Basi di dati distribuite

Paolo Atzeni, Stefano Ceri

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Due esempi introduttivi

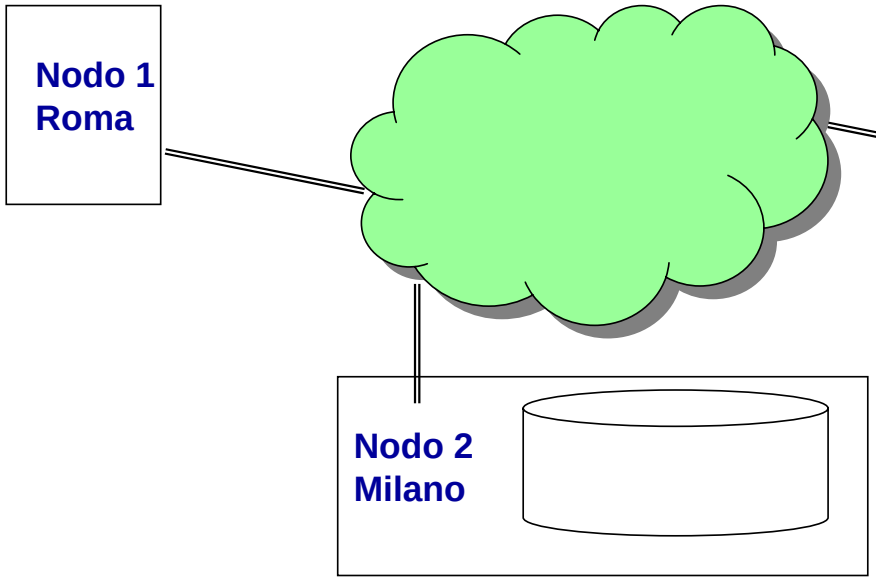
- Sistema informativo aziendale:
  - passaggio da base dati centralizzata a distribuita
- Sistema cooperativo:
  - Il progetto “Servizi alle imprese”

(esempi tratti da materiale del prof Batini)

Un sistema informativo aziendale

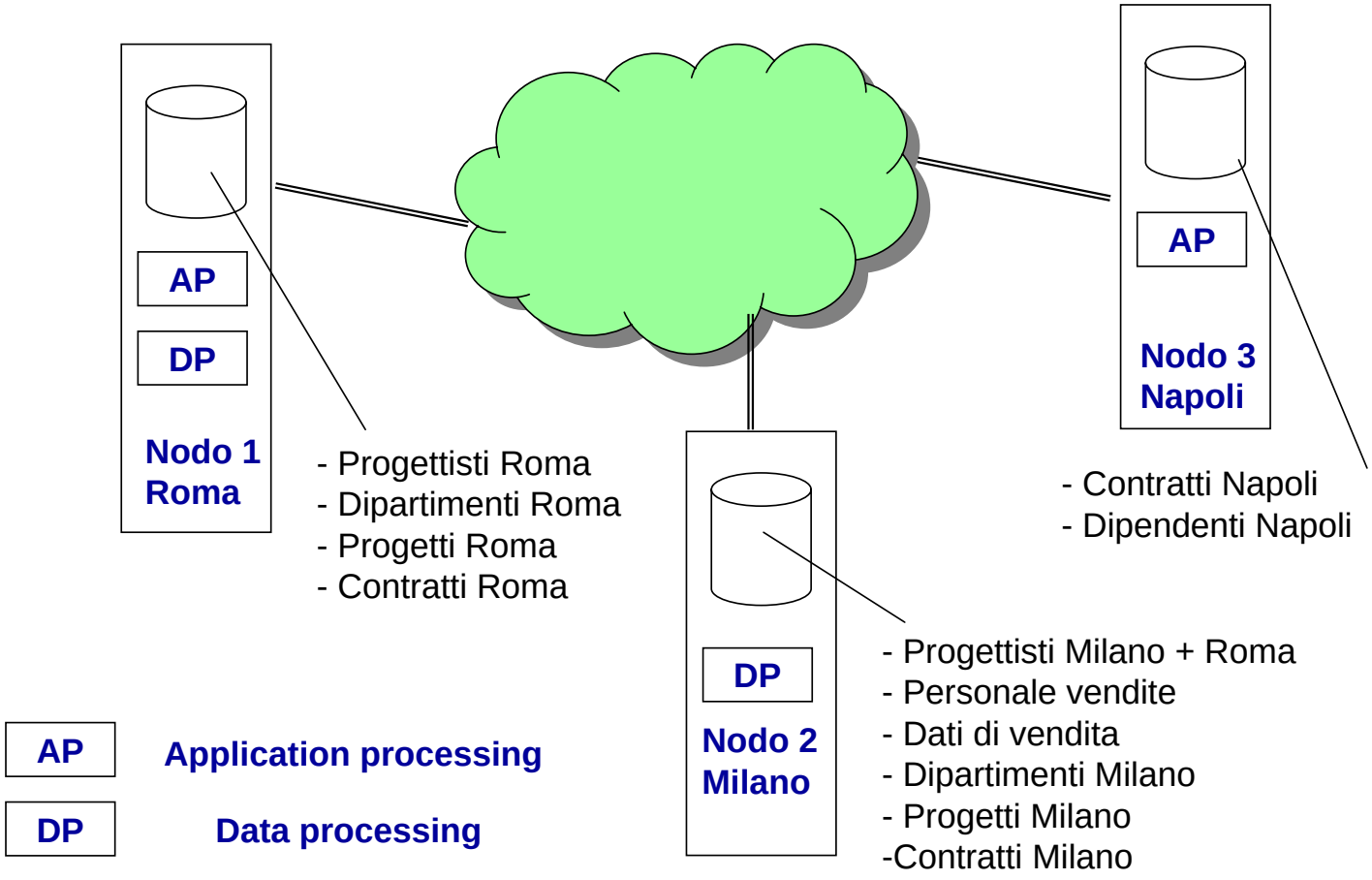
Struttura della organizzazione

Base di dati centralizzata



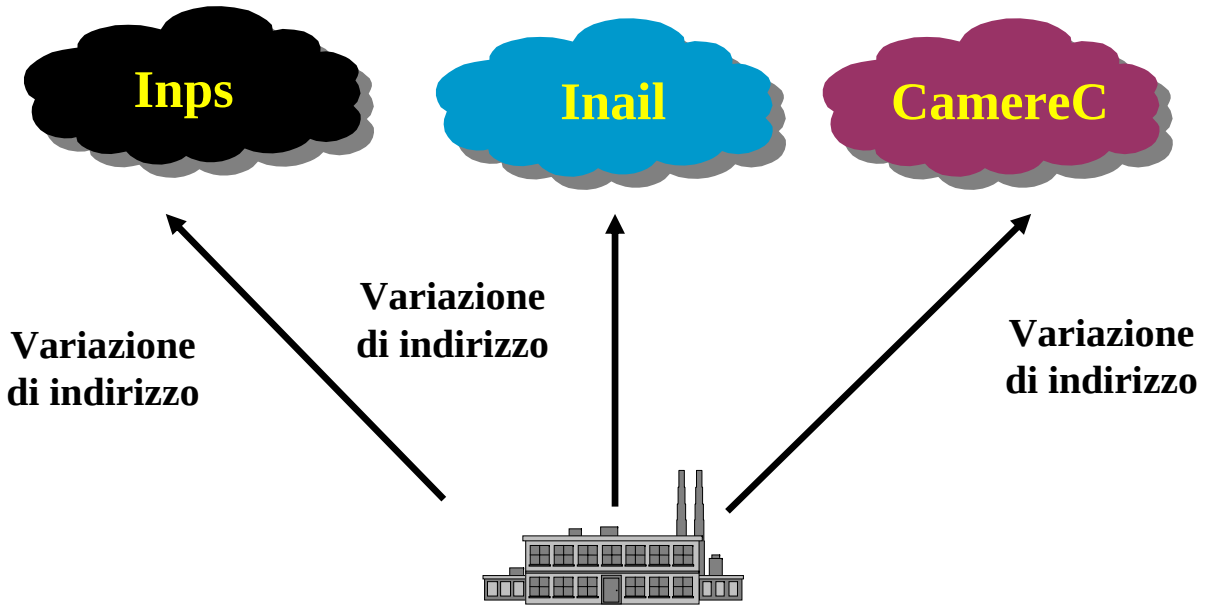
-Personale
  -Progettisti
  -Vendite
- Dipartimenti
- Progetti
- Contratti
- Dati di vendita

