ECMA

EUROPEAN COMPUTER MANUFACTURERS ASSOCIATION

DATABASES AND NETWORKING

ECMA TR/58

June 1992

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Brief History

When a number of computer systems are linked together to enable interworking these computers systems are said to be networked. Within a network of computers there may be many applications using databases at various locations. If users on any of these network locations can access any database on the network, these databases are termed networked databases, irrespective of whether these are local or remote databases.

ECMA TC22 (Databases) considered that the structure and design of networked databases were not well known, and decided to prepare an ECMA Technical Report providing tutorial information on this subject. This report, starting from some general modelling considerations and a number of practical examples, arrives at a model for networked databases and draws some conclusions on the implications for the standardisation work of the architecture of networked databases.

Adopted as an ECMA Technical Report by the General Assembly of June 1992.

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1 Scope

This ECMA Technical Report is intended to provide tutorial information on networked databases. It addresses the area of designing, maintaining and controlling networked database systems providing database services to the users of networked databases.

A joint technical committee of the International Organisation for Standardisation and International Electrotechnical Commission ((ISO/IEC JTC1) and other forums are currently progressing standards to make networking of databases a reality over the 'Open Systems Interconnection' (OSI) reference model.

These groups address the need to integrate data held in database systems that:

- are supplied by different vendors;
- use different technologies;
- are distributed or logically (if not physically) separated;
- form part of an 'open systems' environment.

Such a database environment encompasses a range of:

- network topologies,
- data distribution,
- couplings of application with data,
- transaction management.

Not all technical solutions are developed yet.

The intent of this ECMA Technical Report is to inform readers who are unfamiliar with databases and networks, and to reach conclusions that could be useful to standardisation groups.

2 Structure

The main clauses of this ECMA Technical Report are clause 4, containing the outline description of reference models for generic distributed or networked data systems; clause 5, exploring a number of possible applications and defining an architectural model in an uniform way; clause 6 presenting the results of the analysis of the data collected in clause 5, and clause 7 describing the model emerging from this work. The implications for the standardisation work are presented in clause 8.

3 Acronyms

ACP	Access control point	CAD	Computer-aided design
CD-ROM	Compact disk read-only memory	DB	Database
DBMS	Database management system	DP	Data processor
IND	Intelligent network database	IR	Information retrieval
OPAC	Online public access catalogue	OSI	Open systems interconnection
PSTN	Public switched telephone network	SQL	Sequential query language
UP	User processor	VLSI	Very large scale integration

4 Modelling concepts

4.1 Introduction

Before considering networked databases let us examine the reference model for a single database environment.

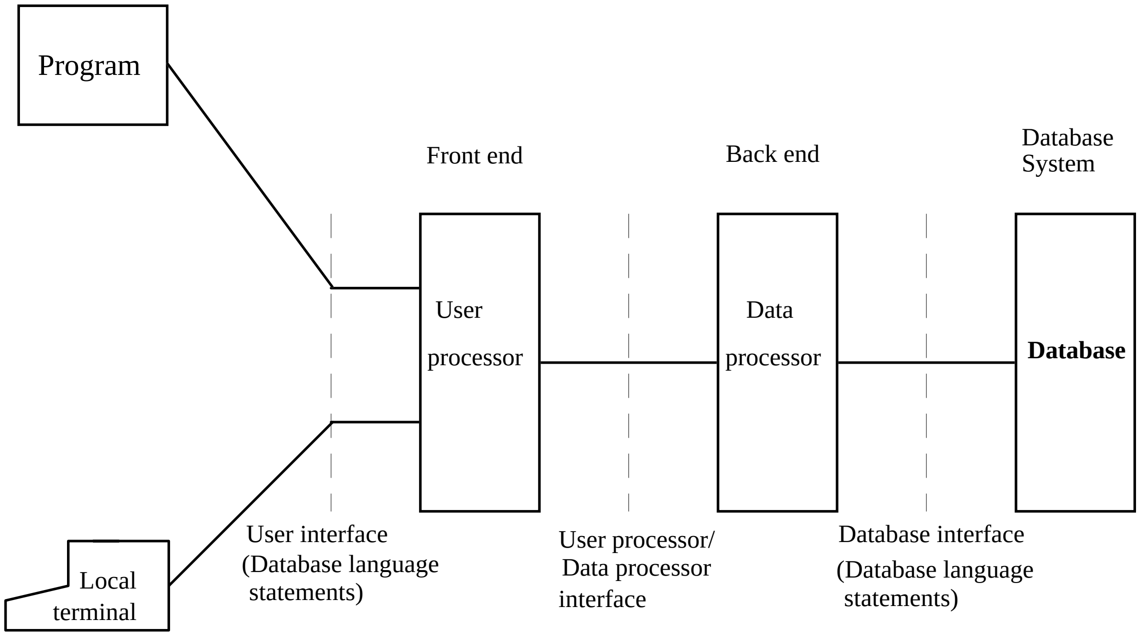

Figure 1 - Single database environment

Note that either a program or a human user may need to access the database. The User Processor (UP) is the front end and the Data Processor (DP) the back end.

In the OSI terminology, UP is referred to as "Client" and DP as "Server" .

Database language commands flow across the user interface and the database interface.

In a networked database, in essence each user at a location needs to be able to access any of the databases be they local or remote. Figure 2 shows what is required.

