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Communications in Computer and Information Science

1754

Optimization, Learning Algorithms and Applications

Second International Conference, OL2A 2022
Póvoa de Varzim, Portugal, October 24–25, 2022
Proceedings

 Springer



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ISSN 1865-0929 ISSN 1865-0937 (electronic)
Communications in Computer and Information Science
ISBN 978-3-031-23235-0 ISBN 978-3-031-23236-7 (eBook)
<https://doi.org/10.1007/978-3-031-23236-7>

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Preface

This CCIS volume 1754 contains the refereed proceedings of the Second International Conference on Optimization, Learning Algorithms and Applications (OL2A 2022), a hybrid event held during October 24–25, 2022.

OL2A 2022 provided a space for the research community on optimization and learning to get together and share the latest developments, trends, and techniques, as well as to develop new paths and collaborations. The conference had more than three hundred participants in an online and face-to-face environment throughout two days, discussing topics associated with optimization and learning, such as state-of-the-art applications related to multi-objective optimization, optimization for machine learning, robotics, health informatics, data analysis, optimization and learning under uncertainty, and Industry 4.0.

Five special sessions were organized under the following topics: Trends in Engineering Education, Optimization in Control Systems Design, Measurements with the Internet of Things, Advances and Optimization in Cyber-Physical Systems, and Computer Vision Based on Learning Algorithms. The OL2A 2022 program included presentations of 56 accepted papers. All papers were carefully reviewed and selected from 145 submissions in a single-blind process. All the reviews were carefully carried out by a scientific committee of 102 qualified researchers from 21 countries, with each submission receiving at least 3 reviews.

We would like to thank everyone who helped to make OL2A 2022 a success and hope that you enjoy reading this volume.

October 2022

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Multi VLAN Visualization in Network Management

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Abstract. The structure of logical networks in large enterprises can be complex. Virtual local area networks (VLANs) can include a large number of connections and intermediate devices. Presentation of the network in the form of a graph diagram simplifies the work of network specialists. We suggest the concept of visualizing a selected VLAN over a physical network diagram. We consider the features of this method using an implementation of a simple tool for displaying the network status by the selected criterion.

Keywords: Network management · Network management station · Network visualization · SNMP

1 Introduction

The visualization of topologies and network equipment is a part of the network management operation. In this context, the Simple Network Management Protocol (SNMP) is the most popular and wide implemented framework, covering a large number of equipment (hardware, software and technical knowledge). Regardless of the detailed OSI Management Framework (or shortly the CMIP/GDMO model) standards [8], the SNMP IETF Management Framework [5, 7, 15] soon gained a larger set of followers, maybe due to its simplicity or ability to be implemented and running in a wide range of devices and platforms.

The use and specification of both SNMP and/or CMIP/GDMO is very low level, presenting protocols and information structure for the download of network devices parameters (GET) and for the change in operational status (SET). The network management operation is further complicated with the size of the network. Large organizations have large local area networks. Many of them use virtual local area networks (VLANs) in order to realize micro-segmentation of the network, increase its controllability and reduce the amount of broadcast traffic [2]. However, the topology of VLAN distribution may be complex: VLANs for video surveillance equipment, Internet of Things (IoT) sensors, and other special devices can often be distributed across many switches. Supporting a functional

and accurate topology requires a visualization tool that presents information more understandable than text or tables. Visualization allows the specialist to quickly understand the output of the program, correlate the desired and available results, quickly find out the problematic element in the structure.

This paper presents and discusses the design and development of a web-based application for the visualization of VLANs in organizations. It is composed of three main parts, namely, the network management backend, the server and the web graphical user interface.

This document is structured in four sections, starting with this introduction. Section 2 describes the related work, followed by Sect. 3, which describes the architecture and main options. Section 4 describes the final application and Sect. 5 finishes with some conclusions and final considerations.

2 Related Work

Communication networks are currently the mainstay of a social and economic model that are an integral part of our way of life. Its importance has grown in recent decades and its role is expected to be increasingly central in this information society.

