Proposal for an online practical work platform for improving the teaching of STEM

Kokou GAGLO*, Massamba SECK**, Samuel OUYA*, Gervais Mendy*

*Laboratory LIRT, Ecole Supérieure Polytechnique
Universite Cheikh Anta DIOP (U.C.A.D.), Sénégal

**Département des Technologies de l'Information et de la Communication
Université Alioune Diop de Bambey (UADB), Sénégal

freemanpolys@gmail.com, massamba.seck@uadb.edu.sn, samuel.ouya@gmail.com, grvmendy@gmail.com

***Abstract*— This paper presents an online practice platform for improving STEM teaching, allowing actors from traditional and virtual universities that are geographically distant to collaborate on practical work.**

In the context of universities operating in the field of STEM, particularly in the field of ICT, practical work is necessary to assimilate skills.

This paper provides a preconfigured environment of practical work to the various actors of these virtual and traditional universities who make ELearning.

Our platform has an administration interface to manage the rights and the allocation of the preconfigured virtual machines to the different actors who access remotely to the different virtual machines through a browser.

To achieve our goals, we used the WebSocket, VNC protocols and the noVNC client.

We show in this work how teachers and students in the field of STEM used our platform to carry out their practical work in networks and programming.

***Keywords*— Online Practice Platform, Virtual University, STEM Teaching, ELearning, WebSocket, VNC**

I. INTRODUCTION

In 2013, the Republic of Senegal organized a national consultation on the future of higher education. At the end of this consultation, two important decisions were taken. The first decision relates to the reorientation of higher education to Sciences Engineering and Mathematical Technology (STEM) [1].

The second decision is the use of ICT for higher education to improve its effectiveness. This last decision was translated into action by the creation of the Virtual University of Senegal (UVS) [2].

This university which started in 2014 with 2000 students including 400 in the field of STEM is today with 17000 students. The ¼ of which is enrolled in STEM courses. This very successful experience is spreading to the African sub-region with the creation of similar public universities in many African countries, including Côte d'Ivoire, Chad, Burkina Faso and Mali.

At the same time of the creation of these fully virtual universities, classical universities integrate distance learning courses or part of distance learning / teaching activities using an Elearning platform.

The question is how to effectively train online students in the field of STEM?

Several authors have shared their experiences in terms of online laboratories in the field of STEM [3] [4].

In this paper, we propose an online practical platform accessible through the web. This paper proposes a preconfigured environment with teaching tools allowing collaboration between students and teachers to carry out practical work.

For this, we used containerization using Docker and virtualization with KVM-VDI and Virtualbox [5] [6] [7]. The choice of these technologies is guided by the possibility of using APIs to duplicate virtual machines more efficiently.

The rest of this paper is organized as follows: Section II describes the state of the art, Section III describes our online practice environment, Section IV presents the main use cases of our solution, Section V presents the results obtained and Section VI is reserved for conclusion and perspectives.

II. STATE OF THE ART

A. Virtual University

Several theories explain the concept of virtual university. A virtual university is a special form of ELearning based on ICT [8]. Most virtual universities use a web platform to provide their lessons. In a virtual university model, interactions between students and teachers are based on ICT. In [8] the authors give more details on the advantages and disadvantages of virtual universities. There are several virtual university approaches [8].

Historically, in virtual universities learners are workers who want to update their knowledge, but today virtual universities are receiving more and more young graduates who have never worked and who are looking for a degree that can give them access to a job. This is the case of the virtual university of Senegal, which enrolled two thousand young graduates in 2013, and seventeen thousand in 2017.

To encourage the reorientation of literary graduates to science, the UVS has created a new educational path that forms halfway between literature and technology. In addition to this, many courses in the field of applied and computer mathematics require practical work in networks and software development.

B. Online practical work platform

In the literature, researchers such as [9] have shown that the distance separating the actors of a collaborative development project is no longer a problem considering the current technological means. Effective models of organizing practical work teams have been tested by researchers such as [10].

