High Performance Transport for Real-time and Quasi-Realtime Applications

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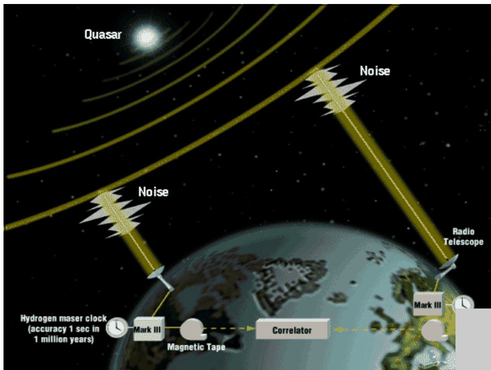
Outline

- Very Long Baseline Interferometry (VLBI)
  - e-VLBI
  - e-VLBI Data/Transmission requirements
  - e-VLBI Model
    - present and future
- Experiment Guided Adaptive Endpoint (EGAE)
- EGAE Optimization Algorithm
- Summary



The Very-Long Baseline Interferometry (VLBI) Technique

(with traditional data recording on magnetic tape or disk)

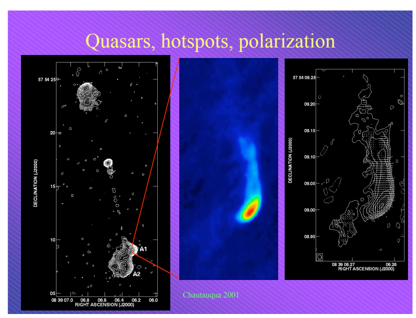
The Global VLBI Array

(up to ~20 stations can be used simultaneously)

VLBI Science

ASTRONOMY

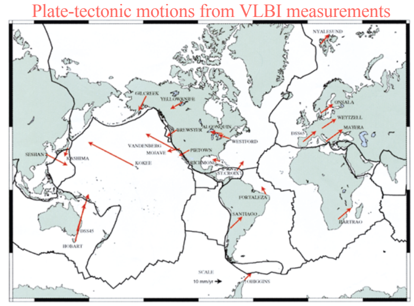
- Highest resolution technique available to astronomers – tens of <u>micro</u>arcseconds
- Allows detailed studies of the most distant objects



GEODESY

- Highest precision (few <u>mm</u>) technique available for global tectonic measurements
- Highest spatial and time resolution of Earth's motion in space for the study of Earth's interior
  - Earth-rotation measurements important for military/civilian navigation
  - Fundamental calibration for GPS constellation within Celestial Ref Frame

Plate-tectonic motions from VLBI measurements



Typical e-VLBI Data Requirements

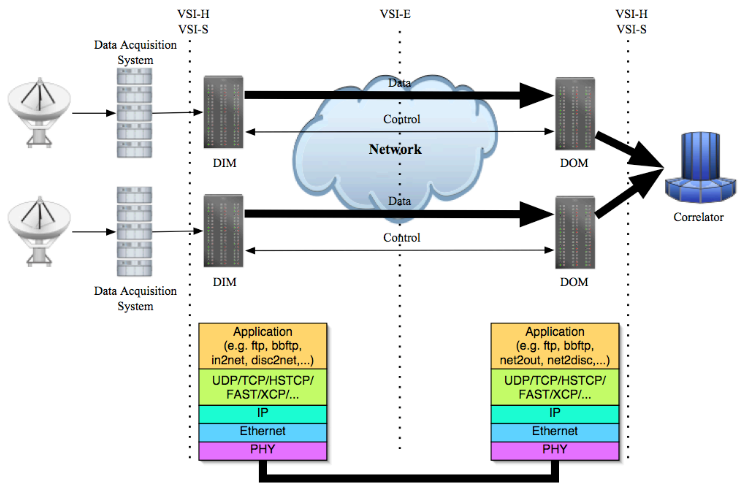
Description	Geodesy	Astronomy
Duration(hours)	24/week	Blocks of several contiguous days
Telescopes	7 (nominal)	Up to 20
% Observation Time	30-50	50-75
Data rate(Mbps)	256	1024
Total data collected (/station/day)	~ 1 TB	~ 7 TB
Current Turnaround time (days)	14-151	> geodesy
Tolerable loss (%)	5	5

