VDIF -
VLBI Data Interchange Format

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Motivation & Execution

- Variety of VLBI data formats used internationally complicates easy international data transfer
- Internationally constituted VDIF Task Force appointed in Shanghai in June 2008 to study problem and create a recommended uniform transport-independent VLBI data-format standard
- Data-transport standard (VTP?) will be addressed separately
- Combination of data-format and data-transport standards will effectively replace proposed VSI-E

Assumptions

- Data are assumed to be one or more time series of uniformly time-sampled data
- Each time series may have its own sample rate, bits/sample and place of origin (i.e. station)

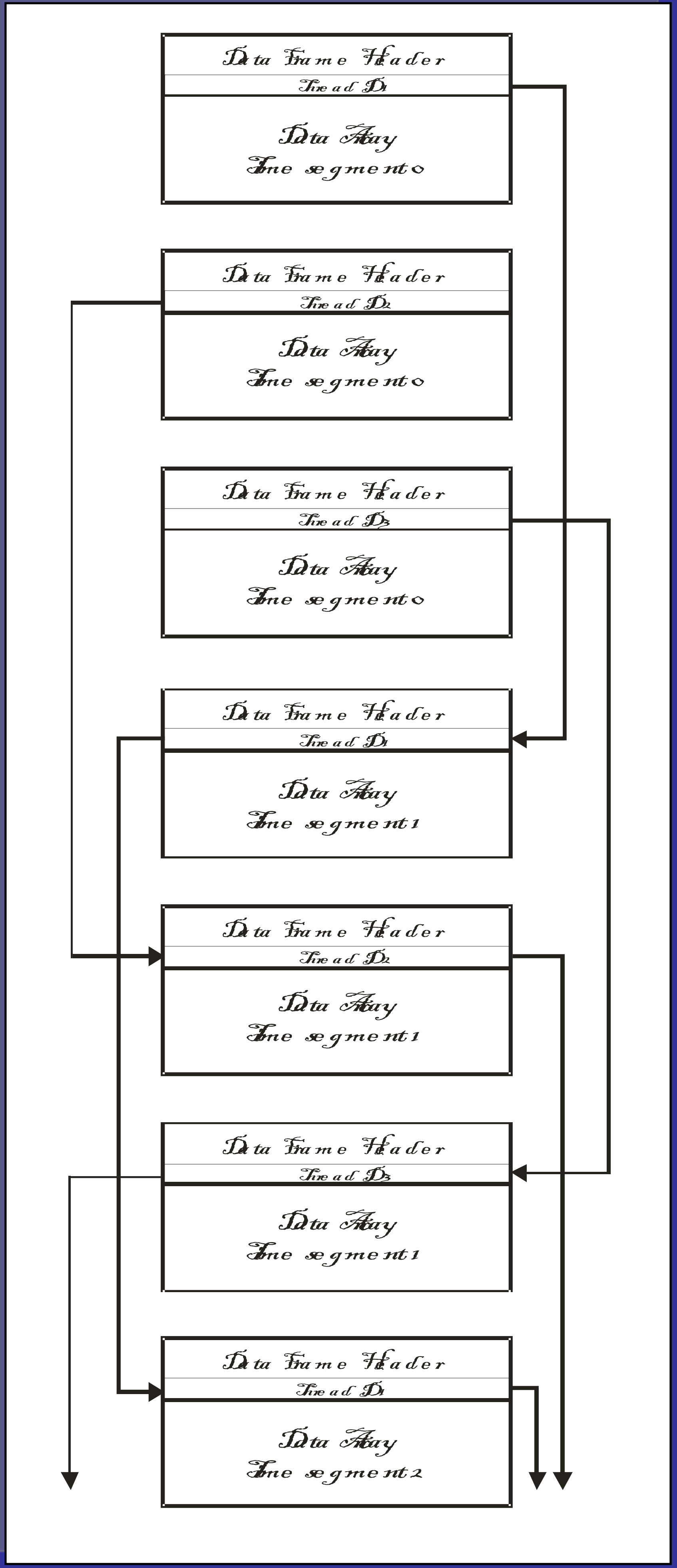
Major VDIF attributes

- Data may be single-channel or multi-channel
- Number of channels can be arbitrary
  (i.e. not confined to 2^n)
- Data may be single bit or multi-bit samples
- Data are self-identifying wrt time tag, data source, #bits/sample
- Data can be decoded without external reference
- Data may be discontinuous in time (e.g. pulsar data)
- Data are packetized into Data Frames suitable for on-wire transfer as well as direct disk file storage
- Support data rates up to at least 100Gbps
- Non-VLBI specific; suitable for most any uniformly time-sampled data set

Hierarchical Data Structure

- Aggregate data flow is defined as a <u>Data Stream</u>
- A Data Stream is organized into self-identifying <u>Data Threads</u>
  - Each Data Thread may have its own #channels, sample rate, and bits/sample
- Each Data Thread contains of a serial set of <u>Data Frames</u>
- Each Data Frame consists of a <u>Data Frame Header</u> followed by a <u>Data Array</u>
  - Data Array length may be chosen by user
  - Data Array may contain single-channel or multi-channel data

