A Comprehensive Informative Metric for Summarizing HPC System Status

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Introduction

The Titan supercomputer at the Oak Ridge Leadership Computing Facility (OLCF):

- 27 Peta FLOP Cray System • 18,688 AMD 16-core Opteron CPUs • 693.5 TiB Memory • 18,688 NVidia Tesla K20X GPUs • 400 hundred cabinets with 24 blades per cabinet and 4 nodes per blade

The Log processing by Spark and Cassandra-based ANalytics (LogSCAN) [1] framework:

- Residing on the Compute and Data Environment for Science (CADES) cloud at ORNL • 256 cores, 328GB memory, and 1TB SSD storage • Titan system log events are stored using Cassandra • Data analyses are performed using Spark

Titan System Log Event Data Characteristics

Counts	Percentage	ID	Description
10	0	1	DVS Confusion
2,998,492	2	2	NVRM Xid
5,671,348	4	3	Machine Check Exception (MCE)
1,229	0	4	NVRM DBE
49	0	5	Unknown GPU Error (UGE)
302,969	0.2	6	Graphics Engine Error (GEE)
5,732	0	7	Kernel Panic
782,337	0.5	8	Out of Memory (OOM)
16,938,194	11.6	9	HWERR
1,215,780	0.8	10	Seg. Fault
43,268,141	29.5	11	Lustre
31,498,746	21.5	12	LNet
992,997	0.7	13	LNet Error
42,809,426	29.2	22	Lustre Error
146,485,450	100		

Table 1: Summary of event types and their occurrences (146.5 million in total) in Titan's logs during [Jan. 2015, Mar. 2018].

Time	Event Type	Source
2015-01-28 05:00:42	3	c10-4c2s6n0
2015-01-28 05:52:18	22	c7-2c1s6n0
2016-04-05 13:48:16	12	c20-0c1s4n3
2016-08-24 01:00:35	11	c2-1c0s1n2
2015-12-16 03:19:36	9	c3-5c0s4n2
2017-12-07 10:05:01	11	c18-7c0s2n1

Table 2: An example of the event table. The event type takes the ID value from Table 1.

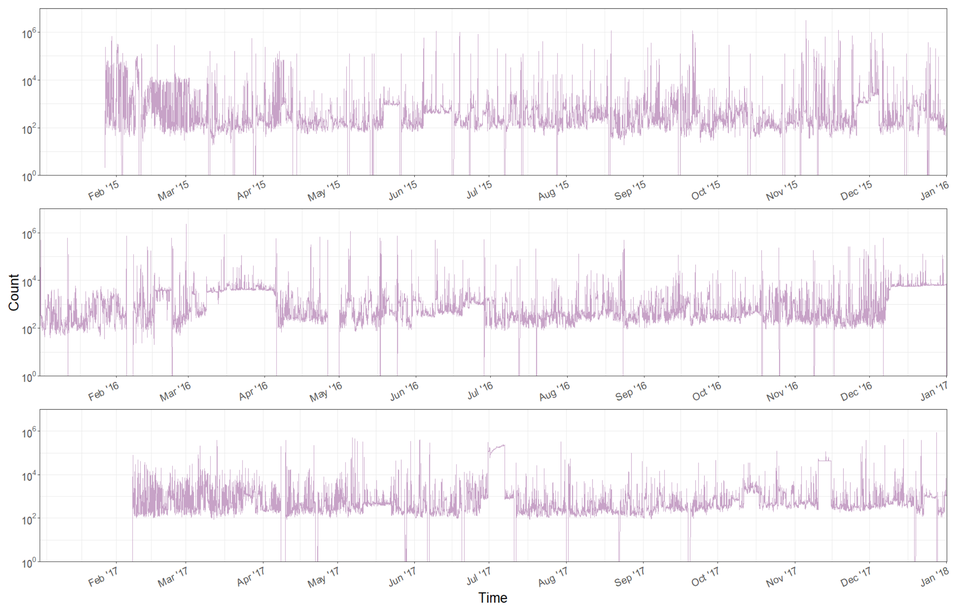


Figure 1: Total event counts in calendar year 2015, 2016 and 2017 from Titan. Resolution in time is by hour.

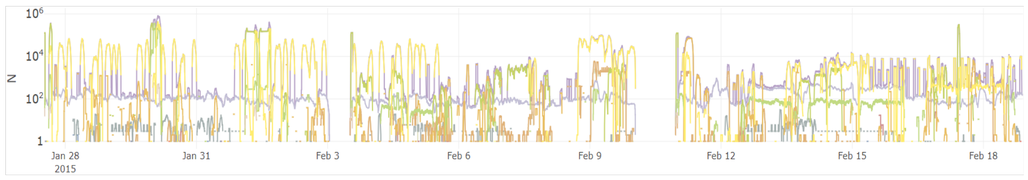


Figure 2: Event counts for different event types (in different colors) during [Jan. 28, 2015 to Feb. 18, 2015].

