Design Concept for a Next Generation Data Recorder for LWA

LWA Memo #207

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Contents

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1 Introduction

The purpose of this memo to outline a design concept for a next generation data recorder, both software and hardware, for use at LWA stations. Although the current data recorders work well at LWA1, the software is largely unsupported and there have been many lessons learned over the past $\sim$5 yr with regards to station operations. This memo is organized as follows: §2 provides an overview of the current approach to data recording at LWA stations. Section 3 explores the limitations of the current approach while §4 provides ta design overview for a next generating recording system.

2 Current Approach

Both LWA1 and LWA-SV use a similar setup for data recording. The setup consists of three parts: a data recorder computer, data recorder storage units that store the data, and a software program known as "DROS" which implements all of the necessary functionality. The relevant details are provided below with a more detail discussion of the design available in [3].

2.1 Data Recorder Computer

The data recorder computers (DRs) are Dell Precision T1500 workstation mini-towers. Each hosts an Intel Core i7 CPU running at a clock speed of 2.93 GHz. This processor has four cores and eight threads with hyperthreading. Each DR also contains 8 to 16 GB of 1333 MHz non-ECC memory, a Silicon Image Serial ATA card with two eSATA ports, and a 10 GbE network card for receiving data. For DRs at LWA1 this 10 GbE card uses a CX4 connector while the cards at LWA-SV are fiber cards with SFP+ slots. Apart from these details the machines are otherwise "stock" T1500s.

Apart from the T1500, the only other machine considered for use as a DR was the Dell Studio XPS. This was also a mini-tower with similar specifications as the T1500. However, only one machine was ever deployed at LWA1 and it was removed after some time due to problems with the machine.

2.2 Data Recorder Storage Units

The data recorder storage units (DRSUs) consist of stand-along 1U disk packs that connect to the DR via eSATA. Each DRSU consists of a 1U DAT Optic shell, five hard drives, a SATA port multiplier[1], an eSATA port, and the associated power and cooling. Currently 2 TB and 3 TB hard drives are certified for use in a DRSU. The drives are configured as a Linux softwre RAID0 (striped) array which places the total capacity of a DRSU at 10 to 15 TB. To increase the storage available on each DR two DRSUs are typically deployed. Due to a combination of the eSATA interface and the drives used the maximum recording bandwidth of a DRSU is $\approx$1 Gb/s.

2.3 Data Recorder Software

The data recorder software, DROS, is a C++ application developed at Virginia Tech specifically for LWA. DROS implements scheduled recordings for all three data modes available at LWA1 through a multi-threaded framework that runs on Linux-based operating systems[2]. The framework consists

[1]The port multiplier is of particular note since it limits which Serial ATA cards can be used to interface with a DRSU. In particular the Silicon Image chip used in the DRs support two port multipliers while newer Marvell chips only support one.

[2]DROS is known to work with Ubuntu 12.04 LTS and 14.04 LTS.

of a manager, a receiver, and a collection of actors that can interface with the data. The manager is responsible for receiving and replying to commands as well as scheduling operations. The receiver collects and provides limited buffering, ∼4 MB, of incoming data while the actors operator on the data. The most common mode of operation is directly recording the data stream to disk. However, for beam formed observations there is also an on-the-fly spectrometer mode that produces channelized linear and Stokes data products. This is implemented using the FFTW3 library [2], with one thread devoted to each of the four tuning/polarization pairs available in a LWA beam.

The DROS software has been through a number of revisions. The initial version only supported raw recordings and the spectrometer mode as added in a later release. Support for the new LWA-SV data formats was added in late 2016/early 2017. Currently the software is not being actively developed and is only updated to address serious issues.

3 Limitations of the Current Approach

Although the current approach outlined in §2 has worked well over the past several years of operation at LWA1 there are several notable limitations that argue for a new approach.

