

SIG-NOC Tools Survey

What software tools do R&E Network Operations Centres use?

December 2023

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1. Introduction

The Special Interest Group – Network Operations Centres (SIG-NOC) is a community effort [\[1\]](#) initiated by the National Research and Education Networks (NRENs) gathered under the GÉANT Association in Europe. The SIG-NOC creates an open forum where experts from the GÉANT Community and beyond exchange information, knowledge, ideas and best practices. These cover specific technical aspects or other areas of business, relevant to the research and education networking community. The SIG-NOC is the successor of the former TERENA Task Force on NOCs (TF-NOC).

The SIG-NOC community has run four surveys since the creation of TF-NOC in 2010. The reason for running surveys from time to time is to gather up-to-date information for the Network Operation Centre community, because the tools and techniques used by the NOCs and the functions covered by them evolve. The first survey was published in 2012 [\[2\]](#) and it covered the NOCs' taxonomy, structures, resources, tools and other aspects. The second was published in 2016 [\[3\]](#) and focused on tools, as this was most relevant to the SIG-NOC members. The survey also contained a section dedicated to the adoption of standards and industry best practices. The third and the fourth survey, also focusing on tools, were run in 2019 [\[4\]](#) and 2023 [\[5\]](#).

Since the surveys mainly focused on tools and operation practices, it was recommended that they should be filled out by someone who has an overview of the entire NOCs' operations.

The survey questions were grouped into different sections, covering 17 major NOC functions:

- Monitoring
- Problem management
- Ticketing
- Knowledge Management and Documentation
- Reporting and Statistics
- Communication, Coordination and Chat
- Configuration Management and Backup
- Performance Management
- Inventory Management
- Resources Management
- Out-of-Band Access
- Change Management
- Training
- Security Management
- Data Aggregation, Representation and Visualisation
- DDoS Mitigation
- Orchestration, Automation and Virtualisation

Demonstrating the evolution of the NOC's tasks, while the 2012 survey contained 14 functions, in 2016 DDoS Mitigation was added to the list, and in 2019 Orchestration, Automation and Virtualisation were included. In 2023, Training was also added to the survey as one of the functions NOC have, at least to train their own staff.

The results of the 2023 survey are summarised in this report. The survey data is also available in MS Excel format for further analysis [\[6\]](#).

2. Survey Participants

The SIG-NOC received 84 individual responses to the survey of which 64 were valid and fully or partly complete. Empty responses, invalid names, and duplicated institutions were not considered (in case of more than one answers for a single institution, the most complete response was kept, except for one institution that answered twice, but informed about different departments being responsible for different functions).

Chart 1 shows the type and range of networks that participated in the survey.

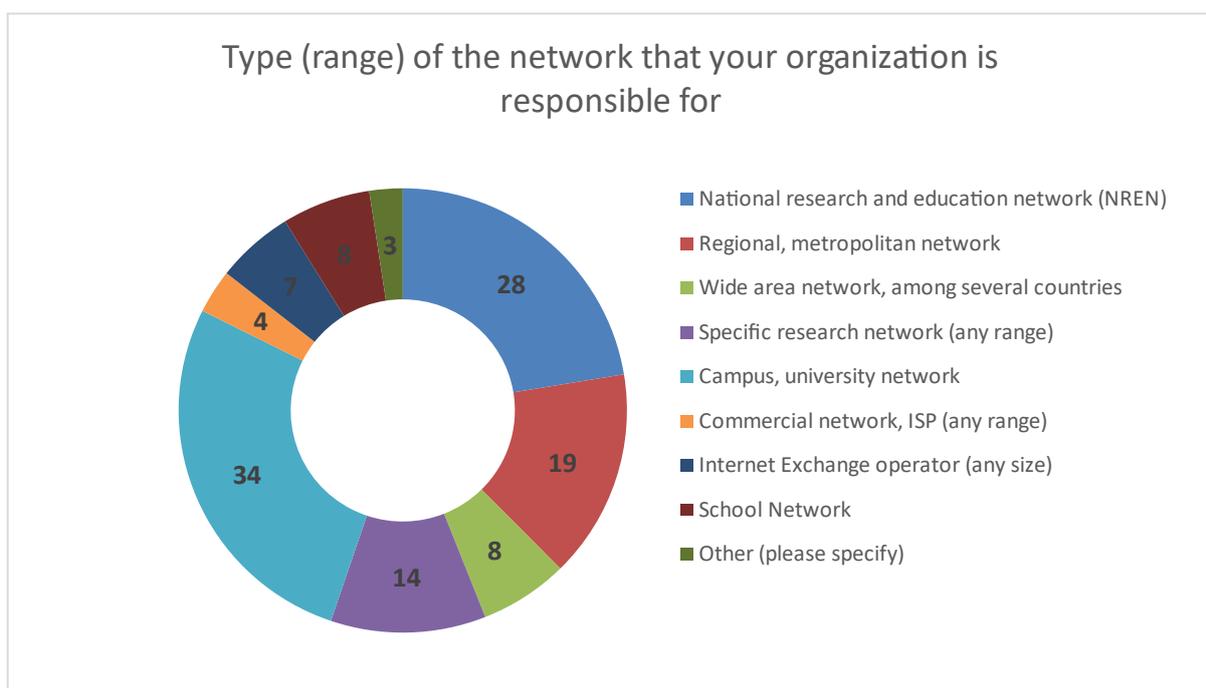


Chart 1. Type (range) of networks answering the survey

As in some cases the same NOCs may manage more than one type of network (for instance, NREN and Campus Networks or Specific Research Networks), the total number of types of networks (125) is more than the number of valid responses. Compared to the number of respondents to the previous surveys, the number of Campus Networks has increased the most, being slightly higher than the number of NRENS for the first time since the survey has been run. School Networks were included in this edition and appear in the results for the first time, although they are many times run from organisations that also run NREN, metropolitan, or campus networks. The respondents who answered “Other” include company and data centre networks.

Chart 2 shows a comparison of the networks that participated in each of the surveys.¹

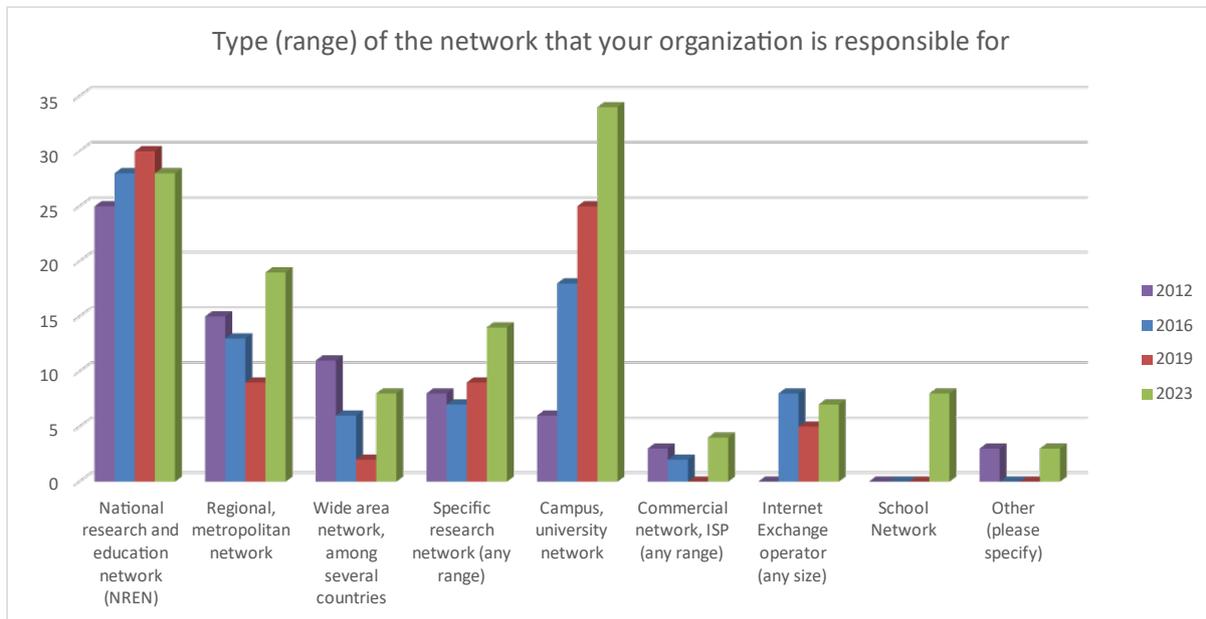


Chart 2. Type (range) of networks answering the survey

¹ The results in the 2016 report for this question were considered as they were, without cleaning duplicates and invalid responses. In order to make a consistent comparison, the results of 2016 were cleaned and recalculated following the same criteria as in 2019 and 2023.

3. NOC Functions

The survey covered 17 functions that the NOCs may be responsible for. *Table 1* lists all the functions, sorted in the order of their importance rated by the respondents in 2023 and compared to the ranking in 2016 and 2019. Monitoring, Problem Management, and Ticketing keep the same three most relevant positions as in 2016 and 2019, but Knowledge Management and Documentation are following a trend to go up in the table and escalated to the fourth position. Communication, Coordination and Chat also went up in the ranking. The most significant drop was for Security Management, and this could be explained by the appearance of Security Operations Centres (SOCs) who specifically take care of security, making the NOCs not directly responsible for this function anymore (although they may always be involved in case of need during security incidents). Training appeared in the survey for the first time, in 13th position, being mentioned by more respondents than Security Management, Data Aggregation, Representation and Visualisation, DDoS Mitigation, and Orchestration, Automation and Virtualisation. For Orchestration, Automation and Virtualisation, more than 70% of the respondents who answered they were not responsible for this function also indicated they had already implemented some kind of automation in their networks, which indicates that the automation is the responsibility of other teams in the company, different from the NOC.

| NOC Functions 2023 | 2016 | 2019 | 2023 | Trend |
|---|------|------|------|-------|
| Monitoring | 1 | 1 | 1 | 0 |
| Problem Management | 2 | 2 | 2 | 0 |
| Ticketing | 3 | 3 | 3 | 0 |
| Knowledge Management and Documentation | 8 | 6 | 4 | 2 |
| Reporting and Statistics | 5 | 4 | 5 | -1 |
| Communication, Coordination and Chat | 7 | 10 | 6 | 4 |
| Configuration Management and Backup | 6 | 5 | 7 | -2 |
| Performance Management | 4 | 7 | 8 | -1 |
| Inventory Management | 12 | 9 | 9 | 0 |
| Resources Management | 14 | 12 | 10 | 2 |
| Out-of-band Access Management | 10 | 11 | 11 | 0 |
| Change Management | 9 | 13 | 12 | 1 |
| Training | | | 13 | NEW |
| Security Management | 11 | 8 | 14 | -6 |
| Data Aggregation, Representation, Visualization | 15 | 15 | 15 | 0 |
| DDoS Mitigation | 13 | 14 | 16 | -2 |
| Orchestration, automation and virtualisation | | 16 | 17 | -1 |

Table 1. Comparison of NOC functions

The 2023 data is also depicted in *Chart 3* (where skipped questions are not counted for the averages). Here, the functions are sorted according to their ranking position in 2019, which was the same order used to create the 2023 survey. If we compare the number of respondents that considered each function as a NOC responsibility and the number of respondents that consider it is not their responsibility, all the functions are covered by more than 50% of the NOCs who answered each question, with Monitoring as the function that most NOCs feel responsible for (95%) and Orchestration, Automation and Virtualisation the function that least of them considered their responsibility (56%).

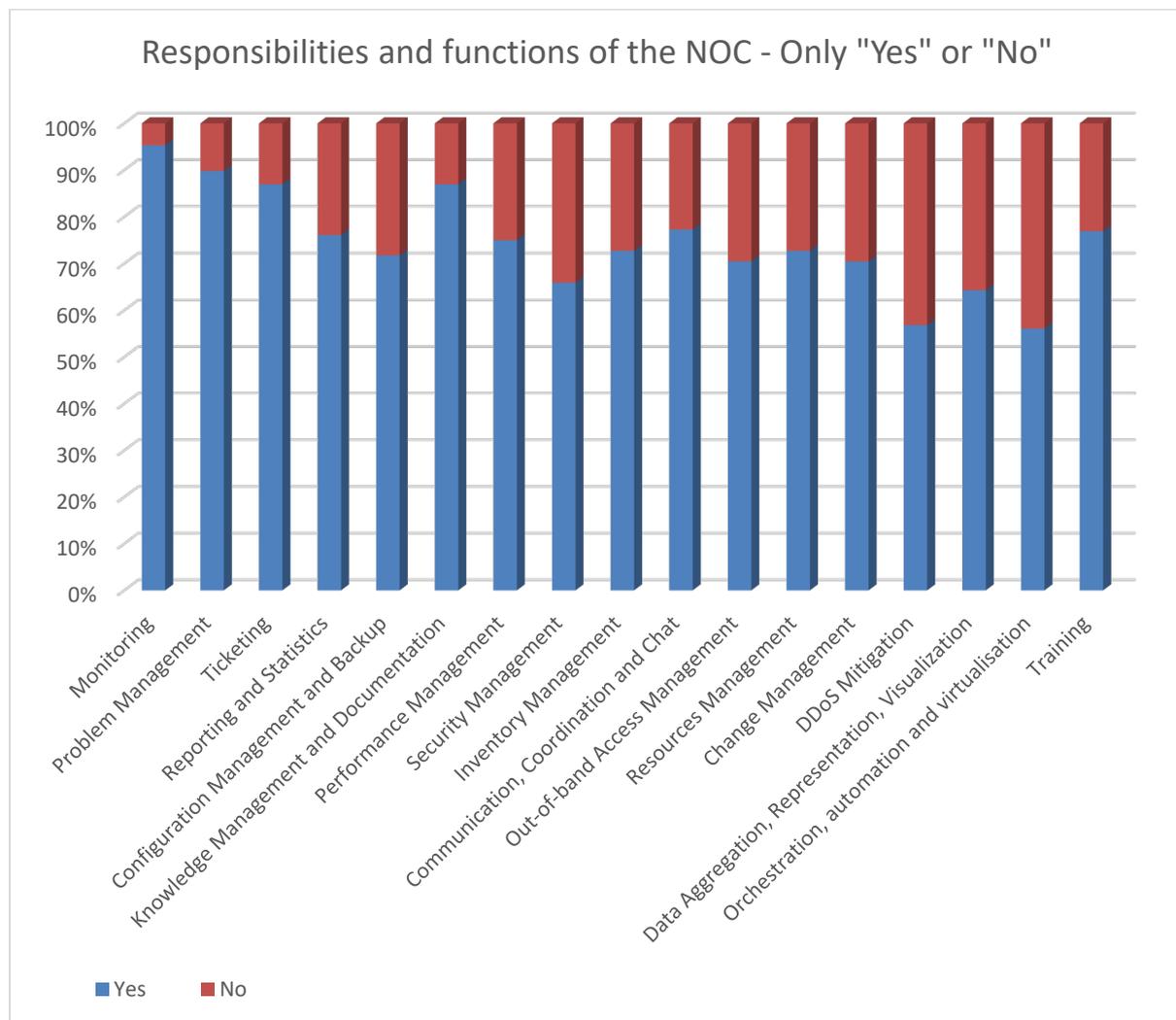


Chart 3. NOCs responsible for the particular functions

4. NOC Tools

This section shows the various software tools used to fulfil the particular functions rated by their importance and quality. The importance is depicted horizontally, whereas the ratings (quality) are shown vertically. The importance ranges from 1 (low) to 4 (high), while the rating goes from 1 (poor) to 5 (excellent). The size of the bubble indicates the number of answers given regarding that particular tool. The larger the circle, the more answers were provided for that tool. The smaller circles represent some tools that may be below or above average, however, this is based on the opinion of a smaller set of respondents only. We suggest taking into account the bigger bubbles or the ones with the same/similar relative sizes in any comparison.

The pre-defined responses in the survey were all the tools that were rated or mentioned by two or more respondents in the 2019 survey. There were also open boxes to list other tools, including in-house developed solutions, for each function. These responses are also included in this report, as separate tables.

Some trends are highlighted in the report, but the final conclusions are up to the reader.

4.1. Monitoring

As in the previous edition, there were two different types of questions for monitoring: methodologies (SNMP-based, Netflow-based, etc.) and tools. *Chart 4* shows the different methodologies used in the NOCs for monitoring, with no significant differences in the graph, compared to the 2019 report. In this case, instead of comparing importance and rating as in the rest of the document, importance and frequency of usage are compared. The size of the bubble indicates the number of answers for that methodology. As shown in the graph, SNMP-based tools are still the most important and most frequently used tools, followed by Syslog-handling and Flowmon-based tools (note that the maximum possible value for the frequency is 5, but the bubble was so big for SNMP-based tools that the maximum number for the Frequency axis was increased to provide enough space for it). Streaming Telemetry is still the least adopted, important, and relevant method for monitoring, but it is used more often than in the 2019 survey, falling between “in case of incident” and “once a month”, whereas it was below “in case of incident” in the 2019 survey.

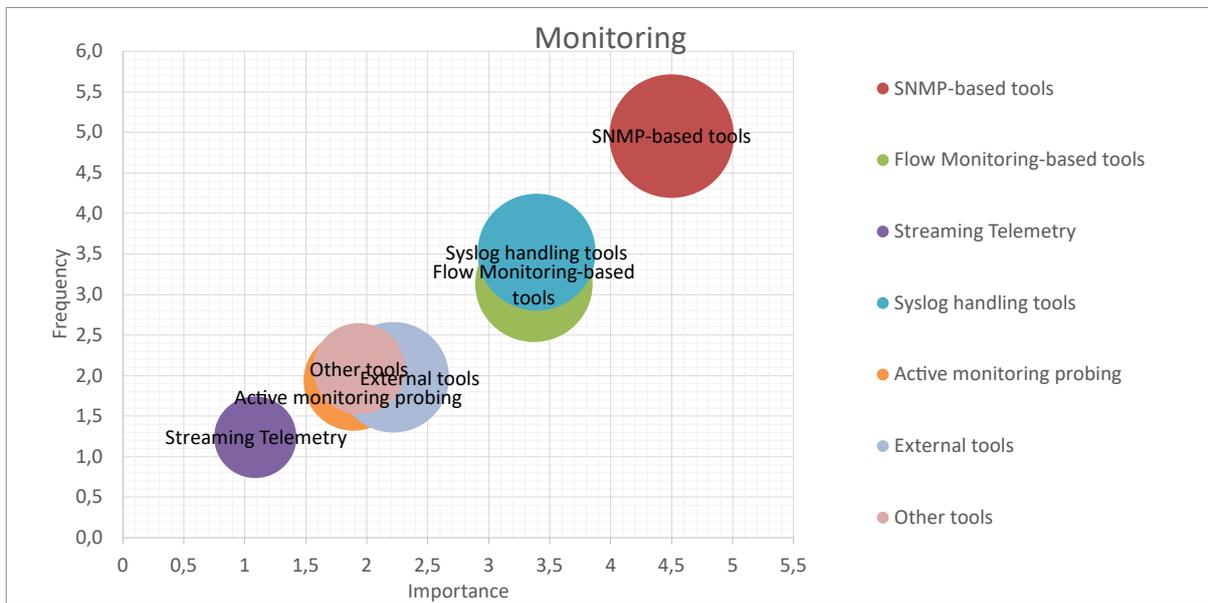


Chart 4. Methods used for Monitoring

Table 2 shows the trends in the ranking for the Top-10 used software monitoring tools, comparing the position they occupy in the responses count table (sorting by number of answers for each tool).

| Tool | 2016 | 2019 | 2023 | Trend |
|-----------------------|------|------|------|-------|
| GRAFANA | | | 1 | NEW |
| NAGIOS | 2 | 1 | 2 | ▼ -1 |
| MRTG | 6 | 6 | 3 | ▲ 3 |
| RIPE Atlas / Stats | 4 | 7 | 4 | ▲ 3 |
| PERFSONAR | 11 | 12 | 5 | ▲ 7 |
| CACTI | 1 | 3 | 6 | ▼ -3 |
| LOOKING-GLASS | 3 | 2 | 7 | ▼ -5 |
| WEATHERMAP | | 4 | 8 | ▼ -4 |
| ELK STACK | | 5 | 9 | ▼ -4 |
| INFLUXDB/INFLUX STACK | | | 10 | NEW |

Table 2. Trends in Monitoring tools

In terms of number of users, Nagios went down from the first to the second position and Cati went down from the third to the sixth position, surpassed by MRTG, and two distributed monitoring tools: RIPE Atlas/Stats and perfSONAR, which has the most significant change in the ranking, going from non-Top10 positions to the 5th one in terms of number of users.

Chart 6 shows the percentage of users per tool for the ten most popular tools.