Studies conducted by researchers [11] [12] [13] have shown the interest of having a practical work environment that unifies social network concepts and collaborative environment applying 3C model (cooperation, communication and coordination) for maintain the motivation of the different members of the development team.

In Elearning environment studies conducted by [14] show the importance of the socio-constructivism model that advocates peer collaboration to build solid knowledge.

In [15] the author raises the problem of monitoring and measuring the contribution of each student in the Elearning environment.

Our approach is to have a practical work environment integrating tools of communication, cooperation and allowing a teacher to follow and measure the contribution of each student on a given project.

III. DESCRIPTION OF THE ENVIRONMENT OF PROPOSED PRATICAL PLATEFORM

A. *Network Architecture*

In the proposed environment, it is made available to actors of virtual machines on which is installed and preconfigured GNS3, the emulation software of Cisco network equipment (Routers, Switches, Firewall, Machines etc.) for practical work in networks or Eclipse software for practical work in software development.

In addition to preinstalled software, users can install and configure network services such as messaging, Web browsing, IP telephony and more.

The features of the proposed environment are :

- Remote access to virtual machines through a browser
- Opportunity for a teacher to publish / unpublish and share his machine with learners,
- Remote access and control of a learner's machine
- Participation in chat, audio and videoconferences
- Creation, management of access rights and allocation of virtual machines to actors
- etc.

Figure 1 shows the network architecture of the environment

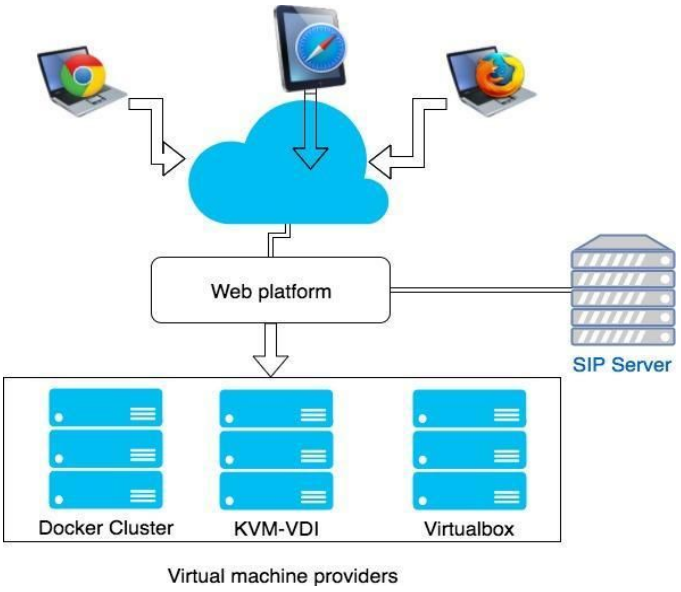

Figure 1. Network architecture of the environment

In the proposal, the chat, audio and videoconference is managed with a Freeswitch SIP server [16] that supports the web-based communication standard called WebRTC. The management and allocation of virtual machines is done via a web application that we have developed.

Actors access virtual machines using a browser.

B. *Software architecture*

The generation of virtual machines is done mainly using Docker containers, KVM-VDI and Virtualbox. The VNC protocol and the web client noVNC manage remote access to virtual machines. [17]

The teacher can publish his machine for reading or writing while modifying the permissions in real time. The dynamic management of access rights in manipulation to these virtual machines is managed by the WebSocket protocol, which notifies the learner's browser in real time, the permissions to be taken into account [18].

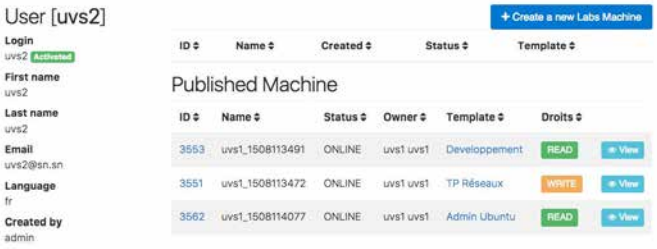

Figure 2. Publishing and managing access rights to machines

Figure 2 illustrates the publication of 3 machines by the teacher:

- Two machines in reading where all the students can only follow the manipulations of the teacher

- One machine in writing where only the student uvs2 can handle.