Base di dati distribuita con DBMS distribuito

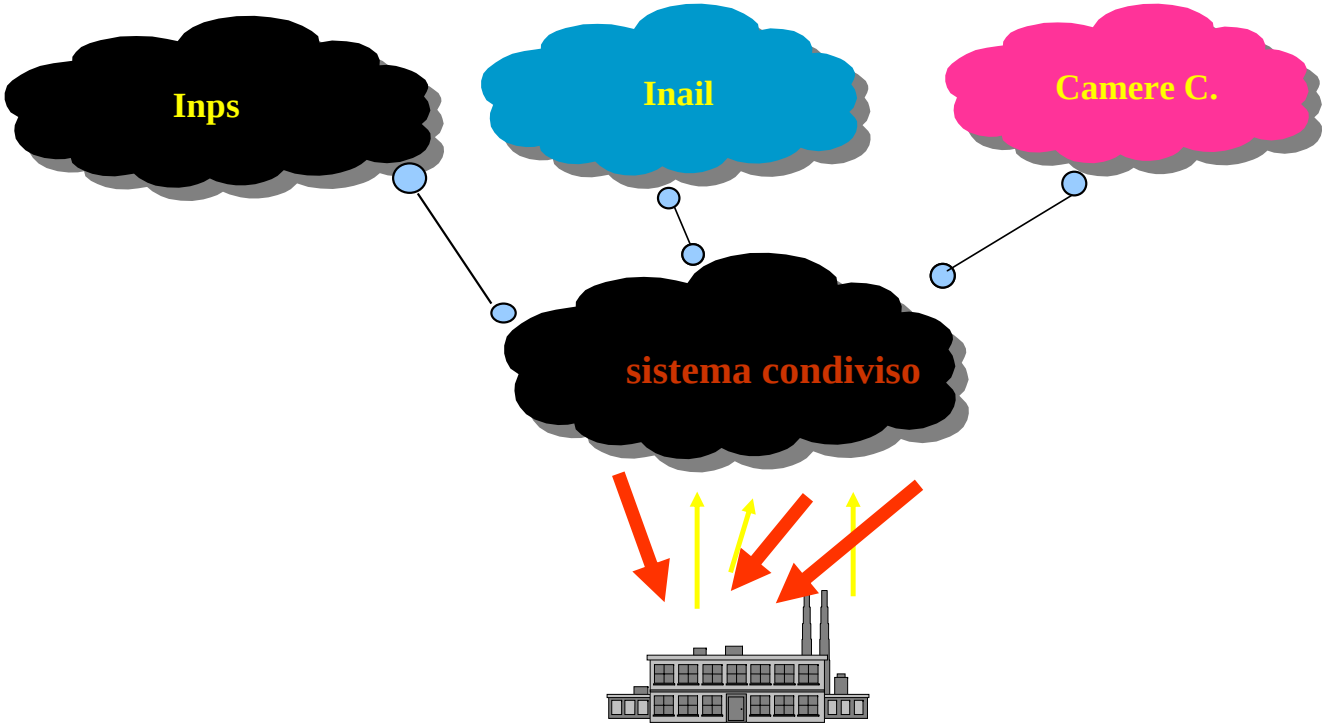


Il progetto “Servizi alle imprese”

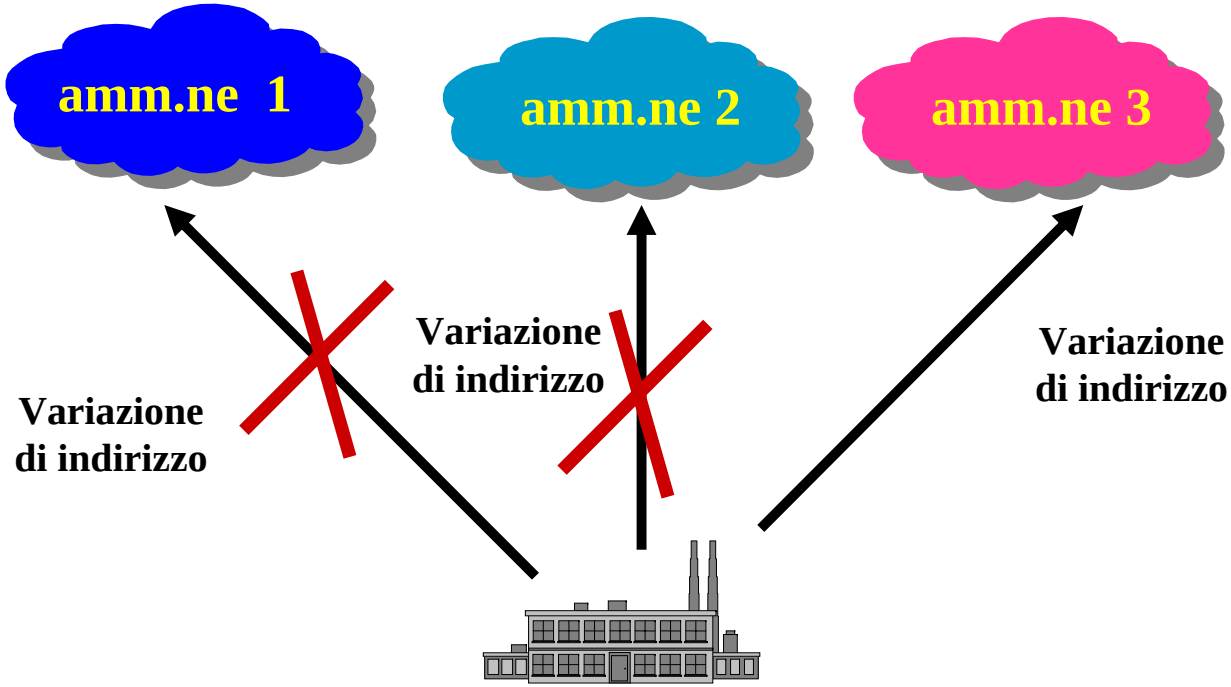
- Scopo : sostituire le notifiche di creazione e variazione che le imprese devono fare a Inps, Inail, Camere di commercio ……



