International e-VLBI Experience

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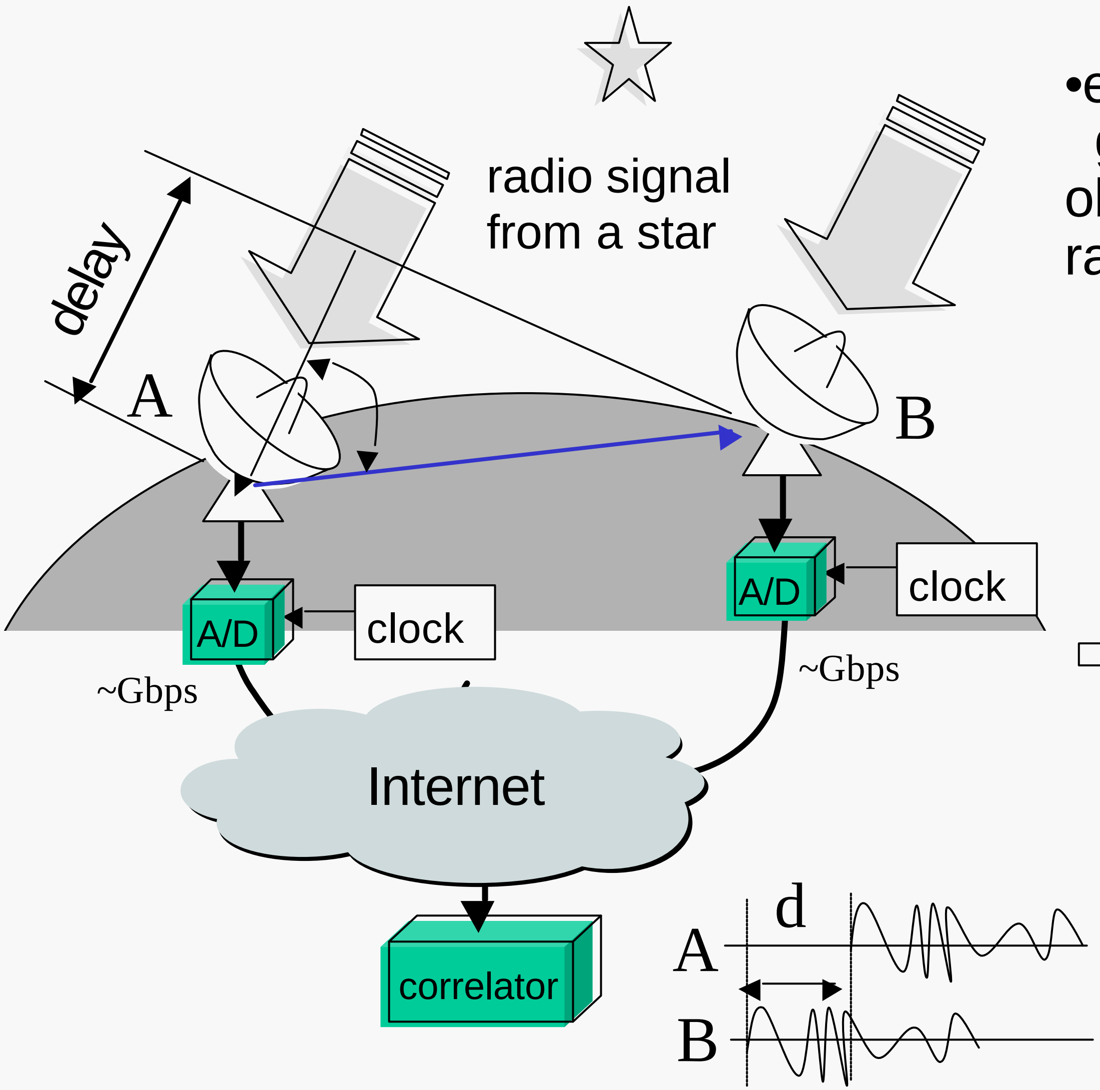
e-VLBI (Very Long Baseline Interferometry)



- e-VLBI
  geographically distributed observation, interconnecting radio antennas over the world

ASTRONOMY
GEODESY

⇨ Large Bandwidth-Delay Product Network issue

VLBI - Characteristics

- Observing Bandwidth $\propto$ (Precision of Time Delay)$^{-1}$
  $\propto$ (SNR)$^{1/2}$
  $\propto$ Data rate

⇨ Faster Data Rate = Higher Sensitivity

- Wave Length / Baseline Length $\propto$ Angular Resolution
- Baseline Length $\propto$ (EOP Precision)$^{-1}$