In social communication, as well as in informal day-to-day conversations, references to devices and technologies that allow access to content and information anywhere and at any time appear with increasing frequency. The Internet continually extends reach beyond the desktop PC to mobile phones, electronic organizers and home devices. This expansion is mainly due to open technologies that support the Internet as well as content based on branded languages, such as HTML/JSON/Javascript and others.

In this context, network management is a task of enormous complexity, whose success or failure has a huge impact on users and depends on the precise knowledge of the operating parameters of the equipment that constitutes it. By equipment we mean not only active and passive material (hardware) but also software, such as operating systems or applications. It is important that this information is as complete and diversified as possible, as it is based on it that decisions are made.

For this reason, each network element is modeled according to the relevant management information to describe its operating status. This information will necessarily have to be accessible to external devices so that they can build a model of how the element works.

The management models are therefore oriented towards retrieving, transporting and changing information, accessed using a virtual database model. The reason for the term “virtual” is that the database does not actually store the operating parameters, obtained through instrumentation operations on the network equipment. According to this architecture, a management model generally consists of one or more entities responsible for instrumentation, commonly known as agents, a communication mechanism and a monitoring and control post where the operating model is created, that is, the management station [12, 13] (Fig. 1).

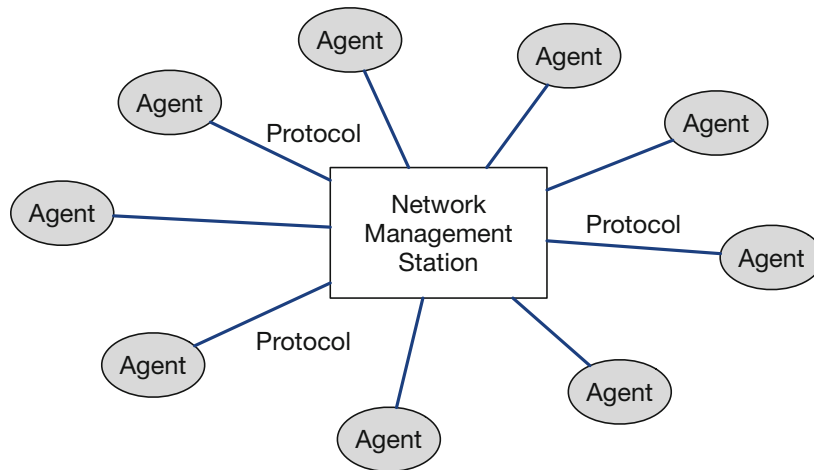


Fig. 1. Network management generic architecture

The management architecture based on SNMP emerged at the end of the 80's as an interim solution aimed essentially at TCP/IP systems. It has survived to the present day through three major evolutions. The first version of the SNMP architecture is described in only three documents, which allows a quick understanding and facilitates the development of management applications [17],?. This simplicity caught the attention of the market, which quickly adopted it for their products.

According to the generic network management model, the SNMP architecture provides an information representation format called SMI (Structure of Management Information) [17]. The functioning of network elements is therefore described in this format, in modules that group related information. Each module is called a MIB (Management Information Base) [16].

The communication protocol associated with the architecture, which gives it its name, consists of a simple protocol that allows the inspection and modification of the management information of a remote network element (agent), as well as the transport of notifications generated by these (traps) [7].

With the increase in the number of users, the need to add more functionality was felt, particularly in terms of protocol and security. Version 2 was relatively successful on the first requirement with the addition of new message types [4]. However, the SNMPv2 security model failed to establish consensual and robust measures, which led to the architecture being often considered unsuitable for configuration operations.

SNMPv3, more recently proposed [6], builds on the protocol defined for version 2 and adds better security mechanisms, particularly in terms of authentication, privacy and access control. Another feature of SNMPv3 is its modularity, which makes it possible to use existing and future protocols in certain functions without the need to update or issue new RFCs for the entire architecture.