Typical e-VLBI Data/Transmission Requirements

Experiment	Length (hours)	Data (GB/day)	Transmission Time (hours) (@30 Mbps)	Transmission Time (hours) (@100 Mbps)	Transmission Time (hours) (@1 Gbps)
Astronomy	24xN	7000	519	156	15.6
Geodesy	24	1000	74.1	22.2	2.22
Intensive	**1**	**40**	**2.96**	**0.89**	**0.089***
T2023	**24**	**543**	**40.2**	12.1	1.21
CRF23	**24**	**489**	**36.2**	10.9	1.09
CRF22	**24**	**443**	**32.8**	9.84	0.98

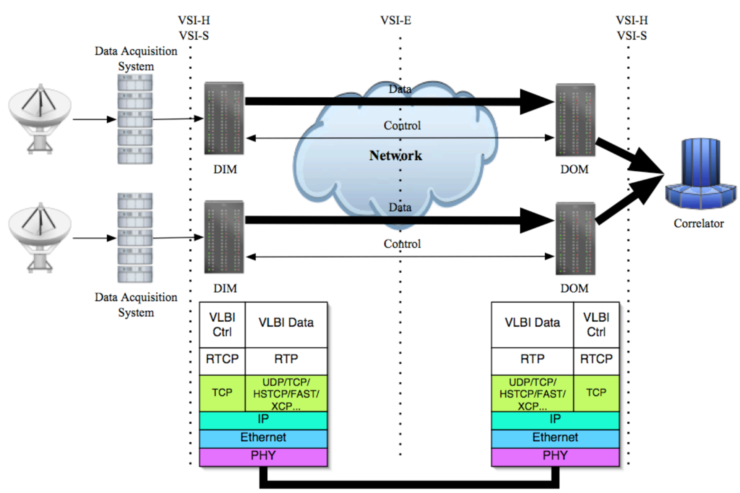
* = projected based on near-Gbps experiment

e-VLBI Model



VLBI Standard Interface - Hardware (VSI-H)
VLBI Standard Interface - Software (VSI-S)
VLBI Standard Interface - Electronic (VSI-E)

VSI-E over RTP Strawman

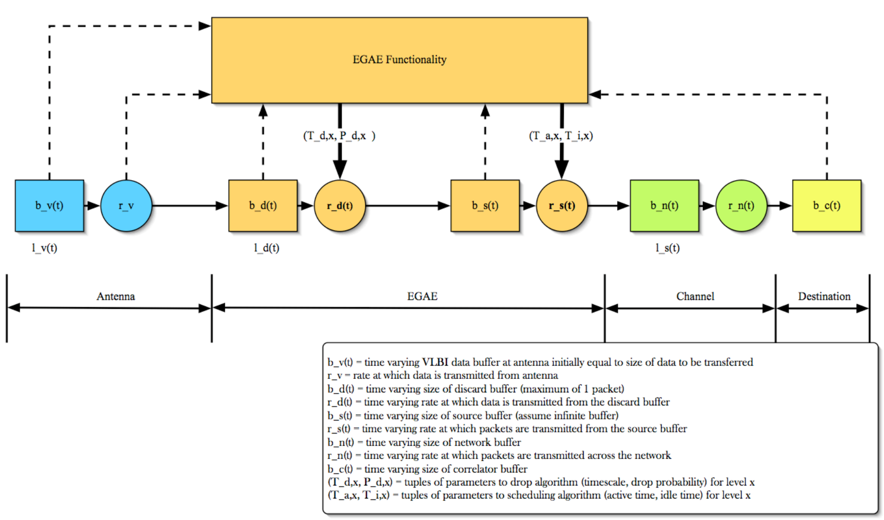


VLBI Standard Interface - Hardware (VSI-H)
VLBI Standard Interface - Software (VSI-S)
VLBI Standard Interface - Electronic (VSI-E)