⇨ Longer Distance = Better Resolution

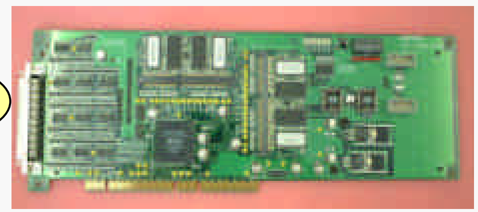
Recent e-VLBI System Developments K5 by NICT

ADS1000
(1024Msample/sec 1ch 1bit or 2bits)

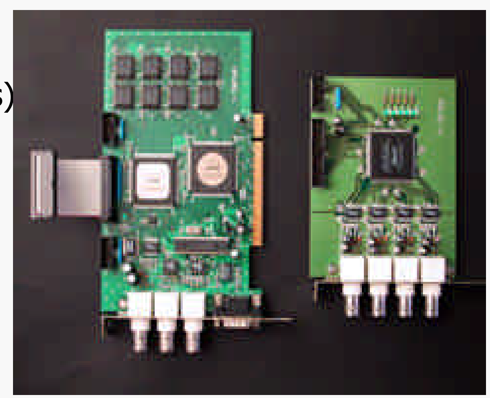
VSI-H

ADS2000
(64Msample/ch·sec, 16ch, 1bit or 2bits)

PC-VSI Board
(Supports VSI-H specifications)



IP-VLBI Board
(~16Msample/ch·sec, ~4ch, ~8bits)

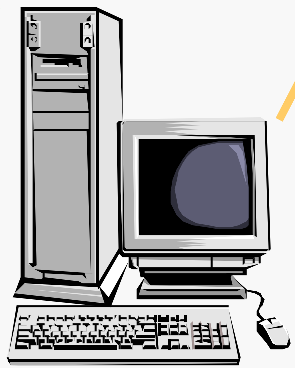


Correlator
other DAS

Internet

VSI-E

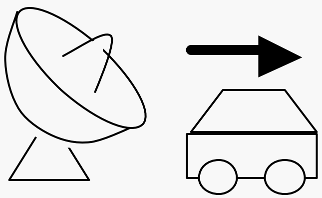
VTP
(RTP/RTCP)