Illustration of multi-thread VDIF Data Stream



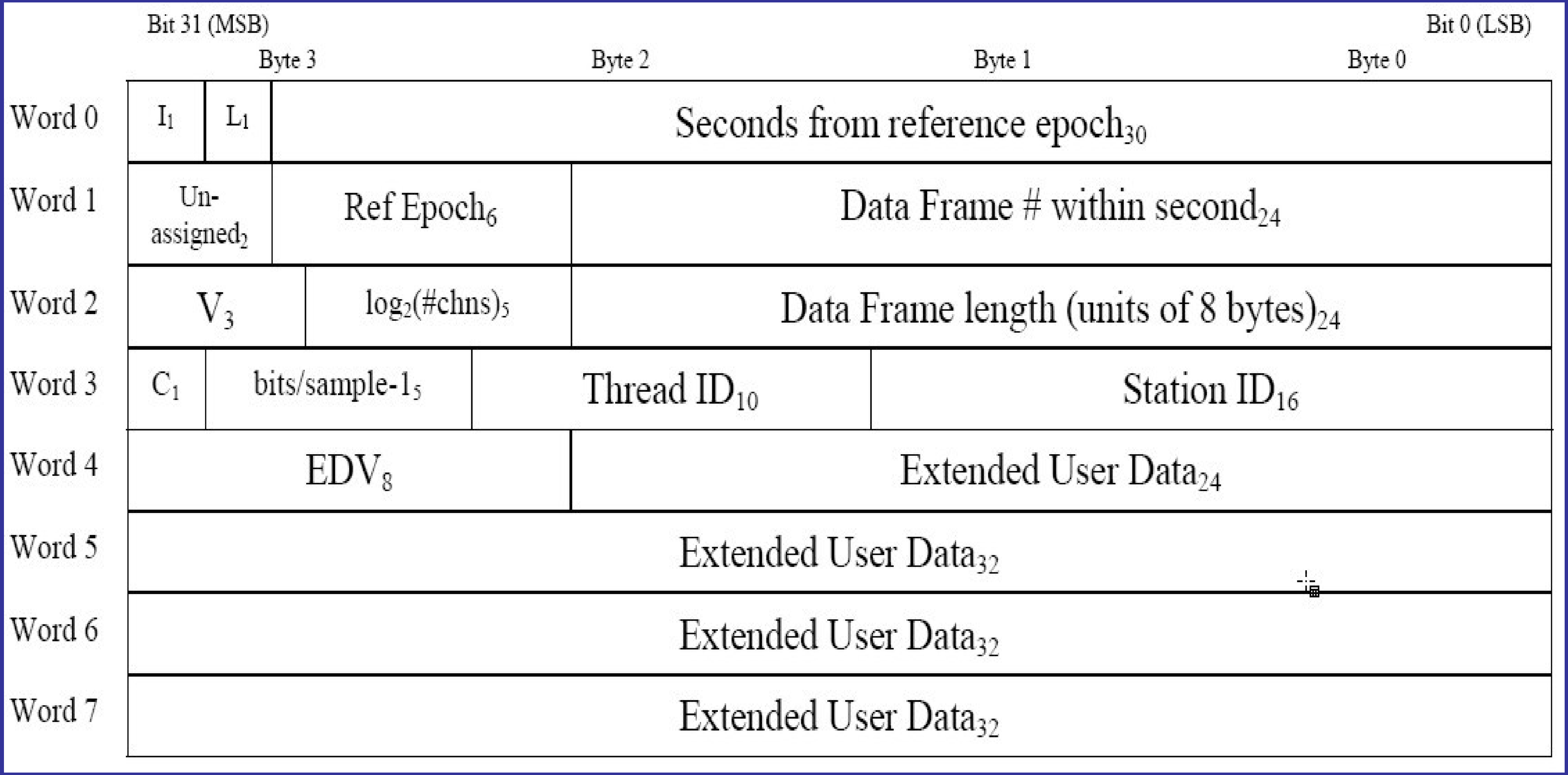
Data Frame Rules

- Each Data Frame has 16/32 byte header followed by a Data Array of user-specified length
- Data Frame length for a single Data Thread is fixed for a particular scan
- #Data Frames per second must be an integer
- Data Frame may not span a second boundary
- Data Frame length must be a multiple of 8 bytes
  - For Ethernet transfer, length would normally be chosen to be <~9000 bytes
  - length is allowed to be as long as one second

Data Frame Header Content

- Time (seconds since specified epoch)
- Frame # within second
- Stream ID
- Station ID (2-char ASCII code)
- ‘Data-invalid’ marker
- #channels
- Bits/sample
- ‘Complex’ (‘In-phase/Quadrature’ channels) data marker
- Data Array length
- VDIF version #
- Optional user-defined 16-byte extension
  - Up to 255 unique user-defined formats may be ‘registered’ so that they are easily identified
  - registry to be set up at Haystack VSI web site

Data Frame Header Format



<table>
<tr><td></td><td colspan="16">Bit 31 (MSB)</td><td colspan="16">Bit 0 (LSB)</td></tr>
