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COSMOS-3: The Third Generation Telescope Control Software System of Nobeyama Radio Observatory

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Abstract. COSMOS-3 is the third generation telescope software system of Nobeyama Radio Observatory, which was designed to control and to monitor the 45 m telescope and Nobeyama Millimeter Array and to acquire observing data from receiver backends.

COSMOS-3 is functionally divided into three layers. Tools at the top layer provide user interfaces for many kinds of observing requirements and various displays of observing results and system monitors. There are MANAGER and MERGER at a middle layer, which control message/data flow between upper layer and lower layers. At a bottom layer, there are many Local Controllers to communicate with each device.

For flexibility and system stability, COSMOS-3 has simple communication interfaces between different layers and no direct connection between subsystems at the bottom layer. For non-expert software engineers, it provides a wrapping mechanism at the bottom layer which makes it easy for non-expert people to develop Local Controllers.

1. Introduction

The Nobeyama 45 m telescope and Nobeyama Millimeter Array has been operated since 1982 at Nobeyama Radio Observatory (NRO), National Astronomical Observatory Japan (NAOJ). COSMOS (*C*ontrol and *O*peration *S*oftware system for *M*illimeter *O*bservation*S*) is the control system for these telescopes, which has evolved from a centralized mainframe architecture to the current hierarchical distributed system running on a distributed environment of workstations and PCs (Morita et al. 1995).

COSMOS was expected to be used for both the single dish telescope and interferometer. Therefore, it must control and monitor a wide range of instruments, and various kinds of observing modes should be available for use by observers.

The first and second generation systems (COSMOS-1 and COSMOS-2) basically had centralized architectures based on IBM compatible mainframe hardware. To realize realtime performance on the mainframe environments, these system were complicated and not flexible. Therefore, it was not easy for maintenance and it took a long time to add new instruments to the system. To overcome these defects, COSMOS-3 has been developed since 1995. That was when NRO replaced the computer hardware with a network of workstations and PCs.

2. Concepts of COSMOS-3

Design goals of COSMOS-3 are to improve flexibility, reliability, and user friendliness. COSMOS-3 runs on the new hardware system. To achieve these goals, we designed the system based on a three layered hierarchical architecture as shown in Figure 1. Important points of this design are:

- The top layer provides user interfaces,
- The middle layer controls message and data flow between layers,
- The bottom layer is directly connected to telescope instruments,
- Sequence control at the middle layer is done by a simple script generated at the top layer,
- There is a simple interface between layers, and
- There is no direct connection between modules in the bottom layer.

3. Architecture

3.1. Top Layer

Modules in this layer are for preparing the observing sequence and monitoring observing status with a user friendly interface.

Communication with the observing system is quite different between the 45 m telescope and NMA. Therefore, we have used different modules for the 45 m telescope and NMA.

There are several tools for preparing observation preparations in a scripting language (OBSTBL) with GUI's for each telescope and various observing modes.

