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BRNO UNIVERSITY OF TECHNOLOGY
VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

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FAKULTA ELEKTROTECHNIKY
A KOMUNIKAČNÍCH TECHNOLOGIÍ

DEPARTMENT OF TELECOMMUNICATIONS
ÚSTAV TELEKOMUNIKACÍ

APPLICATION FOR MONITORING OF LINUX SERVERS
APLIKACE PRO MONITOROVÁNÍ SERVERŮ S OPERAČNÍM SYSTÉMEM LINUX

MASTER'S THESIS
DIPLOMOVÁ PRÁCE

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VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
FAKULTA ELEKTROTECHNIKY A KOMUNIKAČNÍCH TECHNOLOGIÍ

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NÁZEV TÉMATU:

Aplikace pro monitorování serverů s operačním systémem Linux

POKYNY PRO VYPRACOVÁNÍ:

Seznamte se s aplikací vyvíjenou na Ústavu telekomunikací pro vzdálenou práci se servery sítě PlanetLab (www.planet-lab.eu). Tato aplikace je dostupná na adrese pypi.org/project/plbmng/. Aplikaci převeďte do jazyka Python 3 a dále proveďte její aktualizaci na repositáři PyPI. Aplikaci dále rozšiřte o možnost vyhledávaní serverů sítě PlanetLab podle jejich aktuálního stavu činnosti. Vytvořený kód vystavte pod licencí MIT. Aktualizujte popis aplikace v anglickém jazyce.

DOPORUČENÁ LITERATURA:

[1] Linux Dokumentační projekt. 4. vyd. Computer Press, 2008. 1336 s. ISBN: 978-80-251-1525-1.

[2] PILGRIM, M. Ponořme se do Python(u) 3. CZ.NIC, 2010. 435 s. ISBN: 978-80-904248-2-1.

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ABSTRACT

This thesis covers details of the PlanetLab network and its infrastructure. It describes PlanetLab Server Manager (also known as plbmng) and identify its problems in the current version. Thesis aims to address these problems and describes all the improvements made to the application. Finally, it analyze the overall status of PlanetLab network using the newly developed tools for status monitoring. PlanetLab Server Manager is an application helping users to manage their projects in the PlanetLab network. It gives an ability to search for a server by its geographical position. To help enable the network projects even further, this Diploma thesis aims to improve the current plbmng application by re-writing it fully into Python 3 language. As the current application is implemented in Bash reimplementation will require complete re-design and re-implementation of functions and will allow to fully utilize perks of Python 3 language. Thesis also aims to extend existing funcionality by adding support for filtering servers by their operational status and other small improvements. Application source code is available on GitHUB under MIT licesne and application is available in the PyPI repositories as well.

KEYWORDS

PlanetLab Network, PlanetLab Server Manager, Linux, Virtualization, Multi-processing, Critical section, Python

ABSTRAKT

Tato práce popisuje síť PlanetLab a její infrastukturu. Dále popisuje aplikaci PlanetLab Server Manager (také známou jako plbmng) a identifikuje problémy v její aktuální verzi. Práce se zaměřuje na řešení identifikovaných problémů a specifikuje provedená vylepšení do aplikace. Práce také analyzuje stav sítě PlanetLab pomocí nově přidané funkcionality. PlanetLab Server Manager je aplikace, která pomáhá uživatelům realizovat projekty zaměřené na síťové služby. Aplikace primárně umožňuje vyhledávání serverů podle jejich geografické polohy. Tato práce se zaměřuje na vylepšení stávající funckionality tím, že bude aplikace plně přepsána do jazyka Python 3. Kvůli stávající implementaci v jazyce Bash, jehož vlastnosti se od jazyka Python liší, bude nutné kompletně přeplánovat stávající funkce aplikace aby bylo plně využito výhod jazyka Python. Dále se práce zaměřuje na rozšíření stávající funkcionality přidáním možnosti filtrovat servery na základě jejich stavu a další menší vylepšení. Zdrojové kódy aplikace jsou dostupné na repozitáři GitHUB pod licencí MIT a dále je aplikace dostupná v repozitářích PyPI.

KLÍČOVÁ SLOVA

PlanetLab Network, PlanetLab Server Manager, Linux, Virtualization, Multi-processing, Critical section, Python

KAČMARČÍK, Martin. *Application for monitoring of Linux servers*. Brno, 2018, 53 p. Master's Thesis. Brno University of Technology, Fakulta elektrotechniky a komunikačních technologií, Ústav telekomunikací. Advised by doc. Ing. Dan Komosný, Ph.D.

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ROZŠÍŘENÝ ABSTRAKT

PlanetLab Server Manager je aplikace jejímž účelem je pomoc uživatelům akademické sítě PlanetLab spravovat jejich síťové projekty. Cílem této diplomové práce je aplikaci programově unifikovat do Python 3 a rozšířit její funkcionalitu přidáním možnosti vyhledávání serverů na základě jejich aktuálního stavu činnosti. Dále provést aktualizaci aplikace na repozitáři PyPI a vystavení kódu pod licencí MIT. PlanetLab je celosvětová akademická síť nabízejíc přes 1300 serverů, která nabízí uživatelům infrastrukturu pro testování jejich projektů. Každý uživatel je přiřazen do skupiny zvané `slice`. Jednotka serveru se v terminologie PlanetLab nazývá `node`. Více o terminologii je dostupné v sekci 1.1. Infrastruktura sítě PlanetLab obsahuje primárně servery s operačním systémem Linux. Servery jsou ve většině případů virtuální, běžící na virtuální infrastruktuře. Aplikace PlanetLab Server Manager obsahuje ve svém nynějším stavu několik problémů. Největšími problémy jsou programová disparita, nefuknční části, chyby v prostředí, nejpřehledný kód, matoucí správa konfigurace, nutnost instalovat systémové balíčky po instalaci z repozitářů PyPI, nutnost lokalizace skriptu, pády a jiné. Jak již bylo zmíněno, tato práce se snaží problémy vyřešit pomocí nového návrhu, přepisu do Pythonu 3 a následnou aktualizaci v repozitářích. Prvním krokem k vyřešení zmíněných problémů byl nový návrh všech funkcní aplikace pro využití potencionálu jazyka Python 3. Celistvější logické bloky funkcní byly rozděleny do knihoven a napsány tak, aby je bylo možné importovat přímo z hlavní aplikace, který byl nazván jako motor aplikace, anglicky engine. Jádro aplikace je psáno jako knihovna, která sídlí ve složce `plbmng` a lze ji importovat do jinych aplikaci. Výhodou tohoto přístupu je, že PyPI automaticky skript rozpozná a umístí ho po instalaci do spustitelných složek a uživatel není nucen tudíž aplikaci lokalizovat. Naopak konfigurační soubory ve složce `bin` byly přesunuty do složky `config` což opět zjednodušuje orietnaci v aplikaci. Jedna z položek zadání bylo přidat filtraci serverů na základě aktuálním stavu jejich činnosti. Pro tyto účely byla pouzita databáze `SQLite3` a podobné soubory umístěny do nové složky `databases`. Jadro bylo logicky rozděleno na sekce obsahující grafické rozhraní a sekce obsahující vnitřní logické funkce. V rámci práce bylo provedeno spoustu vylepšení do aplikace: například se jedná o odstranění limitace výsledků vyhledávání díky použití konstrukcí jazyka Python 3 a jednodušší práci s knihovnou `dialog` než v jazyce Bash. Konfigurace aplikace byla prepracovana pro usnadneni jeji udrzby. Aplikace byla také psána za pomocí standardu PEP8, který definuje stylizace kódů pro aplikace psané v jazyce Python. Díky jazykové unifikaci také bylo odstraněna nutnost dělat jakékoliv před nebo po instalační kroky. Aplikace je po instalaci ihned připravena k použití. Vylepšení doznalo také zapisování přihlašovacích údajů. Dřívější nefunkční pole pro jednotlivé parametry bylo nahrazeno funkčním textovým editorem se snadnou orientací. Byla přidána funkce pro filtrování serverů

na základě jejich činnosti a byla implementována logika pro aktualizaci této databáze pomocí více procesů. Vykreslování mapy bylo také vylepšeno a nyní dokáže také filtrovat servery. Každý server na mapě nyní po rozkliknutí obsahuje informaci o serveru. Spousta dalších malých rozšíření jako přístup na poslední zobrazený server, menu se statistikama, podpora MacOS, opravy mnoha chyb a jiné vylepšení byly také implementovány v rámci této práce. Aplikace, včetně popisků a aplikace samotné v repozitáři PyPI, byla aktualizována na serveru GitHUB pod adresou `https://github.com/xxMAKMAKxx/plbmng`, kde lze nalézt její zdrojové kódy.
Aplikace doznala značných vylepšeních. Jako hlavní vylepšení lze vyzdvyhnout kompletní odstranění před či po instalačních kroků, přidání filtrování databází, jazykovou unifikaci a vytvoření správy konfigurace aplikace, včetně složek a samotných skriptů. Všechna tato vylepšení by měla pomoci uživatelům aplikaci používat a zároveň, v případě zájmů. Orientace v kodu bude vylepsena.. pochopit aby mohla být aplikace dále vyvíjena jako opensource projekt.

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Brno . . . .

author's signature

Contents

List of Figures

Listings

Introduction

Developing a network project can become a challenging task. Internet is a huge worldwide network and to properly simulate usage and architecture of the internet requires at least several servers on different locations at minimum. PlanetLab Network offers a global research network that enables development of new network services [28]. The goal of this Diploma thesis is to improve the existing tool, make it easier to use and publish the changes by updating the PyPI repositories. PlanetLab Server Manager is a tool that allows users to get information about nodes in the PlanetLab network and creates an user interface that helps interact with them [2]. The current state of the application can be a barrier for more extensive usage of the application and community driven improvements. Diploma thesis aims to re-write the application into Python; a popular community supported multi-platform object oriented programming language [8]. This thesis extends existing tools developed by Ivan Andrašov [2] and Filip Šuba [32].
The approach for achieving the goals of this thesis consists of using existing Bash functions and re-writing them to Python 3. During this process each functions is evaluated whether the used implementation is correct or not. During re-implementation, several enhancements to the tool will be made. Specifically, the enhancements will include removing search limitation, adding library support, eliminating pre and post installations steps, improving credentials set up, writing functions with support of Windows operating system and several minor bug fixes or improvements. To achieve easier usage of the application, main focus is put on removing system package dependencies and scrapping the necessity to localize the installation folder. To achieve better readability improvements to the implementation of functions, their names and names of menu components are added. Special emphasis is laid on logical code structure and good programming practices to empower later community improvements to the tool.
In the Chapter 1 the PlanetLab project will be introduced and characterized. Since PlanetLab infrastructure use Linux as the main operating system on nodes, it will be described in Subsection 1.3.1. Virtualization is described in Subsection 1.3.2 as it is the technology used for provisioning the PlanetLab nodes [28]. Since this thesis improves already existing tool created by other students, in Chapter 2 the tool and summary of previous work is reviewed. In the Chapter 3 the improvements made to the tool will be explained in detail.

1 PlanetLab Network

PlanetLab is a global research network that enables development of new network services. According to the PlanetLab project main page it was used by more than 1000 researches at top academic institutions and industrial research labs to develop a new technologies for distributed storage, network mapping, peer-to-peer systems, distributed hash tables, and query processing since it launch at 2003 [29]. The main page description also states that PlanetLab currently consists of 1353 nodes at 717 sites and their locations worldwide can be seen in Figure 1.1.

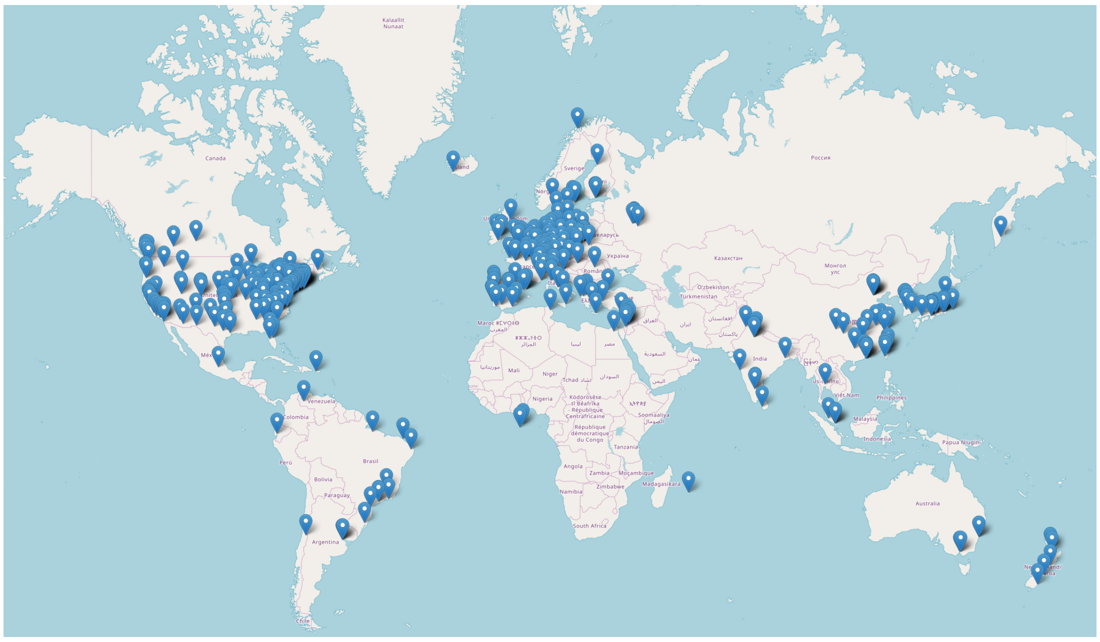


Fig. 1.1: Map displaying location of the PlanetLab network nodes.

