

Facilitating HPC Operation and Administration via Cloud

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Experiencing a tremendous growth, Cloud Computing offers a number of advantages over other distributed platforms. Introducing the advantages of High Performance Computing (HPC) also brought forward the development of HPCaaS (HPC as a Service), which has mainly focused on flexible access to resources, cost-effectiveness, and the no-maintenance-needed for end-users. Besides providing and using HPCaaS, HPC centers could leverage more from Cloud Computing technology, for instance to facilitate operation and administration of deployed HPC systems, commonly faced by most supercomputer centers.

This paper reports the product, EasyOP, developed to realize the idea that one or more Cloud or HPC facilities can be run over a centralized and unified control platform. The main purpose of EasyOP is that the information of HPC systems hardware and system software, failure alarms, jobs scheduling, etc. is sent to the Wuxi cloud computing center. After a series of analysis and processing, we are able to share many valuable data, including alarm and job scheduling status, to HPC users through SMS, email, and WeChat. More importantly, with the data accumulated on the cloud computing center, EasyOP can offer several easy-to-use functions, such as user(s) management, monthly/yearly reports, one-screen monitoring and so on. By the end of 2016, EasyOP successfully served more than 50 HPC systems with almost 10000 nodes and over of 300 regular users.

Keywords: HPC, supercomputer, monitoring, notifications, cloud, operation, administration, EasyOP.

Introduction

Cloud computing definitely takes top rank in recent information technology popular paradigm list, due to the many promising advantages it brings. For example, the access to resources is flexible and cost-effective, since it is neither necessary to invest a large amount of money on a computing infrastructure, nor pay salaries for maintenance [11, 22, 31]. Also, there are series of works which focus on HPC cloud, also known as HPCaaS (HPC as a Service). Some have mainly contributed to understanding the cost-benefits of using cloud over on-premise clusters [10, 23]. Other aimed at evaluating the performance gap between cloud and on-premise resources [12, 20, 28]. Additionally, a lot of effort has been invested into the HPC job scheduling, as well as application testing and tuning within the cloud environments [5, 6, 15, 19, 30]. Therefore, it could be found that most interests of combining HPC and cloud are laid on using cloud as IaaS (infrastructure as a Service).

In fact, besides buying new infrastructure and testing new technology, most HPC centers have to continuously monitor the utilization and the capacity of HPC facilities to ensure research needs are adequately met, to plan and approve operational policies, and to advise & review proposals from related departments for next step planning to ensure adequate usage statistics. HPC systems are complicated combinations of application software, system software, processors, co-processors, memory, networks and storage systems, which evolve rapidly with

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technology changes. What makes it even more challenging is the fact that the HPC systems are getting larger and larger, and by consequence induce higher unreliability and complexity. Many HPC centers have several HPC systems running subsequently or together. Therefore, efficient operating of HPC systems (either several or large) efficiently conducting usage statistics and user administration are inevitable key issues. Smooth operation depends on efficient error-free server operation, stable server room conditions, and stable computing environment, which are quite important to HPC end-users [18]. Note that the qualified and experienced HPC operation engineers are not easy to recruit, because HPC operation engineers require cross-discipline knowledge accumulation and sufficient on-hand experiences.

Most HPC vendors provide operation management and administration software, such as Open Manage Essentials from Dell [13], HP's OperiView [14], Tivoli from IBM [16], and Sugon's Gridview [24] and so on. Some software solutions can even support grid or cloud environment operation. Cacti [17] and MRTG [25] are solutions to create RRD-Tool graphs that are usually used to show bandwidth consumption in network links. Nagios' main features is the support for plugins that are used to collect monitoring information from the monitored objects [2]. PARMON [3] and Rvision [8] can monitor specific systems, while GridEye [9] and Ganglia [21] are able to support grid environments. Zenoss [1], and other operation centric software, have gained a pretty substantial market share, even being adopted in Bank of America and US Air Force. All these operation software and monitoring tool-kits compose a scenario where traditional HPC system operation software is relatively mature.

