HDF5 at ITER
Lana Abadie ¹, Rodrigo Castro ², Yury Makushok ³, David Muir ⁴, Jonathan Hollocombe ⁴, Simon Pinches ¹, Mikyung Park ¹, Anders Wallanders ¹

¹ ITER Organization
² CIEMAT
³ INDRA
⁴ Culham

Disclaimer: The views and opinions expressed herein do not necessarily reflect those of the ITER Organization
ITER

- 7 ITER members (China, E.U, India, Japan, Russia, South Korea, U.S.A) make cash in kind-contributions to the ITER project
- Demonstrate feasibility of fusion energy for peaceful purposes
- A plasma of deuterium and tritium (hydrogen isotopes) is heated to more than 150 millions °C
- The hot plasma is shaped and confined by strong magnetic fields
- Helium nuclei sustain burning plasma
- Neutron transfers energy to blanket
- Conventional steam generator, turbine and motor will transform the heat into electricity

1gr of fusion fuels=8t of oil
ITER TOKAMAK

- Vacuum Vessel: ~8 000 t.
- TF Coils: 18 x ~360 t.
- Central solenoid: ~1 000 t.
- Total: ~23 000 t.
- ~3.5 the Eiffel tower…
- \( R=6.2\text{m}, a=2.0\text{m}, I_p=15\text{MA}, B_T=5.3\text{ T} \)
- Achieve fusion power of 500 MW with \( P_{\text{fus}}/P_{\text{in}} \) (Q) ≥ 10 for 300-500 s
Manufacturing Progress

Vacuum Vessel, Magnets, Cryostat, Thermal Shields, Cryopumps, etc.
A “Staged Approach” to Full Operating Capacity

- Extensive interactions among the ITER Organization and Domestic Agencies to finalize revised baseline schedule (2015-6)
  - Schedule estimates through First Plasma (2025) up to DT operation (2035) consistent with Members’ budget and technical constraints
I&C architecture
### Main control parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Total number of computers (PON)</td>
<td>1,000</td>
</tr>
<tr>
<td>3.1.1 Total number of PSH and controllers</td>
<td>700</td>
</tr>
<tr>
<td>3.1.2 Total number of CODAC servers</td>
<td>80</td>
</tr>
<tr>
<td>3.1.3 Total number of CODAC terminals</td>
<td>150</td>
</tr>
<tr>
<td>3.2 Total number of channel access servers (IOC)</td>
<td>2,000</td>
</tr>
<tr>
<td>3.3 Total number of channel access clients</td>
<td>500</td>
</tr>
<tr>
<td>3.4 Total number of signals (wires)</td>
<td>100,000</td>
</tr>
<tr>
<td>3.5 Total number of process variables</td>
<td>1,000,000</td>
</tr>
<tr>
<td>3.6 Update rate on HMI screen (PON)</td>
<td>200 PV at 5 Hz</td>
</tr>
<tr>
<td>3.7 Total engineering archive rate (PON)</td>
<td>25 MB/s</td>
</tr>
<tr>
<td>3.8 Maximum sustained data flow on PON</td>
<td>50 MB/s</td>
</tr>
<tr>
<td>3.9 Total engineering archive capacity</td>
<td>2.2 TB/day</td>
</tr>
<tr>
<td>3.10 Maximum number of alarms per ctrl group</td>
<td>600</td>
</tr>
<tr>
<td>3.11 Total scientific data rate (DAN)</td>
<td>2-50 GB/sec</td>
</tr>
<tr>
<td>3.12 Maximum sustained data flow on DAN</td>
<td>2-50 GB/sec</td>
</tr>
<tr>
<td>3.13 Total scientific archive capacity</td>
<td>90-2200 TB/day</td>
</tr>
<tr>
<td>3.14 Accuracy of time synchronisation (TCN)</td>
<td>50 ns RMS</td>
</tr>
<tr>
<td>3.15 Number of nodes connected to TCN</td>
<td>500</td>
</tr>
<tr>
<td>3.16 Maximum latency asynchronous event (SDN)</td>
<td>1 ms</td>
</tr>
<tr>
<td>3.17 Number of nodes connected to SDN</td>
<td>100</td>
</tr>
<tr>
<td>3.18 Maximum latency sensor to actuator on SDN</td>
<td>500 μs</td>
</tr>
<tr>
<td>3.19 Maximum jitter sensor to actuator on SDN</td>
<td>50 μs RMS</td>
</tr>
<tr>
<td>3.20 Maximum sustained data flow on SDN</td>
<td>25 MB/s</td>
</tr>
<tr>
<td>3.21 Maximum cable length between two nodes</td>
<td>2 km</td>
</tr>
</tbody>
</table>
Different Sources for Raw Data