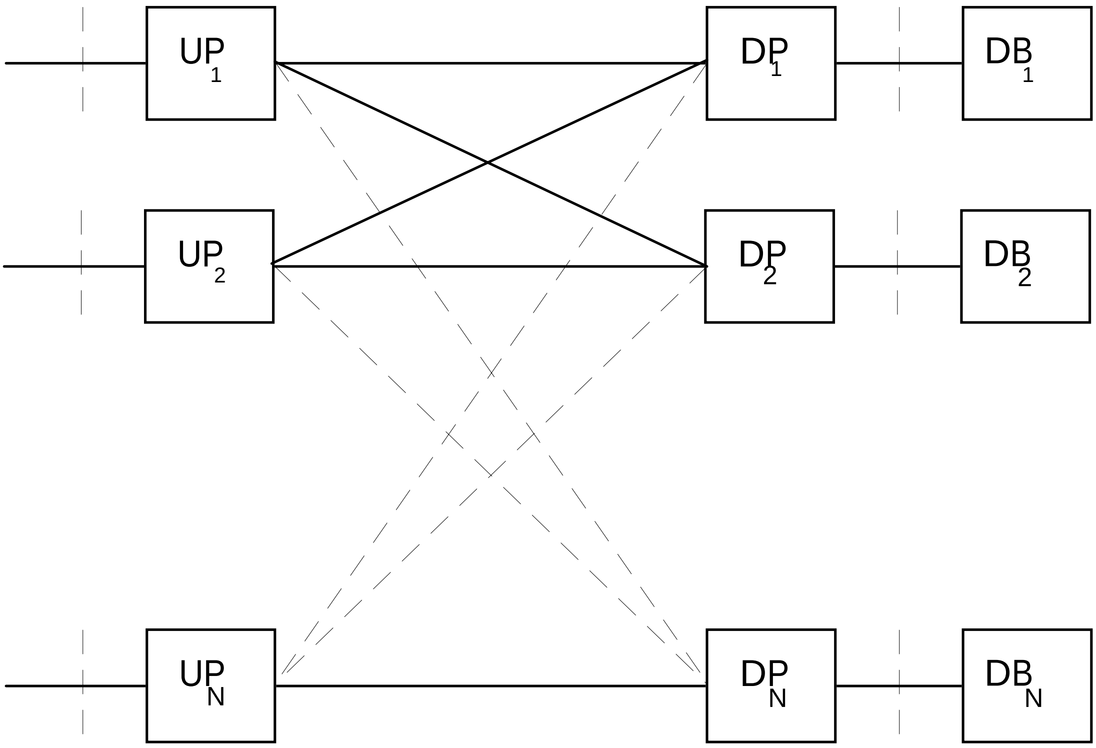

Figure 2 - Networked database environment

The figure can be reduced to the following diagram, which highlights the communication networks.

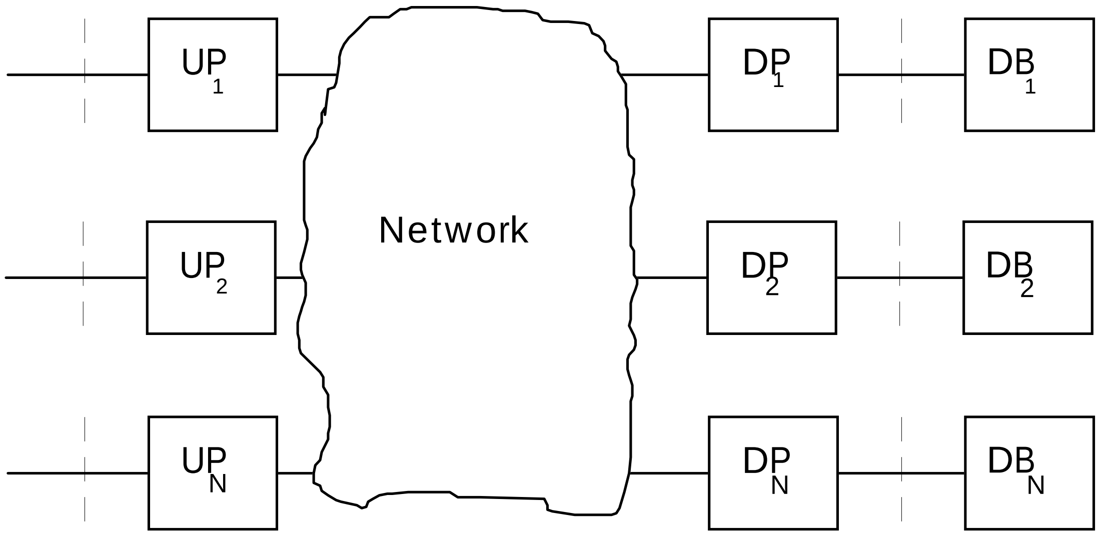

Figure 3 - Networked database environment - alternate representation

4.2 Definitions

Some of the terms used in this ECMA Technical Report are explained below.

4.2.1 Common query language

The language used to define the data held in databases, such as SQL. It is often referred to as the query language.

4.2.2 Common schema

A schema is the design of a database and when this design is common for the whole organisation it is referred to as the common schema.

4.2.3 Data consistency

Integrity of the data held in an organisation's database resource.

4.2.4 Directory

The addressing information for the databases within the system.

4.2.5 Query decomposition

The order in which operations are carried out for a given transaction.

4.2.6 Query optimisation

The way a transaction is carried out, to make the whole operation as efficient as possible.

4.2.7 Replication

The duplication of the data used for achieving better availability of data to the user at various locations.

4.2.8 Routing

The way communication paths are utilised in the course of the transaction.

4.3 Components

Four different reference architecture are identified in a paper prepared by Mr. J.A. Larson - (Four Reference Architectures for Distributed Database Management Systems, Computer Standards and Interfaces, North Holland Pub. Co. vol. 8, 1988/89, pp.209-221). These are discussed in detail in 4.4 to 4.7, a summary is given in table 1.

Table 1 - Reference architecture

	Types of databases			
Features	Loosely coupled	Federated	Distributed	Centralised
Query decomposition	user	user/dbms	dbms	dbms
Query optimisation	user	user/dbms	dbms	dbms
Routing	user	user/dbms	dbms	dbms
Directory	user	user/dbms	dbms	n.a
Replication	user	user/dbms	dbms	n.a
Data consistency	user	user/dbms	dbms	n.a
Common schema	no	no	yes	yes
Common query language	no	no	yes	yes

This table identifies for each feature and type of database:
- if the user is responsible for providing the feature (user)
- if the DBMS is responsible for providing the feature (DBMS)
- if both are jointly responsible (user/DBMS)
- if the feature is supported (YES/NO)
- if it is not applicable (n.a.)

The following components are used in the description of the database architectures.

- **Application program**: it contains calls to the distributed parts of the database.
- **Distributed execution monitor:** routes requests to the respective distributed parts of the database(s), including choice of the distribution strategy and distributed transaction control.
- **User command translator:** accepts user commands from a specific user interface and translates them into a canonical (i.e. unique internal) representation.
- **Constraint enforcer:** enforces integrity constraints independent of a specific database and modifies canonical commands so that security and integrity constraints are enforced in all specific databases.
- **Distributed requests decomposer:** translates a request from a client processor into a distributed execution strategy consisting of several commands to be executed at one or more data processor.
- **Canonical command translator:** converts canonical commands into commands of a specific DBMS to be executed by a specific DBMS at run time.
- **Run-time support** of each specific database (component DBMS).

The four architectures differ primarily in the relative placement of the distributed request decomposer and of the distributed execution monitor. As a reference, the structure of a single database is shown in figure 4.

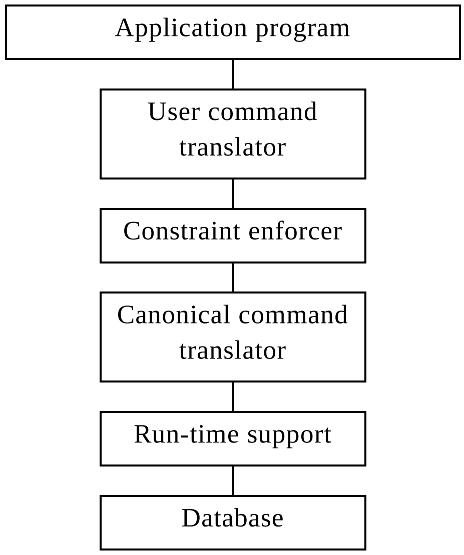

Figure 4 - Structure of a single database

4.4 Loosely coupled databases

In loosely coupled databases, all co-ordination by the distributed execution monitor is done directly beneath the application program level. This leads to a minimal co-operation between the involved databases and little system support in executing distributed requests. In this architecture, the definition of the distributed execution strategy is done by the application programmer.