The tool's internal database created using PlanetLab API (Application Programming Interface) consists of 1001 nodes which differs from the number described on the PlanetLab website and is most probably result of removing several nodes since the time website was updated. Important aspect to mention is that not all of those nodes are accessible. As shown in Figure 1.2, only 196 are responding to ICMP (Internet Control Message Protocol) packets and 805 are not which is only around 19.58 % reponding nodes. That means 1.62 % nodes stopped responding since the last measurement done by Filip Šuba in his thesis [32] in 2017. Important is to mention that this does not mean that the nodes are not accessible using `ssh` protocol. The `plbmng` tool can monitor accessibility of the nodes so its users always has overview which nodes can be actually used for their projects. The current committee of the project consists of members like Princeton University, Cambridge University, Intel, Google and many more [29].

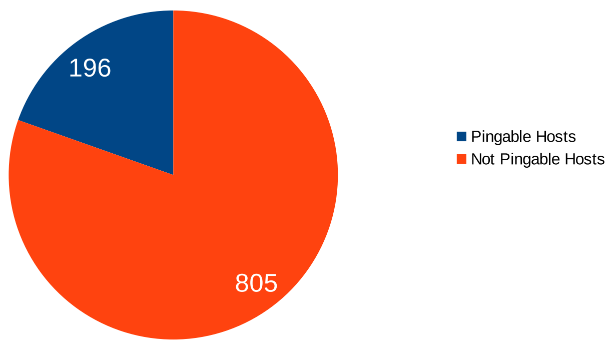


Fig. 1.2: Pie chart displaying number of nodes in PlanetLab network responding to ICMP packets.

1.1 Use and Terminology

During the initial planning of `PlanetLab network` the authors agreed on using common terminology for aspects of the network and defined them in the `Phase 0 document` [23] as follows:

- **Node:** A server machine capable of running components of PlanetLab services.
- **Site:** A physical geographical location where PlanetLab nodes are located.
- **Cluster:** The set of PlanetLab nodes located at a given site.
- **User:** An authorized human being wishing to deploy or run service over PlanetLab network.
- **Client:** A client of a service running over PlanetLab network.
- **Service:** An application running over PlanetLab network.
- **Application:** A PlanetLab service not being part of PlanetLab infrastructure.
- **Capsule:** A component of a PlanetLab service that runs on a single node.
- **Slice:** A distributed set of resources allocated to a service in PlanetLab.

1.2 Selected Projects Based on PlanetLab

In this section various projects, that PlanetLab network enabled to create, will be described. All these projects wouldn't be possible without the resources PlanetLab brings. On PlanetLab site there is partial bibliography of research enabled by

PlanetLab and it consist of over two hundred projects [29]. Having over two hundred projects enabled by PlanetLab network shows that PlanetLab had succeeded in their initial goals which was to provide a useful platform for networking and system research [23]. Example of projects enabled by PlanetLab are described in the following subsections.

Securing Web Service by Automatic Robot Detection This project is focusing on detection of automatic robots by implementing a special form of Touring test. Detection is done by comparing human versus robot behavior on the websites. According to the authors, 95 % of the human users can be detected within the first 57 requests [15].

The Design and Implementation of Next Generation Name Service for Internet Project that is aiming to solve the vulnerability of the current DNS (Domain Name System) and slow delivery of updates to the system. Project paper describes design and implementation of the Cooperative Domain Name System (CoDoNS), a novel name service, which provides high lookup performance through proactive caching, resilience to denial of service attacks through automatic load-balancing, and fast propagation of updates [18].

Slurpie: Cooperative Bulk Data Transfer Protocol Big data transfers can become problematic during peaks when huge amount of clients starts downloading the data at one point. This can occur for example during a launch of a new game or a new operating system. Slurpie is is a a peer-to-peer protocol for bulk data transfer that aims to reduce client download times of large popular files and to reduce load on the providing servers [25].

1.3 PlanetLab Inftrastructure

blabla

1.3.1 Operating System Linux

In this Chapter, the operating system Linux that PlanetLab nodes are running on, and that `plbmng` tool is developed for, will be reviewed and described. Operating system is a connecting layer between hardware and software. It provides interface to work with system resources such as disk, processor or memory and at the same time it provides service layer for client software to run at. Linux is an open-source operating system founded by Linus Torvalds who wrote its kernel using `C language` and began the history of Linux operating system. It was originally developed for personal computers based on the Intel x86 architecture but since its creation it has been ported to many other platforms such as mobile devices, television chips and many others. A package containing Linux operating system is called Linux distribution. The defining component of each distribution is the Linux kernel [4]. Original Linux kernel has been created by Linus in 1991 [9] and since then many other forks of this kernel has emerged. Some of the most famous are `Red Hat Enterprise Linux`, `CentOS`, `Fedora`, `Debian` or `Ubuntu`. More information about mentioned distributions can be found in at the end of this Chapter. The main advantages of Linux are:

- Some Linux distribtuins are free and available for everyone.
- Linux is open-sourced and everyone can contribute and review what his/her machine is running.
- Linux can run on various platforms from personal computers to televisions.
- Linux is considered to be secure. Security model of Linux is based on UNIX security principals which are considered to be robust and verified [1].
- Linux quickly adapt to changes. Since Linux has vast community behind it, it quickly adapt to security threads and new technologies.

On other hand, Linux has some disadvantages which are summarized in the below list:

- Requires more technical knowledge than other systems like `Windows` or `MacOS`.
- Huge amount of distributions can be confusing for new users to choose from.
- Many well known applications are primarily developed for `Windows` or `MacOS` (though many open source variants of these applications exists on Linux).
- Compatibility problems. Proprietary hardware can have issues with driver compatibility. Many hardware vendors are primarily focusing on `Windows` or `MacOS`.

Linux kernel can be found in majority of devices at the moment. According to StatCounter Global Stats, 41.63 % of the machines are running on Linux kernel while 36.23 % are running on Windows-based kernel as of September 2018 [27]. The rise of Linux kernel is conditioned by raising Android popularity and in 2016 the StatCounter states Linux kernel based system had only 28.44 % market share while Windows had 48.42 % market share [27]. Linux can be found also in great amount of devices from phones, desktops, servers to television or cars. Server `opensource.com` states that more then half of all SmartTV devices runs on Linux [10]. Because Linux kernel is originally open-sourced, most of the devices worldwide runs on an open-sourced operating system which shows an interesting trend switching from proprietary software. In the following paragraphs, various popular Linux distributions will be described and their key features will be reviewed.

Red Hat Enterprise Linux Red Hat Enterprise Linux is a Linux based distribution developed by Red Hat Inc. In 1994 the first version of Red Hat Linux has been released [21]. Since it launch Red Hat became a popular enterprise Linux distribution and based on Red Hat's June 2017 statistic 100 % of all airlines, telcos and commercial banks in Fortune 500 runs on their software [22]. Red Hat advertise the system being robust and stable which is its biggest advantage for the enterprise companies. Even though Red Hat is open-sourced, it is not free as it is impossible to run it without having active subscription. Red Hat uses its own packaging system called yum (Yellowdog Updater, Modified).

CentOS The CentOS (Community Enterprise Operating System) is a Linux distribution that has been originally forked from Red Hat Enterprise Linux version 2.1 and released under name `CentOS-2` in May, 2014 [11] by John Newbigin. Since then it became a community-driven project that offers and free alternative to the Red Hat Enterprise Linux. Currently, CentOS Project is part of Red Hat while declaring to stay independent of the development of the Red Hat's Linux. Due to the distribution being free while still aiming for enterprise projects, many companies and academic institutions choose the CentOS as the primary operating system for their servers.

Fedora Fedora is a Red Hat sponsored Linux distribution developed by the Fedora Project and community around it. Currently, Fedora provides several types of system images such as Workstation for personal computers, Server for servers and Atomic for containerized applications. Fedora is distribution primarily used as a desktop operating system and shares many technologies with Red Hat Enterprise Linux and CentOS making packages compatible between these systems. Fedora is often considered to be a beta environment for changes before they make it to the more conservative Red Hat Enterprise Linux.

Debian Originally created in 1993 by Ian Murdock, Debian is a free Linux kernel based Unix like operating system developed by The Debian Project and its community. Debian in oposite to Red Hat Linux based systems uses different packaging system called APT (Advanced Packaging Tool). In February 2016 the repositories of Debian consisted of 50007 binary packages [30]. Debian is popular server distribution and in 2012 it was named by PCWorld magazine the most popular distribution for web servers [12].

Ubuntu Ubuntu is a free and open-source Linux distribution based on Debian operating system. It is being developed by Canonical and Ubuntu community.

Currently Ubuntu offers three version of the system: Ubuntu Desktop for personal computers, Ubutnu Server for server and cloud and lastly Ubuntu Atomic created for IoT (Internet of Things). It is seen that Ubuntu makes the Linux more available for broader audience by having its graphical user interface similar to other operating system like `MacOS`. Ubuntu also achieved great success when Microsoft ported official Ubuntu binaries into its Windows system. Ubuntu is currently the most popular Linux distribution based on Google Trends data [7].

1.3.2 Virtualization

Virtualization is an alternative to the traditional architecture. Comparison schema between virtualization and traditional architecture can be found in Figure 1.3. The traditional architecture consist of a hardware, operating system on the host and the applications running on it. The applications needs to be compatible with the operating system to be able to run on it. On the other hand, virtualization is a layer over the hosting operating system and offers an interface for the guest operating system to use by emulating various resources such as disk, network usb and many more. Guest operating system are operating systems of the virtual hosts running on the hypervisor. Hypervisor is providing resources to each virtual host. This enables better resource handling since all the virtual machines share same resources and theoretically have access to much higher computing power. Another advantage is backward compatibility as various operating systems of a kind can be running one one host. Example is legacy version of a system that is no more compatible with current hardware but is compatible with the virtualization software. This can be particular useful for institutions that requires extremely stable well tested software running on legacy system. Next feature is high availability. If a virtual host crashes, many virtualization software are capable to migrate the run-time data to another virtual host live time. This can be crucial feature for any critical applications. On bare-metal hosts this can be solved by using for example clustered hosts.

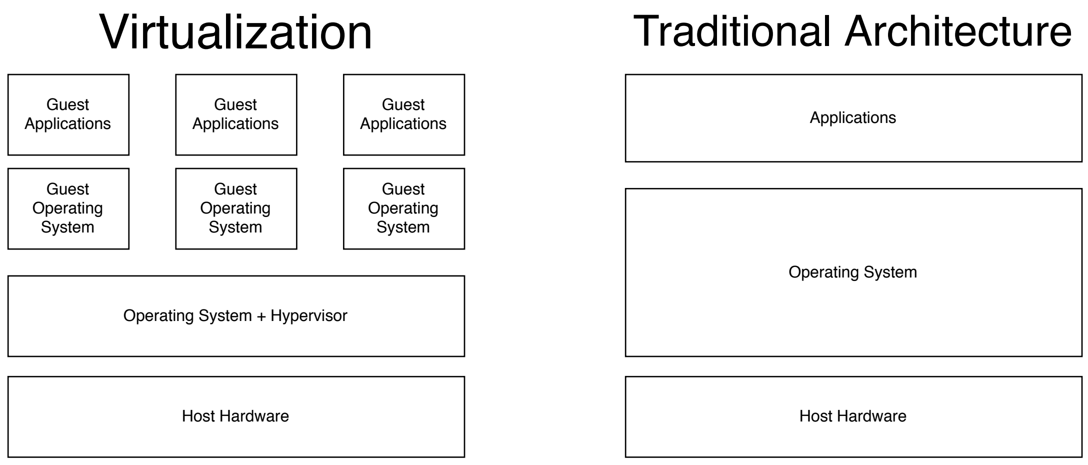


Fig. 1.3: Virtualization vs traditional architecture schema.

Currently there are many virtualization technologies available on the market. Some of the most popular ones are `VMware ESXi`, `Red Hat Enterprise Virtualization`, `Oracle Virtualbox` and `QEMU/KVM` [31]. In the following lines, some of the most popular Virtualization technologies are reviewed.

VMware ESXi VMware is a company providing virtualization software. The company provides several versions of virtualization software including `VMware ESXi` which is an enterprise virtualization solution. `VMware ESXi` was developed to run directly on the bare-metal hardware and doesn't require any other operating system to be installed on the host as it uses its own operating system called VMkernel [34]. This allows the software direct access to the hardware as it includes its own vital OS components. As VMware states in their architecture document [34], this also allows better hypervisor security, increased reliability, and simplified management.

Red Hat Enterprise Virtualization As Red Hat states on their website, `Red Hat Enterprise Virtualization` is an open, software-defined platform that virtualizes Linux and Microsoft Windows workloads [19]. `Red Hat Enterprise Virtualization` is a software that is developed to run on Red Hat Enterprise Linux, a Linux distribution developed by the same company. As Red Hat states in `Red Hat Enterprise Virtualization` datasheet, the biggest advantage of the software is its integration with other `Red Hat` products [20]. Red Hat also offers a complete operating system designed for creating virtual machines called `Red Hat Enterprise Virtualization Hypervisor`.

Oracle Virtualbox `Oracle Virtualbox` is open source virtualization software available for both enterprise as well as home use and is developed by Oracle Corporation.