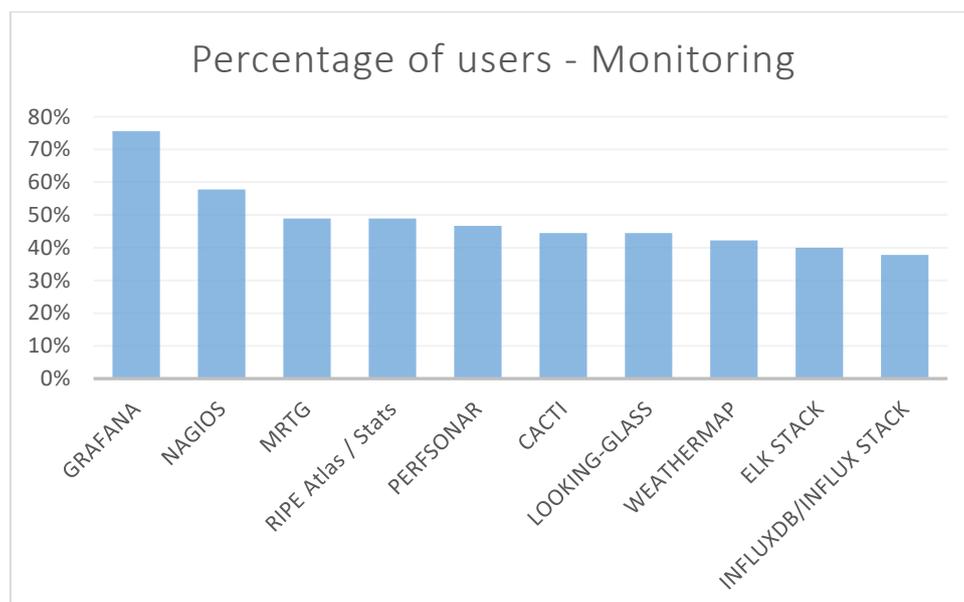


Chart 6. Monitoring: Percentage of Users per Tool (Top-10)

An interesting output of the survey is that, on average, each institution uses 11.5 tools for monitoring, which means not all the information is extracted from a single tool or a small number of them. The respondents are using more tools than methodologies. Although databases or visualisation tools can be found among the results, this may mean that different tools are better for certain features than others, even if using the same methodology (for instance, tools like Nagios, MRTG, Cacti or Weathermap use SNMP, and some respondents use all of them). Tools managed by external parties, such as RIPE Atlas or perfSONAR are also a factor to consider when evaluating the high average number of tools per institution, as they complement on-site tools with views of the network from external networks.

Table 3 below lists other tools and in-house developed solutions not pre-defined in the survey. The first two were mentioned more than once; the number of institutions that mentioned it is shown in parentheses. From the number of answers to “Other tools” and “In-house developed tools” in this question (39 tools/responses), it is clear that many institutions complement standard monitoring tools with commercial tools, their own scripts, and in-house developed solutions.

| | | |
|--------------------------------------|--|---|
| Other tools | <ul style="list-style-type: none"> • LibreNMS (5) • Sensu (2) • Aruba Airwaves • Blueplanet (Ciena) • Cisco Prime • Flowmon • HPE IMC • IBM Tivoli • NEMO • Netdisco | <ul style="list-style-type: none"> • NetVizura • OpenBMP • Optical Manager (Adva) • PacketVIS • Palo Alto Panorama • OPENSEARCH • Qrator.Radar • VictoriaMetrics • WANGuard • XIQ Extrem Networks |
| In-house developed solutions: | <ul style="list-style-type: none"> • Argus • AUTOMATOR • Communication tools • Dashboard y SWD • Dmon • FTAS • G3 | <ul style="list-style-type: none"> • Geomap • Inventory tools • Looking glass • NAV • Scripts • Shiba • Zino |

Table 3. Other tools and in-house developed solutions for Monitoring

4.2. Problem Management

Chart 7 shows the software tools that NOCs use for Problem Management.

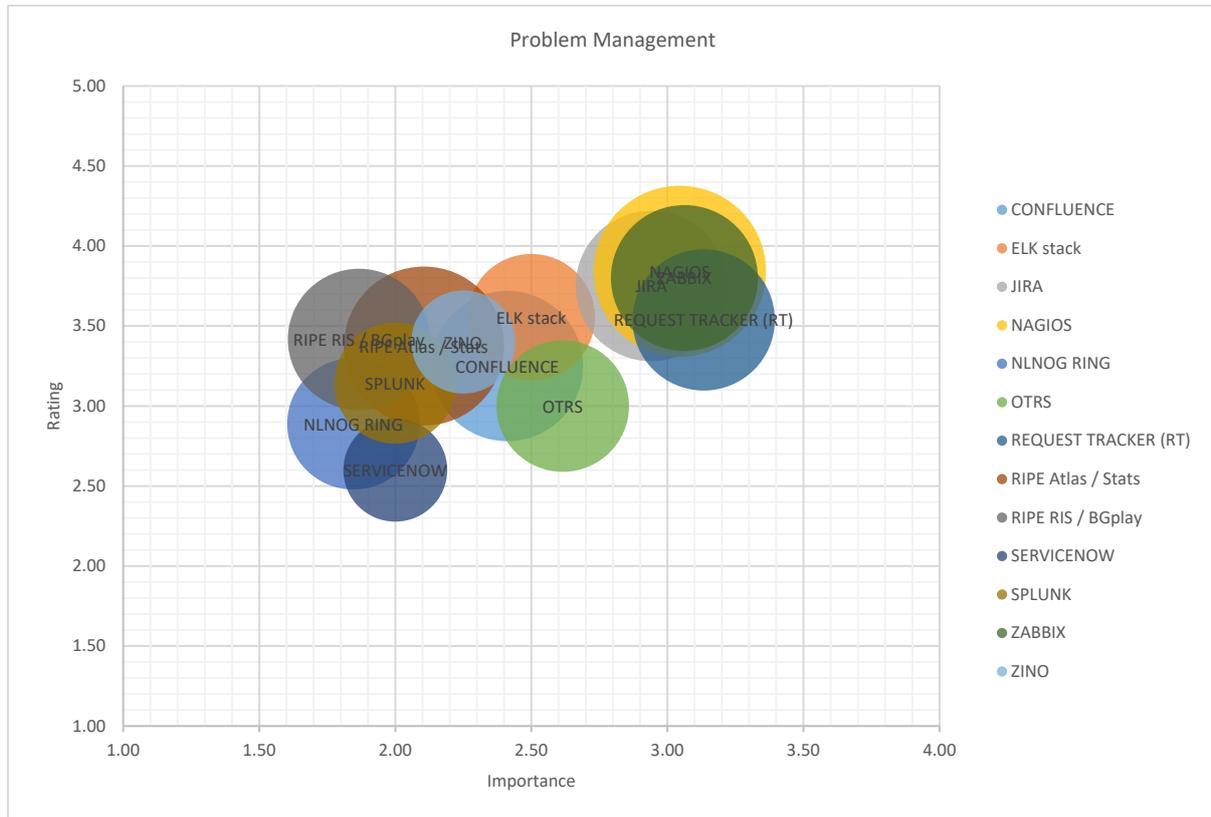


Chart 7. Software tools used for Problem Management

Nagios, Jira and Zabbix are rated the highest for quality with relatively high importance, although Request Tracker is the most important tool, but used by fewer respondents. Confluence is the most popular tool, but with lower importance for Problem Management than other tools like Request Tracker or OTRS. Some external and distributed tools like RIPE RIS/BGPlay, RIPE Atlas, or NLNOG Ring are popular and have good ratings but are not significantly important for this function, which means that they are probably used to complement other more relevant tools, or that they are used only in case of need. However, all the tools are in the middle of the table for the Importance Axis and in the middle-upper part of the table for the Rating axis, which means that all the tools are good (not excellent), and there are neither essential nor dismissible tools.

Table 4 shows the tools and their usage ranking over the last eight-year period for Problem Management, comparing the position they occupy in the responses count table (sorting by number of answers for each tool). The Top-10 remains quite stable if we compare it with previous editions of the survey, as all the tools in the 2023 Top-10 were also in the 2019 one and nine of them appeared also in the 2016 Top-10. As in previous editions, there is a mix of open-source, vendor-based and distributed tools. In this edition, Nagios went back to the first position after being substituted by Jira in the last survey. Jira and Confluence, from the Atlassian family, have the same number of users. The ELK Stack has dropped seven positions in the table, compared to 2019.

| Tool | 2016 | 2019 | 2023 | Trend |
|----------------------|------|------|------|-------|
| NAGIOS | 1 | 2 | 1 | ▲ 1 |
| RIPE Atlas / Stats | 3 | 6 | 2 | ▲ 4 |
| CONFLUENCE | | 4 | 3 | ▲ 1 |
| JIRA | 11 | 1 | 4 | ▼ -3 |
| ZABBIX | 8 | 5 | 5 | ▬ 0 |
| REQUEST TRACKER (RT) | 2 | 9 | 6 | ▲ 3 |
| RIPE RIS / BGplay | 5 | 7 | 7 | ▬ 0 |
| NLNOG RING | 7 | 10 | 8 | ▲ 2 |
| OTRS | 4 | 8 | 9 | ▼ -1 |
| ELK stack | 9 | 3 | 10 | ▼ -7 |

Table 4. Trends in Problem Management Tools

Chart 8 shows the percentage of users per tool for the Top-10 for Problem Management.

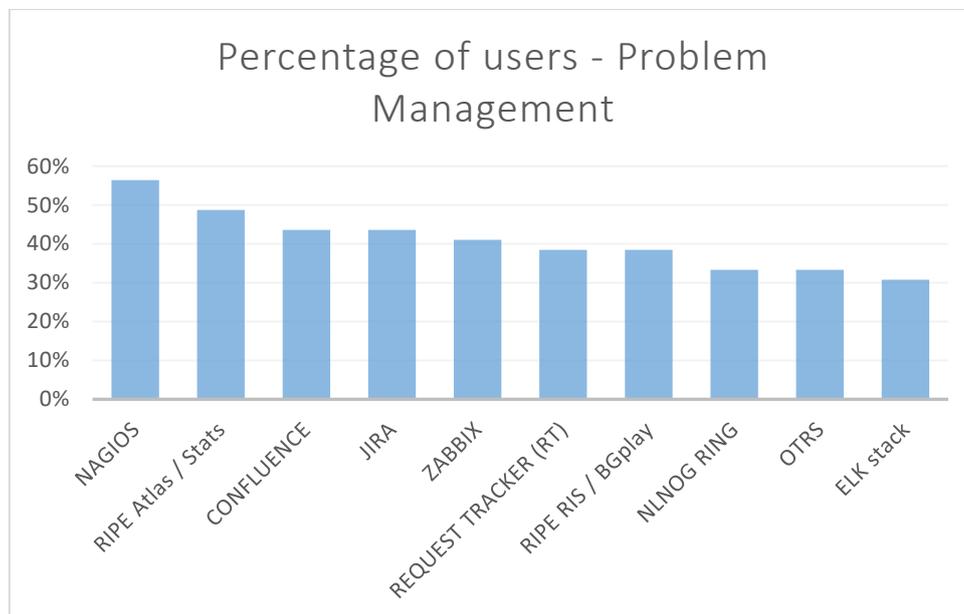


Chart 8. Problem Management: Percentage of Users per Tool (Top-10)

On average, each institutions uses 4.7 different tools for Problem Management, significantly fewer than for Monitoring. Considering some tools are used for diagnosis, others for the documentation of the problems, and there are open-source, vendor-based and distributed tools, it is not a surprising average.

Table 5 below lists other tools and in-house developed solutions not pre-defined in the survey for Problem Management. No tools were mentioned more than once, but there was a reference pointing out that one institution uses no tools, but human awareness and diligence. There are clearly fewer in-house and commercial tools in the list than for Monitoring, which means most of the existing tools are probably doing the work correctly for Problem Management.

| | | |
|--------------------------------------|--|---|
| Other tools: | <ul style="list-style-type: none"> • CienaMCP • ClearPass • GLPI • Ivanti Service Management | <ul style="list-style-type: none"> • LibreNMS • Mattermost • Omnivista |
| In-house developed solutions: | <ul style="list-style-type: none"> • DMon • Geomap • Inventory tools | <ul style="list-style-type: none"> • |

Table 5. Other tools and in-house developed solutions for Problem management

4.3. Ticketing

Chart 9 shows the software tools that NOCs use for Ticketing.

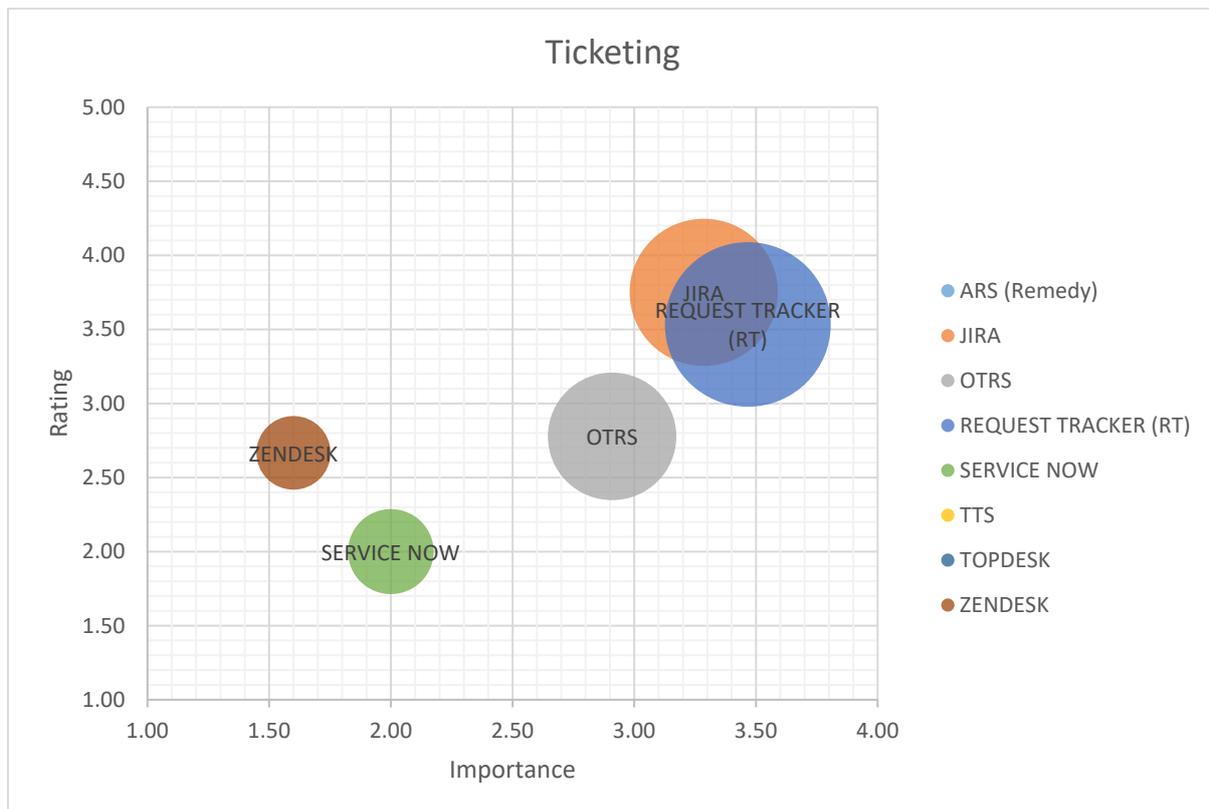


Chart 9. Software tools used for Ticketing

Request Tracker is the most important and popular tool, although Jira is considered to provide better quality, and not even the most popular tool reaches 50% of the respondents for this question. OTRS, which was considered an important and highly rated tool in the previous report, has gone down in both axis and in the number of users. Other tools are used by a lower number of institutions.

Table 6 shows the trends in the ranking for all the software tools for Ticketing, comparing the position they occupy in the responses count table (sorting by number of answers for each tool). Request Tracker went up to the first position, as in 2016, after having been replaced by Jira in 2019. ARS Remedy, TTS, and TOPdesk, that were used by some of the respondents in 2019, disappear from the table in 2023, although one respondent mentions RemedyForce, the cloud version of ARS Remedy, and another mentions TOPdesk in “Other Tools”, but without the corresponding importance and rating marks to include it in the graph.

| Tool | 2016 | 2019 | 2023 | Trend |
|----------------------|------|------|------|-------|
| REQUEST TRACKER (RT) | 1 | 3 | 1 | ▲ 2 |
| JIRA | 3 | 1 | 2 | ▼ -1 |
| OTRS | 2 | 2 | 3 | ▼ -1 |
| SERVICE NOW | 5 | 4 | 4 | ▬ 0 |
| ZENDESK | | 5 | 5 | ▬ 0 |
| ARS (Remedy) | 4 | 6 | | |
| TTS | 6 | 7 | | |
| TOPDESK | | 8 | | |

Table 6. Trends in Ticketing Tools

Chart 10 shows the percentage of users per tool for the Top-5 for Ticketing (only 5 tools were mentioned).

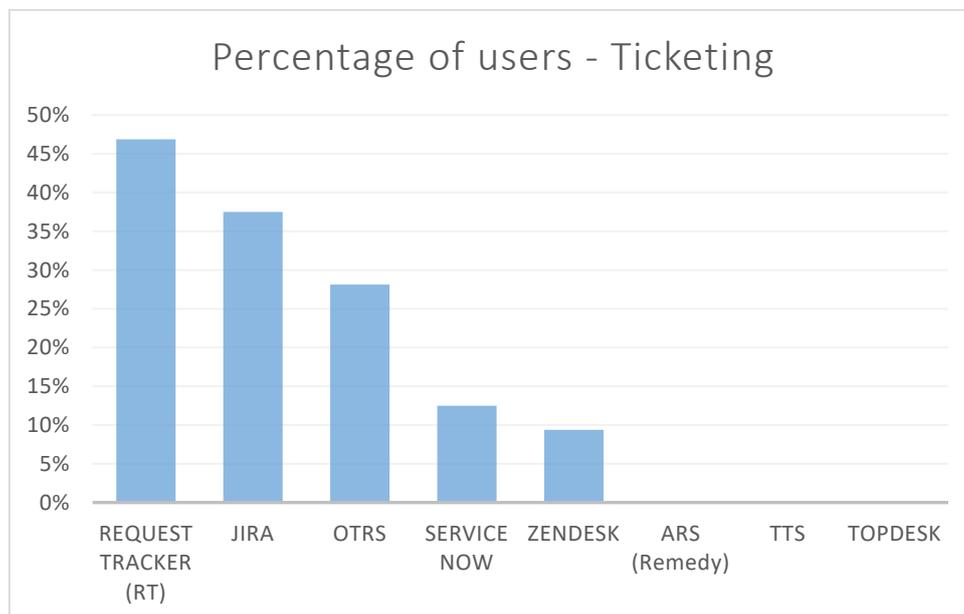


Chart 10. Ticketing: Percentage of Users per Tool (Top-5)

On average, each institution uses 1.5 tools for ticketing.

Table 7 below lists other tools and in-house developed solutions not pre-defined in the survey for Ticketing.

| | | |
|--------------------------------------|--|--|
| Other tools: | <ul style="list-style-type: none"> • EasyVista • GLPI • Ivanti • ProactivaNet | <ul style="list-style-type: none"> • RemedyForce • TOPdesk • YouTrack |
| In-house developed solutions: | <ul style="list-style-type: none"> • GGUS (maybe left in favour of Zammad) • Very old custom tool. Due to be replaced (probably by JIRA or OTRS) | |

Table 7. Other tools and in-house developed solutions for Ticketing

4.4. Knowledge Management and Documentation

Chart 11 shows the software tools that NOCs use for Knowledge Management and Documentation.

