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REAL-TIME DATABASES IN TELECOMMUNICATIONS

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1 INTRODUCTION

Databases will, already in the near future, have an important role in telecommunication. The databases will contain the persistent and temporal information needed in operations and management of the telecommunication networks and services. Such databases exhibit stringent reliability, availability, and performance requirements.

Most of the recommendations issued in the 90's by ITU-T and other standardization bodies are object oriented. Therefore, object orientation is also a natural starting point for the telecommunications database system. However, current object-oriented databases are primarily designed for situations where objects have complex structures and transactions are long-living. In telecommunications the situations are different; most objects have quite simple structures and transactions are short. In addition, we anticipate that real-time properties, guaranteed response time in particular, are soon needed.

2 TELECOMMUNICATIONS SYSTEMS

In telecommunications there are currently several architectures that need database services. In this section we briefly introduce four of them: 1) Intelligent Network (IN), 2) Telecommunications Management Network (TMN), 3) Telecommunications Information Networking Architecture (TINA), and 4) the third generation mobile systems (UMTS and FPLMTS/IMT-2000).

2.1 Intelligent Network

The reference model of Intelligent Network (IN) has four planes of which the Distributed Functional Plane (DFP) is the most important one in database design. The DFP defines the functional entities that constitute the IN functional architecture. The functional entities and their relationships that are of interest in the database design are: 1) the Service Control Function (SCF) is responsible of IN service control; 2) the Service Data Function (SDF) is responsible of IN data management; and 3) the Service Management Function (SMF) is responsible of IN management functions.

The SDF is responsible for real-time access and maintenance of global network related data. IT is a data server for SCFs that provides the functionality needed for storing, managing, and accessing information. Thus it offers regular data management services but not necessarily database management services. The following five basic types of database operations needed in the IN Capability Set 1 (CS-1) have been identified [1]:

1. Retrieval of structured objects from persistent subscriber data objects. Some of the retrievals trigger a later update. An example is the Freephone Service with option to provide routing statistics to the subscriber.
2. User management actions that modify persistent subscriber data objects. These actions must be protected against unauthorized use. Some updates may also have to be verified against other criteria. For example, the subscriber must have the possibility to cancel or prohibit call forwarding to his or her phone number.
3. Verification of Personal Identification Number (PIN). For security reasons the PIN verification must be done in the database system when services are globalized. The actual PIN cannot be delivered into a foreign network.
4. Writing sequential log records.
5. Mass calling and Televoting. They need high-volume small updates that must be serialized. A special aspect of these updates is that they can be done in large blocks.

It should also be noted that IN CS-1 defines the data distribution to be hidden from SCF. This implies that every database providing the functionity of the IN SDF is a member of a large distributed database. Detailed description of database access in Intelligent Networks can be found in [2].

2.2 TMN

TMN or Telecommunications Management Network (ITU-T Recommendations in M.3000 Series) is a generic architecture to be used for all kinds of management services. TMN is based on the principles of the OSI Management (ITU-T Recommendations in X.700 Series).

The fundamental idea in the OSI Management is that the knowledge representing the information used for management is separated from the functional modules performing the management actions. OSI Management is based on interactions between management applications that can take the roles of *manager* and *agent*. The interactions that take place are abstracted in terms of *management operations* and *notifications*. Management activities are effected through the manipulation of *managed objects* (MOs).

An agent manages the MOs within its local system environment. It performs management operations on MOs as a consequence of management operations issued by a manager. An agent may also forward notifications emitted by MOs to a manager. The agent maintains a part of the *Management Information Tree* (MIT), which is a dynamic database. The MIT contains instances of MOs organized as a hierarchical database tree. In brief, the principles of OSI Management (and TMN) require that the database system contains the functionality of an OSI Management Agent.

2.3 TINA

TINA-C, a worldwide consortium developing the Telecommunications Information Networking Architecture, has the goal to define and to validate an open architecture for future telecommunications services. The architecture is based on distributed computing, object orientation, and other standards and recommendations in telecommunications and distributed processing fields, especially Open Distributed Processing (ODP), Intelligent Networks (IN), Telecommunications Management Networks (TMN), Asynchronous Transfer Mode (ATM), and Common Object Request Broker Architecture (CORBA).