According to the previous, the purpose of a network management system is to provide a common framework for remote administration of network devices. Nothing is said (or standardized) in relation to the visualization of both data and network topology and status. Visualization of a computer network structure is a developed and well-established discipline. Physical and logical diagrams are well suited to present a network view. Most popular monitoring systems support network mapping in a diagram. However, the display of information about VLAN is still a space for experimentation. Basically, the information is provided individually for the device or its interface. Or the visualization tool displays a graph of devices, ports and connections for the selected VLAN. The second option is more obvious, but with its help it is still difficult to imagine the spread of VLAN in the whole set of the organization's network devices.

Krothapalli et al. [10] consider a graphical approach to obtaining information about VLANs. They made a toolkit for displaying VLAN spread as a graph to simplify network troubleshooting operations, that can also be used to detect and diagnose root bridge placements and misconfigurations, such as missing and redundant links. The visualization is performed through an interactive graphical interface, that, in addition to the topology, also presents the effect and impact of various VLAN design changes.

Basu et al. [3] approach the problem of designing and implementing an enterprise wide network monitoring system across 27 countries and more than 10000 buildings. To deal with the massive scale, they used a Kafka cluster with an OpenNMS backend. The system operates mainly on events, by listening for SNMP Traps, and start polling operations when necessary. Moreover, they forward notifications to different user interfaces, such as Microsoft Teams or Slack.

Shidhani et al. [1] support the use of Free and Open Source Software (FOSS) for automated network monitoring tools and, as such, describe the main features and make a comparison between three of the most popular systems, namely Nagios, OpenNMS and Zabbix.

Ljubojević et al. [11] describe the use of the Zenoss Core Software Platform for centralized monitoring. By using scripting and resorting to SNMP, ICMP and syslog, the tools allows to present several visualizations of the status of the network. In a similar approach, Pinzón et al. [14] use SNMP and information processing to monitor several equipment of an electrical power system. They get data from SNMP MIBs and process them to build simple visualizations.

Kontsek et al. [9] make a survey of the most popular tools for monitoring. This is performed in SNMP, Intelligent Platform Management Interface (IPMI), and Windows Management Instrumentation (WMI) and visualized in Zabbix, Nagios, TICK Stack, and Prometheus. The authors conclude that the monitoring platforms are versatile able for dealing with complex environments, such as in Cloud Computing environment.

All of these provide interesting approaches to monitoring and management of networks of several sizes and dimensions. Of the references above, none is able of providing complex visualizations of the physical topology and of VLAN topology. Other commercial tools also exist, such as IBM Tivoli Monitoring. However,

sometimes this constitutes a very expensive solution, for simple visualization tasks.

3 NetGlance

The objective of this work, as mentioned above, is the design and development of a network management tool that can provide information about operational parameters as well as display information about VLAN over a logical network diagram using color coding. Additional information about topology elements are displayed as tooltips. Such an approach will make it possible to cover all possible VLAN conditions on devices and connections without overloading the user with a large amount of data. This display method makes it easy to compare VLAN topologies with each other and correlate them with the general network diagram.

NetGlance should display a topology of network devices along with summarized information, which include name, address, and model, as well as the connections between them. The user should be able to add, delete and modify network elements, as well as arrange devices on the screen. Also, zooming and panning should be supported, like geographic online maps.

The current state of network elements should be updates in real-time, using different colors to highlight states. The user can use filters to select different types of information, and specify specific query parameters. Due to the possibility of quick changes, a brief summary of the latest network events should also be presented in textual format.

NetGlance must have the flexibility to support multiple heterogeneous devices, accessible through different network management protocols or even accessible only via ICMP. It should be possible to extend NetGlance with other protocols or even to be able to retrieve device information from a third-party data sources. The state of each device can be represented in 7 different levels: unknown, error, warning, normal and 3 user-defined.

Because of the possibility of the human operator being away from the network management station, there should be also the possibility to send notifications through a messenger app (like Telegram or Signal). To reduce the amount of notifications, these should be parameterized according to their severity.

Figure 2 represents a visual concept. The reach of VLAN N is shown on all supporting devices and connections. Solid lines show the connections where untagged frames are transmitted for this VLAN, and dotted lines are links where this VLAN is allowed as tagged. Unaffected items are grayed out. This visualization is useful for troubleshooting problems with VLAN.