- … con un sistema condiviso …



- … con una unica comunicazione



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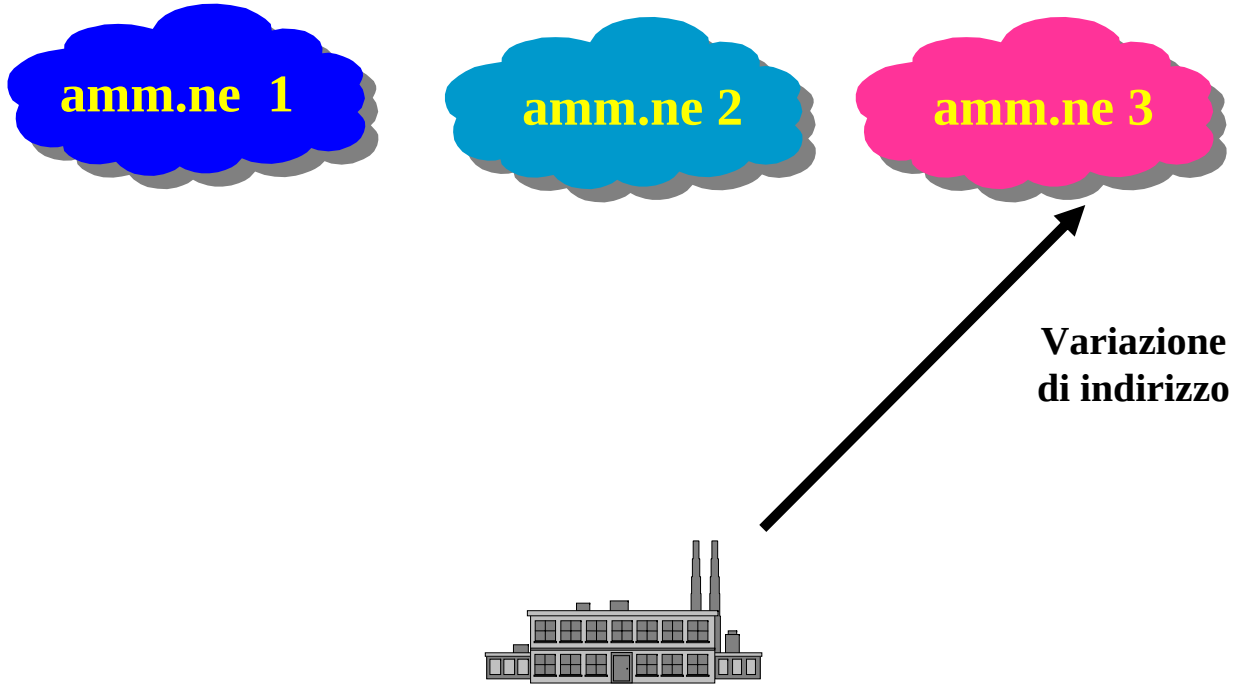

Un sistema cooperativo

- Un "nuovo" sistema che:
  - interagisce con i sistemi preesistenti
  - gestisce propri dati

- Note:
  - è necessaria una riorganizzazione delle attività (il problema non è solo tecnologico)
  - i sistemi preesistenti continuano a svolgere tutte (o quasi) le attività precedenti, insieme ad altre, nuove

Paradigms for data distribution

- **Client-server architecture**: separation of the database server from the client
- **Distributed databases**: several database servers used by the same application
- **Cooperative database applications:** each server maintains its autonomy
- **Data warehouses**: servers specialized for the management of data dedicated to decision support.
- **Replicated databases**: data logically representing the same information and physically stored on different servers
- **Parallel databases**: several data storage devices and processors operate in parallel for increasing performances

Client-server architecture

- **Client-server**: a general model of interaction between software processes, where there are processes of two types:
  - **clients** (which require services)
  - **servers** (which offer services)
- Requires a precise definition of a **service interface**, which lists the services offered by the server
- The client process performs an active role, the server process is reactive
- Normally, a client process requests few services in sequence from one or more server processes, while a process server responds to multiple requests from many process clients.

Client server architecture and data management

- In data management, allocation of client and server processes to distinct computers is now widespread, because:
  - The functions of client and server are well identified
  - They give rise to a convenient separation of design and management activities
- SQL offers an ideal programming paradigm for the identification of the ‘service interface’
  - SQL queries are formulated by the client and sent to the server
  - The query results are calculated by the server and returned to the client
  - The "reasonable" standardization, portability and interoperability of SQL give good flexibility and reuse

Allocation of servers and clients to different computers

- The computer dedicated to the client must be suitable for interaction with the user and support productivity tools (electronic mail, word processing, spreadsheet, Internet access, and workflow management)
- The server computer must have a large main memory (to support buffer management) and a high capacity disk (for storing the entire database)

Client: "thin" or "thick"?

- **Thick client**: includes application logic and leaves to the server only the data management responsibility; the language of communication is SQL
- **Thin client**: does as little as possible (essentially presentation); used with dumb terminals, but also reasonable with PCs; the application logic is on the server, and communication is essentially procedure call
- Intermediate solutions:
  - some logic on the server and some on the client (potentially clumsy; reasonable only if there is a natural separation of functions)
  - three-tier solutions …

Two-tier vs three-tier architecture

- **Two-tier** architecture: client and server
- **Three-tier** architecture: a second server is present, known as the **application server**, responsible for the management of the application logic common to many clients
  - The client is **thin**; it is responsible only for the interface with the final user.
  - Web applications almost always fall in this category
  - Cooperative applications often even extend it

Paradigms for data distribution

- **Client-server architecture**: separation of the database server from the client
- **Distributed databases**: several database servers used by the same application, with a strong coordination
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Distributed databases

- A **distributed database** is a system in which at least one client interacts with multiple servers for the execution of an application; with a strong coordination

Advantages of distributed databases

- Distributed databases respond to application needs:
  - Enterprises are structurally distributed, distributed data management allows the distribution of data processing and control to the environment where it is generated and largely used
- Distributed databases offer greater flexibility, modularity and resistance to failures
  - Distributed systems can be configured by the progressive addition and modification of components, with great flexibility and modularity
  - Although they are more vulnerable to failures due to their structural complexity, they support ‘graceful degradation’ (respond to failures with a reduction in performance but without a total failure)

Local independence and interaction between nodes

- In a distributed database each server has its own capacity to manage applications independently
  - A distributed database should not maximize the interaction and the necessity of transmitting data via networks
  - On the contrary, the planning of data distribution and allocation should be done in such a way that applications should operate independently on a single server

Data fragmentation

- A technique for data organization that allows efficient data distribution and processing
- Given a relation *R*. Its fragmentation a set of fragments R_i
  - In **horizontal fragmentation**, fragments R_i are groups of tuples having the same schema as *R* (**selection** operator). Horizontal fragments are usually disjoint
  - In **vertical fragmentation**, each fragment R_i has a subset of the schema of *R* (**projection**). Vertical fragments include the primary key of *R*

Fragmentation: properties

- The fragmentation is correct if it is:
  - **Complete**: each data item of *R* must be present in one of its fragments R_i
  - **Restorable**: it should be possible to obtain back the content of R from its fragments

- It could be useful that fragmentation is **disjoint** (or **non-redundant**), but this need not be the case, for the sake of efficiency (but with additional costs for maintenance)