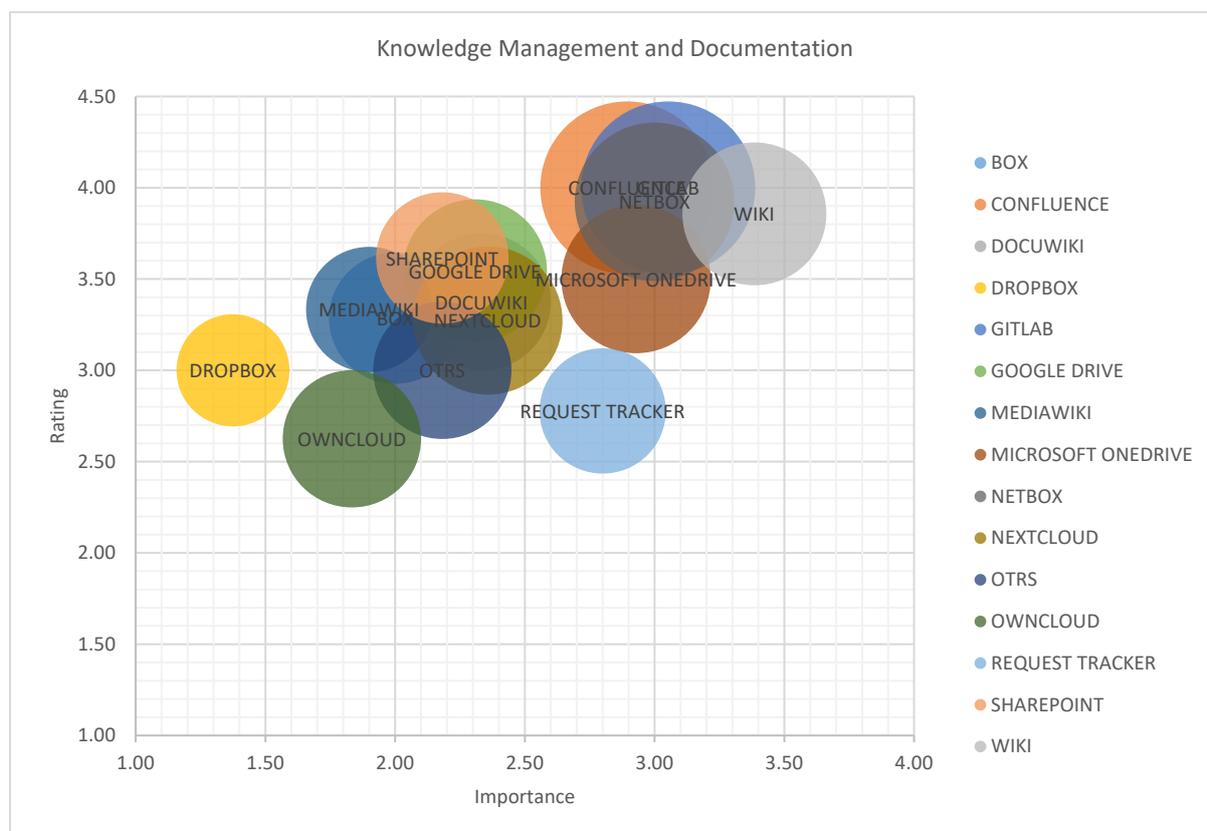


Chart 11. Software tools used for Knowledge Management and Documentation

GitLab and Confluence are the most used platforms, followed by NetBox. GitLab is the most important and has the same and highest rating for quality as Confluence. NetBox is rated well for quality, but with less importance for the respondents. Google Drive or SharePoint have fewer users and are perceived as less important by the NOC community but have good ratings for quality.

Table 8 shows the trends in the number of NOCs that use the Top-10 software tools for Knowledge Management and Documentation, comparing the position they occupy in the responses count table (sorting by number of responses for each tool). Three new tools (GitLab, NetBox, and NextCloud) appear in the table in the Top-5, whereas Google Drive, Wiki, and OwnCloud go four positions down, and OTRS, SharePoint, MediaWiki, Request Tracker, and Dropbox disappear from the Top-10.

| Tool | 2016 | 2019 | 2023 | Trend |
|--------------------|------|------|------|-------|
| CONFLUENCE | 5 | 1 | 1 | 0 |
| GITLAB | | | 2 | NEW |
| NETBOX | | | 3 | NEW |
| MICROSOFT ONEDRIVE | 10 | 4 | 4 | 0 |
| NEXTCLOUD | | | 5 | NEW |
| GOOGLE DRIVE | | 2 | 6 | -4 |
| WIKI | 1 | 3 | 7 | -4 |
| DOCUWIKI | 6 | 7 | 8 | -1 |
| OWNCLOUD | 9 | 5 | 9 | -4 |
| BOX | | 12 | 10 | 2 |

Table 8. Trends in Knowledge Management and Documentation Tools

Chart 12 shows the percentage of users per tool for the Top-10 for Knowledge Management and Documentation.

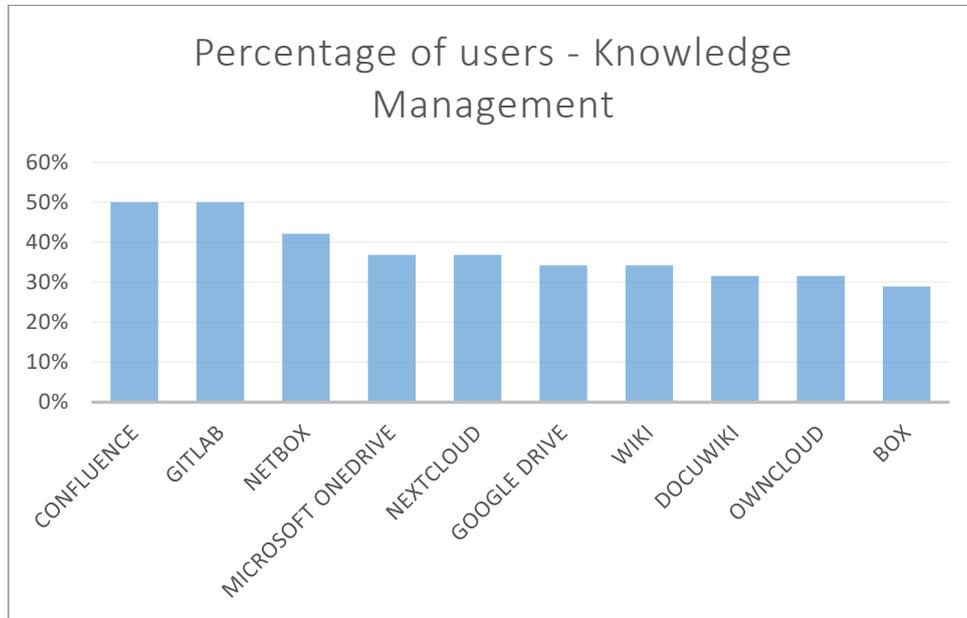


Chart 12. knowledge Management and Documentation: Percentage of Users per Tool (Top-10)

On average, each institution uses 5.2 tools for Knowledge Management. The number might be unexpectedly high, but an ecosystem of tools for different purposes is the most common case, as some tools are used on premise for written documentation, others are cloud-based tools, and others are mainly used for version control and collaboration.

Table 9 lists other tools and in-house developed solutions that were not pre-defined in the survey for Knowledge Management and Documentation.

| | |
|--------------------------------------|--|
| Other tools: | <ul style="list-style-type: none"> • Bookstack • DocuWiki • Microsoft Excel • Microsoft Word • MoinMoin • ProactivaNet • ServiceNow |
| In-house developed solutions: | <ul style="list-style-type: none"> • QGIS Webservice (mostly layer 1) |

Table 9. Other tools for Knowledge Management and Documentation

4.5. Reporting and Statistics

Chart 13 shows the software tools that NOCs use for Reporting and Statistics.

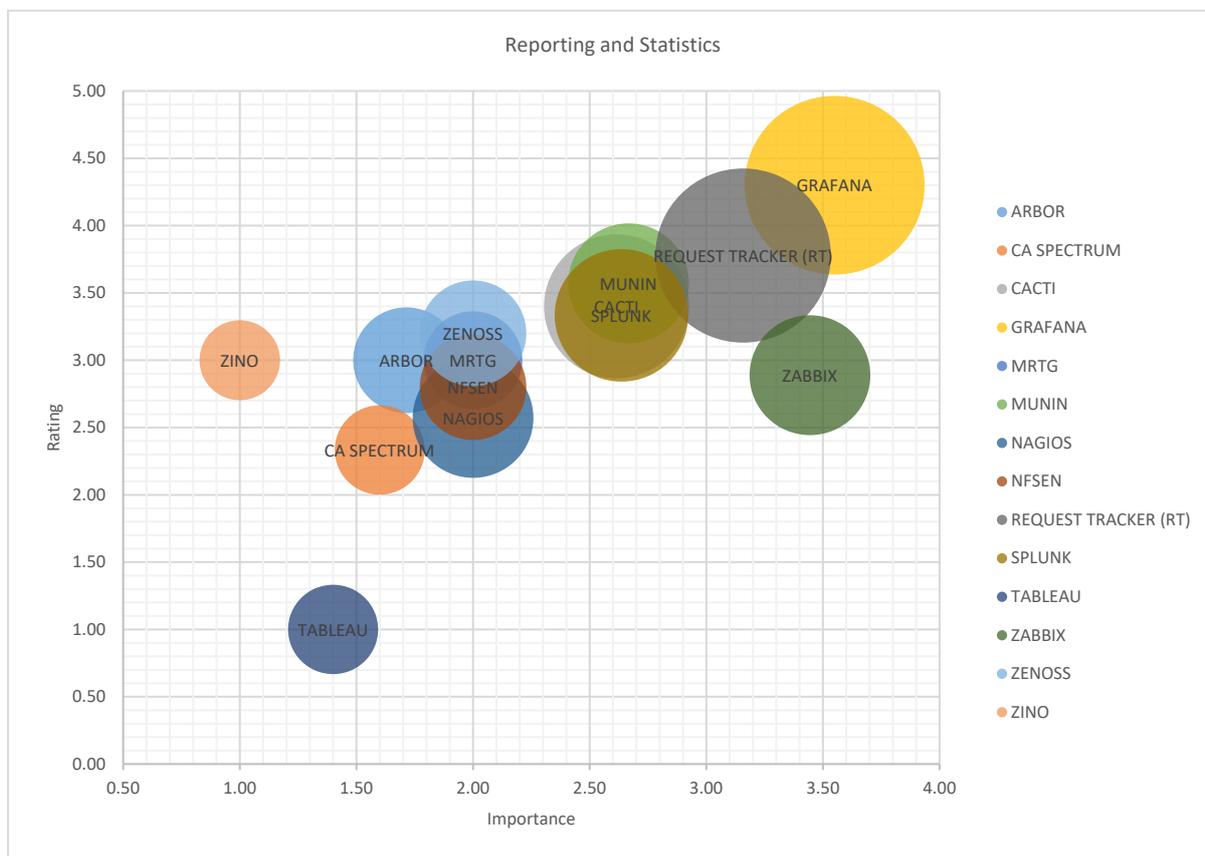


Chart 13. Software tools used for Reporting and Statistics

Grafana is the most commonly used tool, the most important and the best rated, according to the respondents of the survey, followed by Request Tracker. Cacti and Splunk have fewer users and of good quality but are less important for the NOCs. Other tools are perceived to be less relevant and have more or less value, depending on the tool, but are less used within the community.

Table 10 shows the trends in the ranking for the Reporting and Statistics tools, comparing the position they occupy in the responses count table (sorting by number of answers for each tool). Request Tracker, Munin and Splunk experience the largest increases.

| Tool | 2016 | 2019 | 2023 | Trend |
|----------------------|------|------|------|-------|
| GRAFANA | 5 | 1 | 1 | 0 |
| REQUEST TRACKER (RT) | 12 | 9 | 2 | 7 |
| CACTI | 1 | 2 | 3 | -1 |
| SPLUNK | 8 | 8 | 4 | 4 |
| MUNIN | 6 | 11 | 5 | 6 |
| NAGIOS | 3 | 4 | 6 | -2 |
| ZABBIX | 13 | 5 | 7 | -2 |
| ARBOR | 7 | 6 | 8 | -2 |
| NFSEN | 4 | 7 | 9 | -2 |
| ZENOSS | 9 | 13 | 10 | 3 |

Table 10. Trends in Reporting and Statistics tools

Chart 14 shows the percentage of users per tool for the Top-10 for Reporting and Statistics.

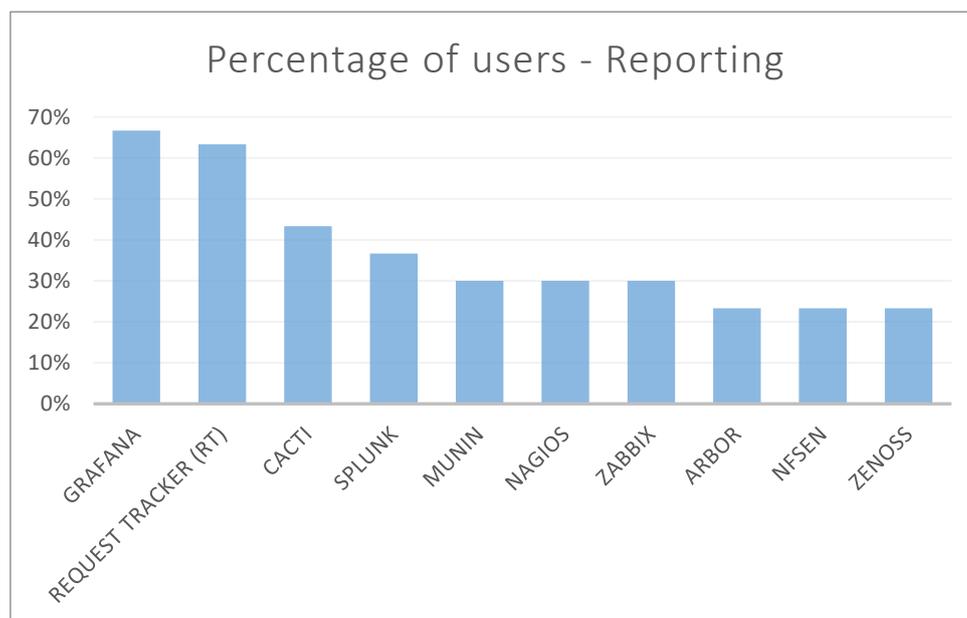


Chart 14. Reporting and Statistics: Percentage of Users per Tool (Top-10)

On average, each institution uses 4.4 tools for Reporting and Statistics, as the information comes from different sources and is represented by several tools.

Table 11 lists other tools used by the community that were not pre-defined in the survey. Icinga was mentioned by two institutions.

| | |
|--------------------------------------|---|
| Other tools: | <ul style="list-style-type: none"> • Icinga (2) • Airwave • Flowmon • OmniVista • ServiceNow • SmokePing |
| In-house developed solutions: | <ul style="list-style-type: none"> • "Capacity Planning Tool" based on Prometheus and RRD files. • Dmon. • SLA reporting tool is in-house and feed from Icinga and SmokePing. • SLA reports are generated by custom made scripts that correlate downtime with services. |

Table 11. Other tools and in-house developed solutions for Reporting and Statistics

4.6. Communication, Coordination and Chat

In previous surveys, Communication, Coordination and Chat were generally mentioned. In this survey, we distinguished between bidirectional and unidirectional tools, as the results may be very different depending on the interaction the institutions have with their customers and partners.

This section includes both software tools and communication methods, like landlines or mobile phones, as they are also considered relevant tools for Communication, Coordination and Chat by the NOCs.

Chart 15 shows bidirectional communication tools, whereas *Chart 16* shows unidirectional communication tools.

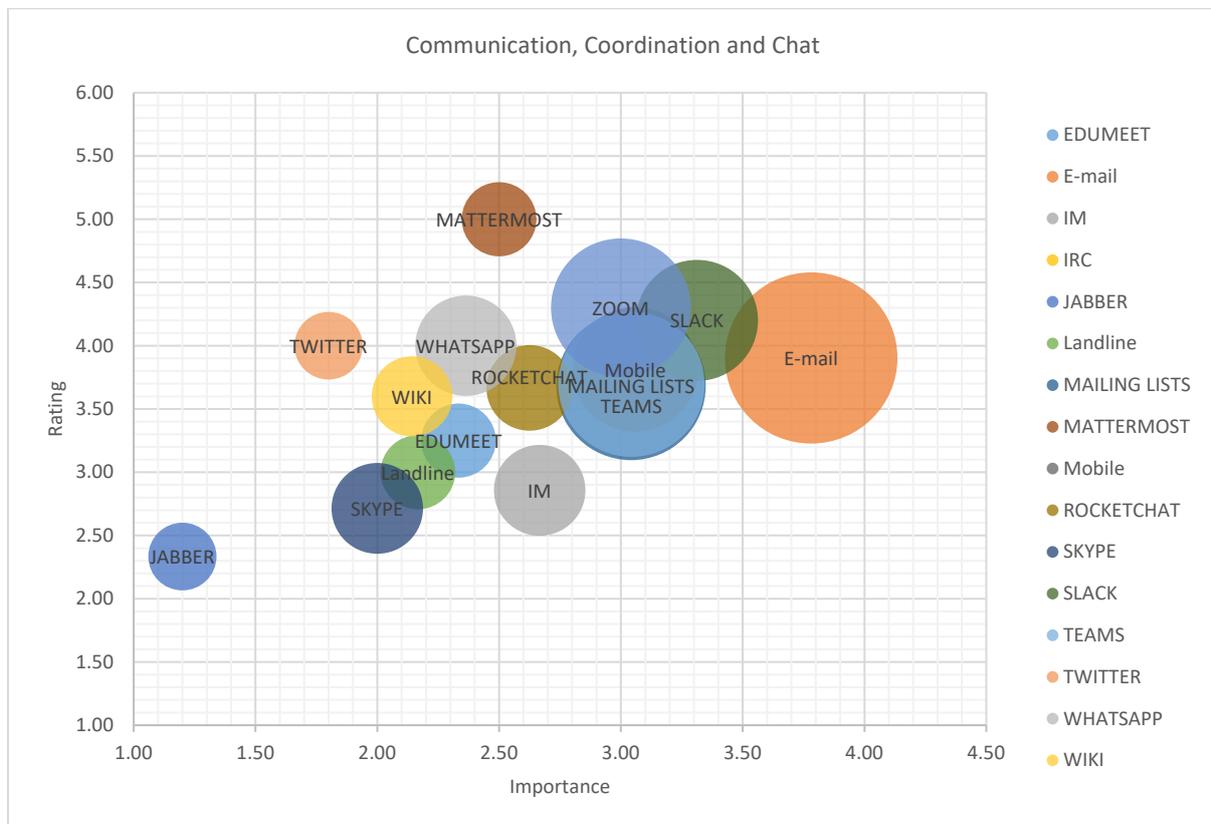


Chart 15. Software tools used for Communication, Coordination and Chat – Bidirectional

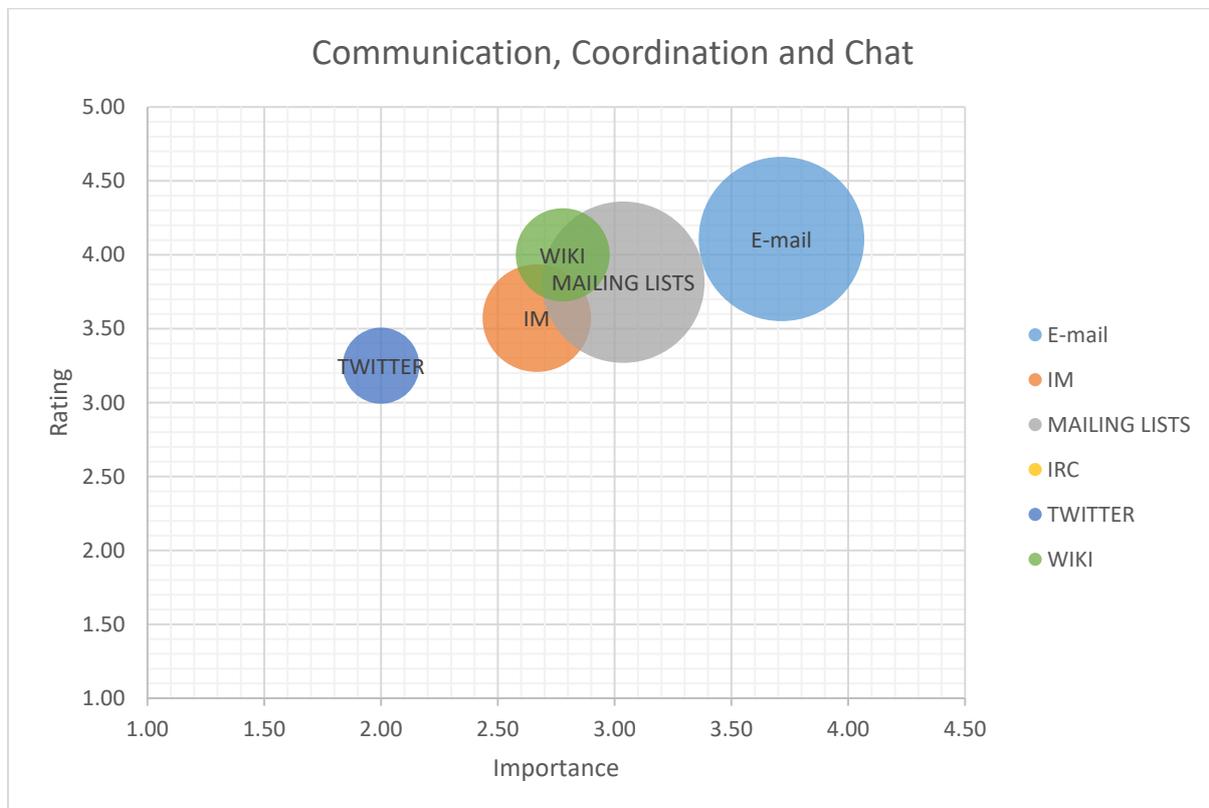


Chart 16. Software tools used for Communication, Coordination and Chat – Unidirectional

The traditional email is still the most used and more important tool for both types of communications, even if it is not ranking highest in terms of quality for bidirectional communications, replaced by other popular and more interactive tools like Slack or Zoom.