As stated on the Oracle Virtualbox website: "Presently, VirtualBox runs on Windows, Linux, Macintosh, and Solaris hosts and supports a large number of guest operating systems including but not limited to Windows (NT 4.0, 2000, XP, Server 2003, Vista, Windows 7, Windows 8, Windows 10), DOS/Windows 3.x, Linux (2.4, 2.6, 3.x and 4.x), Solaris and OpenSolaris, OS/2, and OpenBSD." [14] which is a considerable availability. `Oracle Virtualbox` offers many features, which are more described in the User Manual [13], such as:

- VBoxManage, a command-line interface for `Oracle Virtualbox`.
- No hardware virtualization required, supporting even older hardware without build-in virtualization support.
- Guest Additions, which is a software packages that offers features like folder sharing, automatic window focus, 3D virtualization and more.
- Multigeneration branched snapshots, which allows taking snapshot of the virtual host in any point of time completely saving the machine state allowing users to later revert machine to the saved state.

KVM with QEMU KVM (Kernel-based Virtual Machine) is a kernel module that provides a CPU (Central Processing Unit) virtualization through the use of Intel VT or AMD-V hardware extensions. KVM runs in kernel space and handles elements like processor switching or MMU (Memory Management Unit) registers, which are used to handle the virtual machines. On the other hand, QEMU is a free open source emulator that performs hardware virtualization in the user space part of the operating system. On its own, QEMU provides also CPU emulation through binary translation however the best results are delivered when combined with KVM and it can deliver near native performance [33]. During measurement of virtual machine versus host performance using the KVM technology the Geekbench's GPU test shown only 1.19 % score decrease over the bare-metal host [17].

2 Present State Of Application Development

Plbmng application, originally called `Data miner for PlanetLab`, is a supporting application for developing projects in the PlanetLab network. It gives its user an ability to discover and search PlanetLab servers, connect to them and upload or execute scripts. The tool is available at public PyPI repository[1]. The tool allows managing `PlanetLab` nodes, gathering information about them and pulling the latest data from the `PlanetLab` API service. Its core is written in Bash and additional modules are written in Python 3 [32]. At the moment, it is depended on both Bash and Python modules and its installation consists of several steps:

- Installing the application from PyPI repository or downloading the source codes from GitHub.
- Installing additional system packages like dialog,pssh and fping.
- Locating installation folder and putting symlink into `$PATH` directory.

Since improvement of the installation process is in scope of this Diploma thesis, detailed post-improvement installation steps are described later in the Chapter 3.

2.1 Description of Current Functionality

The tool consist of two layers. First one is the application logic layer and second one is graphical user interface layer, also known as menu, and consists of several options. First menu option is `Search nodes` for retrieving a node from internal database. This options allows user to either search by DNS (Domain Name System), IP (Internet Protocol) address or by node location. Second option is `Measure Menu` that allows user to schedule gathering of data about the nodes using `crontab`, select elements to monitor or start the data gathering right now. In the `Map Menu` option user has option to generate map showing location of the nodes and select map element. After the first start of the application, user is required to fill credentials and `SSH` public key details to be able to access `PlanetLab` API and nodes using the menu option `Settings`. Menu is created using bash library `dialog` and is shown in Figure 2.1. Graphical interface can be run directly in terminal making it available even through `ssh` client without setting up any graphical tools.

[1]Link to PyPI repistory containing Data miner for PlanetLab tool: `https://pypi.org/project/plbmng/`

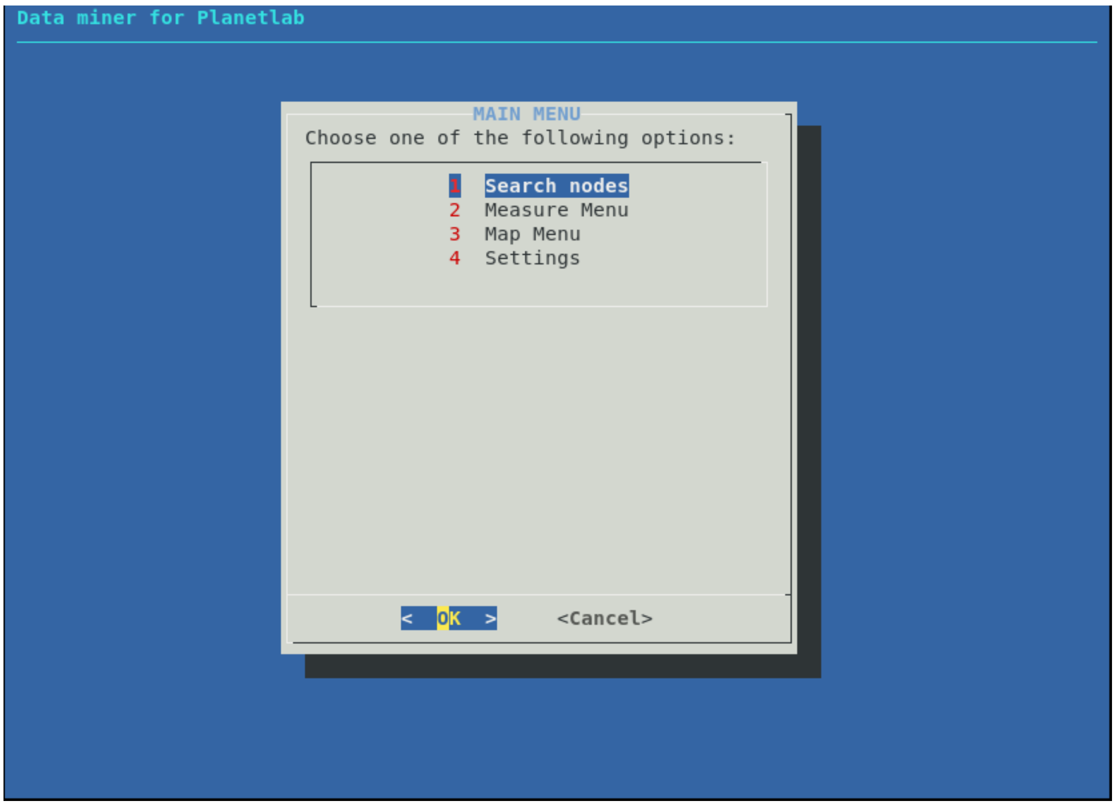


Fig. 2.1: Menu of previous version called Data miner for PlanetLab.

2.2 Identified Problems

The first problem of the existing tool is language disparity having half of the functionality in Bash and half of the functionality in Python 3. This makes it difficult to make adjustment to the tool as one needs to study a vast amount of scripts that are in several different folders. Since some of the functionality is done in Python 3, which is according to portal StackOverflow fastest-growing major programming language [26], and because it is available at PyPI (Python Package Index), Python is an ideal candidate as a main language of the project. As a part of the Diploma thesis the existing code will be re-written into Python 3. Another great advantage of Python 3 is that it is multi-platform. As Mark Pilgrim mentions in his book [16], Python 3 is available on many platform such as `Windows`, `MacOS`, `Linux`, `BSD` and `Solaris` and their derivatives.
Second area of improvement is installation of the tool and post-installation steps. At the moment, it is required to install additional packages and tool is not automatically put into `$PATH` folders forcing its users to locate the installation folder and run the script from there. Because of the single programming language being `Python 3` the dependencies for system packages will be removed and their `Python 3` counter-

parts will be added as dependency for the PyPI package. PyPI installer takes care of these dependencies automatically during the installation procedure. To remove post-installation steps the tool will be written as library allowing to create a simple `Python` script in `bin` folder which is put into `$PATH` folder by the PyPI installer during the installation.
Another improvement is renaming certain menu components and adding more information to the tool itself. This change is not significant and is purely cosmetic but can make it easier for new users to get familiar with the tool. The specific rename details will be later described in Subsection 3.2.3.
The tool currently contains a lot of bugs and bad coding practices. Example of a typical bug is whole application crashing because of missing file when returning back from `Search nodes` menu. During the rewriting into `Python 3` there is space to improve certain controls to avoid these crashes and needs to restart the application. As for bad code practices, as an example the tool currently calls functions recursively during returning from child menu page into parent one. This means the previous function menu is stored in the `stack` waiting for the application to end before released. During rewriting of the tool these implementation details can be changed to stick with the good coding practices.

3 Implemented Improvements to PlanetLab Server Manager

This Chapter will discuss improvements made to the PlanetLab application. The improvements are based on the analysis made in the Section 2.2. The implementation details will be described and shown. The goal of the re-implementation is to make the `plmbng` tool simple to use, easier to contribute into by re-writing it fully into Python 3, using good coding practices, remove any post-installations steps and making small improvements. Improvements includes:

- Removing result limitation by dynamically creating menu using Python `list`.
- Adding support to use application as library by logically separating each function.
- Increasing readability and improve orientation in the application by renaming menu components and using descriptive functions names.
- Eliminating pre and post installation steps by using automatic `pip` dependency installer.
- Improving credentials set up by adding internal text editor.
- Extending Windows support to several functions by detecting operating system and dynamically changing parameters.
- Few minor bug fixes and improvements.

3.1 Re-design of Application

This Section will describe the approach taken to improve the application. The issues of the application, described more in Section 2.2, are that there are two different languages, functions are scattered and configuration management is not existing. During re-design, all these problems were taken into consideration and addressed. First problem, already well described, was solved by re-writing the application fully into Python 3 language. Second and third problem were resolved using re-design of the application folder structure and architecture. The overall architecture of re-designed application is shown in Figure 3.1 and will be described in the next paragraph.

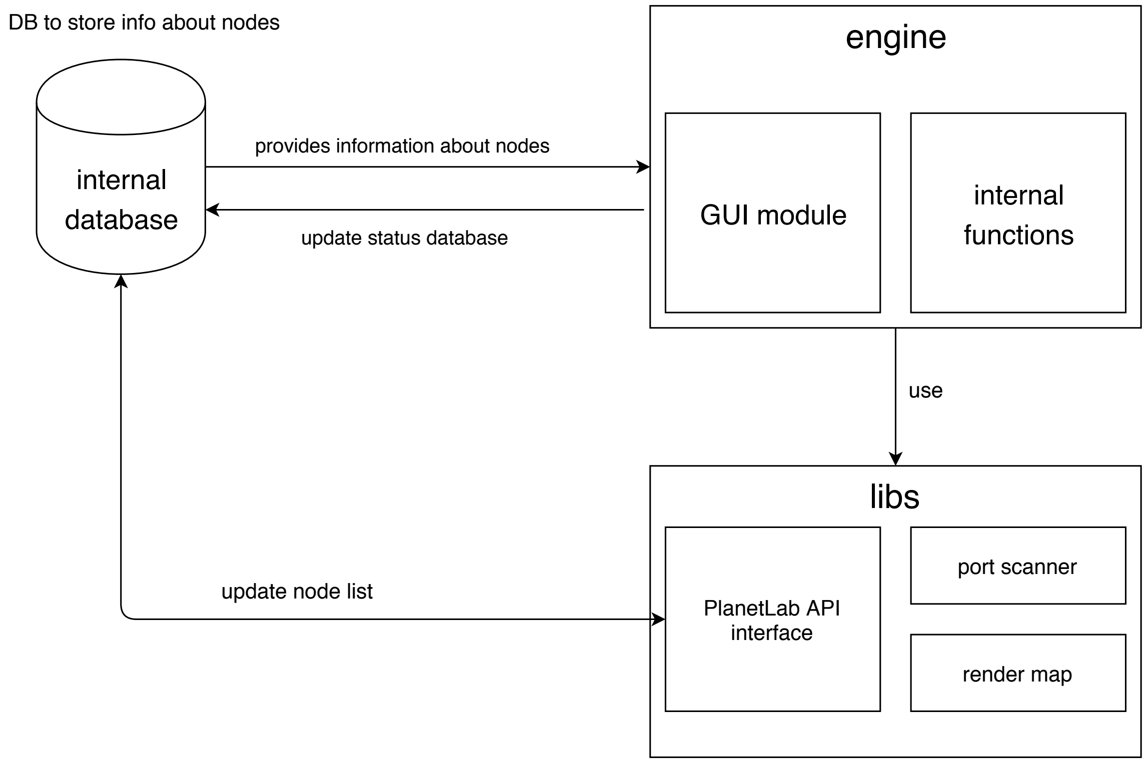


Fig. 3.1: PlanetLab Server Manager architecture diagram.

Issue with scattered functions was solved using single file, the `engine.py`, for all the common internal functions and graphic functions and libraries for more complex functionality of the application. To make it easier to navigate inside the engine file, it was divided between graphic and internal logic sections. A question why not to split the graphical and internal logic might come to a mind. Currently, the engine module graphical and internal functions are calling each other as an reaction to certain states. Splitting them would mean importing each other in a circle which is not an ideal state. Having both sections in one file makes it one solid logical component, called the engine. However as mentioned, there are certain independent components that are split into their own files. In the Figure 3.1, these are described as `libs` and contains several utility functions that can be called independently and are imported as a library inside the `engine`. Currently, there are three of these utility modules. PlanetLab API interface, which provides functionality to update the list of servers, port scanner which allows to check port accessibility of remote host and lastly module that allows to render map of nodes using a dictionary of nodes as input. On of the challenges during re-design was a placeholder for all the information about nodes that application can later used. Previously, a text file was used to store this data. Issue with this is to implement a filter function for example, it would require to write a custom module for queries which is an unnecessary overhead as there are already solutions available to provide such module. One of these solution is relational database with SQL used as a query language. SQL is a structured query language designed to manipulate data in relational tables which are nothing more than set of related information [3]. This fits perfectly application needs as it stores a set of nodes with their related status information. In the Figure 3.1, this is shown as an internal database module. Engine triggers update of status of available nodes whereas PlanetLab API interface library updates the list of nodes. Python provides a `SQLite3` library that allows creating a custom database stored on disk. This database file is placed inside the database folder in the application configuration management. Mentioned architecture decisions will allow application to be more easily salable and maintainable in the later development phases.