<tr><td></td><td colspan="8">Byte 3</td><td colspan="8">Byte 2</td><td colspan="8">Byte 1</td><td colspan="8">Byte 0</td></tr>
<tr><td>Word 0</td><td colspan="1">I_1</td><td colspan="1">L_1</td><td colspan="30">Seconds from reference epoch$_{30}$</td></tr>
<tr><td>Word 1</td><td colspan="2">Un-assigned$_2$</td><td colspan="6">Ref Epoch$_6$</td><td colspan="24">Data Frame # within second$_{24}$</td></tr>
<tr><td>Word 2</td><td colspan="3">V_3</td><td colspan="5">$\log_2$(#chns)$_5$</td><td colspan="24">Data Frame length (units of 8 bytes)$_{24}$</td></tr>
<tr><td>Word 3</td><td colspan="1">C_1</td><td colspan="5">bits/sample-1$_5$</td><td colspan="10">Thread ID$_{10}$</td><td colspan="16">Station ID$_{16}$</td></tr>
<tr><td>Word 4</td><td colspan="8">EDV$_8$</td><td colspan="24">Extended User Data$_{24}$</td></tr>
<tr><td>Word 5</td><td colspan="32">Extended User Data$_{32}$</td></tr>
<tr><td>Word 6</td><td colspan="32">Extended User Data$_{32}$</td></tr>
<tr><td>Word 7</td><td colspan="32">Extended User Data$_{32}$</td></tr>
</table>

