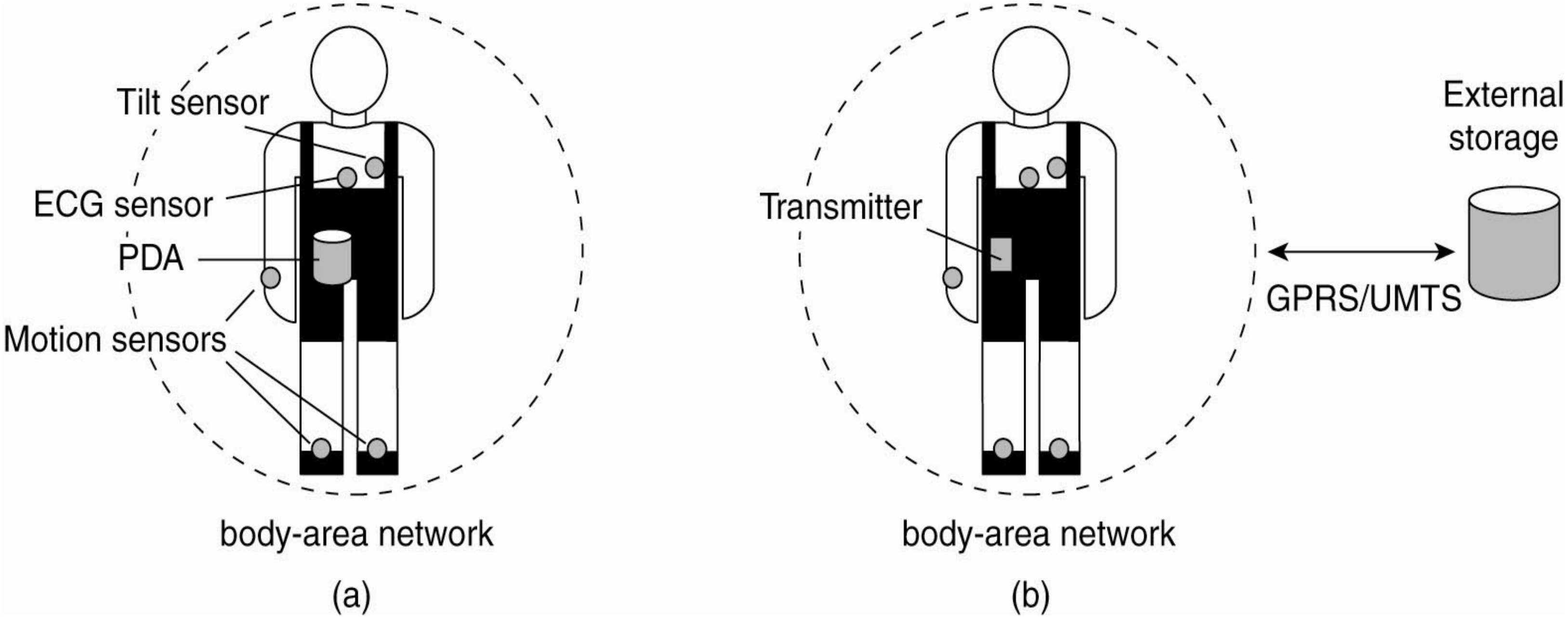
Distributed Pervasive Systems

- Requirements for pervasive systems:
  - Embrace contextual changes
  - Encourage ad hoc composition
  - Recognize sharing as the default
  - Support distribution transparency

Electronic Health Care Systems (1)

- Questions to be addressed for health care systems:
  - Where and how should monitored data be stored?
  - How can we prevent loss of crucial data?
  - What infrastructure is needed to generate and propagate alerts?
  - How can physicians provide online feedback?
  - How can extreme robustness of the monitoring system be realized?
  - What are the security issues and how can the proper policies be enforced?