As for the usage statistics and reporting side of operation, only a few software options have implemented sufficient solutions. TACC Stats is a continuous monitoring tool for HPC systems that collects data at the core and processor level for every job executing on a monitored system [7]. This data can be aggregated at the system, group, user, application, job, node or core level. TACC Stats also includes capabilities for generating several different reports including a report giving a resource use profile. Open XDMoD portal provides a rich set of analysis and charting tools that let users quickly display a wide variety of job accounting metrics over any desired timeframe [26]. Two additional tools, which provide quality-of-service metrics and job-level performance data, have been developed and integrated with Open XDMoD to extend its functionality. On the other hand, some niche software companies have been working on report-generating service, such as Zenoss [1] and Rizhiyi [27].

Leveraging the advanced characteristics of cloud computing makes it practical to send the HPC systems' information, including data regarding CPU, network, memory, storage, and job etc., to a cloud computing center, and then spread the information (after certain data-mining) to the persons in charge of reorganization. This is the main idea of EasyOP, a product recently developed. The benefits of EasyOP include:

- operate several HPC systems at the same time;
- satisfy both remote operating and security demands by only allowing the operating information to go out;
- generate live data of computing resource and jobs, triggering notices for hardware alarms, job starts, job ends, abnormal job exit, and so on;
- automatically generate reports not only for a certain HPC System, but also all the connected systems;
- spread the analyzed data through email, SMS, or Wechat;
- realize the remote monitoring of HPC systems, specially on smart portable devices.

This article is organized as follows. In Section 1, we explain the used methods and challenges behind the EasyOP. We also share the principle functions designed for HPC system operation and administration in Section 2 and 3, respectively. Section 4 exhibits the practical observation we mined through the data already collected from 50+ HPC systems. Finally, the last Section contains conclusions and our plans for future work.

1. Method

1.1. Sugon and HPC

Sugon was born from the Institute of Computing Technology of the Chinese Academy of Sciences (ICT), and was the first (and now largest) supercomputer vendor in China as shown in Fig. 1. Since 1990, Sugon has been working on supercomputing, producing seven generations of HPC systems, such as Dawning I and Dawning 1000 to 6000. It has successfully supported more than 10,000 HPC projects. In 2014, Sugon was successfully listed on the Shanghai Stock Exchange (Stock code: 603019). Besides the Silicon Cube, Sugon has successfully developed the Sugon 4000A (#10, Top500 2004) and Nebulae (#2, Top500 2010). Sugon has continuously dominated the China HPC Top100 for the past 9 times in 10 years and hit the 3rd of Top500 (Nov, 2015) per vendor market share. In 2016, Sugon was appointed as the only company to develop the prototype of Chinese Exascale HPC by the Ministry of Science and Technology in China.

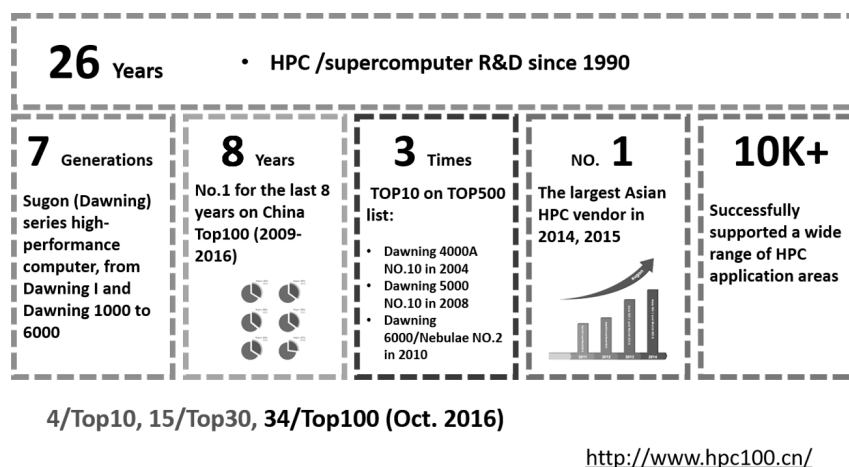


Figure 1. Sugon and HPC

1.2. Methodology and Challenges for EasyOP Development

EasyOP cloud service platform collects the operation and administration information of HPC systems without geographical limitations and sends the information to the Wuxi cloud computing center. It analyzes the status and performance data of HPC systems, generates live graphs and reports graphically, and then spreads the reports to end-users through Email, SMS, and WeChat. Fig. 2 shows the topology strategy of EasyOP. From the perspective of data flow, the whole process of EasyOP is composed by data collection and acquisition, data transmission, data storage, data processing, data analysis, data display etc. The architecture design of EasyOP is shown in Fig. 3.