Figure 3 represents an erroneous network configuration. VLAN N does not exist in the database of Switch A , and, therefore its traffic will not be transmitted through it. In addition, the interface of Switch B is not configured to accept frames of this VLAN.

Various visual techniques can be used to display VLAN status on devices and connections, but color changes are recommended on color diagrams. This makes the smallest changes to a diagram view, and is noticeable for the user.

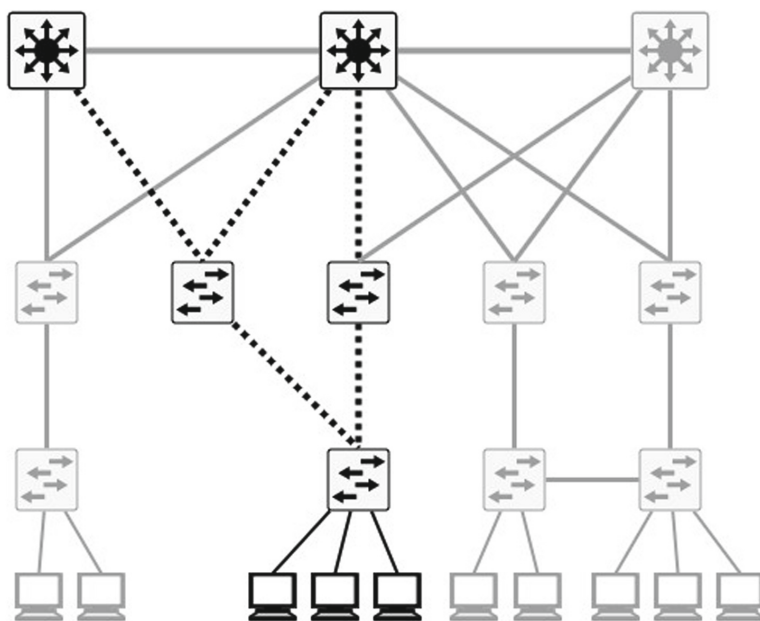


Fig. 2. On a network diagram

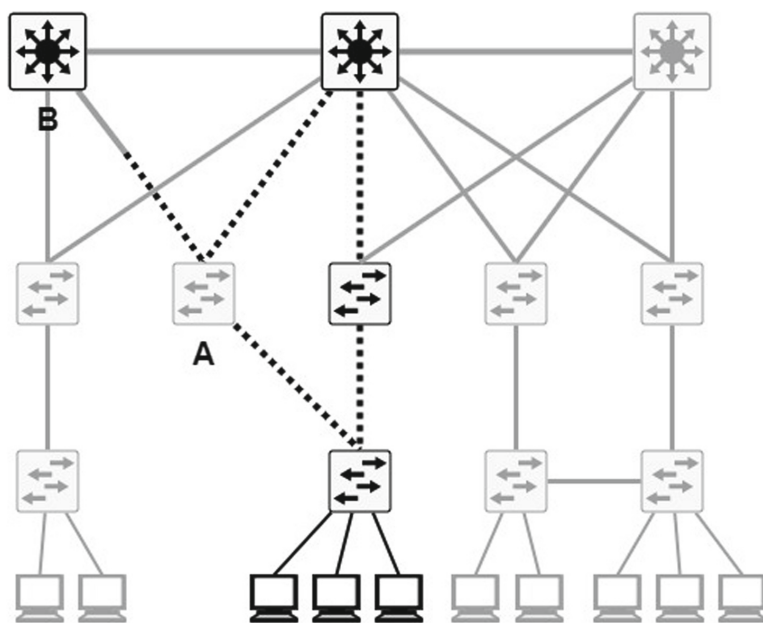


Fig. 3. A misconfigured network

4 Implementation Details

NetGlance, by design, is a Web-based application, composed of two components. One is constantly online, and is the target of the notifications and the responsible for constantly monitoring the network status and devices. The other is responsible for the visualization, and can be accessed anytime, anywhere from a web browser. Both are implemented and deployed as Windows services (Fig. 4).