Electronic Health Care Systems (2)

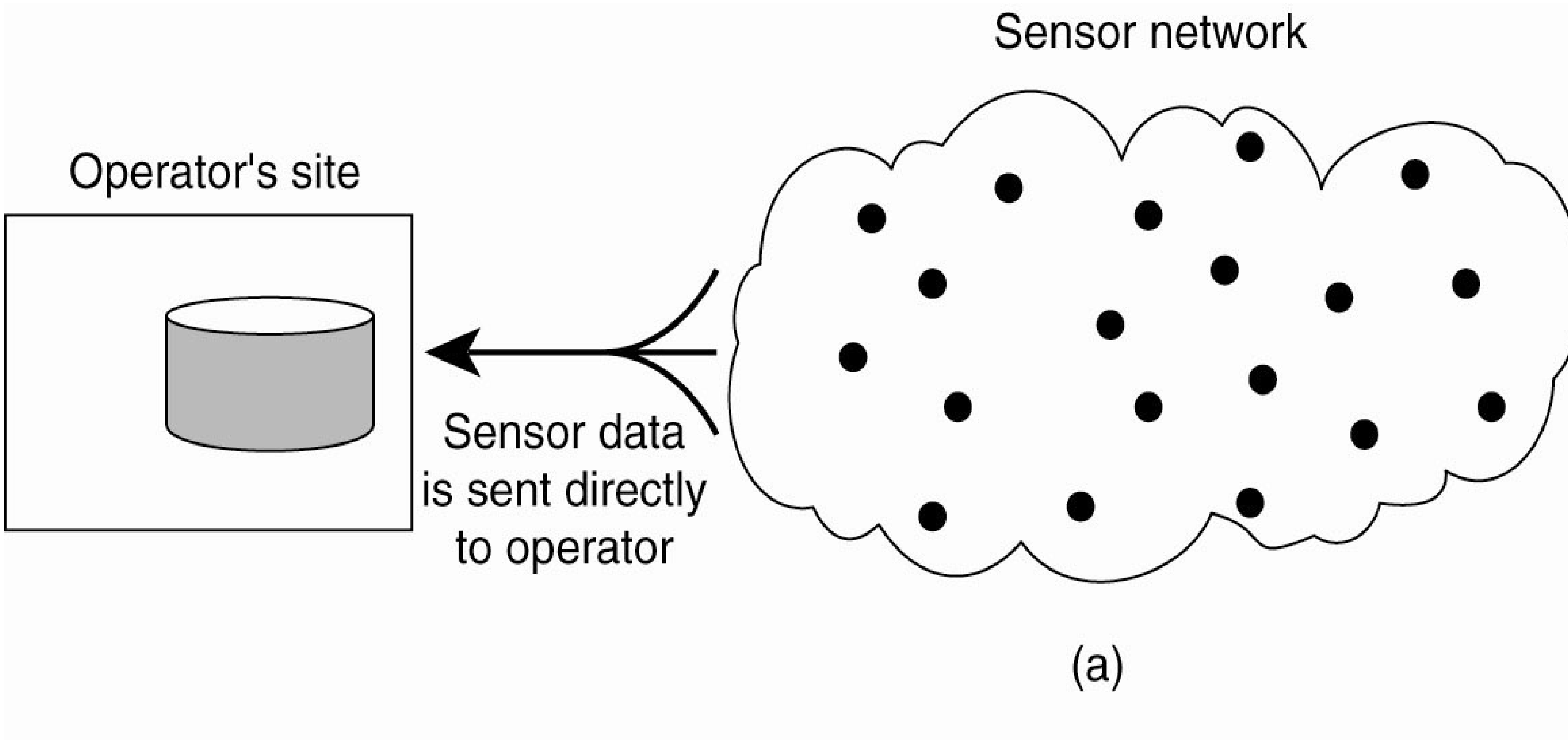


Monitoring a person in a pervasive electronic health care system, using (a) a local hub or (b) a continuous wireless connection

Sensor Networks (1)

