Contribution to the Setting up of a Remote Practical Work Platform for STEM: The Case of Agriculture

Bessan Melckior Degboe(✉), Ulrich Hermann Sèmèvo Boko,
Kéba Gueye, and Samuel Ouya

LIRT Laboratory, High Polytechnic School,
University Cheikh Anta Diop of Dakar, Dakar, Senegal
bessanmelckior.degboe@ucad.edu.sn,
bulrich91@gmail.com, mamekeb@gmail.com,
samuel.ouya@gmail.com

Abstract. Several approaches have been proposed to make practical work available in e-learning trainings. The visits of field represent an indispensable complement to the theoretical course given to students in the natural sciences and life sciences. Biodiversity areas may be politically unstable and potentially dangerous for non-residents. The purpose of this paper is to contribute to the improvement of distance education in agricultural sectors by providing a collaborative platform for virtual field visits and even sharing resources.

To do this, we combine the intelligence of the Web of Things (WoT) with the power of WebRTC. Our contribution applies first to distance education in agriculture. However, our experimental results may be relevant for other STEM disciplines.

This platform, based on the WebRTC Kurento multimedia server and the Web of Things (WoT), allows the teacher and a group of students to go to the field to carry out practical work. The results of this outing are broadcast in real time for other students who are not on site.

Keywords: WoT · STEM · WebRTC · Kurento

1 Introduction

Previous research has demonstrated the positive impact of practical work on students' knowledge [1, 2]. This is why in recent years research on line labs has become very popular. In fact, online labs are distributed and flexible computing environments that allow a learner to conduct experiments alone or in collaboration with other participants in a distance learning context.

Several approaches have been proposed to make practical work available in e-learning courses [3, 4]. Each approach solves a specific problem [5]. There are certain disciplines such as biology and agriculture where it is difficult to do e-learning. In the case of e-agriculture training, field visits are an indispensable complement to the theoretical course given to students. However, the areas where biodiversity is sought may be politically unstable and potentially harmful to non-residents.

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Thus, the purpose of this paper is to contribute to the improvement of distance learning in agricultural sectors by providing a collaborative platform for virtual field visits and even sharing of resources. To do this, we combine the intelligence of the Web of Things (WoT) with the power of the WebRTC Kurento multimedia server. The proposed solution allows teachers/tutors and students to do remote labs.

The rest of the article is structured as follows: Sect. 2 gives an overview of previous work using WoT in the field of agriculture. Section 3 describes the technologies used to implement the proposed platform. Section 4 presents the architecture of the model. Section 5 outlines the methodology for implementing the KMS-IoT-Agriculture platform. Finally, Sect. 6 provides the conclusion and future work.

2 Related Works

In the literature, studies have shown that precision electronic agriculture can be used to improve watering, soil fertilization and crop yield. The authors of [6–8] propose solutions based on arduino and sensors (pH sensor, water level sensor, servo …) to save the use of water and fertilizers on small cultivable areas. Those of [9] have set up a LoRa and bluetooth-based transmission system to retrieve sensor information (temperature, humidity, CO2, brightness) in a field. This information is stored in a database and can be viewed using a smartphone. In article [10, 11], the authors propose a website to regulate the sale of agricultural products. The authors of the article [12] propose an online learning module to train farmers on the right choice of seeds, pest control, side effects of pesticide use, etc. Despite the relevance of this work, few solutions are focused on distance education of students in agricultural sectors.

3 Technology

The first part presents the technology used to establish communication between the different users of the system. Then, the Web of Things allows to control and interact with different intelligent objects of architecture.

3.1 Web of Things

The Web of Things (WoT) is a specialization of the Internet of Things (IoT). On the one hand, it provides an abstraction of the connectivity of smart objects. On the other hand, WoT adds a standard web standards-based application layer to simplify the creation of IoT applications. In IoT, the communication protocols are multiple (MQTT, CoAP, ARMQP …), which creates groups of users.