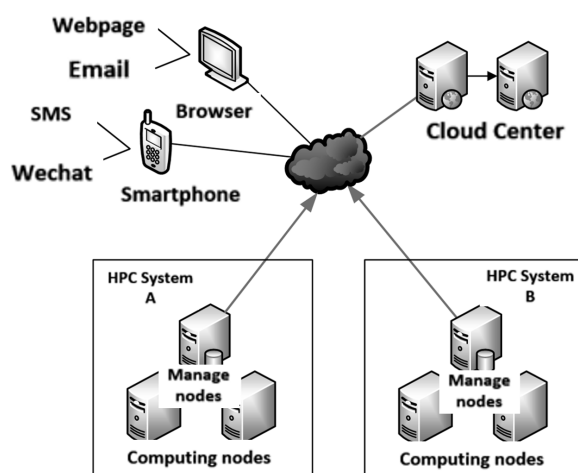


Figure 2. The network topology of EasyOP

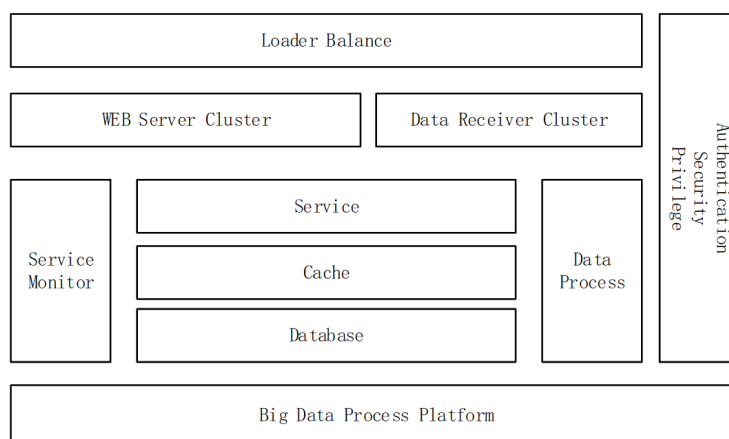


Figure 3. Architecture design of EasyOP

To develop EasyOP, we had to overcome a series of challenges. The first challenge of EasyOP R&D comes from data collection and acquisition. EasyOP relies on Gridview, a mature HPC system management product used for more than ten years. Gridview collects many data and indicators of HPC system by series of add-ins. The collected data are verified to be correct, reliable, and in a reasonable format. In order to send this data to the cloud center, we need to select the appropriate communications and transfer protocol, set up the service platform, identify the suitable carrier, choose the cloud center, assign a domain name, and so on. The HTTPS protocol has been adopted to ensure the data security is transferred. A private protocol was also developed based on HTTPS considering appropriate commonality, which shares the compatibility of various data format and data package size. The Wuxi cloud computing center has been chosen as our partner, because the center operates for 5+ years with good users assessment and can support the internet service from China Mobile, China Unicom, and China Telecom. The three companies provide 95 % of internet service in China. In testing, we found that some cities only connect with a certain internet service company. Therefore, we set up two IP address (China Unicom and China Telecom each) to resolve the EasyOP’s domain. All HPC systems linked to EasyOP transmit the system information and job information to the Wuxi cloud computing center automatically. By default, the sending time interval is 1 minute, which

could be customized for each HPC center. After the data analysis at EasyOP, the results will be sent to the EasyOP's public account on Wechat and the public webpage of EasyOP.