Mailing lists are still very relevant for unidirectional communications, although they show a trend to be less relevant for the NOCs for bidirectional communication, replaced in importance but not in number of users by communication channels like Slack, Teams, or Rocket.Chat.

Landlines are also showing a trend to be less used for bidirectional communications, as they disappear from the Top-10 most-used tools. Social networks like Twitter or WhatsApp are among the less important tools for the NOCs, together with Skype or Jabber. Mattermost is considered an excellent tool, but not used by many NOCs and with a medium importance.

Wiki is seen as a good quality unidirectional tool, although it is used by less than a third of the respondents who use email.

Table 12 shows the trends in the number of NOC that use the Top-10 tools for Communication, Coordination and Chat tools and mechanisms (bidirectional), comparing the position they occupy in the responses count table and sorting by number of responses for each tool. Table 13 presents the same for unidirectional tools. The comparison against the 2016 and 2019 results, where there was no distinction between bidirectional and unidirectional tools, may not show the same trends as in the previous survey, as there were bidirectional and unidirectional tools.

| Tool | 2016 | 2019 | 2023 | Trend |
|---------------|------|------|------|-------|
| E-mail | 1 | 1 | 1 | 0 |
| MAILING LISTS | 2 | 2 | 2 | 0 |
| TEAMS | | | 3 | NEW |
| ZOOM | | | 4 | NEW |
| Mobile | 5 | 3 | 5 | -2 |
| SLACK | 12 | 8 | 6 | 2 |
| WHATSAPP | 10 | 7 | 7 | 0 |
| IM | 7 | 11 | 8 | 3 |
| SKYPE | 4 | 6 | 9 | -3 |
| ROCKETCHAT | | | 10 | NEW |

Table 12. Trends in Communication, Coordination and Chat Tools (Bidirectional)

Videoconferencing tools like Zoom, Teams or eduMEET appear for the first time in the responses, although eduMEET does not appear in the Top-10 (it is in 12th position). As well as landlines, mobile phone calls are also decreasing, indicating that institutions and/or the users prefer using asynchronous chat tools instead.

| Tool | 2016 | 2019 | 2023 | Trend |
|---------------|------|------|------|-------|
| E-mail | 1 | 1 | 1 | 0 |
| MAILING LISTS | 2 | 2 | 2 | 0 |
| IM | 7 | 11 | 3 | 8 |
| WIKI | 3 | 5 | 4 | 1 |
| TWITTER | 8 | 10 | 5 | 5 |
| IRC | 11 | 13 | 6 | 7 |

Table 13. Trends in Communication, Coordination and Chat Tools (Unidirectional)

Email and mailing lists are the most popular options for unidirectional Communication, Coordination and Chat.

Chart 17 and Chart 18 show the percentage of users per tool for the Top-10 for Communication, Coordination and Chat tools, both bidirectional and unidirectional. For unidirectional communication, not enough tools are mentioned to have a Top-10, as there are only 5.

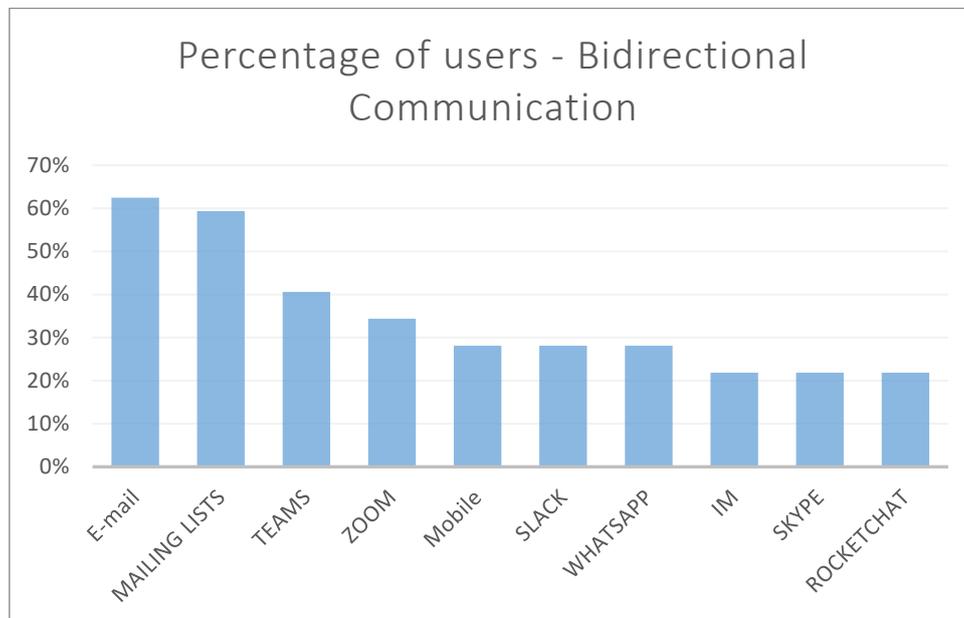


Chart 17. Bidirectional communication: Percentage of Users per Tool (Top-10)

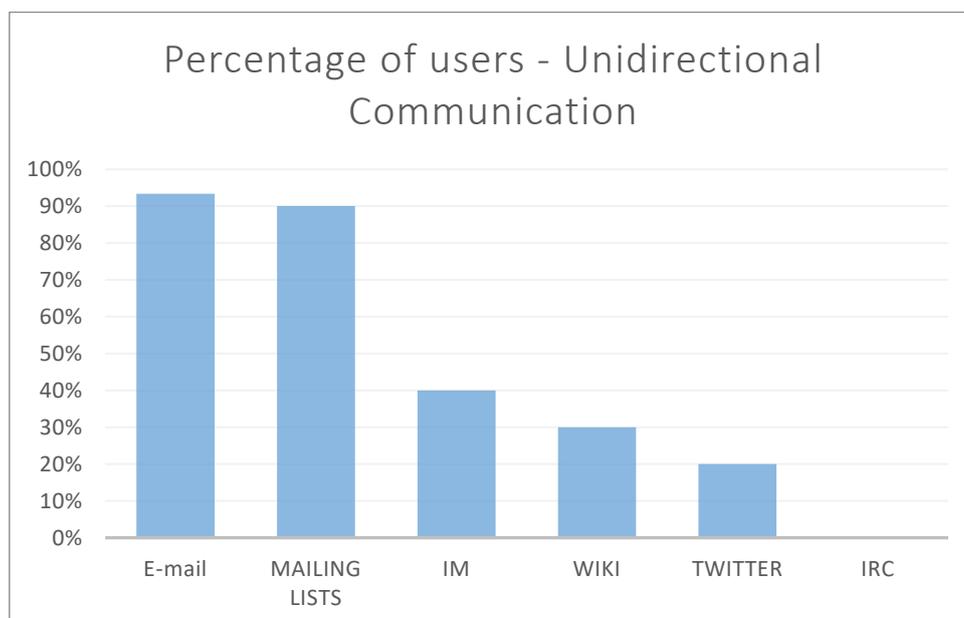


Chart 18. Unidirectional communication: Percentage of Users per Tool (Top-5)

On average, each institution uses 6.4 tools for bidirectional and 2.8 for unidirectional Communication, Coordination and Chat.

Table 14 lists other Communication, Coordination and Chat tools that were not pre-defined in the survey, both for bidirectional and unidirectional communication. Although the mass mailing functionality in ServiceNow is mentioned in the bidirectional question, that would probably fall into the unidirectional communication tools. According to the responses, there are no in-house developed solutions for Bidirectional Communication, Coordination and Chat.

| | |
|--|--|
| Other tools (bidirectional): | <ul style="list-style-type: none"> • ClickUp • Element • Jitsi • Miro • Telegram • We also use mass mailing functionality in ServiceNow, e.g., in the case of warning multiple customers of planned work |
| Other tools (unidirectional) | <ul style="list-style-type: none"> • Element • Public Ticket Systems (via RT) with public webpage • SMS lists |
| In-house developed solutions (unidirectional) | <ul style="list-style-type: none"> • Interfaces for mailing list/email communication of incidents / planned maintenance to affected organisations using inventory information. • Password sender |

Table 14. Other tools for Communication, Coordination and Chat

4.7. Configuration Management and Backup

The survey included questions about six Configuration Management and Backup software tools. The results are shown in *Chart 19*.

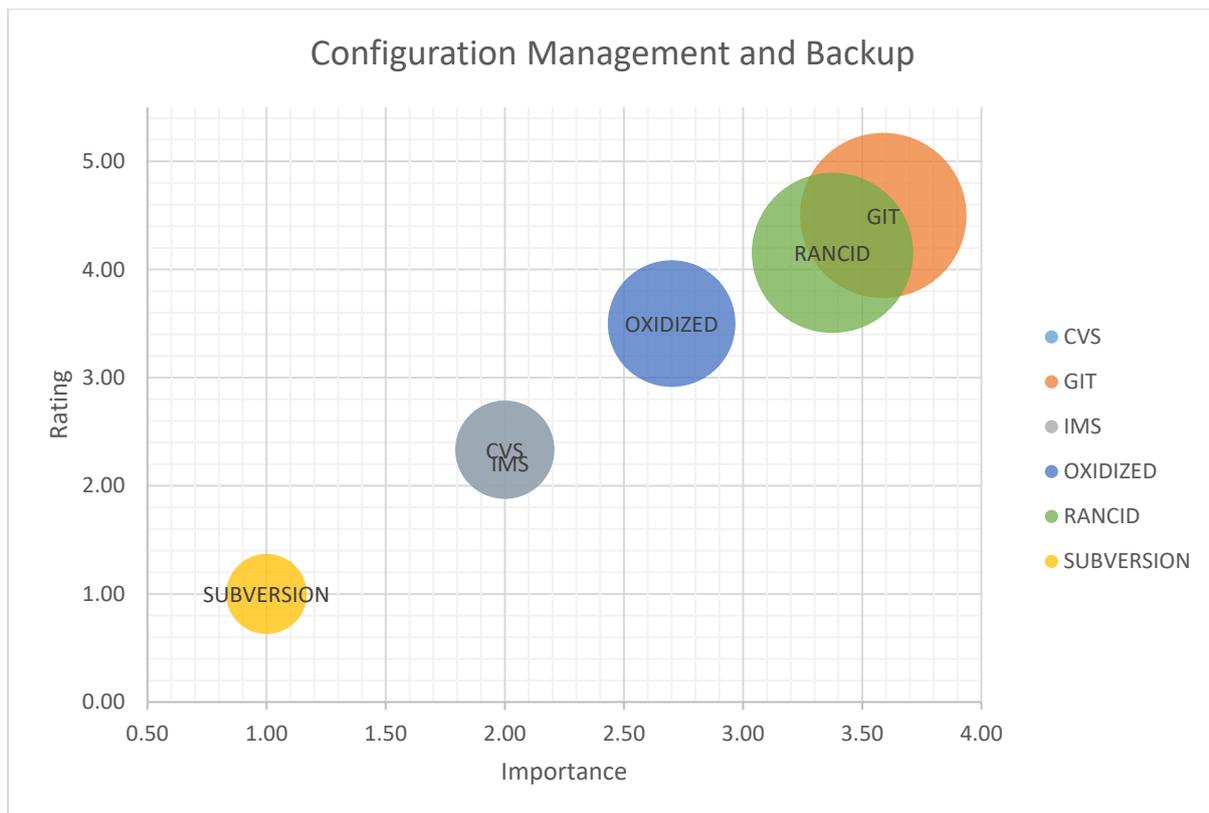


Chart 19. Software tools used for Configuration Management and Backup

Git tools are the most common, important, and best rated Configuration Management and Backup tools. In the 2019 results, Rancid was perceived to be slightly more important than Git, but in 2023 it goes down in importance, with a similar rating for quality. All the other tools are used by less than 50% of the respondents. Oxidized, which was very important but not very popular in 2019, is now used by more respondents, who consider it less important and rate it lower than in 2019. Subversion clearly goes down, not only in importance and rating, but also in number of users.

Table 15 shows the usage trends of the different Configuration Management and Backup tools, comparing the position they occupy in the responses count table (sorting by number of responses for each tool).

| Tool | 2016 | 2019 | 2023 | Trend |
|------------|------|------|------|-------|
| GIT | 2 | 2 | 1 | ▲ 1 |
| RANCID | 1 | 1 | 2 | ▼ -1 |
| OXIDIZED | 6 | 5 | 3 | ▲ 2 |
| CVS | 4 | 3 | 4 | ▼ -1 |
| IMS | 5 | 6 | 5 | ▲ 1 |
| SUBVERSION | 3 | 4 | 6 | ▼ -2 |

Table 15. Trends in Configuration Management and Backup Tools

There are no significant changes in the most popular tools, although Git and Rancid have switched positions. Chart 20 below show the percentage of users per tool for the Top-6 for Configuration Management and Backup.

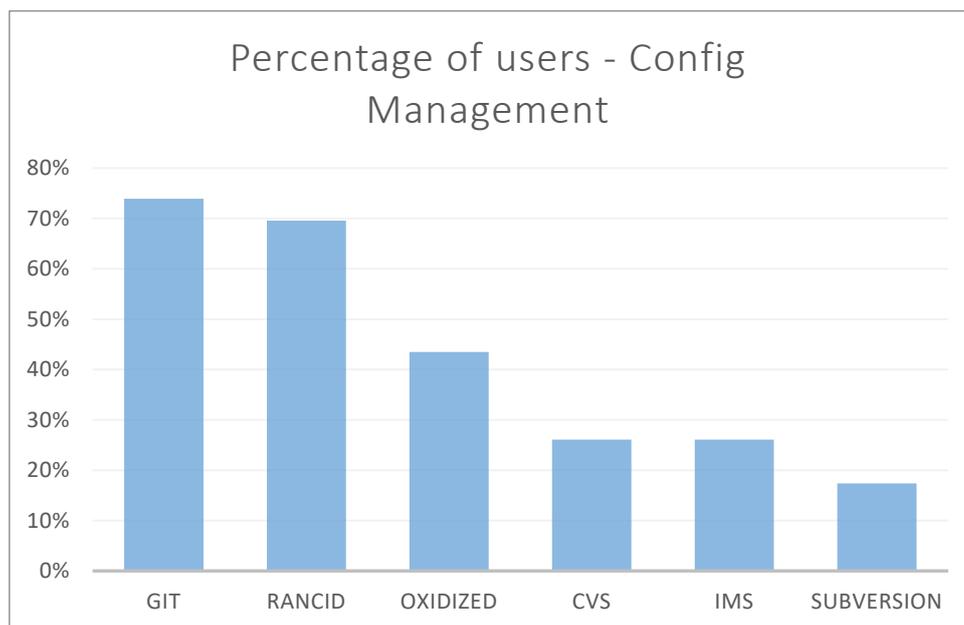


Chart 20. Configuration Management and Backup: Percentage of Users per Tool (Top-6)

On average, each institution uses 2.3 tools for Configuration Management and Backup.

Table 16 lists other tools used by the community which were not pre-defined in the survey. They are mostly vendor-specific software tools for the “Other tools” category, or references to manual intervention, or the usage of ad-hoc scripts for the “In-house developed solutions” category. Compared to the 2019 survey, there are fewer references to scripts, which may indicate that they have been integrated in Git tools like GitLab.

| | |
|--------------------------------------|--|
| Other tools: | <ul style="list-style-type: none"> • Ciena MCP for L1 node backup • Cisco Prime • Juniper Mist • Junos Space • OmniVista • RCS • Vendor NMS |
| In-house developed solutions: | <ul style="list-style-type: none"> • CVSWEB • Custom build scripts • No tools used. Manual. • Plain copy configs • Scripts |

Table 16. Other tools and in-house developed solutions for Configuration Management and Backup

4.8. Performance Management

Chart 21 shows the software tools that NOCs use to identify the source of performance problems in the network (Performance Management).

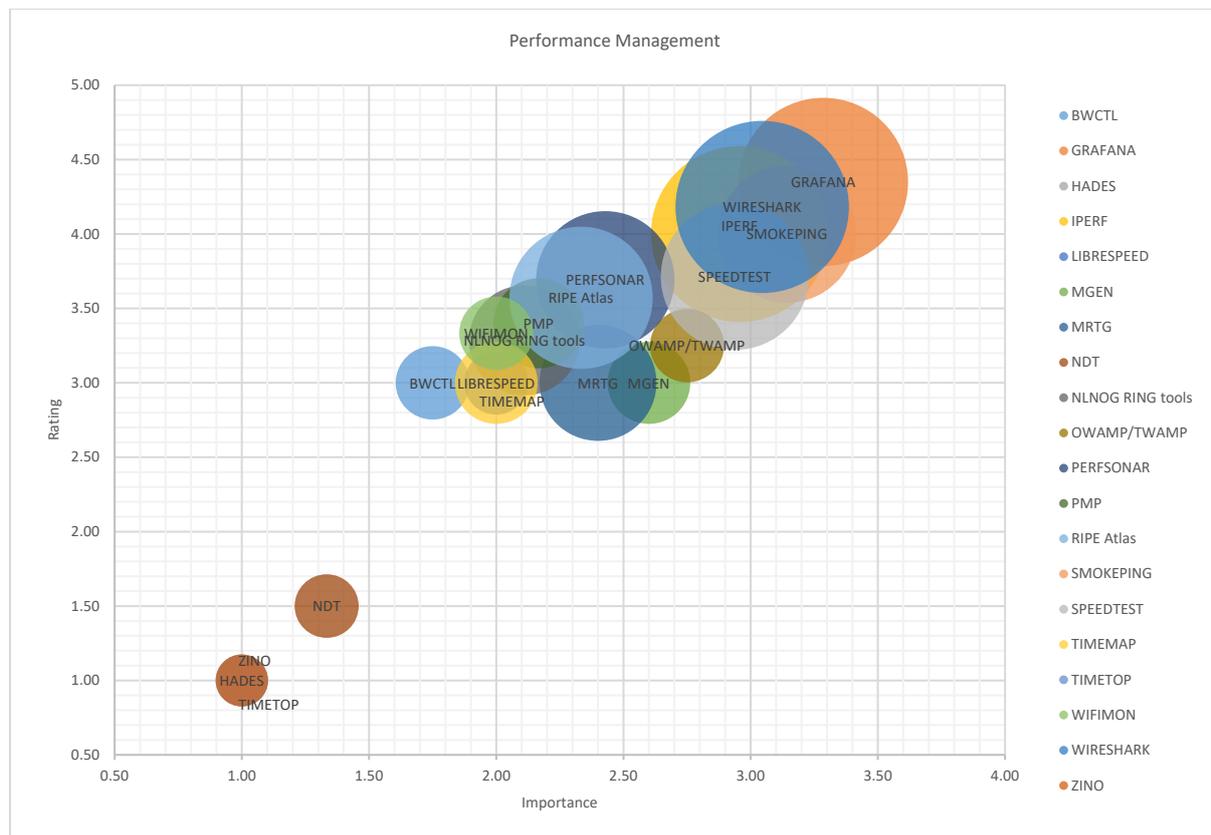


Chart 21. Software tools used for Performance Management

Performance Management tools are in general highly valued by NOCs, although the graph in 2023 is different to the one in 2019, where all the tools were in the right upper corner of it. This time there is more dispersion, and some tools have lower importance and rating for the respondents. IPerf is still the most commonly used tool, but the rating is higher for Grafana (which appears in the graph for the first time), and Wireshark. SmokePing gets the same rating as IPerf, and it is more important, but for fewer users. After SmokePing, Speedtest and perfSONAR appear next in the ranking. RIPE Atlas and Speedtest have high ratings and a similar number of users. MRTG seems to be more relevant for Monitoring than for Performance Management.

Table 17 shows the trends in the number of NOCs that use the Top-10 software tools for Performance Management, comparing the position they occupy in the responses count table (sorting by number of responses for each tool). This table shows more changes between 2019 and 2023 than between 2016 and 2019, where they were quite similar. Although the two most popular tools are still the same, new tools appear in the table and some of them clearly go down in terms of number of users. For instance, MGEN, NDT or BWCTL disappear from the Top-10.

| Tool | 2016 | 2019 | 2023 | Trend |
|------------------|------|------|------|-------|
| IPERF | 1 | 1 | 1 | 0 |
| WIRESHARK | 2 | 2 | 2 | 0 |
| GRAFANA | | | 3 | NEW |
| SPEEDTEST | | | 4 | NEW |
| RIPE Atlas | 6 | 6 | 5 | 1 |
| PERFSONAR | 4 | 4 | 6 | -2 |
| SMOKEPING | 5 | 5 | 7 | -2 |
| MRTG | 3 | 3 | 8 | -5 |
| NLNOG RING tools | 9 | 9 | 9 | 0 |
| PMP | | | 10 | NEW |

Table 17. Trends in Performance Management Tools

Chart 22 shows the percentage of users per tool for the Top-10 for Performance Management.