3.2 Description of Improvements

In this Section, the steps to achieve goals; which were described in the Chapter introduction; will be shown in detail in their own Subsections. For each Subsection the approach, specific steps, code examples and results will be illustrated. Since the new implementation uses `pythondialog` module, at the start of the tool an instance of the `Dialog` class is spawned and will be later described just as the `instance`.

3.2.1 Removing Result Limitation

The previous version of `plbmng` tool has been limited to 10 result when searching for a node. This issue was introduced due to difficulty of creating a menu based on dynamic results since author needed to always add a new argument to the overall command. This also can hit limitation of characters that can be passed in a Bash command line. In Python 3 this problem is non-existing since `pythondialog` module is creating menu functions based on list. During the search of the nodes, results are added to the list which is after completed search passed to the instance which renders the GUI (Graphical User Interface). Example of this functionality is shown in Listing 3.1. Currently, the tool is returning all results found.

```python
def searchNodesGui(prepared_choices):
  if not prepared_choices:
    d.msgbox("No results found.", width=0,height=0)
    return None
  while True:
    code, tag = d.menu("These are the results:",
                  choices=prepared_choices,
                  title="Search results")
```

Listing 3.1: Removing Result Limitation

3.2.2 Writing the Application as Library

For the application to be used in other scripts and reduced the need to re-write certain code parts it is desired to write application to be able to run as a library. During the re-implementation this was considered and application is available both as library and standalone script. This will be later used in the Subsection 2.2. If the application is called as a standalone script, it will trigger part of the code that is shown in 3.2 and initialize a graphical interface for the user to use. If imported as a library, it allows the user to call any function defined in the script.

```python
if __name__ == "__main__":
  initInterface()
  exit(0)
```

Listing 3.2: Condition to recognize that application is being called as a standalone script.

3.2.3 Increasing Readability

Community is a powerful group that helps develop a tool and to add more functionality to it. To have community contribute to a tool, it should follow good practices and be easily readable. Previous version of the tool was using Bash script which was calling Python script and creating new Bash scripts on a disk which was merging using different pieces of code from pre-created `.dat` files in a `bin` folder. Finding a bug in this structure was difficult and non-intuitive. All these pieces of code were fully re-written into single Python script and logically divided into two sections. One section is for GUI functions and other is for logical functions. Each functions is very descriptive in its name as shown in Listing 3.3.

```python
def searchNodes(option,regex=None):
def initInterface():
def plotServersOnMap(mode):
def getPasswd():
def searchNodesGui(prepared_choices):
def printServerInfo(chosenOne):
def setCredentialsGui():
```

Listing 3.3: Example of Function Names

Each functions is trying to be as atomic as possible only having one purpose. This is helping to increase modularity of the application. Outside of this functions "categories" application is removing any `magic numbers` by defining constants at the beginning of the source code. This greatly helps to understand what is being passed as an argument and is shown in Listing 3.4 where it is descriptive what option is being passed as a search key to the `searchNodes` function. Also, the application has a block for `Initial settings` at the beginning for one single place where outside of functions definitions can be placed. Application is also honoring the conventions defined in PEP (Python Enhancement Proposal) 8 [24], like naming convention and space usage instead of tabs, as much as possible. In default, scripts like `pylint` uses snake case style naming convention however camel case that is actually described in the official pep 8 standards as a recommended descriptive naming style [24]. All these small items described are increasing the overall readability of the application for others to quickly become familiarized with it. Currently, `engine.py` received score of 7.38 `pylint` with main complains being about missing doc strings and certain small warnings regarding wrong import and other small deviation from the PEP 8 standard.

```
code, tag = d.menu("Choose one of the following options:",
          choices=[("1", "Serach by DNS"),
                   ("2", "Search by IP"),
                   ("3", "Search by location")],
                   title="ACCESS SERVERS")
if code == d.OK:
  #Search by DNS
  if(tag == "1"):
    code, answer = d.inputbox("Search for:",title="Search")
    if code == d.OK:
      searchNodes(OPTION_DNS,answer)
    else:
      continue
```

Listing 3.4: Example of Constant Usage

As mentioned in the Section 2.2, renaming certain parts of the tool can improve the readability. Since the tool is not data mining rather than server manager, the tool is internally renamed from `Data miner or PlanetLab` into `PlanetLab Server Manager`. Version is added next to the name for users to see which they are running immediately. Another example is renaming `Search nodes` to `Access servers` since primary function of this menu item is to access the servers while search is just supporting it. The re-designed application can be seen in Figure 3.2.

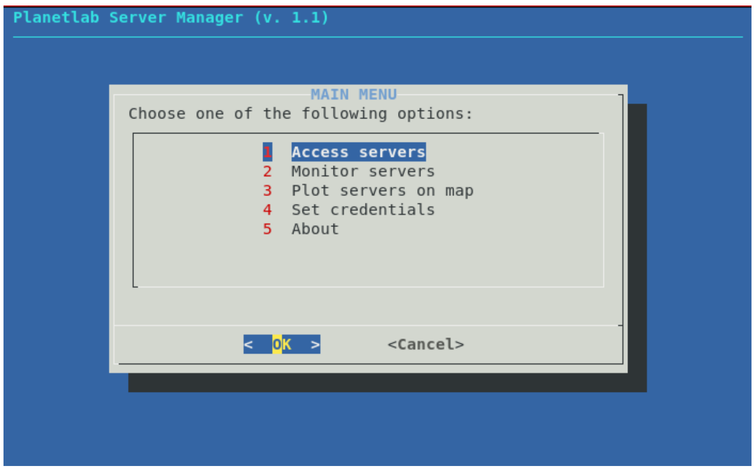


Fig. 3.2: New re-designed menu with added name, version and various name changes.

3.2.4 Removal of Pre and Post Installation Steps

Previous version of application required several pre and post installation steps. In the new version developed as part of this Diploma thesis, all these steps were removed. Pre-installation steps were eliminated by completely getting rid of dependencies on additional system packages. All the dependencies were moved into the PyPI package definition and are taken care off PyPI installer during installation of the tool. Post-installation steps were removed by adding the application into `bin` folder in the PyPI package. During installation, the PyPI installer automatically puts any scripts in the `bin` folder into a `$PATH` folder making it accessible directly from command line without the need of accessing installation folder. The contents of the script located in `bin` folder can be seen in Listing 3.5. The duplication of names seen in the Listing are created by having the `plbmng.py` script in the `plbmng` folder describing the library. This area is a good candidate for additional improvements that will be made later in the following Diploma thesis.

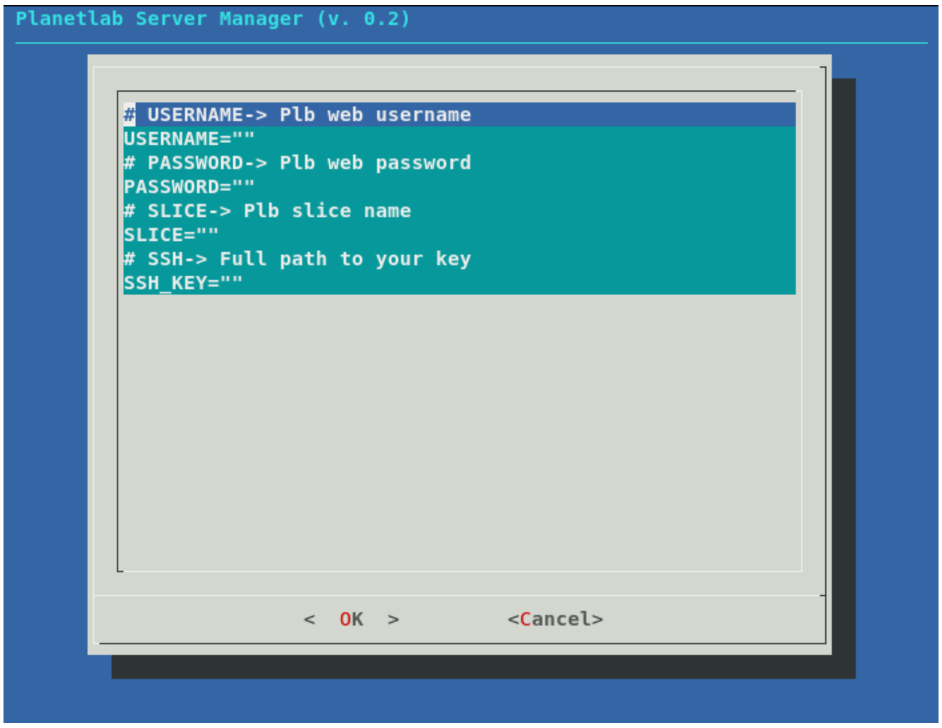
```python
#!/usr/bin/env python3
import plbmng.plbmng
import sys

if len(sys.argv) > 1:
  if(str(sys.argv[1]) == 'crontab'):
    plbmng.plbmng.crontabScript()
    exit(0)
plbmng.plbmng.initInterface()
```

Listing 3.5: Source Code of Plbmng Executable Script

3.2.5 Credentials Improvement

In the previous version of the tool the credentials were filled using `dialog` forms. When typing the credentials, nothing was shown except stars thus user was unaware where is the position of the cursor. Also saving of the credentials was not working properly resulting into the need to adjust the configuration file itself which required locating the file first by inspecting the source code. In the new version settings credential is improved by creating a virtual editor in the graphical interface itself, as shown in Figure 3.3, that allows the user transparently set the credentials. One of the disadvantage of this approach is plain text visible password in the editor as it is not hidden and user needs to be careful about setting the credentials in a safe environment. To the addition of this improvement, various credentials checks were added to the application. First run of the application will always trigger window advising user to fill credentials first. If a user chose to update a database without having credentials filled a warning message will pop-up warning the user about that fact. Also, when user wants to ssh to a server without having username and key filled he will have warning text near the ssh option. These improvements should prevent users forgetting about filling credentials and failing actions in the application.


```
Planetlab Server Manager (v. 0.2)

# USERNAME-> Plb web username
USERNAME=""
# PASSWORD-> Plb web password
PASSWORD=""
# SLICE-> Plb slice name
SLICE=""
# SSH-> Full path to your key
SSH_KEY=""

<  OK  >          <Cancel>
```

Fig. 3.3: New window for setting up credentials using internal text editor.

3.2.6 Application Folder Structure Re-design

With changes to the architecture of the application, folder management needs to be also adjusted accordingly. The root folder of the application contains two main parts, outside of necessary `PyPi` files. It is the `bin` folder with `plbmng` script itself and the `plbmng` folder which contains the whole application logic and graphical interface. This folder will be now described in detail. As shown in Section 3.1, libraries are placed in the `lib` folder instead of `python_scripts` previously. In past, the configuration files were stored in `bin` folder with some shell libraries. This is now re-named to `conf` folder and library functions are moved to the `lib` folder. There are information that needs to be stored persistently, like information about accessibility of nodes. For this purposes, there is a folder called `database` which contains file like `internal.db` which is already mentioned `SQLite3` database. With all these changes to the folder structure, the project should be now more transparent, clear and easier for other developers to join the project.

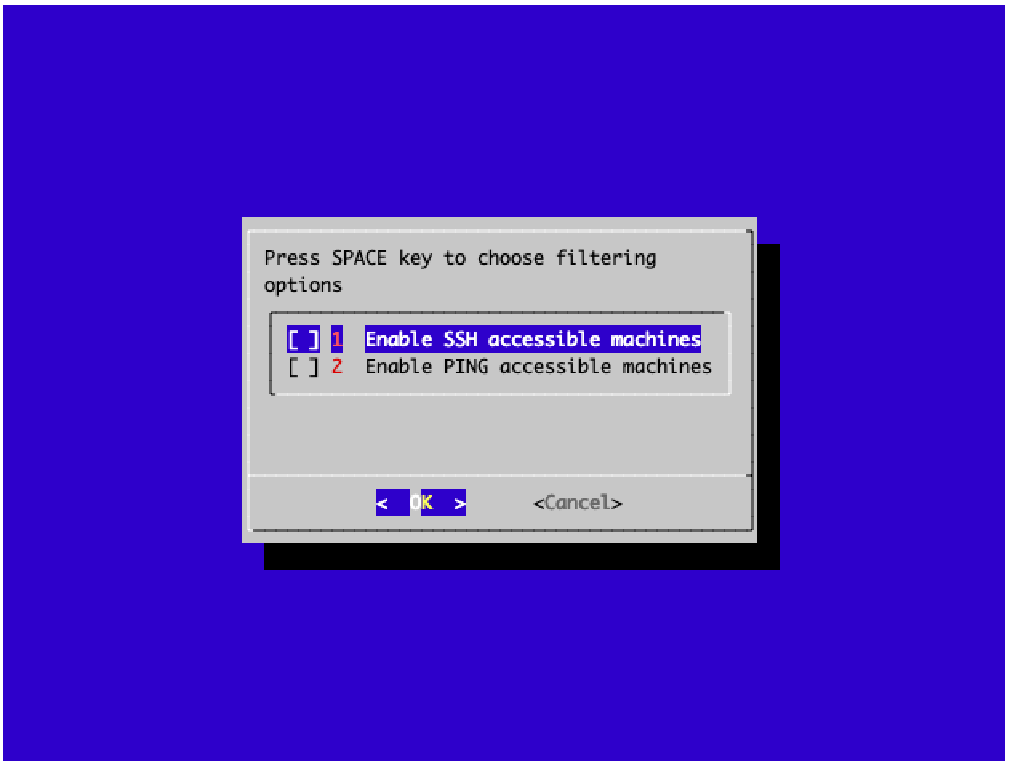
3.2.7 Filtering Nodes Based on Accessibility

