MULTI-LEVEL MONITORING SYSTEM FOR MULTIFUNCTIONAL INFORMATION AND COMPUTING COMPLEX AT JINR

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Multifunctional Information and Computing Complex (MICC) is one of the basic scientific facilities of Joint Institute for Nuclear Research (JINR). It provides a 24×7 implementation of a vast range of competitive research conducted at JINR at a global level. MICC consists of four major components: grid-infrastructure, central computing complex, JINR private cloud and high performance heterogeneous cluster HybriLIT. All major components rely on the network and engineering infrastructure. It is important to monitor all of the components on three levels: hardware level, network level, and service level. Currently there are many monitoring systems applied for MICC. These systems are used by different groups and built on different technologies. All monitoring systems are mostly independent despite the fact that some systems collect the same monitoring data. Their independence makes it difficult to see the overall effectiveness and bottlenecks of MICC because the data are scattered among many systems. The role of the multi-level monitoring system for MICC is to unite existing systems and solve the problem: to provide high level information about the whole computing complex and its services. All monitoring systems currently used in MICC, approaches and methods are described and analyzed in this article: monitoring platforms, data collection methods, data storage, visualization, notification and analytics.

Keywords: monitoring, grid computing, cloud computing, heterogeneous computing

1. Multifunctional Information and Computing Complex

Modern scientific research and studies in physics often require not only an experimental facility but also a vast amount of computing resources, storage resources and special software. To support all scientific groups working at the Joint Institute for Nuclear Research and its Member States the Multifunctional Information and Computing Complex has been created. It is a complex multi-component system which is orientated to process, store and analyze scientific data. The main components of this computing infrastructure are Tier-1 [1] for CMS experiment [2] and Tier-2 centers of Worldwide LHC Computing Grid (WLCG)[3], the JINR Cloud infrastructure [4], the heterogeneous cluster HybriLIT which utilize advantages of using co-processors and GPU accelerators, and local batch processing system which accepts MPI and OpenMP jobs. These components rely on the common engineering and network infrastructures.

It is important to support the reliable 24x7 operation of the center. In the process of providing uninterrupted operation of the computing complex there is a need for monitoring tools to detect failures, send notifications, provide accounting data, form reports, etc. These tools are supposed to be used by several groups: users (consumers of services), system administrators, engineers and executives. These groups have different needs, access policies and areas of interest. There is no single monitoring system which would satisfy all groups of users and all requirements, so we adopted general purpose monitoring tools and also developed several tools for special tasks.

2. Our approach to infrastructure monitoring

All consumers of MICC monitoring could be divided into three groups:

1. Users - people who use the MICC for their needs. It is important to provide monitoring tools for users when it can help them to make right decisions during their work and to provide an explanation of occurring issues which are relevant for users.
2. System administrators and engineers - persons who are responsible for MICC components including system administrator, engineering staff of electrical equipment, cooling equipment, etc., and operators. They need more detailed information about all the systems. The most important part is issue alarming and notification system since it directly affects quality of provided service and failure reaction time. Another task for a monitoring system is to provide aggregated information about monitored components state, since most of the time that information is scattered among many sources on different levels and in different forms.
3. Executives - persons who are responsible for budget and take decisions about MICC development. They are mostly interested in summary information about components performance and operation. This information is crucial for "bottlenecks" discovery, development planning and reports preparation. Despite the fact that this kind of systems is more related to accounting, the data they are using usually collected by monitoring systems.

Three groups of users described above have different interests and requirements. It is a complex task to create a single monitoring system which would satisfy all user groups of all MICC components. That is the reason why the groups responsible for different components are allowed to elaborate their own approach to monitoring. The basic requirement is that all components` performance should be measurable. However, due to the fact that all components are based on the same network and engineering infrastructure, there are some space for unification.

Information about different monitoring systems which were adopted or developed for MICC components will be described in the following subsections.

2.1. Tier-1, Tier-2 and local batch farm monitoring

The monitoring system for Tier-1, Tier-2 and local batch farm at JINR is based on Nagios3.5 [5]. This is an open source product which has a modular approach that makes system flexible. Monitoring system based on Nagios allows operators to keep track of the components' states providing web interface and alarm system. Such information allows one to optimize work of the monitored component and to increase its reliability.

The monitoring system includes the following parts:

1. Data acquisition and processing. It is provided by Nagios and relies on Nagios plugins that acquire and evaluate data from local batch farm and grid related components. This data contain information about hardware and software state.
2. Data storage. It is based on Round-robin Database for a new data and MySQL for an archive.
3. Alarm system. It's used to send e-mail and SMS for notification about issues.
4. Visualization. That part is based on the Nagios NagVis plugin to provide monitoring information in the form of dashboard.