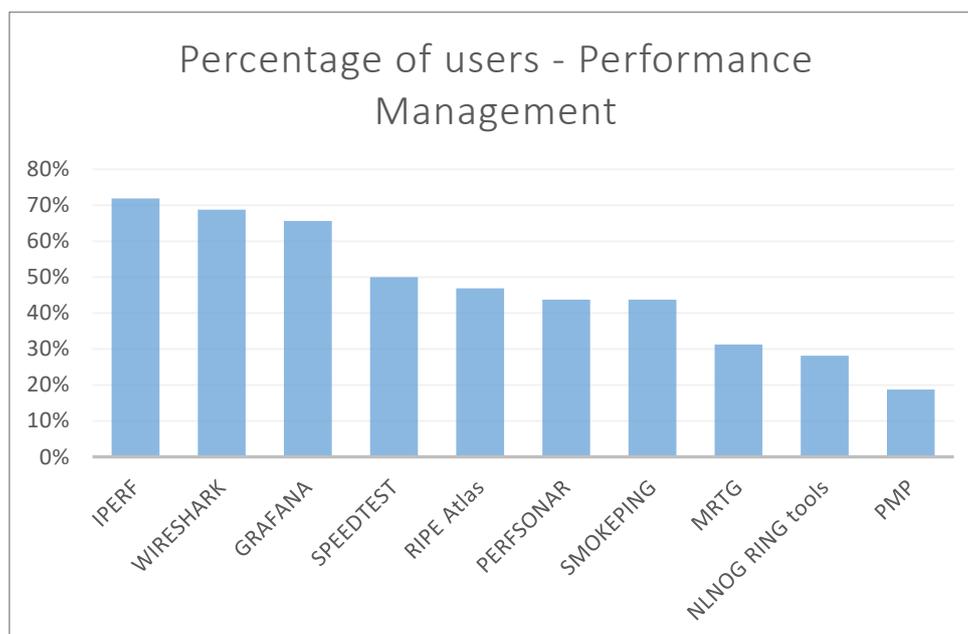


Chart 22. Performance Management: Percentage of Users per Tool (Top-10)

On average, each institution uses 5.7 tools for Performance Management, which is normal because not all of them are used for the same purpose.

Table 18 lists other tools used by the community that were not pre-defined in the survey. No in-house tools are mentioned, and the number of other tools has decreased compared to the 2019 results.

| | |
|---------------------|---|
| Other tools: | <ul style="list-style-type: none"> • Cisco Prime • Juniper Mist • Zabbix |
|---------------------|---|

Table 18. Other tools for Performance Management

4.9. Inventory Management

The survey included questions about eight Inventory Management tools. The results are shown in Chart 23.

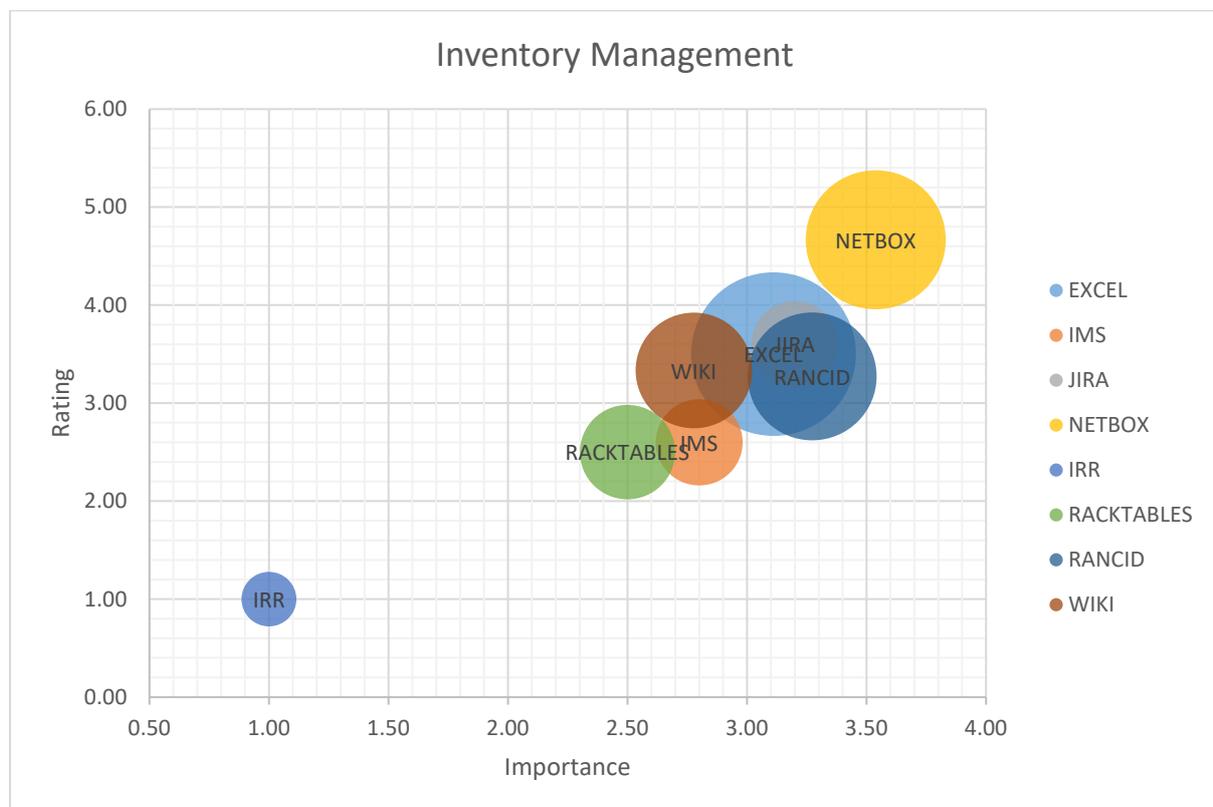


Chart 23. Software tools used for Inventory Management

Despite the existence of other specific tools, Microsoft Excel is still the most popular tool for Inventory Management, and one of the highest rated after NetBox, Wiki, and Jira. However, NetBox appears in the graph for the first time, and it is the highest rated both in terms of quality and importance. Jira also appears for the first time, with a few users who consider it slightly less important than Rancid. RackTables has a medium importance and rating and is used by a third of the users compared to Excel.

Table 19 shows the trends in the number of NOCs that use the software tools for Inventory Management, comparing the position they occupy in the responses count table (sorting by number of responses for each tool). Excel is still the most popular, but there are no significant changes in the table.

| Tool | 2016 | 2019 | 2023 | Trend |
|------------|------|------|------|-------|
| EXCEL | 1 | 1 | 1 | 0 |
| NETBOX | | | 2 | NEW |
| RANCID | 2 | 3 | 3 | 0 |
| WIKI | 3 | 2 | 4 | -2 |
| RACKTABLES | 6 | 4 | 5 | -1 |
| IMS | 4 | 5 | 6 | -1 |
| JIRA | | | 7 | NEW |
| IRR | | 6 | 8 | -2 |

Table 19. Trends in Inventory Management Tools

Chart 24 shows the percentage of users per tool for the Top-8 for Inventory Management.

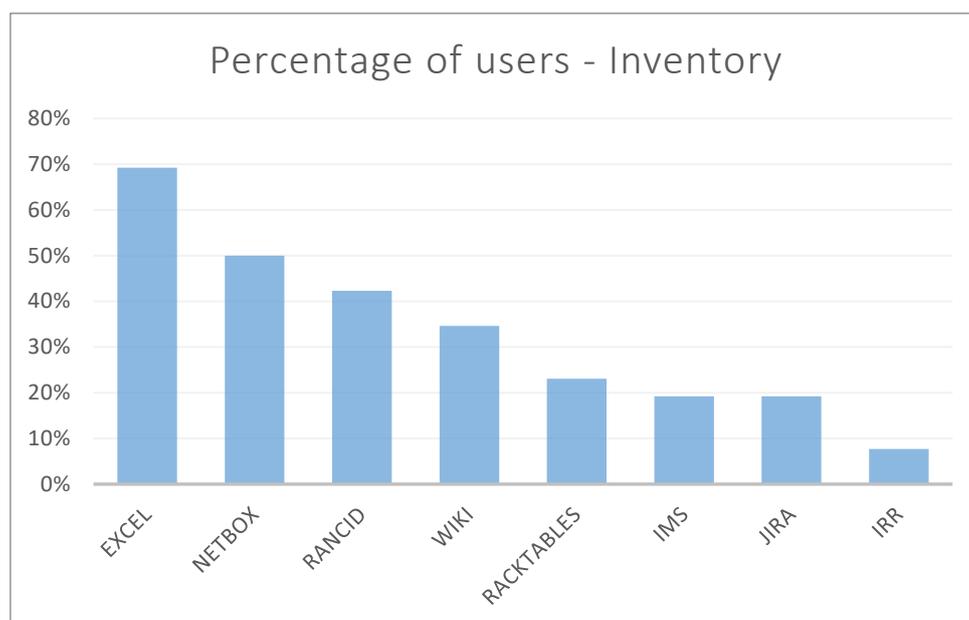


Chart 24. Inventory Management: Percentage of Users per Tool (Top-8)

On average, each institution uses 2.6 tools for Inventory Management.

Table 20 lists other tools that are not pre-defined in the survey. GLPI is mentioned more than once. The table also shows that there is a variety of commercial and in-house developed solutions for Inventory Management.

| | |
|--------------------------------------|--|
| Other tools: | <ul style="list-style-type: none"> • GLPI (2) • Ciena MCPfor optical and L2 kit • EfficientIP • FastGIS (for fibre infrastructure management) • FileMaker • Infoblox IPAM • Nautobot • Netdisco • OmniVista • OTRS • ProactivaNet |
| In-house developed solutions: | <ul style="list-style-type: none"> • Ancient custom scripts based on Perl • AssetDB • BDCOM • ClientDB • NI: Network Inventory • We have some custom scripts that display both our live inventory as our inventory in the stock. |

Table 20. Other tools and in-house developed solutions for Inventory Management

4.10. Resources Management

Chart 25 shows the software tools that NOCs use for Resources Management.

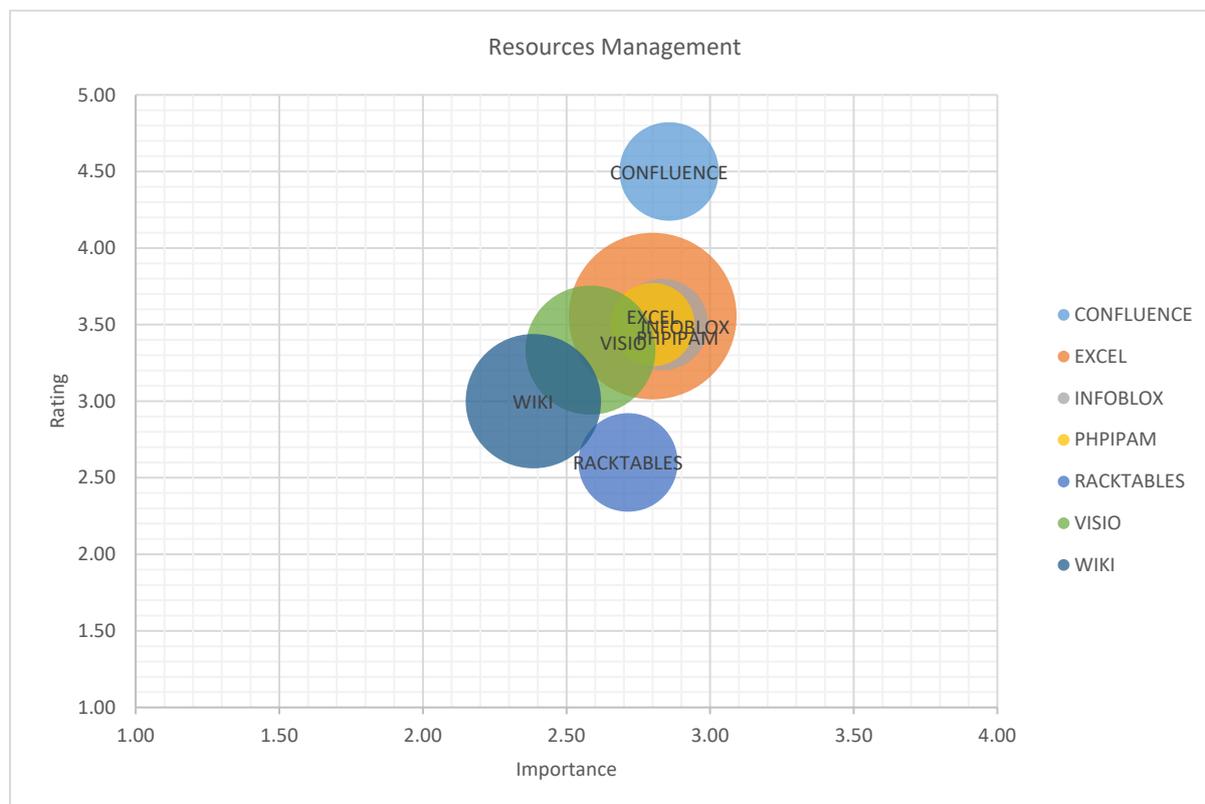


Chart 25. Software tools used for Resources Management

All the bubbles in the graphs are located in the central part of it, with different ratings but a very similar level of importance. This means there are no critical tools for Resources Management. As in the case of Inventory Management, Microsoft Excel is by far the most popular tool, although Confluence is much higher rated, with fewer than half the users, and both Confluence and Infoblox are considered more important than Excel for the respondents. Other tools like Visio, Wiki or RackTables have a lower rating.

Table 21 shows the trends in the number of NOCs that use the tools for Resources Management, comparing the position they occupy in the responses count table (sorting by number of responses for each tool). NetBox and phpIPAM appear for the first time in the survey, and Visio continues going down in the ranking, but this table has no significant changes compared to the previous ones.

| Tool | 2016 | 2019 | 2023 | Trend |
|------------|------|------|------|-------|
| EXCEL | 2 | 1 | 1 | 0 |
| WIKI | 3 | 3 | 2 | 1 |
| VISIO | 1 | 2 | 3 | -1 |
| CONFLUENCE | 5 | 4 | 4 | 0 |
| RACKTABLES | 4 | 5 | 5 | 0 |
| INFOBLOX | 9 | 6 | 6 | 0 |
| PHPIPAM | | | 7 | NEW |
| NETBOX | | | 8 | NEW |

Table 21. Trends in Resources Management Tools

Chart 26 shows the percentage of users per tool for the Top-8 for Resources Management.

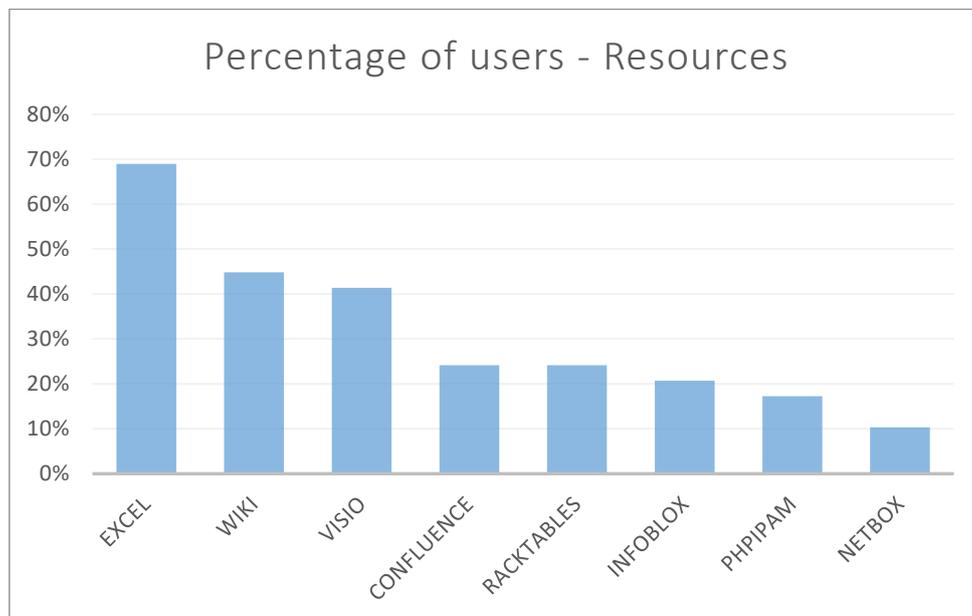


Chart 26. Resources Management: Percentage of Users per Tool (Top-8)

On average, each institution uses 2.4 tools for Resources Management.

Table 22 lists other tools and in-house developed solutions that were not pre-defined in the survey. NETBOX, which appeared in the survey for the first time for Inventory Management, is mentioned four times for Resources Management too.

| | |
|--------------------------------------|--|
| Other tools: | <ul style="list-style-type: none"> • NETBOX (4) • 6CONNECT • EfficientIP • GLPI • MSIPAM • Nautobot • NIPAP • ProVision |
| In-house developed solutions: | <ul style="list-style-type: none"> • BDCOM • GIS (G* Information System) • In-house developed IPAM • IP address/Switchport management tool • Perl based custom development • Rotproofing (IP-addresses in use) |

Table 22. Other tools and in-house developed solutions for Resources Management

4.11. Out-of-Band Access

Chart 27 shows the software tools and methodologies that NOCs use for Out-of-Band Access.

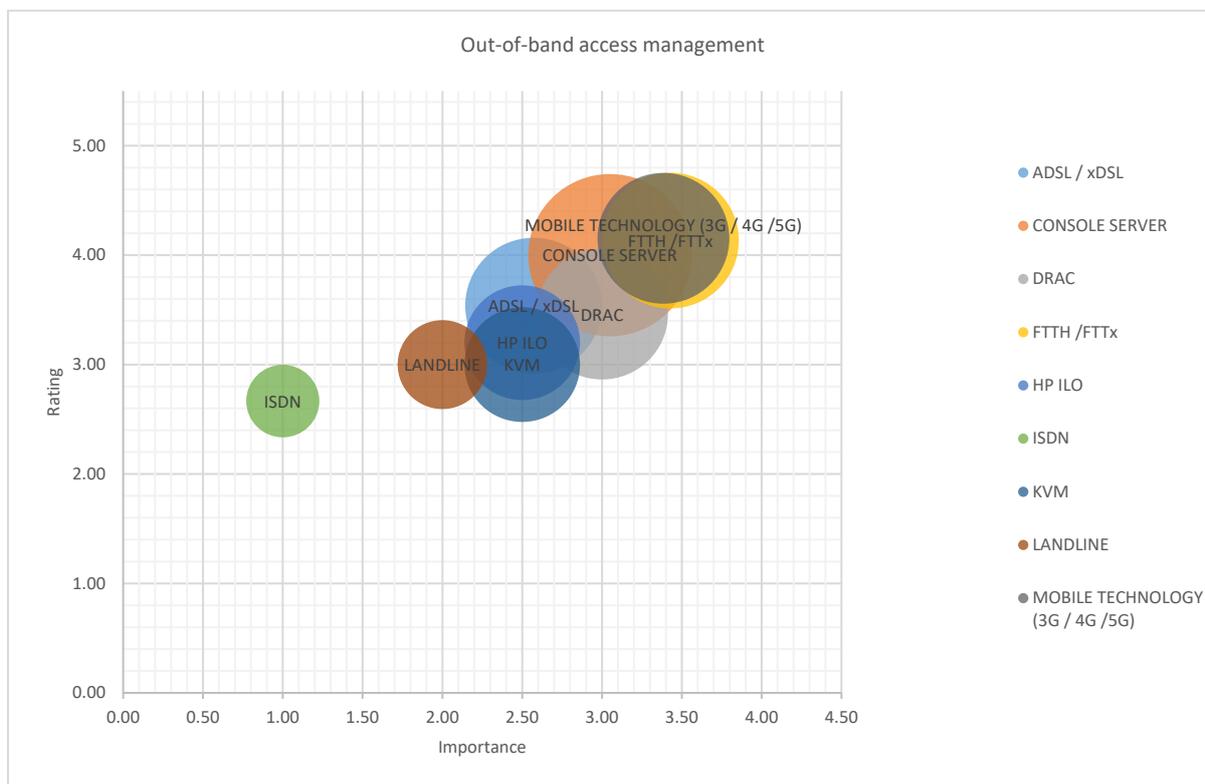


Chart 27. Software tools and methodologies used for Out-of-Band Access

Most of the tools and technologies for Out-of-Band Access are located in the central horizontal part of the graph, with no excellent or very bad ratings, and with various levels of importance. The best rated technologies for out-of-band access are Mobile technologies like 3G, 4G or 5G, followed by FTTH/FTTx, and Console servers. In terms of importance, mobile technologies are again the most relevant, followed by console servers and DRACs.