Byte order: little-endian

Data Array Format

- Data Array format is based solely on the #chans and #bits/sample (as specified in the corresponding Data Array Header)
- Adherence to the Data Array format specification is necessary to ensure that the data are properly interpreted

Data Frame ordering

- Data Frames from a single source will normally be transmitted and received in strict time order
- Data Frames transmitted through a switch or over a network are not guaranteed to arrive in order
- VDIF does not mandate strict Data Frame ordering within a Data Thread or among Data Threads, but some correlators (particularly legacy hardware correlators) may require strict ordering

Usage example 1

- Data Stream with multiple single-channel Data Threads (VLBI2010 model)
  - Supports arbitrary # of channels (one Data Thread per channel)
    - allows better fine-tuning of aggregate data rate for better utilization of e-VLBI transfers
  - Supports 1 to 32 bits/sample (some packing inefficiency for some values of bits/sample)
  - Preferred for new equipment and applications
  - Best compatibility with software correlators

Usage example 2

- Data Stream with one or more multi-channel Data Threads
  - Multiple channels in a single Data Stream
  - Primarily targeted at legacy VLBI data sources
  - Limited to 2^n channels ($0 \leq n \leq 31$)
  - Limited to 2^k bits/sample ($0 \leq k \leq 5$)
  - Avoids ‘corner turning’ requirement
  - Adaptable to support some older equipment

‘Simple’ VDIF Data Stream

- Each Data Thread within a ‘simple’ VDIF Data Stream must have same:
  - # of channels
  - #bits/sample
  - data type (‘real’ or ‘complex’)
  - #Data Frames/sec
  - Data Frame Header Length
  - Data Array Length
- Expected to be most common usage
- Useful VDIF Format Designator is constructed as

  “<total sample-data rate> - <total #chans> - <#bits/sample> [- <#threads>]”

  e.g. 1024-16-2-1 or 1024-16-2

  Note similarity to VLBA mode designation

‘Compound’ VDIF Data Stream

- A ‘compound’ VDIF Data Stream contains two or more intermixed ‘simple’ Data Streams, each of which is called a ‘Data Group’
- Set of numerical Thread IDs within each Data Group must occupy a unique, non-overlapping range
- Useful VDIF Format Designator is constructed as
  “DataGroup1 Designator> + <DataGroup2 Designator> + ….”
  e.g. 1024-16-2-16+256-8-2

File-naming conventions

- Applies only to data stored in named disk files
- File-name suffix ‘vdif’
- Otherwise, should conform to internationally agreed file-naming convention available at http://www.haystack.mit.edu/tech/vlbi/vsi/index.html
- Example:

  gre53_ef_scan035_fd=1024-16-2.vdif

  which specifies

  Experiment: gre53
  Station: ef
  Scan name: scan035
  VDIF Format Designator: 1024-16-2

