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IP Data Transfer System for Real-time VLBI

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Abstract

We constructed a data transfer system for real-time very long baseline interferometry (VLBI) using Internet protocol (IP) in GALAXY project. The system achieves maximum transfer rate of 256 Mbits/sec based on parallel transfer using multiple IP streams. This system features bandwidth scalability by increasing the number of PCs for transmitting and receiving IP data. Using the system, we conducted experiments transmitting VLBI observation data at 128 Mbits/sec and successfully detected a fringe. This is the first IP-based real-time VLBI in the world.

1. Introduction

This paper presents our data transfer system for very long baseline interferometry (VLBI) using Internet protocol (IP) in GALAXY project.

Since 1998, GALAXY project, which is composed of Communications Research Laboratory, National Astronomical Observatory of Japan, The Institute of Space and Astronautical Science and NTT, has been conducting experiments on real-time VLBI. In the experiments, observation data is transmitted over NTT's 2.4 Mbps asynchronous transfer mode (ATM) network; therefore, we can catch up with real-time phenomena as well as improve observation efficiency.

In addition to the experiments based on ATM, we have been focusing on IP transfer for VLBI data delivery. Adopting IP technique into real-time VLBI brings the following advantages that are essential to our goal.

- Improvement of interconnectivity with other observation sites far apart
- Easiness to introduce distributed processing schemes
- Utilization of low-cost but high-performance equipment

2. IP Transfer Architecture for Real-time VLBI

As policies in constructing an IP transfer system, we focused on the following points:

- Making the most use of the existing equipment such as samplers and cross correlators,
- Achievement of transparency in data transfer,
- Examining performance of multi-purpose PC in IP transfer for real-time VLBI.

A configuration of our IP transfer system is shown in Figure 1. The system consists of an ID1 parallelizer, an ID1 serializer, IP-transmitting PCs, and IP-receiving PCs.

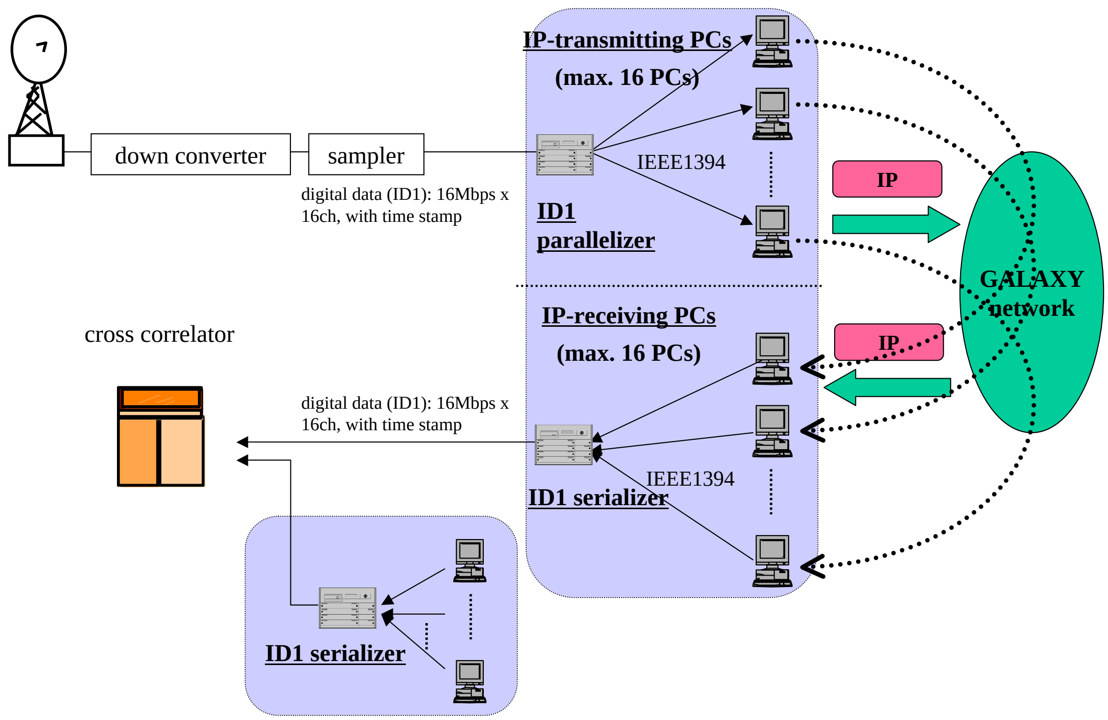

Figure 1. Configuration of IP transfer system for real-time VLBI

In order to achieve high transfer-rate required for real-time VLBI observation, we adopted a parallel IP transfer schemes, using multi-purpose PCs. In the system, the ID1 parallelizer receives the data stream from the sampler through the ID1 interface, and divides it into multiple IEEE1394 streams. Each IP-transmitting PC receives the IEEE 1394 stream, extracts observation data, and transmits it in IP packets.