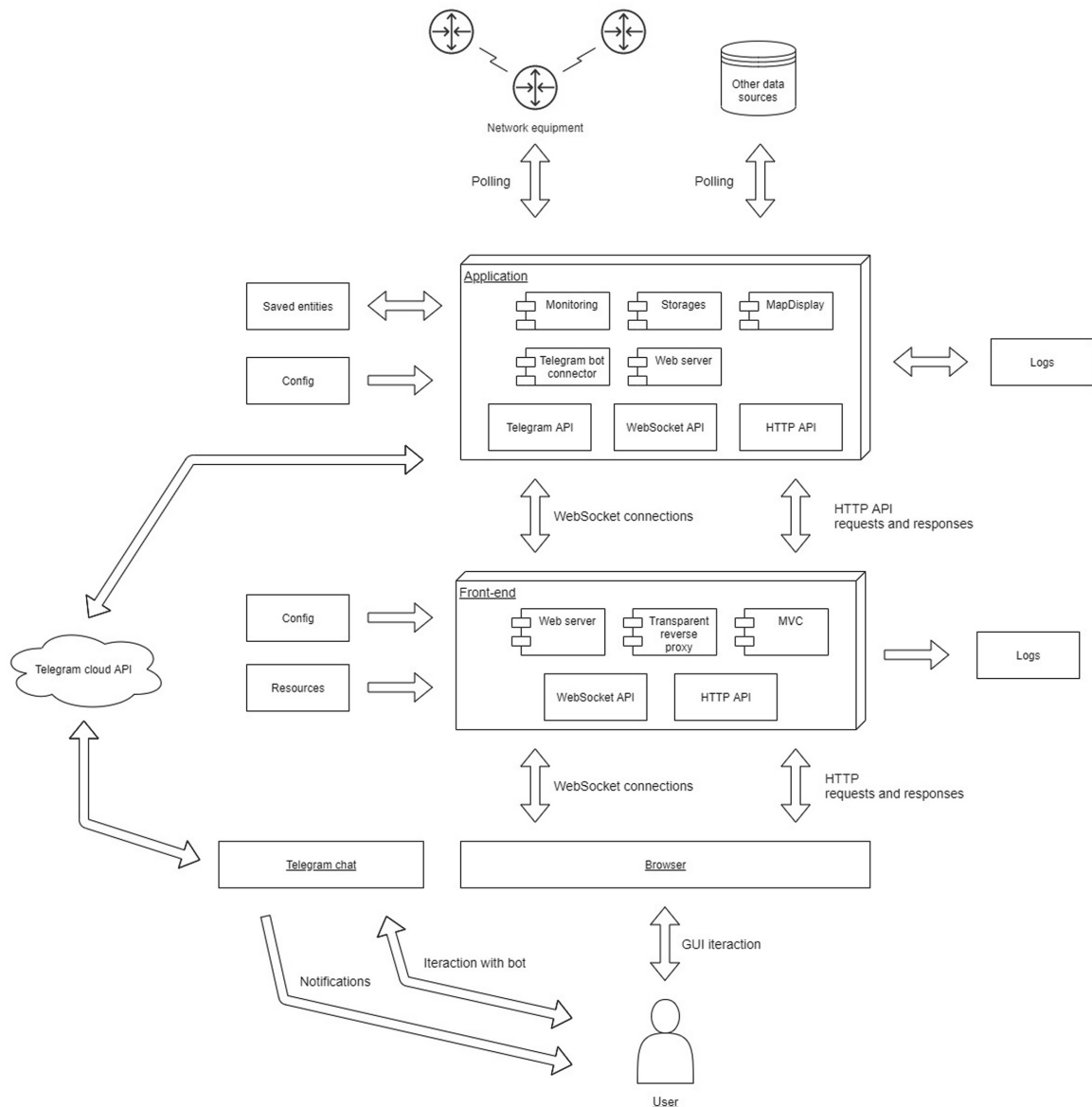


Fig. 4. NetGlance architecture

An example of the interaction is depicted in Fig. 5, highlighting the operation and architecture of NetGlance. In this, the user connects to the frontend through a browser which requests a web page. After authentication, the web page rendered with information retrieved from the backend (Application server). Depending on the operation, the interaction between both components continues, until the user logs out or closes the browser.