Data storage and analysis are the next challenges observed right after data collection and transfer. In the cloud center, a highly available and high reliable data injection and storage solution is indispensable for completely receiving and almost real-time calculating mass data (currently 300G per day). We have set up the load balancer and realized multi-point concurrent data processing. The data used in EasyOP can be classified into static configuration data, real-time status data, and history data, etc. We took different storage solutions for different data. For instance, the big history data were stored and processed by a Hadoop cluster with good scalability. In contrast, the real-time status data are stored both in the Hadoop cluster and cache. As the number of served HPC systems increased, real-time status data grew quickly. To solve this problem, we designed the storage alarms and conducted data compression for repeated data, such as indicators' name and time.

We also paid much attention to function planning and user interface design, especially to data presentation. This is the core competitive advantage of EasyOP. From user authentication, rights management, contents composition, workflow planning, to letter style selection, many technologies and experiences of web development and design have been implemented. To balance the cost and stability, we borrowed the advantages of web service SOA and EasySOC [4], and the suggestion from Sheng's review [29], and then set up the operation platform for EasyOP. The design of the interface and the inner business process are independent of each other. The browser compatibility has been included in our design by adopting jQuery and Bootstrap.

EasyOP receives regular updates every two weeks. We have implemented automatic development technologies to support code writing, testing, and deploying. Specifications of demands analysis, prototype design, solution design, coding, code debug, test, and new version release have been confirmed and put into the practice with the automatic development tools.

2. Operation

EasyOP offers the functions of single-page monitoring, specific cluster monitoring, alarming, and setting change and control. Using the single-page monitoring, operation engineers are able to take a quick glance across the live working status for all systems under their command. It is especially suitable for an HPC center with multiple systems. On the initial page the system size distribution, system nodes/cores, jobs, major application, busy system ranking can be quickly summarized. The specific monitoring furthermore displays information of one chosen HPC system. In addition to the information similar from the single-page monitoring, the specific monitoring also shows the live updates of job scheduling for each queue. Examples for one-page monitoring and specific monitoring are shown in Fig. 4.

"Nip in the bud" minimizes the damage on the HPC system and helps to minimize downtime and ultimately save money. Alarms from EasyOP make this possible. Some alarm examples are shown in Fig. 5. Various alarms can come from switches, servers (e.g. computing network, CPU temperature, disk usage, file system, GPU temperature, IPMI network, MIC temperature, MIC availability, management network, disk availability, server power off, fan abnormal, etc.), RACK (e.g. management network, node abnormal, fan abnormal), storage, blade cabin (e.g. abnormal blade communication, abnormal power, management network). Who and how is supposed to receive this alarms can be set through the setting page. If one wants to change the threshold value of the alarm, he/she needs to set the value at the level of the Gridview system, meaning