The focus in development of TINA architecture has been on information and computational viewpoints. Therefore, the database requirements are not (at least in public) examined in details. The distribution in TINA is based on ODP (ITU-T Recommendations in X.900 Series) and CORBA, , both of which relies on object-orientation. Therefore, TINA needs a storage for persistent objects, that is an object-oriented database supporting ODP transparencies. Moreover, when telecommunication services based on the TINA architecture are in operation, the access to persistent objects must be fast. In the current public TINA-C documentation real-time is not mentioned but the inclusion of IN functionality implies that also TINA requires real-time features. As an external interface the database system must support the object invocation mechanisms of CORBA and communication through an ODP channel.

2.4 Third Generation Mobile Networks

Today, the specification of the third generation mobile networks is very active. These networks will rely on IN services supporting multimedia applications. Such systems are the Future Public Land Mobile Telecommunication Systems (FPLMTS) [3] and Universal Mobile Telecommunication System (UMTS) [4].

The mobility specific control functions that UMTS needs are planned to be available in the IN Capability Set 3. While IN CS-1 services use mostly read operations on IN databases, UMTS functions also frequently update the database. Access delay to the data is of crucial importance.

It is anticipated that future mobile systems, such as UMTS, will generate 7–8 thousand real-time query transactions per second in a regional calling area and 7–8 thousand real-time updates per second in a regional calling area. In addition, the performance and reliability requirements are stringent. For 96% of queries the response time should be 150 ms or less. The response time of updates should be 1–3 seconds. The availability should be7 days a week and 24 hours a day and practically no downtime at all. [5]

The main functions of UMTS database services are: 1) the basic functions that provide read and write access, 2) to locate the requested data within the database, 3) to move data to locations close to the user when the user has roamed in order to provide fast access in locations where data is frequently used, 4) to provide mechanisms that ensure the integrity and reliability even when data is copied between locations and possibly duplicated, and 5) to ensure that data is only accessed by entities that have been authorized to do so.

3 KEY DATABASE REQUIREMENTS

If a database only supports CS-1 service logic programs, a good choice would be a distributed relational database that is fault tolerant and that is primarily tailored for reads and writing sequential log records. However, the future trends give new functional requirements. Below we summarize the key requirements including *data distribution, data replication, object orientation, object directories, multiple application interfaces, fault tolerance,* and *real-time transactions.*

Data distribution. A set of database nodes may cooperate to accomplish database tasks. A node may request information from other nodes in case information needed is not locally available. It is possible to implement the underlying database system without data distribution. In such an implementation all applications use a single database server. This differentiates logical data distribution from physical data distribution among database nodes. The former is necessary but the latter is a decision internal to the design of the database architecture. Our current belief is that only a few requests need access more than one database node.

Data replication. It is stated in ITU-T Recommendation in Q.1204 that a database node contains customer and network data for real time access. We believe that currently most distributed operations are reads. Therefore, replication is an effective way to speed up distributed operations because it gives better throughput.

Object orientation. It is a common belief that the best long term telecommunications architectures are object oriented. The implication is that a database system must support object access. In other words, the database system must either be object oriented or have an object interface.

Object directories. The conceptual model of IN Service Control Function (ITU-T Recommendation Q.1214) defines a Service Data Object Directory that is used to access data stored in the SDFs. This implies that object directories must be supported. The invocation mechanism of CORBA is a good alternative to implement the functionality.

Multiple application interfaces. In telecommunications different architectures define different access interfaces. The IN Capability Set 1 defines IN Application Protocol (INAP). TMN has its own access methods based on the OSI (X.700) management protocols. The current definition in TINA is based on TINA ODL which is quite similar to the OMG IDL interface. Therefore, OMG

IDL interface is also needed. In addition, OQL interface—probably without response-time guarantees—would be convenient for ad hoc queries and database maintenance.

Fault tolerance. Real time access implies that data must be continuously available. The result of the implications is that the database system must be fault tolerant. In the current definitions the maximum allowed down time is a few seconds a year.

Real-time transactions. Although the real time data access as stated in ITU-T Recommendation Q.1204 does not directly imply that the underlying database system must support real time transactions, we believe that the most convenient way to support real time access to data is to use a real-time database system. In telecommunications we will need both soft and firm transactions. We do not believe that hard transactions will be used in near future because systems supporting hard transactions are too expensive for open telecommunication markets. Detailed discussion can be found in [6].

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