One of the goals if this Diploma thesis was to add a functionality to filter nodes based on their accessibility. This subsection will describe how the functionality was designed and implemented. The overall idea was to add a way to filter current node based on their availability, have an option to change these settings, show these settings and have a way to update the data. In the following paragraph, all these items will be described more in detail.
As it was mentioned in Section 3.1, the core of this functionality was to have a placeholder for the data about the nodes. This was achieved using the `SQLite3` Python library. To store the information, table `availability` was created and its structure can be seen in Table 3.1. First, `nkey` column is a primary key column that contains ID of the table row. Next is `shash` that contains unique hash of the node hostname. This hash is used to find already existing records so these are not duplicated but only updated. Hash is generated using md5 function and `hashlib` Python library. Next column is a `hostname` of the node for purposes of filtering and lastly there is the double `bssh` and `bping` which are Boolean flag displaying node accessibility. During inserting into the database, `nkey` is automatically incremented so only the other values needs to be specified. Before the filtering is explained, first the internal logic working with nodes needs to be explained. When an user asks to show nodes, the search function takes a dictionary of nodes as an input parameter. This simple logic is used for the filtering itself. In the function `getNodes()`, before the list of nodes is parsed, the current settings are loaded from the database from the `configuration` table which contains simply ID, name of the setting and Boolean if it is enabled or not. These settings are used to get all hostnames of the nodes that fits the current settings. For example if user wants to filter only ssh available nodes, the query will be `select * from availability where bssh='T'`. With the list of desired nodes the function will always return only nodes that fits user's filter criteria.

nkey	shash	shostname	bssh	bping
2	fe27ca7d1707e86e1739b1819743dc79	planetlab2.fri.uni-lj.si	F	F
3	57da801bf4370f2a163a81bdf6bafa8c	ple01.fc.univie.ac.at	T	F
4	3c956d5e295f17cb303773f83c84bf17	aladdin.planetlab.extranet.uni-passau.de	T	T

Tab. 3.1: Structure and examples of availability table for filtering functionality.

Applying filters is done using `Filtering options` in the `Access servers` menu. As shown in Figure 3.4, user can choose between ssh or ping available nodes. The selection is done using checkboxes. The choices are then shown in the `Access servers` menu on the top as *Active filters* line with the listing of the active options.


```
Press SPACE key to choose filtering
options

[ ] 1  Enable SSH accessible machines
[ ] 2  Enable PING accessible machines

        <  OK  >        <Cancel>
```

Fig. 3.4: Figure showing menu where user can select active filters.

3.2.8 Updating Status Database

Updating the status database, or to be precise updating table inside the database, can be triggered from the `Monitor servers` menu. This will start a progress bar that takes approximately two minutes after optimization. Before optimization, the procedure took around 40 minutes. This speed was reached using multi-processing. Once procedure to update database is triggered, fifty processes are spawned at a same time using Python *multiprocessing* library. List of nodes is passed as an iterator to go over in a loop to the Pool object as shown in Listing 3.6. In addition, one lock is created to take over critical section of updating the shared status database and progress bar. Critical section can be defined as an area in a computer program where process operates on the shared variable by changes its value [5]. Once a process reaches the critical section, it needs to acquire the lock to enter into it. Once a process has acquired the lock, it can start writing into the shared memory without any issue. As soon as it is done, the lock is released and another process can acquire it and start writing into the critical section. To be able to show correctly the progress, once a process finishes a task, it will lock the progress bar value, increase the progress variable with an increment that is derived from total number of nodes and then unlock the progress bar iterating to another node to gather information about it. The code of entering the critical section can be seen in Listing 3.7

```
pool = Pool(50, initializer=multiProcessingInit,
      initargs=(lock,base,increment, ))
pool.map(updateAvailabilityDatabase, nodes)
```

Listing 3.6: Creating a multi-processing object with fifty processes three shared variables and list of nodes as iterator.

```
lock.acquire()
base.value = base.value = increment.value
updateProgressBarMultiProcessing(base.value)
lock.release()
```

Listing 3.7: Entering a critical section and acquiring a lock.

3.2.9 Map Improvements

In the previous version of the application, user could render all nodes in the node database on a map. It displayed markers which, upon clicking, showed hostname of the node. During implementation of filters, maps were also enhanced. Now, user can select between three maps to render; full map, map of nodes available over ssh and map of nodes that are ping-able. In addition, upon clicking, user can see all the stored information about the node as can be seen in Figure 3.5. The library for rendering the map was changed to use the same principle as search function. Instead of reading nodes from a file, it gets them passed as a parameter. While triggering the map module, nodes are loaded using `getNodes()` function that takes filtering into consideration in default. The filter in this case is only adjusted by the user's choice. Later, in Chapter **??** the information from map filters will be used to analyze *PlanetLab Network* more in detail. For user, maps filters are good opportunity to see which server are actually available for project testing and possibly create an uniform list of candidate nodes that are spread all over the world.

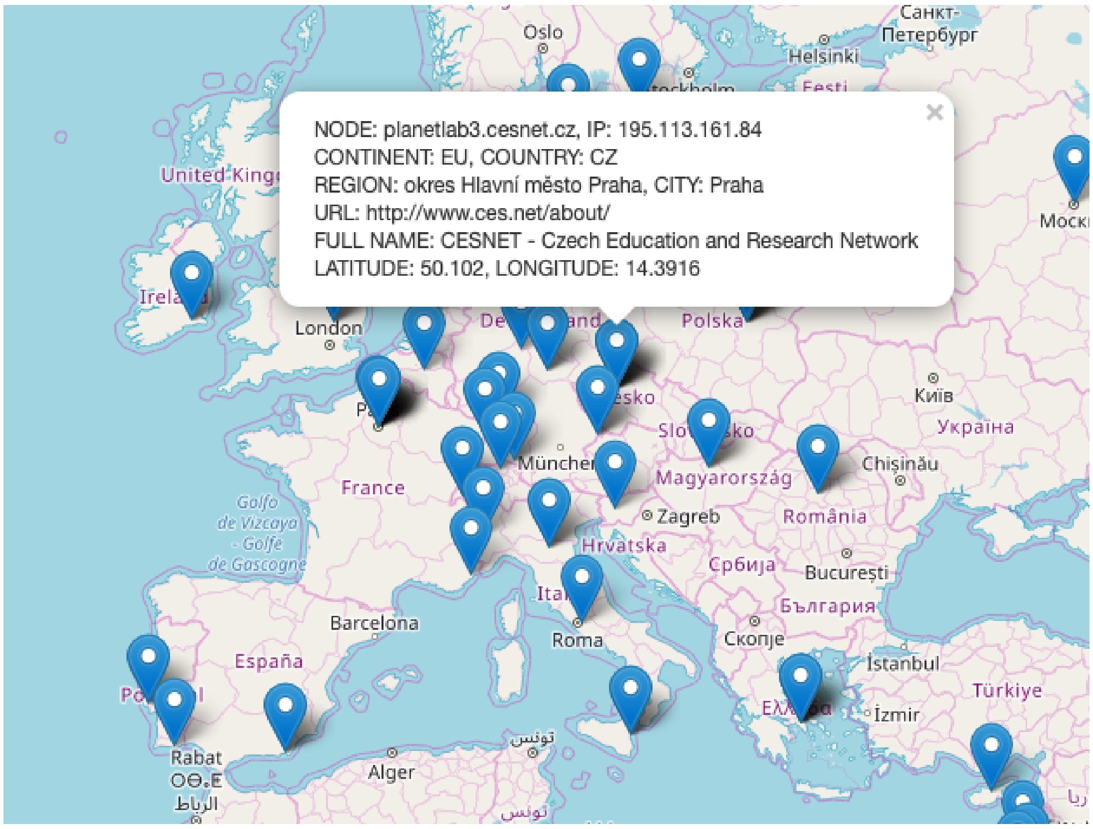

NODE: planetlab3.cesnet.cz, IP: 195.113.161.84
CONTINENT: EU, COUNTRY: CZ
REGION: okres Hlavní město Praha, CITY: Praha
URL: http://www.ces.net/about/
FULL NAME: CESNET - Czech Education and Research Network
LATITUDE: 50.102, LONGITUDE: 14.3916

Fig. 3.5: Figure showing the detail of a node upon clicking on its marker.

3.2.10 Minor Improvements

In this Subsection, minor improvements done during the re-implementation are described. All these improvements were considered minor hence these are not having separate Subsection. More improvements to the tool will be done in the Diploma thesis following up on this Diploma thesis.

Clearing of the screen after cancel When signal was send to the application using `CTRL + C` key combination, the previous version of the application was not clearing the current terminal window and the GUI. To use the same terminal user was forced to clear the window manually. In the new version, when signal is send to the application, signal handler will catch it and clean after itself.

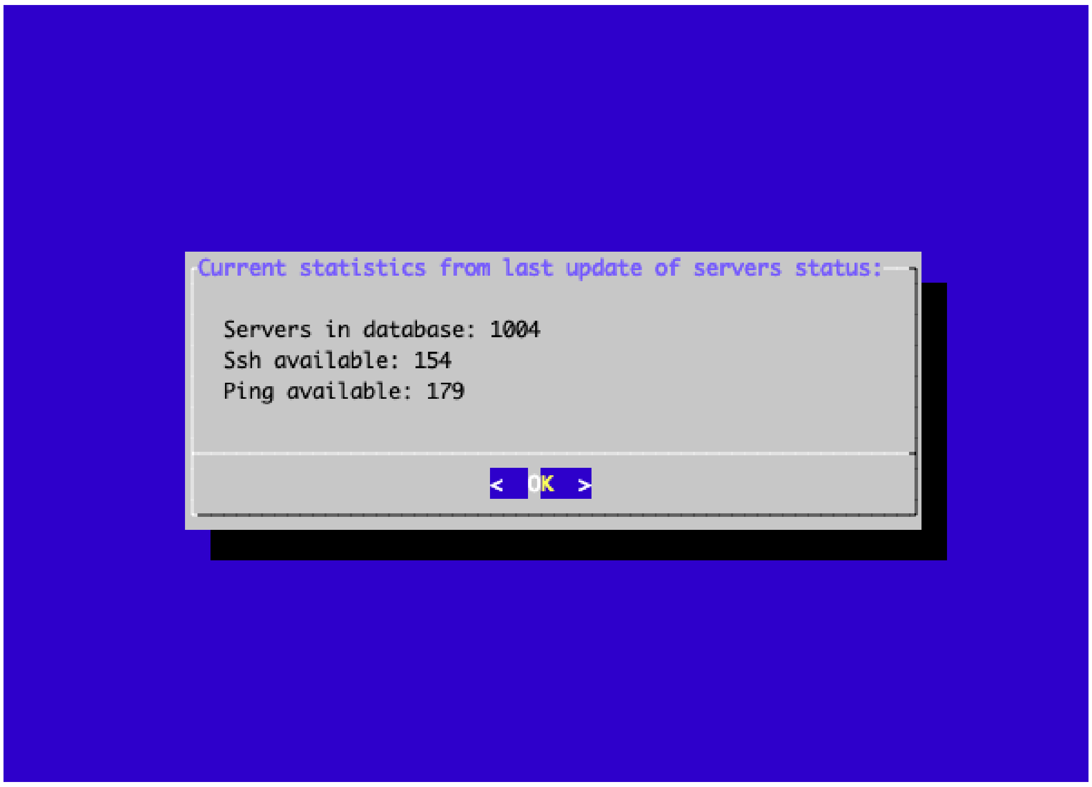
Recursion removal for return When returning from child window to a parent page, the previous version of application was recursively calling the GUI function. This is not following good coding habits as each recursive call means storing the previous function details into the system stack, unnecessarily filling it. In the new version, while cycle is used instead and returning from a function results into new iteration of the while cycle not storing anything onto the system stack.

About is added to the menu About section is added to the menu displaying version, authors and the license.

Crontab mode created Application is possible to run with `crontab` argument which will trigger just monitoring of the nodes. This is in particular useful when setting the `crontab` since the call can be simply `plbmng crontab`. This mode can be used to setup a regular updates in background to the node database.

Last server access User has now ability to return to last accessed server it the `Access servers` menu. In default, this option will just print warning message that no node was accessed. However, as soon as user access first node, this node is stored into the database in form of dump of the node dictionary variable. If user wants to access the last accessed node, this dictionary is dumped back to an internal variable and used to show this node with all the information and options.

Menu with statistics Since status database already contains all the necessary information a simple functionality regarding accessibility of the stored nodes was added to the application as can be seen in Figure 3.6.



```
Current statistics from last update of servers status:

  Servers in database: 1004
  Ssh available: 154
  Ping available: 179
```

Fig. 3.6: Newly added option to display current statistics about accessibility of stored nodes.