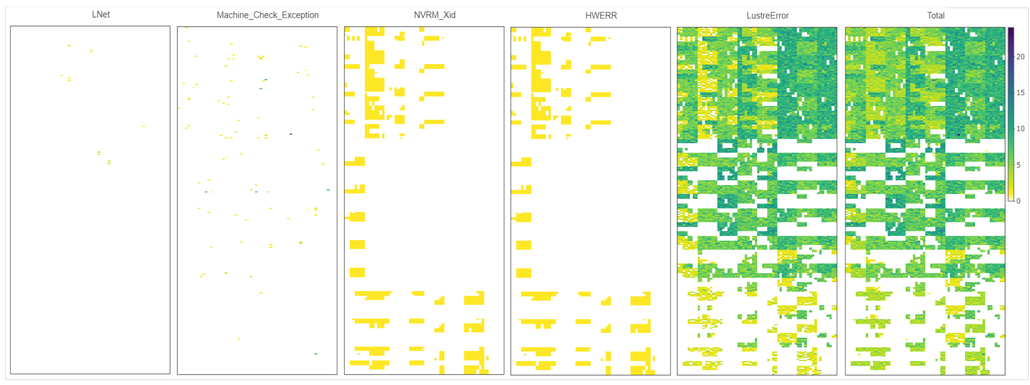


Figure 3: The nodal layouts for every event type and the combined total for one-hour window prior to "2015-02-09 01:49:54". Each layout has dimensions of [300, 64] in pixel and each pixel represents a unique Titan node with its coordinates [X, Y] (definition in following section).

It is impossible to efficiently inspect system status by relying on the counts either of total system events or any specific event types!

Solution

General Form of Data Table

	Feature 1	Feature 2	...	...	Feature N
Record 1					
Record 2					
...					
...					
...					
...					
Record M					

Principal Components [2] in Feature Space

SVD $\Longrightarrow \sigma_i$

σ_i: i-th variance out of k eigenvalues of the SVD decomposition

Variance Distribution of Principal Components

$$\xi_i = \frac{\sigma_i}{\sum_1^k \sigma_i} \qquad (1)$$

Shannon Entropy [3]

$$H = -\sum_1^k \xi_i log_b(\xi_i) \qquad (2)$$

Entropy: in a general "b-ary" form

System Information Entropy (SIE) [1]

$$W(t) = b^{H(t)} \qquad (3)$$

b: the logarithmic base used in calculating H. In our analysis, b = 10.

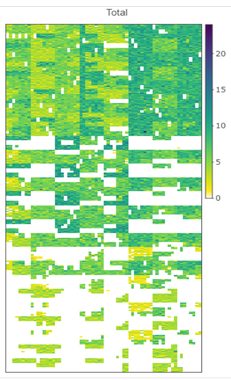
Event Table Layout

Source vs. Type

Source	Machine Check Exception	Out of Memory	Seg. Fault	Lustre
c0-2c2s1n2	1	0	0	0
c10-4c0s0n0	0	0	0	4
c10-4c0s3n0	0	1	0	3
c10-4c1s6n1	0	0	3	1

Table 3: An example of the time-windowed event table for one hour starting from "2016 Jan. 27, 05:00:00" and ending at "2016 Jan. 27, 06:00:00". For an illustrative purpose, only 4 rows are shown out of a total of 400.

Nodal Map



$$X = 12 \times Cabinet_{Row} + 4 \times Chassis + Node$$
$$Y = 8 \times Cabinet_{Column} + Slot$$

Figure 4: The nodal map for total events in an hour prior to "2015-02-09 01:49:54". The layout has dimensions of [300, 64] in pixel and each pixel represents a unique Titan node with its coordinates [X, Y] translated from its source name, like those shown in Table 3. For detailed definition of the transformation, please see [1].

Application of System Information Entropy (SIE)

Figure 5: System Information Entropies are plotted for two event data layouts - "Source Type" (TOP) and "Nodal Map" (BOTTOM).

