Remote Practical Work Environment based on Containers to replace Virtual Machines

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***Abstract*— In this paper, we are interested in solutions to improve remote practical work in the field of computing, more specifically in programming, networks and telecommunications. In the literature, practical work solutions, based on the cloud or on synchronous / asynchronous monitoring and collaboration tools or on shared writing spaces, are proposed to enable practical work to be carried out remotely. However, the cloud based solution, which uses virtual machines, consumes a lot of resources, and therefore brings cumbersome. Each virtual machine contains an image of the operating system, libraries, and applications and can therefore grow very large. The solution based on collaboration tools does not integrate IT development environments, and therefore the programmer resorts to screen shares or basic editors which waste a lot of time when it comes to find certain modules, classes or native functions of the language.**

In this paper, we propose to replace virtual machines with containers to optimize resources, and provide a collaborative and easy-to-access lab interface. Each user connects to their own workspace provided by the container, which is accessible by the teacher and other learners in the same group. The practical work will be carried out from a web interface connected to the virtual environment via an API. Real-time communication between learners and teachers will be ensured by WebRTC technology.

Keywords—remote labs, cloud, virtual machines, docker container, collaboration

I. INTRODUCTION

According to UNESCO, more than 1.5 billion students and teenagers across the planet are or have been affected by school and university closures due to the COVID-19 pandemic [1] [2]. Face Due to the impact of covid-19 on education systems, many countries have turned to distance learning to make up for lost hours of teaching lessons and hands-on learning [1]. In addition, we note that distance education is easier to achieve in language courses, unlike in science subjects (STEM) which require practical work. The field of STEM requires practical and advanced skills to overcome the demands of science and distance education platforms as currently designed do not allow the realization of practical work in many STEM disciplines. However, research work offers the possibility of carrying out practical work remotely using remote laboratories or online laboratories. This was the case with REM Lab, a Remote Laboratory developed for training in electronics, where students can build their circuits using a remotely controlled robotic arm [3] ; and much more research from remote laboratories in the field of electronics [4] [5] [6]. In the field of physics, remote laboratories based on experimentation and measurement instrumentation are offered [7] [8]. Online laboratories are distributed and flexible computing environments that allow a learner to perform experiences, alone or in collaboration with other participants in a distance learning context [9]. They promote the sharing of educational and human resources as well as interactivity, cooperation and collaboration between actors placed in a distance learning situation.Indeed, the research that we have carried out reveals that most of the research projects which attempt to provide solutions for remote practical work are based on virtual machines for the simulation of educational materials [10] [11] [14]. These virtual machines are often very heavy in terms of resources. From another perspective, IT containers offer huge advantages that can be exploited to pusachines [15] [16] [17]. In this paper, we therefore propose to replace virtual machines with containers based on Docker technology. The remaining part of the article will be organized as follows. In Section 2, we present the state of the art on existing solutions for remote labs and containers. In Section 3, we present our container-based lab model. In section 4, we present the results obtained and end, in section 5, with a conclusion.

II. RELATED WORK ON REMOTE LAB SOLUTIONS

A. Related work on remote lab solution

Carrying out practical work remotely is a research issue that has been studied for more than a decade because of the educational and economic challenges it generates. Indeed, it is a category of essential education in science, technology, mathematics and engineering STEM disciplines aimed at achieving particular learning objectives related to the acquisition of practical and professional skills. In the field of distance education, research has made it possible to improve the functionality of distance education platforms to include the possibility of carrying out practical work at a distance. The authors in [18] [22] propose with the help of virtual classes, integrating video, audio, chat, audio recording of the different actors, solutions allowing learners to learn to write or to do homework in line requiring the massive use of mathematical symbols and tools [23]. A more interactive optimization of this distance practical work for mathematics courses is proposed in [19]. On the other hand, the field of Tele-laboratories has made it possible to highlight educational and technical problems which hinder the development and acceptance of tele-tas by training actors, which our work attempts to bring some answers. In [9] [10], we have implemented a private IaaS type Cloud Computing, a web platform through which users authenticate to access virtual resources provided by the cloud and a cloud-based videoconferencing implementation and the WebRTC. The objective of these papers is to implement a virtual environment based on virtual machines provided by a private cloud of the IaaS type accessible via a web platform which allows students to carry out tele-TP in IT to improve performance, availability and scalability of existing TP [10]. However, the launch of virtual machines can become slow because it requires the establishment of a set of configurable and shared computing resources: networks, servers, storage, applications and services.