Loosely coupled databases are used in:

- Inter-banking co-operation with high local autonomy requirements (example 1, 5.1);
- access to independent databases (hotels, flight booking) in travel applications (example 3, 5.3).

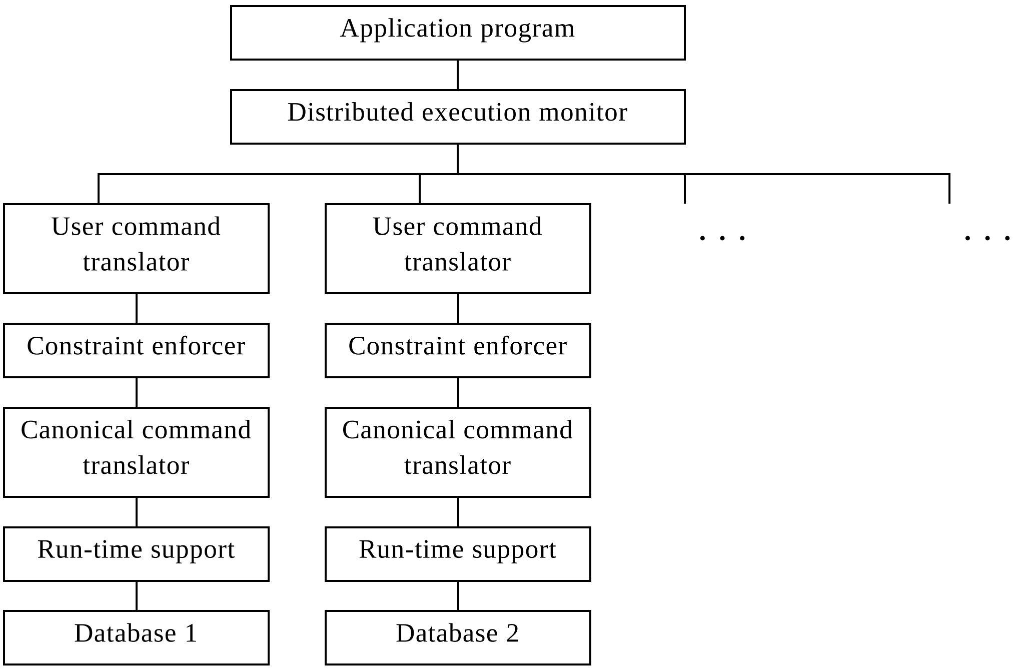

Figure 5 - Structure of loosely coupled databases

4.5 Federated databases

The basic idea of a federated database architecture is that independent databases provide support for global (distributed) database integration, with minimal co-operation. This means that, in general, for federated databases there is no global conceptual schema for the integrated distributed database, although some, partial, database integration is supported at the user interface for some classes of applications.

In federated databases some global co-ordination is provided at and above the distributed execution monitor level. User commands are translated into an internal representation, and distributed requests are routed independently from each other to the local database components. This still leads to a fairly high degree of autonomy of the involved database systems, but it also supports a distributed application by some system-wide co-ordinating function.

According to a federated architecture, the distributed request decomposer and the distributed execution monitor are logically centralised and provide some distribution transparency for the application program. In a federated database, no consistency constraints can be expressed across sites, global control does not exist. As the constraint enforcers reside at the local site, only the local sites have complete control of the access to their local data.

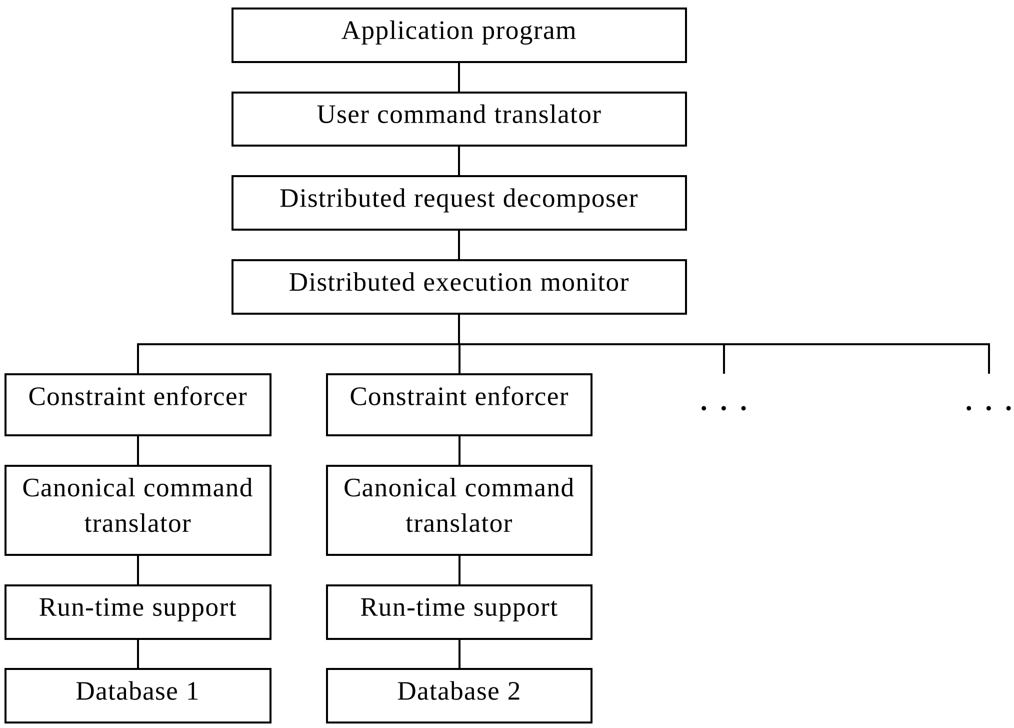

Figure 6 - Structure of federated databases

Cases where hierarchically structured organisations need computer-based support for data management at different levels of their organisation tend to use federated databases. For example:

- within a department, the widespread use of intelligent workstations and appropriate software support allows for data management for 'private' or locally restricted use at a 'personal level';
- for the common needs of a department, common data management functions are provided at a 'department level', and may be in several stages;
- data management support for whole (sub)organisations is provided at the organisational level.

As - at least occasionally and potentially - organisational units at **all** levels have to network, an integrated data management should be supported by an appropriate distributed DBMS. But for, e.g., organisational, privacy, financial, optimisation, etc. reasons, a high degree of autonomous responsibility over their own data has to remain with all respective local data management functions, too.

A federated database environment provides an architectural compromise between, on one hand, system-wide integration and, on the other, local site autonomy based on a distributed and only partially integrated data management system. Members of such a federation have the freedom to join or leave the integrated environment at any time. Taken to its logical conclusion this leads to a multi-database system.

Federated databases are used in:

- co-operation of different departments in the same organisation;
- co-operation of parallel workstations with common management services (example 2, 5.2);
- integrated travel applications.