The communication between both components is performed through a standard web API (REST/JSON and Web Sockets), which allows the development of

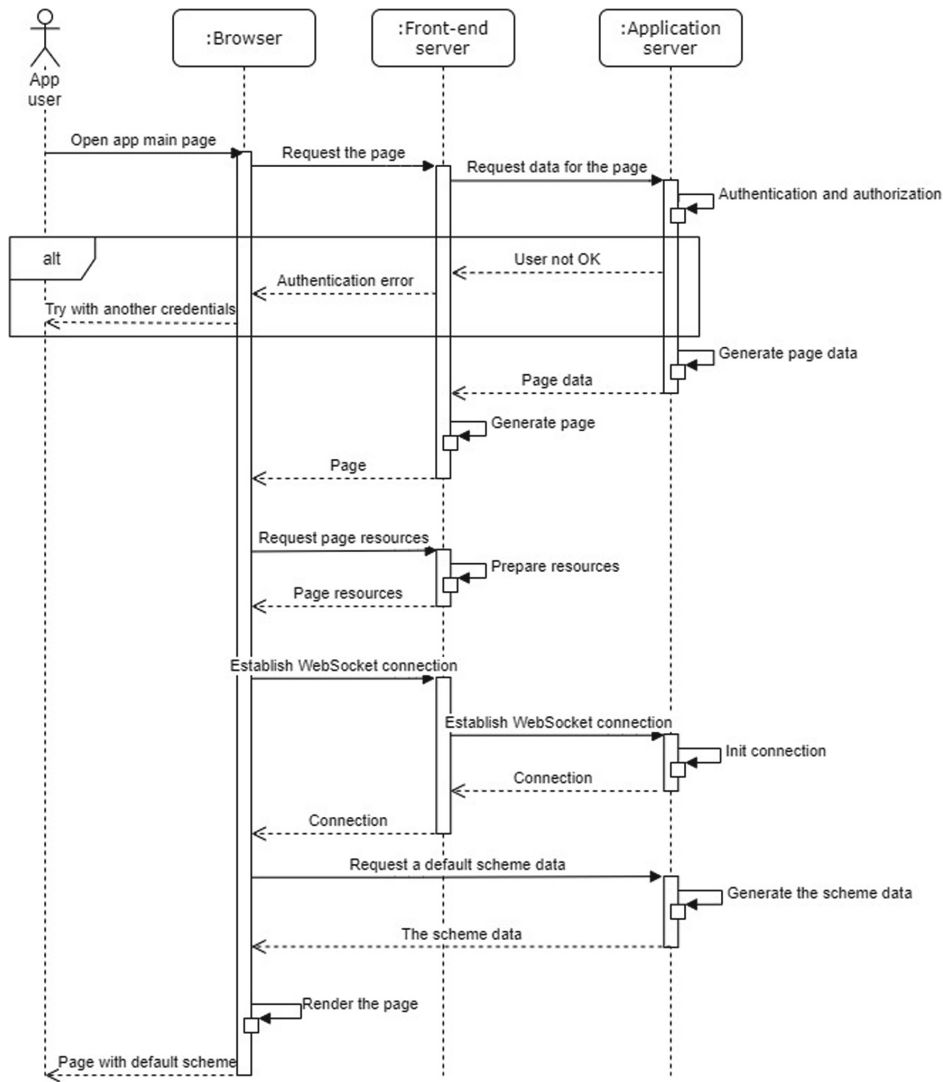


Fig. 5. NetGlance architecture

mobile or desktop application in the future. Moreover, it also paves the way for multiple monitoring stations for in-band traffic optimization and load balancing, for example, by placing different components in different hosts.

