Integrated Monitoring and Control: A New Approach

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This article presents the architecture of a new integrated monitoring and control system that has been implemented for several of the ground-segment subsystems involved in the processing and dissemination of the vast quantities of data produced by the Agency's ERS satellites.

Introduction

The System Monitoring market has evolved dramatically in recent years, due mainly to the need to guarantee the quality of a service to the users. Whilst in the early 1990s almost all system monitoring was performed using specially designed and proprietary software, with the evolution of networks and network-management tools industry has now developed a wide offering of Monitoring and Control (M&C) products and consolidated standards.

A series of technological and infrastructure projects run at ESRIN since 1995 have shown that the commercial network-management tools and standards fully satisfy not only the network-monitoring requirements, but also those related to the platform and higher level applications resources. This results from the commonality of requirements in the M&C area regardless the type of information handled.

Following this trend, some of the original M&C subsystems of the European Remote-Sensing Satellite (ERS) ground segment have been replaced with a new system called 'MIMS' (Multi-mission Integrated Monitoring System). MIMS monitors internal subsystems, the Internet servers of the Earth Observation User Services at ESRIN, and the outsourced commercial telecommunication links used in the ground-segment network. One of the applications monitored is the ESRIN Interface Sub-Set (ISS), an application whose main task is to provide data-exchange services (at file-transfer level) between the various ERS ground-segment entities (facilities).

Integrated monitoring and control in the exploitation of Earth-observation satellites

High-level indicators of Quality of Service (QoS) guide the exploitation of Earth-observation missions. The types of indicators used range from processed-data availability, to mission-planning performance. Their continuous monitoring and control is essential to guarantee the desired quality of service, provide early warnings of critical situations, prevent adverse impacts on the mission, and facilitate tight control over any anomalous situation that might arise.

The QoS indicators are used to monitor a series of heterogeneous systems, starting with the satellite and its payload and ending with the various ground-segment subsystems. A traditional M&C environment based on each subsystem's functionality allows only a scattered collection of information, which means that the synthesis of the overall QoS status remains difficult. Continuous monitoring of mission QoS can be only performed through an Integrated M&C environment, in which data is collected by a system with a specially conceived, and thereby unique architecture. Information can then be made available to operators and administrators directly involved in the maintenance of any ground-segment subsystem, as well as the managers of the overall exploitation activity.

In summary, the Integrated M&C system is essential for a complex ground segment in order to efficiently:
– highlight any anomaly for corrective action
– detect the cause of a problem, avoiding parallel investigation by different subsystem managers
– support the configuration-control and anomaly-handing tasks
– collect activity and status information to provide a graphical status representation and activity statistics.

