Alan R. Whitney: High-Speed e-VLBI Demonstration: Haystack Observatory to NASA/GSFC, IVS 2002 General Meeting Proceedings, p.137–141
http://ivscc.gsfc.nasa.gov/publications/gm2002/whitney2

High-Speed e-VLBI Demonstration: Haystack Observatory to NASA/GSFC

Alan R. Whitney

MIT Haystack Observatory

e-mail: awhitney@haystack.mit.edu

Abstract

Haystack Observatory, with support of a grant from DARPA, is preparing a high-speed e-VLBI demonstration using antennas at Westford, MA and NASA/GSFC in Maryland, with correlation at Haystack Observatory. The link between Haystack and GSFC includes a number of both private and public network facilities, including the Bossnet, Glownet, Supernet and GSFC/HECN networks. The Mark 5 system will be used at both stations and at the Haystack Mark 4 correlator to interface VLBI data through a standard TCP/IP Gigabit Ethernet connection at a sustained rate of ~900 Mbps. Due to the many different networks involved, much effort is being undertaken to examine every link in the path and to optimize and upgrade components as necessary in order to achieve the desired speed. Expansion of this effort to include stations in Europe and Japan is being explored.

1. Goals of the e-VLBI Experiment with Haystack and NASA/GSFC

Under the sponsorship of DARPA, Haystack is preparing a high-speed e-VLBI demonstration between Haystack Observatory in Westford, Massachusetts and NASA/GSFC in Greenbelt, Maryland, a direct-path distance of ~650 km, as illustrated in Figure 1. The significant features of this demonstration are:

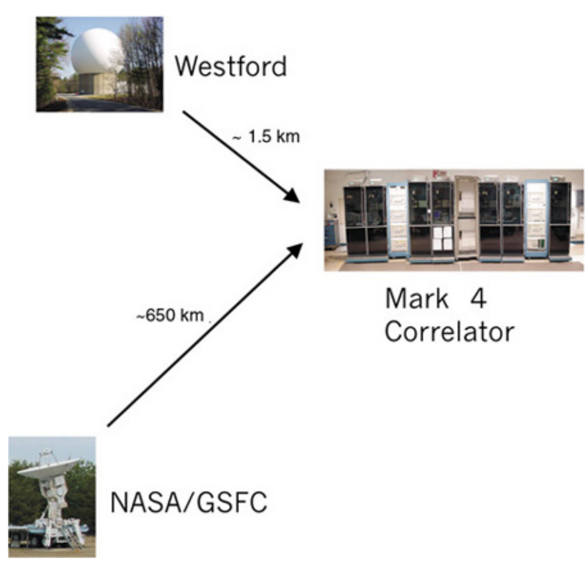

Figure 1. Gbps e-VLBI demonstration

- To demonstrate ∼1 Gbps near-real-time and real-time VLBI data transmission from Westford antenna at Haystack Observatory and GGAO antenna at NASA/GSFC to the Mark 4 correlator at Haystack Observatory.
- Utilize Mark 5 systems for data transmission and reception.
- Use standard Gigabit Ethernet connections at all sites

This experiment is not the first e-VLBI at Gbps speed, as at least one network in Japan has already operated at this speed. However, it may be the first Gbps e-VLBI experiment to operate over ordinary shared networks with many users.

2. The Mark 5 System and e-VLBI Connectivity

The Mark 5 system is being built to support e-VLBI requirements up to ∼1 Gbps. It supports a "triangle of connectivity" between the VLBI data port (source or sink), a disc array, and a high-speed network connection attached to a standard PCI bus, as shown in Figure 2. The path between any of these three nodes of the "triangle of connectivity" may be exercised at up to 1 Gbps.

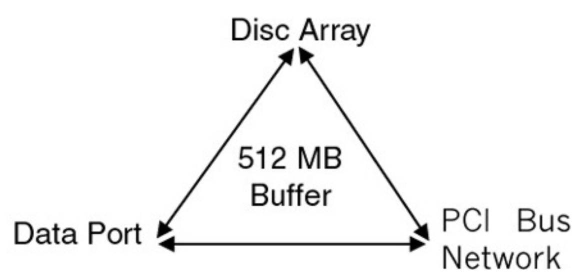

Figure 2. Mark 5 'triangle of connectivity'

As a result of this 'triangle of connectivity', the Mark 5 can support several practical e-VLBI data-transfer modes:

1. VLBI data may be recorded on disc, then transferred at a later time to a correlator, where it can either be processed in real time or re-recorded onto disc for later processing.
2. VLBI data may be transferred directly to a correlator, where it may either be processed in real time or re-recorded onto disc for later processing.