4.6 Distributed databases

Tightly coupled distributed databases integrate different databases distributed among different sites in a network providing the application program with a logical view of only one database. So, at the user interface of a distributed database there is only one global conceptual schema; all integrity and consistency constraints are expressed and enforced at the global database level. As a consequence, distributed databases require a degree of close co-operation. This has an impact on local control and autonomy. The distributed database management system has to provide support for data distribution in a networking environment. Specifically, this means that a user need not know where the data resides. Such a characteristic of a distributed database systems is usually called "distribution transparency" or "location transparency".

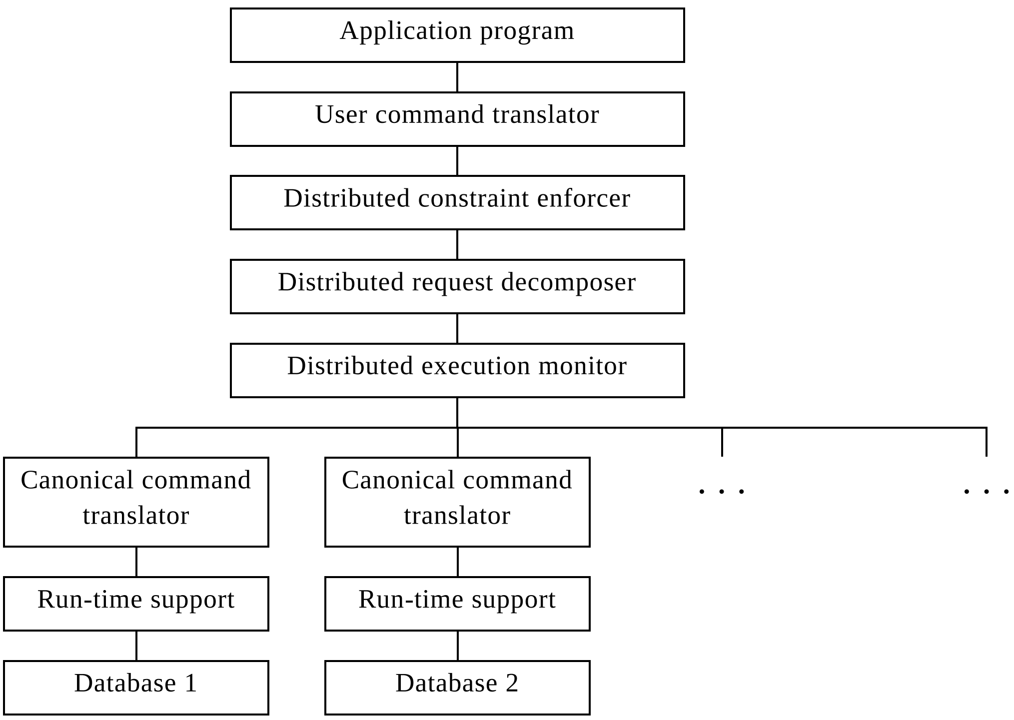

Figure 7 - Structure of distributed databases

In a distributed database environment, database operations are executable at a local or at a remote (i.e. global) level, as appropriate. An integrated distributed transaction management involves co-ordinating transactions spanning one or more locations. This can, in general, only be achieved at the expense of an additional management overhead and of restrictions to the respective autonomy of the involved local database components.

Distributed databases may be either homogeneous or heterogeneous systems. If the databases in a distributed database environment are based on a single data mode (e.g. relational or hierarchical) then the distributed databases are said to be homogeneous, otherwise they are said to be heterogeneous.

In a distributed database environment, programming language support can be generalised from what is known from a centralised system in order to express the specific requirements of remote processing. A user-friendly way of expressing this is to hide distribution aspects at the programming language level, i.e. to make remote data access transparent to the application programmer. Separately developed program components (potentially at different sites) could be separately compiled and also executed in cases where no remote processing is involved.

Distributed databases are used in data management in homogeneous distributed applications (example 1, internally).

4.7 Centralised multi-processor databases

In a centralised multi-processor environment, nearly all processing of requests for data residing on different processors is executed centrally. Here, users may access data on several nodes only through one centralised DBMS. Distribution aspects only occur and are managed by the distributed execution monitor directly above the local DBMS run-time system.

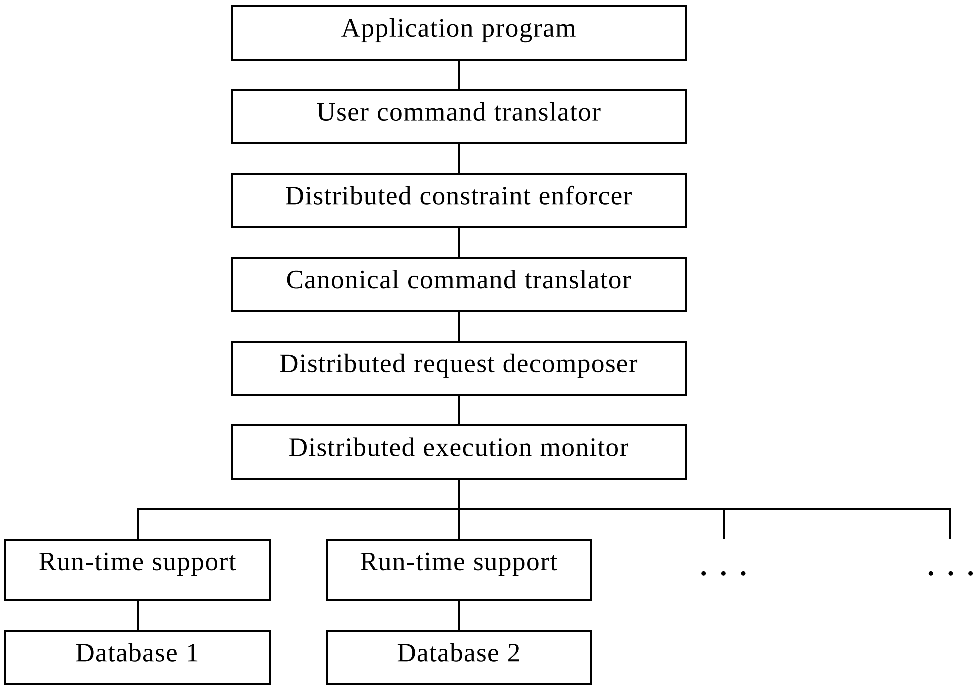

Figure 8 - Structure of centralised databases

Centralised databases are used in library applications running on separated processors (example 6, 5.6).

5 Outline of selected applications

Clause 4 defines only the theoretical aspects of database structure. In this clause 5, a number of applications are described to provide material for the analysis that will be carried out in clause 6.

An uniform approach is being followed for each application described, outlining for each a scenario, the design characteristics and the characteristics of application.

Scenario

The following items will be outlined:

- physical architecture and layout of the system;

- distribution of functions;
- nature of interconnections.

A justification of the choices made will be provided where possible.

Design characteristics
The design characteristics of the application will be outlined in this clause.

Characteristics of the application
The following characteristics of each application will be described:

- Scope;
- Motivation;
- System structure;
- Functions;
- Security;
- Speed of response;
- Consistency;
- Availability;
- Transactions;
- Threats.