The backend is constantly online, monitoring and storing the instrumentation information. It was developed in ASP.NET using .NET Framework and hosted with Microsoft.Owin. The information it stores is multiple, registering network topology, receiving events, implementing polling operation for different devices, and others. If some event or pooling matches some condition, it also notifies subscribers.

In addition to network operation information, it also logs its internal events, such as start and stop of operation, changes made by users, authorization procedures, among others. It uses several log levels in a broad set of detail, used during normal use as well as for debug. The application configuration is stored in a file, containing polling settings, log level, files location, buffering output information, for example.

4.1 User Interface

The correct use of the network management station depends heavily on the user interface. If it is not simple, intuitive and extensible there will be no advantages in using the system, so much of the development effort was focused on the user interface.

The user interface should reflect the state of the network and its components, as well as represent the way they are organized. The organization can take many forms and usually follows some logical grouping of topological information. NetGlance opt for a schematic representation of connections, where lines between various components are visualized (Fig. 6). In addition, the main web page comprises a navigation element, a toolbar, a selector for displayed parameters, and a log of recent events. In the figure, Device “SW_2” stopped responding, so it is highlighted with the “Error” state in red. The connection of “SW_2” with the router is in the “Warning” state.

Monitoring functions are also configured and accessed in a similar maner (Fig. 7). This user interface provides access to several properties, allowing the configuration of pooling threads. These include the access protocol and the active (triggering) code. It also allows selecting the action that should be triggered.

4.2 Use Cases

The use of NetGlance can be further illustrated with some use cases, as follows.

Routine monitoring is a frequent operation. In this, the system administrator evaluates the network in the beginning of the day or in different moments. For that, the main page is opened in a browser, where a network map is displayed along with a predefined set of parameters. By default, the device availability and the link state is represented. The user analyses network topology, paying attention to the colors of the elements and associated labels, if necessary, by holding the cursor over them. He can move or zoom the schematic representation as well as accessing a summary of recent events. Based on all this information, he assesses if further diagnostics are necessary. Using the high visibility of the information, he can determine the location of inaccessible network segments (if any) and make assumptions about the most likely reasons of the failure.

In the event of unexpected failure, the organization’s system administrator gets to work before the start of the working day. He receives a messenger notification on his smartphone that two important routers became unavailable 5 min ago, and that the ports on other devices connected to them went down. To better understand the extent of the problem, the administrator activates a VPN connection with the organization’s network on the smartphone and opens the web application page. He sees more detailed information about the state of the network in almost real time and has the ability to plan actions to restore the network even before he reaches his office.