In addition, the Mark 5 allows data to be simultaneously recorded to disc and transferred to the network at data rates up to ∼800 Mbps in cases where it may be desirable to keep a "backup" copy of data being transmitted in real time to a correlator. Initially we plan to use Gigabit Ethernet for the network connection, though any standard network connection can be supported, with 10 Gigabit Ethernet on the near horizon.

3. Network Details

The network connection between the Westford antenna and Haystack correlator is dedicated. However, the connection from the GGAO antenna to Haystack is a combination of dedicated and shared networks, as illustrated in Figures 3a and 3b. Starting at Haystack Observatory, a dedicated fiber network called Glownet links to another dedicated network called Bossnet, which carries data from Washington, D.C. At Washington, D.C., the link connects over several segments of both dedicated and shared network links to the GGAO antenna. Use of some shared segments of the path must be coordinated with other users in order to achieve the necessary data throughput rate.

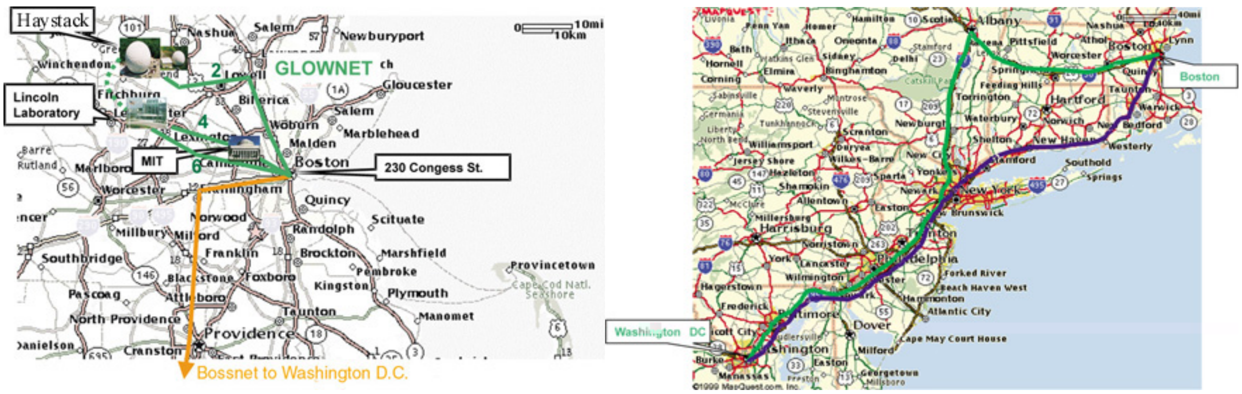

Figure 3. a:Connection of Haystack to Glownet, b:Bossnet route from Boston to Washington, D.C.

Figures 4 and 5 show the details of the path between Haystack Observatory and GGAO, including more than a dozen routers and switches along the way. Each piece of equipment in this path must be carefully examined for suitability to operate at 1 Gbps and upgraded or replaced as necessary.

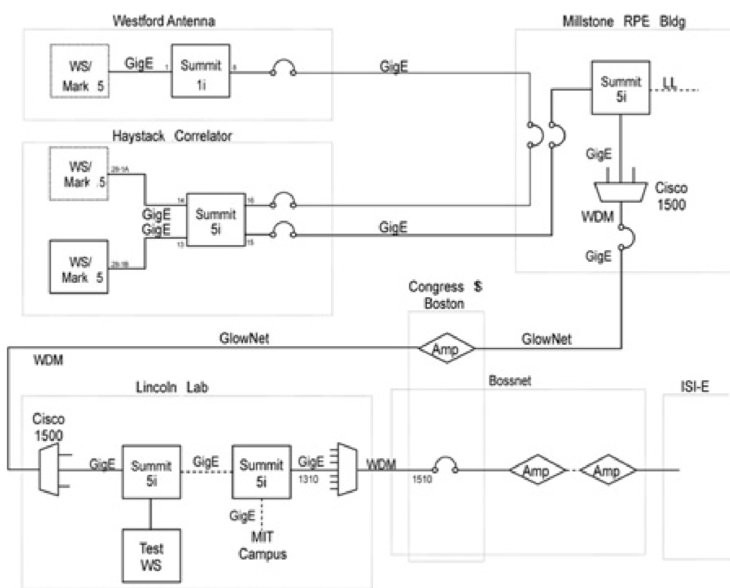

Figure 4. Detailed connection diagram part 1

Test workstations are placed at several points along the route in order to facilitate network testing. To date, the segment between Haystack Observatory and the beginning of Bossnet have