5.1 Application 1 - Banking

5.1.1 Scenario

Many banks, as distributed services developed (including automatic tellers in different locations) maintained the structure of having a large computer centre, with a single database. This systems could have adverse effects, reducing efficiency and impairing security. In addition, communication costs and the dependency on telecommunication lines increase. Advantage can be taken from the communication delays, for instance it will not be possible to report, on real time, all operations on automatic cash machines. This delay could be used to withdraw a large number of small amounts of money from different machines.

The following scenario was therefore proposed for the "Appiani Bank of Genova":
- the database of the bank is distributed between the central site and the peripheral offices;
- the central site holds general information relating to the whole bank, main customer data, global directories and restricted information;
- the outgoing offices hold information on local customers and local operations.

The main advantages were considered to be:
- reduced cost of communication;
- reduced overall response time. Non-local operations, performed via the network, will profit from the reduced load on the telecommunication lines;
- improved security, with faster update of the customer situation;
- improved fault tolerance, the loss of computing power at the centre will not halt the bank activity.

It will be very important, in this kind of operation, to pay attention to the management of the database, with regular updates of replicated data.

5.1.2 Design characteristics

The systems should have the following design characteristics:
- be able to accept transactions at branches without on-line access to a central machine;
- allow duplication of some data (e.g. last night balance) on another machine;
- use controls to ensure that no loss of data occurs;
- be able to handle exceptions (stolen cards, empty accounts).

The systems design should avoid the use of transactions spanning a transaction tree and require no replication of volatile data.

5.1.3 Characteristics of the application

- **Scope**: to design a distributed database network for a banking application, able to handle:
  - customer checking accounts;
  - cash dispensing machines.
- **Motivation**: the goals to be reached are the following ones:
  - provide a faster service for the customer;
  - provide a 24-hours availability for cash dispenser;
  - provide better security for all bank transactions;
  - provide better credit control;
  - reduce the administrative costs.
- **System structure**: the system will include a central computer, containing the directories, main database, central statistics, and a series of peripheral sites, each containing the part of the database relevant to that location, and able to handle the terminals at that location and the cash dispensing machines. The peripheral sites will log the transactions, handle the client management information, the clients account and the local directory. Supplementary information could be located at each peripheral site to allow them to act as a back-up for another site.
- **Functions**: The following functions should be possible at any bank:
  - allow to enquire from any site on the balance of an account located at any other site;
  - handle deposits, even for accounts located at a different site;
  - provide services (payment of bills), possibly limited to accounts located on the same site.
  - allow to enquire from any site on the balance of an account located at any other site;
  - handle deposits, even for accounts located at a different site;
- **Security**: In order to satisfy the need of the banking service and the requirement of the privacy legislation, the following assumptions shall be made:
  - the system is impenetrable;
  - the communication lines are impenetrable or data is encrypted;
  - authentication is required for any access;
  - practical realisation.
- **Speed of response**: on-line access with an acceptable response time is required from anywhere.
- **Consistency**: no loss of data is permitted, but it will not be required that update of the different parts of a database (main and back-up, for example) be made within the transaction time.
- **Availability**: near 100% availability is required. Terminals should be able to work even if the local computer or the lines are down. The cash dispensing machines should not be dependent on local computers. Dual systems and back-up systems should be provided where necessary.
- **Transactions**: these should be possible from any terminal.
- **Threats**: The system should protect from:
  - improper use of cards and identification (impersonation)
  - use of "dud" cheques;
  - exploitation of the delays in the system;
  - loss of data, due to hardware and/or media failure.

5.2 Application 2 - Design project support environment

5.2.1 Scenario

A number of "engineers" co-operating in the design of a complex object, e.g. an operating system or a space station.

Powerful workstations with graphic and other programs are used as tools interconnected with servers for data, printing, plotting, etc.

Interconnection to the server can be subject to intermittent failures.

Objects interchanged are huge, e.g. 1 Mbyte to 10 Mbyte. History of design is kept. Good visibility of who is designing what is needed. Management support facilities are provided.

5.2.2 Design characteristics

Version Control - Distributed items booked out. Data replicated - more than one centre synchronised.

Consistency across sites not required at all times.

5.2.3 Characteristics of the application

- **Scope**: typical of large distributed "engineering" projects, including hardware, software, VLSI, CAD. Individual tasks are of long duration in days or weeks. Work is planned, co-ordinated, quality controlled, etc. It is distributed to use expertise and knowledge of individuals.
- **Motivation**: Control plus visibility plus rapid response to design changes. Better use of expertise and resources.
- **System structure**: tightly coupled in a site, loosely coupled between sites. Sites can work without continuous interconnection.
- **Functions**:
  - Workstations: support of individual tasks (drawing, documents, specifications).
  - Processors: support of large computational tasks.
  - Data Centers: directory functions, what/who/where, information exchange, reconciliation, long time consistency, logical consistency - quality management - Version logging control, design status, etc. Cross-references between objects - Configuration - structural relationship. Administration functions and back up. Object naming.
- **Security**: Authentication, Access-control, Collaboration, Co-operation among individuals versus hostile. Note that audit trails enable detection.
- **Speed of response**: high locally, less important for remote.
- **Consistency**: database may become inconsistent but must be reconciled.
- **Availability**: locally high, network low, most local work must be able to continue without sublinks.
- **Transactions**: long duration, nested transactions, visibility of transactions - who is doing what.
- **Threats**: Minimise loss of confidential design through duplication. Challenge to property rights.

5.3 Application 3 - Travel agency

5.3.1 Scenario

A large travel agency handling booking on a number of transport media, hotels, facilities, for a number of customers. More than one database is to be accessed to put together a package, involving transportation, hotels and different services (e.g. car rentals). There is the need to maintain the databases updated, handle incidents (flight cancellations, hotel unavailable) and inform customers. Sale at the last minute of remaining seats, and of overbooking shall be considered.

5.3.2 Design characteristics

The travel agency will be able to access a number of databases (for trains, airlines, shipping agents, hotels). Each of these databases is in realty a master, giving access to separate databases, one for each company. Each database holds a set of standing data (timetables) and transactions: enquires, booking, payments, cancellations. Another database will probably be needed, handling the customer data, to allow backtracking of transactions in case of incidents. One of the problems is the need to keep a number of sub-transactions open (e.g. travel arrangements, hotels) until all the arrangements have been completed and agreed.