The main interests of using WoT instead of IoT are the simplicity of development using APIs, standardization and simple coupling. The idea is that all intelligent objects can communicate using a Web language through an API. This API can be present in the intelligent object itself or in an intermediary that can act on behalf of the intelligent object [13]. This has become possible with the improvement of embedded systems. Nowadays, we can run small servers such as lighttpd [14] and Nginx [15] inside constrained devices.

3.2 Kurento Media Server

Traditional WebRTC applications are standardized so that browsers can communicate directly without the mediation of third-party infrastructures. This is sufficient to provide basic multimedia services, but features such as group communications, stream recording, streaming, or transcoding are difficult to implement. For this reason, the most interesting applications require the use of a multimedia server.

There are many other services we can offer with media servers: augmented reality, computer vision and alpha blending. These services can add value to applications in many scenarios such as e-agriculture, e-learning, security, entertainment, games or advertising. Kurento Media Server (KMS) is an evolution of traditional media servers that provides a modular architecture where other features can be added as modules.

Kurento is an open source WebRTC multimedia server that allows you to create media processing applications based on the pipeline concept. Media pipelines are created by interconnect modules called Media Elements. Each Media Element provides a specific feature. KMS contains Media Elements capable of recording and mixing streams, computer vision, etc.

From the point of view of the application developer, Media Elements are like Lego pieces: just take the necessary elements for an application and connect them according to the desired topology. This type of modularity is new in the field of RTC multimedia servers.

Kurento Media Server offers the capabilities of creating media pipelines through a simple JSON-RPC-based network protocol. However, to further simplify developer work, a client API that implements this protocol and directly leverages Media Elements and pipelines is provided. Currently, the Java and JavaScript client API is ready for developers [16].

Taking into account the integrated modules, the Kurento Toolbox is detailed in Fig. 1.

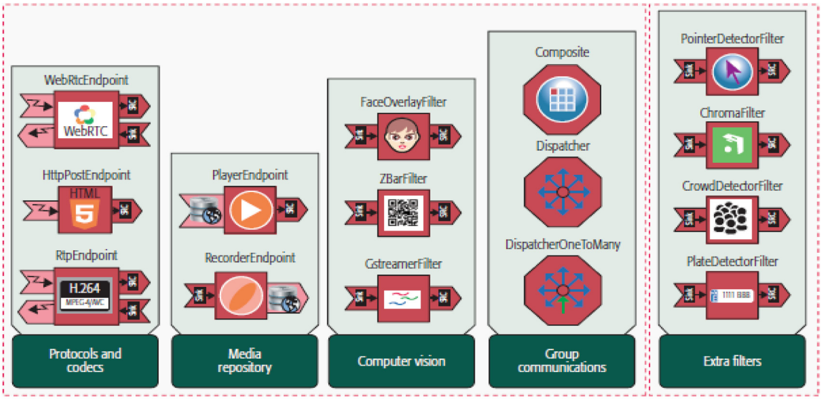


Fig. 1. Kurento media elements toolbox

4 Presentation of the Proposed Architecture

To exploit the advanced features of the WebRTC, the proposed architecture integrates Kurento Media Server (KMS). During a WebRTC multimedia session, the solution provides access to the information collected by the sensors and sends it to the other end of the communication in real time. The Fig. 2 describes the architecture of the proposed system.