3.1 Availability of Parts

One of the greatest limitation is the availability of parts to build DRs and DRSUs, both from the standpoint of deploying new systems at new LWA stations and for the repair of existing systems. First, the T1500 platform was released in circa 2010 and has reach end-of-life. Machines are no longer available except through surplus channels or in used condition. This makes it difficult to deploy new systems and will eventually translate to problems finding replacement parts, particularly those unique to the T1500. Similarly, the 1U cases used for the DRSUs have gone through a number of iterations over the last several years that have changed the case design and part layouts. This introduces physical compatibility issues for newer replacement parts for older cases. Finally, hard drives have a quick development and replacement pace that makes finding drives that are compatible with the requirements of the DRSU a moving target. In addition, changes to the firmware of a hard drive may lead to some drives of the same model number being too slow or unreliable to be used for data recording.

3.2 Additional Maintenance

The current setup requires one DR, with two DRSUs, for each output that needs to be recorded. At LWA1 this translates to five DRs (four beams + TBN/TBW), 10 DRSUs, and 50 hard drives. Although 50 hard drives may not seem like a large number the fact that they are grouped into RAID0 arrays with *no* redundancy leads to almost constant maintenance to replace drives before they fail and data is lost. Recovering from a failing drive not only costs the time it takes to drive out to the site, pull the DRSU, install a new one, and drive back but also that required to recover data from the drive.

There is also the possibility that the data cannot be recovered. This leads to a more conservative approach to disk health monitoring and prompts more frequent changes of the DRSUs. Currently, we are performing site trips about ∼1.3 times per month at LWA1 to replace failing or failed drives.

3.3 Limited Flexibility

The tight coupling between the hardware and software requirements of DROS make deploying new systems or adding new features difficult and lead to limited flexibility. Although the difficulty in procuring new parts has already been discussed there are also other aspects to this. One is that, because each DR has two dedicated DRSUs, there is inherent over-provisioning of storage at the station since the load on the DRs is uneven. Specifically at LWA1, there are many more beam formed observations than transient buffer observations and limitations of the Digital Processor lead to observers avoiding beam 1. Interestingly, the most flexible part of the DR/DRSU approach is the ability to easily change the DRSUs for replacement and transport. Although this was originally a design requirement we find that we only swap DRSUs when there is a problem. Otherwise, observers typically request that their data be copied over to the LWA Users Computing Facility cluster for analysis.

The other major limitation in the flexibility of DROS is that the original developer of the software is not longer actively developing or maintaining it. Although it was relatively easy to add support for the LWA-SV data format, more advanced features would likely require significant effort. Thus, new features are almost impossible to add due to the complexity of the existing code base and lack of familiarity.

3.4 Changes in Technology

The rate of technological development has been increasing in recent years. This quick develop/deploy/replace cycle for both hardware and software is at odds with the requirements for deploying a new data recorder. There are several examples of this:

- The eSATA interface for external drives has largely been supplanted by USB3;
- There are few modern disk enclosures that support multiple drives since the emphasis has been on deploying larger single drives;
- There has been a shift away from standard BIOS to uEFI setups on newer machines. This is at odds with the Serial ATA cards that can support two port multipliers since they are not compatible with uEFI-only machines; and
- Rapid development of software that is utilized in DROS, particularly changing APIs, leads to additional time required to deploy the software on a newer operating system.

From a more philosophical viewpoint it is also difficult to ignore the recent advancements in computing efficiency in favor of a system that is tied to older hardware. Power consumption, including power needed to run air conditioners to remove heat from the electronics, is a large factor at an LWA station.

4 Design Concept

In light of these limitation we are proposing a new concept for recording data at LWA stations. This concept is centered around creating a setup that is both more flexible than what is currently used and is easier to adapt as technology changes. The principle features of this concept are:

- A single machine that support recording several gigabit streams or one multi-gigabit stream to disk,

- A pooled storage approach where all available storage is attached to the machine,
- Redundancy built in the pooled storage, along with spare disks, to reduce the urgency to immediately address problems,
- Additional buffering to help decouple the bandwidth requirements from the individual disk speeds, and
- Software developed using an open source streaming processing framework.