5.3.3 Characteristics of the application

- **Scope**: Organisation of travel packages, including booking passages on different transport means, booking of hotels and of services. Maintaining enough information to be able to inform users of incidents and to suggest alternatives. Handle billing and charging for the services offered.
- **Motivation**: improve the service to the customer, including better services and better information. Improve filling of transport and hotels. Improve management of facilities.
- **System structure**: there will be a number of databases, possibly at different levels, each one using a mixture of fixed and variable data. Variable data will have a limited life when accessed, The travel agent will not be the only one updating these databases. A master database will contain customer information.
- **Functions**: handling booking, personal information, accounting.
- **Security**: secure information is mixed with common one. Personal data, transfer of money, information on booking need to be kept secure. Authentication of operator at terminal is needed.
- **Speed of response**: the requirements are variable, the "response time" of the customer at the teller being probably the dominant one. However, a low response time has economic benefits.
- **Consistency**: databases shall be kept up to date. the information is propagating out in loose fashion.
- **Availability**: variable. Some databases are to be accessed at any time, others only at office hours. Time zones might have an influence here. The cost of non availability of data is to be estimated.
- **Transactions**: Multi-site 2-phase commitment process handled as part of the application. Transactions subject to re-negotiation.
- **Threats**: Security, loss of data.

5.4 Application 4 - Intelligent network databases

5.4.1 Scenario

Telephone service is provided by a public switching telephone network (PSTN). Intelligent network databases (INDs) are an overlay network of databases over the PSTN. They provide the routing intelligence necessary to process calls related to special services (such as Freefone in the UK).

Destination number derived from translation of dialled digits for specific IND services may be under the control of the subscribing customers e.g. a call may be diverted to one of many telephone terminals depending on the service telephone number dialled, time of the day, day of the week and other considerations. Such data should be readily accessible to and updateable by the subscriber.

Access to IND from a PSTN is only possible via a special gateway PSTN node (telephone exchange), known as the access control point (ACP), on the PSTN.

An intelligent database would be exclusively dedicated to providing one or more of the IND type services. Since IND services are distributed among the IND nodes a particular IND is accessed by an ACP (located anywhere on the PSTN) for its services.

For reliability and maintaining the quality of the IND service, each intelligent network database is twinned with another database on the network. The twin operates in a 'hot standby' mode and takes over the 'work load' if the main database fails for any reason. Under normal conditions the output of the standby is constantly monitored by the 'active' database to check for discrepancy. When processing a call, no discrepancy should be detected if everything is functioning as it should. If a discrepancy is detected then some action has to be taken by the database network manager to resolve the problem. For some faults the action may be automatic while for others there has to be a manual intervention.

A single intelligent network database (IND) node will have three major communication interfaces:
- Interfaces to the PSTN for access and update to the customer data;
- Interfaces to other IND nodes;
- Interfaces to the network management function.

The PSTN access to INDs is for:
- customers updating data which is under their control;
- translation of the dialled digits for routing and destination.

The IND inter-node communication is for:
- the active 'hot' node to monitor output of the twin.

The network management function is for controlling the IND network and its resources. It communicates to the IND for:
- entering and modifying data in customer records;
- operational and maintenance requirements for the network;
- accessing billing information;
- operational and maintenance activities.

Thus there are times when requirement is for real time responses on each of these interfaces.

The advantages of an IND are:
- makes the telephone service more user friendly;
- allows customer control over the service data;
- providing for flexible, itemised billing facility;
- allows prevention and control of congestion on the PSTN.
- allows rapid introduction of new services on the PSTN;
- forms networks that are easier to upgrade than the PSTN (which can have hundreds of local and trunk exchanges).

5.4.2 Design characteristics

The system should have the following design characteristics:
- any ACP should be able to access any IND node for the services required by the caller;
- data on the standby node and the worker node databases need to be consistent. Data out of step with each other over short periods (24 hours maximum) may be tolerable;
- loss of data while exchanging messages between the IND and the PSTN is not crucial and may be tolerated but the data exchange between IND nodes and the management function must be very reliable;
- the system must be very tolerant of faults on the links to the PSTN, INDs and management controls and continue to offer a lower grade of service if necessary for as long as users require it;
- routine maintenance should be possible without taking the IND node totally out of service.

5.4.3 Characteristics of the application

- **Scope**: To design a network of intelligent databases as an overlay to the PSTN to provide new and value added services to the subscriber in an easily manageable and flexible way.

- **Motivation**:
  - to provide new services to the PSTN subscribers;
  - to provide a service to the customer where he can have responsibility for some of the service data;
  - to provide a flexible billing mechanism;
  - to provide a consistent user friendly front end service;
  - to provide an infrastructure capable of graceful evolution over a long period of times (decades).

- **System structure**: The network is part of a three tier structure.
  - The top layer is the centralised management function which monitors and controls the IND.
  - The IND is the middle layer;
  - The PSTN forms the last layer

  The telephone network is divided into a number of geographical regions, and typically an IND node is assigned per region. Thus the number of IND nodes is substantially lower than the PSTN, typically eight to ten database nodes.

  The IND services are divided and distributed amongst the databases according to the requirements. Each service is installed on two databases, one being a worker, the other a standby. Each of these databases carry a complete set of data necessary to provide the IND service concerned. Dedicated links are used between the management node and each of the twinned IND service databases providing a radial or star network topology Dedicated links are also used between the twinned databases.

  The links between the IND service databases and the ACP nodes on the PSTN are set up as and when the PSTN node identifies that access to an IND is required. There is sufficient intelligence in the PSTN node to translate the received dialled digits from the caller to determine which IND database is to be accessed. Existing dedicated links that have been set up between the worker and the twin database ensure that the twin also simultaneously receives all the data sent by the PSTN node.

- **Functions**: The following functions must be provided:
  - rapid response to ACP requests;
  - quality IND service with a minimum number of interruptions and/or lost calls;
  - built in redundancy in the system for reliable service and security.

- **Security**: No special requirements other than user identity and password. Access to the billing records needs very secure measures (see under 'threats' below).

- **Speed of response**: While the smallest possible system response time is desirable, the requirement relates to two aspects, feedback information to the caller to assure him; and actual time necessary to process the call.

  If the caller is assured by an announcement immediately upon end of dialling and at appropriate regular intervals that the call is being processed, then call processing need not be very fast and reasonable time delays are acceptable.

- **Consistency**: Data held by each of the INDs should be consistent with the data held by its twin for the pertinent service.

- **Availability**: The system must be available continuously round the clock, although the grade of service will vary from period to period. A lot of factors impact the availability and the grade of service. Some of these factors will be beyond the control of the IND system.

- **Transactions**: Transactions take place between an IND and the PSTN, the network management function and other INDs.

  The majority of transactions originating from the PSTN involve digit translation algorithms which are well tried and efficient. Such transactions are of short duration but the number of transactions is very high (i.e. high volume traffic).

The transactions between the IND and the network management are fewer in number by comparison. However most of these result in insertion of data, modification to data or data updates and so take longer to complete especially as they require co-ordination of data using 'two phase commit'.

- **Threats**: Since IND subscribers can change their own data relative to services such as 'call diversion', the onus is on them to take adequate steps to guard against threats to their data.
  The IND operator relies on data held in customer records, billing information etc. to generate his revenue. Separate interfaces are provided for access to these data and the communication is over dedicated links.
  Isolation of subscriber-controlled data from the IND operator-controlled data is achieved by providing separate specific interfaces for access to each. This minimises the threats to the system.