In [11], the author tried to justify that Docker technology is far superior to virtual machine mode. He therefore proposed a simulation training system based on Docker, the dispatch and control cloud.

B. *Containers vs virtual machines*

In this part, we present some research work related to virtual machines and containers. Containers and virtual machines are packetized computing environments that combine various components and isolate them from the rest of the system. Their main differences lie in their scalability and portability.

Server virtualization allows, through a software layer called Hypervisor, to create virtual machines on a physical server that use the physical resources of the server with their own OS. The Hypervisor ensures the allocation of physical resources between the VMs, and each of them behaves like a stand-alone server integrating its own OS on which the applications will be deployed and run. Virtual machines have many advantages. For example, the ability to run different operating systems on the same server, more efficient and cost-effective use of physical resources, and faster server provisioning. However, each virtual machine contains an image of the operating system, libraries, applications, etc. and can therefore become very bulky.

Unlike virtualization, a container does not embed an OS, it relies directly on that of the server on which it is deployed. A container is therefore much lighter than a VM which will integrate an OS. A VM is measured in GB when the volume of a container is in MB.

The diagram below illustrates the differences between containers and virtualization:

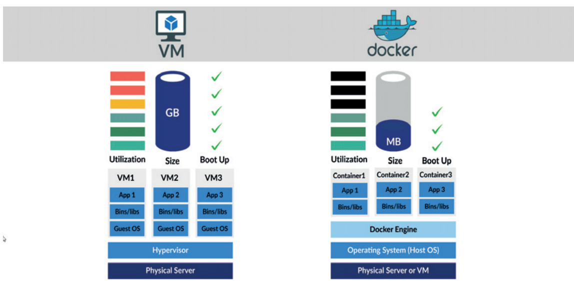

Fig. 1. Virtual Machines vs. Containers

Containers allow software to be isolated and run independently on different OS, hardware, networks, and storage systems, with different security policies. A containerized application can thus flow seamlessly between development, test and production environments. Since the operating system is not integrated into the container, the container uses minimal computing resources; it is therefore light and easy to install. Containers have a set of particularly interesting characteristics:

• Size - A container weighs only a few tens of MB.

• Speed - Containers run almost instantly.

• Portability - Containers work in any environment.

• Modularity - Developers can break containers intosmaller modules.

• Autonomy - Each application runs virtually in its ownsmall container.

• Cost - Containers generate little additional cost.

Because containers share the host operating system, they do not need to start an operating system or load any libraries. This allows the containers to be much more efficient and lighter [12] [13] [15]. Containerized applications can start in seconds, and it is possible to place many more instances of the application on the computer compared to the scenario with a virtual machine. The authors in [20] made a comparison between Linux containers and virtual machines in terms of performance and scalability. According to them, Linux containers can be an alternative to traditional virtualization technologies due to their high resource usage and overhead.

In [21], authors used Docker to deploy and run our containers, KVM hypervisor for the Virtual Machines and we executed a series of well-known benchmarks on different operating systems. However, running containers on virtual machines affects the performance of the container. In this paper, we aim to carry out remote practical work for programming, networking and telecommunications courses directly from virtual docker environments which have the capacity to integrate development and system configuration environments.

III. Container-Based Model

In our previous work, we started with a virtual environment based on Cloud Computing which provides Vms for the realization of remote computer labs [10]. Then, we extended the virtual environment by integrating a videoconferencing solution based on WebRTC technology for synchronous monitoring of labs [11 10]. In [10] and [11], we have implemented a private IaaS type cloud computing and a web platform through which users authenticate to access virtual resources provided by the cloud. The web platform allows, among other things, teachers to schedule practical work and share materials that will be accessible by students while remaining on the same platform. The main advantage of this is to lighten the server that hosts the cloud.

However, taking into account the concerns of optimizing and pooling educational resources allowing the realization of remote practicals, we propose to replace VMs by containers using Docker technology. Indeed, with Docker, we can containerize network simulation applications (gns3, packet tracer) and development environments (python, java, PHP, MySQL, PHPMyAdmin, etc…) in order to carry out practical work remotely.

In this part of the paper, we will explain the proposed system and show, for illustration, the realization of two types of remote TP.

We have deployed the free version of the docker server known as Community Edition or Docker CE and the WebRTC server on a linux centos 8 server locally. For the creation of the containers, we extracted images from the Docker Hub platform which is currently the largest library of container images in the world. Containerized resources are accessible from the web platform hosted on another server. The platform communicates with Docker and WebRTC via Docker APIs and SDKs. Teachers and learners authenticate at the web platform level to access applications running from containers while staying on the same platform.