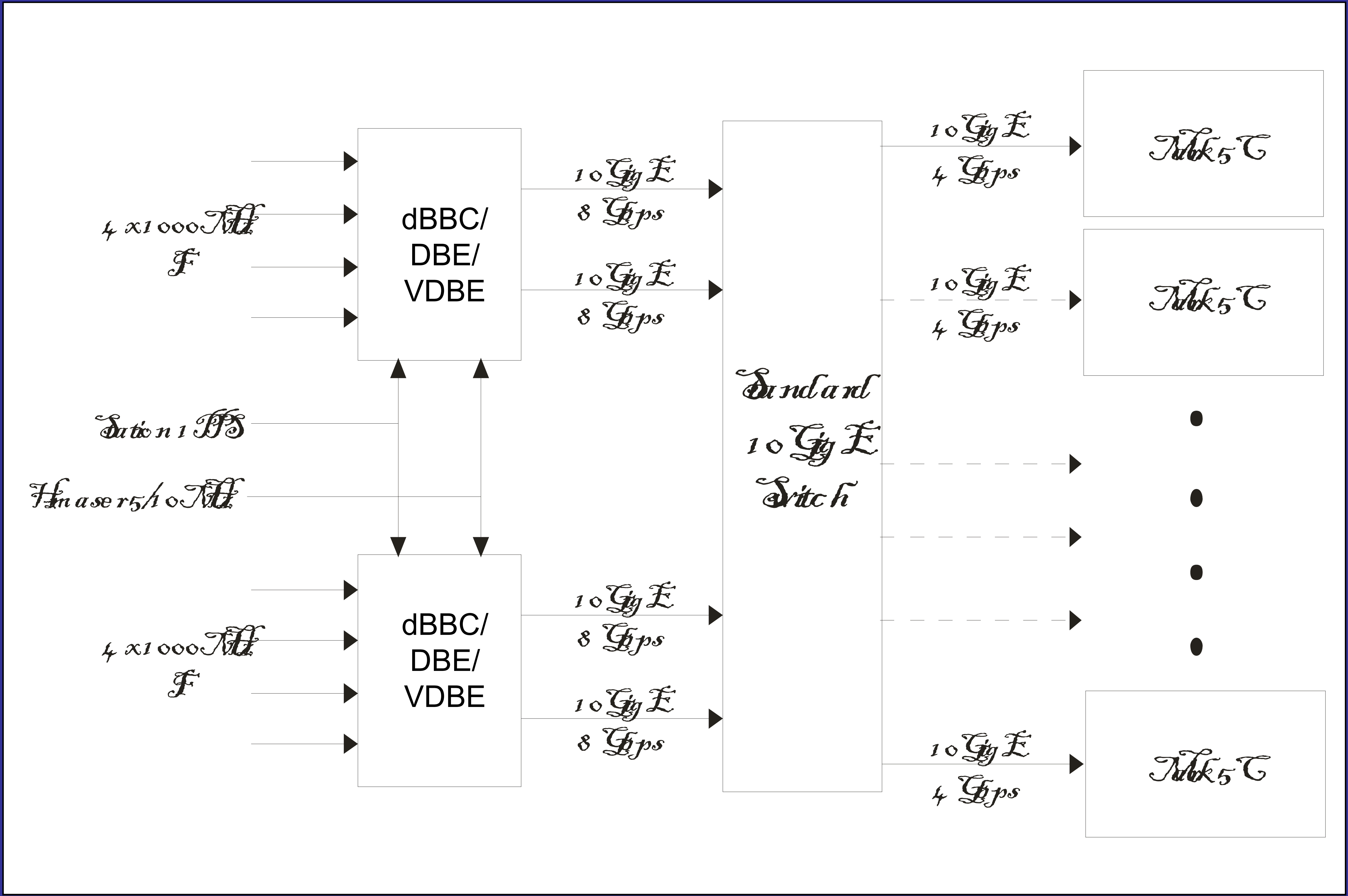
VDIF Status

- VDIF Draft Release 1.0 has been available for community comment for ~6 months
  - Available at http://www.haystack.mit.edu/tech/vlbi/vsi/index.html
  - Has been carefully reviewed by several key members of global VLBI community
  - Final ratification hoped for at this meeting
  - Ratification important because it allows FPGA/hardware designers to proceed

The Next Step – VLBI Transport Protocol (VTP)

- VTP is complementary to VDIF for data transported over high-speed networks
- What are the possible characteristics of VTP?
  - Transparently support current and future transport protocols (i.e. TCP, UDP, Tsunami, etc, etc)
  - Multi-cast support?
  - Negotiate (via TCP?) a mutually acceptable transport protocol between data source and data sink
  - Normally will be one VDIF Data Frame per transport packet
  - Define a ‘wrapper’ around each VDIF Data Frame to enhance data accountability
  - Support easy integration into VEX and SNAP command streams
  - Must be simple, easy to implement and easy to use
- Goal is to have draft VTP spec ready in a few months

Generalized 10GigE Data Distribution Concept



Thank you