Sorts of Distributed Systems

Distributed Systems

Sistemi Distribuiti

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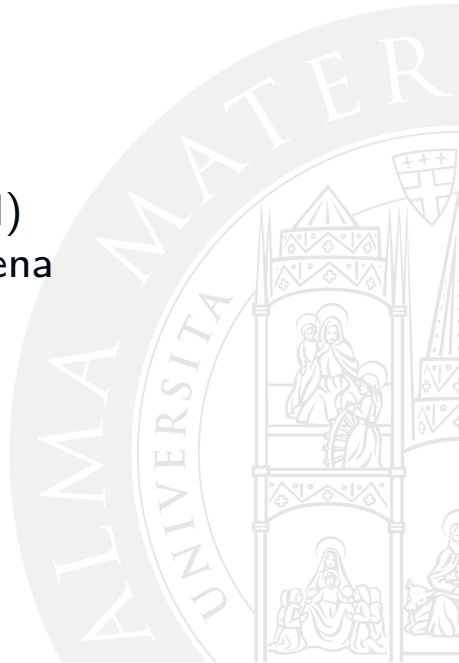
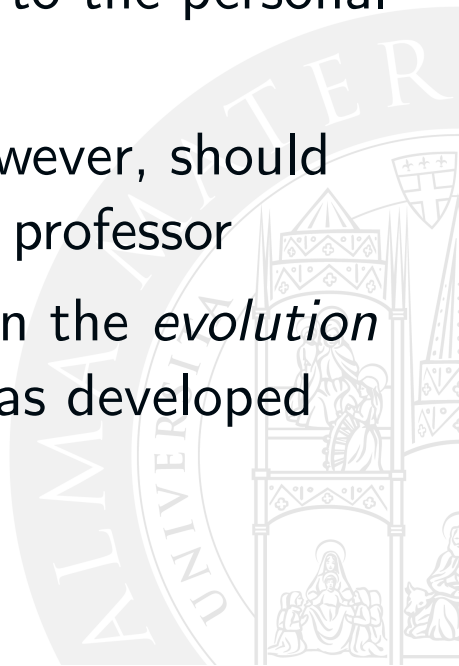


About these Slides

- the following slides borrow a great deal from the slides coming with the book adopted as the basic one for this course

  [Tanenbaum and van Steen, 2007]
- material from those slides (including pictures) has been re-used in the following, and integrated with new material according to the personal view of the professor
- every problem or mistake contained in these slides, however, should be attributed to the sole responsibility of this course's professor
- the goal, here, is to be exposed to the classical view on the *evolution* of distributed systems that the scientific community has developed over the last decades



Evolution of Distributed Systems

Evolving technological and application scenarios...

- ... forced new requirements, structure, and goals for distributed systems
- resulting in the emergence of diverse classes of distributed systems over time

Sorts of Distributed Systems

Three main classes of distributed systems

- distributed computing systems
- distributed information systems
- distributed pervasive systems

Next in Line...

1. Distributed Computing Systems
2. Distributed Information Systems
3. Distributed Pervasive Systems

Distributed Computing Systems

The main characteristic

- using a *multiplicity of distributed computers* to perform *high-performance* tasks

Two classes

- cluster computing systems
- grid computing systems

Cluster Computing Systems I

The basic idea

- a collection of similar workstations / PCs
- running the same OS
- located in the same area
- interconnected through a high-speed LAN

Motivation

- the ever increasing price / performance ration of computers makes it cheaper to build a supercomputer by putting together many simple computers, rather than buying a high-performance one
- also, robustness is higher, maintenance and incremental addition of computing power is easier