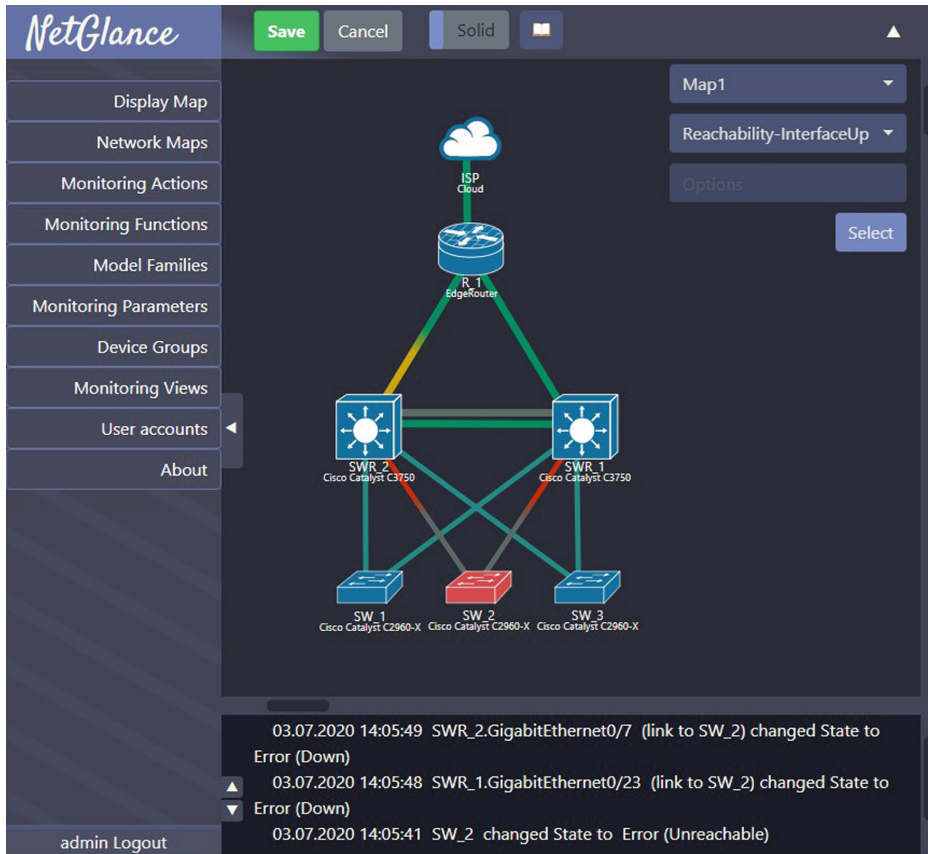


Fig. 6. Example network scheme

The screenshot shows the 'MonitoringFunction' configuration page in NetGlance. It includes a 'Save' button and a toggle switch set to 'On'. The 'Action (valuable Function result)' is set to 'Reachability'. Under 'Select network Protocol or set new', 'UniFi' is selected. The 'Select Execution type' is set to 'C# Method'. The 'Set Function code' section contains a C# script:

```

Command: i
Script must return: One string
1 using KoenZomers.UniFi.Api;
2
3 const int trycount = 2;
4 string[] address = _ADDRESS.Split('.');
5 string caddr = (string)_OTHERDEVINFO["ControllerUri"];
6 for(int t = 0; t < trycount; ++t){
7     try{
8         // Get saved UniFi API connector or create it
9         Api uniFiApi = null;
10        if(_COMMONSTORE["$cunifi{caddr}"] == null){

```

The bottom left has a 'Logout' button.

Fig. 7. "MonitoringFunction" entity page

If a VLAN topology changes, the administrator needs to quickly forward a VLAN over the network from the distribution router through a series of switches to an end device. He must create the VLAN on those devices where it does not exist, and correctly configure upstream and downstream ports. However, after completing the configuration, the end device cannot communicate with the rest of the network. The administrator opens the web application, indicates the observed parameter type (VLAN) and its number. After 1 period of polling devices (approximately 20 s), he receives the VLAN status on devices (exists or not) and connections (tagged, untagged, absent, not applicable). The administrator saved time on finding a configuration error.

The addition of new devices is a frequent operation. In this use case, several new managed switches were added to the network that are already in use on the network. This model is already in use on the network. They must be added to the monitoring system. The administrator in a few clicks tells the system to add a device. After specifying the connection address and authentication data, the system adds the device to the scheme, automatically receiving information about the name and ports. The device monitoring starts immediately according to the settings for this model and the selected device group. After that, the administrator adds the necessary connections to the device to the scheme, moves the devices for beautiful displaying.

5 Conclusion

NetGlance is a web application for VLAN representation and monitoring. It is modular, separating the network operations from the visualization and business processes, and it is successfully deployed in the KubSAU university network. The use of an easily editable network diagram facilitates its updating, including for temporary network segments. Moreover, it also makes it easier to work with changes in the VLAN topology. Creating an up-to-date and easily updated network management system allowed keeping reliable information about the topology. In this work, a simple and flexible way of grouping devices was used - families of models identical in interaction from the point of view of the program. Since Higher Education Institutions often have a large local network that has developed over time using different generations of network equipment, NetGlance also provides a useful tool, since it can grow and integrate heterogeneous equipment.

The proposed approach is successful and useful. The functionality reduces operation time for VLAN troubleshooting and maintenance works. It also facilitates understanding of the VLAN topology in the network by means of visibility and the use of a common logical network diagram as the basis.

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