Last year, the section about Out-of-Band Access did not contain any questions about the tools, as they were mostly hardware-based tools. However, NOCs considered it relevant to have information about how many NOCs felt responsible for this function. 75% of the NOCs that answered the question in 2019 considered they were responsible for Out-of-Band Access management and the question was

included in the 2023 survey, but the comparison in this case is between the 2016 and the 2023 results (no results for 2019).

Table 23 shows the trends in the number of NOCs that use the tools for Out-of-Band Access, comparing the position they occupy in the responses count table (sorting by number of responses for each tool).

| Tool | 2016 | 2023 | Trend |
|---------------------------------|------|------|-------|
| CONSOLE SERVER | 1 | 1 | 0 |
| ADSL / xDSL | 2 | 2 | 0 |
| FTTH /FTTx | | 3 | NEW |
| DRAC | 3 | 4 | -1 |
| MOBILE TECHNOLOGY (3G / 4G /5G) | 7 | 5 | 2 |
| HP ILO | 4 | 6 | -2 |
| KVM | 6 | 7 | -1 |
| LANDLINE | 5 | 8 | -3 |
| ISDN | | 9 | NEW |

Table 23. Trends in Out-of-Band Tools and Methodologies

Interestingly, the first and second most popular methodologies to access equipment remotely are the same as in 2016, and ISDN, not really a new technology, appears in the table for the first time. Landlines are decreasingly used.

Chart 28 shows the percentage of users per tool for the Top-9 for Out-of-Band Access.

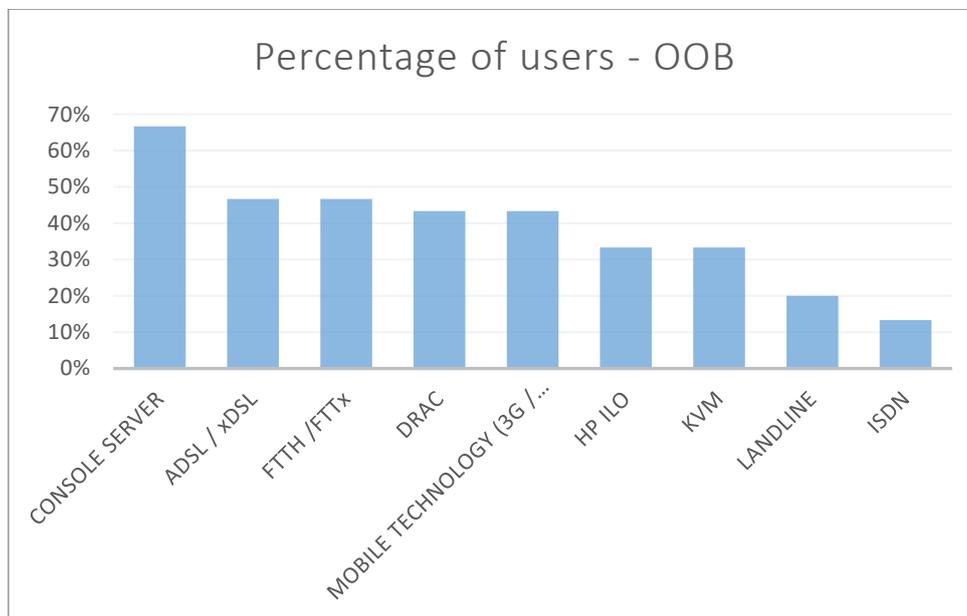


Chart 28. Out-of-Band Access: Percentage of Users per Tool (Top-9)

On average, each institution uses 3.4 tools for Out-of-Band Access management.

Table 24 lists other tools and in-house developed solutions that were not pre-defined in the survey. No in-house tools were specified in the responses.

| | |
|---------------------|---|
| Other tools: | <ul style="list-style-type: none"> • Dedicated DCN of DWDM equipment. • Some leased circuits are used for Out-of-Band (OOB) management, with other channels on the same circuit used for traffic. |
|---------------------|---|

Table 24. Other tools and in-house developed solutions for Out-of-Band Access

4.12. Change Management

The survey included questions about six Change Management software tools. The results are shown in *Chart 29*.

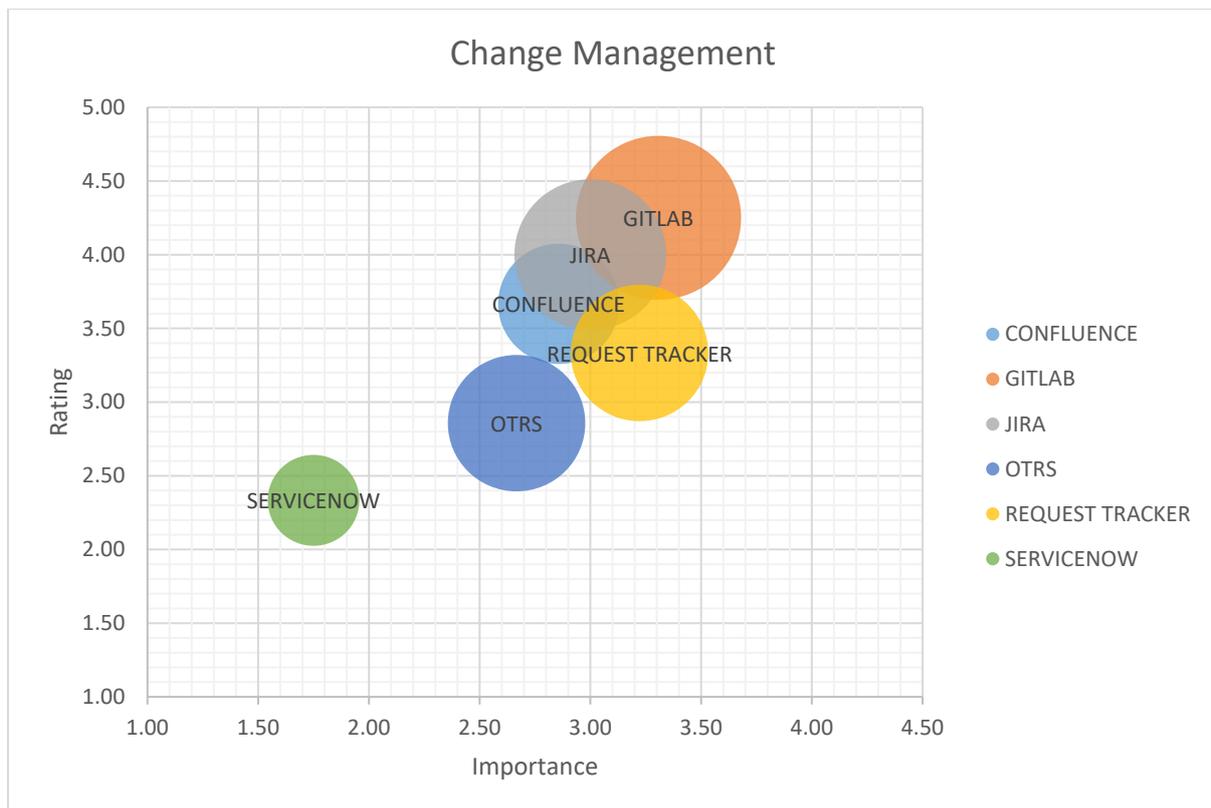


Chart 29. Software tools used for Change Management

GitLab is the most important Change Management tool for the NOCs. It is used by more than 50% of the respondents and it is the highest rated. Jira has a similar level of adoption and is the second in rating, but the third in importance. Request Tracker is the third highest valued tool, and the fourth one in importance. Other tools have a lower level of adoption, importance, and rating.

Table 25 shows the trends in the number of NOC that use Change Management tools, comparing the position they occupy in the responses count table (sorting by number of responses for each tool). GitLab is in the first position and ServiceNow appears for the first time in the table, with a low number of users. The number of Jira and Confluence users has gone down.

| Tool | 2016 | 2019 | 2023 | Trend |
|-----------------|------|------|------|-------|
| GITLAB | 5 | 2 | 1 | ▲ 1 |
| JIRA | 3 | 1 | 2 | ▼ -1 |
| OTRS | 2 | 4 | 3 | ▲ 1 |
| REQUEST TRACKER | 1 | 5 | 4 | ▲ 1 |
| CONFLUENCE | 4 | 3 | 5 | ▼ -2 |
| SERVICENOW | | | 6 | NEW |

Table 25. Trends in Change Management Tools

Chart 30 shows the percentage of users per tool for the Top-6 for Change Management.

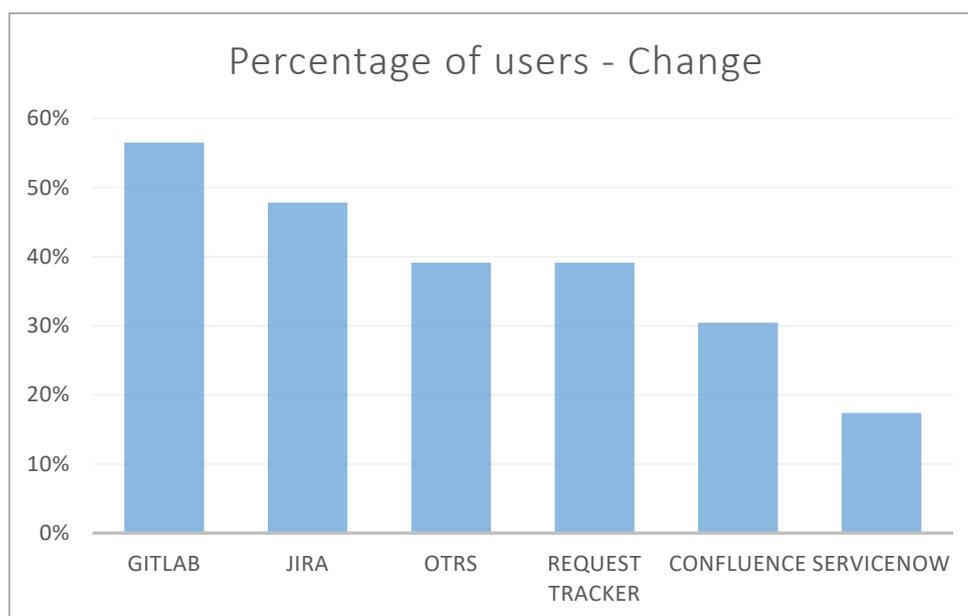


Chart 30. Change Management: Percentage of Users per Tool (Top-6)

On average, each institution uses 2 tools for Change management.

Table 26 lists other tools and in-house developed solutions that were not pre-defined in the Change Management survey.

| | |
|--------------------------------------|--|
| Other tools: | <ul style="list-style-type: none"> • GLPI • MS Forms • Omnivista • ProactivaNet • Rancid • RemedyForce • Wiki • Youtrack |
| In-house developed solutions: | <ul style="list-style-type: none"> • In-house Tracker |

Table 26. Other tools and in-house developed solutions for Change Management

4.13. Training

This function was included for the first time in the 2023 survey, although there was an open question about training in the standards section. For this survey, no specific tools were mentioned, but the first question was about the types of training, followed by open questions about the tools and the portals used for training. The results regarding the types of training are shown in Chart 31.

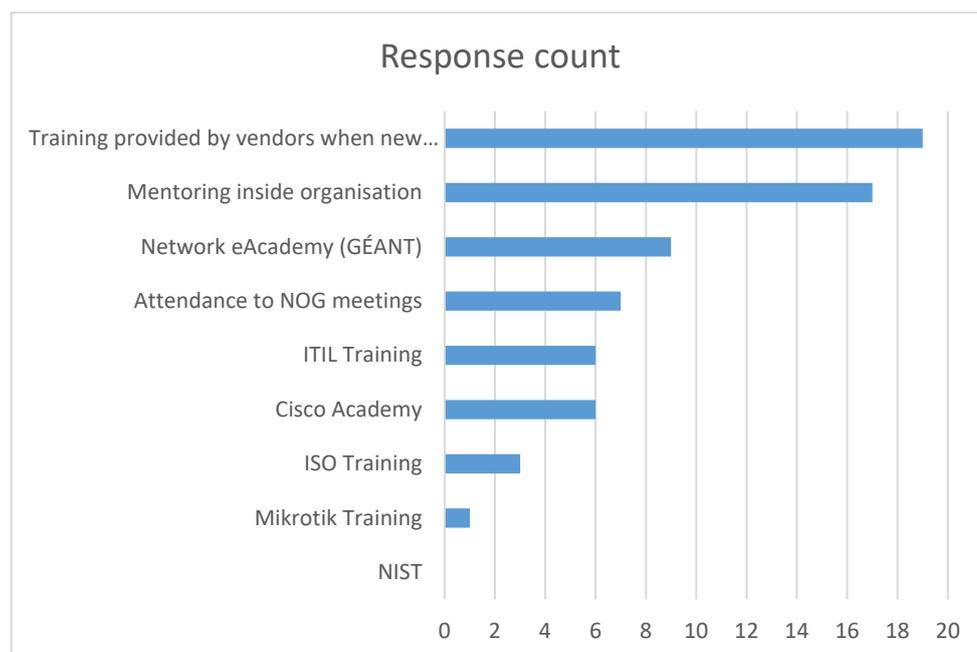


Chart 31. Types of Training

The most popular type of training in the NOCs is that provided by vendors when new equipment or software is deployed, followed by mentoring inside the organisation, the usage of GÉANT’s Network eAcademy, and the attendance of Network Operators Group (NOG) Meetings. Other trainings offered by accreditation companies like ITIL, Cisco training, ISO, or Mikrotik Training are used by fewer respondents.

Table 27 shows other answers not specified in the graph above but provided by the respondents in open boxes. In some cases, these trainings are offered by internet exchanges or training providers.

| | | |
|------------------------|--|--|
| Other trainings | <ul style="list-style-type: none"> • BGP Tutorials • INEX lead/sponsored training • DE-CIX webinars • Internal Learning platform EOLAS | <ul style="list-style-type: none"> • Juniper All Access Pass • RIPE certification • Udemy |
|------------------------|--|--|

Table 27. Other Trainings and Training Tools

Table 28 contains the list of tools mentioned by the respondents in open boxes as the ones they use for training. In the first row we asked about software tools (although not all the answers describe software tools) and, in the second row, about online training portals:

| | | |
|---|---|--|
| Tools used for training: | <ul style="list-style-type: none"> • Coffee - lots • EOLAS • EVE-NG • GÉANT e-academy • GITLAB • Hands on experience • Internal training • JIRA • Miro | <ul style="list-style-type: none"> • Moodle NOC Tools • PowerPoint • Teams • Udemy • VISUAL STUDIO CODE • Webinars • Wiki • Zoom |
| Training Portals used for Training | <ul style="list-style-type: none"> • Angeles • Axelos • GÉANT e-academy • Infinera • Infoblox • LinkedIn Learning | <ul style="list-style-type: none"> • Moodle • Nokia • OpenWebinars • TM Forum • Udemy • Vendor portals |

Table 28. Software and Online Training Tools

4.14. Security Management

Compared to the 2016 survey, the percentage of NOCs who feel responsible for Security Management decreased from 63% to 45% (if we considered only the respondents who answered “Yes” or “No” the percentage would decrease from 77% to 66%).

Chart 32 shows the software tools that NOCs use for Security Management.

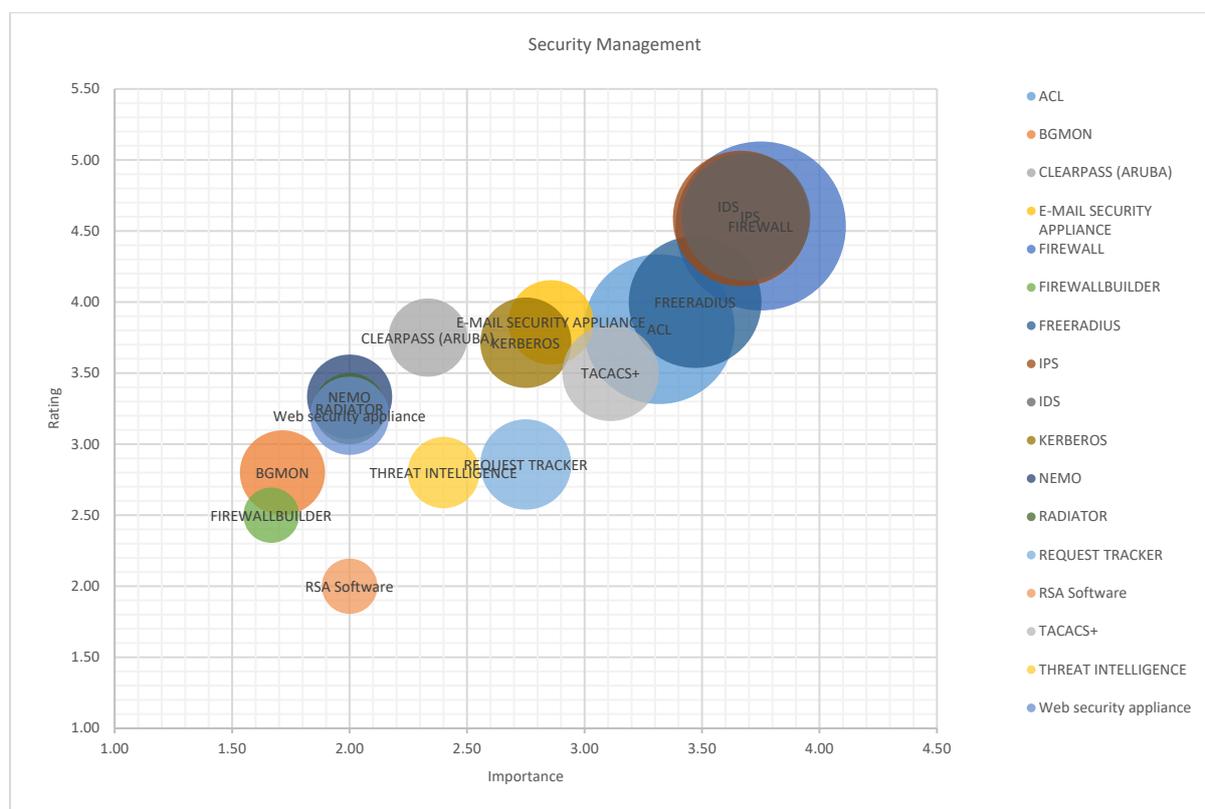


Chart 32. Tools used for Security Management

This chart shows more dispersion than the graph from 2019, where most of the tools were in the right upper corner. Firewall and ACLs are still the most commonly used to handle security issues by the NOCs (Firewalls are used by 97% of the respondents and ACLs by 80%) but, in terms of importance, IDS and IPS are on top of the ranking. Firewall, IDS and IPS are also the most important tools for them, and FreeRadius is in fourth place both for importance and for rating. Some other tools are less used and less relevant for the NOCs.

Table 29 shows the usage trends of the Security Management tools, comparing the position they occupy in the responses count table (sorting by number of responses for each tool). There are no significant changes in the first five positions of the table, and Request Tracker goes up six positions compared to 2019, but it is still below the position in 2016. Nemo is included, although it is in 11th position, because it is used by the same number of users as the email Security Appliance in the 10th position and BGMON, in the 9th position.

| Tool | 2016 | 2019 | 2023 | Trend |
|---------------------------|------|------|------|-------|
| FIREWALL | 1 | 1 | 1 | 0 |
| ACL | 2 | 2 | 2 | 0 |
| IPS | | 4 | 3 | 1 |
| FREERADIUS | 3 | 3 | 4 | -1 |
| IDS | | 5 | 5 | 0 |
| TACACS+ | 5 | 7 | 6 | 1 |
| KERBEROS | 8 | 11 | 7 | 4 |
| REQUEST TRACKER | 4 | 14 | 8 | 6 |
| BGMON | 6 | 8 | 9 | -1 |
| E-MAIL SECURITY APPLIANCE | | 6 | 10 | -4 |
| NEMO | | | 11 | NEW |

Table 29. Trends in Security Management Tools

Chart 33 shows the percentage of users per tool for the Top-10/11 for Security Management.