Experiment Guided Adaptive Endpoint

- Interfaces VLBI hardware to IP networks, transmits and receives VLBI data
- Uses several techniques to provide efficient, economical transport of data:
  - Multi-dimensional performance optimization
  - Protocols for high speed, quasi-real-time transport
  - “Scavenged” bandwidth
  - Adapts transmission rates to suit network congestion
  - Allows characteristics of adaptive behavior to be determined by high level experimental profile

EGAE Functionality



EGAE Optimization Algorithm

Let,

$$\hat{d}(t) = \sum_{i \in \{d,s,n\}} \frac{b_i(t)}{r_i(t)} + \frac{b_v(t) r_d(t)}{r_v r_s(t)}$$
$$\hat{l}(t) = l(t) + (r_v - r_d(t))\hat{T}(t) + (r_s(t) - r_n(t))\hat{T}(t)$$

where, $\hat{d}$ is the projected remaining transfer delay at time t, $\hat{l}(t)$ is the projected total loss, $l(t)$ is the total loss at time t, $\hat{T}(t)$ is the projected time until completion at time t.

Let,

$$\begin{aligned} B_d(r_s, r_d) &= \frac{1}{d_{max}} \left[d_{max} - \hat{d}(t) - t \right] \\ &= \frac{1}{d_{max}} \left[d_{max} - \sum_{i \in \{d,s,n\}} \frac{b_i(t)}{r_i(t)} - \frac{b_v(t) r_d(t)}{r_v r_s(t)} \right] \\ B_l(r_s, r_d) &= \frac{1}{l_{max}} \left[l_{max} - \hat{l}(t) \right] \\ &= \frac{1}{l_{max}} \left[l_{max} - l(t) - (r_v - r_d(t))\hat{T}(t) - (r_s(t) - r_n(t))\hat{T}(t) \right] \end{aligned}$$

where $B_d(r_s, r_d)$ is the delay benefit function and $B_l(r_s, r_d)$ is the loss benefit function.

Define the overall benefit function, $B(r_s, r_d)$ as:

$$\begin{aligned} B(r_s, r_d) &= B_d(r_s, r_d) + B_l(r_s, r_d) \\ &= \frac{1}{d_{max}} \left[d_{max} - \sum_{i \in \{d,s,n\}} \frac{b_i(t)}{r_i(t)} - \frac{b_v(t) r_d(t)}{r_v r_s(t)} - t \right] \\ &\quad + \frac{1}{l_{max}} \left[l_{max} - l(t) - (r_v - r_d(t))\hat{T}(t) - (r_s(t) - r_n(t))\hat{T}(t) \right] \end{aligned}$$

EGAE Optimization Goal

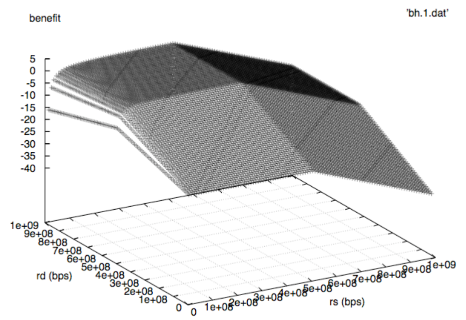
Our goal:

$$\max_{\mathbf{r_{min}} \leq \mathbf{r} \leq \mathbf{r_{max}}} B(\mathbf{r})$$

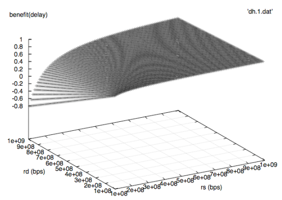
where, $B(\mathbf{r})$ is the overall benefit function, $\mathbf{r}$ is the rate vector, $\mathbf{r_{min}}$, $\mathbf{r_{max}}$ are vectors that bound $\mathbf{r}$ below and above respectively.Subject to the following constraints:

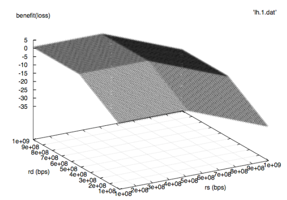
$$\hat{d}(t) + t \leq d_{max}$$
$$\hat{l}(t) \leq l_{max}$$

EGAE Benefit Function



r_v=512e6, r_n=512e6, b_v=44.2e12, d_max=86,400, l_max=2.2e12





EGAE Optimization Solution

Use the gradient algorithm to find the optimal operating point:

$$\mathbf{r}(t+1) = \mathbf{r}(t) + \gamma \nabla B(\mathbf{r}(t))$$

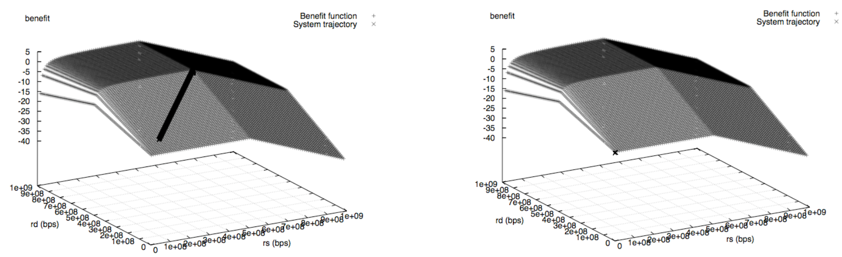
where, $\mathbf{r}(t) = [r_s(t), r_d(t)]$ is the rate vector, γ is the step size, $\nabla B(\mathbf{r}(t))$ is the gradient of B and points in the direction of steepest ascent.

$\nabla B(\mathbf{r}(t))$ is given by:

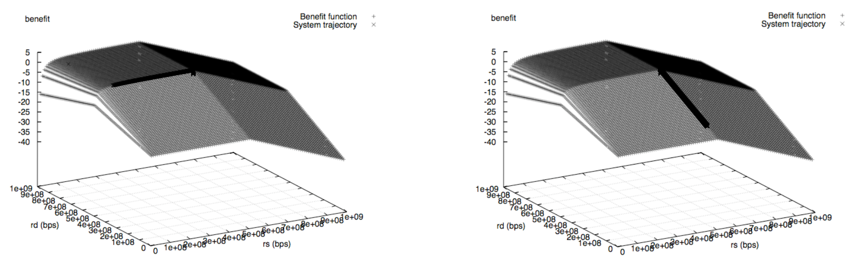
$$\nabla B(\mathbf{r}(t)) \quad = \quad \left[\frac{b_v(t) r_d(t)}{d_{max} r_v r_s^2(t)} - \frac{\hat{T}(t)}{l_{max}}, \frac{b_v(t)}{d_{max} r_v r_s(t)} + \frac{\hat{T}(t)}{l_{max}} \right]$$

where, $b_v(t)$ is the amount of data to be transmitted from the telescope, $r_d(t)$ is the current discard buffer transmission rate, r_v is the telescope transmission rate, $r_s(t)$ is the EGAE transmission rate into the network and $\hat{T}(t)$ is the estimated remaining time until completion.

EGAE Simulation Results



r_v=512e6, r_n=512e6, b_v=44.2e12,d_max=86,400,l_max=2.2e12



Summary

- e-VLBI:
  - Large, real-time, loss tolerant flows, some delay tolerance
- VSI-E Framework for e-VLBI Data Transfers
- Experiment Guided Adaptive Endpoint
  - VSI-E Interface
  - RTP Transport Proposal
  - EGAE Optimization Algorithm under development

Thank you

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