Example

- Consider the relation:
  - EMPLOYEE (Empnum, Name, DeptName, Salary, Taxes)
- Horizontal fragmentation
  - EMPLOYEE1 = $SEL_{Empnum<=3}$ EMPLOYEE
  - EMPLOYEE2 = $SEL_{Empnum>3}$ EMPLOYEE
- Reconstruction requires a union:
  - EMPLOYEE = EMPLOYEE1 U EMPLOYEE2
- Vertical fragmentation:
  - EMPLOYEE1 = $PROJ_{EmpNum,Name}$EMPLOYEE
  - EMPLOYEE2 = $PROJ_{EmpNum,DeptName,Salary,Tax}$EMPLOYEE
- Reconstruction requires an equi-join on key values (natural join).
  - EMPLOYEE = EMPLOYEE1 JOIN EMPLOYEE2

Initial table

EMPLOYEE

EmpNum	Name	DeptName	Salary	Tax
1	Robert	Production	3.7	1.2
2	Greg	Administration	3.5	1.1
3	Anne	Production	5.3	2.1
4	Charles	Marketing	3.5	1.1
5	Alfred	Administration	3.7	1.2
6	Paolo	Planning	8.3	3.5
7	George	Marketing	4.2	1.4

Example of horizontal fragmentation

EMPLOYEE1

EmpNum	Name	DeptName	Salary	Tax
1	Robert	Production	3.7	1.2
2	Greg	Administration	3.5	1.1
3	Anne	Production	5.3	2.1

EMPLOYEE2

EmpNum	Name	DeptName	Salary	Tax
4	Charles	Marketing	3.5	1.1
5	Alfred	Administration	3.7	1.2
6	Paolo	Planning	8.3	3.5
7	George	Marketing	4.2	1.4

Example of vertical fragmentation

EMPLOYEE1

EmpNum	Name
1	Robert
2	Greg
3	Anne
4	Charles
5	Alfred
6	Paolo
7	George

EMPLOYEE2

EmpNum	DeptName	Salary	Tax
1	Production	3.7	1.2
2	Administration	3.5	1.1
3	Production	5.3	2.1
4	Marketing	3.5	1.1
5	Administration	3.7	1.2
6	Planning	8.3	3.5
7	Marketing	4.2	1.4

Fragmentation and allocation schemas

- Each fragment R_i corresponds to a different physical file and is allocated to a different server
- Thus, the relation is present in a virtual mode (like a view), while the fragments are actually stored
- The **allocation schema** describes the mapping of relations or fragments to the servers that store them. This mapping can be:
  - **non-redundant**, when each fragment or relation is allocated to a single server
  - **redundant**, when at least one fragment or relation is allocated to more than one server

Transparency levels

- There are three significant levels of transparency: **fragmentation, allocation and language transparency**
- In **absence of transparency**, each DBMS accepts its own SQL 'dialect': the system is heterogeneous and the DBMSs do not support a common interoperability standard
- Given:
  - relation: SUPPLIER(SNum,Name,City)
  - fragments: SUPPLIER1 = $SEL_{City='London'}$ SUPPLIER
    SUPPLIER2 = $SEL_{City='Manchester'}$ SUPPLIER
- and the allocation schema:
  - SUPPLIER1@company.London.uk
  - SUPPLIER2@company.Manchester1.uk
  - SUPPLIER2@company.Manchester2.uk

Language transparency

- On this level the programmer must indicate in the query both the structure of the fragments and their allocation
- Queries expressed at a higher level of transparency are transformed to this level by the distributed query optimizer, aware of data fragmentation and allocation
- Query:

```
procedure Query3(:snum,:name);
select Name into :name
  from Supplier1@company.London.uk
  where SNum = :snum;
if :empty then
  select Name into :name
    from Supplier2@company.Manchester1.uk
    where SNum = :snum;
end procedure;
```

Allocation transparency

- On this level, the programmer should know the structure of the fragments, but does not have to indicate their allocation
- With replication, the programmer does not have to indicate which copy is chosen for access (**replication transparency**)
- Query:

```
procedure Query2(:snum,:name);
select Name into :name
  from Supplier1
  where SNum = :snum;
if :empty then
  select Name into :name
    from Supplier2
    where SNum = :snum;
end procedure;
```

Fragmentation transparency

- On this level, the programmer should not worry about whether or not the database is distributed or fragmented
- Query:

```
procedure Query1(:snum,:name);
select Name into :name
  from Supplier
  where SNum = :snum;
end procedure
```

Optimizations

- This application can be made more efficient in two ways:
  - By using **parallelism**: instead of submitting the two requests in sequence, they can be processed in parallel, thus saving on the global response time
  - By using the **knowledge on the logical properties of fragments** (but then the programs are not flexible)

```
procedure Query4(:snum,:name,:city);
case :city of
"London":     select Name into :name
                from Supplier1
                where SNum = :snum;
"Manchester": select Name into :name
                from Supplier2
                where SNum = :snum;
end procedure;
```

Classification of operations

- **Remote requests***:* read-only transactions made up of an arbitrary number of SQL queries, addressed to a single remote DBMS
  - The remote DBMS can only be queried
- **Remote transactions** made up of any number of SQL commands (select, insert, delete, update) directed to a single remote DBMS
  - Each transaction writes on one DBMS
- **Distributed transactions** made up of any number of SQL commands (select, insert, delete, update) directed to an arbitrary number of remote DBMSs, but each SQL command refers to a single node
  - Transactions may update more than one node
    - Requires distributed transaction management
- **Distributed requests** are arbitrary transactions, in which each SQL command can refer to multiple nodes
    - Requires a distributed optimizer

Typical transaction: fund transfer

- Assume: ACCOUNT (AccNum,Name,Total) with accounts lower than 10000 allocated on fragment ACCOUNT1 and accounts above 10000 allocated on fragment ACCOUNT2
- Code:

```
begin transaction
update Account1
  set Total = Total - 100000
  where AccNum = 3154;
update Account2
  set Total = Total + 100000
  where AccNum = 14878;
commit work;
end transaction
```

- Comment: It is an unacceptable violation of atomicity that one of the modifications is executed while the other is not

Technology of distributed databases

- Data distribution does not influence consistency and durability
  - **Consistency** of transactions does not depend on data distribution, because integrity constraints describe only local properties (a limit of the actual DBMS technology)
  - **Durability** is not a problem that depends on the data distribution, because each system guarantees local durability by using local recovery mechanisms (logs, checkpoints, and dumps)
- Other features and subsystems require major enhancements:
  - Concurrency control (for **isolation**)
  - Reliability control (for **atomicity**)
  - Query optimization (for **efficiency**)

Distributed query optimization

- Required when a DBMS (a node in the distributed system) receives a distributed request; the node that is queried is responsible for the 'global optimization'
  - It decides on the breakdown of the query into many sub-queries, each addressed to a specific node
  - It builds a strategy (plan) of distributed execution: consisting of the coordinated execution of various programs on various nodes and in the exchange of data among them
- The cost factors of a distributed query include the quantity of data transmitted on the network

$C_{total} = C_{I/O} \times n_{I/O} + C_{cpu} \times n_{cpu} + C_{tr} \times n_{tr}$

n_{tr}: the quantity of data transmitted on the network

C_{tr}: unit cost of transmission

Concurrency control

- In a distributed system, a transaction t_i can carry out various sub-transactions t_{ij} , where the second subscript denotes the node of the system on which the sub-transaction works.