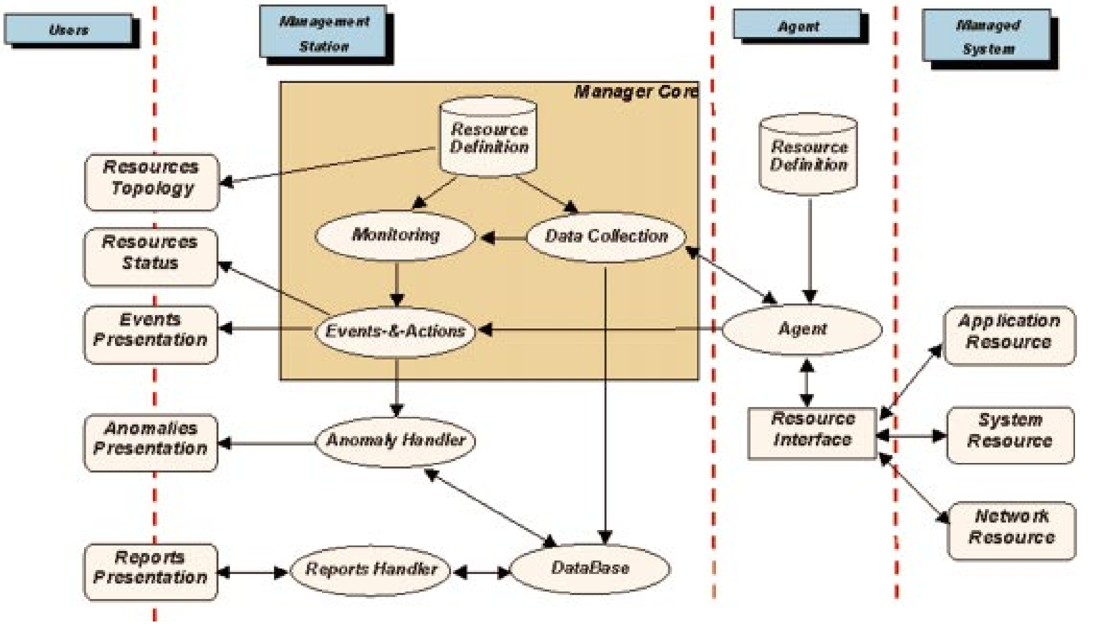

Figure 1. M&C functional model

The performance required of such a system and the complexity of the environment in which it must operate represented the main challenges during the MIMS development.

M&C functionality

MIMS is accessed and distributes information to users mainly via a World-Wide Web (WWW) interface which shows the topology of the ground-segment elements being managed and resource status as coloured icons. It also provides warning messages (e-mail, pop-up windows and event browser interface) to the operators to flag asynchronous events.

The key concept of MIMS is to gather together as much system status information as is required to furnish a reliable picture of the operational situation of the ground-system components. This information is collected from the managed systems through M&C 'agents' and stored in a database for further analysis and presentation.

The MIMS Manager is the set of components providing central system management functionality. Its main functions are to:
– provide the user interface
– host the Management Information Base (MIB)
– interface the agents in the managed systems
– collect and store managed object data from the agent
– handle and store the asynchronous events
– handle and store anomalies
– generate statistics.

Object status definition and representation

Each monitored object has been represented by a set of maps and related sub-maps. The maps contain symbols (icons) that can be associated with a more detailed sub-map or an object resource (Fig. 2). This approach allows a hierarchical presentation of the managed objects, showing an increasing level of detail. Different maps can be used for defining different management regions, or for different presentations of the same management region. Multiple sub-maps can be displayed at any given time. The status of objects is represented by different colours with, for example, green showing good behaviour, meaning that all attribute values – disk mounted, occupation under a configured threshold, failures etc. – are nominal. An icon turning red indicates that an abnormal attribute value has been detected; double clicking on that icon will then show a dialogue box with the exact status of the item concerned.

Data collection and agent interface

The MIMS Manager and its agents support several protocols and interfaces. The standard interface is SNMP (Simple Network Monitoring Protocol) for IP networks, but the interface capability has been enlarged by a management link to CORBA (Common Object Request Broker Architecture) objects and integration of BMC's PATROL. The SNMP data collection is guided and controlled by the manager and it is intrinsically 'value-oriented': the manager system can obtain the value of a variable on the managed system and start configured actions depending on the sampled value. MIMS has implemented enhanced data-collection management, i.e. using logs, activity reporting, etc., and a collection database. SNMP's simplicity and minimal impact on the data transportation media makes it very useful for continuous monitoring, since the network is not loaded by the management traffic as it could be in the case of a CORBA-based monitoring, allowing a tight control on the application behaviour. SNMP is also useful for alarm-

