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e-VLBI Applications of Chinese VLBI Network

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Abstract

The Chinese VLBI Network (CVN) adopts the strategy of "one network, two purposes" for deep-space exploration and scientific applications. To achieve the new e-VLBI capabilities, we have upgraded the stations and the data processing center of the Chinese VLBI Network (CVN). The Chinese Next Generation Internet (CNGI) project also will give support to e-VLBI applications.

1. CVN Infrastructure

The Chinese VLBI Network (CVN) includes four radio telescopes and one data processing center. The four telescopes are in Beijing (Miyun station, 50-meter diameter), Urumqi (Nanshan station, 25-m), Kunming (Kunming station, 40-m), and Shanghai (Sheshan station, 25-m), and the Data Center is in the Shanghai Astronomical Observatory. The new 65-m station near the existing Shanghai Sheshan station will start operations at the end of 2012. All of the CVN stations have S/X band observation capability and a Mark 5B+ VLBI recording terminal. The longest (Shanghai-Urumqi) baseline of the CVN is 3249 km, which provides the highest angular resolution of 2.3 mas in X-band (∼8GHz). Therefore, besides the routine IVS and astronomy observations, CVN is a powerful tracking and navigation tool in the Chinese deep-space projects, such as the Moon and the Mars exploration missions. There are dedicated network links between the four VLBI stations and the data center.

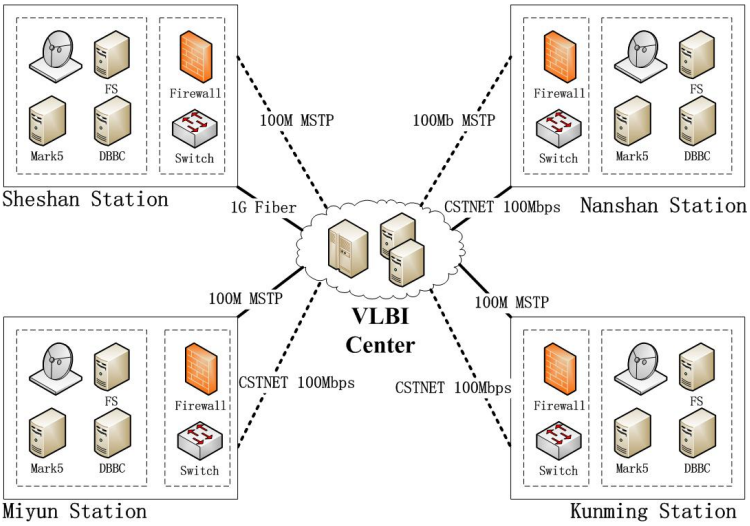

Figure 1. e-VLBI network of CVN.

There is a backup network of each station to the Data Center in the critical deep-space mission (Figure 1). The e-VLBI data rate of each station to the Data Center is 16 to 64 Mbps, and the full network capacity can be up to more than 128 Mbps/station if required. For example, 256 Mbps e-VLBI experimental observating was carried out between the Shanghai Sheshan station and the Urumqi Nanshan station in 2009. Although the Sheshan station connects to the VLBI Center with 1G fiber and other stations can be updated if necessary, the actual bottleneck of the data rate is the network fee [1, 2].

Because the application requirements are different, usually the VLBI network for the deep-space mission and for scientific applications need independent stations and data center. However, CVN adopts the strategy of "one network, two purposes" for deep-space and scientific applications. The observation stations are the same, but in the data center, two data processing platforms have been built for different needs.

In the deep-space mission there are two data pipelines headed by the software correlator and by the hardware correlator independently. This kind of primary and backup system is meant for high reliability. The core processers are the software correlator (primary machine) and the hardware correlator (backup machine). There are some dedicated software configuration items such as an angle measurement unit and an orbit measurement unit. For scientific applications such as extragalactic radio source mapping and rapid UT1 measurement, there is another set of data processing configurations (Figures 2–3). The software correlator running on a cluster of 40 x 86 CPU cores is used for data correlation.

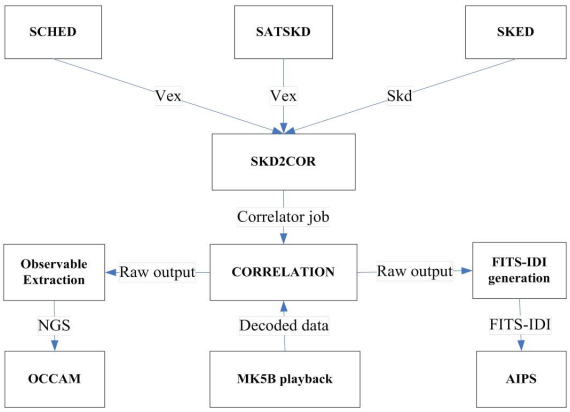

Figure 2. Software correlator structure.