Cluster Computing Systems II

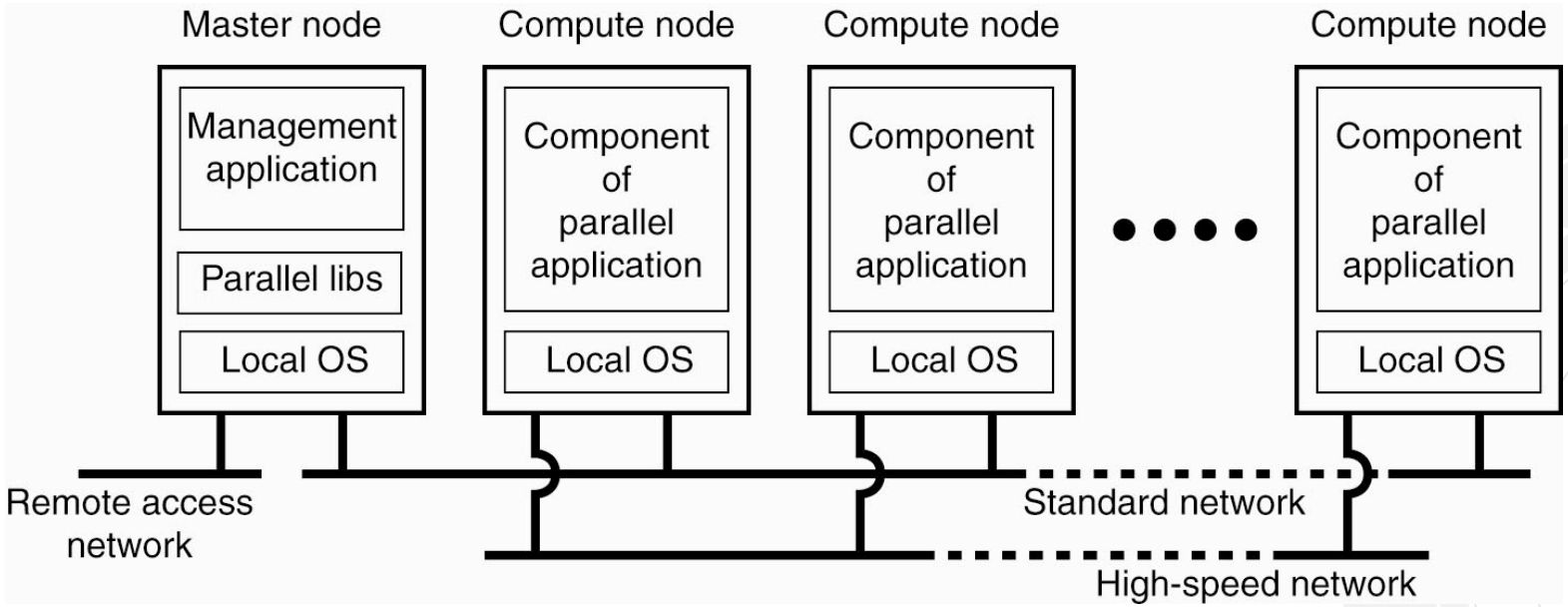
Usage

- parallel computing
- typically, a single computationally-intensive program is run in parallel on multiple machines

Cluster Computing Systems: Example

Beowulf clusters

- Linux-based
- each cluster is a collection of computing nodes controlled and accessed by a *single* master *node*



[Tanenbaum and van Steen, 2007]

Cluster vs. Grid Computing Systems

Homogeneity vs. heterogeneity

- homogeneity
  - computers in a cluster are typically similar
  - computers in a cluster have the same OS
  - computers in a cluster are connected to the same (local) network
- in essence, cluster computer systems are homogeneous
- grid computer systems instead are typically heterogeneous

Grid Computing Systems

The main idea

- resources from different organisations are brought together to promote *collaboration* between individuals, groups, or institutions, by passing organisation boundaries
- collaboration is built in the form of a *virtual organisation*
  - essentially, a new virtual organisational entity including people from existing organisations
  - accessing resources made available by participating organisations
  - including servers, databases, hard disks, ...
- by their very nature, grid computer systems deal with different administrative domains

Architecture of a Grid Computing System I

A layered architecture for a grid computing system [Foster et al., 2001]

fabric layer — interface to local resources at a specific site

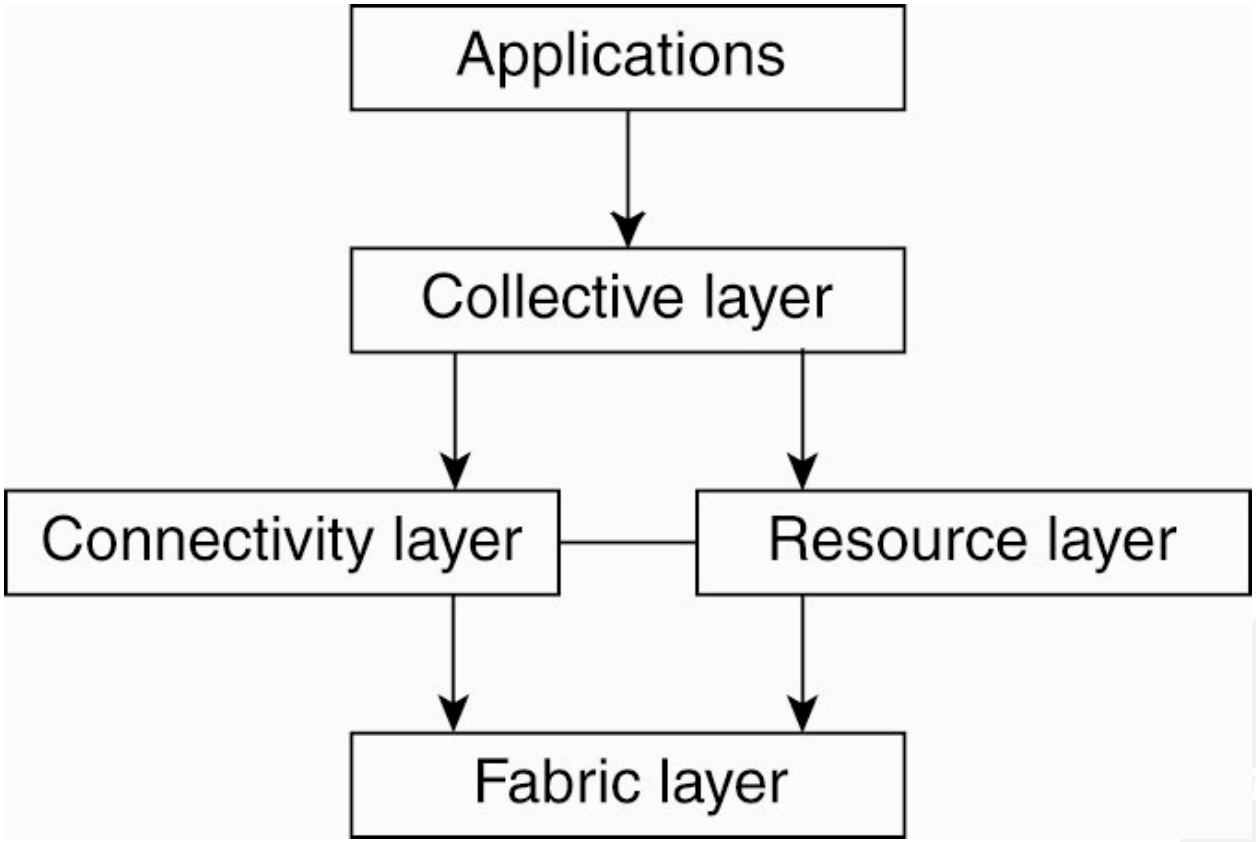
resource layer — management of single resources—e.g., access control