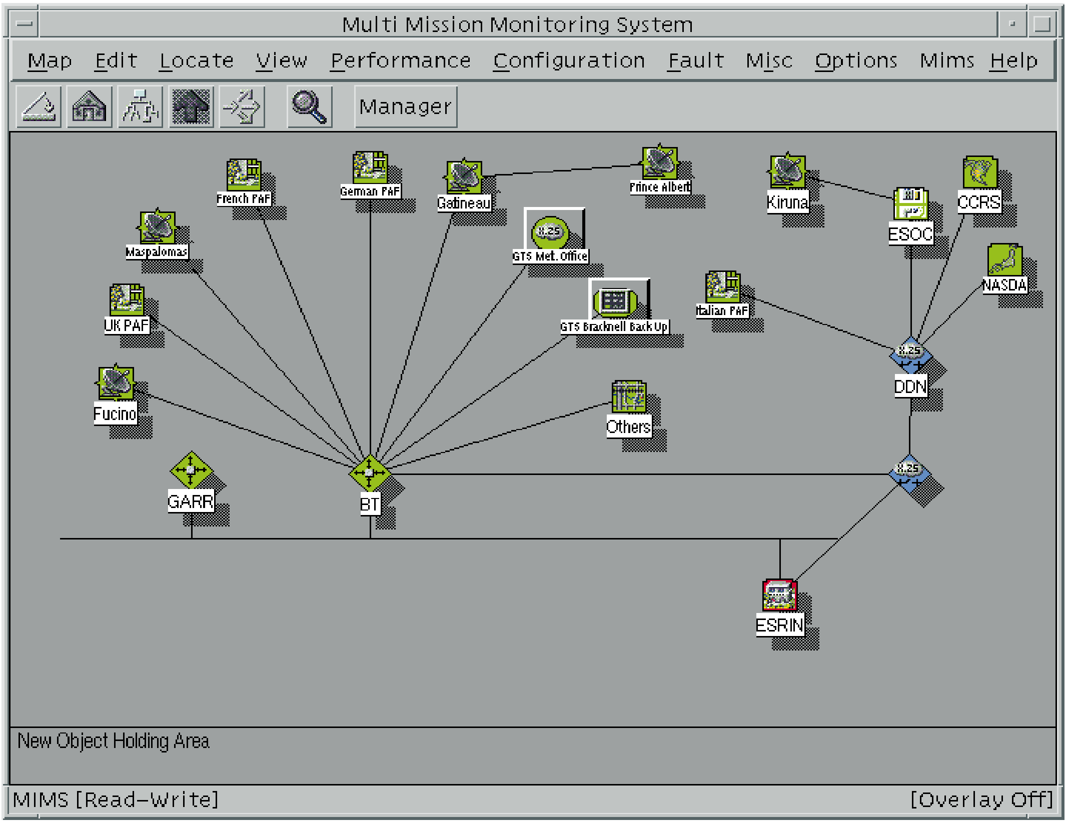

Figure 2. MIMS user-interface sample: Map Browser for managed objects

sending in case of a resource crisis (disk full, network collapsing, etc.).

CORBA in the MIMS infrastructure

CORBA is an emerging standard for distributed infrastructure architectures, and as a consequence also in monitoring and control environments. CORBA and the CORBA collector are an experimental component within the MIMS monitoring architecture. CORBA agents can complement SNMP because they can be highly autonomous.

CORBA specifies a system, which provides interoperability between objects in a heterogeneous, distributed environment and in a way transparent to the programmer. Its design is based on the OMG Object Model. The latter defines common object semantics for specifying the externally visible characteristics of objects in a standard and implementation-independent way. In this model, clients request services from objects (which will also be called ‘servers’) through a well-defined interface. This interface is specified in OMG IDL (Interface Definition Language). A client accesses an object by issuing a request to the object. The request is an event, and it carries information including an operation, the object reference of the service provider, and actual parameters (if any). The object reference is an object name that defines that object unambiguously.

The ORB Core is the most crucial part of the Object Request Broker: it is responsible for the communication of requests. The basic functionality provided by the ORB consists of passing requests from clients to object implementations.

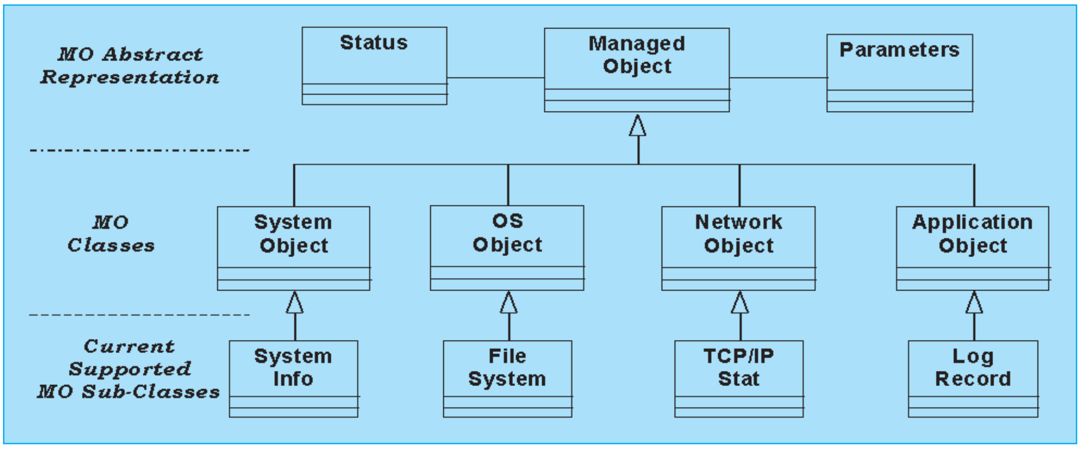

Figure 3. CORBA Managed Objects (MOs)