Support of Multiple Platforms As was mentioned previously, Python is multi-platform language and brings possibility of porting the application to all kinds of operating systems. During the re-implementation of the application this was taken into considerations and new functions were written to be able to run on Linux, Mac and possibly later on even Windows. Example of this multi-platform implementation can be seen in Listing 3.8 showing function `testPing` supporting all mentioned operating systems. As both Linux and Mac are Unix based, the implementation for these operating system is fairly simple and only minor changes are usually in several parameters. Perfect example is `ping` function. On Mac, time-out parameter takes one integer in millisecond as input variable. However, on Linux, the time-out parameter takes the integer variable in seconds. These little differences needs to be kept in mind when implementing platform-based functions. For Windows however, the differences are even more complex and all the libraries used in `plbmng` have to have Windows support. This was never tested yet even though most of the functions were written with Windows in mind. Adding full Windows support is a good initiative for the future development of `plbmng`.

```python
def testPing(target, returnbool=False):
  pingPacketWaitTime = None
  if system().lower() == 'windows':
    pingParam = '-n'
  else:
    pingParam = '-c'
  #for Linux ping parameter takes seconds while MAC OS
     ping takes miliseconds
  if system().lower() == 'linux':
    pingPacketWaitTime = 1
  else:
    pingPacketWaitTime = 800
  command = ['ping', pingParam, '1', target, '-W', str(
     pingPacketWaitTime)]
  p = subprocess.Popen(command, stdout=subprocess.PIPE,
  stderr=subprocess.PIPE)
  # prepare the regular expression to get time
  if system().lower() == 'windows':
    avg = re.compile('Average = ([0-9]+)ms')
  else:
    avg = re.compile(
    'min/avg/max/[a-z]+ = [0-9.]+/([0-9.]+)
       /[0-9.]+/[0-9.]+')
    avgStr = avg.findall(str(p.communicate()[0]))
  if p.returncode != 0:
    if not returnbool:
      return "Not reachable via ICMP"
    return False
  else:
    p.kill()
    if not returnbool:
      return avgStr[0]+" ms"
    return True
```

Listing 3.8: Multi-Platform Function testPing

3.2.11 Minor Bug Fixes

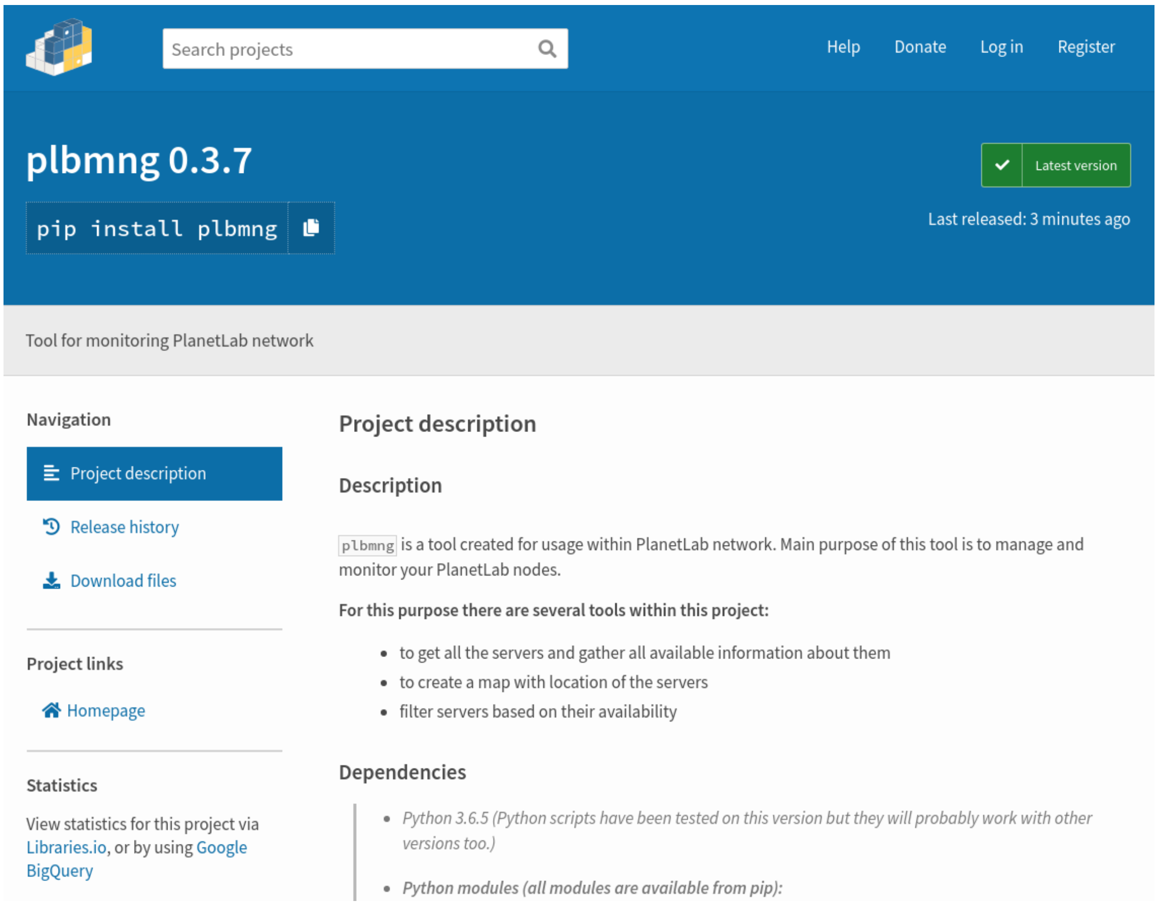
In this Subsection, minor bug fixes will be described which were not considered as enough improving to be included in separate Subsection.

Removing headers from the searches During the search, previous version of the script has also included header of the file containing information about nodes resulting into false search results. Header is now skipped and these false results are removed.

Application crashes during return When returning from a child menu window to a parent page, the application tend to crash on `grep` tool not being able to find file. During re-implementation this bug was fixed and returning now fully works.

3.3 Improved Installation and Use of Application

In this Section, the post-improvements installation procedure is described and workflow diagram is shown in Figure 3.8. After implementing improvements, application has been updated in the PyPI repository and is available at `https://pypi.org/project/plbmng/` in version `0.3.7`. Application repository web page can be seen in Figure 3.7 and is describing the tool purpose, its Python package dependencies, installation steps, basic usage and authors. Repository page gives ability to the user to see release history or download the source files of the project. It also show the maintainers of the projects and allows users to contact them. License under which the application is written can be found the repository page as well. As part of this Diploma thesis, the description was completely changed to reflect the current settings. It was improved to be more simple for the user by reducing amount of text on the page and keeping only necessary information.



plbmng 0.3.7

```
pip install plbmng
```

Last released: 3 minutes ago

Tool for monitoring PlanetLab network

View statistics for this project via Libraries.io, or by using Google BigQuery

Project description

Description

`plbmng` is a tool created for usage within PlanetLab network. Main purpose of this tool is to manage and monitor your PlanetLab nodes.

For this purpose there are several tools within this project:

- to get all the servers and gather all available information about them
- to create a map with location of the servers
- filter servers based on their availability

Dependencies

- *Python 3.6.5 (Python scripts have been tested on this version but they will probably work with other versions too.)*
- *Python modules (all modules are available from pip):*

Fig. 3.7: PlanetLab Server Manager web page in PyPI repository.

The installation steps are described in detail in the tool's repository page and consist of:

1. Installing the application using `pip3 install plbmng` command.
2. Starting the application using `plbmng` command.
3. In first start it is required to set up credentials using the `Set credentials` option in menu.

After this basic setup all the application functionality is available. It is recommended though, to update the list of nodes using `Get nodes` option in `Monitoring` menu. Installation steps are successfully reduced compared to the old version which consisted of:

1. Installing system packages using `sudo dnf install -y dialog pssh fping` command.
2. Installing the application using `pip install plbmng` command.
3. Locating the application in a hidden folder of pip tool.
4. Finding a configuration file and using an editor to update it.
5. Running the application using absolute path.

To summarize, current application functionality workflow diagram can be seen in Figure 3.8. For clarity, the Figure is missing returning arrows however each node in the diagram is able to return to its parent. As seen in the Figure, first step is when menu is being initialized. From there user has option to either open `Access server menu`, `Monitor servers`, `Plot servers on map`, `Set credentials` or select `About`. `About` is a single window option that will show information about the software, its authors and license. `Set credentials` option will open an interactive editor where user can fill the credentials for PlanetLab network. Next option is `Plot servers on map` which offers user to choose which map elements should be rendered. After confirmation the map is generated and opened in the system default browser. `Monitor servers` option divides into three different options. First enables user to setup `crontab` to periodically scan for nodes, second option is for setting up monitoring elements and third triggers the scanning immediately. At last, `Access servers` allows users to access the nodes by searching for them either using DNS name, IP address or location. After the search key is inserted, the available results are shown. When specific node is chosen, information about the node are displayed and user has options to connect to the node using ssh, Midnight Commander or show the node on map.

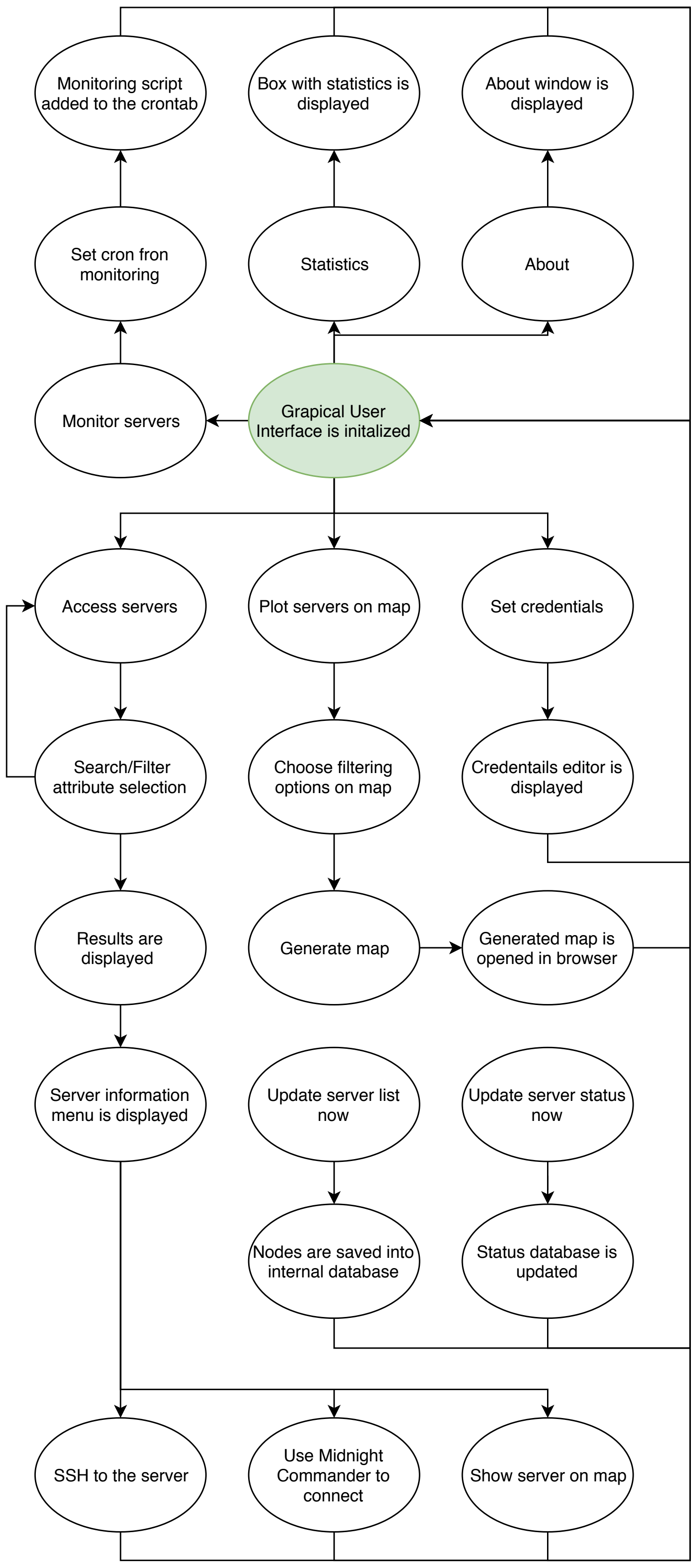

Monitoring script added to the crontab
Box with statistics is displayed
About window is displayed
Set cron fron monitoring
Statistics
About
Monitor servers
Grapical User Interface is initalized
Access servers
Plot servers on map
Set credentials
Search/Filter attribute selection
Choose filtering options on map
Credentails editor is displayed
Results are displayed
Generate map
Generated map is opened in browser
Server information menu is displayed
Update server list now
Update server status now
Nodes are saved into internal database
Status database is updated
SSH to the server
Use Midnight Commander to connect
Show server on map

Fig. 3.8: PlanetLab Server Manager behavioral diagram.

4 PlanetLab Server Manager Use Cases

In this Chapter, various use cases of the PlanetLab Server Manager tool will be revised and described. First, analysis of the PlanetLab Network will be done in Section 4.1. In Section 4.2, the very basic use case of the application, testing network projects in the PlanetLab Network, will be described and shown.

4.1 PlanetLab Network Analysis Using Plbmng Tool

In this Section, the Planet Lab network will be analyzed and discussed using the newly developed features plus using the `plbmng` database of servers pulled from the PlanetLab API. Also, data from Chapter 1 introduction will be compared to new ones with time difference of five months.
PlanetLab Network is a huge project which consists of 1353 nodes at 717 sites [29]. Currently, there are around one thousand servers available to the *cesnet_utko* user from 52 countries world wide. The Figure 4.1 shows 20 countries, represented by their country code, with the most node contribution to the network which X axis showing the country and on the Y axis showing the node count for the specific country. Most of the countries are from United States with the impressive node count of 388, second is China with its 58 nodes and third is Germany with their 49 nodes.