  $t_1 : r_{1A}(x)\ w_{1A}(x)\ r_{1B}(y)\ w_{1B}(y)$

  $t_2 : r_{2B}(y)\ w_{2B}(y)\ r_{2A}(x)\ w_{2A}(x)$

- **Local serializability within the schedulers is not a sufficient guarantee of serializability.**
- Consider the two schedules at nodes A and B:

  $S_A : r_{1A}(x)\ w_{1A}(x)\ r_{2A}(x)\ w_{2A}(x)$

  $S_B : r_{2B}(y)\ w_{2B}(y)\ r_{1B}(y)\ w_{1B}(y)$

- These are locally serializable, not globally:
  - on node A, t_1 precedes t_2 and is in conflict with t_2
  - on node B, t_2 precedes t_1 and is in conflict with t_1

Global serializability

- Global serializability of distributed transactions over the nodes of a distributed database requires the existence of a unique **serial schedule** *S* equivalent to all the local schedules S_i produced at each node
- The following properties are valid.
  - If each scheduler of a distributed database uses the **strict two-phase locking** method on each node (and so carries out the commit action when all the sub-transactions have acquired all the resources), then the resulting schedules are globally conflict-serializable
  - If each distributed transaction acquires a single timestamp and uses it in all requests to all the schedulers that use concurrency control based on timestamp, the resulting schedules are globally serial, based on the order imposed by the timestamps

Distributed deadlocks

- Distributed deadlocks can be due to circular waiting situations between two or more nodes
- The time-out method is valid and most used by distributed DBMSs
- Deadlock resolution can be done with an asynchronous and distributed protocol (implemented in a distributed version of DB2 by IBM)

Failures in distributed systems

- A distributed system is subject to failures, message losses, or network partitioning
- **Node failures** may occur on any node of the system and be soft or hard, as discussed before
- **Message losses** leave the execution of a protocol in an uncertain situation
  - Each protocol message (*msg*) is followed by an acknowledgement message (*ack*)
  - The loss of either one leaves the sender uncertain about whether the message has been received
- **Network partitioning**. This is a failure of the communication links of the computer network which divides it into two sub-networks that have no communication between each other
  - A transaction can be simultaneously active in more than one sub-network

Two-phase commit protocol

- **Commit protocols** allow a transaction to reach the correct commit or abort decision at all the nodes that participate in a transaction
- The **two-phase commit protocol** is similar in essence to a marriage, in that the decision of two parties is received and registered by a third party, who ratifies the marriage
  - The servers – who represent the participants to the marriage – are called **resource managers** (RM)
  - The celebrant (or coordinator) is allocated to a process, called the **transaction manager** (TM)
- It takes place by means of a rapid exchange of messages between TM and RM and writing of records into their logs. The TM can use:
  - broadcast mechanisms (transmission of the same message to many nodes, collecting responses arriving from various nodes)
  - serial communication with each of the RMs in turn

New log records

- Records of TM
  - The **`prepare`** record contains the identity of all the RM processes (that is, their identifiers of nodes and processes)
  - The **`global commit`** or **`global abort`** record describes the global decision. When the TM writes in its log the **`global commit`** or **`global abort`** record, it reaches the final decision
  - The **`complete`** record is written at the end of the two-phase commit protocol

New log records

- Records of RM
  - The **`ready`** record indicates the irrevocable availability to participate in the two-phase commit protocol, thereby contributing to a decision to commit. Can be written only when the RM is “recoverable”, i.e., possesses locks on all resources that need to be written. The identifier (process identifier and node identifier) of the TM is also written on this record
  - In addition, **`begin`**, **`insert`**, **`delete`**, and **`update`** records are written as in centralized servers
- At any time (before the ready) an RM can autonomously abort a sub-transaction, by undoing the effects, without participating to the two-phase commit protocol

First phase of the basic protocol

- The TM writes the **`prepare`** record in its log and sends a **`prepare`** message to all the RMs. Sets a timeout indicating the maximum time allocated to the completion of the first phase
- The recoverable RMs write on their own logs the **`ready`** record and transmit to the TM a **`ready`** message, which indicates the positive choice of commit participation
- The non-recoverable RMs send a **`not-ready`** message and end the protocol
- The TM collects the reply messages from the RMs
  - If it receives a positive message from all the RMs, it writes a **`global commit`** record on its log
  - If one or more negative messages are received or the time-out expires without the TM receiving all the messages, it writes a **`global abort`** record on its log

Second phase of the basic protocol

- The TM transmits its global decision to the RMs. It then sets a second time-out
- The RMs that are ready receive the decision message, write the **`commit`** or **`abort`** record on their own logs, and send an acknowledgement to the TM. Then they implement the commit or abort by writing the pages to the database as discussed before
- The TM collects all the *ack* messages from the RMs involved in the second phase. If the time-out expires it sets another time-out and repeats the transmission to all the RMs from which it has not received an *ack*
- When all the *ack*s have arrived, the TM writes the **`complete`** record on its log