Details of an example hardware and software setup are provided below.

4.1 Hardware

The design concept is based on the Rackform U623.v6 "StorX 1Z Controller Node" available through Silicon Mechanics that is designed to support disks writes up to 10Gb/s. This system consists of a 2U chassis couple with a 4U JBOD that hosts 44 hot-swap 3.5" drive bays. The machine contains two Intel Xeon E5-2623v4 quad-core processors and 256 GB of RAM. The pooled storage consists of a single ZFS pool composed of five 24 TB "bricks" that implement RAIDZ-2[3] on eight 4 TB drives. The drives are connected to the system via three serial attached SCSI host bus adapters and solid state drives are used store the various ZFS logs (ARC, L2ARC, and SLOG). In total, this system allows for 120 TB of storage with a estimated power requirement of 907 W (4.5 amps at 208 VAC). The details of the system are provided in Appendix A.

Although the storage is integrated into the machine this does not exclude the ability to attached large single disks for off-loading data. 10 TB drives are currently available and a can be attached to the machine via a USB3 toaster.

4.2 Software

The framework that the design concept data recorder is based on is bifrost [1], a new streaming writing in C++ with Python bindings. This is the same framework that is used to implement the Advanced Digital Processor at LWA-SV. Using bifrost one can build multiple pipelines that can be run on the hardware, one pipeline for each data product. This "micro-pipeline" approach would make it easier to integrate the monitor and control requirements into the software and make it easier to deploy additional software, e.g., to support additional beams or data products. Running the pipelines on the same machine also allows all of them to write to the pooled storage which is handled independently by ZFS. Additionally, each pipeline would have its own ring buffer(s) to deal with temporary slow downs in the disk backend. The framework would also allow for spectrometer or other analysis modes, e.g., incoherent dedispersion or real-time transient detection, to be added relatively easily through blocks available in bifrost[4].

Furthermore, the bifrost framework is more hardware agnostic than what is currently used. This feature would allow the software to be deployed in a stand-along fashion on the existing DR machines with DRSUs without significant modification. This would allow for development and testing before the pooled hardware storage would to be purchased. This also helps to mitigate any development risks by allowing key components, i.e., LWA data format-specific readers, to be developed sooner rather than later. Beyond recording LWA data one could also envision using this software as a basis for building other LWA pipelines. e.g., for the eLWA correlator or dedicated pulsar pipelines.

[3] This is the equivalent of RAID6 with two parity disks.

[4] Adding support for a spectrometer mode may require a modification to the hardware listed above to include an Nvidia GPU if the computation load is too much for the CPU.

References

[1] M. Cranmer et al. "Bifrost: a Python/C++ Framework for High-Throughput Stream Processing in Astronomy," JAI, in press.

[2] M. Frigo and S. G. Johnson, "The Design and Implementation of FFTW3," Proceedings of the IEEE 93 (2), 216231 (2005)

[3] C. Wolfe, S. Ellingson and C. Patterson, "MCS Data Recorder Preliminary Design & Verification," Long Wavelength Array Memo No. 165, Aug 26, 2009. [online] http://www.phys.unm.edu/∼lwa/memos

A Pooled Storage System Details

Silicon Mechanics quote for a 120 TB storage system, quote #331678.

Silicon Mechanics

22029 23rd Dr SE
Bothell, WA 98021-4410
(425) 424-0000

Quote

Date	Quote #	Confirmation #
05 / 24 / 2017	331678	1445993422

Please note that due to unusually high volatility in memory and storage component prices in recent months, Silicon Mechanics quotes are now valid for 30 calendar days from date of issue.

