Mark 6 Next-Generation VLBI Data System

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Data rates for VLBI2010

• VLBI2010 data rates are dictated by
  - Small antennas (12m class)
    - Antennas must be able to move very quickly around sky
  - Weak sources
    - Sources need to be ~uniformly distributed in the sky and have simple or no structure, which severely constrains available sources
  - Short observations
    - VLBI2010 on-source observations will be ~10 secs each
    - Antenna must move around sky quickly to map temporal atmospheric fluctuations
    - Most of observation period is spent moving antenna from source-to-source

All these factors conspire to dictate very high data rates (both instantaneous and average)
VLBI Data Rates and Volume are not for the faint of heart!

- VLBI2010 at 4 Gbps/station average, 4 to 20 stations
  - ~5-40 TB/station/day
  - Global 10-station experiment @ 4 Gbps/station up to ~400 TB/day
  - Single 10-day experiment can produce up to ~4 PB
- Higher data rates (8-32 Gbps) are already on the horizon; higher data rates → more sensitivity
- Available disk supply can support only few days of observations at these rates
- 1967: 720 kbps, 1st VLBI
- 1971: 4 Mbps
- 1979: 224 Mbps
- 1990: 512 Mbps
- 2002: 1 Gbps
- 2006: 2 Gbps
- 2011: 4 Gbps
- 1990: 512 Mbps
# Mark 5 Data Acquisition System

(Mark 5A/B/B+/C all look the same)

<table>
<thead>
<tr>
<th>Mark 5</th>
<th>Year introduced</th>
<th>Record rate (Mbps)</th>
<th>Interface</th>
<th>Cost (USk$)</th>
<th>#deployed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mark 5A</td>
<td>2002</td>
<td>1024</td>
<td>Mk4/VLBA</td>
<td>21</td>
<td>~130</td>
</tr>
<tr>
<td>Mark 5B</td>
<td>2005</td>
<td>1024</td>
<td>VSI-H</td>
<td>22</td>
<td>~40</td>
</tr>
<tr>
<td>Mark 5B+</td>
<td>2006</td>
<td>2048</td>
<td>VSI-H</td>
<td>23</td>
<td>~30</td>
</tr>
<tr>
<td>Mark 5C</td>
<td>2011/12</td>
<td>4096</td>
<td>10GigE</td>
<td>21</td>
<td>~20</td>
</tr>
</tbody>
</table>

Mark 5 includes a significant amount of proprietary technology.
Next up – Mark 6

- 16Gbps sustained record/playback and burst-mode capability
- 4 x 10GigE input ports
- Based on inexpensive high-performance COTS hardware
- Linux OS with open-source software
- Resilient File System to manage slow and failed disks
- e-VLBI support
- Fully VDIF/VTP compliant
- Goal is to preserve as much investment in existing Mark 5 systems and disk libraries as possible
- Mark 6 collaboration:
  - Haystack Observatory – all software and software support
  - NASA/GSFC High-End Network Computing group – consultation on high-performance COTS hardware
  - Conduant Corp – Mark 6 disk module
Basic Mark 6 System

Mark 6 controller

- 4 x 10GigE
- 4 x 4Gbps sustained (demonstrated)
- 4 x 8Gbps burst (untested)

8-disk module x 4

Commodity SATA disks

Completely COTS data electronics

RAID or Resilient File System

16Gbps sustained (demonstrated)
16 Gbps VLBI demonstration with Mark 6
24 October 2011

- 16 Gbps VLBI demonstration with Mark 6 Data System
- 32-disk array
- DiFX Software Correlator
- Fringes!
Correlation results (single 500MHz channel)
Mark 6 Project Status

• Sustained 16Gbps from four 10GigE interfaces to disk has been demonstrated
• To be completed:
  – Full VSI-S command set
  – Resilient File System (current implementation is RAID-based)
  – Playback as standard Linux files
• Prototype Mark 6-specific hardware pieces arrived at Haystack last week from Conduant
  – New Mark 6 chassis-backplane power-management boards
  – Mark 5-to-Mark 6 SATA disk module upgrade kit
  – New cable-management panel
Prototype Mark 6 hardware