2. e-VLBI Applications

2.1. Rapid UT1 Measurement Experiment

On February 23, 2011, a two-hour rapid ΔUT1 measurement session was conducted on the Shanghai–Urumqi baseline. Limited by the budget, the data rate was only 64 Mbps; and data were transferred from the two stations to the Data Center over the TCP/IP protocol. One hour later, ΔUT1 was achieved (-175.200 ± 0.225 ms). One week later, the IERS result (-175.252 ± 0.007 ms) was downloaded. The difference was about 50 μs.

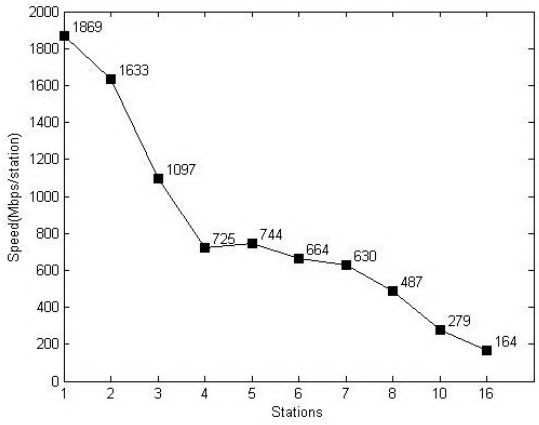

Figure 3. Speed of the CVN software correlator.

This experiment demonstrated the rapid UT1 measurement capability of CVN. If higher bandwidth and a longer baseline is available, a better result and shorter latency will be achieved.

2.2. Applications in Lunar Exploration Missions

From 2007 to 2010, two lunar orbiters (CE-1 and CE-2) were sent to the Moon. CVN has taken important roles in both missions. During the critical flying mission, CVN worked in the near real-time mode with e-VLBI, and the total data latency of the CVN Data Center was less than five minutes (Figure 4). In future lunar explorations, especially in the Rendezvous and Docking (RVD) procedure, close-to real-time VLBI will be welcome. So we are trying to shorten the VLBI processing latency from five minutes to less than one minute.

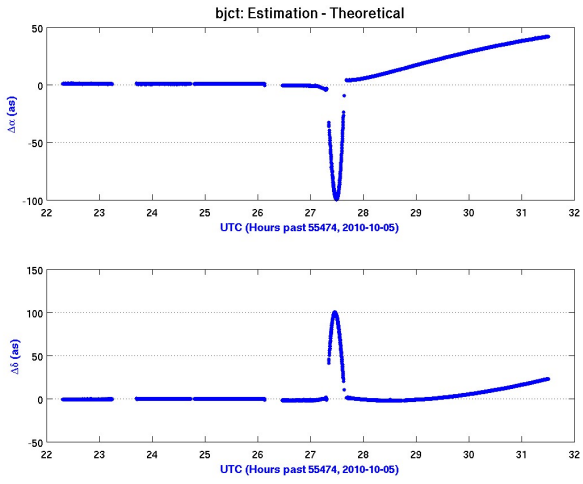

Figure 4. Real-time e-VLBI positions from CE-2's lunar orbit injection.

3. CNGI Demonstration

The project of demonstrating applications based on the Chinese Next Generation of the Internet (CNGI) has been carried out. Its overall goal is to develop the CNGI network environment, the scientific research data storage, the analysis application environment, and the scientific research collaborative environment by taking advantage of CNGI to connect the large scientific device, the field stations, the mass data storage, the high performance computing infrastructure and the resources. The e-VLBI application is selected by Shanghai Astronomical Observatory and Computer Network Information Center of Chinese Academy of Sciences. This application will build

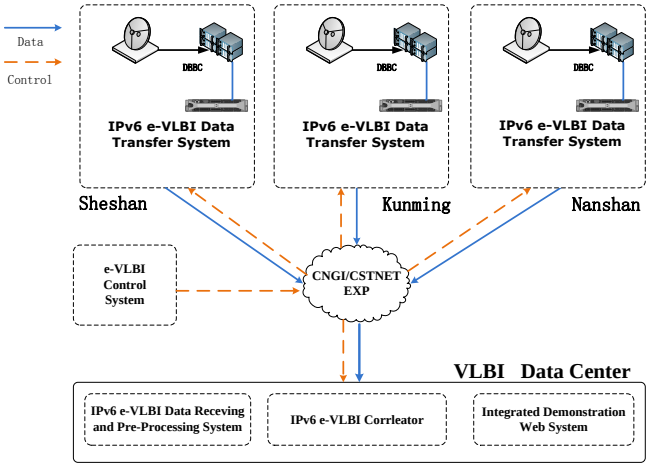

Figure 5. e-VLBI based on CNGI.

the e-VLBI network connection and the demonstration platform based on IPV6 technology. Three VLBI stations (Shanghai Sheshan station, Xinjiang Urumqi Nanshan station, and Yunnan Kunming station) and the Shanghai VLBI Data Center will join the CNGI facilities. The demonstration platform structure is in Figure 5. The higher speed will be accessible in the CNGI network.

Acknowledgements

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