Bill To:	Ship To:
acctspay@unm.edu	

Description	120TB - 1 Controller - 1 JBOD - 5 x 24TB vdev
Notes	

Quantity	Description	Price Each	Amount
1	**Rackform U623.v6 "StorX 1Z - Controller Node"** CPU: 2 x Intel Xeon E5-2623v4, 2.6GHz (4-Core, HT, 10MB Cache, 85W) 14nm RAM: 256GB (8 x 32GB DDR4-2400 ECC Registered 4R 1.2V LRDIMMs) Operating at 2400 MT/s Max I/O Controller: Intel Quad-Port X540 10GbE Controller (RJ45) - No PCI Slot 2 Drive Controller: 10 Ports 6Gb/s SATA3 from Intel C612 chipset Management: IPMI 2.0 & KVM with Dedicated LAN - Integrated Expansion Slots: See Image Gallery or Tech Specs for expansion slot details GPU Kit: No Item Selected Note: The following PCIe slots are controlled by CPU1 PCIe 3.0 x16 - 1: No Item Selected PCIe 3.0 x8 - 2: This slot not available if 4-port X540 10GbE controller selected in I/O Controller, above LP PCIe 3.0 x8 - 3: Supermicro 12Gb/s SAS HBA (LSI 3008), 8-Port Internal, RAID 0,1,10 - up to 63 Devices Note: The following PCIe slots are controlled by CPU2 LP PCIe 3.0 x8 - 4: No Item Selected PCIe 3.0 x8 - 5: LSI 9300-8e 12Gb/s SAS HBA (8-Port Ext) PCIe 3.0 x8 PCIe 3.0 x8 - 6: LSI 9300-8e 12Gb/s SAS HBA (8-Port Ext) PCIe 3.0 x8 PCIe 3.0 x8 - 7: No Item Selected PCIe 3.0 x8 - 8: No Item Selected SATA DOM: No Item Selected Drives: Please choose up to 12 hot-swap SAS or SATA drives total Drive Set 1: 2 x Intel 480GB DC S3520 Series 3D MLC (6Gb/s, 1.1 DWPD) 2.5" SATA SSD RAID Configuration: RAID 1: Mirroring Drive Set 2: No Item Selected RAID Configuration: No Item Selected Power Cables: IEC60320 C13 to NEMA 5-15P Power Cable, 18AWG, 120V/15A, Black - 6' Power Supply: Redundant 1000W Power Supply with Digital Switching Control - 80 PLUS Titanium Certified Rail Kit: Quick-Release Rail Kit for Square Holes, 26.5 - 36.4 inches OS: Ubuntu 16.04 LTS Server Edition (64-bit) Community Support Management SW: Supermicro Update Manager (SUM) Out-of-Band Management Software	7678.00	7678.00

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Quantity	Description	Price Each	Amount
	Standard Warranty: 3 Year Silicon Mechanics Standard Warranty NOTE: Advanced Parts Replacement service covers the cross shipping of replacement parts. Advanced Parts Replacement: 3 Year Advanced Parts Replacement NOTE: For onsite service, international coverage, or additional options please contact our Sales department. Notes: Notes: Environment --------------------- - Ubuntu 16.04LTS Server - - Filesystem: ZFS - - Reference: https://wiki.ubuntu.com/Kernel/Reference/ZFS - Additional Packages: zfsutils-linux OR - CentOS 7 - - Filesystem: ZFS - - Reference: http://zfsonlinux.org/ - Additional Packages - - EL7 Package - - http://download.zfsonlinux.org/epel/zfs-release.el7.noarch.rpm Volumes --------------------- Controller - OS/ZFS_Utils: - 480GB [linux md, 2 x 480GB SSD] - SATA3 - Internal Storage Controllers --------------------- SATA3 - Internal - 4 x SATA3 (6Gb/s) Hot Swap HDD Bays - - HDD 0:0..3 SAS3 - Internal: - 8-Port SAS3 HBA -- [12Gb/s, LSI 3008, (2 x SFF-8643)] - 2 x SAS3 (12Gb/s) Hot Swap HDD Bays - - HDD 0:04..11		