On receiving the IP packets, each IP-receiving PC extracts observed data and transfers it to the ID1 serializer in an IEEE 1394 stream. Upon receiving the IEEE 1394 data streams from the IP-receiving PCs, the ID1 serializer constructs the observation data and sends it to the cross correlator.

Thus the cross correlator can process cross-correlating calculation, also by receiving other observation data from the other IP transfer system.

3. ID1 Parallelizer and ID1 Serializer

Internal action of ID1 parallelizer and ID1 serializer is shown in Figure 2.

An ID1 parallelizer divides received data into multiple blocks of a fixed length and stores each of them in the internal queues, by a round robin manner. Accordingly, the top data blocks of each queue are transmitted in parallel IEEE 1394 streams.

An ID1 serializer collects data blocks of fixed length via IEEE 1394 interfaces. After receiving enough numbers of the data blocks, the ID1 serializer constructs observation data, also by adopting the same round robin scheme as the ID1 parallelizers, and outputs it through the ID1 interface.

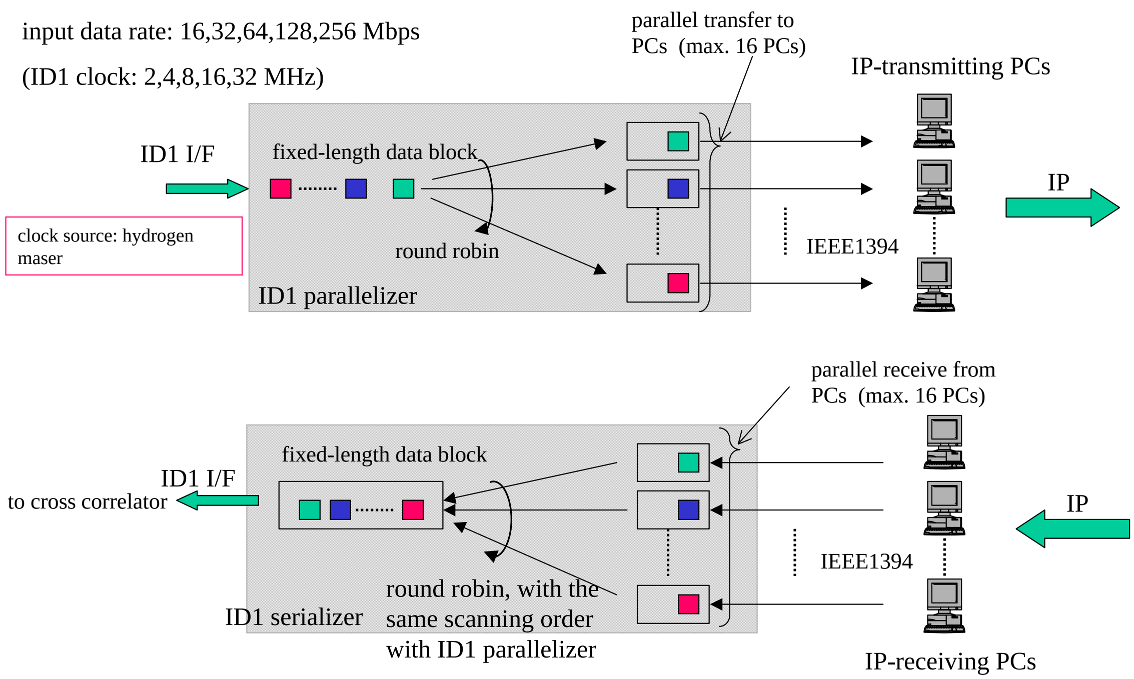

Figure 2. Internal action of ID1 parallelizer/serializer.

4. IP-transmitting PC and IP-receiving PC

Each IP-transmitting PC receives data in an IEEE 1394 data stream, and transmits it in UDP/IP packets to the corresponding IP-receiving PC. The IP-receiving PC extracts data from received UDP/IP packets, and sends it in an IEEE 1394 stream. Accordingly, multiple UDP sessions are set up between the IP-transmitting PCs and the IP-receiving PCs.

The reason we use UDP instead of TCP is to reduce the PC's CPU load and not to be influenced by round trip time.

Generally, a parallel transfer scheme must guarantee data to correctly be ordered. In this system, by the round robin manner common both in the ID1 parallelizer and the ID1 serializer, the same data can be obtained from the ID1 serializer as the input data to the ID1 parallelizer.

Another important issue to consider is possibility of packet loss, caused by lacking of retransmission mechanism on UDP. This can disturb the construction of correct data in ID1 serializer. In order to solve this problem, we decided to generate random data of the same size on the IP-receiving PC when packet loss is detected. Detection of packet loss on receipt can be easily achieved by adding a sequence number at the top of each payload of UDP packets before transfer. This simple handling causes no problem for cross correlation because result of cross correlation will be influenced little by inserting up to 0.1% of dummy data.