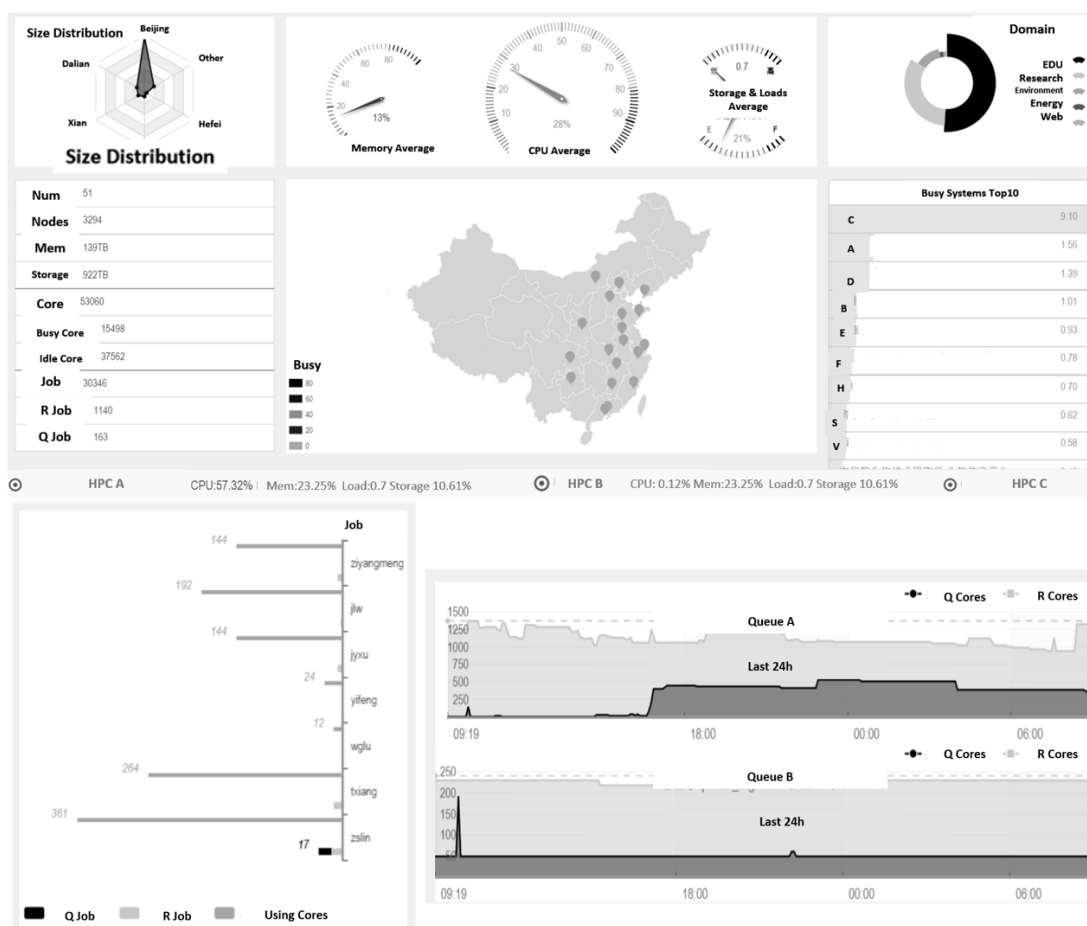


Figure 4. Examples for one-page monitoring and specific monitoring

one level below with higher privileges. Because the SMS might be charged by telecommunication companies, users are suggested to take email or smart phone notifications as the primary choice.

Live		Past		Level		Name	
#	Type	Node	Alarm	Level	Time	Latest value	
1	LINUX	test	Network Not Available	High	2017-01-05 16:14:58	0	
2	TC6600	TC6600	Network Not Available	High	2016-05-10 10:31:11	0	
3	TC5600-H	TC5600H	Network Not Available	High	2016-05-05 14:59:42	0	
4	LINUX	dcv20	IPMI Network Not Available	High	2016-04-26 11:27:27	0	
5	LINUX	123456	Network Not Available	High	2016-04-08 20:40:02	0	
6	LINUX	test-linux	Network Not Available	High	2016-04-08 20:19:21	0	
7	LINUX	dcv20_SYS_Fan6	System Fan Rate Low	Low	2016-03-02 15:22:16	0.000rpm	
8	LINUX	dcv20_SYS_Fan5	System Fan Rate Low	Low	2016-03-02 15:22:16	0.000rpm	

Figure 5. Alarm examples in EasyOP

No doubt, Smartphone is the most efficient way to convey the alarms to users. Therefore, EasyOP developed the alarm function based on WeChat. Users can also watch the basic monitoring page and job page via EasyOP official account on WeChat. In the meantime, the EasyOP service group can directly contact and communicate with users by using WeChat. Snapshots of using EasyOP on Smartphone are shown in Fig. 6.