connectivity layer — communication protocols for grid transactions spanning over multiple resources, plus security protocols for authentication

collective layer — handling access to multiple resources—resource discovery, allocation, ...

application layer — applications operating in the virtual organisation

Architecture of a Grid Computing System II



[Tanenbaum and van Steen, 2007]

Architecture of a Grid Computing System III

Grid middleware layer

- the *core* of a grid middleware layer is represented by *connectivity*, *resource*, and *collective* layers
- altogether, they provide *uniform access* to otherwise dispersed *resources*

Next in Line...

Distributed Information Systems

Origin

- Many separate networked applications to be integrated
- Structural problems of interoperability

Sorts

- Several non-interoperating servers shared by a number of clients: distributed queries, distributed transactions

→ Transaction Processing Systems

- Several sophisticated applications – not only databases, but also processing components – requiring to directly communicate with each other

→ Enterprise Application Integration (EAI)

Transaction Processing Systems

Distributed transactions for distributed databases

- operations on databases are usually performed in terms of transactions
- when databases are distributed, transactions should be *distributed*
- *special primitives* from the distributed system or the runtime system

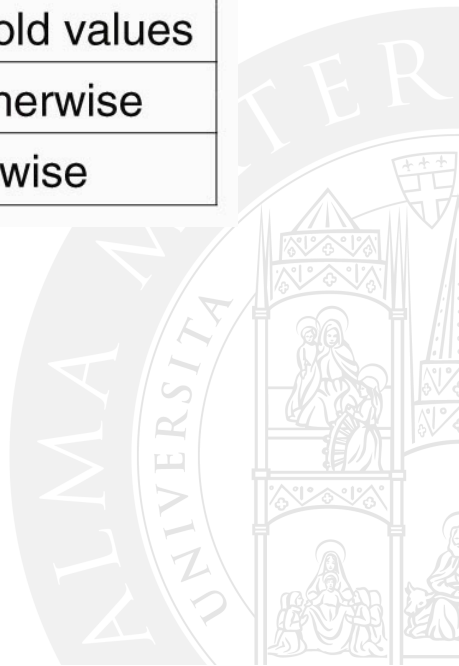
ACID properties

atomic	steps of a transaction occurs *invisibly* to the outside world
consistent	the transaction does *not violate* system *invariants*
isolated	*concurrent* transactions do *not interfere* with each other
durable	once a transaction *commits*, its effects are *permanent*

