VLBI@home – VLBI correlator by GRID computing system

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Abstract

Kashima VLBI group have been developing a VLBI software correlator system using GRID computing technology. Like SETI@home, client/server model is used in the system and screensaver-type correlator program runs only when the client PC is idle. No expensive dedicated hardware correlator is necessary, but standard personal computers in observatories provide CPU resources. Using software correlator system, the type of a correlation process is selectable (e.g. XF or FX, geodetic purpose or astronomical purpose) and correlation processes can be easily repeated, changing various kind of correlation parameters (e.g. integration time, phase center of the map, number of lags, FFT size). Current processing speed of the system has reached 70Mbps by using sixteen low-cost PCs. The processing speed has been improving day by day, by means of algorithm improvements for the correlation program and installations of high-speed network equipments. This paper describes a configuration of the system in detail and reports on a first experimental result of GRID computing in VLBI.

1. Introduction

In conventional VLBI systems, received radio signal at observing stations have been recorded to magnetic tapes and hardware correlators have been used for data processing. In the meantime, recent developments of personal computers enable us to use standard PC system for the VLBI data analysis. We have developed K5 VLBI system (see [1],[2]) in which raw VLBI data are transferred through the Internet and geodetic correlation analyses are made by software programs. K5 has been used in various experiments, such as spacecraft positioning observations, a multiple baseline geodetic experiment in which five VLBI stations paticipated, and e-VLBI observations between Kashima and Westford observatory to determine UT1-UTC within 24hours. Since the K5 system is connected to the Internet directly, we can construct the low cost and high performance VLBI analysis system using GRID computing technology. To improve performance of the software correlator program, we have been developing a client/server type distributed computing system like SETI@home (see [3]).

Client/server-type distributed computing system is characterized by having following three features. First, a large amount of data is divided in small units and transferred to client PCs. Second, sent data are processed by the PCs. And third, the result data are sent back to the server. This type of system generally works well when the network speed is faster than the processing speed in client PCs. At present, XF-type K5 software correlator which is used for a geodesy have a capability to process 4 Mbps data in real time when it runs on a PC equipped with a Pentium3 1GHz. Thus, distributed computing method has the potential to increase the software correlation speed if the 10Mbps, 100Mbps or more high speed network environments are equipped.

2. Overview of the System

In the present system, raw VLBI data are divided into appropriate short-time period data and each segmented data are assigned to each PC. In the case of multi-baseline observations, all the data received at the same moment at different stations are gathered into one client to minimize data transmission costs. As shown in Figure 1, system consists of following components: control server that controls whole system, database server that stores processing conditions of VLBI data and statistics of each client PC, FTP servers at each VLBI station that transmit observed raw data to clients, and a lot of clients by which VLBI data are correlated. When a screensaver-type client software (a screenshot is shown in Figure 3) activates, it ask the control server about filenames of the data to be processed and IP addresses of observed VLBI stations. The client downloads the data from the FTP servers and correlates the data. Resulting data and related information such as download time and correlation time are reported to the database server via the control server.

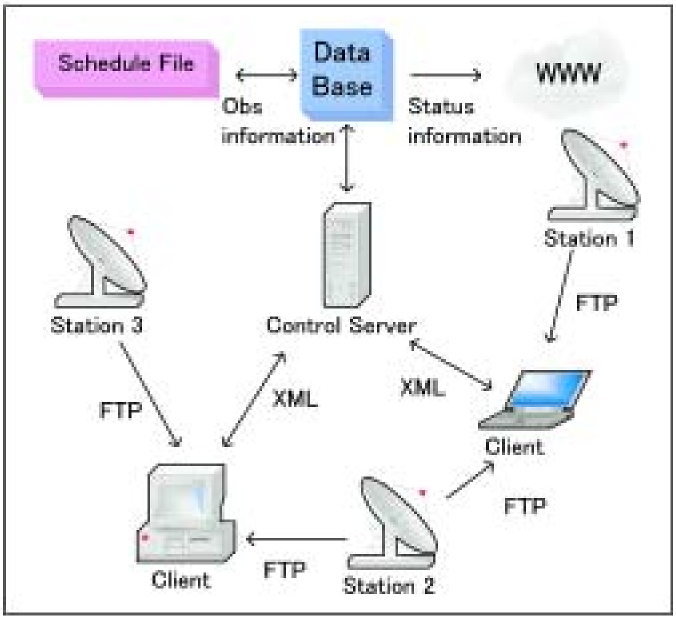

Figure 1. Schematic diagram of the whole system. It consists of a controlserver, a databese server, FTP servers at each VLBI stations, and a number of client PCs.