The audio and video chat communication is done through a browser thanks to the WebRTC standard built into the Freeswitch IP telephony server.

IV. DESCRIPTION OF SOME USE CASES OF THE PLATFORM

A. Assignment of a virtual machine to a user

Figure 3 shows the creation and assignment of a virtual machine to a user

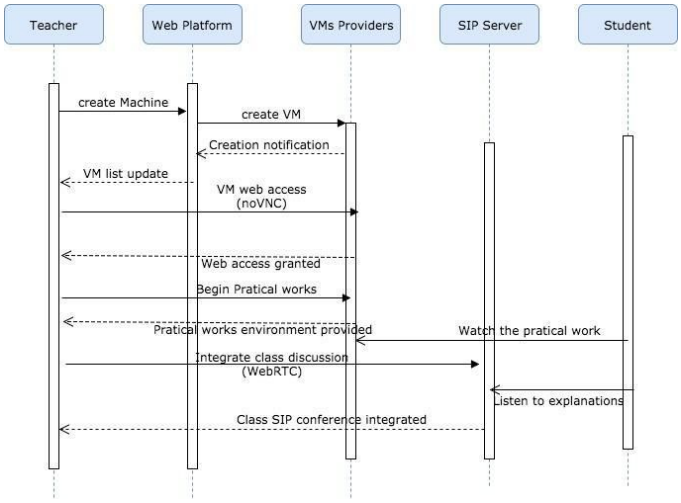

Figure 3. Virtual machine assignment Diagram

B. Collaboration in a practical work

A teacher creates a virtual machine containing the prerequisites according to the content of his teaching and invites a group of students who are geographically dispersed or not to work together.

In the case of software development teaching, learners can use programming languages such as Java, C / C ++, PHP, Python, HTML5 / CSS3 already preinstalled.

In the case of networked teaching, the GNS3 environment and all the prerequisites are already available and accessible to students, allowing learners to concentrate on practical work rather than wasting time on setting up the working environment.

Figure 4 describes the process of creating and managing permissions on newly created machines.

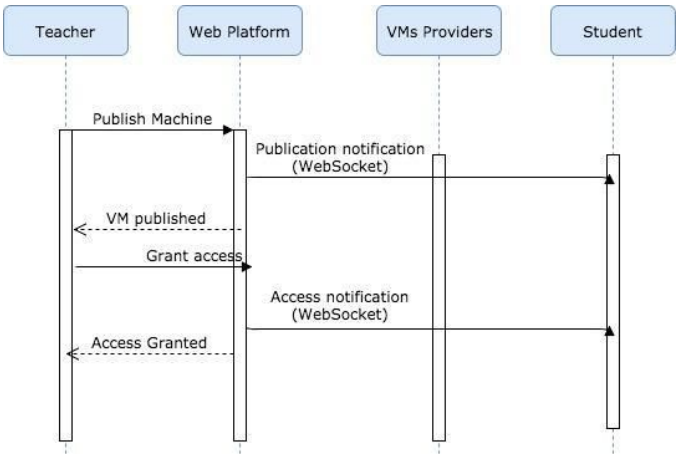

Figure 4. Diagram describing permissions management

V. RESULTS

Access to the proposed platform is via the URL http://virtulabs.rtn.sn using a browser

A. Access to an application development platform

Figure 5 shows the user interface after authentication with the Eclipse development platform installed

