Design for the Control and Data-Acquisition System for the TAMA300 300m Laser Interferometer

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Abstract

A five-year project, "TAMA300", was started in 1995. The purpose of the project is to construct a 300m laser interferometer in Tokyo to search for gravitational waves. The studies of the control and the data-acquisition system for TAMA300 have been carried out and a conceptual design is presented. We are evaluating an EPICS system for devices which are well distributed along the interferometer arms and need to be supervised at a rate of 1–100 Hz. We also need a data-acquisition system with high-speed ADCs to record 14 interferometer signals at the rate of 20 kHz. In addition, we are investigating a scheme to merge the signals from both the EPICS and the data-acquisition systems into a raw-data archiver. The scheme includes a data server to provide sampled data for online analysis.

I. Introduction

Although the existence of gravitational waves is predicted by the general theory of relativity, there has so far been no direct observation. Much effort has been put at many places in the world into the direct detection of gravitational waves.

Recent interest has been concentrated on long-baseline laser interferometers [1]. Virgo (the French-Italian project to construct a laser interferometer with 3-km arms in Pisa [2]) and LIGO (two interferometers with 4-km arms in Washington and Louisiana [6], [7]) are typical examples, which are now under construction and are expected to make their first observations in 2000 or 2001. In Japan, a five-year project, "TAMA300" (Tokyo Advanced Medium-scale Antenna), was started in 1995.

The aim of the TAMA300 project is to construct a 300-meter laser interferometer in Tokyo [9]. Though the TAMA300 has a shorter baseline compared with the other km-size interferometers and accordingly less sensitivity, it has two significant advantages. First, the operation of TAMA300 is expected to start in 1998, which is earlier than other projects. Second, the location of TAMA300 in Asia is quite important to complete the world-wide coverage with gravitational antennas, since coincidence studies between separated interferometers are necessary to determine both the direction and phase of the arriving gravitational waves.

Some studies concerning the control and data-acquisition system for large interferometers have already been carried out. The Virgo group has studied control, monitoring and data taking systems [3], [4] as well as a simulation code [5]. For the LIGO project, a system called CDS (Control and Data System) has been developed to control interferometers and to manage various data [8]. We also carried out early studies of interferometer control systems in 1991 [10], [11].

In order to develop a control and data-acquisition system for TAMA300, we started a collaboration between NAO, KEK, ISAS and ICRR in 1994. The primary aims of the system are as follows:

a) data acquisition for interferometer signals with a 20-kHz sampling rate
b) remote control, monitoring and data logging of interferometer devices
c) online pre-analysis for gravitational-wave candidates.

Although the systems used for offline analysis and the simulation of gravitational signals are also of interest, they will be discussed elsewhere in the future.

II. Signals to be recorded

As a first step, we discuss the signals to be recorded (or at least monitored). Signals can be divided into two groups: The first group contains the high-rate signals. Interferometer signals, laser signals and signals related to online analysis belong to this group. Since the shapes of gravitational waves may have a structure with components of up to a few kHz, we have set the sampling frequency at 20 kHz. As given in Table I, 14 signals are planned to be recorded.

The second group contains the low-rate signals. The major part of the second group contains signals related to mirrors. Alignment control signals to keep the mirrors stable against seismic noise and the signals of the mirror positions will be recorded at a rate of 100 Hz. Signals from vacuum controllers and from environmental monitors are also included in this group. Those will be recorded at a rate of 1 Hz or lower. A summary of the signals belonging to the second group is also given in Table I.

The total amount of signals is estimated to be 600 kbytes per second. The major contribution comes from the high-rate signals.