Monitoring data are collected from the wide range of hardware and software related to Tiers and local batch farm: cooling systems, temperature sensors, uninterruptable power supplies (UPS), computing servers, disk arrays, managing services, L2 and L3 switches and routers and tape robot. So this monitoring system aggregates the information from four levels: engineering, network, hardware and software. It uses SNMP, IPMI or SSH protocols depending on the type of monitored object.

Monitoring results are displayed on the web page in the form of a dashboard (see Figure 1). The dashboard is divided into several areas to show various metrics of MICC components (temperature, UPS load, network channels and switches load, status of work nodes and data storages, an amount of running/queued jobs, etc.). This dashboard could be displayed both on the personal computers and on the big screens in control rooms. In case of any issue or emergencies SMS and e-mails are sent as well as the sound alarm is played to draw operator's attention.

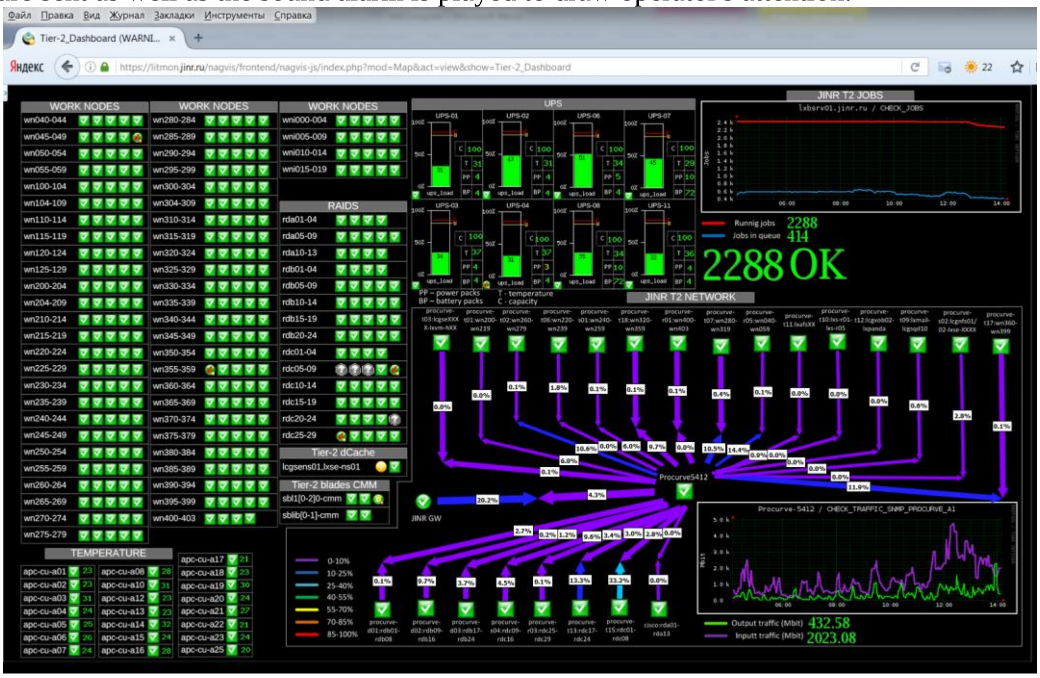

Figure 1. Example of dashboard for Tier-2 monitoring

This monitoring system always grows with new components and checks. There is ongoing development to move this system to Icinga2 software which is a fork of Nagios project. This would allow implementing a load distribution among several monitoring servers, more flexible configuration and visualization.

On the top of the JINR Tier-1 hardware services are running [6]. The services are programs which run all the time and work as a layer between Tier-1 hardware and applications or users. Their reliability determines the quality of Tier-1 component. These services run on the top of the whole pyramid "Engineering→ Network→ Hardware→ Software". So in case of any failure at any level services could fail as a result. A new system was developed to perform service monitoring and to collect data from different sources including local hosts, web pages and central REST services of

WLCG infrastructure. The aims of that monitoring system (see its screenshot on the Figure 2) are the following:

1. To provide an information about all Tier-1 services in comprehensive format on the web interface.
2. To determine status of different services and show occurring events.
3. To notify about service state change from good to bad or about critical events