5. Implementation

We implemented the ID1 parallelizers and ID1 serializers as specific equipment. Major specifications of ID1 serializer and ID1 parallelizer are described in Table 1.

Table 1. Specifications of ID1 parallelizer/serializer

	ID1 parallelizer	ID1 serializer
input I/F	ID1 x1 port	IEEE1394 x16 port
output I/F	IEEE1394 x16 port	ID1 x1 port
maximum PCs to connect	16	16
internal data-block size [KB]	32,64,128,256,512,1024	⟵
ID1 clock [MHz]	sychronization to input ID1 I/F	2,4,8,16,32
maximum throughput [Mbits/sec]	256	256

For IP-transmitting and IP-receiving PCs, we use Pentium2/400 PCs, on which Linux 2.4.6 is running. On these PCs, we implemented application software in C language to send and receive IEEE1394 packets and IP packets.

6. Experiment

We conducted IP-based real-time VLIB observation, using our IP transfer system. The configuration is shown in Figure 3.

Important information is as follows.

- date: Jan. 17, 2002
- antenna: 64 m (Usuda site) and 34 m (Kashima site)
- baseline: 200 km
- observation band: C band
- observed object: J0136+47
- data rate: 128 Mbps
- network: GALAXY experimental network (based on 2.4 Gbits/sec SDH)
- data transfer protocol: IP (Usuda - Musashino, 115km), ATM (Kashima - Musahino, 100km)
- PCs: four PCs (two PCs for each sending and receiving IP)
- IP streams: 32 Mbps x4 streams (each pair of PCs to handle two IP streams)

In the experiment, observed data at Usuda 64 m antenna was transmitted to Musashino (NTT R&D Center) by the IP transfer system at the rate of 128 Mbps. At the same time, another observation data was sent from Kashima 34 m antenna also to Musashino by ATM. By conducting cross-correlation processing at Musashino, we confirmed fringes. We are convinced that this is the first successful experiment in the world on real-time VLBI observation based on high-speed IP transfer.

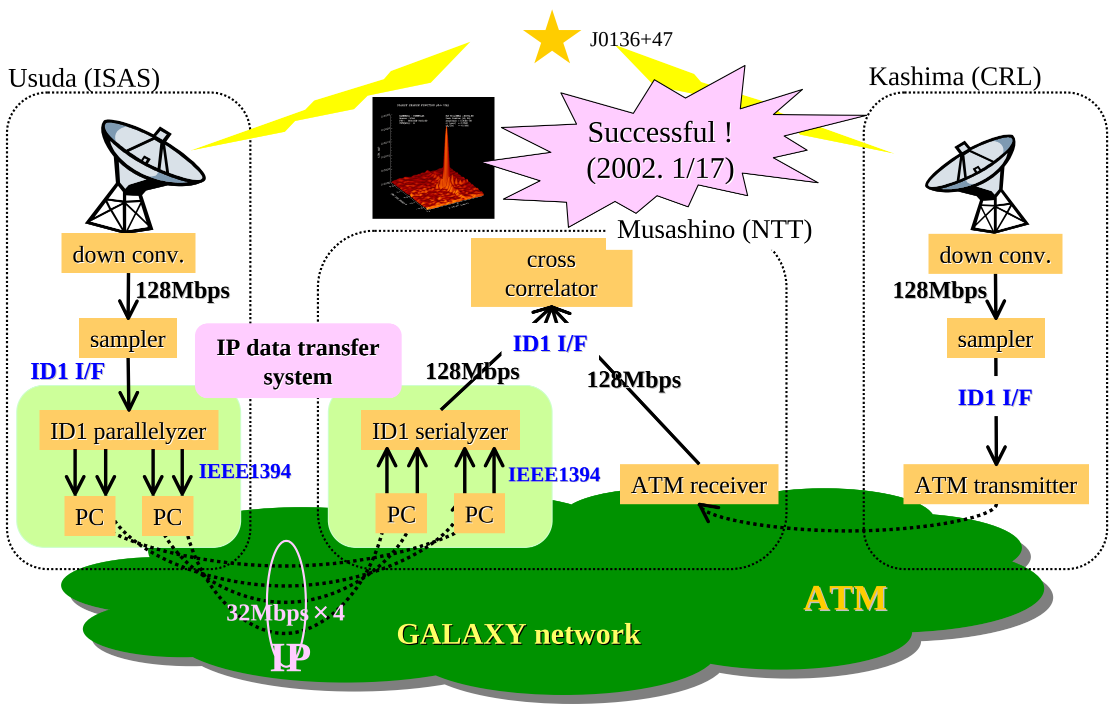

Figure 3. IP-based real-time VLBI experiment

7. Future Plans

We are currently working on the following issues.

- Implementing appropriate protocol between IP-transmitting PC and IP-receiving PC, which can adapt to dynamic change of network quality,
- Increasing transfer rate up to order Gbits/sec,
- Application to other scientific fields that require high speed data transfer.