- High-speed data connections to module front-panel via two standard SAS cables
- Existing Mark 5 chassis is upgradeable to Mark 6
- New chassis backplanes for disk power management
- Cable-management panel (unused cables retract into panel)
- Existing Mark 5 SATA disk modules are upgradeable to Mark 6 (new backplane and front panel)
Projected Mark 6 schedule

- Mar 2012 – GGAO/Westford Mark 6 test with broadband VLBI2010 system (dual-pol with 2GHz BW/pol)
- Mar 2012 – Test Conduant prototype hardware; integrate complete hardware system; begin integration with Field System
- mid/late 2012 – System complete and fully tested; (new complete Mark 6 system <$15k)
VDIF
(VLBI Data Interchange Format)

- Standardized format for raw time-sampled VLBI data
- Compatible with both VLBI data-recording systems and e-VLBI data transmission
- Highly flexible to accommodate a large variety of channel and frequency configurations, including mixed sample-rate data
- VDIF being implemented for all new VLBI2010 systems
- Accompanying VLBI Transport Protocol (VTP) specifies e-VLBI data-transmission protocol for VDIF-formatted data stream

For details: www.vlbi.org
VTP
(VLBI Transmission Protocol)

• Companion specification to VDIF
• Specifies e-VLBI data-transmission protocol for VDIF-formatted data streams
  – Normally must use UDP or UDP-like protocol to maintain necessary data rate
  – Addition of Packet Serial Numbers (PSNs) helps to keep packets organized and identify missing packets (a few missing packets are not normally a problem)
Thank you
Backup slides
Thank You’s

Haystack/Westford –
  Chris Beaudoin, Pete Bolis, Roger Cappallo, Shep Doeleman,
  Geoff Crew, Rich Crowley, Dave Fields, Alan Hinton, David Lapsley,
  Arthur Niell, Mike Poirier, Chet Ruszczyk, Jason SooHoo, Ken Wilson

NASA/GSFC VLBI Group –
  Tom Clark, Ed Himwich, Chopo Ma

NASA/GSFC GGAO –
  Roger Allshouse, Wendy Avelar, Jay Redmond

NASA/GSFC High-End Computer Networking Group –
  Bill Fink, Pat Gary (recently deceased), Paul Lang

Conduant –
  Phil Brunelle, Greg Lynott, Ken Owens
Recording-rate cost vs. time

- Mark 1
- Mark 2
- Mark 3
- VLBA
- Mark 4
- Mark 5A
- Mark 5B+
- Mark 5C
- Mark 6
- Mark 7

- COTS
- Mostly COTS

k$/Gbps
Recording-rate capability vs time

- Mark 1
- Mark 2
- Mark 3
- VLBA
- Mark 4
- Mark 5A
- Mark 5B+
- Mark 5C
- Mark 6
- Mark 7?

Mostly COTS

COTS Disk Projection

Gbps

Mark 6 M&C and concepts

• VSI-S command set
• Recording units are defined as ‘volumes’, each of which consists of one or more physical disk modules
  – Multi-module volumes are required for recording rates >~4Ggps
  – Multi-module volumes retain identity thru correlation processing, then are returned to single-module volumes
• Volumes are managed on an ordered ‘Volume Stack’ that allows multiple volumes to be mounted simultaneously
  – Allows volumes to be queued in specific order for usage
  – Supports automated switchover to next volume in Volume Stack when current module becomes full; switchover takes place between scans
• Disk statistics gathered during recording allow easy identification of slow/failing disks by disk serial number
Mark 6 16Gbps demonstration system

Asus P6T6 WS Revolution motherboard
2 x Myricom 10G-PCIE2-8B2-2C 10GE NIC
2 x LSI 9280-24i4e RAID controller

Mark6 Controller (4U Chassis)

Mark6 Disk Module (8-pack)
Mark6 Disk Module (8-pack)
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Mark6 Disk Module (8-pack)
How will Mark 6 be available?

- Several options:
  - Purchase new Mark 6 system from Conduant
  - Upgrade existing Mark 5 system (either yourself or with kit from Conduant)
  - Upgrade Mark 5 SATA-modules (with upgrade kits from Conduant)
  - Purchase Mark 6 modules (with or without disks)