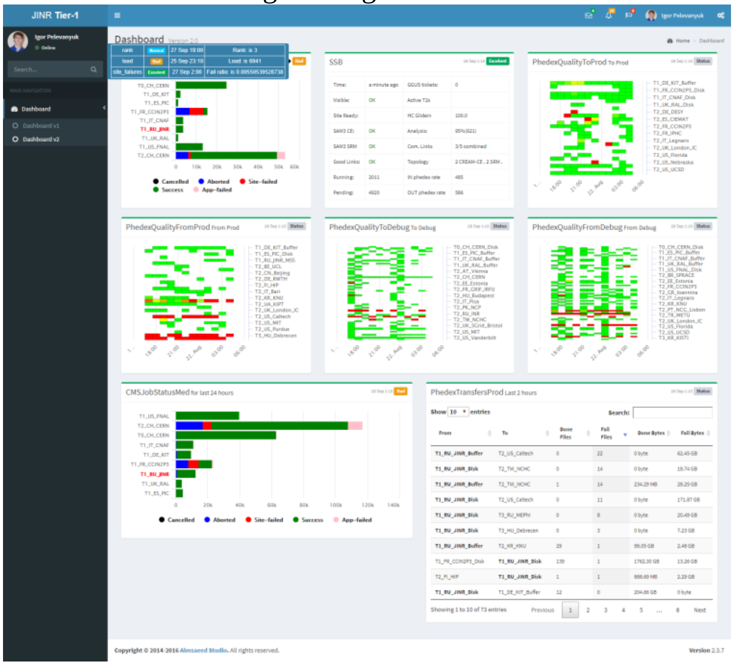

Figure 2. Tier-1 service monitoring system

Service monitoring system was implemented using Python language [7], Django framework [8] and web technologies. It is in development stage and lacks some of required functionality but it is already useful to display aggregated information from different sources and to determine services status. There are many sources of information for service monitoring system: local hosts, special CLI commands, web-sites, REST API, etc. Once the system is completed it can be used for monitoring of other systems and components which require complex web interface for representation of monitoring information.

2.2. Engineering and network infrastructure

Engineering and network infrastructures are the basic part of the MICC. The monitoring system for it should be highly reliable and always available. Primary consumers of this monitoring system are specialists responsible for different engineering subsystems and shifters who look after MICC all the time 24x7. SMS and e-mail notifications are configured to inform about occurring issues. Web interface based on NagVis plugin is provided for visual control too.

2.3. The JINR Cloud

The JINR Cloud is a cloud infrastructure built on the OpenNebula platform[4]. It implements so called "Infrastructure as a Service" (IaaS) model. It is available for all JINR employees and widely used by more than 150 users (including students, researchers, system administrators and software developers) for a variety of different activities: from hosting production services and using virtual machines (VMs) as personal computers to running computational workload on VMs as work nodes of global grid infrastructures within BES-III [9], NOvA, etc.

The monitoring for it consists of several parts. The first part is based on Nagios and it monitors health of every physical host on which VMs are running on. That part is used by cloud admins for issue notifications like failure of HDD, network connection and so on.

The second monitoring component is responsible for virtual machines and hosts usage monitoring. It is built in the OpenNebula platform. The purpose of that part is to provide information about CPU and RAM usage inside virtual machines and physical servers for the last 4 hours period (hardcoded in the OpenNebula code). Such data can be used by cloud users to keep track on the load of their VMs. Short time frame of this monitoring does not allow long term analysis.

The JINR cloud team is working on an increasing of resources effectiveness utilization within the development of a software framework called "SmartScheduler" [10]. That scheduler heavily relies on the monitoring data. Two described above monitoring components of the JINR cloud don't cover all needs of SmartScheduler. That's why a special monitoring system was developed. It collects performance metrics related to virtual machines and hypervisors: CPU, RAM and network usage. This data are collected by Icinga2 agents installed on every host with hypervisor. Graphite monitoring tool was also evaluated for the monitoring data storage role. Collected data are saved into InfluxDB database for analysis and visualization [11] (graphite monitoring tool was also evaluated for such role but a choice was made in favor of InfluxDB). Grafana[12] is used for visualization. It is perfect for displaying current state of virtual machines and hosts. Information received from Grafana helps administrator to understand deeper different virtual machines operational modes. A schema of VMs and hosts monitoring workflow is shown on Figure 3.