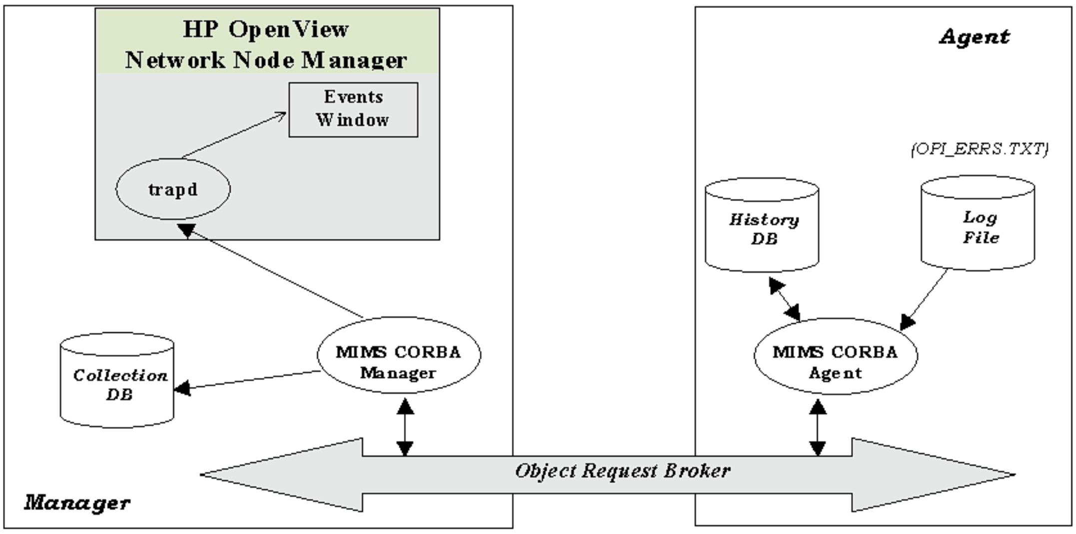

Figure 4. CORBA log-file manager-agent architecture

In the present MIMS CORBA Managed Object (MO) architecture (Fig. 3), any resource is represented by a general (abstract) object, i.e. an object of class MO (as reported in the model). Each of these objects has associated with it a number of parameters (depending on the type of resource) and an operational status.

While a MIMS CORBA-based agent needs to create the specific object type (FileSystem, LogRecord, etc.) in order to interface the resource (a file system, a log record, etc. – see Fig. 4), the manager only needs to have its abstract representation provided by an object of class MO. This approach allows the CORBA-based manager to have a common representation of all resources managed by the agents and the possibility to act on them in a consistent way.

CORBA's usage in MIMS is still considered an experimental infrastructure. The potential benefits of its distributed-object architecture within application-management systems are being evaluated and the correct engineering approach to the modelling of managed objects must be consolidated.

Event and anomaly handling
The SNMP Manager can also receive and processes asynchronous event messages as SNMP traps. The collector can also perform a threshold-based check on the collected data and internally generate an asynchronous event (Fig. 5). This will start user-defined actions if the received value is above a configured threshold, or if it returns below it. The M&C system is configurable to automatically insert an anomaly report into a database as soon as a certain abnormal situation is detected. The operator/manager should complete the report afterwards with remarks and solution proposals. The database contains an abstract and description of the problem, mission affected, downtime, related anomalies from other sources and more.

Statistics generation
The generation of exploitation activity statistics and reports for Management is an important task of the exploitation staff. The manual generation of such reports requires considerable effort. MIMS automates this task and efficiently produces high-impact reports based on templates and the collected data, every month, week, day or on request (Fig. 6).