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Quantity	Description	Price Each	Amount
	SAS3 - External - 1: - External: 8-Port SAS3 HBA -- [12Gb/s, LSI 3008, (2 x SFF-8644)] SAS3 - External - 2: - External: 8-Port SAS3 HBA -- [12Gb/s, LSI 3008, (2 x SFF-8644)] Network --------------------- 4 x 1000BASE-T/10GBASE-T - Function: Storage Network, management PCIe 3.0 x16 - 1: Available for Expansion PCIe 3.0 x8 - 4: Available for Expansion PCIe 3.0 x8 - 7: Available for Expansion PCIe 3.0 x8 - 8: Available for Expansion **Configured Power:** **Total Power Solution Requirement:** 428 W, 445 VA, 1459 BTU/h, 4.0 Amps (110V), 2.1 Amps (208V) **Total rackmount units:** 2U x 1 = 2U		
1	**Storform D59J.v3 "Disk Shelf"** Backplane: 12Gb/s SAS3 Dual-Expander Backplane NOTE: SED and 4Kn Drives may have an extended lead time.To order, please contact our sales department. Front Drive Set: No Item Selected SAS3 Expander: Expander provides connectivity to front drives (24) and expansion port (SAS Controller Required) Host Port: Connection to host system: External SAS3 (SFF-8644) Expansion Port: Connection for storage expansion: External SAS3 (SFF-8644) Rear Drive Set: No Item Selected SAS3 Expander: Expander provides connectivity to rear drives (20) and Expansion Port Host Port: Connection to host system: External SAS3 (SFF-8644) Expansion Port: Connection for storage expansion: External SAS3 (SFF-8644) NOTE: 8-Port SAS3 HBA or RAID Controller recommended for optimal performance	3122.00	3122.00

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Quantity	Description	Price Each	Amount
	External SAS Cables: 2 x 2m External SAS Cable - x4 SFF-8644 SAS connectors Power Cables: IEC60320 C13 to C14 Power Cable, 16AWG, 240V/15A, Black - 6' Power Supply: Redundant 1280W (1 + 1) Power Supply with PMBus - 80 PLUS Platinum Certified Rail Kit: Quick-Release Rail Kit for Square Holes, 26.5 - 36.4 inches Standard Warranty: 3 Year Silicon Mechanics Standard Warranty NOTE: Advanced Parts Replacement service covers the cross shipping of replacement parts. Advanced Parts Replacement: 3 Year Advanced Parts Replacement NOTE: For onsite service, international coverage, or additional options please contact our Sales department. Notes: Disk Path - Configured as Single Path to disk - Dual path to disk capable Chassis Expander Config: Independent Expanders ---------------------------- Front SAS3 Expander: Expander provides connectivity to front (24) and expansion port - Front Drive Set: (24) x SAS3 (12Gb/s) Hot Swap HDD Bays - Front IN Port: Host: Connection from host system - Front OUT Port: Expansion: - - Available for future expansion - - - Example: Cascade to "New_JBOD"-Front-In ---------------------------- Rear SAS3 Expander: Expander provides connectivity to rear (20) and expansion port - Rear Drive Set: (20) x SAS3 (12Gb/s) Hot Swap HDD Bays - Rear IN Port: Host: Connection from host system - Rear OUT Port: Expansion: - - Available for future expansion - - - Example: Cascade to "New_JBOD"-Rear-In		

