Scheduling, deploying and monitoring 100 million tasks

Andreas Wicenec
& The ICRAR team
Shire of Murchison

Population density: 0.002/km²

Geraldton

750 km fibre

Perth
**SKA Data Flow**

- **4 Tbit/s sustained into SC memory**
- **Voltage Measurements** (Analog, Digital, FPGA, Murchison)
- **Complex Numbers**
- **Image Cubes** (SC, Perth)
- **High-level Products** (SC)
- **SRCs**
- **24/7 operations**
- **RT calibration solutions**

**ICRAR**
## Scaling to SKA

<table>
<thead>
<tr>
<th>Telescope</th>
<th>Raw Data Rate</th>
<th>x average internet speed in Australia</th>
<th>x 4K Netflix Video</th>
</tr>
</thead>
<tbody>
<tr>
<td>MWA</td>
<td>3000 Mbps</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>ASKAP</td>
<td>23,300 Mbps</td>
<td>715</td>
<td>1,555</td>
</tr>
<tr>
<td>SKA1-LOW</td>
<td>3,000,000 Mbps</td>
<td>100,000</td>
<td>200,000</td>
</tr>
</tbody>
</table>

**NOTES:**
(1) As of May 2018 Australian citizens have access to 30.53 Mbps average download speed. SOURCE: http://www.speedtest.net/global-index.
(2) 4k video is streaming at around 15 Mbps
The DALiuGE System

A scalable, graph oriented workflow development, scheduling and execution system.
Execution System: DALiuGE

- In-house development: **Data Activated Flow Graph Engine**.
- Manage tasks and data locality and execution monitoring.
- Unique feature: Data is represented by active tasks during execution.
- \(\Rightarrow\) Scalability verified up to tens of millions of tasks.
- \(\Rightarrow\) Applications and Data are tasks collectively called ‘Drops’.
- DALiuGE is a graph based system, using graph optimisation and scheduling.
DALiuGE: Motivation

\[ 2^{16} \times 300 \times 4 = 78643200 \]

Channels Facets Polarisations

Lower boundary for maximum number of tasks

..and that's a really rough estimate
Separation of Concerns

- **Pick Algorithms**
  - best algorithm to get the desired answer

- **Develop Pipeline Logic**
  - reduction components and sequence

- **Specify Component Parameters**
  - default parameter values of components

- **Optimise Data Parallelisation**
  - hints about the potential of parallelism

- **Parallel Execution**
  - what is executed where

- **Parallel Coding**
  - writing parallel code

- **Code Optimisation**
  - optimise parallel code

- **I/O Optimisation**
  - optimise I/O on hardware

- **OS and hardware co-design**
  - optimise hardware for code to be run

---

Roles:
- Astronomer
- Operator
- HPC Software Engineer
- OS level S/W Engineer
- Computer H/W Engineer
Highly non-trivial on many of these levels!!
'Scalable' for DALiuGE design means thinking about whether a feature could scale and then... asking again whether it really scales.

Result is a share nothing and distributed design and implementation *almost everywhere!*
The Challenges of Simulating the SKA1-LOW:

- 512 stations
- 131,072 antennas
- $2^{16}$ channels
- Complex antenna and station beam patterns
- Complex sky model
Simulating 131,072 Antennas
Input: Model of Theoretical Signal

Input: Layout and Response of Antenna Array

512 antenna stations, 256 antennas/station
Simulating 131,072 Antennas

$$\langle V_{p,q} \rangle = \sum_s K_{p,s} E_{p,s} G_{p,s} P_{p,s} R_{p,s} (B_s) R_{q,s}^H P_{q,s}^H G_{q,s}^H E_{q,s}^H K_{q,s}^H$$

Complex Numbers

Metadata

OSKAR-2

Files

cImager
We had been running a SKA1-LOW simulation on SUMMIT using
4,561 nodes
27,360 V100 GPUs

essentially the whole machine available at the time of launching the job...
Workflow

Domain Palette

Logical Graph under development

Component Parameters

Development
SKA Simulation Run

Video credit: Baoqiang Lao, Shanghai Astronomical Observatory
Key Figures:

- 3 hours run-time
- 2x faster than actual SKA
- 27,360 channels
- $3.3 \times 10^{10}$ visibilities/s
- 2.6 PB total data flow
- output 112 TB in 760 filesets
- 11 GB/s sustained write rate
- $5 \times 10^{14}$ total visibilities written
- Final image cube: ~3.1 GB!!
Does it Scale?

- Complex workflow simulations on Tianhe-2.
- Measured plain overhead imposed by DALiuGE during execution.
Does it Scale?

• Yes!

• Test run: 12.6 Million tasks on 400 compute nodes means 31,500 tasks/node.

• Current expectation for SDP 2,500 nodes running 78M tasks. With actual numbers: 31,450 tasks/node.

• Test execution time 420 seconds.

• SDP: several hours.
DALiuGE

The

Data Activated Flow Graph Engine

Open source, under GitHub and PyPi

https://github.com/ICRAR/daliuge

(https://github.com/ICRAR/EAGLE)