Example Primitives for Transactions

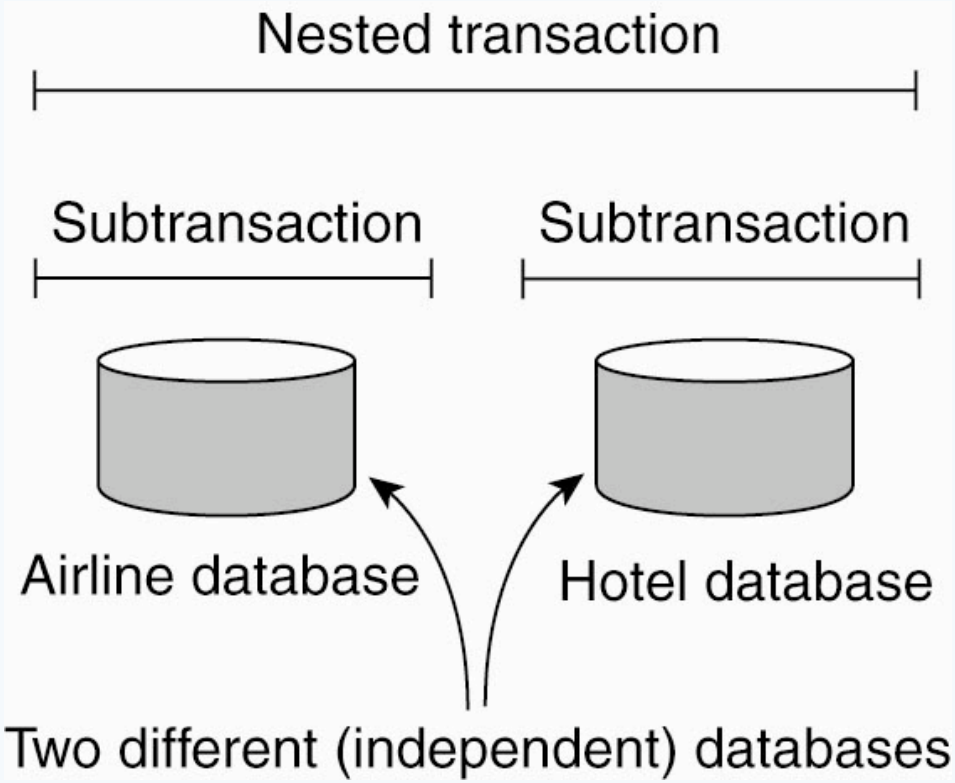
Primitive	Description
BEGIN_TRANSACTION	Mark the start of a transaction
END_TRANSACTION	Terminate the transaction and try to commit
ABORT_TRANSACTION	Kill the transaction and restore the old values
READ	Read data from a file, a table, or otherwise
WRITE	Write data to a file, a table, or otherwise

[Tanenbaum and van Steen, 2007]



Nested Transactions

A nested transaction is made of a number of subtransactions



[Tanenbaum and van Steen, 2007]

Nesting in transactions could be arbitrarily deep

The Problem with Nested Transactions I

Durability of nested and sub-transactions

- a *whole* nested transaction should exhibit ACID properties
- so, if a subtransaction fails, all subtransactions till there should be *undone*, even though they already committed
- the effects of subtransactions could not be really durable if the whole transanction does not succeed

$\rightarrow$ *durability* here refers to the *top-level* transaction

The Problem with Nested Transactions II

Private copy of the world as a solution

- all transactions are performed over a copy of the data, so subtransactions could keep ACIDity in the *local world*
- the effect of a *successful* nested transaction would be *propagated* only *after* it *succeeds*

$\rightarrow$ in case, the *copy* of the world transformed *becomes* the *world*

$\rightarrow$ in any case, transactions are ACID

Nested Transactions in Distributed Information Systems

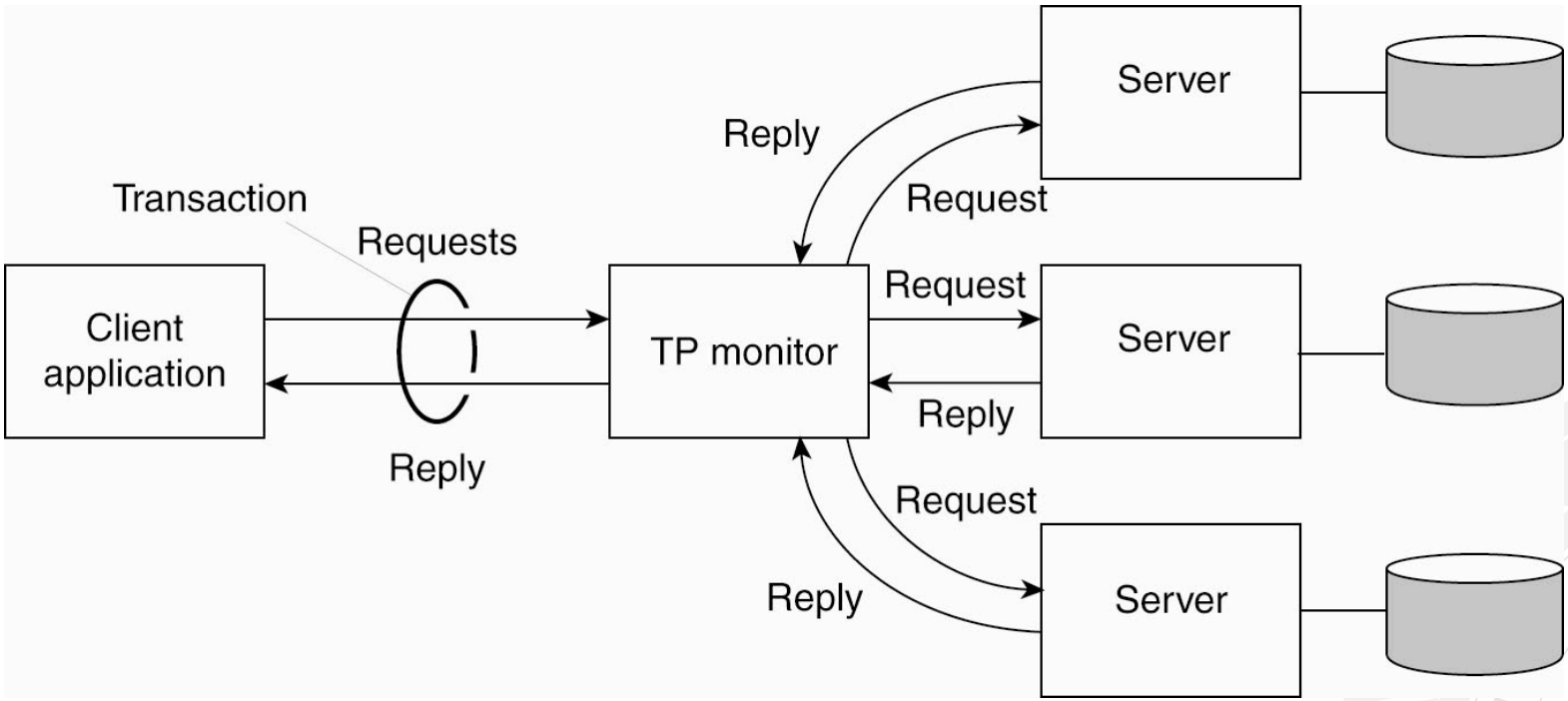
Nested transactions are a natural way for distributing transactions