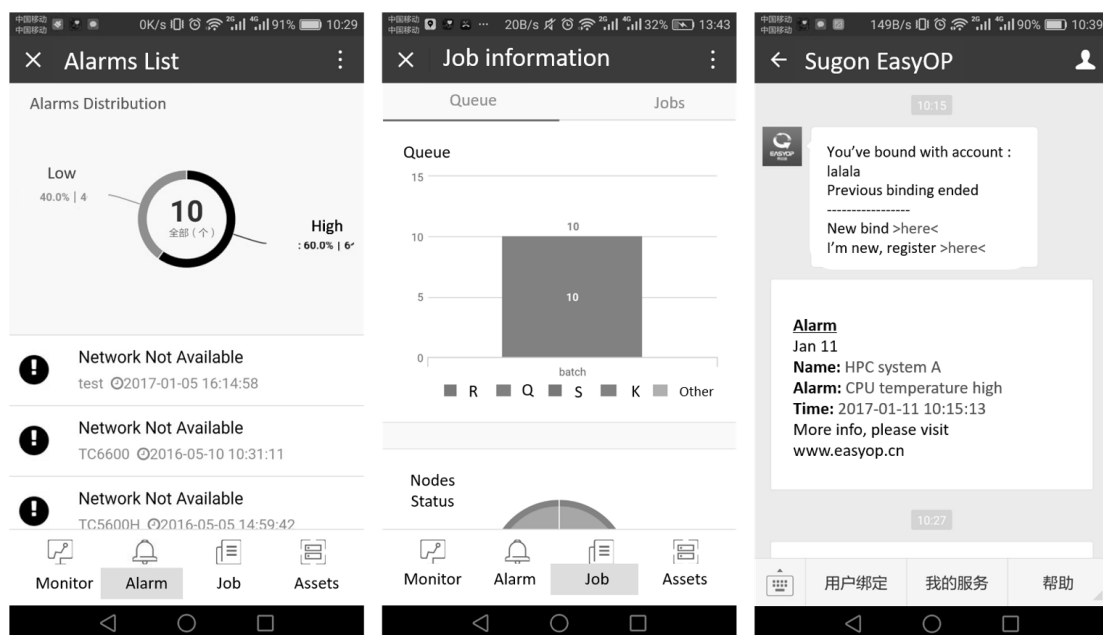


Figure 6. Examples of EasyOP service on a Smartphone

3. Administration

Through EasyOP, we can conduct asset management, job tracing, user management, customized statistical analysis, monthly/yearly report, and setting via browser or smart phone. For the asset management, EasyOP displays the general information, including name, joining time, node number, node type, switch SN, city address, version of Gridview, key contact person, etc. within a webpage. Part of the information can be read also on the smart phone.

#	Job ID	Job Name	Owner	Queue	Status	Start Time	Run Time
1	145211.gvadmin	granular	ywzhang	n_cpu	Q	2016-08-14 02:15:06	
2	157294.gvadmin	l0_2_c1000_d0_k3	Tiantianli	n_cpu	R	2016-10-27 12:43:24	26days3h34m21s
3	162717.gvadmin	vortex	ljia	n_cpu	R	2016-11-03 18:59:36	18days21h18m9s
4	169073.gvadmin	granular	ywzhang	n_cpu	Q		
5	169076.gvadmin	gamma	weicc	n_cpu	Q		
6	169102.gvadmin	granular	ywzhang	n_cpu	Q		
7	170041.gvadmin	ground	ljia	n_cpu	R	2016-12-02 20:15:36	1days20h35m25s
8	170301.gvadmin	ground	JQPam	n_cpu	R	2016-12-03 11:17:21	1days5h33m40s

Figure 7. Tracing jobs at webpage of EasyOP

Jobs on the HPC system can be traced by EasyOP in terms of live job, history job, abnormal job, and the specification & working status of each node as shown in Fig. 7. When the job quits out with error, alarms are automatically sent out to users through email, SMS, or smartphone according to the users' preference setting.

With EasyOP, administrators are able to evaluate user applications in addition to managing the users account database. Super administrators can assign the permission on certain HPC system(s) to certain ordinary administrator(s), if needed.

Reports can cause a lot of problems for many HPC centers. Here, EasyOP offers two types of reports to free administrators from the tedious work. First, customized report can be created for



Figure 8. An example of a customized report

monitoring indicators and jobs (29 in total), such as system performance trend, system status, performance Top10, performance trends, job status, job number, and so on. The performance is described in terms of CPU loads, memory loads, disk capacity, alarm, energy consumption, etc. All these reports for job can be classified for each queue or for all queues. An example of a customized report is shown in Fig. 8.