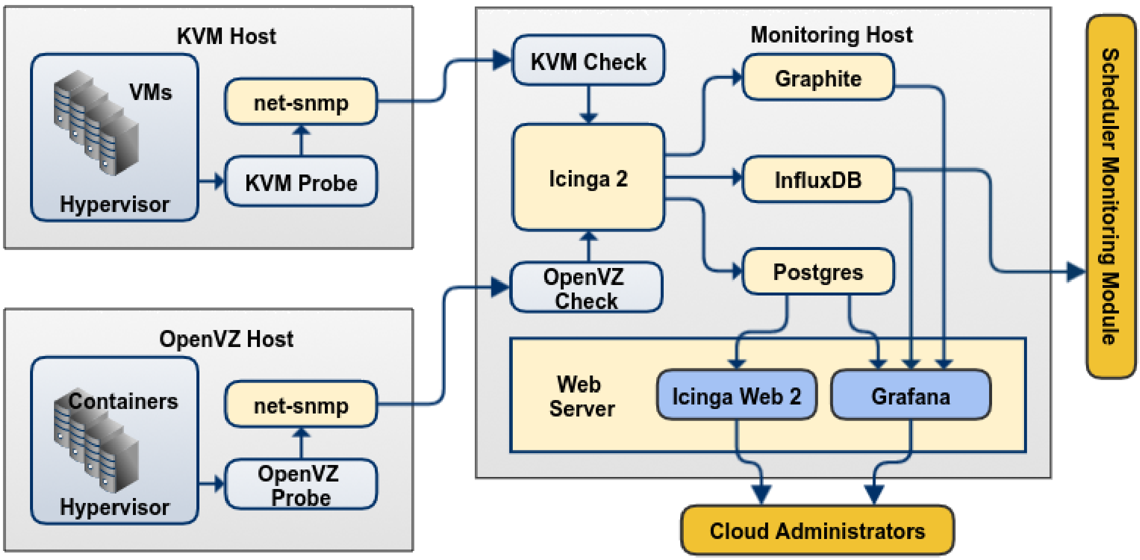

Figure 3. Schema of virtual machines monitoring in the JINR cloud

2.4. Heterogeneous cluster HybriLIT

HybriLIT is a high performance cluster which consists of servers with Nvidia GPGPU and Intel Xeon Phi co-processors. Its main purpose is to run fast parallel jobs based on OpenMP, OpenCL and MPI technologies. In order to perform workload management Slurm[13] software was installed and configured with queues for tasks. Since computing power in disposal of this cluster is limited users' tasks stay in the queue from time to time and users need source of this information.

The monitoring system has been developed to provide information about the cluster for its users, administrators. It provides the following information: amount of running tasks, free slots, total CPU and RAM load, tasks running now, finished tasks, detailed information about every server. There are two sources of data for this information: agents running on every server of cluster and sending messages about CPU, RAM and network load to the message broker ZeroMQ and Slurm database. Data coming to ZeroMQ also saved in MySQL database for analysis of long terms of work.

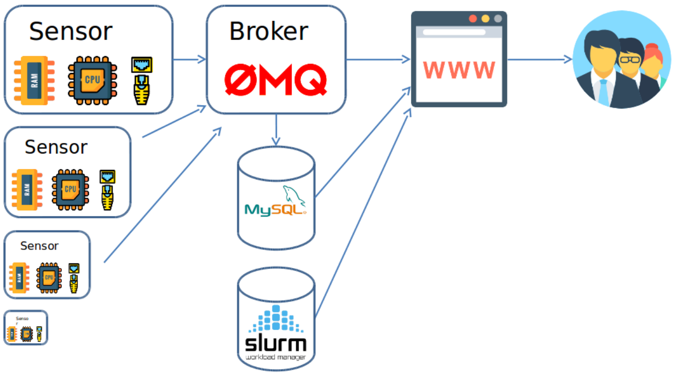

Figure 4. Schema of HybriLIT monitoring

To build this monitoring sensor was written on C++ to collect metrics on servers and send them to message queue. Data from message queue goes to MySQL and to clients if they connected to the web-interface. Part of the data for users of monitoring taken from database of Slurm software. Schema of HybriLIT monitoring and data flows is presented on Figure 4. Biggest advantage of this monitoring is that it provides present time information about HybriLIT cluster which allow using it as one of debug tools. It is also useful for administrators because it allow seeing how cluster is used right at the moment.

3. MICC Operational Center

One of the crucial requirements to any monitoring or control system is its reliability. This could be satisfied by system itself. But there is also another important requirement - availability. And to satisfy this requirement, special arrangements are required to ensure a stable access to monitoring and control systems during power cuts, network failures or other emergencies. The MICC Operational Center was formed to provide 24x7 availability of MICC systems [14]. The MICC Operational Center is located at a room dedicated for operators of MICC. It is equipped with 6 big (55 inch in diagonal) screens for the monitoring information display (Fig. 5). Normally, these screens show information about all MICC components: Tier1 services, Tier-1 hardware, Tier-2 hardware, HybriLIT load, WLCG Google Earth Dashboard, JINR Cloud load. UPS to keep a hardware operational up to 2 hours, 2 workstations for operators and 2 network links with MICC. This equipment together with supported monitoring systems allows reliable and effective control of all MICC components under different critical conditions.

