Correlators in 2010 and Beyond

Correlation and Fringe Finding

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Things to consider?

- Correlator
  - architecture : custom LSI, FPGA, multi-purpose CPU, …
  - design : FX or XF, lag length, …
  - capability / capacity : processing speed, baselines, interface to multiple data media, …
- Fringe Finding and Processing
- Post Correlation Processing

Correlators at Present

- Mark-4 correlator (~1 Gbps, ~16 stations)
  - Haystack, USNO, JIVE, Bonn
- S2 correlator (~128 Mbps, ~6 stations)
  - Penticton
- K4 correlator (~256 Mbps, ~4 stations)
  - Kashima, Tsukuba, Koganei
- Gigabit Correlator : GICO2 (~2 Gbps, 2 stations)
  - Kashima
- VLBA correlator (~512 Mbps, ~24 stations)
  - Socorro
- VSOP/VERA correlator (~1 Gbps, ~10 stations)
  - Mitaka
- CVN (China), LBA (Australia), …

Correlators in near Future

- e-VLA
- KVN (Korea VLBI Network)
- ALMA
- SKA
- VSOP-2

EVLA correlator

- WIDAR : Wideband Interferometric Digital ARchitecture
- Number of stations : 32 (1st stage), 48 (2nd stage)
- Bandwidth : 16GHz (8 x 2GHz basebands)
- Sampling Rate : 4096 Gs/sec 3bits/sample
- Type : XF

ALMA correlator

- Sampling rate per baseline : 4000 MHz
- Number of antennas : 64+16
- Number of correlations : 2016+160
- Digitizing format : 3 bits