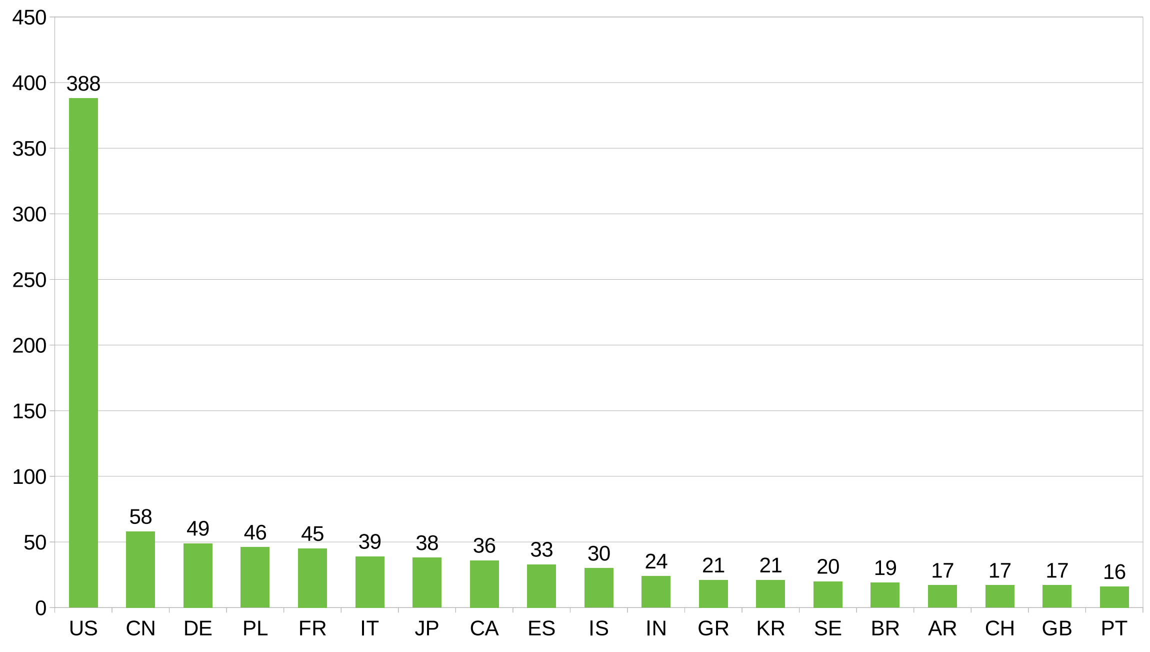


Fig. 4.1: Graph displaying top twenty countries and number of nodes they have contributed to the PlanetLab Network.

Geographically, the nodes are all over the world and are more then suitable to test large scale network project requiring multiple servers in different locations all over the world. All the nodes on a world map can be seen in Figure 4.2 which was created using `plbmng` application.

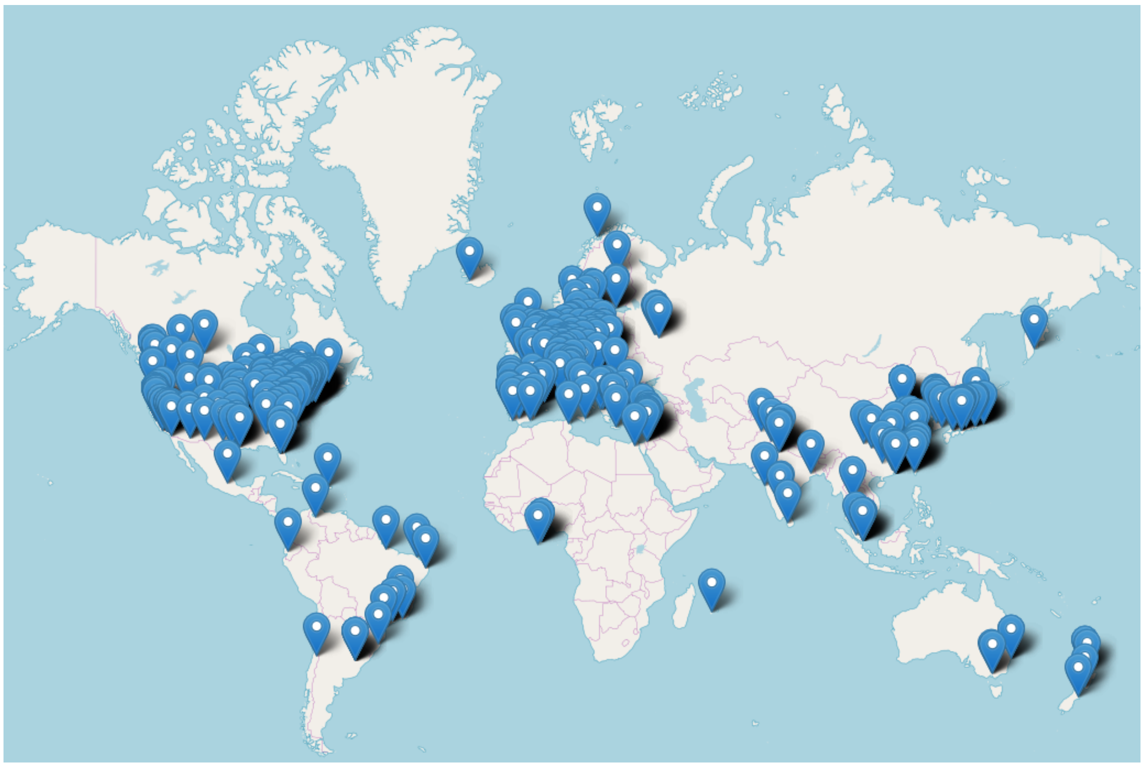


Fig. 4.2: Map of nodes on world map using the PlanetLab Server Manager node database and map rendering functionality with data from April 2019.

However, not all the nodes are available. As seen in Figure 4.3, from the database 1004 nodes only 168 nodes are responding to ICMP packets and only 140 are listening on port 22 which is usually used for ssh. That is a very low availability percentage of only 16.7 % nodes responding to ping and even less 13.9 % listening on port 22. That is extremely low number of available nodes and shows that the universities offering their nodes often do not maintain them to make sure these are still available or have left the project without decommissioning the node in the PlanetLab interface. Also, an interesting fact is that there are 28 nodes that are responding to ICMP packets but are not listening on port 22. Explanation can lie in stuck `sshd` agent or some network restrictions which are preventing to access the port 22 on specific server.

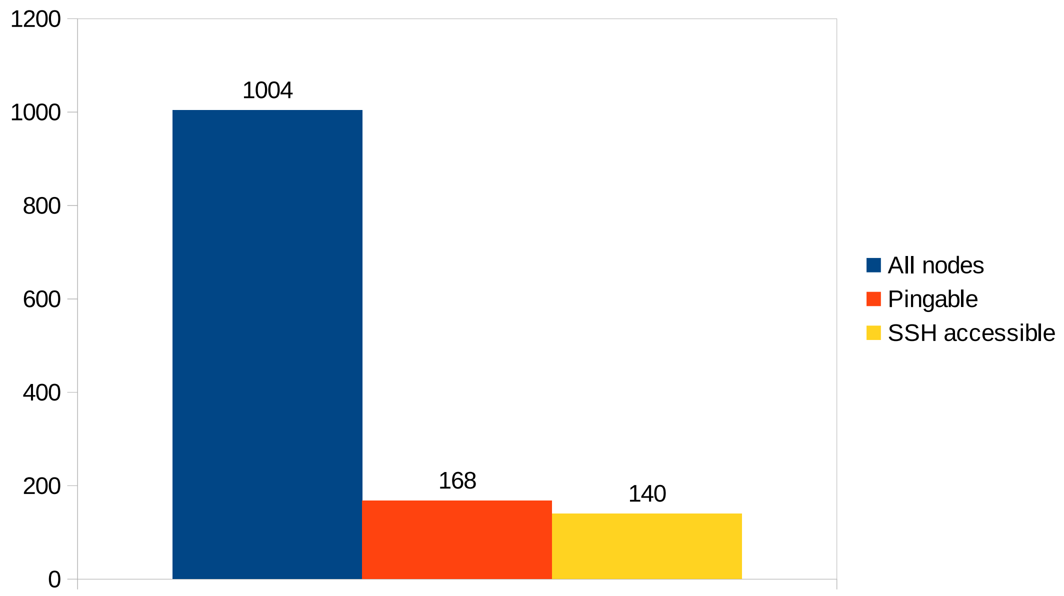


Fig. 4.3: Number of PlanetLab nodes logically divided by their accessibility by April 2019 using `cesnet_utko` slice.

If the data are pulled for continents respectively, we will get graph with `ssh` accessible nodes in Figure 4.4. On the X axis, you can see continents and on the Y axis you can see number of accessible nodes on that particular continent. For Europe and America, the numbers are very similar. Interesting is that from South America, only 6 nodes are accessible and all are from Brazil.

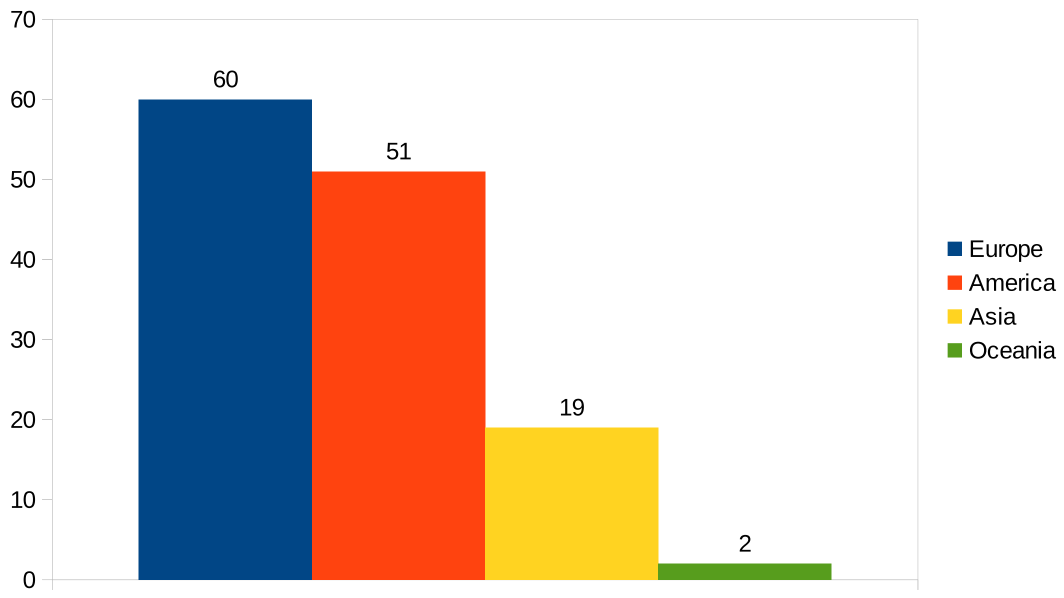


Fig. 4.4: Number of ssh accessible nodes logically divided into continents.

In more detailed breakdown, that can be seen in Table 4.1, it can be observed that Europe, with its 12 %, has the biggest percentage of ssh-accessible servers compared to overall number of nodes of all continents. Ssh accessible node means node available for project testing. On the other hand, the lowest percentage of available server has China with only 10.7 %.

Europe		America		Asia		Oceania	
All nodes	Ssh accessible	All nodes	Ssh accessible	All nodes	Ssh accessible	All nodes	Ssh accessible
332	60	422	51	177	19	18	2
100 %	18.6 %	100 %	12 %	100 %	10.7 %	100 %	11.1 %

Tab. 4.1: Table comparing number of all nodes versus ssh accessible nodes per continent using plbmng status database.

When map with all nodes, seen in Figure 4.2, is compared to map with only ssh accessible nodes, seen in Figure 4.5, the difference is even more clear. Map rendering functionality can be used to plan project testing and offers filtering only ssh available nodes.

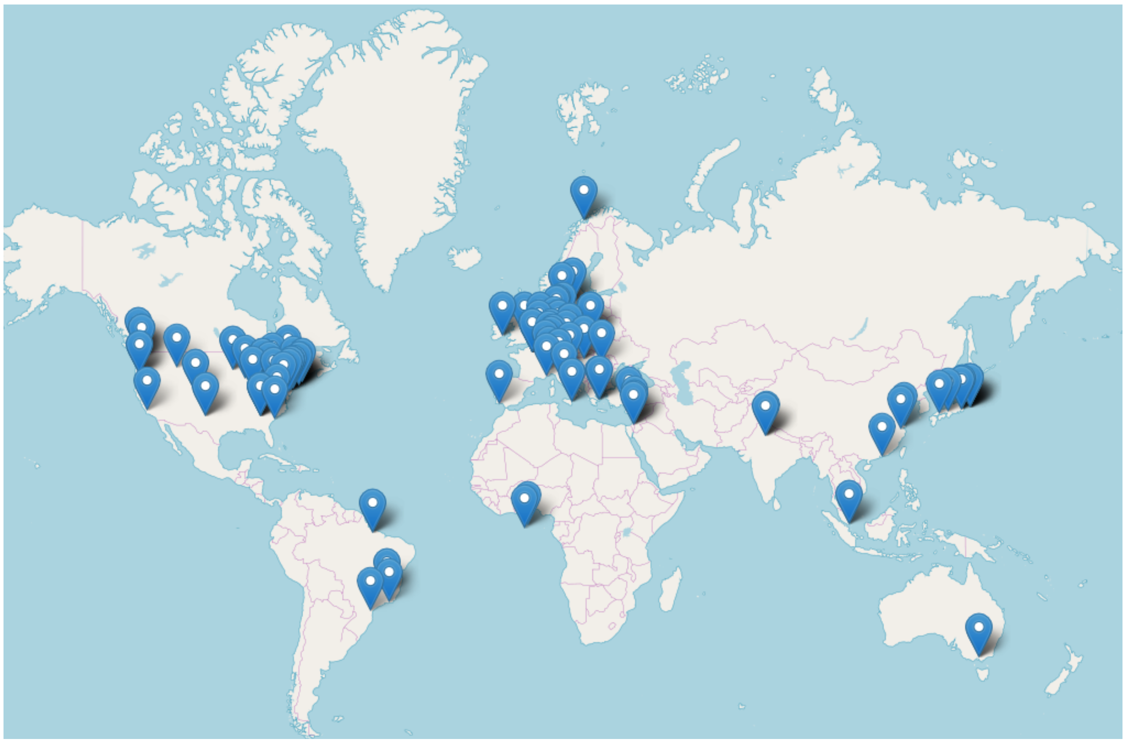
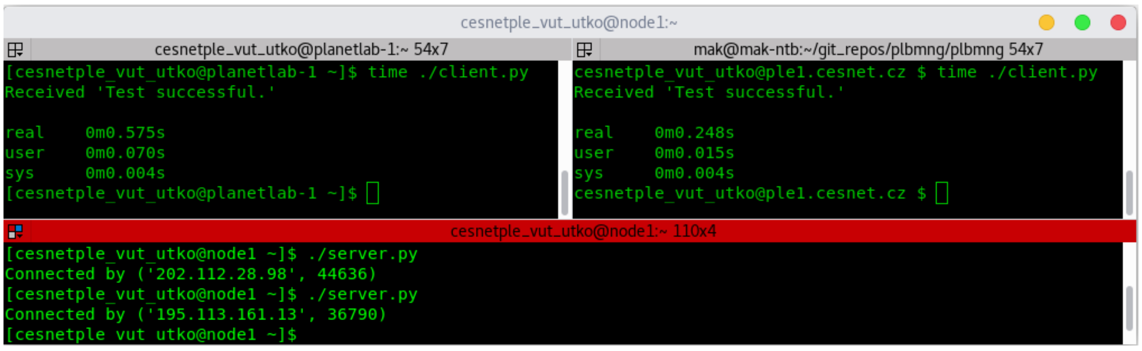