The diagram below illustrates the architecture of the proposed system for carrying out remote labs with containers.

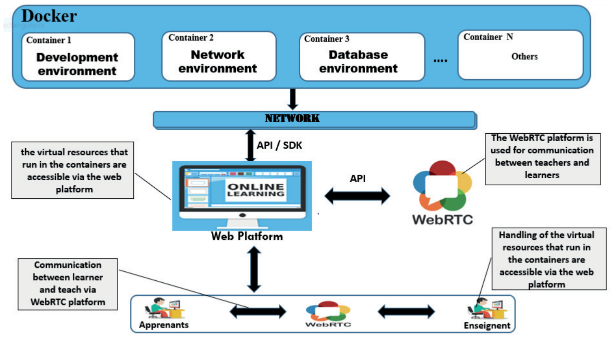

Fig. 2. Proposed sytem architecture

The advantage of the model from a practical point of view is that several learners can work on the same project, each interested in particular module of the project. The parts of code will be visible to everyone and the teacher can intervene to improve or correct the code written by another learner. This promotes collaborative remote work.

IV. Expected Results

To demonstrate the relevance of our model, we first implemented a container-based virtual environment using Docker containerization technology; then a web interface accessible to learners and teachers. The practical work will be carried out from the web interface connected to the virtual environment via an API; and finally we have integrated WebRTC technology for real-time monitoring and communication between learners and teachers.

In what follows, we illustrate the proof of our model through programming practical works like java, python and networks practical works. The same model can be applied to practical works of telecommunications; all you have to do is integrate docker images into containers for telecommunications simulation software.

A. Illustration of a practical work in java

a) Teacher's space

Figure 3 shows the teacher authentication interface from a web platform:

Fig. 3. Teacher authentication

After successful authentication, the teacher accesses the list of practical work and chooses one to start the practical session. A teacher can only see the list of labs they have created. To start a lab, the teacher chooses for example a java lab, as shown in figure 4.

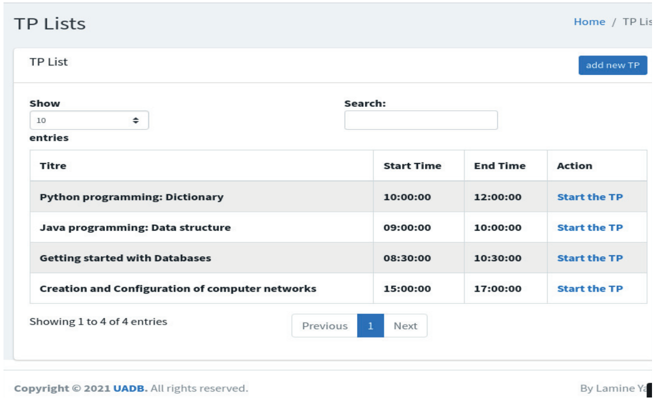

Fig. 4. List of practical work in the teacher's space

In the hands-on interface, the teacher can see in real time the work that the learner is doing, as shown in Figure 5.

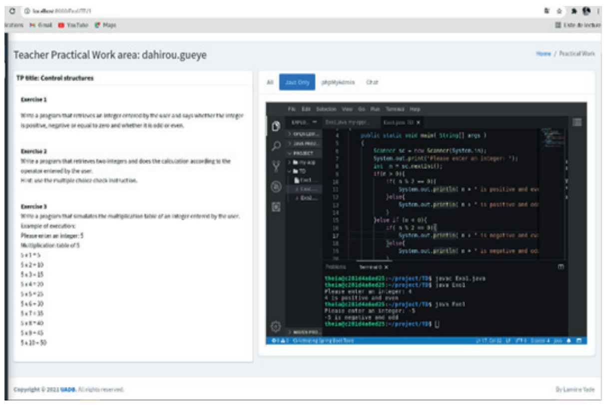

Fig. 5. Visualization of a practical work by the teacher

b) Student's space

Figure 6 shows the student authentication interface

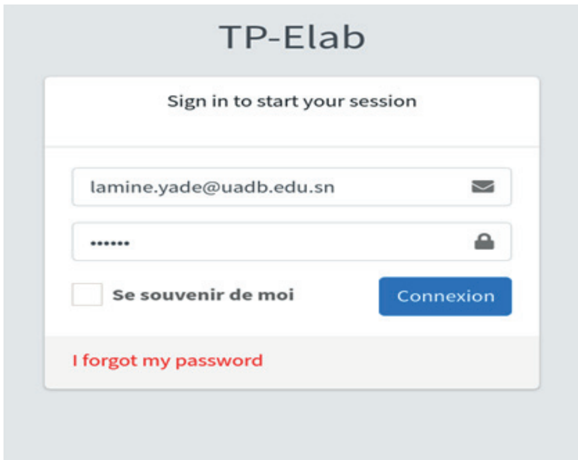

Fig. 6. Student authentication interface

After successful authentication, the student accesses the list of practical work that the teacher has created and chooses one to start the lab session.