It is found that more HPC centers want to have monthly or yearly reports. A rich analysis of job status is always welcomed. Therefore, besides all the information included in the customized report, EasyOP also delivers reports for the number of jobs, running time, the variation within months, proportion, top jobs, top submitters, queue distribution, abnormal job analysis, and the comparison to the year before. Part of the snapshots of the yearly report is shown in Fig. 9. This monthly or yearly reports are the most popular functions in EasyOP ranked by users.

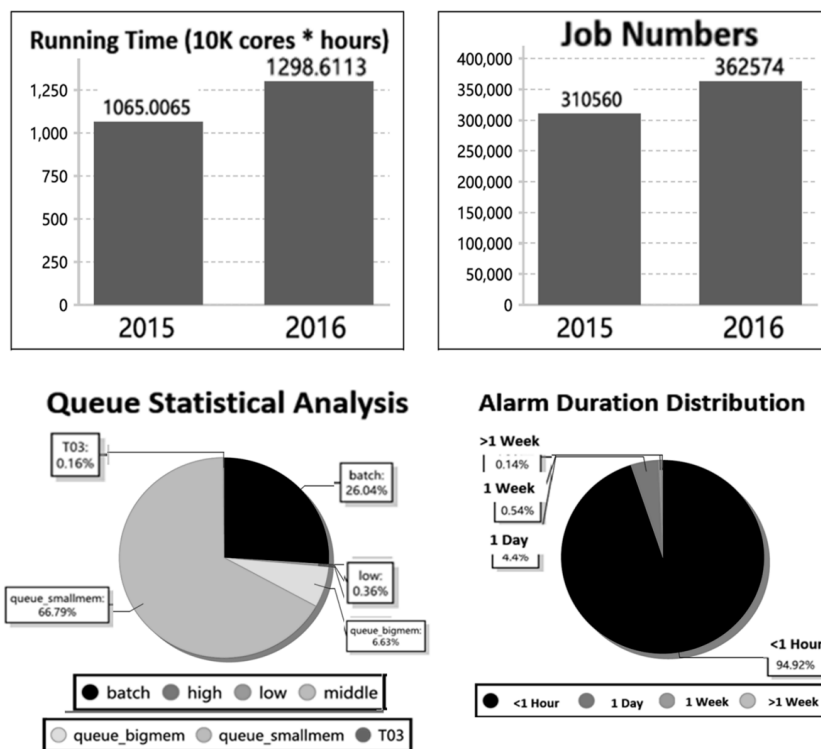


Figure 9. Part snapshots of the yearly report generated by EasyOP

4. In Practice

By the end of 2016, EasyOP has successfully served more than 50 HPC systems (seen in Fig. 10) with almost 10000 nodes and more than 300 regular users and many more random users. These systems are located in the most HPC active 18 cities in China. Within those systems, 2 % of the systems have more than 1000 nodes and 86 % systems have less than 100 nodes.



Figure 10. 18 cities have HPC systems serving by EasyOP

By the end of 2016, EasyOP has already generated 5000 alarms (as shown in Fig. 11), about 4000 of the alarms were minor, i.e. quickly self-repaired, such as “temperature is higher than the set threshold”. The number of serious alarms was 500, which mainly lay on three aspects, unstable IPMI network, CPU overloaded, and storage module broke.

Most of the 50+ systems, EasyOP is serving, are quite busy. The average CPU utilization ratio is 75.69 % with the peak at 85 %. The average memory utilization ratio is 32.31 % with the peak at 45 %. As for storage use these are 24.7 % and 38 %, respectively as shown in Fig. 12.

