NTT’s Ultra-High-Speed Networking Experiment on Real-time VLBI

Joint Trials with CRL, NAOJ and ISAS (KSP and GALAXY)

Hisao Uose, Kazunari Irie & Sotetsu Iwamura

NTT Laboratories
History

- A part of NTT's Ultra-High-Speed Networking Research Project which started in June 1995
- “Real-time VLBI” is a joint effort of NTT Laboratories, Communications Research Laboratory (CRL), National Astronomical Observatory of Japan (NAOJ) and Institute of Space and Astronautical Science (ISAS)
- We’ve built a large-scale dedicated network spanning Kanto/Shin-etsu areas (total fibre length was about 1,000km) connecting radio telescopes and processing units with OC-48 (2.4Gb/s) circuits, ATM Switches and high-performance IP and started its operation in 1996
Why do we (NTT) do this????

• Establish technologies for very high speed communications (Gb/s class for each application)
  - We’ve developed a special purpose network equipment for the trial

• Explore the effectiveness of ultra-high-speed communications technologies in advanced science and create new communications application

• Contribute to Science and Society
Real-time VLBI Applications

• Geodesy (KSP: Key Stone Project)
  - High precision crustal deformation measurement system using realtime VLBI in Kanto Area
  - Challenges for advanced earth science and precise space navigation technologies

• Radio astronomy (OLIVE & GALAXY Projects)
  - Ultra-high resolution/sensitivity radio telescope combining VLBI and Gigabit class networks
  - Challenges for opening a new vista of radio astronomy
GALAXY/KSP Network: Geographical View

- ISAS Usuda Deep Space Center (Nagano)
- NTT Musashino R&D Center
- CRL Kashima Research Center
- ISAS Usuda Deep Space Center (Nagano)
- NAOJ Nobeyama Radio Observatory (Nagano)
- CRL (Koganei)
- NAOJ (Mitaka)
- NTT Musashino R&D Center

Dedicated Network
- OC-48 (2.4Gb/s)
- OC-48 x n (with WDM)

208km

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Antennas Used for our Experiments

Usuda 64m

Nobeyama 45m

Kashima 34m

11m antennas for KSP
(Koganei, Tateyama, Miura, Kashima)
(Simplified) Logical Network Configuration

Under construction

Disconnected (11/02)

ID1 I/F to connect samplers and correlators

Network Equipment

ATM NW IF

ATM-SW

Router

Network Interface

ATM

GbE

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KSP: Geodesy using Realtime VLBI

• NTT joined the CRL’s Key Stone Project (KSP) to help them achieve the very high resolution measurement system of crustal deformation in Kanto area using realtime VLBI in 1995

• Regular (every other day) measurement has been conducted until November 2001 and the obtained data were utilized for the research of earth science
  - A major deformation due to a sudden volcanic activity around Izu Island has been observed last year
  - A large amount of measurement data is publicly offered to earth science community through the CRL web site
KSP Measurement Sites in Tokyo Area

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Ultra-high Resolution Radio Telescope

- Started as NTT·NAOJ·ISAS project (OLIVE) to implement the largest virtual radio telescopes using multiple terrestrial/space antennas with realtime VLBI

- Flexible and precise observation can be obtained only with realtime data transmission and processing
  - First fringe (cross correlation) was detected in 1997 between the signals received by a terrestrial antenna (Usuda) and a satellite antenna (HALCA)
  - Realtime correlation has been successfully established among large terrestrial antennas (Usuda, Nobeyama and Kashima) in 1998

- **GALAXY** started as a joint project of KSP and OLIVE in 1999
Significance of Our Observation System

- The first realtime VLBI system using ultra high speed digital communications networks (several Gb/s)
- High sensitivity/resolution obtained by high-speed connections
  - The sensitivity obtained of our system is comparable to the highest sensitivity achieved (5~10mJy) which is only available on a magnetic tape-based system (non-realtime)
- Flexible Observation with realtime data processing
  - Experiment plan can be easily rescheduled according to the results obtained with the realtime observation
- Experiment support system utilising multimedia conference system and ultra high speed networks
Future (1): Upgrading Connectivity

• Performance Upgrade with Higher Data Transmission Rate
  - We’ve succeeded an experiment with higher speed (1Gb/s) last year which outperforms any system in the world

• Addition of Antennas
  - Addition of other antennas to the GALAXY network are being sought which improve both sensitivities and resolution of the resulting radio telescope

• International Cooperation
  - We are seeking the possibility of international cooperation with research organizations abroad including MIT Haystack Observatory and the Internet2 project
Future (2): Internet-based VLBI

• Adoption of very high speed IP technology to realtime VLBI, which will make the realtime VLBI observation more economical and widespread
  - High speed IP stream transmission system applicable to the realtime VLBI has been developed
  - Distributed processing utilizing a huge number of PCs on the net should be very interesting as well (just started)

• Supporting tools for distributed realtime VLBI observations
  - Multimedia conferencing system using IP Multicast

• The standardization of interface between data acquisition/processing units and network is crucial for Internet VLBI
  - Expansion of VSI (VLBI Standard Interface) ??
Supporting Environment for Observation

- Sharing of critical information among participating sites is a must
- Multimedia Communications tools with IP multicast is being tested
- Multicasting of radio signal is interesting for distributed processing
Future (3): Cooperation with Other Projects

- **Cooperation with Internet2 project**
  - NTT is a Corporate member of I2 since 1998
  - GEMnet has been connected to Abilene (I2 backbone) this year
- **Cooperation with ASTE/ALMA project and U. Chile**
  - NTT started to cooperate in developing new photo detectors and data processing technologies applicable for ALMA/ASTE project
  - NTT has been working with University of Chile which is helping the ALMA project in Chile (AccessNova Project) for over five years
  - High-speed link between Chile and Japan has been established with Internet2’s ITS (International Transit Service) to REUNA via AMPATH
- **New research initiative within NTT labs**
  - We’ve started to cooperate with other sections of NTT Labs to accelerate R&D with “synergy” effect
  - “AWG-STAR” photonic device and HD video transmission system are already deployed in our network
**GEMnet-Abilene Connections**

- Connections through STARTAP (April 2001) and Sunnyvale (June 2001)
- Connectivity to 187 I2 member universities
- International Transit Service which enables us to connect 15 other academic networks

- **Connection Point (OC-3)**
- **33Mbps (10Mbps for Abilene)**
- **To Japan**

*GEMnet-Abilene Connections*:
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Cooperation with NAO and U. Chile

Remote monitoring/control of ASTE/ALMA telescope will start soon with the cooperation of Internet2(Abilene), AMPATH and REUNA2

ASTE 10m Prototype Telescope at the height of 4,800m
Conclusion

• We did very well considering the limited resources
  - Though, we might have been able to do more!!
  - and, other groups are working very hard!!

• Necessity of widening our perspective in technological sense
  - “Network computing” can be another big business for NTT
  - GALAXY could be a nice testbed not only for advanced networking technologies but also for those new middleware and applications technologies

• and cultural aspects
  - International collaborations (and joint effort in general) will multiply the results of each participating group