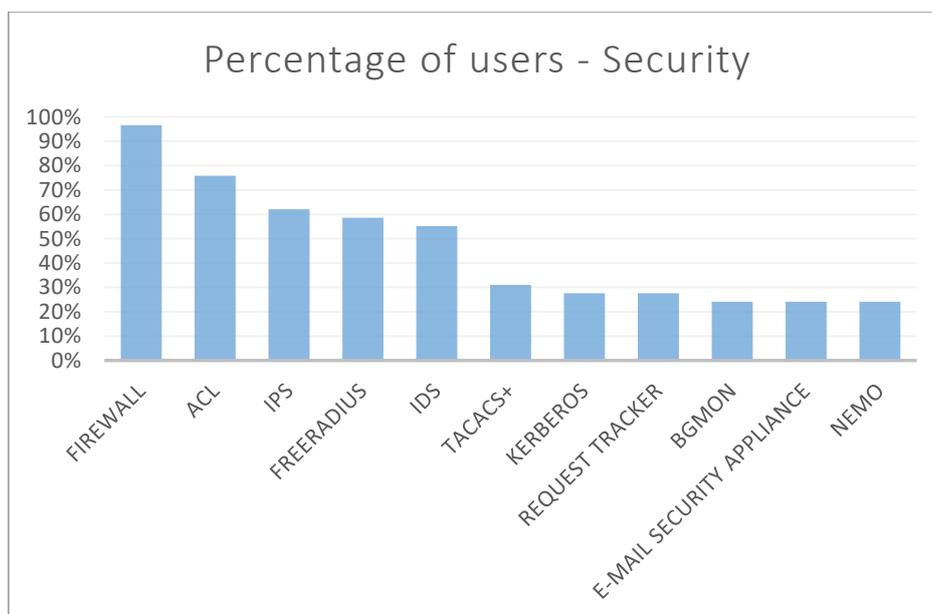


Chart 33. Security Management: Percentage of Users per Tool (Top-10/11)

On average, each institution uses 6 tools for Security Management.

Table 30 lists other tools used by the community that were not pre-defined in the survey. As in 2019, there are no in-house developments for Security Management.

| | |
|---------------------|--|
| Other tools: | <ul style="list-style-type: none"> • QRadar • Microsoft Defender |
|---------------------|--|

Table 30. Other tools for Security Management

4.15. Data Aggregation, Representation and Visualisation

NOCs were asked about the tools they use to aggregate live data from various tools and visualise them in a human readable way. The results are shown in Chart 34.

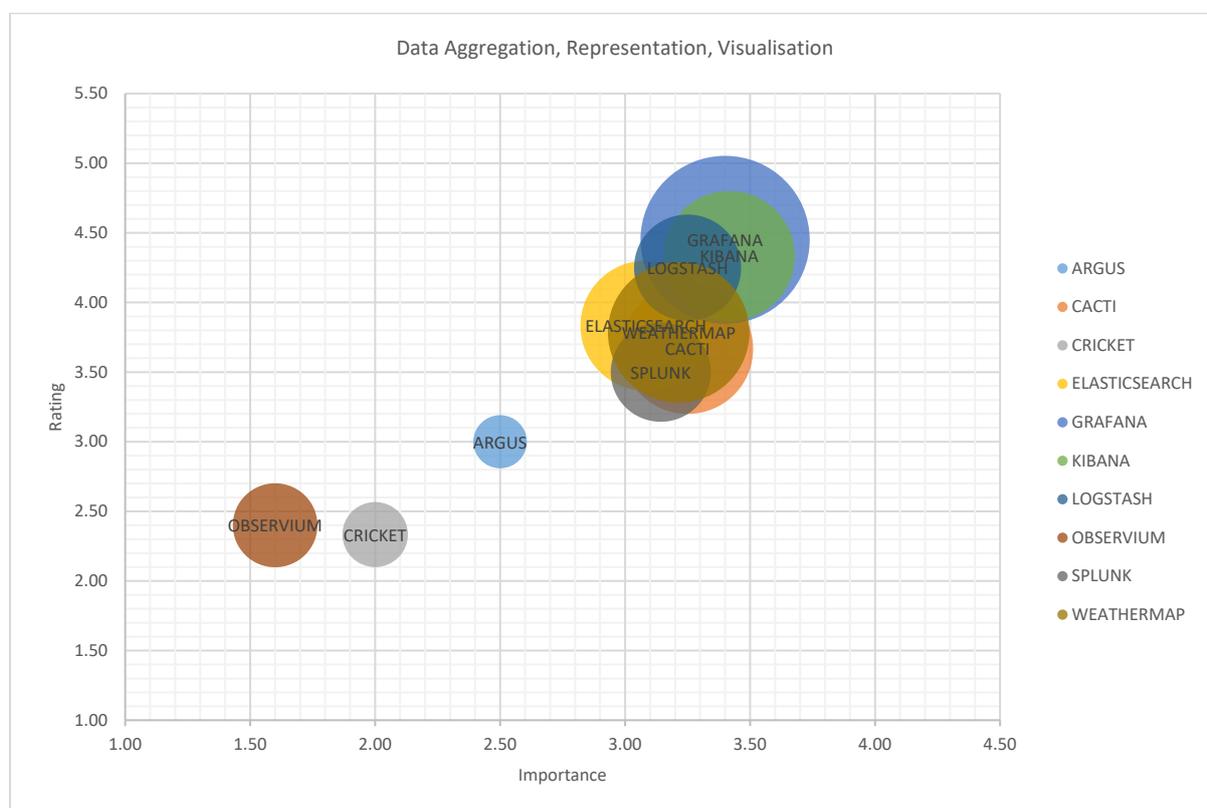


Chart 34. Software tools used for Data Aggregation, Representation and Visualisation

As for Monitoring or Performance Management, Grafana stands out in the first position in number of users and rating, although Kibana is slightly more important than Grafana on average, but with nearly half the users that Grafana has (the same number of users as ElstiSearch and Cacti). Logstash is the third tool both in importance and rating.

Table 31 shows the usage trends of the Data Aggregation, Representation and Visualisation tools, comparing the position they occupy in the responses count table (sorting by number of responses for

each tool). The tools that were already in the table do not suffer important changes in the ranking, but three new tools appear, with not many users: Observium, Cricket, and Argus.

| Tool | 2016 | 2019 | 2023 | Trend |
|---------------|------|------|------|-------|
| GRAFANA | | 1 | 1 | 0 |
| WEATHERMAP | 2 | 2 | 2 | 0 |
| KIBANA | 5 | 5 | 3 | 2 |
| ELASTICSEARCH | 3 | 4 | 4 | 0 |
| CACTI | 1 | 3 | 5 | -2 |
| LOGSTASH | 4 | 6 | 6 | 0 |
| SPLUNK | 6 | 7 | 7 | 0 |
| OBSERVIUM | | | 8 | NEW |
| CRICKET | | | 9 | NEW |
| ARGUS | | | 10 | NEW |

Table 31. Trends in Data Aggregation, Representation and Visualisation Tools

Chart 35 shows the percentage of users per tool for the Top-10 of Data Aggregation, Representation and Visualisation.

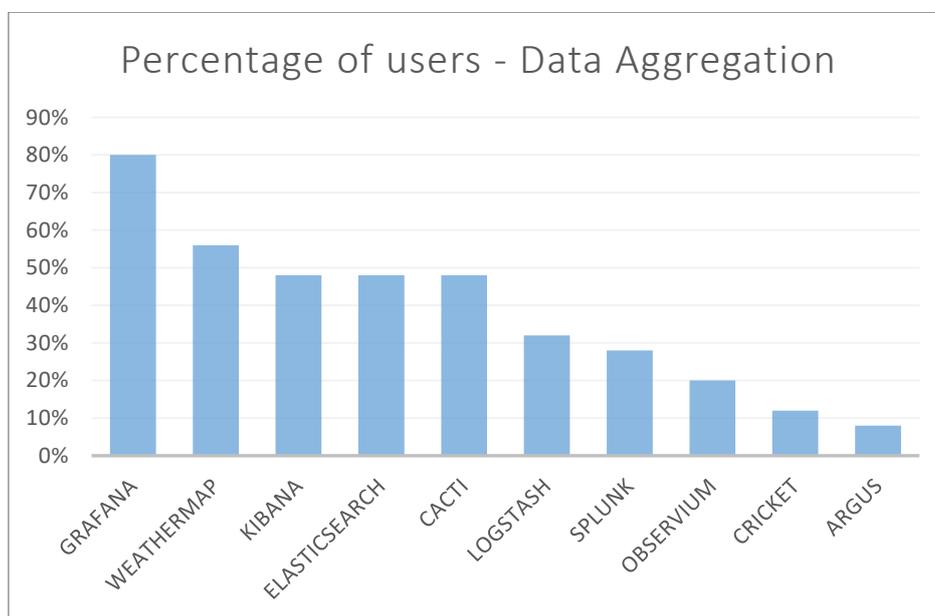


Chart 35. Data Aggregation, Representation and Visualisation: Percentage of Users per Tool (Top-10)

On average, each institution uses 3.8 tools for Data Aggregation, Representation and Visualisation.

Table 32 lists other tools and in-house developed solutions that were not pre-defined in the survey. Kentik is mentioned three times and LibreNMS is mentioned twice.

| | |
|--------------------------------------|---|
| Other tools: | <ul style="list-style-type: none"> • Kentik (3) • LibreNMS (2) • Intermapper • MRTG • OpenSearch • Zabbix |
| In-house developed solutions: | <ul style="list-style-type: none"> • Argus • DMon |

Table 32. Other tools and in-house developed solutions for Data Aggregation, Representation and Visualisation

4.16. DDoS Mitigation

Several questions were asked regarding DDoS Mitigation solutions. The first one was about the mechanisms used for detection, the second about the mechanisms used for mitigation, and the third about the tools. Chart 36 shows the results for detection mechanisms.

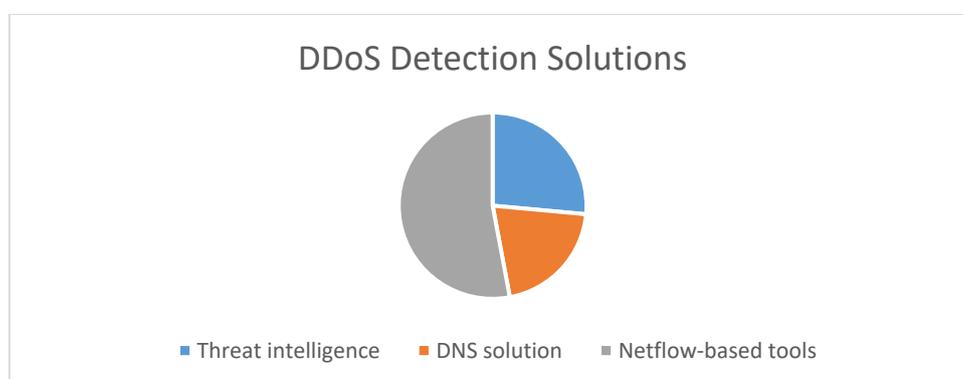


Chart 36. DDoS Detection Mechanisms

Netflow-based tools are the most popular DDoS detection solutions (they are used in 53% of the cases). Threat intelligence, the most popular detection solution in 2019, is now mentioned by 26% of the respondents. DNS Solutions are used by 21% of them.

Chart 37 shows the DDoS mitigation solutions.

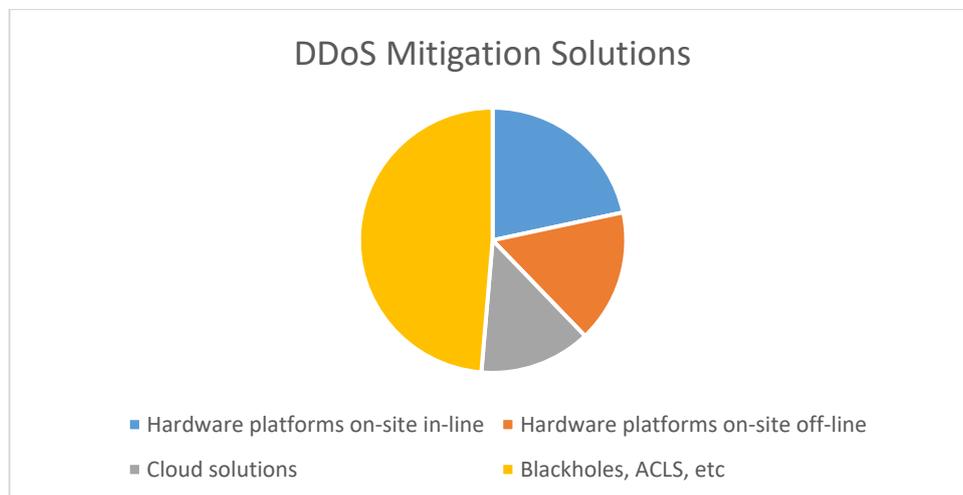


Chart 37. DDoS Mitigation Mechanisms

The percentage of NOCs not using specific tools, but blackholes, ACLs, etc., is quite high (49% of the NOCs who responded to the question). The rest of responses are distributed between hardware platforms on-site in-line (22%), hardware platforms on-site off-line (16%) and cloud platforms (14%).

Table 33 lists other mechanisms for detection and mitigation that were not pre-defined in the survey, although some of them are in fact the tools that were asked for in the next question.

| | |
|----------------------------------|--|
| Other tools (detection) | <ul style="list-style-type: none"> • Arbor Peakflow SP • We use an external solution |
| Other tools (mitigation): | <ul style="list-style-type: none"> • NEMO • We use an external solution |

Table 33. Detection and Mitigation mechanisms for DDoS mitigations

Chart 38 shows the responses for the mitigation tools.

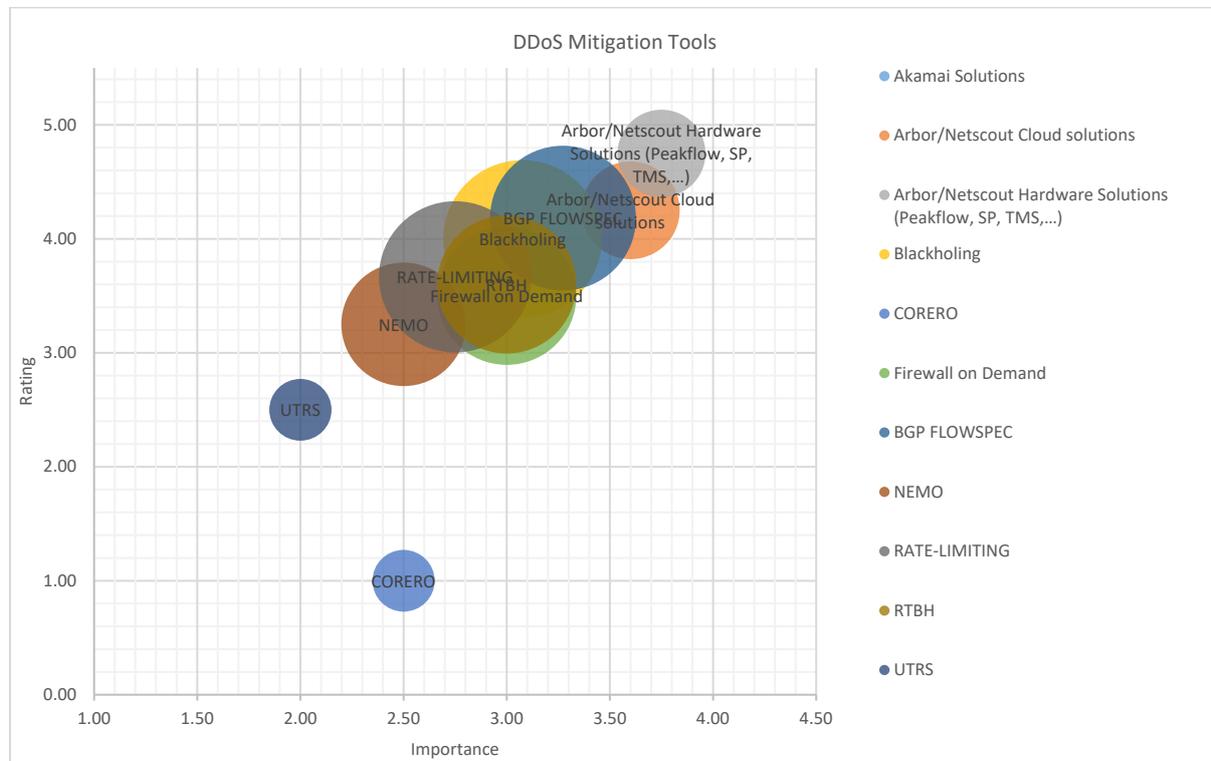


Chart 38. DDoS Mitigation Tools

The most popular tools (Blackholing, Rate-limiting, BGP Flowspec, and RTBH) are not really software tools, but mechanisms to apply on network devices (to divert all the traffic for the attacked host to Null0, limit the bandwidth or apply dynamic filters). As such, they do not get the highest ratings and they are not the most important on average. The highest rated tools are commercial tools from Netscout/Arbor (both hardware and cloud solutions). GÉANT’s Firewall-on-demand (FoD) is the fourth in number of users, but the sixth in importance and rating. Akamai solutions, which were mentioned in the 2019 survey, disappear in this one.

Table 34 shows the tools and their usage ranking over the seven-year period for DDoS Mitigation.

| Tool | 2016 | 2019 | 2023 | Trend |
|---|------|------|------|-------|
| Blackholing | 2 | 2 | 1 | ▲ 1 |
| RATE-LIMITING | 3 | 4 | 2 | ▲ 2 |
| BGP FLOWSPEC | 5 | 3 | 3 | ▬ 0 |
| Firewall on Demand | 4 | 1 | 4 | ▼ -3 |
| RTBH | | | 5 | NEW |
| NEMO | | | 6 | NEW |
| Arbor/Netscout Cloud solutions | | 6 | 7 | ▼ -1 |
| Arbor/Netscout Hardware Solutions (Peakflow, SP, TMS, | 6 | 5 | 8 | ▼ -3 |
| CORERO | | | 9 | NEW |
| UTRS | 9 | 7 | 10 | ▼ -3 |

Table 34. Trends in DDoS Mitigation Tools

Chart 39 shows the percentage of users per tool for the Top-10 for DDoS Mitigation.

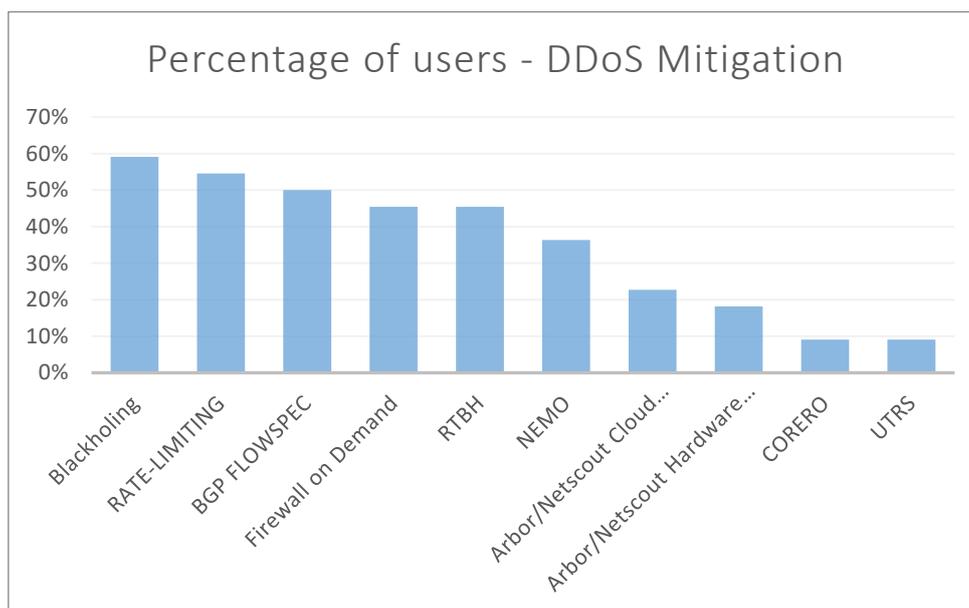


Chart 39. DDoS Mitigation: Percentage of Users per Tool (Top-10)

On average, each institution uses 3.5 tools for DDoS Mitigation.

Table 35 lists other tools and in-house developed solutions that were not pre-defined in the survey.

| | |
|---------------------|--|
| Other tools: | <ul style="list-style-type: none"> • WANGuard |
|---------------------|--|

Table 35. Other tools and in-house developed solutions for DDoS Mitigation

4.17. Orchestration, Automation and Virtualisation

Several questions were asked regarding Orchestration, Automation and Virtualisation (OAV). The first one was about the kind of tasks that NOCs automate, the second about the number of devices with automation in the core, the third concerned the number of devices with automation in the access, and the fourth about the tools. *Chart 40* shows the automated tasks and *Chart 41*, the median number of devices (not the average).