- "leaf" subtransactions are usual transactions over single servers
- distributed transactions are nested transactions

An early solution: TP monitor

- transaction processing monitor (or, *TP monitor*)
- to allow applications to access *multiple* DB *servers*
- with a *transactional semantics*

TP Monitor



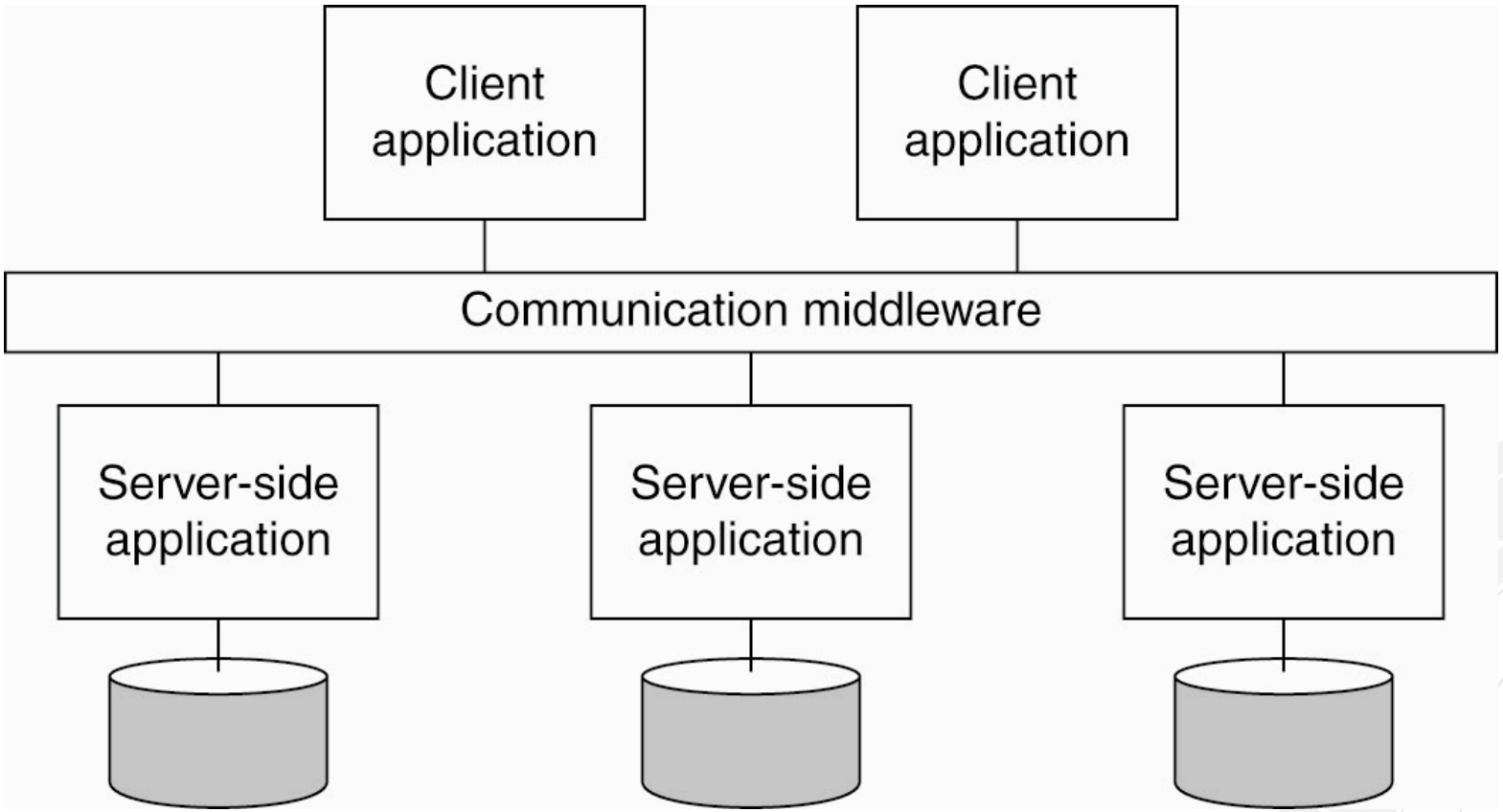
[Tanenbaum and van Steen, 2007]