5.5 Application 5 - Telephone network traffic control

5.5.1 Scenario

This application deals with traffic control in a telephone network. This traffic control has an influence on the quality of the service: what is needed is a high success rate for dialling. There is a central node, collecting data from all the other nodes. This information is analysed, and used to re-configure the network when needed. The local nodes control (up to an extent) the local resources, in case of power down, for example.

The information is collected by local exchanges (local nodes), using traffic monitors, and transmitted at regular intervals to the central node. The database at the centre is not fully on-line, but the frequency of updates is sufficient.

The advantages are a better control of the traffic throughout the network, and a most efficient way of using the network. Customers and operators benefit from this.

Dedicated links are used between the data gathering nodes and central nodes, and therefore security access considerations do not apply.

5.5.2 Design characteristics

The data dumps take place at frequent intervals automatically and the decision of the central control is broadcast to the whole network.

Duplication of data can occur in this system through built-in redundancy, however loss of data is not that crucial, since polling takes place automatically and only statistical results are used.

Data are collected at a central node so that an overall picture of the status of the network can be obtained.

5.5.3 Characteristics of the application

- **Scope**: to handle data that is generated on the traffic in the network. All nodes regularly dump their data to central site. Analysis to get statistics which are kept for a longer period. At local exchanges when downloaded and received okay, then data overwritten.

- **Motivation** (see also above)
  - To use networks most efficiently and economically.
  - Timeliness.
  - Figures used for forecasting, e.g. no maintenance at peak period (charity appeals, football matches leading to high use).

- **System structure** (see also scenario)
  - Dedicated lines.
  - Show the hierarchies. Local exchanges, main exchange, trunk exchange, traffic monitors.

- **Functions** (see Scenario): Central node collects data from all nodes. Data are analysed. Decisions are taken. The network is re-configured according to decisions and information is disseminated.

- **Security**: Not critical.
- **Speed of response**: Not critical
- **Consistency**: Not that critical or not applicable.
- **Availability**: Twenty-four hours. Continuous. Not online. Collection plus dumping. Database of statistics plus local traffic data.
- **Transactions**: Not applicable.
- **Threats**: Not important.
- **Others**
  - Because dedicated networks, already done access control (when system set up).
  - Because telephone network a central control would have duplication. The central control would need to be more secure and have processors going all the time.
  - Reliability of all nodes not so important.

5.6 Application 6 - Electronic library

5.6.1 Scenario

An electronic library providing a range of integrated library and information services to the user.

This is a system used for a wide variety of applications ranging from cataloguing books, searching local and remote catalogues and other databases, managing loans, exchanging records and general management.

Users will range from data managers, specialist library staff, front desk staff, regular and casual library users. The system will be required to manage a significant amount of data, much of which is relatively stable. A key factor is the response time by the system not only for individual transactions, but also in responding when undertaking a search of a large database.

Confidentiality of search content and of financial information are among the security requirements.

There would be requirements for both real time interaction for immediate enquiries and grouping of less urgent transactions, such as catalogue updating.

There are currently no services which can be said to be fully integrated, but many which are integrated to a lesser or greater extent. Among these is the "Pike's Peak" Library in Colorado.

Services which may be available to the user are:
- access to local library services, including catalogue, reservation, inter-library loans, notice boards, local news, new additions, viewdata and internal databases.
- access to external bibliographic and non-bibliographic databases, viewdata.
- links to other local services, e.g. social, welfare, transport.

In addition, library staff would need to:
- maintain the catalogue;
- manage the reservation and inter-library loans system;
- edit and update the local databases and services;
- manage stock efficiently and effectively;
- move data between library databases;
- gather and analyse management statistics;
- interact with other services in other networks at a local, regional, national and international level.

Because of the range of users and uses there needs to be emphasis on user friendly interfaces (appropriate to the user ability).

Different users may require or be provided with different levels of service, one reason for this being that services which place a high cost/resource burden on the library, or have easily identifiable costs associated, are likely to have these charges passed on to the user.

5.6.2 Design characteristics

Characteristically there may be a variety of databases, possibly of different structures (e.g. bibliographic, numeric, chemical structures, "factual" e.g. hazardous substances coding) some may be distributed, some interlinked.

There would be a requirement for different levels of access, e.g. data manager, library staff, fee paying and non-fee paying public access, etc.

Catalogue transactions might include read, select record, identify location, request loan, update catalogue records, search external database and compare for new records, acquire and merge externally obtained records.

Transactions using other databases might include read, search, retrieve, manipulate, download.

Some database (particularly bibliographic) are not expected to yeld single non-ambiguous records in answer to a given enquiry. Search strategies might involve complex Boolean logic, and the result may be a set of records each of which may be more or less relevant to the search query.

Services acquired by the library incur costs. Dependent on the service some or all of the cost is passed to the user. This could comprise payment by the library for:
- external records;
- external searches;
- interlibrary loans.

The loans system relates together information on borrowers and their interests. Care has to be taken that there is no unauthorized access to this data for data protection reasons, and that such information is deleted after the transaction is complete, save for any de-personalised management statistics.

The system will manage links to external databases outside its control.

Bibliographic data can be roughly divided into two kinds, the formats for which although having common elements are a little different, either using different implementations of the same standard, or in some cases based on different standards. Hence as a rule records for monographic data can be found in catalogues, and records to articles from serial publications will be found in IR (information retrieval) databases. As a rule, catalogues represent local stock, and IR databases references to documents covering a specific subject not necessarily related to stock.

Whereas catalogues are usually updated on a continuing basis, IR databases are usually updated at discrete intervals. More IR databases are now being provided on CD-ROM.

Records in catalogues and IR databases are usually stable and not altered except to correct mistakes. Records will be deleted from local catalogues as a result of changes to the stock it represents. Older IR records are often transferred to archiving, but not deleted.

The catalogue may be duplicated and held locally for local access, online public access catalogues (OPACs) now being common.

The key transactions relate to loan of stock, and local transactions need to continue in the event of a system down. This process needs to be capable of operating on a stand-alone basis at the local access point.

5.6.3 Characteristics of the application

- **Scope:**
  - To maintain records of material held, material relevant to users, and records of use of material, and transactions regarding similar records with other appropriate organisations.
  - Synchronisation of records with the partners. Transaction response times. Length of "elapsed" transaction times. Records discarded when material related to is discarded, or when data "out of date" - purging of files. Importance of recovery or lagging of changes is less, except for loan transactions "circulation files". Potential for billing and charging for services offered.
- **Motivation:** Improve services to clients. Better management information. Better access to information. Central service points to user, more friendly user interfaces.
- **Systems structure:** A number of databases, some local, some remote, of varying database structure, text, graphic, numeric. The life span of data may vary. Means of updating may vary with regard to frequency, batch/online, and whether individual records are altered. Records originating from various locations, combined creation (include diagram) complex structure, variable length. Dealing also with full text, hypertext. Dialogue type of operation.
- **Functions**: Library / Information.
- **Security:**
  - access to personal information held on the circulation system;
  - confidentiality of search content;
  - surrounding billing, charging, payments;
  - loss of records relating to own stock a problem;
  - data duplicates held at another site.
- **Speed of response:**
  - Response times expected by the users. By design. Specified maximum response time.
  - Mixture of experienced (library staff) and casual users (library users).
- **Consistency:** database kept up to date. Can't guarantee uniqueness of records. Can't guarantee consistency of records. Database and stock not 1:1 relationship (e.g. walking books, weeding) like shop stock control.
- **Availability**: library opening hours.
- **Transactions**:
  - Different levels of users and uses;
  - Some transactions read only. A variety of transactions;
  - How updated if available on line 24 hours a day.
- **Threats:** misuse of public access terminals.