The two-phase commit protocol

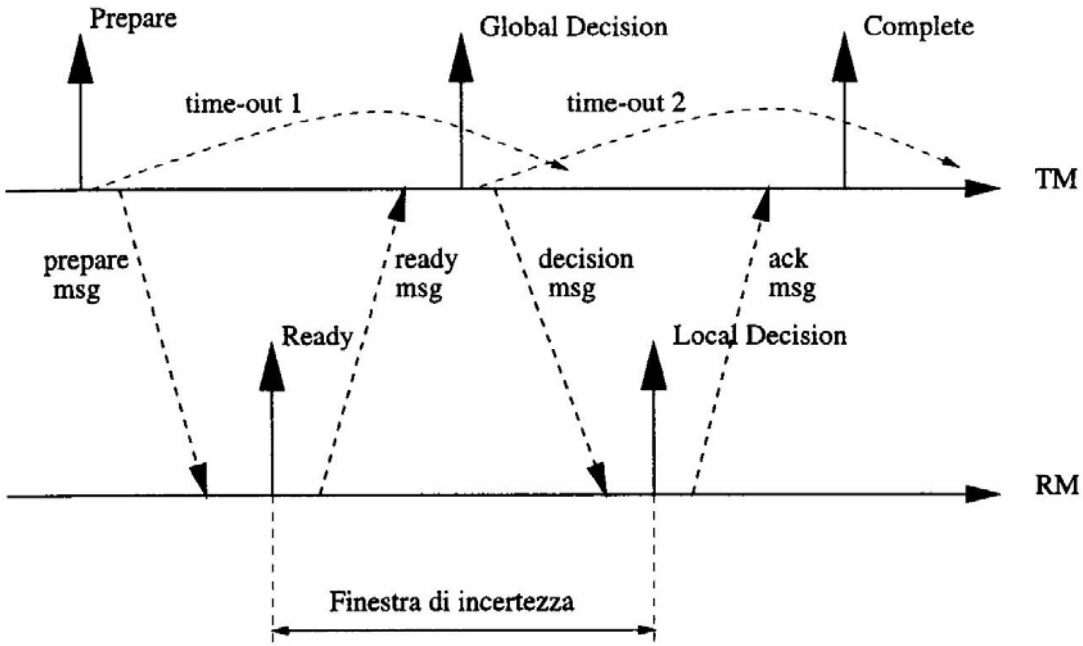

Figura 10.9 Protocollo di commit a due fasi

2PC dal punto di vista di una transazione

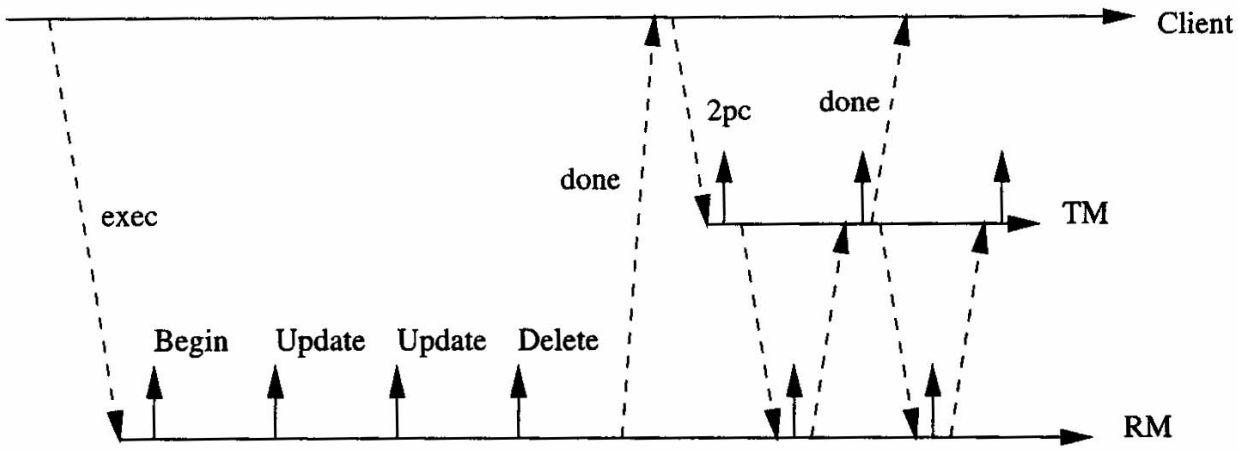

Figura 10.10 Protocollo di commit a due fasi nel contesto di una transazione

Blocking, uncertainty, recovery protocols

- An RM in a ready state loses its autonomy and awaits the decision of the TM. A failure of the TM leaves the RM in an uncertain state. The resources acquired by using locks are blocked
- The interval between the writing on the RM's log of the **`ready`** record and the writing of the **`commit`** or **`abort`** record is called the **window of uncertainty**. The protocol is designed to keep this interval to a minimum
- Recovery protocols are performed by the TM or RM after failures; they recover a final state which depends on the global decision of the TM

Recovery of participants

- Performed by the warm restart protocol. Depends (for each transaction) on the last record written in the log:
  - when it is an action or **`abort`** record, the actions are *undone*; when it is a **`commit`**, the actions are *redone*; in both cases, the failure has occurred before starting the commit protocol
  - when the last record written in the log is a **`ready`**, the failure has occurred during the two-phase commit. The participant is *in doubt* about the result of the transaction
- During the warm restart protocol, the identifier of the transactions in doubt are collected in the *ready* set. For each of them the final transaction outcome must be requested to the TM
- This can happen as a result of a direct *(remote recovery*) request from the RM or as a repetition of the second phase of the protocol

Recovery of the coordinator

- (Again, for each transaction) When the last record in the log is a **`prepare`**, the failure of the TM might have placed some RMs in a blocked situation. Two recovery options:
  - Write **`global abort`** on the log, and then carry out the second phase of the protocol
  - Repeat the first phase, trying to arrive to a global commit
- When the last record in the log is a global decision, some RMs may have been correctly informed of the decision and others may have been left in a blocked state. The TM must repeat the second phase

Message loss and network partitioning

- The loss of a **`prepare`** or **`ready`** messages are not distinguishable by the TM. In both cases, the time-out of the first phase expires and a global abort decision is made
- The loss of a decision or *ack* message are also indistinguishable. In both cases, the time-out of the second phase expires and the second phase is repeated
- A *network partitioning* does not cause further problems, in that the transaction will be successful only if the TM and all the RMs belong to the same partition

Presumed abort protocol

- The presumed abort protocol is used by most DBMSs
- Based on the following rule:
  - when a TM receives a remote recovery request from an in-doubt RM and it does not know the outcome of that transaction, the TM returns a global abort decision as default
- As a consequence, the *force* of **`prepare`** and **`global abort`** records can be avoided, because in the case of loss of these records the default behavior gives an identical recovery
- Furthermore, the **`complete`** record is not critical for the algorithm, so it needs not be forced; in some systems, it is omitted. In conclusion the records to be forced are **`ready`**, **`global commit`** and **`commit`**

Read-only optimization

- When a participant is found to have carried out only read operations (no write operations)
- It responds **`read-only`** to the **`prepare`** message and suspends the execution of the protocol (from its point of view)
- The coordinator ignores read-only participants in the second phase of the protocol

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Co-operation among pre-existing systems

- *Co-operatio*n is the capacity of the applications of a system to make use of application services made available by other systems, possibly managed by different organizations
- Needs for co-operation arise for different reasons, which range from the simple demand for integration of components developed separately within the same organization, to the co-operation or fusion of different companies and organizations
- The integration of databases is quite difficult. Over-ambitious integration and standardization objectives are destined to fail. The ‘ideal’ model of a highly integrated database, which can be queried transparently and efficiently, is impossible to develop and manage

Iniziative di cooperazione - 1

- Le iniziative di cooperazione possono essere occasione per razionalizzare i sistemi oggetto di cooperazione, modificandone di conseguenza eterogeenità, distribuzione, autonomia.
- Ciò richiede in generale una valutazione costi benefici e una rimozione di vincoli normativi.
- Esempio:
  - da 30 anni esistono in Italia due basi delle automobili e dei proprietari di automobili, gestite da Ministero dei Trasporti e Aci, tra loro non coerenti.
  - Recentemente è stata fatta (c'è voluta) una legge per unificarle.

Iniziative di cooperazione - 2

- Esempio 2:
  - Nel sistema Inps, Inail, Camere di Commercio, si è colta l'occasione della creazione del record indici, per effettuare record matching tra le tre basi di dati, cioè riconciliazione tra record con errori che rappresentano la stessa impresa, per migliorare la qualità dei dati delle tre basi di dati

Data-centered co-operation

- Two kinds of co-operation:
  - *process-centered co-operation*: the systems offer one another services, by exchanging messages, information or documents, or by triggering activities, without making remote data explicitly visible
  - *data-centered co-operatio*n, in which the data is naturally distributed, heterogeneous and autonomous, and accessible from remote locations according to some co-operation agreement
- We will concentrate on data-centered co-operation, characterized by data autonomy, heterogeneity and distribution