Enterprise Application Integration

It is not only a matter of accessing distributed databases

- integration should happen at the application level, too
- beyond data integration, process integration
- application should interact and communicate meaningfully with each other

Middleware as a Communication Facilitator



[Tanenbaum and van Steen, 2007]

Sorts of Communication Middleware

Different middeware supports different sorts of communication

- RPC Remote Procedure Call
- RMI Remote Method Invocation
- MOM Message-Oriented Middleware
  - Publish & Subscribe

Next in Line...

1. Distributed Computing Systems
2. Distributed Information Systems
3. Distributed Pervasive Systems

Distributed Systems with Instability

What happens when instability is the default condition?

- . . . like, with mobile devices with batteries and sporadic network connection?
- . . . like, in modern *distributed pervasive systems*?

Main features

- a distributed pervasive system is *part of* our *surroundings*
- a distributed pervasive system generally *lacks* of a *human* administrative *control*

Requirements for Pervasive Systems

Three requirements [Grimm et al., 2004]

- embrace contextual changes
- encourage ad hoc composition
- recognise sharing as the default

Remarks

- a device must be continually *aware* of the fact that its *environment may* change at any time
- many devices in pervasive system will be *used in different ways* by different users
- devices generally join the system in order to access (provide) information: *information* should then be easy to read, store, manage, and *share*

Home Systems

Systems built around home networks

- no way to ask people to act as a competent network / system administrator

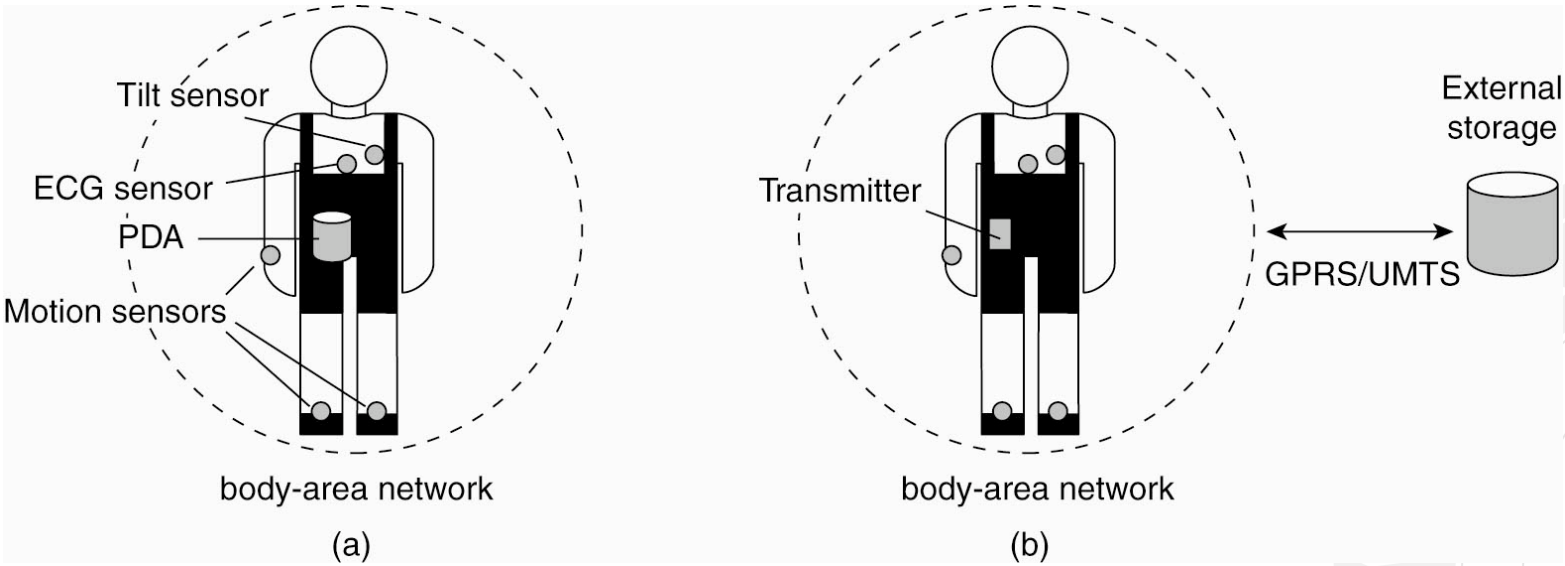
→ home systems should be self-configuring and self-maintaining in essence