6 Analysis of applications

Analysis consists of looking at system characteristics against the description of applications provided in clause 5.

It is obvious that there are a number of perspectives that affect the system design and implementation. These perspectives are:

- company perspective;
- customer perspective;
- designer perspective;
- engineering perspective;
- hardware perspective;
- user perspective.

- **Company perspective**: this affects the system in that a strong case has to be made out for the motivation for and the need of the system to the company.
- **Customer perspective**: as the company would wish to provide some service(s) to its customers this perspective will have a considerable impact on the final system realisations
- **Designer perspective**: this perspective influences the system design since the system has to provide appropriate functionality and meet the requirements of the user.
- **Engineering perspective**: the choice of available technologies will limit the number of ways in which the system can be implemented. This perspective influences the technology chosen.
- **Hardware perspective**: the hardware chosen to implement the system will influence the way the system operates. In addition the hardware will dictate how the various functionalities can be implemented to achieve the optimum for the system.
- **User perspective:** in its everyday use, the people interacting with the system will have certain expectations of the system. These must be provided for, and hence these perspectives - much overlooked in the past by the designers, is equally important.

The following table shows various aspects of the system (used to describe the applications in clause 5) that are impacted by these perspectives.

Table 2- Impact of perspective on system aspects

Company perspective	Scope, motivation, security, consistency, transactions, threats.
Customer perspective	Motivation, functions, security, speed of response, consistency, availability, transactions, threats.
Designer perspective	Physical architecture, layout of the system, nature of interconnections, speed of response, consistency, distribution of functions, scope, system structure, functions, security, availability, transactions, threats.
Engineering perspective	Functions, security, speed of response, availability, transactions, threats.
Hardware perspective	Nature of interconnections, security, speed of response, transactions, threats.
User perspective	Layout of the system, nature of interconnections, consistency, distribution of functions, security, speed of response, transactions, threats.

The networks and databases provide a number of benefits and advantages:

- sharing of data and resources across the organisation;
- cost benefits through economy of scale;
- efficiency benefit through reduction in duplication and redundancy;
- consistency (data, data formats and standards) within the organisation;
- improved availability of data, resources and processing power throughout the organisation;
- enables common approach (interface) throughout the organisation;
- increase in productivity.

A number of disadvantages are inherent in this approach, i.e. networking and databases:

- strict security measures need to be installed;
- speed of response may be unacceptable under some circumstances;

- degree of control over all aspects of the system, in particular, communications, e.g. if other communications networks are involved;
- reliability may not be what was intended or expected;
- interworking and multi-vendor products may be a problem;
- lack of common standards and application programming interfaces compound the problem of achieving an open system;
- vulnerable to new threats.

On the whole, in the final analysis the benefits derived from networking databases outweigh the disadvantages.

7 Modelling considerations

The model that emerges for the networked databases is given below:

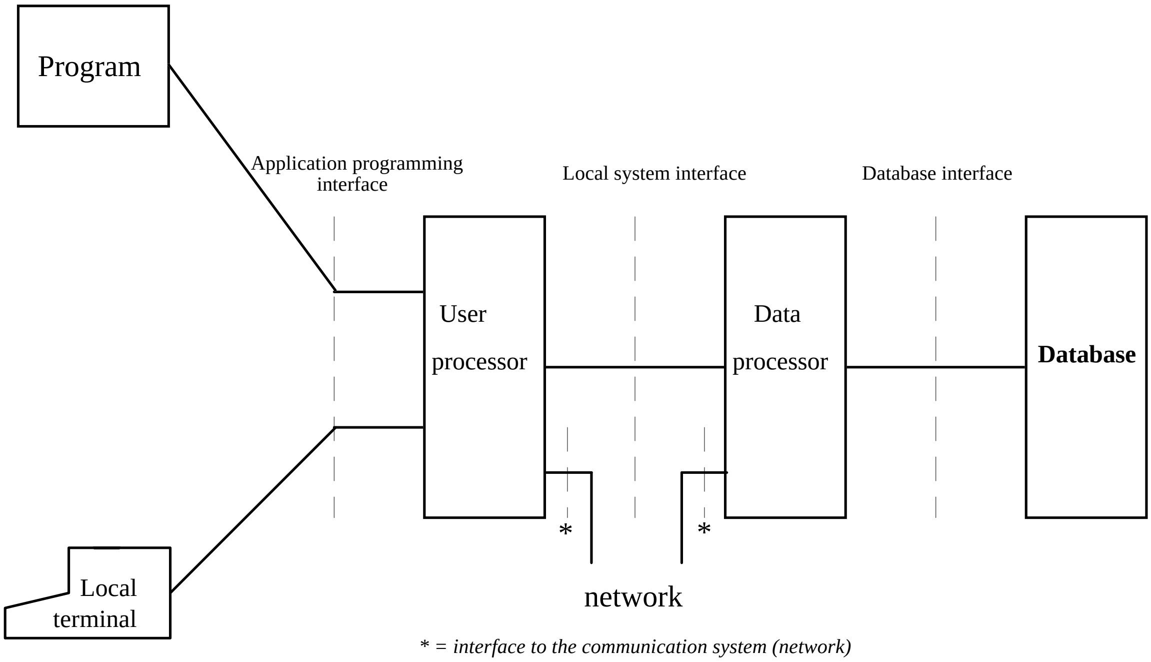

Figure 9 - Model for networked database

The number of interfaces could be reduced to a common standardised set. These are
- standard interfaces between user processors, data processors and communication systems;
- common user interface (APIS) to the UP and DB.

8 Implications for standardisation

The process of achieving international standards is driven by many factors:

- **Marketing**
  User have their requirements and that affects the market. In addition, whether vendors are prepared to meet these requirements or not also affects the market.

- **Political**
  The decision to go for networking of databases would be influenced by the investment in the technology already in use within a given organisation. vendors who are already developing products may try to influence standards to align with their own approach.

- **Commercial**
  The uptake of any new technology is very much dependent on the timing of the market, the degree of maturity of the new technology and the overall price.

- **Legal**
  This concerns the degree to which a new system may be compromised by new threats and gaps in the security. Moreover, the legislation may not be in step with what the new technology enables, e.g. data transfer across international borders.
- **New technology**
  Advances in development making previous technology obsolete e.g. object oriented databases and relational databases.

The progress of standardisation is hampered by these factors and consequently standardisation takes a long time. On the other side of the coin, lack of standardisation reduces progress of development of networking and databases. In particular, moves towards co-operative activities, which are very dependent upon agreed standards.

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