Figure 1: 4-Gsps 2-bit FX Correlator with 262144-point FFT

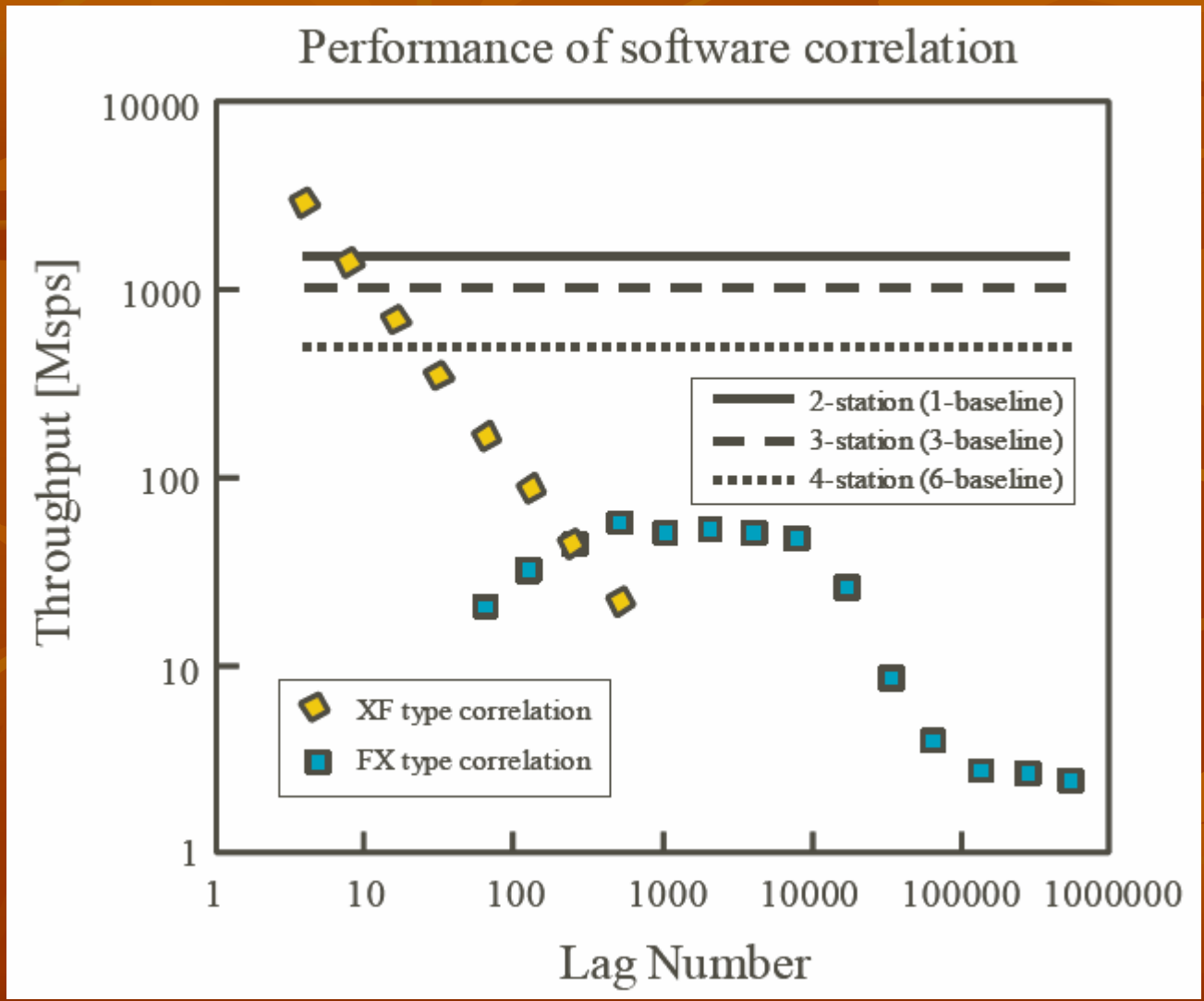
Architechture

- Maximum Processing Data Rate
  - Custom Chip > FPGA > CPU
- Cost
  - Custom Chip > FPGA > CPU
- Flexibility, Expandability
  - Custom Chip < FPGA < CPU

Architecture

- If extremely high data rate signals have to be correlated (>>1Gbps), custom LSI chip or FPGA have to be chosen.
- If data rate of the single data stream is ≤ 1Gbps, multipurpose CPU can do the job.

1 Baseline Processing Performance with 1 PC



AMD Athron 1.6GHz
Dual CPU
4Gbyte RAM

Design

- FX? or XF?
- Lag length? (= Frequency Resolution)
  - Astronomical applications requires fine frequency resolution whereas Geodesy doesn't.
  - Common Purpose Correlator vs. Single Purpose Correlator.
    - Common Purpose => Software Correlator
    - Single Purpose => Hardware (custom chip or FPGA) Correlator
- Station based fringe stopping? or Baseline based?
  - Station based fringe stopping can be done at station before transmitting data to the correlator.
  - Cautions have to be paid not to lose SNR.
  - If multi-point fringe stopping is required for wide field imaging, at station fringe stopping will not be adequate.

Capability/Capacity

- Maximum processing data rate?
  - ~ 1Gbps for operational sessions
  - ~ 10Gbps for R&D?
- Number of Stations : How many?
  - 48 for EVLA
  - 80 for SKA
  - Antenna time is a current limiting factor for IVS sessions.

Correlators in 2010

- Technologies are available.
- Important items which have to be in mind...
  - Compatibility / Inter-Operability of Different Systems
    - VSI-H, VSI-S, VSI-E
  - Expandability
  - Cost
  - Flexibility
    - frequency resolution, pulsar gating, multiple tone detections, mixed mode correlation, ...

Fringe Finding and Processing

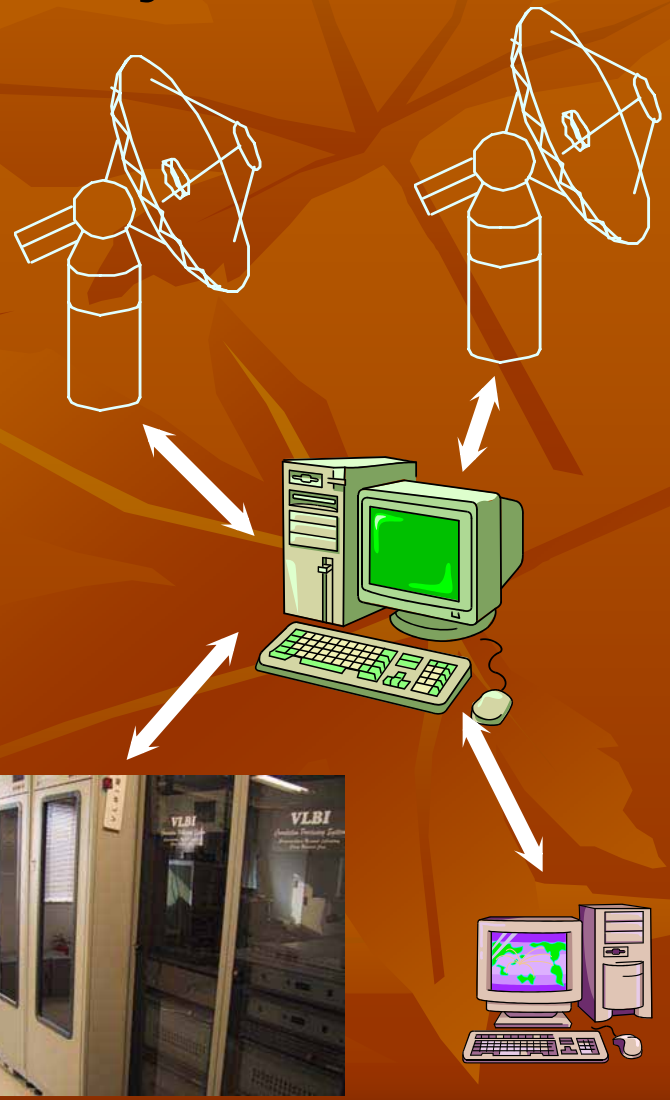
- e-VLBI will be operational stage.
- However, some stations may not have high speed Internet connection even in 2010.
  - ex. O'Higgins, Syowa, …
  - Satellite Link?