PC

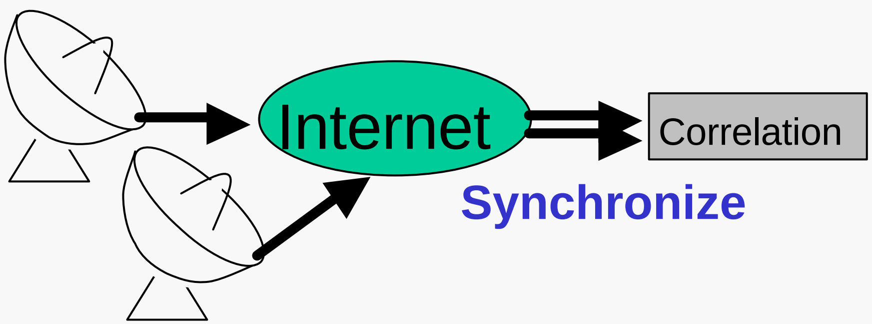
e-VLBI Data Transfer

Traditional e-VLBI – file transfer



Carry a disk to the nearest station
to put on-line

Real-time e-VLBI – flat-rate live data streaming



Typical Network Usage

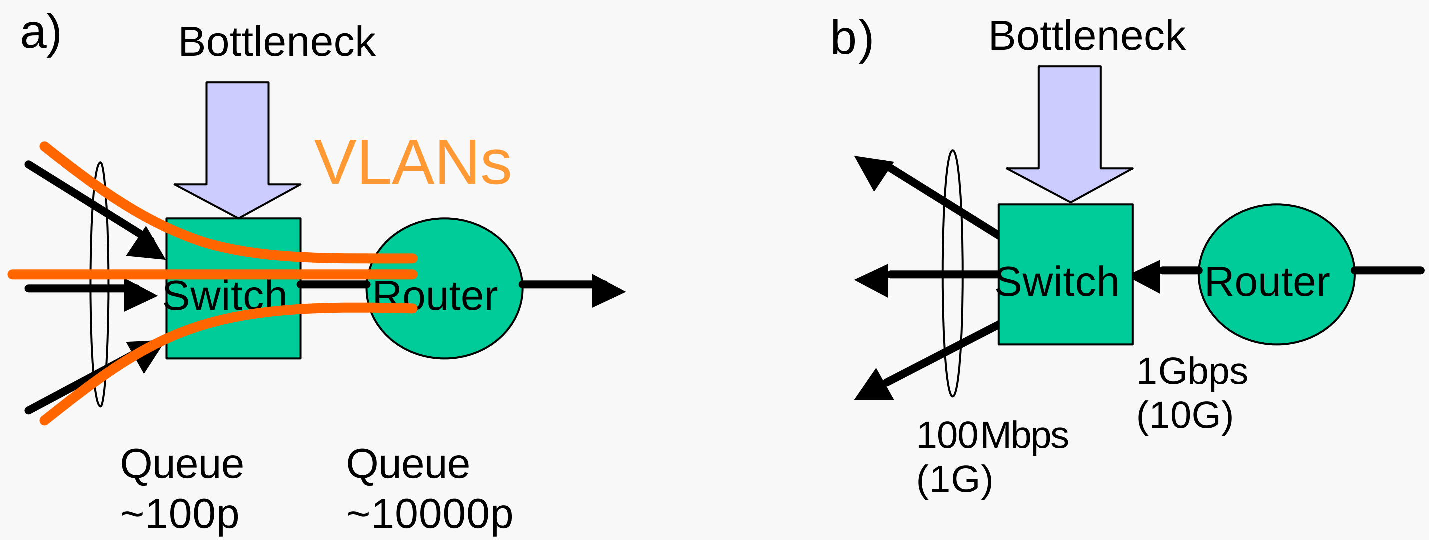
- Traditional e-VLBI (off-line)
  - File transfer
    e.g. 64 Mbps x 24 hours = 691 GB
    e.g. 512 Mbps x 2 hours = 460 GB
- Quasi-Real-time
  - Turnaround time (observation + transfer + correlation)
    e.g. 4.5 hours for UT1-UT
- Periodical (e.g. once a week)
  - Utilize available b/w
- Real-time
  - two one-way streaming
  - loss allowance depending on S/N (~0.1% OK)
  - time allowance to retransmit (~ sec?)
  - e.g. Huygens tracking

Transfer Examples

- NICT, JP - Haystack, US (Aug. 2003) ~100 Mbps by TCP [parallel]
- [test] JIVE, NL – NICT, Japan (Dec. 2004) by HUT ~400Mbps by tsunami
- CISRO, AU – JIVE, NL (Jan. 2005) by AARNET ~450 Mbps by TCP over UCLP
- [test] Haystack,US - NICT, JP (Jan. 2005) ~700 Mbps by TCP
- [no fringe] NICT, JP - Haystack, US (SC2005) ~512Mbps by VTP (RTP) via GMPLS

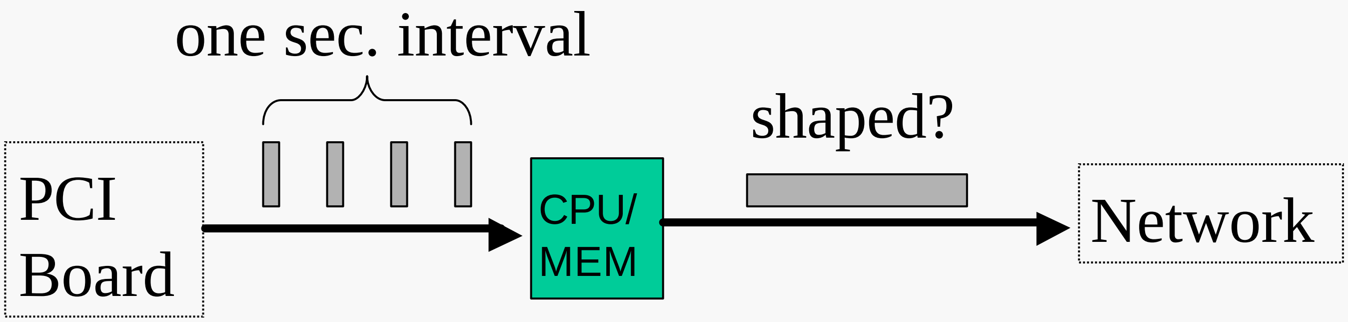
TCP Experience

- A single flow TCP did not get the performance as expected because the network is designed with a short queue (cheap?) L2/L3 switch.
  The queue holds for ~1ms (Routers ~100 ms or more)



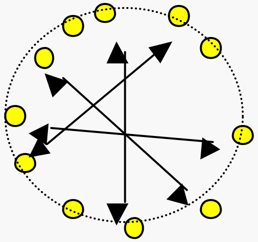
UDP Experience

- Difficulty in rate-control: Bursts from data source



- Difficulty in identifying a location of lost packets along a path

Future e-VLBI Data Transfer



multicast and automated

Correlate among many combinations concurrently
to get more precise data (like a virtual huge antenna)