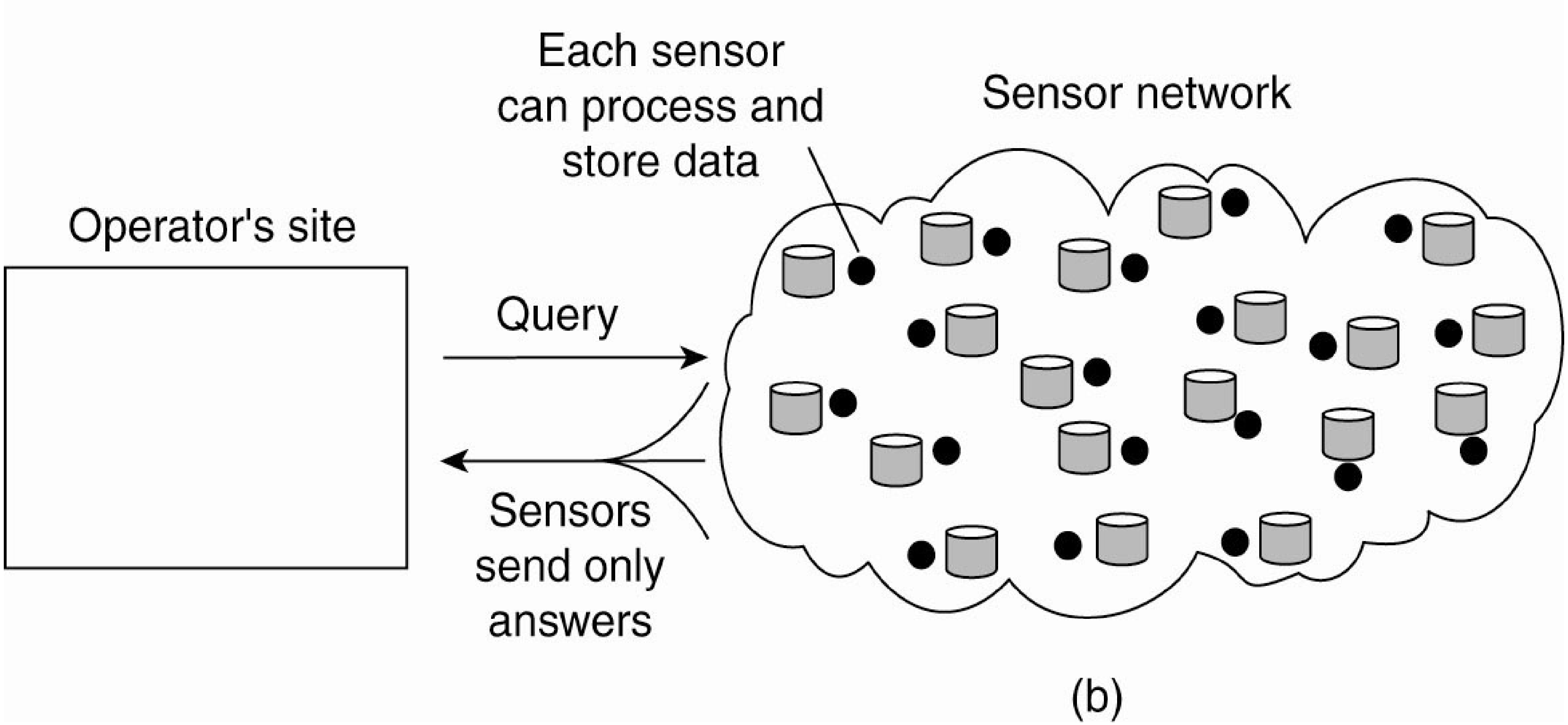
- The nodes to which sensors are attached are:
  - Many (10s-1000s).
  - Simple (i.e., hardly any memory, CPU power, or communication facilities).
  - Often battery-powered (or even battery-less).
- Questions concerning sensor networks:
  - How do we (dynamically) set up an efficient tree in a sensor network?
  - How does aggregation of results take place? Can it be controlled?
  - What happens when network links fail?

Sensor Networks (2)



Organizing a sensor network database, while storing and processing data (a) only at the operator's site or …

Sensor Networks (3)



Organizing a sensor network database, while storing and processing data … or (b) only at the sensors