Post Correlation Processing

- Consider half of the participating stations are connected with high speed network, and the others are not…
  - Part of the data will be correlated during the session for fast turn-around data production.
  - The remaining baselines will be correlated later.
  - Is current style of database system effective for such a case?
  - Probably, “clearing house” style data archive will become necessary.

VLBI data clearing house
Data Archiving and Analysis

- All the post-correlation data will be archived on a few data servers and the data are continuously mirrored with each other.
- Correlators will put the post-correlation data each time one scan of data are correlated.
- Analysis Systems will retrieve the most recent available data set for their analysis purposes.



VLBI data clearing house
e-VLBI distributed processing

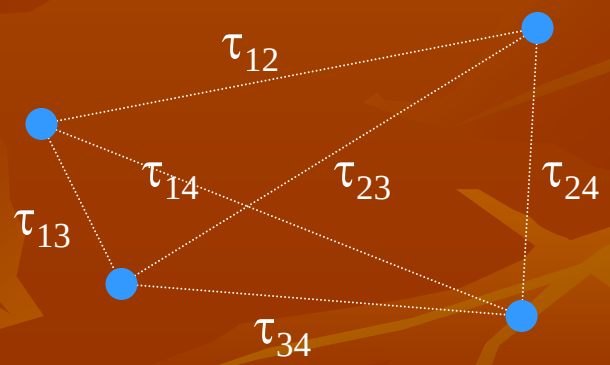
- Network Stations will report the locations of the observed data to the Clearing House each time one scan of recording is completed.
- Distributed correlators will look for the data to correlate. The Clearing House will assign a specific data set to each correlator.
- In a time-slicing distributed correlation scheme is applied, careful coordination and scheduling of resource assignments will be necessary.

XML data handling for VLBI2010 database

- XML (extended makeup language) type data archiving and data handling seem to be efficient for multiple-platform environment.
  - If one analyst want to estimate UT1-UTC of the specific date, he will request the data taken during the specific time period.
  - If the other analyst want to obtain radio map of the specific source, he will request the data for the source.
  - Nominal post-analysis data (such as clock parameters of each station, atmosphere, …) also have to be archived at the Clearing House.

Post Correlation Processing : Delay

- Currently, delay and its rate of change for one baseline at certain epoch are the fundamental observables for the data analysis.
- However, these data are not truly independent except for single baseline scans.



Global Fringe Fitting

- The problem is to find maximum likelihood estimates of delays (and rates) of (n-1) stations with respect to the reference station from the observed raw data signals.

$$\max_{i} \int_{2}^{n} x_1(t) x_i(t - \tau_i) dt$$

- Even if fringes can not be detected for a very small dish from single baseline correlations, delay might be estimated by combining data from many large telescopes.

Summary

- Correlator
  - Large scale correlator developments are under developments and planning
  - Software correlation is becoming feasible
- Fringe Finding and Processing
  - Mixture of e-VLBI and tape-based VLBI have to be considered.
- Post Correlation Processing
  - VLBI data clearing house
  - XML based data handling and archiving
  - Global Fringe Fitting