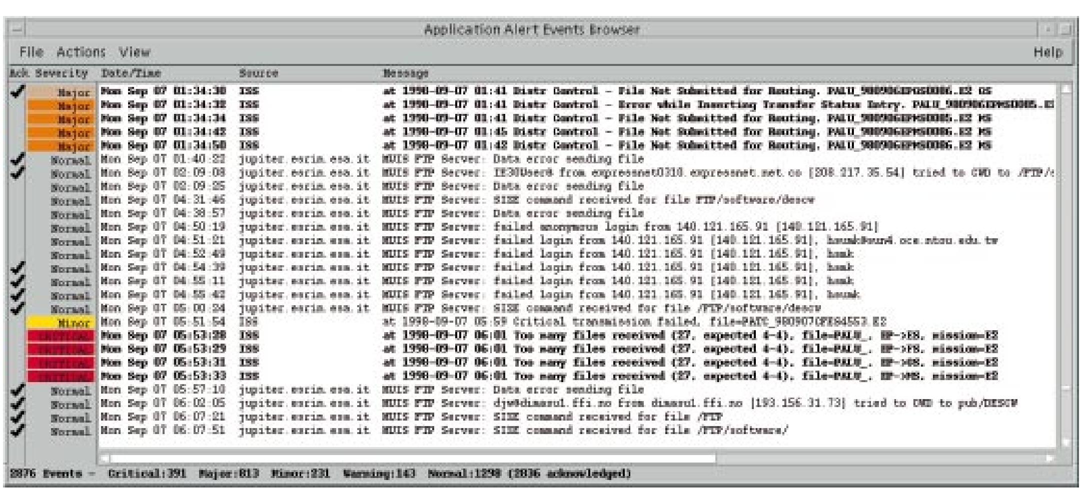

Figure 5. MIMS user-interface sample: Event Browser

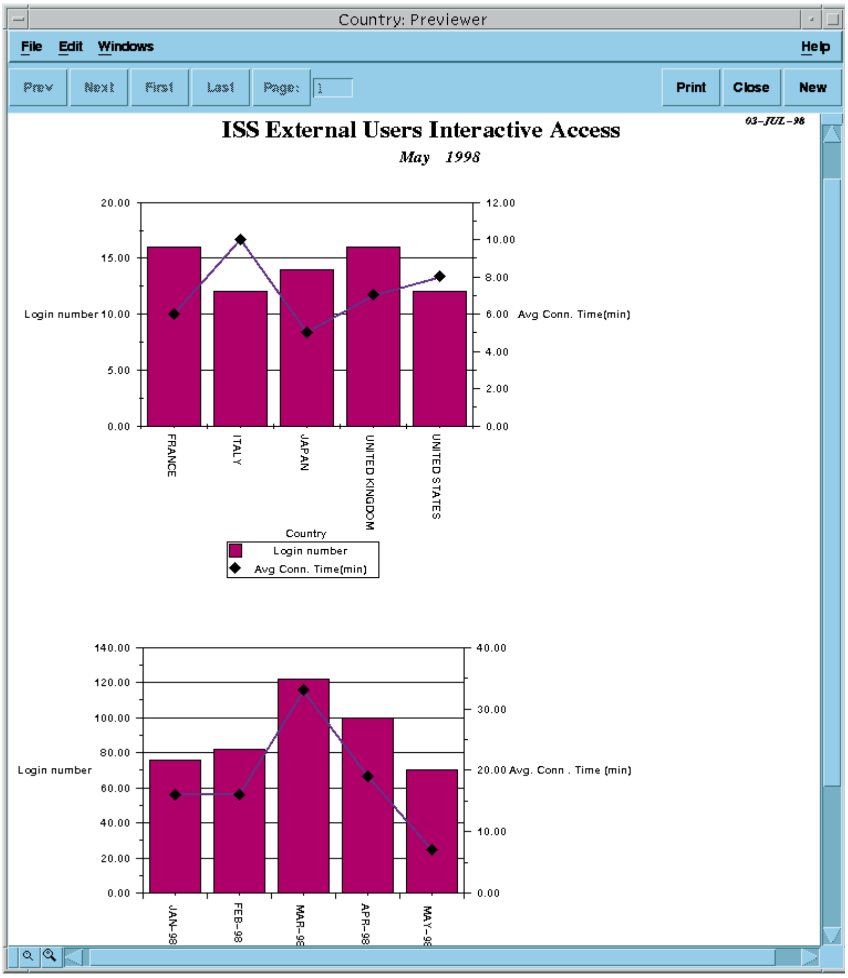

Figure 6. MIMS user-interface sample: Report Generator

Architecture

As noted in the introduction, an essential aspect of MIMS is the integration of commercial software packages. Figure 7 shows the various interacting components:

- HP OpenView Network Node Manager (basic MIMS basic management functionality set, such as IP network devices and interfaces discovery, SNMP protocol-management station, managed-objects representation through hierarchical configurable maps, event-handling infrastructure, SNMP data collection, simple collected data-analysis capability)
- HP OpenView SNMP Extensible Agent (SNMP agent for Sun/Solaris systems)
- DEC-OpenVms SNMP Extensible Agent
- BMC's PATROL Management Suite and PATROL View (integrated in the HP-OpenView NNM provides a number of user interfaces to the remote objects interfaced by the PATROL Agents/Knowledge Modules installed in remote systems)
- BMC's PATROL Agent/ORACLE Knowledge Module (together with the PATROL View installed in the MIMS management station, it provides the infrastructure to monitor the CUS Oracle instance)
- IONA's Orbix and OrbixTalk (IONA implementation of the CORBA 2.0 standard adopted by MIMS for interfacing the UK ERS Processing and Archiving Facility (PAF))
- ORACLE Server and ORACLE Reports (archive system for collected data and enhanced reporting capabilities)
- Remedy's Action Request (anomaly tracking functionality).

Core components

The network-management product HP-OpenView NNM has been put at the core of MIMS. The main characteristics are:

- MAP system: is the standard NNM view of the monitored object status.
- Data Collector: data is collected from the Agent systems via a SNMP Collector element. It polls, under user configuration (for each managed object from which data is to be retrieved), the Agent systems (get requests) and stores the returned managed

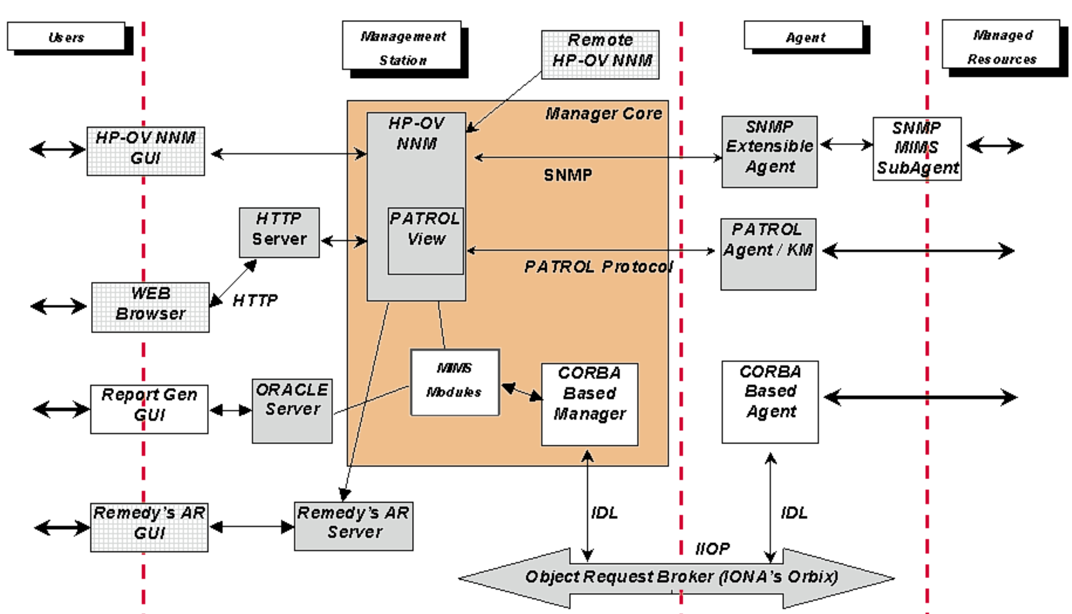

Figure 7. MIMS architecture

object value in a flat-file repository. Data collection presents the following functionality:

- frequency of the get requests
- thresholds can be set for the value of the retrieved data; if the value retrieved is not within the defined threshold, an event can be configured to which an action is associated, and the action can be an OpenView task (such as a change of the colour of a symbol in the MAP) or a user-defined action (such as to send an e-mail to a user list)
- user-defined algebraic (and hence if necessary also logical) expressions which provide a means of generating higher level parameters
- collected data-analysis tool: a graphical tool is provided with the standard HP-OpenView NNM, which allows one to display the collected data values over time
- SNMP browser: a user window interface through which it is possible to navigate on the loaded MIBs in order to get (or set on the write-access variables) managed systems SNMP MIB variables.