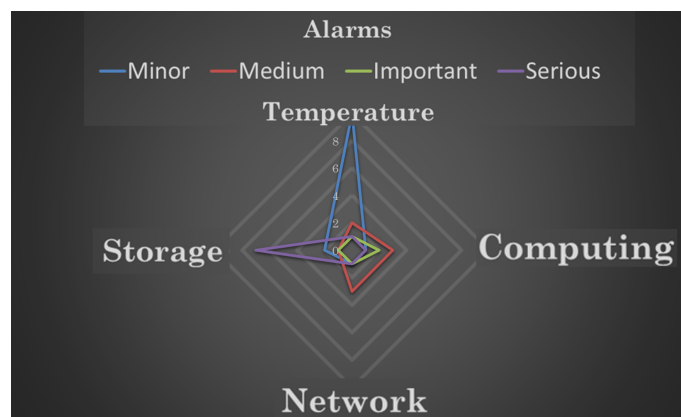


Figure 11. Alarms distribution from Oct. 2015 to Nov. 2016

The job running status shows an interesting drop at Feb. 2016, which is just during the Spring Festival of China as shown in Fig. 13. This indicates that during the holiday season, less scientists ran their calculations. Another drop is around Aug. 2016. This is the summer holiday for most universities and institutions. The waiting jobs always exit and take 15 % of the total jobs number. As for the jobs running time periods, we found all periods are quite even to each

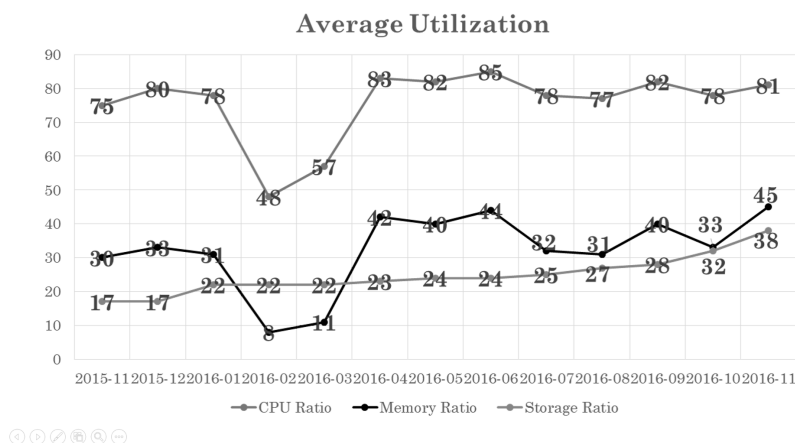


Figure 12. The average utilization of HPC systems serving by EasyOP

other, if we classify the period as > 500 hours, > 100 hours, 50–100 hours, 10–50 hours, and < 10 hours.



Figure 13. Job status on HPC systems serving by EasyOP

Conclusions and Future Work

EasyOP, i.e. Easy Operation, is an on-line cloud service platform developed to facilitate HPC centers’ operation and administration. From 2015, we identified the technological method, grouped related engineers, developed the product, and provided service through Wuxi Cloud Supercomputing Center. In addition to the R&D group, we also have a service group, who can keep track of alarms and offer support to users in emergency, fix the HPC system problems per users’ requests, and also compose the trend reports on average status for all HPC centers in service. Currently, we have been serving 10000 nodes, distributed in 18 Chinese cities.

This is worth a try to grasp cloud ideas and their advantages for HPC centers’ operation and administration after system deployment. EasyOP could also be taken as a good model for Software as a Service (SaaS) to expand the internet+ applications. Probably, EasyOP offers a different way to combine HPC with cloud compare to commonly noticed HPCaaS. However, please keep in mind that EasyOP has no intention to replace operation engineers or administration officials. It is just a convenient tool for them.

Next step, we will make efforts on monitoring HPC applications, trouble shooting tracing, multi-level service centers, and on-line sharing of HPC related resources, including but not

limited to computing resource, document resource etc. As a blueprint, we hope to emerge and support the HPC eco-system with both HPC facility enthusiasts and application scientists. The really big challenge that lays ahead in the development of EasyOP as a monitoring and support system is the long reaching plan of Sugon to start service for the European market. With its strategic partner Arctur, Sugon will now start to (re)develop and localize the EasyOP application to be better applicable to the European market. The specific challenges that are now becoming apparent are the complete translation of the application in to at least English language, but maybe also in to some other major European languages, for instance German and French. After that the subsequent step will be to have an automated deployment system of EasyOP at the customer solution since we are aware that many different European HPC centres cannot be run and operated from a central location, but rather require a on-site solution. The first successful deployment of EasyOP has already been established in Slovenia at the Arctur's location. It is now the challenge that faced by Sugon and Arctur to strengthen the foothold in Europe and develop EasyOP in a reliable and stable solution to support the systems that will serve European HPC customers.

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