A New 1Tbps Ethernet Streaming Data Interface Between FPGA and GPU Based Digital Signal Processing Systems for a Phased Array Feed

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1. Extended Abstract

In 2015 the Max Planck Institute for Radio Astronomy (MPIfR) contracted the Astronomy and Space Science Group at the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) to produce an additional Phased Array Feed (PAF) receiver system, designed for the Australian Square Kilometre Array Pathfinder (ASKAP). The additional PAF system is for use on the Effelsberg 100m diameter single-dish radio telescope in the North Rhine-Westphalia region of Germany. ASKAP is a new 36-antenna aperture synthesis imaging radio telescope array being built by the CSIRO in a remote and radio quiet area of Western Australia [1]. ASKAP introduces a new approach in radio astronomy: the use of phased arrays at the focus of each dish antenna in the telescope array, rather than the conventional single feed element. The PAF permits multiple beams to be formed on the sky simultaneously at each antenna resulting in a dramatic increase in the instantaneous Field-of-View (FoV) of the telescope [2]. The beams can overlap, which allows continuous FoV to be formed. The large FoV advantages of the PAF system translate directly to the single-dish application, however one of the key architectural changes from ASKAP to the single-dish configuration for MPIfR was the replacement of the FPGA-based correlator hardware (used for synthesis imaging) with a commercial network switch and GPU-based digital signal processing back-end as shown in Figure 1.

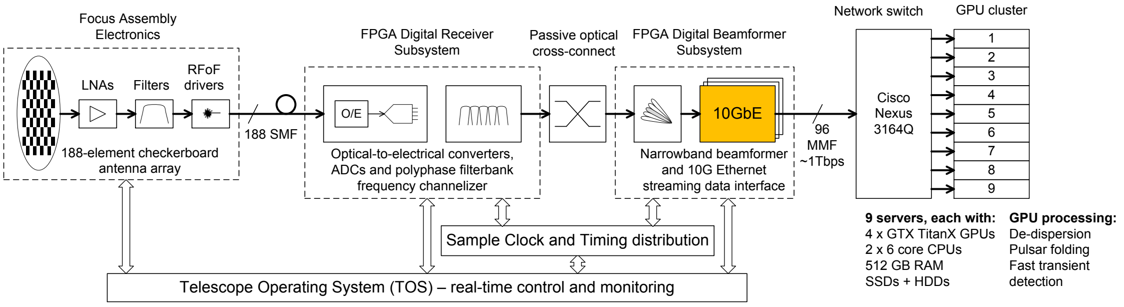
Focus Assembly Electronics
LNAs
Filters
RFoF drivers
188-element checkerboard antenna array
188 SMF
FPGA Digital Receiver Subsystem
O/E
Optical-to-electrical converters, ADCs and polyphase filterbank frequency channelizer
Passive optical cross-connect
FPGA Digital Beamformer Subsystem
10GbE
Narrowband beamformer and 10G Ethernet streaming data interface
96 MMF ~1Tbps
Network switch
Cisco Nexus 3164Q
GPU cluster
1
2
3
4
5
6
7
8
9
9 servers, each with:
4 x GTX TitanX GPUs
2 x 6 core CPUs
512 GB RAM
SSDs + HDDs
GPU processing:
De-dispersion
Pulsar folding
Fast transient detection
Sample Clock and Timing distribution
Telescope Operating System (TOS) – real-time control and monitoring

Figure 1. End-to-end signal chain for the MPIfR PAF system.

To support this new architecture, the firmware of the ASKAP FPGA-based PAF digital beamformer was modified to provide real-time streaming of beam voltage data from the PAF in a new 10Gbps Ethernet format. This paper provides an overview of the MPIfR single-dish PAF system and focusses on the design of the FPGA-based 10GbE streaming data interface and a new Ethernet data format that transports PAF beam voltages to a GPU compute cluster via a commercial network switch. The Ethernet output interface implements a User Datagram Protocol (UDP) transmission model and we present a new, efficient Ethernet packet format with a structure designed specifically to cater for streaming the multidimensional data that comes with PAF receiver systems. The new format, termed CODIF (CSIRO Oversampled Data Interchange Format) is based on the VLBI Data Interchange Format (VDIF) [3], however it has been substantially modified and extended from this standard to allow for the transport of rich meta-data and to accommodate fractionally oversampled data streams that are becoming more common in radio astronomy signal processing systems. The Ethernet interface firmware has been designed with the flexibility to route each data stream through a commercial Ethernet switch to any GPU end point. The switch provides a flexible data cross-connect function, concentrating all bandwidth for a subset of beams to a given GPU end-point. The A total of 1728 data streams deliver thirty-six 336 MHz dual polarized beams at a total raw line rate of 915 Gbps to the GPU processing cluster with a granularity of 7MHz per stream.

2. References

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2. Hotan, A. W. et al, “The Australian Square Kilometre Array Pathfinder: System Architecture and Specifications of the Boolardy Engineering Test Array,” in Publications of the Astronomical Society of Australia, **31**, 2014, e041
3. VDIF Taskforce, *VLBI Data Interchange Format (VDIF) Specification*, http://www.vlbi.org/vdif/, 2009