Table I
List of signals to be recorded with the TAMA300 gravitational-wave antenna.

signal category	signal name	sampling	channels
interferometer	main signal	20kHz	1ch
	visibility	20kHz	1ch
interferometer feedback	main	20kHz	2ch
	beam splitter	20kHz	1ch
	recycling mirror	20kHz	1ch
	mode cleaner	20kHz	1ch
laser	power	20kHz	1ch
	frequency stability	20kHz	1ch
	visibility	20kHz	1ch
online analysis	h	20kHz	1ch
	matched filter	20kHz	3ch
mirror control	main(4deg.freedom)	100Hz	4ch
	recycling(4deg.freedom)	100Hz	1ch
	mode cleaner(4deg.freedom)	100Hz	2ch
mirror isolation	main(5deg.freedom)	100Hz	4ch
	recycling(5deg.freedom)	100Hz	1ch
	mode cleaner(5deg.freedom)	100Hz	2ch
	beam splitter(5deg.freedom)	100Hz	1ch
environment	seismic noise, acoustic noise, etc.	100Hz	30ch
	temperature, etc.	1Hz	100ch
vacuum	vacuum status	1Hz	20ch
	valve status	1Hz	50ch
GPS monitor	clock	1Hz	2ch

III. Proposed system for control and data acquisition

A. EPICS for low-rate signals

Since most of the signal sources are well spread along the interferometer arms, it is obvious that a network-oriented control and data-acquisition system is necessary. In addition, we do not have much manpower and have only three years remaining to complete the project. We have thus looked for a platform on which to develop our own system, and have found that EPICS (Experimental Physics and Industrial Control System) [12] seems to be the best choice among several commercial products and public-domain tools.

We have installed an EPICS test bench at ISAS and are now evaluating its performance with dummy signals. At present, the EPICS seems to satisfy our requirements for low-rate signals. The proposed system consists of a few Unix workstations, X-terminals and roughly ten VME-bus computers, which are connected through a network to each other. We expect EPICS to be an easy supervisor of the low-rate signals.

B. High-rate data acquisition

It is not easy to collect high-rate signals with EPICS, mainly due to network capacity. Since all of the high-rate signals are localized near to the central control room in our case, we have looked for another high-rate data-acquisition system. At present, we are interested in a commercial data-recorder with VXI-ADC modules and an archiver. A serious problem is that we need to record signals continuously. In order not to interrupt an observation, we require an intelligent raw-data storage, such as a tape-robot. In addition, we must decide on the archiver media among several candidates such as tapes (DAT, Exabyte, DLT, etc.) or removable disks. Since progress in this field is very fast, we will leave the final decision until 1997, which is one year prior to the start of observations.

C. Event builder and Data server

We need an "event builder" to merge both the high-rate and low-rate signals together. As shown in Figure 1, the event builder is in charge of creating a data package, called an "event packet", every two seconds, which contains the raw data of both the high-rate and low-rate signals. Each event packet exists in memory for roughly 10 seconds and is then overwritten with a new one. During this interval it remains in memory and is transferred into a raw-data archiver. The data transfer from the high-rate data-acquisition system to the archiver is made through a dedicated high-speed communication channel.

An event packet is used as a basic unit during the various data treatment, including the online and offline analysis. For easier handling of the data, the size of one packet has been designed to be on the order of 1 MB. It may include an additional header, such as a time stamp, a serial number, and so on, for later analysis[1]. The detailed structure of a packet is to be determined in the future.

The data server is also shown in Figure 1. Its role is to provide the latest data for an online analysis. Sampled packets, as many as the CPU power allows, are copied into the files on large scratch disks. The size of the disks is roughly 400 GB in total, so as to keep the data for one week.

We are investigating a physical scheme to realize the mechanism mentioned above. The most promising idea is to use a reflective memory in order to share on-memory packets with many nodes, including the high-rate data-acquisition, the event builder and the data server. A feasibility study is in progress.

D. Network

The network is an essential part of our system. We have the idea of dividing it into a few segments. We will install at least two networks along each arm. One will be an FDDI network having a sufficiently high capacity for data transfer for the EPICS system. This network will be used only for data transfer. Another is the popular Ethernet, which is to be used for very low-rate data transfer, such as the vacuum-monitoring signals, and for general purposes, including X-window protocols. In order to avoid troubles caused by lightning during the summer season, optical isolation is to be introduced.

E. Schedule

The schedule of the TAMA300 project for the next 5 years is summarized in Table II. The time limit for completing the control and data-acquisition system is 1998.

[1] Early consideration was found in [13].

Table II
Schedule for developing the system for TAMA300.