3. Detailed Structure of Control Server and Client Program

A schematic diagram of a control server is shown in Figure 2. In the server program, file information of each segmented data are stored in a C++ structure (see the right-hand side of Figure 2). Structures relevant to unprocessed segments are listed in a queue (Upper queue in Figure 2). Referring the database server, new structure is added to this queue in real-time. If a client connects to the server, information in the structure at the forefront of the queue is transmitted and the structure is transferred to another queue in which information of processing segments are listed (Lower queue in Figure 2). When the correlation process in the client finished, it is reported to the server and relative structure is deleted from the second queue. Finally, reported information is stored in the database server. If a client connects to the control server while the first queue is empty, file information is transmitted from the second queue so as not to remain unprocessed data.

In client PCs, VLBI-data transfer is realized by a built-in FTP-client function in the screen-saver type client program. A multi-thread simultaneous downloading from different VLBI stations is possible and it has resume capability, which will restart interrupted downloads. Correlation process is performed by the external correlator program, cor.exe (see [4]). In a socket connection between a control server and a client PC, all information is represented in XML format.

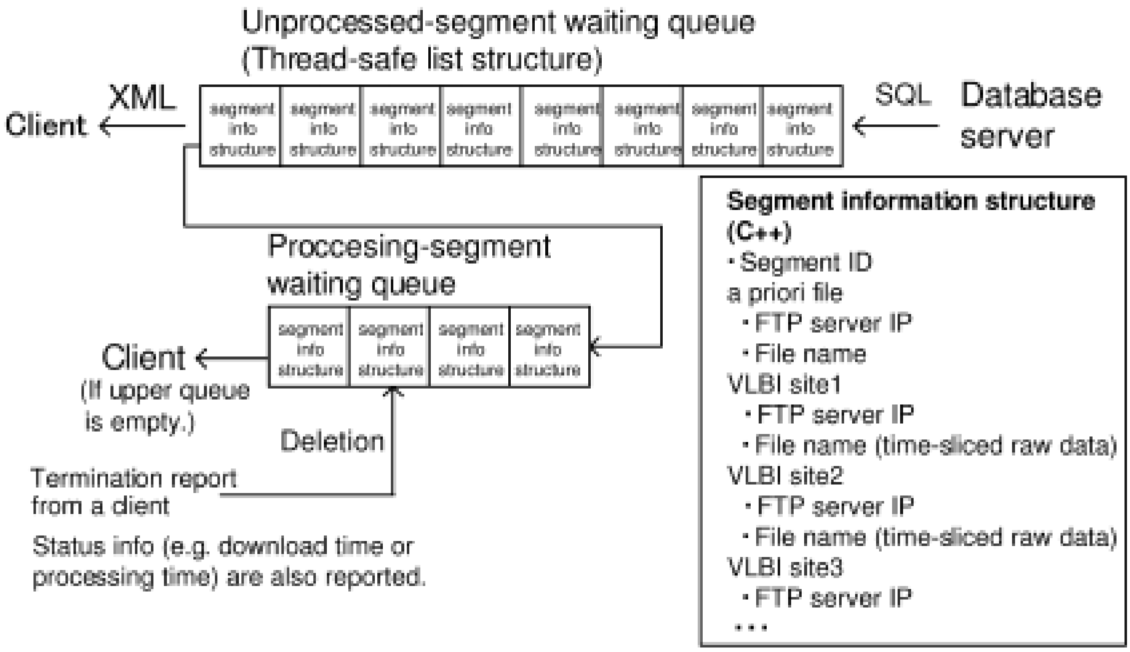

Figure 2. Schematic diagram of a control server, in which file information of a segmented VLBI data is represented in a C++ structure.

4. System Bottleneck Detection

There are three factors which can become a bottleneck of the system: data processing rates of clients, network speed, and data transfer rates of FTP servers. These three factors can be monitored using statistical data stored in the database server. Data processing rates of clients can be calculated from recorded correlation times. A typical value of the rate using a 1CPU PC is 2 to 12 Mbps. If this factor becomes a system bottleneck, it is necessary to increase the number of clients or to improve the algorithm of correlation programs. The statistics of download time in each client is used to evaluate a network performance. A typical network speed is 10Mbps to several Gbps. The network speeds around FTP servers determine the total performance of the system. If it is not enough compared to a total data processing rate of the clients, it becomes a bottleneck of the system. The data transfer rate of a FTP server is limited by the access speed of hard disks. A typical value is 200Mbps for random accesses and 1Gbps for sequential accesses. If it becomes a bottleneck of the system, FTP mirroring is effective and Ramdisk can be used for real-time observations. Eliminating these factors, overall system performance can be increased up to 10Gbps, the highest network rate we can use at this time.