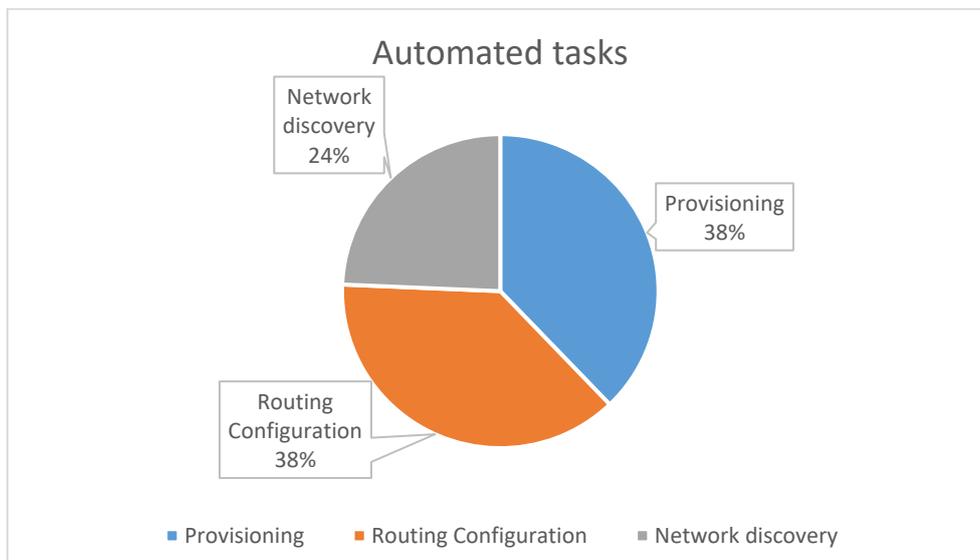


Chart 40. Automated Tasks

According to the results, provisioning and routing configuration are the task that is more frequently automated by NOCs, followed network discovery. The number of devices where automation is used is smaller in the core than in the access (which is normal, because the core always has fewer devices than the access network). However, compared with the 2019 results, more institutions are automating and in more devices than in 2019, and both the median number of devices in the core network and in the access network have increased, as *Chart 41* shows. Still, Orchestration, Automation and Virtualisation is the functionality the NOCs feel least responsible for, but, as we saw in the first pages of this reports, many organisations are already automating processes in their networks, but not from the NOC.

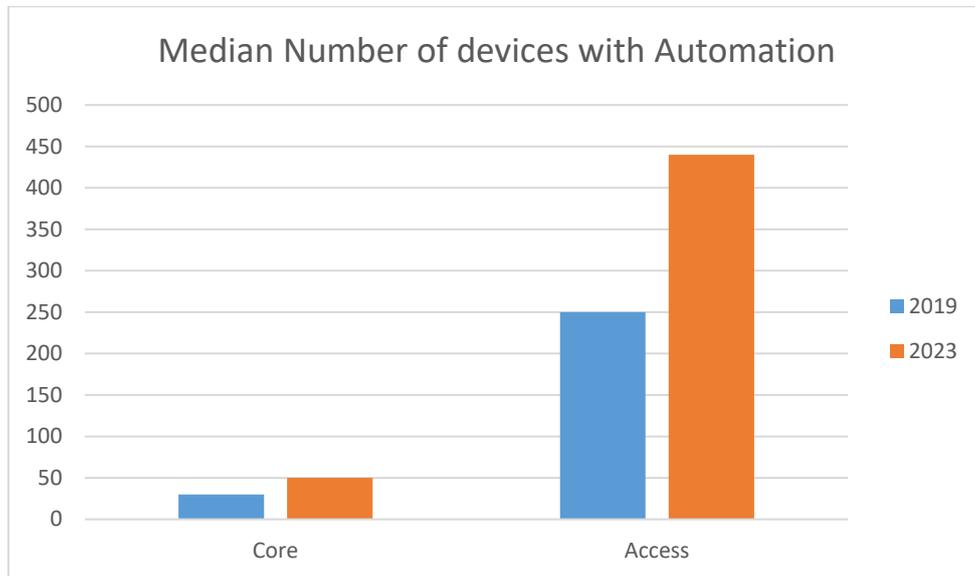


Chart 41. Median Number of Devices with Automation

Chart 42 shows the results for the tools and languages used for Orchestration, Automation and Virtualisation.

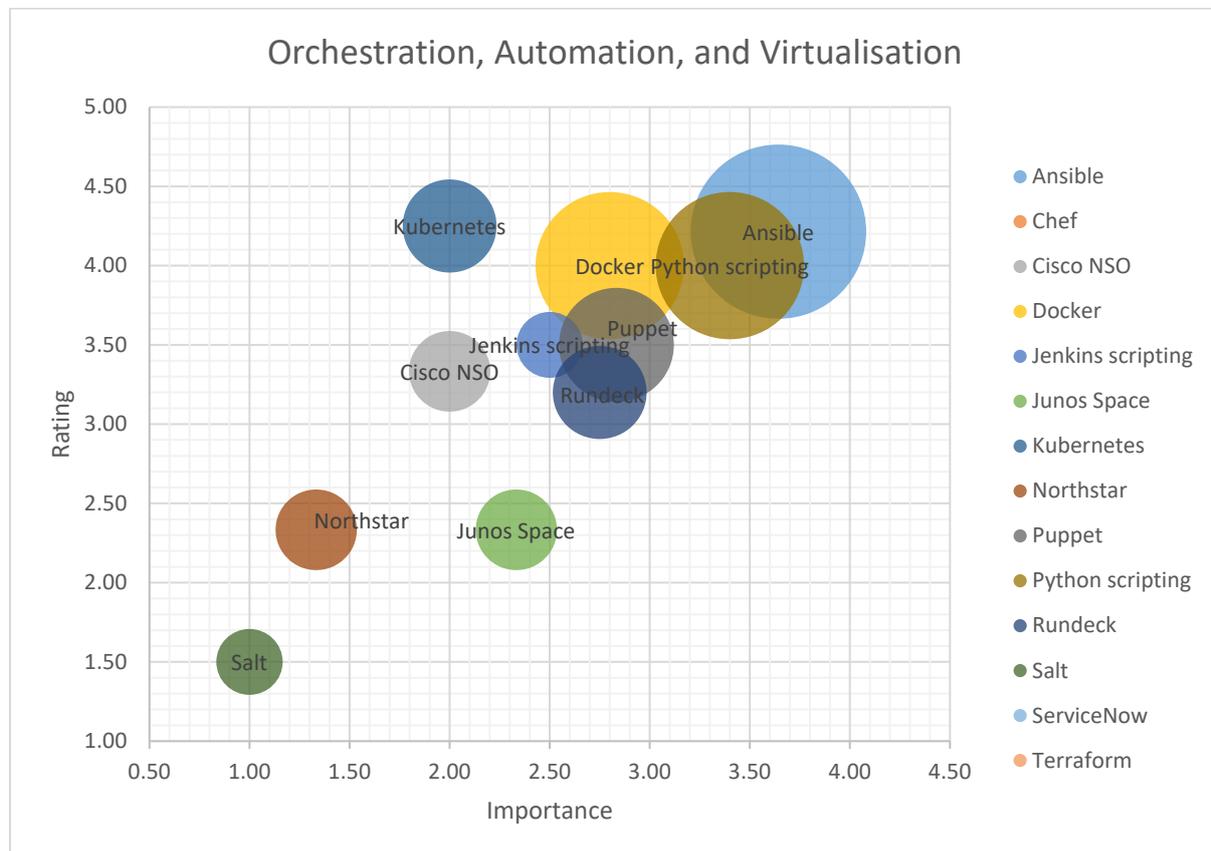


Chart 42. Software tools and languages used for Orchestration, Automation and Virtualisation

Ansible is the most popular tool for automating tasks for the NOCs and the most important. It is also highly rated, but Kubernetes is slightly higher in the quality rating, although it is used by less than a third of the users, compared to Ansible. Regarding the number of users and quality rating, Python and Docker are the next most popular and better tools, according to the respondents. Puppet is a bit more important than Docker, but less popular. Salt does not have many users, but those who mentioned it rated it quite low both for importance and for rating.

Table 36 shows the usage trends of the Orchestration, Automation and Visualisation tools, comparing the position they occupy in the responses count table (sorting by number of responses for each tool). Puppet disappears from the Top-10 and Terraform and ServiceNow have no users.

| Tool | 2019 | 2023 | Trend |
|-------------------|------|------|-------|
| Ansible | 1 | 1 | 0 |
| Docker | | 2 | NEW |
| Python scripting | 2 | 3 | -1 |
| Puppet | 9 | 4 | 5 |
| Kubernetes | 5 | 5 | 0 |
| Rundeck | 10 | 6 | 4 |
| Cisco NSO | 7 | 7 | 0 |
| Junos Space | 4 | 8 | -4 |
| Northstar | 8 | 9 | -1 |
| Jenkins scripting | 6 | 10 | -4 |

Table 36. Trends in Data Aggregation, Representation and Visualisation Tools

Chart 43 shows the percentage of users per tool for the Top-10 for Orchestration, Automation and Virtualisation.

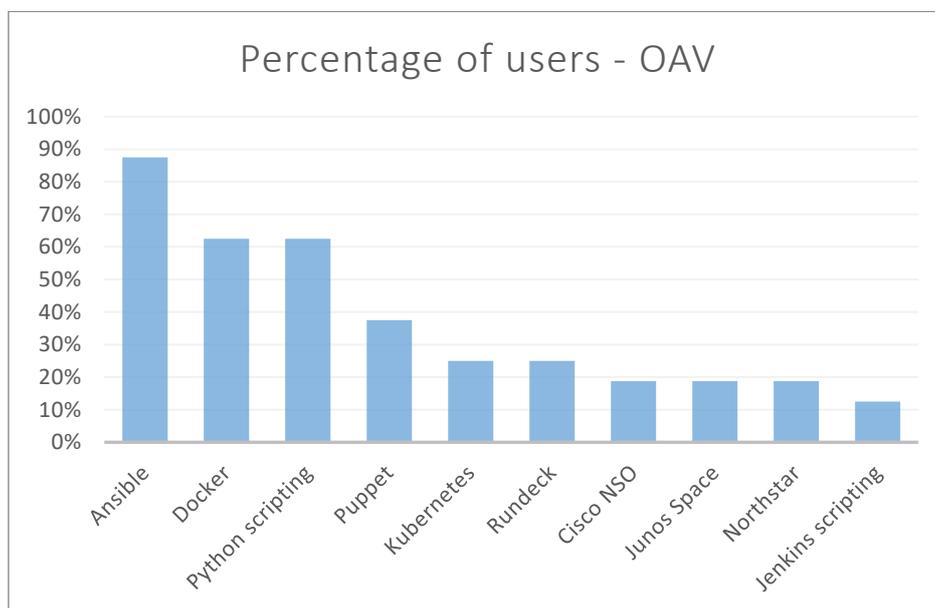


Chart 43. Orchestration, Automation and Virtualisation: Percentage of Users per Tool (Top-10)

On average, each institution uses four tools for Orchestration, Automation, and Virtualisation (OAV).

Table 37 lists other tools and in-house developed solutions that were not pre-defined in the survey. Expect and Perl scripting are mentioned twice. Several vendor tools are also mentioned.

| | |
|--------------------------------------|---|
| Other tools: | <ul style="list-style-type: none"> • Expect scripts (2) • Perl scripts (2) • Aruba Netedit • Bash scripting • Ciena MCP • Cisco DNA • CNaaS NMS • Git • GitLab • IMS • OKD • Spectrum • Workflow Orchestrator (SURF) |
| In-house developed solutions: | <ul style="list-style-type: none"> • GIS (our database) and a suite of self-developed scripts |

Table 37. Other tools and in-house developed solutions for Orchestration, Automation and Virtualisation

5. Standards

As part of the survey, SIG-NOC wanted to explore the level of adoption of the various standards and industry best practice-based procedures and methodologies at NOCs.

Chart 44 shows the various standard adoptions, considering the average level of adoption and the average level of training for the employees in the organisations.

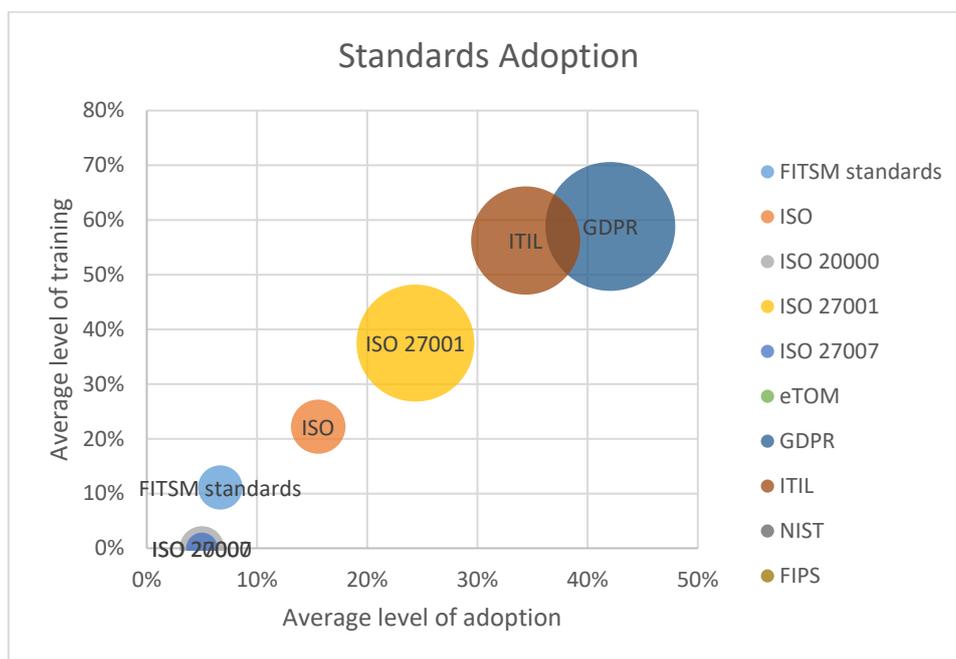


Chart 44. Estimated level of adoption vs average of trained employees

The results of the survey show an increasing adoption of some standards, frameworks, and regulations. Most of the respondents have already adopted and trained their employees for GDPR. ISO27001 is the more widely adopted, but more organisations train their employees in ITIL. Other frameworks, such as ISO20000, ISO27007, NIST or FIPS are not adopted by the NOCs who responded to the survey.

Chart 45 shows the percentage level of certification or training for NOC employees.

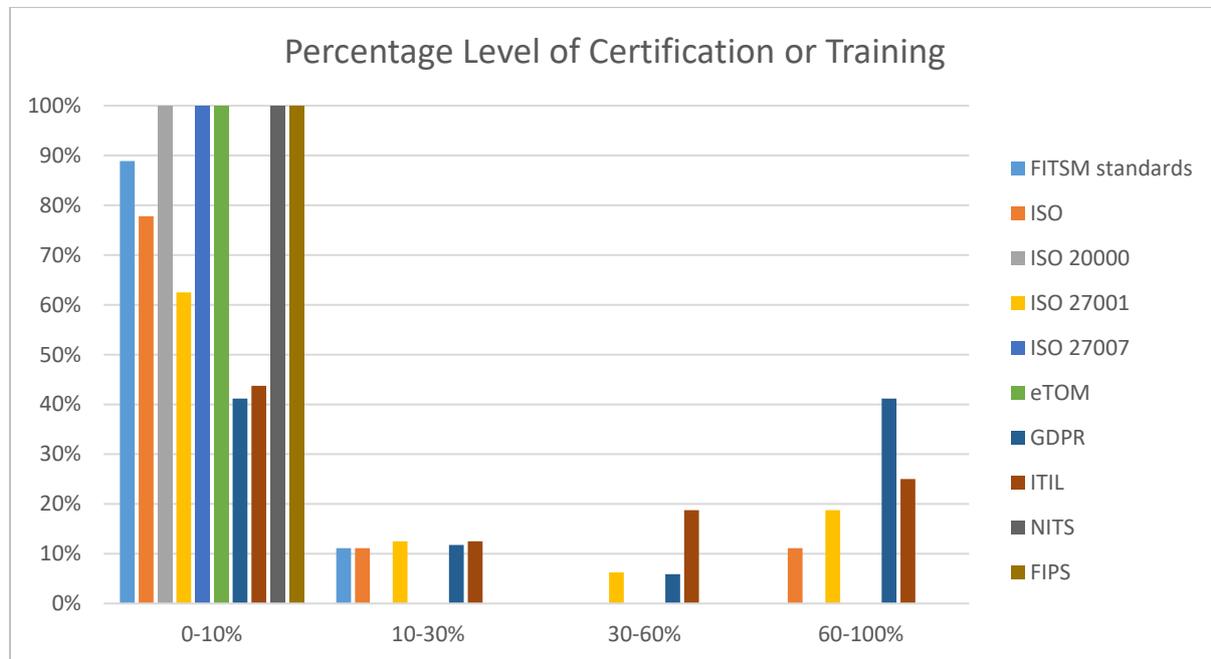


Chart 45. Percentage of Certified or Trained NOC Employees

The X axis shows the percentage of employees trained or certified by the organisation, whereas the Y axis indicates the percentage of employees that fall into each category. Focussing on the right-hand side of the table, 41% of the organisations train between 60 % and 100% of their employees in GDPR, 25% of the organisations train between 60% and 100% of their employees in ITIL, 19% of the organisations train between 60% and 100% of their employees in ISO27001, and 11% of the organisations train between 60% and 100% of their employees in ISO. However, focussing on the left-hand side, we can see that, for ISO20000, ISO27007, eTOM, NIST, and FIPS, 100% of the organisation have trained between 0% and 10% of their staff.

Table 38 contains other standards and methods mentioned by the respondents.

| | |
|------------------------|--|
| Other standards | <ul style="list-style-type: none"> • ENS • ISO9001 |
|------------------------|--|

Table 38. Other standards

6. Conclusions

Network Operation Centres are responsible for a broad range of functions that have increased over time and use a wide variety of tools to support them. In many cases, multiple tools are used for a single function, while some tools are used for more than one function. The number of in-house developed tools has decreased, compared to previous editions of the survey, and the number of commercial and vendor tools has increased. This report explicitly does not attempt to draw any conclusions on which tools are the best, as this depends on usage and can be subjective. Its aim is to show visually the results provided by the NOCs in the research and education community. However, it should be helpful in determining which tools are most commonly used and, therefore, likely to have a healthy community that is active and collaborative around them. It also illustrates situations where tools are widely used, but perhaps users do not find them fit for purpose, or the contrary, where tools are not so popular, but are very useful to their users. While further conclusions are left to the reader, questions regarding the findings of this report can be raised with the SIG-NOC community [\[1\]](#).

7. Acknowledgements

SIG-NOC acknowledges the contributions of all the organisations and their NOCs who participated in the survey and extends its special thanks to the SIG-NOC Steering Committee members: Tony Barber (GÉANT), Maria Isabel Gandía Carriedo (CSUC), Ivana Golub (PSNC), Jonny Lundin (NORDUnet) and Ana Maria Medina (RedIRIS), to the SIG-NOC coordinator, Magda Haver (GÉANT), and to the Community Research Officer, Daniel Wüstenberg (GÉANT).

8. References

- [1] GÉANT SIG-NOC home page <https://wiki.geant.org/display/SIGNOC/>
- [2] NOC Survey 2012: <https://wiki.geant.org/download/attachments/121342210/TF-NOC-Survey-Report-Final.pdf?version=1&modificationDate=1465489309157&api=v2>
- [3] SIG-NOC Survey 2016: <https://wiki.geant.org/display/SIGNOC/SIG-NOC+Tools+Survey+2016>
- [4] SIG-NOC Survey 2019: <https://wiki.geant.org/display/SIGNOC/SIG-NOC+Tools+Survey+2019>
- [5] SIG-NOC Survey 2023 : <https://wiki.geant.org/display/SIGNOC/SIG-NOC+Tools+Survey+2023>
- [6] Spreadsheet for the SIG-NOC Tools Survey 2023:
<https://wiki.geant.org/download/attachments/708051531/SIG-NOC%20Tools%20Survey%202023-Results-final.xlsx?version=1&modificationDate=1713738464089&api=v2>

9. Glossary

| | |
|----------------|---|
| ACL | Access-Control List |
| DDoS | Distributed Denial-of-Service |
| FIPS | Federal Information Processing Standard |
| FoD | Firewall-on-Demand |
| GDPR | General Data Protection Regulation |
| IP | Internet Protocol |
| ISO | International Organization for Standardization |
| ISP | Internet Service Provider |
| ITIL | Information Technology Infrastructure Library |
| SIG-NOC | Special Interest Group – Network Operations Centres |
| MRTG | Multi Router Traffic Grapher |
| MS | Microsoft |
| NOC | Network Operations Centre |
| NOG | Network Operators Group |
| NREN | National Research and Education Networks |
| OAV | Orchestration, Automation, and Virtualisation |
| OOB | Out Of Band |
| OTRS | Open-Source Ticket Request System |
| SNMP | Simple Network Management Protocol |
| SOC | Security Operations Centre |
| TF-NOC | TERENA Task Force on NOCs |



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