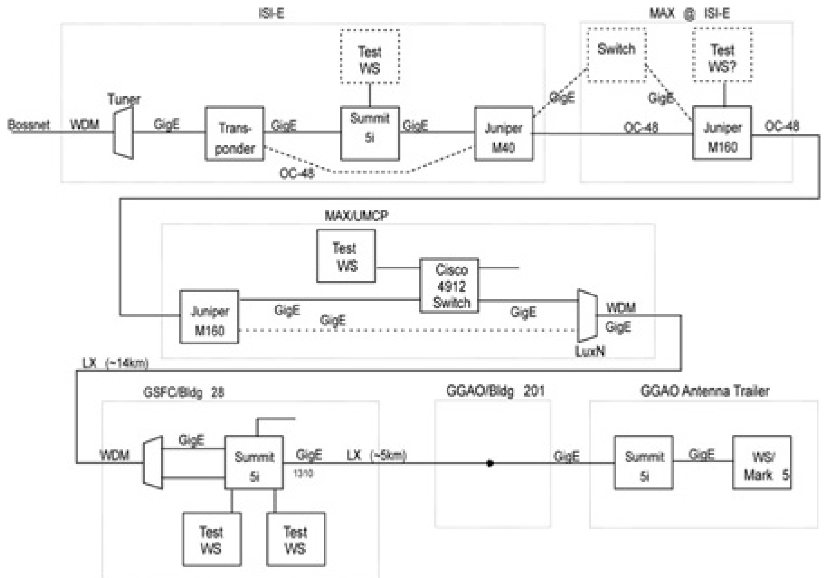

Figure 5. Detailed connection diagram part 2

been tested, achieving a sustained data rate of ~988 Mbps, near the theoretical limit of Gigabit Ethernet. We expect soon to be able to test the remainder of the network and expect this level of performance to be achievable over the entire routine between Haystack Observatory and GGAO.

4. The Experiment

The demonstration experiment will be conducted in two phases:

1. Data will be collected on discs at the antennas, then transferred through the network to discs at the Haystack correlator, and then will be correlated. This is dubbed “near-real-time” correlation and will be used to gain experience with the network and understand its characteristics and limitations.
2. Data will be transmitted in real time from the antennas to the Haystack correlator. Success in this mode will require careful coordination of both antennas, network and correlator. In addition, it will require some upgrade to software in the Mark 4 correlator to accommodate this real-time operation.

The timetable for the demonstration is as follows:

- Initial testing: Jan 2002 - Mar 2002
- Full Demonstration: Apr 2002 - May 2002

5. Possibilities Beyond e-VLBI Demonstration

This demonstration e-VLBI experiment is the first step to a broader application of global e-VLBI technology. We plan to pursue several applications to broaden both the scope and geography of high-speed e-VLBI:

1. The daily UT1 Intensive measurements between Wettzell in Germany and Kokee Park in Hawaii are an obvious early target for conversion to e-VLBI. Each daily observation collects ~100 GB of data, easily manageable with the Mark 5 system. Because there are no direct high-speed network connections to either site, the discs will be transported to a nearby high-speed node where they will be re-played through the network and re-recorded on disc at the correlator. When the transfers are complete, the data will be correlated in the normal way. This mode of operation should reduce the interval from observation to results from several days to several hours and significantly improve important UT1 predictions.
2. Several high-speed international science links exist which might be used for e-VLBI, particularly to Europe and Japan. The Surfnet link is jointly supported by the U.S. and Europe and provides a >1 Gbps link between Amsterdam and Chicago. We are currently investigating possible high-speed connections from Haystack to Chicago; the European VLBI community is planning high-speed connections to Surfnet in Amsterdam in the near future. Similarly, the TransPAC link connects Chicago and Tokyo with a high-speed connection (currently OC-12, but with anticipated upgrades). Efforts are currently underway in Japan to connect telescopes to TransPAC, which will allow real-time and near-real-time experiments between the U.S. and Japan.

6. Summary

Though currently in its infancy, e-VLBI is expected to develop rapidly to provide connectivity unimagined only a few years ago. For many telescopes, the “last mile” problem is still a severe impediment to full real-time operation. However, interim operation of buffered data (on discs) transported to nearby high-speed nodes is an attractive step in the right direction. Eventually, it is likely that full global e-VLBI operation will not only become possible, but will extend VLBI observations to new levels of sensitivity and timeliness.