Fig. 4.5: World map displaying only ssh-accessible nodes using application database from April 2019.

4.2 Testing Network Projects with Planet Lab Server Manager

In this Section, a use case of testing a network projects, on of the most crucial use cases, will be shown and illustrated. For the purpose of illustration a simple imaginary project of running a listener on port 8765 in America and accessing it from China and Europe will be described. The idea of the project is to record the times that are required to establish a connection and log necessary time for a packet to travel between continents.
First, credentials needs to be updated in the `Set credentials` menu options. As a next step, filter is turned on to show only ssh accessible servers in the `Access servers` menu section. Next, a server is found using the `Search by location` menu option and credentials are verified. If the connection is successful, testing can continue. For this purposes, simple Python script will be used. There will be a server as seen in Listings 4.1 and client as seen in Listings 4.2 which all are inspired from `cyberciti.biz` site [6]. Server will be listening on port 8765 address 0.0.0.0 and client will send a packet with message "`Test successful.`" that will be send back to the client from the server as an echo reply. The results can be seen in Figure 4.6 where, in the terminal, three consecutive runs of plbmng application were started and using the filter and `Search by location` menu option the ssh available servers from America, China and Europe were found and connected into. On the bottom, server from America is shown running the echo server script. On the top left, server from China is shown running the echo client script and on the right top corner the server from Europe is shown running also echo client script.


cesnetple_vut_utko@node1:~
cesnetple_vut_utko@planetlab-1:~ 54x7
mak@mak-ntb:~/git_repos/plbmng/plbmng 54x7
cesnetple_vut_utko@node1:~ 110x4

```
[cesnetple_vut_utko@planetlab-1 ~]$ time ./client.py
Received 'Test successful.'

real    0m0.575s
user    0m0.070s
sys     0m0.004s
[cesnetple_vut_utko@planetlab-1 ~]$
```

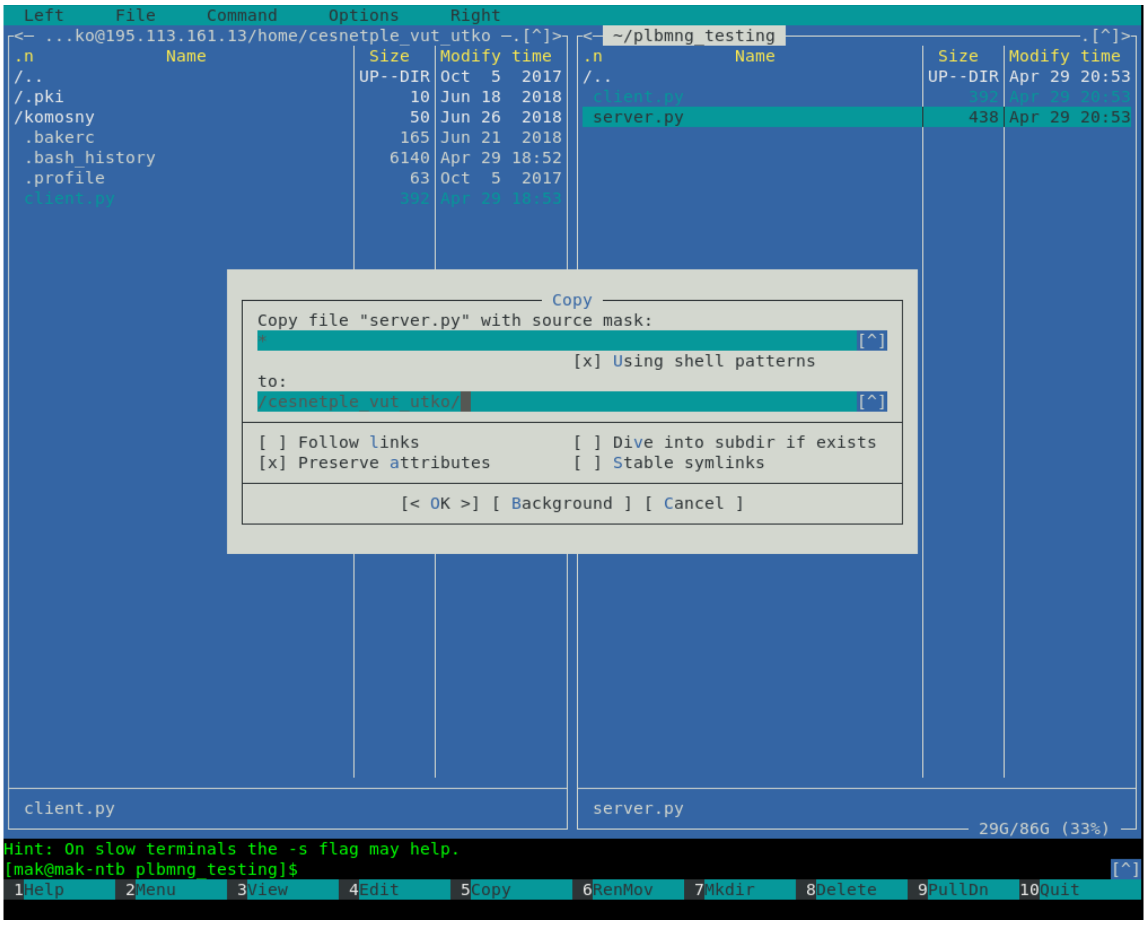
```
cesnetple_vut_utko@ple1.cesnet.cz $ time ./client.py
Received 'Test successful.'

real    0m0.248s
user    0m0.015s
sys     0m0.004s
cesnetple_vut_utko@ple1.cesnet.cz $
```

```
[cesnetple_vut_utko@node1 ~]$ ./server.py
Connected by ('202.112.28.98', 44636)
[cesnetple_vut_utko@node1 ~]$ ./server.py
Connected by ('195.113.161.13', 36790)
[cesnetple_vut_utko@node1 ~]$
```

Fig. 4.6: Terminal view illustrating usage of PlanetLab Server Manager to find proper servers and run server/client echo script on them to measure round times of packets between Europe, China and America.

Script was copied into servers using Midnight Commander which provides extensive interface for managing files on both local and remote locations and can be seen in Figure 4.7. As you can see by the results, the packets were successfully delivered and the packet round time were 0.248 seconds for Europe and 0.575 second for the China. This use case demonstrate very simple project but the same use case can be applied basically to any project as long as it use existing tools available on the servers. Even though only a bit above 10 % servers are available, PlanetLab still offers a vast network of nodes for project testing.



```
  Left       File        Command       Options      Right
┌<─ ...ko@195.113.161.13/home/cesnetple_vut_utko ─.[^]>┐┌<─ ~/plbmng_testing ──────────────────────────.[^]>┐
│.n               Name               │ Size │Modify time ││.n               Name               │ Size │Modify time │
│/..                                 │UP--DIR│Oct  5  2017││/..                                 │UP--DIR│Apr 29 20:53│
│/.pki                               │    10│Jun 18  2018││ client.py                          │   392│Apr 29 20:53│
│/komosny                            │    50│Jun 26  2018││ server.py                          │   438│Apr 29 20:53│
│ .bakerc                            │   165│Jun 21  2018││
│ .bash_history                      │  6140│Apr 29 18:52││
│ .profile                           │    63│Oct  5  2017││
│ client.py                          │   392│Apr 29 18:53││

                    ┌──────────────────────── Copy ────────────────────────┐
                    │ Copy file "server.py" with source mask:              │
                    │ *                                                 [^]│
                    │                              [x] Using shell patterns│
                    │ to:                                                  │
                    │ /cesnetple_vut_utko/                              [^]│
                    ├──────────────────────────────────────────────────────┤
                    │ [ ] Follow links               [ ] Dive into subdir if exists
                    │ [x] Preserve attributes        [ ] Stable symlinks   │
                    ├──────────────────────────────────────────────────────┤
                    │          [< OK >] [ Background ] [ Cancel ]          │
                    └──────────────────────────────────────────────────────┘

│ client.py                                           ││ server.py                                           │
└─────────────────────────────────────────────────────┘└──────────────────────────────── 29G/86G (33%) ─┘
Hint: On slow terminals the -s flag may help.
[mak@mak-ntb plbmng_testing]$                                                                          [^]
 1Help      2Menu      3View      4Edit      5Copy      6RenMov    7Mkdir     8Delete    9PullDn   10Quit
```

Fig. 4.7: Illustration of midnight commander used to copy scripts from localhost to a remote server inside the PlanetLab network.

```python
#!/usr/bin/python

#Demo echo server for use case example
import socket

SOURCE_HOST = source_server_ip
PORT = 8765

s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.bind((SOURCE_HOST, PORT))
s.listen(1)
conn, addr = s.accept()
print 'Connected by: ', addr
while 1:
  data = conn.recv(1024)
  if not data:
    break
  conn.send(data)
  conn.close()
```

Listing 4.1: Code of echo server.

```python
#!/usr/bin/python

#Demo echo client for use case example
import socket

TARGET_HOST = target_server_ip
PORT = 8765

s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.connect((TARGET_HOST, PORT))
s.send('Test successful.')
data = s.recv(1024)
s.close()
print 'Received: ', repr(data)
```

Listing 4.2: Code of echo client.

5 Conclusion

The goal of this Master thesis was to get familiarized with the PlanetLab Server Manager, re-implement the application into Python 3, extend its functionality by adding an ability to filter the servers by their status and update the PyPI repository of the application. Getting familiarized with the tool has been a pre-requisite of the other goals. Planet:Lab Server Manager was described in Chapter 1. The previous PlanetLab Server Manager tool is, in Chapter 2, reviewed, analyzed and weak points were found. This thesis also contains discussion over state of the application and possible improvements. Since the PlanetLab network is primarily using Linux and virtualization, these technologies were also covered in Subsection 1.3.1 and Subsection 1.3.2 respectively.
The improvements, as the result of this thesis, are described in Chapter 3. First, application logic was re-defined to use Python 3 advantags and its diagram can be seen in Section 3.1. One of the main improvements is `SQLite3` database where all data are stored and independent library modules providing functionality to the core engine. Python usage has enabled various advancements, such as removing result limitation, removing pre and po installation steps, having application available as library, increased readability by having core functions logically divided in one file instead of being composed from different files into script saved and run from disk, pre and post installation steps were removed, set credentials function has been improved, functions were written in a multi-platform way, few minor bugs were fixed and minor improvements were added. Folder structure was completely re-designed to be more transparent and easily oriented. Filter function was added to help find only available nodes. Logic to update availability database in multi-processing way was implemented. Small features like accessing last server or having statistics available in the application are improving PlanetLab Server Manager usability. The behavioral diagram with the improvements has been described in Section 3.3.
Last goal was to update the application's PyPI repository[1] with new code and updated description to fit the latest information. The repository was successfully updated with the newest code changing from version `0.1.10` to version `0.3.7`. The description has been updated containing latest information regarding installation process of the tool. Dependencies were removed to reflect this change. With the update all the goals that this Diploma thesis aimed to accomplish were successfully achieved. Overall, described changes will help further development of the tool and increasing its usability for the PlanetLab users.

[1]The PlanetLab Server Manager tool is available at: https://pypi.org/project/plbmng/

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List of symbols, physical constants and abbreviations

DNS	Domain Name System
IP	Internet Protocol
KVM	Kernel-based Virtual Machine
MMU	Memory Management Unit
CPU	Central Processing Unit
CentOS	Community Enterprise Operating System
yum	Yellowdog Updater, Modified
APT	Advanced Packaging Tool
IoT	Internet of Things
GUI	Graphical User Interface
PEP	Python Enhancement Proposal
PyPI	Python Package Index
API	Application Programming Interface
ICMP	Internet Control Message Protocol
UML	Unified Model Language