- **PON-Data**
  - EPICS traffic – conventional control & monitoring
  - 25-50 MB/sec
  - Two back-end RDB and HDF5 files

- **SDN-Data**
  - Real-time data for feedback control
  - Multicast topics
  - Max. 10Khz
  - In-house implementation
  - Stored in HDF5 files

- **DAN-Data**
  - Archiving of data with High throughput
  - Up to 50GB/sec for cameras
  - In-house implementation
  - Stored in HDF5 files

- **Data access shall be transparent and independent of data source and data type**
  - UDA (Unified Data Access)

<table>
<thead>
<tr>
<th></th>
<th>FP</th>
<th>PFPO-1</th>
<th>PFPO-2</th>
<th>FPO-1</th>
<th>FPO-2, …, -8</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data (PB)</td>
<td>0.1-1</td>
<td>10-100</td>
<td>100-300</td>
<td>200-500</td>
<td>+500 each</td>
<td>5000</td>
</tr>
</tbody>
</table>
HDF5

- Use of HDF5 as it is a powerful self-described data format
- Data preservation: need a format for the lifetime of ITER project (Similar to NASA)
- Use of SWMR, 1.10.3
- Use low-level C API + h5py (for test script + some plotting tools)
- Env. : linux R.H 6.5, 7.4, 7.6 + CentOS
- Different HDF5 layouts per Data sources
PON layout

• Data is essentially time-series, always on

• PON layout -
  – Many datasets in one file (one dataset per variable). Limit to 100K dataset in one file.
  – Use of compound data types to store values, timestamp and alarm information
  – Implementation of file rotation
  – Main issues: cannot create the dataset on the fly, requires to disable the memory cache of the dataset
  – Usually low rate (max. 10Hz) so writing performance is OK
  – Use of attributes for static metadata such as data type, units
SDN layout

• Data is essentially time-series, on during plasma experiments
• SDN layout –
  – A few datasets in one file (one dataset per SDN topic).
  – Use of compound data types: structure different from one topic to another topic. Size of structure can be big
  – Implementation of file rotation
  – Usually higher sampling rate (max. 10KHz)
  – Use of attributes for static metadata such as units, descriptions
DAN layout

- 2 datasets
  - Block header (fixed part + user-defined part)
  - Payload (buffer is multiplexed)
- Support for atomic types + compound types
- Same layout used for images
- Optimized for writing
- Use of attributes for metadata (units, calibration factors, user-defined attributes)
- Performance limitation is mainly due to the disk speed
  - Test 1 stream at 800MB/sec for 1 hour without loss
- Error handling was not easy, especially when the storage is full, we could see from times to times some zeros being written at the end of the files
- Inform the clients that the file is not being written? No flags?
DATA ACCESS - UDA

- Access the different source of raw data transparently
- Pre-compute min/max/avg to ease interactive zooming and speed data access
- Based on a modular solution (plugin-based), C and C++ based
- Basically two types of data access
  - Given a time range
  - Given a pulse number
- Many data types to support
  - Scalar value
  - Structure
  - Profiles (2-D)
  - Images/video
- Access the metadata (at given time)
- Performance issues found with hyperslab method reported to HDF group
Matlab Windows UDA interface

Real data from Electrical system
~30K variables
~more than 1 year data
~100GB of data
Python Interface
courtesy from MAST (diagnostics data)
C++/Qt based tool
C++/Qt based tool
Summary

- Good progress, waiting for diagnostics to make more tests, but still a lot to do…
- Scalability tests for UDA on-going
- Overall satisfaction with SWMR
- Good support from HDF group
- Next steps:
  - Evaluation of HSDS (object store)
  - Better integration with physics workflow
- How the scientific community sees use of cloud and object storage?