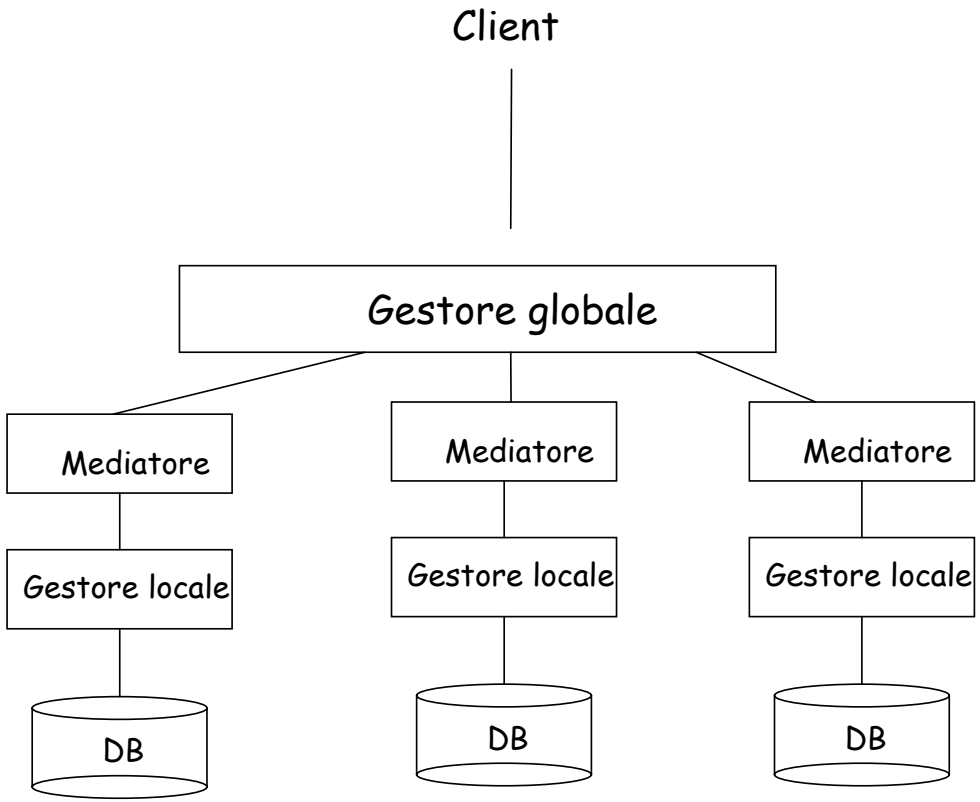
Features of data-centered co-operation

- The **transparency level** measures how the distribution and heterogeneity of the data are masked
- The **complexity of distributed operations** measures the degree of coordination necessary to carry out operations on the co-operating databases
- The **currency level** indicates whether the data being accessed is up-to-date or not
- Based on the above criteria, we can identify three architectures for guaranteeing data-based co-operation

Multidatabases

- Each of the participating databases continues to be used by its respective users (programs or end users)
- Systems are also accessed by modules, called *mediator*s, which show only the portion of database that must be exported. They make it available to a *global manage*r, which carries out the integration
- In general, data cannot be modified by means of mediators, because each source system is autonomous
- Features:
  - presents an integrated view to the users, as if the database were integrated
  - provides a high level of transparency
  - currency is also high, because data is accessed directly

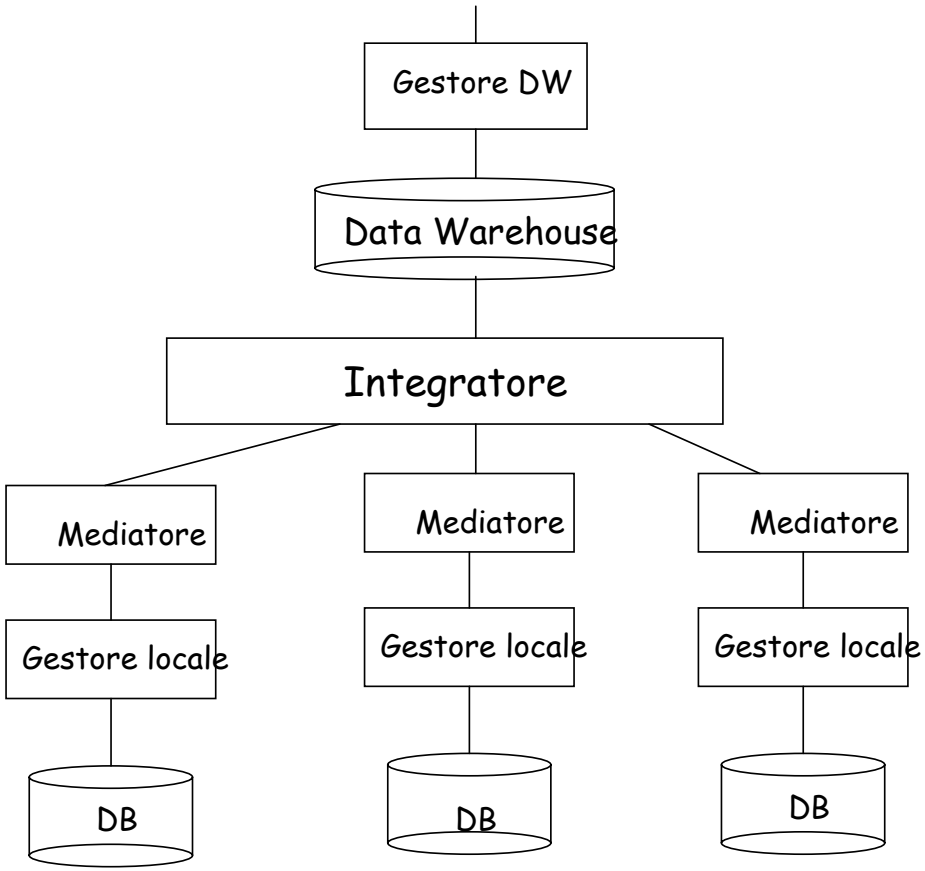
Multidatabases



Systems based on replicated data

- They guarantee read only access to secondary copies of the information provided externally
- These may be stored in the **data warehouse**, which contains data extracted from various heterogeneous distributed systems and offers a global view of data
- Features:
  - present a high level of integration and transparency, but have a reduced degree of currency