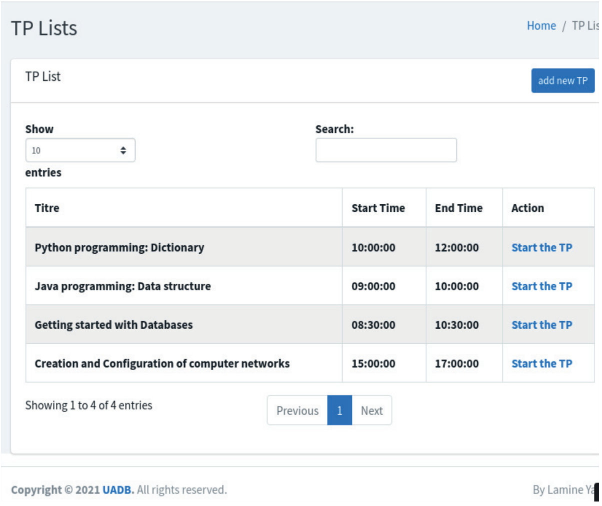

Fig. 7. List of labs in a learner's profile

In the student lab interface, the learner sees on the same page the lab statement that the teacher created and the virtual development environment running from a Docker container. He can see in real time the suggestions that the teacher is making.

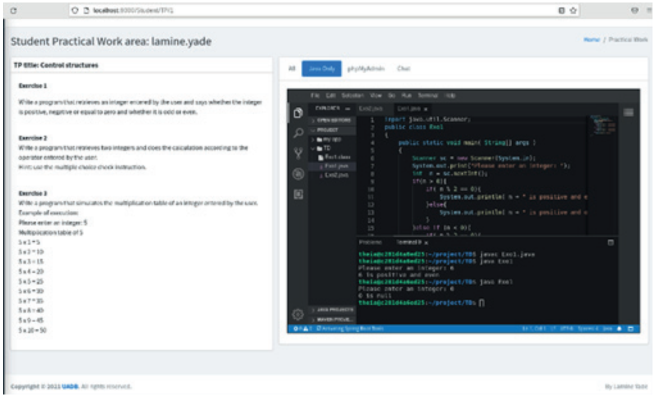

Fig. 8. Interface for carrying out a practical work by a learner

Students from the same group can work on the same project remotely and in synchronous mode. One student can initiate a bet with one end of the code and another can continue the other part of the code and so on; and all this while remaining in the same project.

B. Illustration of a practical work in python

For remote practical workspace in python, we have the same access methods as for labs in java. Figure 9 shows the performance of a practical work in python by a learner done from a Docker container and shared by all learners in the same group. Practical work in python can be done from a terminal or a python IDE editor like visual studio or pycharm, etc. It should be noted that the container groups several docker images and each image does specific practical work.

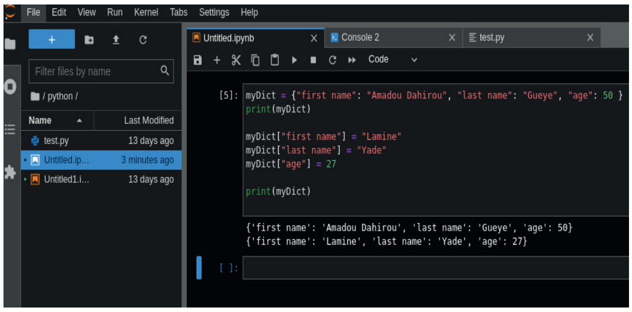

Fig. 9. Practical work in python

C. Illustration of a practical work in networks

In this part, we show the realization of a simple practical work in network with GNS3 which is started from the container; and we provide access to practical networking work done from a web platform. In figure 10, we show the topology of the network for a practical work that allows to network two machines through a switch.