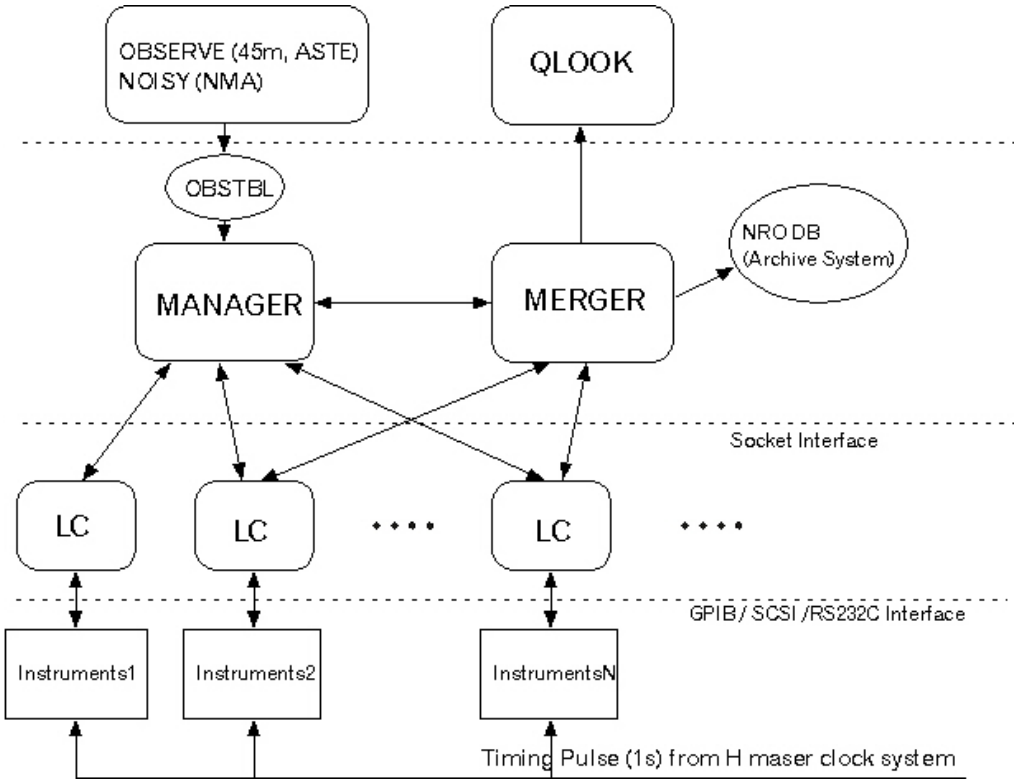

Figure 1. COSMOS-3 three layers hierarchical architecture.

3.2. Middle Layer

This layer consists of MANAGER and MERGER. MANAGER is a concentrator for control information flow. MANAGER reads, checks, and expands an OBSTBL. Then, according to the expanded OBSTBL, it sends control messages to requested Local Controller (LC) at appropriate timing. MERGER receives backend data and monitor data from LCs and generates archive data or QLOOK data.

3.3. Bottom Layer

At the bottom layer, there are many LCs, which are directly connected to telescope instruments mostly via GPIB. An LC analyzes each message from MANAGER, converts it to device commands if necessary, and sends it to the instrument with timing accuracy of about 50 msec. For exact realtime operation, a 1 second timing pulse from H-maser clock system is distributed to each instrument. The system provides a wrapping mechanism for simple PC programs. Instrument developers do not need expert software skills to make LCs for their instruments.

4. OBSTBL: A Simple Scripting Language for Observations

Observing sequence information for MANAGER is written in OBSTBL, which is a simple scripting language. Observing preparation tools in the top layer automatically generate OBSTBLs for typical observing modes according to a few input parameters from observers. In the case of special observing modes, experienced observers can directly write their OBSTBLs with editor tools.

As an example, a simple position switch observation is as follows:

```
OPEN ANT         % <-- Connect to Antenna LC.
OPEN AOSW        % <-- Connect to  AOS backend LC.
SET ANT TRK_TYPE 'RADEC'
SET ANT SCAN_COOD 'AZEL'
SET ANT SRC_POS (149.645883,55.920967)
SET AOSW INTEG_TIME 20
EXECUTE ANT OFFSET(0.00, 0.00)  % <- Start antenna tracking.
WAIT_READY ANT                  % <- Confirm antenna tracking.
REPEAT 10        % <-- Start of the switching loop.
    EXECUTE ANT OFFSET(0.00, 0.00)
    WAIT_READY ANT
    EXECUTE AOSW                % <- Start backend integration.
    EXECUTE ANT OFFSET(0.05, 0.00)
    WAIT_READY ANT
    EXECUTE AOSW
REPEAT_END       % <-- End of the switching loop.
CLOSE ANT        % <-- Disconnect with Antenna.
CLOSE AOSW       % <-- Disconnect with AOS.
```

5. Summary

COSMOS-3 is the third generation telescope operation software system at NRO, which was designed based on a three layered hierarchical architecture. In about five years of operation at Nobeyama it has showed its excellent performance and reliability. Recently we have started to use a modified version of COSMOS-3 for remote operation of a new sub-millimeter 10 m telescope in the Atacama desert in northern Chile.

References

Morita, K.-I., et al. 1995, in Telescope Control Systems, ed. P. T. Wallace, Proc. SPIE Vol. 2479, 70