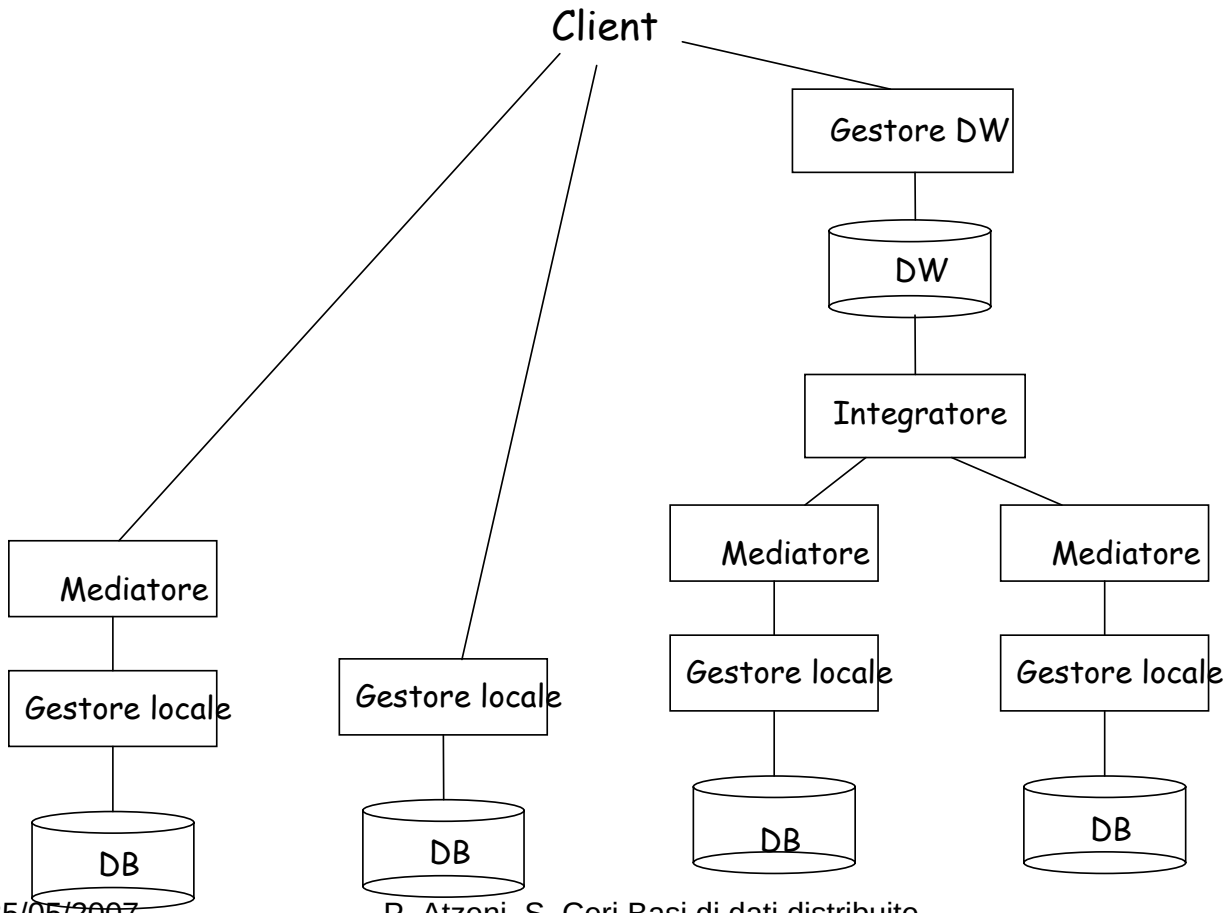
Systems based on replicated data



Systems based on external data access

- Data integration is carried out explicitly by the application
- In the next example, three sources are integrated: an external database, a local database and a data warehouse, which in turn uses three sources of information
- Features:
  - Low degree of transparency and integration, with a degree of currency that depends on specific demands

A system based on external data access



Interoperability

- Interoperability is the main problem in the development of heterogeneous applications for distributed databases
- It requires the availability of functions of adaptability and conversion, which make it possible to exchange information between systems, networks and applications, even when heterogeneous
- Interoperability is made possible by means of standard protocols such as FTP, SMTP/MIME, and so on
- With reference to databases, interoperability is guaranteed by the adoption of suitable standards

Open Database Connectivity (ODBC)

- It is an application interface proposed by Microsoft in 1991 for the construction of heterogeneous database applications, supported by most relational products
- The language supported by ODBC is a restricted SQL, characterized by a minimal set of instructions
- Applications interact with DBMS servers by means of a driver, a library that is dynamically connected to the applications. The driver masks the differences of interaction due to the DBMS, the operating system and the network protocol
  - For example, the trio (Sybase, Windows/NT, Novell) identifies a specific driver
- ODBC does not support the two-phase commit protocol

ODBC Components

- The *application* issues SQL queries
- The *driver manager* loads the drivers at the request of the application and provides naming conversion functions. This software is supplied by Microsoft
- The *drivers* perform ODBC functions. They execute SQL queries, possibly translating them to adapt to the syntax and semantics of specific products
- The *data source* is the remote DBMS system, which carries out the functions transmitted by the client

X-Open distributed transaction processing (DTP)

- A protocol that guarantees the interoperability of transactional computations on DBMSs of different suppliers
- Assumes the presence of one client, several RMs and one TM
- The protocol consists of two interfaces:
  - Between client and TM, called *TM-interface*
  - Between TM and each RM, called *XA-interface*
- Relational DBMSs must provide the XA-interface
- Various products specializing in transaction management, such as *Encina* (a product of the Transarc company) and *Tuxedo* (from Unix Systems, originally AT&T) provide the TM component

Features of X-Open DTP

- RM are passive; they respond to remote procedure calls issued by the TM
- The protocol uses the two-phase commit protocol with the presumed abort and read-only optimizations
- The protocol supports *heuristic decisions*, which in the presence of failures allow the evolution of a transaction under the control of the operator
  - When an RM is blocked because of the failure of the TM, an operator can impose a heuristic decision (generally the abort), thus allowing the release of the resources
  - When heuristic decisions cause a loss of atomicity, the protocol guarantees that the client processes are notified
  - The resolution of inconsistencies due to erroneous heuristic decisions is application-specific

TM interface

- `tm_init` and `tm_exit` initiate and terminate the client-TM dialogue
- `tm_open` and `tm_term` open and close a session with the TM
- `tm_begin` begins a transaction
- `tm_commit` requests a global commit

XA Interface

- `xa_open` and `xa_close` open and close a session between TM and a given RM
- `xa_start` and `xa_end` activate and complete a transaction
- `xa_precom` requests that the RM carry out the first phase of the commit protocol; the RM process can respond positively to the call only if it is in a recoverable state
- `xa_commit` and `xa_abort` communicate the global decision about the transaction
- `xa_recover` initiates a recovery procedure after the failure of a process (TM or RM); the RM consults its log and builds three sets of transactions:
  - Transactions *in doub*t
  - Transactions decided by a *heuristic commi*t
  - Transactions decided by a *heuristic abor*t
- `xa_forget` allows an RM to forget transactions decided in a heuristic manner

Interazioni tra client, RM e TM per il protocollo X-Open

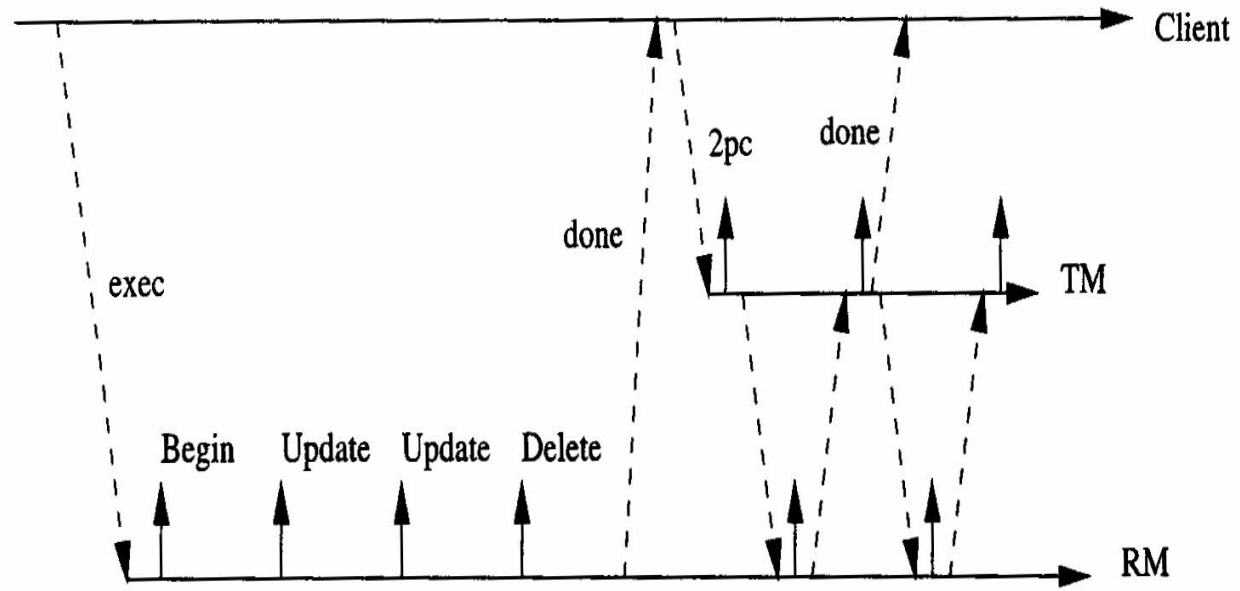


Figura 10.10 Protocollo di commit a due fasi nel contesto di una transazione