Year	Goal(s) for each year
1995	Evaluation of EPICS with a test bench
1996	Construct the EPICS Supervisory system for low-rate signals Install network environment
1997	Construct the data-acquisition system for high-rate signals
1998	Install systems for actual observation and analysis Short observations for performance check
1999	Start the continuous observation for gravitational waves

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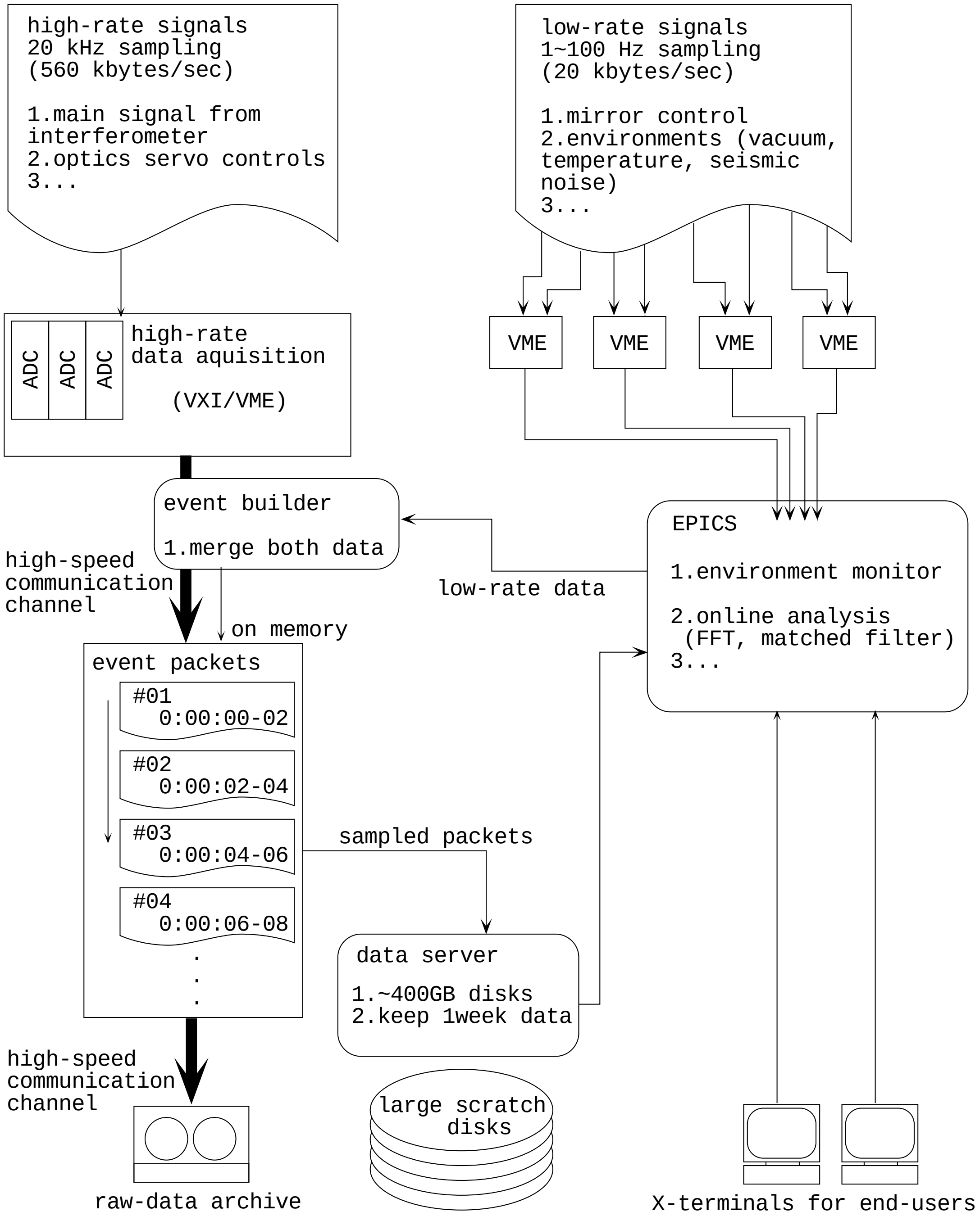

Figure. 1. Schematic view of the data flows between the high-rate data-acquisition, the EPICS, the event builder, the data server, and the raw-data archiver.