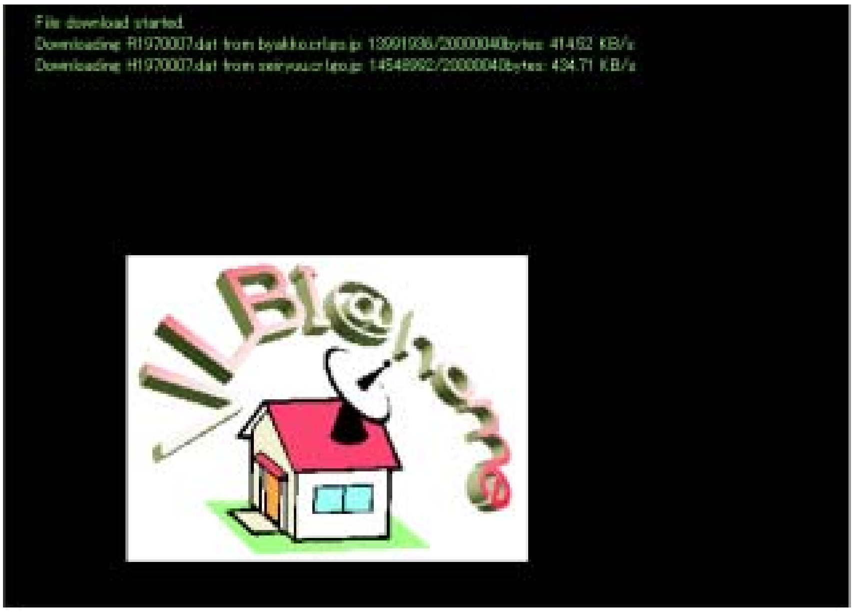

Figure 3. Screenshot of screensaver-type client program downloading two VLBI raw data simultaneously. Two data are cross-correlated by a XF-type software correlator and result data are sent back to a server.

5. New Features as a GRID Computing System

In the case of existing GRID system like SETI@home, unanalyzed original data are always stored in one location. On the other hand, VLBI raw data are stored in multiple locations in nature, and each client PC must download the data from separated data storages. Additionally, in the case of multi-baseline observations, analyzed raw data are reusable on the other PC for the analysis of different baselines. Because of these unique features, there are some new possibilities as a distributed computing system as follows:

- Allocate different set of FTP servers to each client in order to optimize total network transmission cost.
- Multicast data transmissions from a VLBI station to multiple client PCs.
- Reuse of the analyzed VLBI raw data by P2P (peer-to-peer) data transmissions between clients.

Basically, all the data taken at the same moment at different VLBI stations should be gathered into one PC to minimize data transmission costs. However, if the number of observation stations (N) is increased, data processing time in one PC is increased on the order of N^2 and it may become impossible to analyze all baselines by one PC. The above methods are effective to distribute a segmented data to multiple PCs in such a case.

6. Current Status of the System and Future Plans

The overall performance of the system for a 32-lag XF-type correlation is 70Mbps using sixteen standard PCs in our observatory. We are planning to perform a 64-Mbps real-time experiment. In this year, we will improve the network capacity and file server performances to achieve 1Gbps using a large number of PCs. In future, all the information concerning VLBI experiments shall be integrated in a database (see Figure 1) for the easy management of VLBI experiments. The concrete proposal of such kind of database system is shown in [5]. We expect that distributed computing method will become a key technology for VLBI analysis in the next decade. Various type of distributed computing methods have also suggested (see [6],[7] for details) besides this system.

References

[1] Kondo, T., Technology Development Center at CRL, In: International VLBI Service for Geodesy and Astrometry 2002 Annual Report, NASA/TP–2003-211619, N. R. Vandenberg and K. D. Baver (eds.), 297–300, 2003.

[2] Koyama, Y., T. Kondo, H. Osaki, K. Takashima, K. Sorai, H. Takaba, K. Fujisawa, Evaluation of the K5 system in geodetic VLBI experiments, In: IVS CRL Technology Development Center News, No.23, 26–30, 2003.

[3] SETI@home web page
`http://setiathome.ssl.berkeley.edu/`

[4] Kondo, T., Y. Koyama, H. Osaki, Current Status of the K5 Software Correlator for Geodetic VLBI, In: IVS CRL Technology Development Center News, No.23, 18–20, 2003.

[5] Takashima, K., Total VLBI data management system using database server -The organizer for VLBI@home-, In: IVS CRL Technology Development Center News, No.23, 21–22, 2003.

[6] Kondo, T., M. Kimura, Y. Koyama, H. Osaki, Current Status of Software Correlators Developed at Kashima Space Research Center, In: IVS 2004 General Meeting Proceedings, NASA/CP–2004-212255, N. R. Vandenberg and K. D. Baver (eds.), ?–?, 2004.

[7] Kimura, M., J. Nakajima, The implementation of the PC based Giga bit VLBI system, In: IVS CRL Technology Development Center News, No.21, 31–33, 2002.