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Quantity	Description	Price Each	Amount
	Configured Power: **Total Power Solution Requirement:** 101 W, 105 VA, 345 BTU/h, 1.0 Amps (110V), 0.5 Amps (208V) **Total rackmount units:** 4U x 1 = 4U		
1	**StorX ZFS Pool "FileStore"** ZFS Pool - ARC: ZFS Pool Config - ARC: 96GB (3/4 of 128GB/Main Memory) ZFS Pool - L2ARC: 400GB usable [ZFS Stripe, 2 x 200GB] ZFS Pool - L2ARC - Device: 2 x HGST 200GB Ultrastar MM MLC (12Gb/s, 10 DWPD, Crypto Erase) 2.5" SAS SSD ZFS Pool - SLOG: 100GB usable [ZFS Mirror, 2 x 100GB] ZFS Pool - SLOG - Device: 2 x HGST 100GB Ultrastar MH.B MLC (12Gb/s, 25 DWPD, Crypto Erase) 2.5" SAS SSD Notes: Capacity: 120TB - 5 x 24TB vdev JBOD Utilization: 42 Drive Slots Used [44 Available (1 x 44)] - DATA: 40 - - JBOD 1 - SLOG: 2 - - Host - L2ARC: 2 - - Host - Spare: 2 - - JBOD 1	1937.00	1937.00
5	**StorX ZFS Capacity Device - vdev "FileStore"** ZFS Virtual Device (VDEV) - Selection: 24.0TB usable [RAID Z2, 8 x 4TB, 75% Utilization] ZFS Virtual Device (VDEV) - Device: 8 x Seagate 4TB Enterprise Capacity 3.5 HDD V.5 (12Gb/s, 7.2K RPM, 128MB Cache, 4Kn) 3.5" SAS **Configured Power:** **5 x StorX ZFS Capacity Device - vdev "FileStore":**	1720.00	8600.00

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Quantity	Description	Price Each	Amount
	72 W, 72 VA, 246 BTU/h, 0.7 Amps (110V), 0.3 Amps (208V) **Total Power Solution Requirement:** 360 W, 360 VA, 1230 BTU/h, 3.3 Amps (110V), 1.7 Amps (208V)		
2	**StorX ZFS Capacity Device - vdev "FileStore"** ZFS Virtual Device (VDEV) - Selection: ZFS Pool Spare Drive/s for Pool - Installed in chassis ZFS Virtual Device (VDEV) - Device: 1 x Seagate 4TB Enterprise Capacity 3.5 HDD V.5 (12Gb/s, 7.2K RPM, 128MB Cache, 4Kn) 3.5" SAS **Configured Power:** **2 x StorX ZFS Capacity Device - vdev "FileStore":** 9 W, 9 VA, 31 BTU/h, 0.1 Amps (110V), 0.0 Amps (208V) **Total Power Solution Requirement:** 18 W, 18 VA, 62 BTU/h, 0.2 Amps (110V), 0.1 Amps (208V)	215.00	430.00

Total Configured Power

1 x Rackform U623.v6 "StorX 1Z - Controller Node":
Sub-total Configured Power: 428 Watts, 445 Volt-Amps, 1459 BTU/h, 4.0 Amps(110V), 2.1 Amps(208V)
1 x Storform D59J.v3 "Disk Shelf":
Sub-total Configured Power: 101 Watts, 105 Volt-Amps, 345 BTU/h, 1.0 Amps(110V), 0.5 Amps(208V)
5 x StorX ZFS Capacity Device - vdev "FileStore":
Sub-total Configured Power: 360 Watts, 360 Volt-Amps, 1230 BTU/h, 3.3 Amps(110V), 1.7 Amps(208V)
2 x StorX ZFS Capacity Device - vdev "FileStore":
Sub-total Configured Power: 18 Watts, 18 Volt-Amps, 62 BTU/h, 0.2 Amps(110V), 0.1 Amps(208V)

Total Configured Power: 907 Watts, 928 Volt-Amps, 3096 BTU/h, 8.4 Amps(110V), 4.5 Amps(208V)

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Total Rackmount Units

1 x Rackform U623.v6 "StorX 1Z - Controller Node":
Sub-total Rackmount Units: 2U
1 x Storform D59J.v3 "Disk Shelf":
Sub-total Rackmount Units: 4U

Total Rackmount Units: 6U

Subtotal	21,767.00
Sales Tax (0%)	0.00
Total	USD 21,767.00

Orders shipped to WA, CA, CO, and TX are subject to the appropriate tax rate. The quoted tax amount is subject to change.
Subject to Silicon Mechanics' Warranty Terms and Conditions - https://www.siliconmechanics.com/terms-and-conditions.php