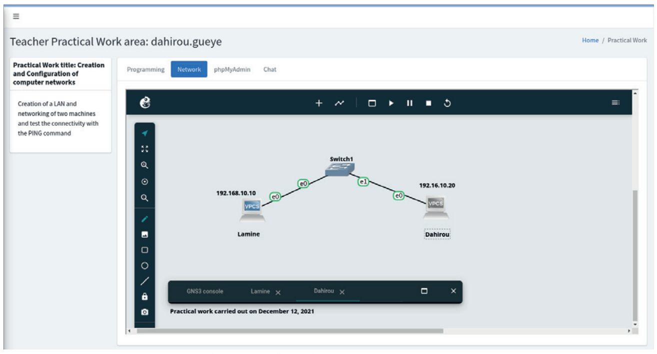

Fig. 10. Network topologie

In what follows, we assign an IP address to the two communicating entities, as shown in figure 11.

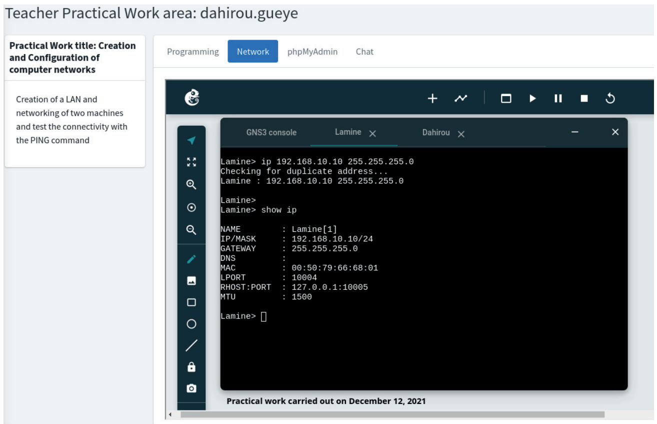

Fig. 11. IP assignment

The figure 12 shows a ping test from learner Lamine to teacher Dahirou.

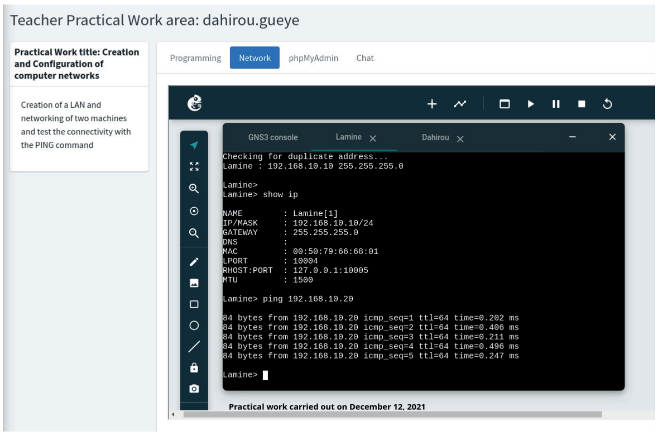

Fig. 12. Ping test from Lamine to Dahirou

D. Illustration of a audio visual communication

In addition to the messages sent, the teacher and students can see and hear each other verbally using WebRTC technology.

Fig. 13. Audiovisual communication

Figure 14 shows the possibility of sending messages between learners and teacher.

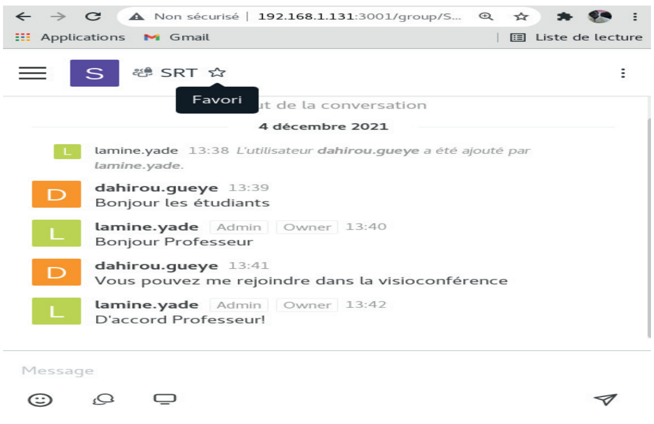

Fig. 14. Message exchange

CONCLUSION AND PERSPECTIVES

This paper provides a more flexible and flexible solution in cThis article provides a more flexible and flexible solution in carrying out remote practical work in the field of computer science, especially in practical work based on simulation software. For each type of practical work, we used containers using Docker technology to run this software (images) in virtual environments accessible to teachers and learners from a web platform.

In perspective, we plan to study and show the possibility of carrying out remote practical work in the fields of physics and electronics using the Internet of Things (IoT). This will allow us to improve our telelaboratory model proposed in the previous sections and thus push its limits by giving it the possibility of remotely manipulating real objects allowing practical work in physics, chemistry and electronics.

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