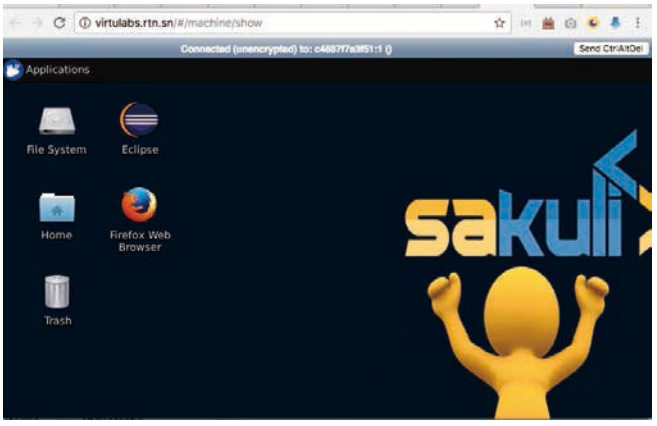

Figure 5. User interface with an Eclipse shortcut

The user clicks on the Eclipse icon shown in Figure 5 to get an environment to develop applications as shown in the figure 6

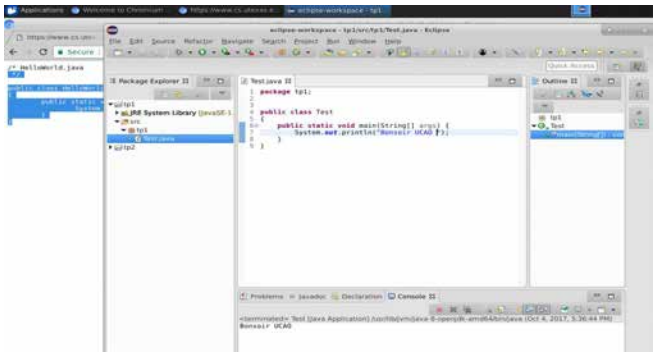

Figure 6. Application development with Eclipse environment

B. Access to a platform of practical work in Networks

After authentication and choice of practical work in Networks the user obtains the same interface as that of figure 5 with a shortcut GNS3 instead of shortcut Eclipse

Figure 7 shows the follow-up of collaborative network work by a teacher who has the opportunity to communicate with learners using a softphone built into his browser.

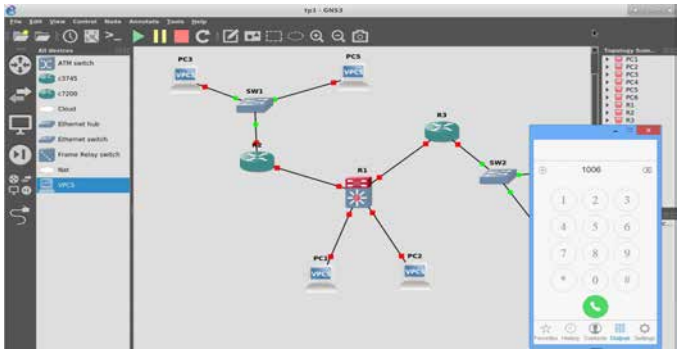

Figure 7. Collaborative Practical Work in Networks

C. Management platform for virtual machines and users

Figures 8 and 9 show the resource and user management platform.

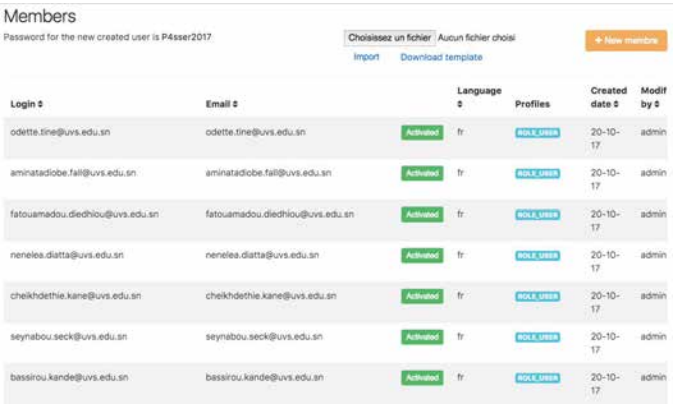

Figure 8. Users management

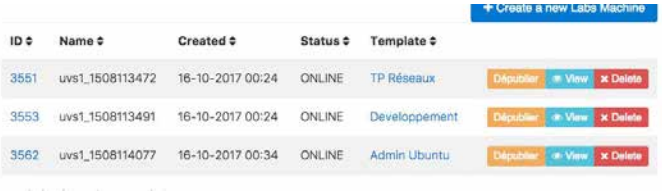

Figure 9. Publication of machines

Once the student is connected using a browser, he can start or stop the virtual machine assigned to him, connect to it and begin to carry out practical work with the help of pre-installed software or software that he can install himself.