Systems built around personal information

- *huge amount* of heterogeneous personal *information* to be managed,
- coming from *heterogeneous sources* from inside and outside the home system

Health Care Systems

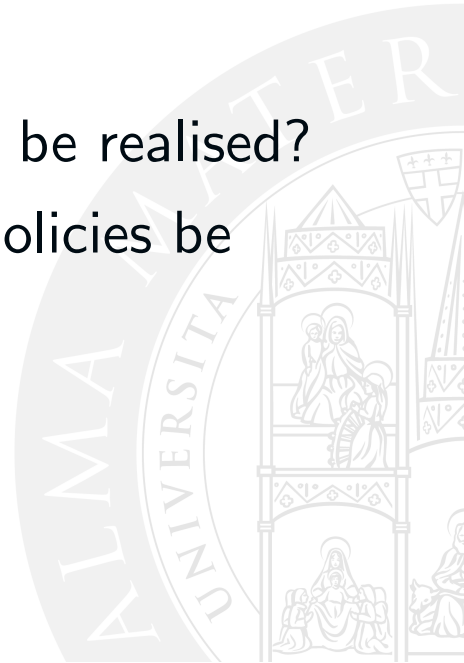
- Personal systems built around a Body Area Network
- Possibly, minimising impact on the person—like, preventing free motion



[Tanenbaum and van Steen, 2007]

Health Care Systems: Questions to be Addressed

- 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 realised?
- what are the *security* issues and how can the proper policies be enforced?



Sensor Networks

An enabling technology for pervasive systems

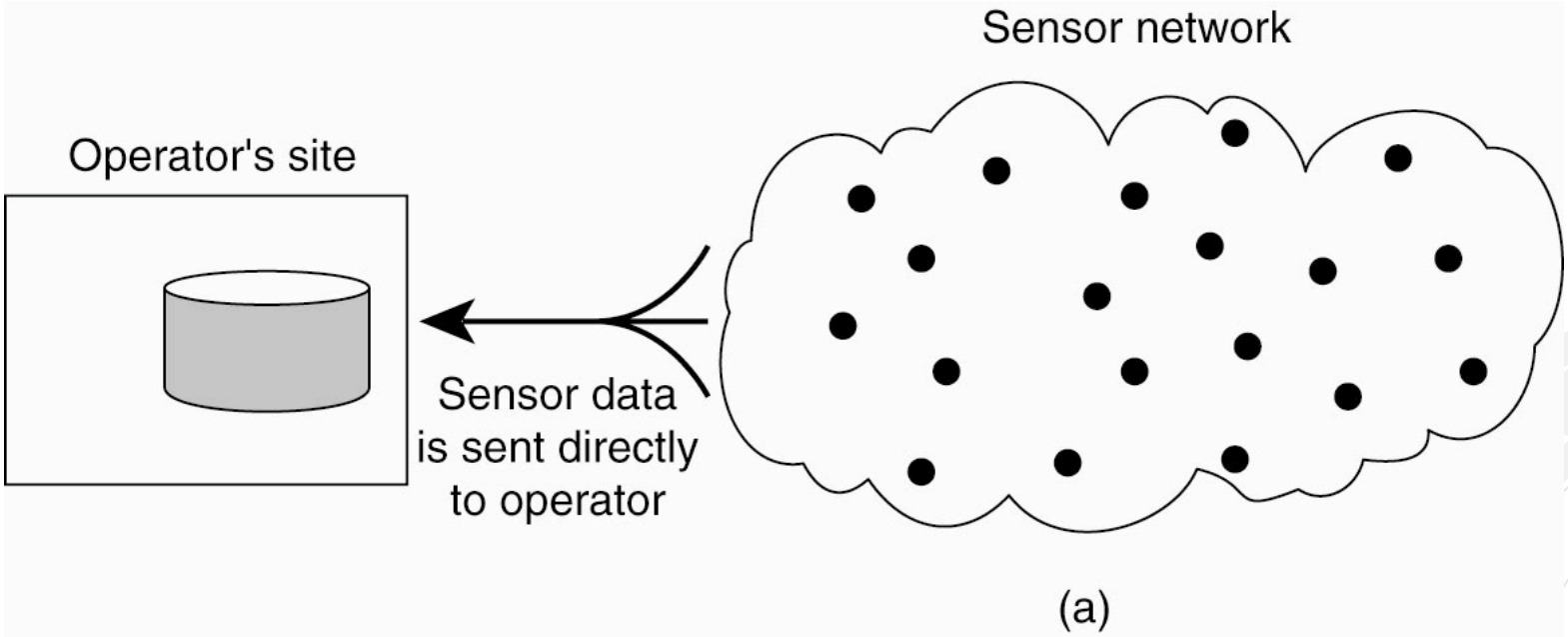
- clouds of *spatially-distributed sensors*—from tens to thousands of nodes with a sensing device
- acquiring, processing and transmitting *environmental information*