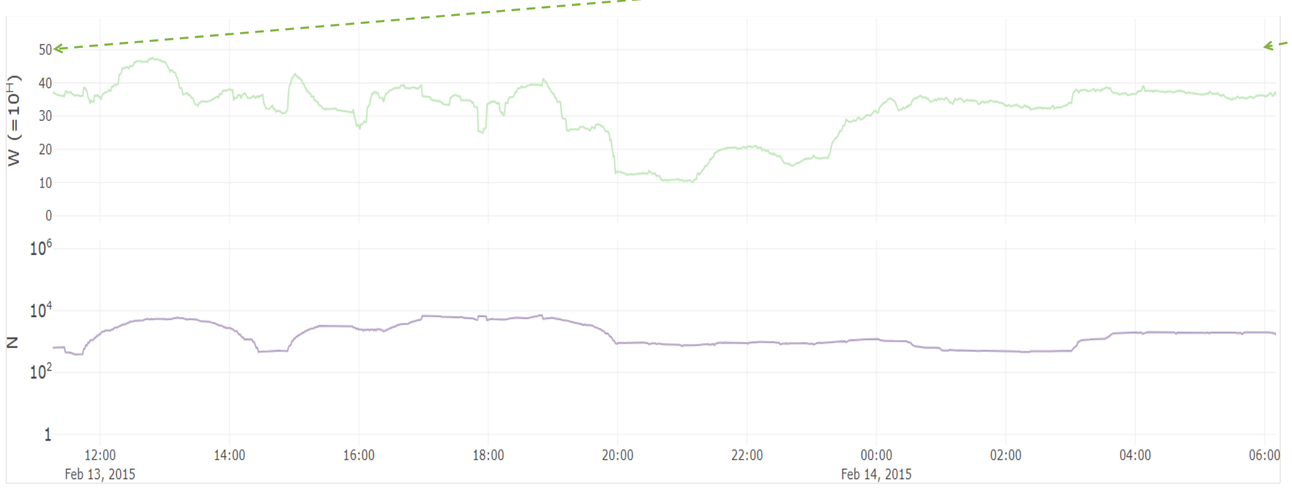


Figure 6: Close-ups for time series of "Nodal Map" SIE (TOP) and "Total Count"(BOTTOM), from 12:00 Feb. 13 to 06:00 Feb. 14, 2015.

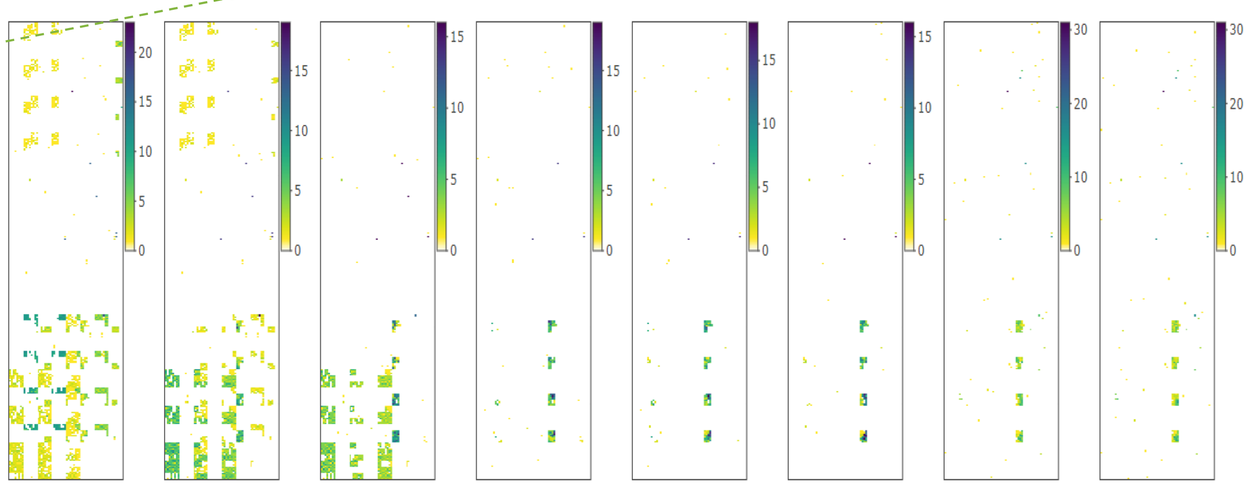


Figure 7: Titan nodal layouts showing event aggregation patterns at representative moments from 18:30 to 22:00 (interval at 30 mins) on Feb. 13, 2015.

Conclusion and References

With no assumption about the relative significances among system properties, we created a general-purpose metric which reflects system status by taking a concise form of a time series of system information entropy (SIE). We demonstrated that this system metric can comprehensively and sensitively summarize overall system characteristics without compromising on computational efficiency.

1. B. H. Park, Y. Hui, S. Boehm, R. A. Ashraf, C. Layton, and C. Engelmann. "A Big Data Analytics Framework for HPC Log Data: Three Case Studies Using the Titan Supercomputer Log", HPCMASPA, IEEE International Conference on Cluster Computing (CLUSTER), Belfast, Northern Ireland, 2018
2. K. Pearson F.R.S. LIII. "On lines and planes of closest fit to systems of points in space". The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, 2(11):559–572, 1901
3. C. E. Shannon. "A mathematical theory of communication". The Bell System Technical Journal, 27(3):379–423, 1948

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