Figure 5. Photo of the MICC Operational Center

5. Conclusion

The JINR Multifunctional Information and Computing Complex requires exhaustive monitoring to provide information which is relevant for its effective use and control. Different components require different monitoring approaches and hardly there is a system which would satisfy all requirements and would be flexible enough to follow the changes. Our experience shows us that modern open source monitoring systems like Nagios are reliable and useful. These systems can look after critical metrics, reliably provide notifications and dashboards for administrators. That is why they could be used for center wide monitoring of hardware. However, sometimes they are not flexible enough to be suitable for all groups of monitoring consumers, especially when complex visualization is required. That leads to new software development which allows providing as complex system as it is required.

The multi-level monitoring system was created for JINR MICC. It is based on different technologies: Nagios, Icinga2, Grafana and systems that was developed from scratch in JINR. Nagios/Icinga2 system proved to be suitable and reliable tools for hardware monitoring of all MICC components. Grafana as a visualization tool is used only by JINR Cloud team but could be useful for other components. The Tier-1 service monitoring system and HybriLIT monitoring system were developed in JINR.

6. Acknowledgement

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References

[1] Astakhov N.S., Baginyan A.S., Belov S.D. et al. JINR Tier-1 centre for the CMS Experiment at LHC // Physics of Particles and Nuclei Letters, ISSN 1547-4771, eISSN: 1531-8567, 2016, vol. 13, No. 5, pp. 714–717. DOI: 10.1134/S1547477116050046.

[2] Gavrilov V., Golutvin I., Kodolova O. et al. Status of RDMS CMS computing // Physics of Particles and Nuclei Letters, ISSN 1547-4771, eISSN: 1531-8567, 2016, vol. 13, No. 5, pp. 718–720. DOI: 10.1134/S1547477116050216.

[3] The Worldwide LHC Computing Grid (WLCG). http://wlcg.web.cern.ch/LCG.

[4] Baranov A.V. et al. JINR cloud infrastructure evolution // Physics of Particles and Nuclei Letters, ISSN 1547-4771, eISSN: 1531-8567, 2016, vol. 13, No. 5, pp. 672–675. DOI: 10.1134/S1547477116050071.

[5] Kashunin I.A et al. The monitoring system of Multifunctional Information and Computing Complex // CEUR Workshop Proceedings (CEUR-WS.org), ISSN:1613-0073, Изд:RWTH Aachen University, vol. 1787, pp. 256-263 (in Russian).

[6] Kadochnikov I.S, Pelevanyuk I.S. JINR Tier-1 service monitoring system: Ideas and Design // CEUR Workshop Proceedings, Vol. 1787, Pages 275-278, 2016

[7] Python Software Foundation. Python Language Reference, version 2.7. http://www.python.org.

[8] Django high-level Python Web framework. https://www.djangoproject.com.

[9] Belov S.D. et al. BES-III distributed computing status // Physics of Particles and Nuclei Letters, ISSN 1547-4771, eISSN: 1531-8567, 2016, vol. 13, No. 5, pp. 700–703. DOI: 10.1134/S1547477116050113.

[10] N. Balashov, A. Baranov, V. Korenkov Optimization of over-provisioned clouds // Physics of Particles and Nuclei Letters, ISSN 1547-4771, eISSN: 1531-8567, 2016, vol. 13, No. 5, pp. 609–612.

[11] Kadochnikov I., Balashov N., Baranov A., Pelevanyuk I., Kutovskiy N., Korenkov V., Nechaevskiy A. Evaluation of monitoring systems for metric collection in intelligent cloud scheduling // CEUR Workshop Proceedings, Vol. 1787, Pages 279-283, 2016

[12] Grafana. https://grafana.com.

[13] Alexandrov E.I. et al. Research of Acceleration of Calculation in Solving Scientific Problems on the Heterogeneous Cluster HybriLIT. Bulletin of PFUR. Series: Mathematics. Information Sciences. Physics. 2015. No 4. Pp. 20-27.

[14] Golunov A.O et al. Operation center of the JINR Multifunctional information and computing complex // CEUR Workshop Proceedings (CEUR-WS.org), ISSN:1613-0073, Изд:RWTH Aachen University, vol. 1787, pp. 235-240 (in Russian).