A possible view: distributed databases

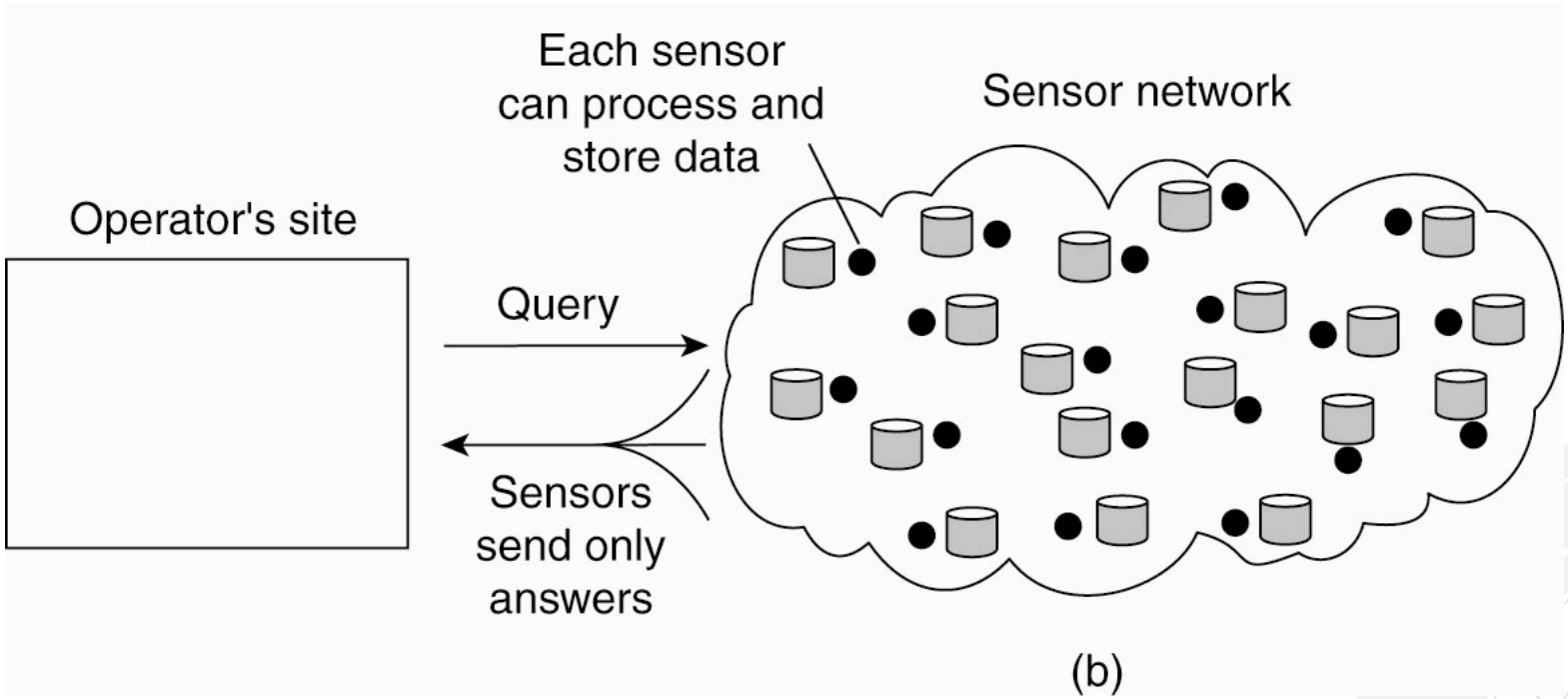
- distributed sources of information
- that can possibly be queried along time
- two possible extremes: either sensors just send information in without cooperating, or they do all the computation and return the results

↑ both solutions are bad ones, since they require either too much network consumption or too much node power consumption

Architecture of Sensor Networks: Two Extremes I



Architecture of Sensor Networks: Two Extremes II



[Tanenbaum and van Steen, 2007]

Sensor Networks: A Solution

In-network data-processing

- setting up a tree network among sensors
- passing queries through the sensor tree
- aggregating the results at the different levels of the tree

Questions to be addressed

- 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?

Summing Up

Diverse sorts of distributed systems exist

- roughly telling the story of the *evolution* of distributed systems over the years
- depending on both the *environment* where they are developed, the *goals* they have to achieve, and the level of the available *technologies*
- different *models*, *methodologies*, and *technologies* are to be used to design and develop different sorts of distributed systems

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