The design of the event-collection and storage sub-system is shown in Figure 8.

Extensible SNMP Agent

The HP-OpenView Extensible SNMP Agent software includes a master Emanate Agent and three subagents (HP-UNIX subagent, MIB-II subagent and the Extensible Agent subagent). The master agent implements the SNMP communications stack and protocol (SNMP manager-agent interface) and the interface mechanism with the subagents. The MIB-II subagent implements the SNMP MIB-II standard, which provides interfaces to system and network variables to be managed in the agent host. The HP-UNIX subagent provides system information such as the number of UNIX processes currently running, or the percentage utilisation of each file system. The third component (Extensible Agent) allows one to develop subagents for any resources.

Hierarchical manager- to-manager communication

The ERS ground system makes use of outsourced network services via the ESRIN network infrastructure support. A manager-to-manager communication, using the SNMP trap mechanism, was chosen to link MIMS to relevant status messages of the external commercial network services. This allows anticipation and detection of data-dissemination and connectivity problems.

Conclusions

The MIMS project has provided a practical demonstration that commercial network-management tools and standards can satisfy the stringent applications monitoring and control requirements of complex space projects. Several major achievements have been recorded:

- the high efficiency of the system development effort, achieved by the integration of commercial off-the-shelf tools, customisation and configuration for the ground-segment managed objects
- reduction of the efforts needed to add a new sub-system to the monitoring environment
- the high system modularity, allowing simplified replacement of any of its components.

Use of these new-generation network-management tools for the mission-critical tasks in the ERS satellite ground segment has been a positive experience. Currently, additional ERS ground-segment systems located at ESRIN are therefore being integrated into MIMS. esa

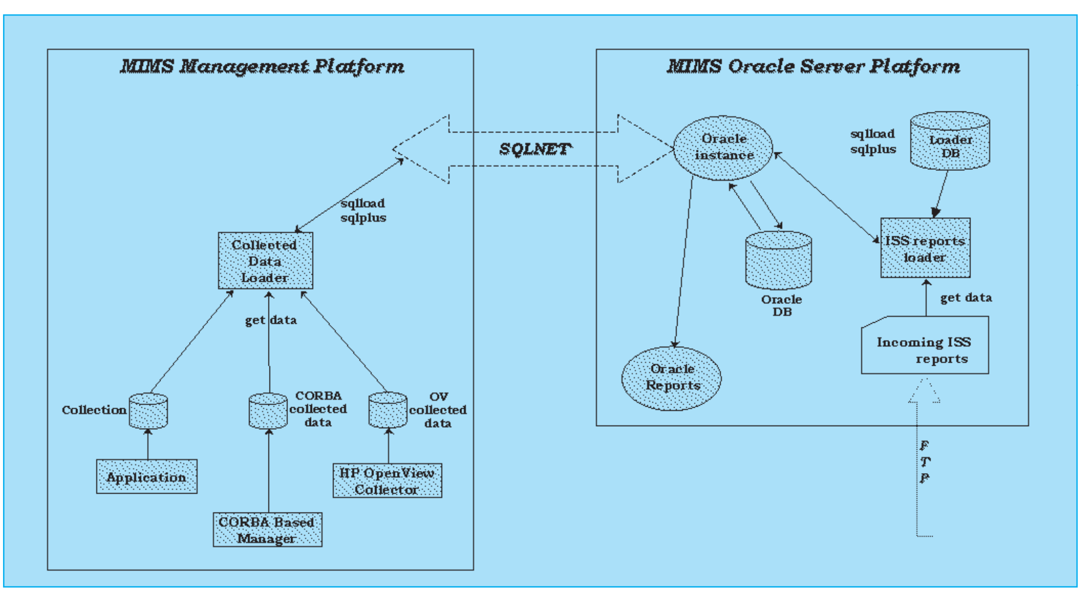

Figure 8. Event collection and storage sub-system