Figure 10 shows the connection interface of a student with all the parameters he will need.

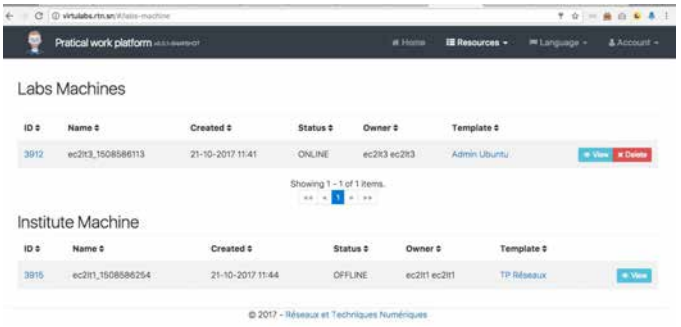

Figure 10. User Interface

VI. CONCLUSION ET PERSPECTIVES

In this paper we have proposed a platform of online practical work allowing teachers to organize practical work sessions with their geographically dispersed students.

Students and teachers in the applied mathematics and computer sciences tested the proposed environment at the Virtual University of Senegal. This allowed them to collaborate on projects using C / C ++ programming languages, Java, Python, PHP, HTML5 / CSS3 and practical work in computer networks and network services.

The ease of access to platforms offered by the web and the integration of real-time communication through the web have contributed to increase the level of motivation of students and constitute an appreciable contribution to the classical functionalities of the platforms of practical work for the teaching of STEM.

The administration interface developed relies on containerization and virtualization to automatically generate preconfigured virtual machines that can be used remotely by the actors using the noVNC web access protocol. This automation of virtual machines enables non-virtual classical universities to deal with the problem of insufficient infrastructure of practical work:

In perspective, we intend to use the platform proposed in this article and already integrated in a cloud computing to better manage the teaching of STEMs with MOOCS.

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Kokou GAGLO is currently a PhD student at Computer, Network and Telecom Laboratory (LIRT) at University Cheikh Anta DIOP of Dakar.
Holder a Master's degree in Research "Engineering Sciences" from the University Cheikh Anta Diop (UCAD) of Dakar-Senegal. He is interested in applications of innovative telecom services to virtual organizations.

Massamba SECK is currently a PhD student at Computer, Network and Telecom Laboratory (LIRT) at University Cheikh Anta DIOP of Dakar.
Holder a Master's degree in Applied Mathematics, a Diploma of Aptitude in Secondary Education, a degree in Computer Engineering, and a Master's Degree in Computer Modeling Research from Cheikh Anta DIOP University of Dakar, he is currently assistant lecturer-researcher and Director of the IT Resources Center of Alioune DIOP University of Bambey. His research interests are in innovative telecom applications and services for e-learning, service learning, and community service.

Pr. Samuel Ouya is currently the Director of Computer, Network and Telecom Laboratory (LIRT) at University Cheikh Anta DIOP of Dakar. He was from 2013 to May 2017 the first Director of Infrastructure and Information System of the first virtual university of Senegal (UVS).
Holder of a Thesis in Applied Mathematics from the Gaston Berger University of Saint-Louis in Senegal and a Telecommunications Thesis from the Cheikh Anta Diop University (UCAD) in Dakar-Senegal, he is interested in Applications of innovative telecom services to virtual organizations

Pr. Gervais MENDY is a researcher-scientist at the Polytechnic School of Cheikh Anta DIOP University of Dakar where he was head of the IT department from 2012 to 2016.
Holder of a PhD in Computer Science from Paris-Sud XI University, his research interests are in Computer Combinatory, Social Network Analysis, Internet of Things (IoT) and IT Security.
He is a member of the Laboratory of Computer Science, Networks and Telecoms (LIRT) of Cheikh Anta Diop University of Dakar.