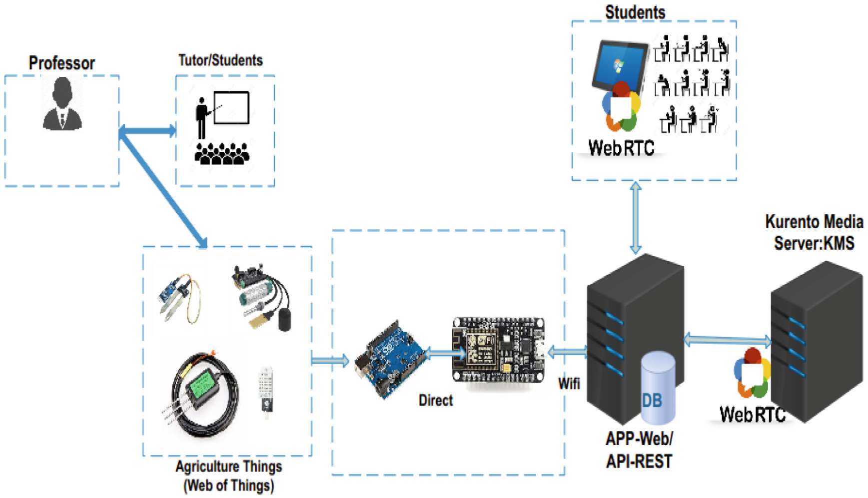


Fig. 2. Proposed system architecture

Distance education in the field of agriculture, biology, etc. is faced with many technical and logistical difficulties. Field visits are an indispensable complement to the theoretical course given to students. Biodiversity areas may be unstable and potentially dangerous for non-residents. The proposed solution allows students of the National School of Agriculture (ENSA) Thies to conduct an educational excursion to study the biodiversity of southern Senegal. To do this, a group resident in the region is selected for taking measurements (soil moisture, chemical composition, ambient temperature, etc.) under the supervision of a tutor. The collected data is directly transmitted to the application and then shared in real time with the other students via the platform. With the help of a connected computer, tablet or smartphone, any student can view the measurements and follow in real time the comments/explanations of the tutor. Each student can also interact by asking questions.

5 Implementation

A platform using Node.js and KMS is implemented in this paper. On the one hand, it allows to establish a multimedia communication between several users by simply using their browser. On the other hand, it allows users to access data from predefined connected objects. The proposed architecture consists of three distinct entities: Internet of Things, API and Web Application.

5.1 Internet of Things

The first part is the WoT part. Each endpoint is considered a gateway to its set of smart objects. In addition, each user has control over these objects. The NODEMCU ESP8266 aggregation node is not responsible for reading the sensors. It simply provides a gateway between the user and the sensor network, and then performs data analysis. The sensor node is the lowest level of a sensor network. It is responsible for gathering information from sensors, performing user actions, and using communication mechanisms to send data to the aggregation node (see Fig. 3).

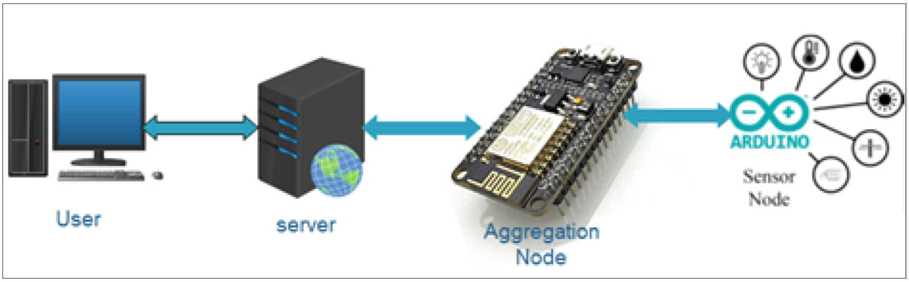


Fig. 3. Architecture WoT

The ESP8266 gateway can then communicate with the sensors using one of the well-known communication protocols (Lora, Zigbee, Bluetooth, WIFI …). In the current platform, a DHT11 humidity and temperature sensor, sensors for the chemical composition of the soil and an HD camera to visualize the medium can be used. These are connected to the NODE MCU Gateway (ESP8266) which sends data using 4G or WIFI. Using the current architecture, the implementation of a remote pedagogical outing is possible, where a tutor communicates with students using Kurento Media Server. Figure 4 shows the wiring of the Node MCU Gateway with the DHT11 temperature and humidity sensor.

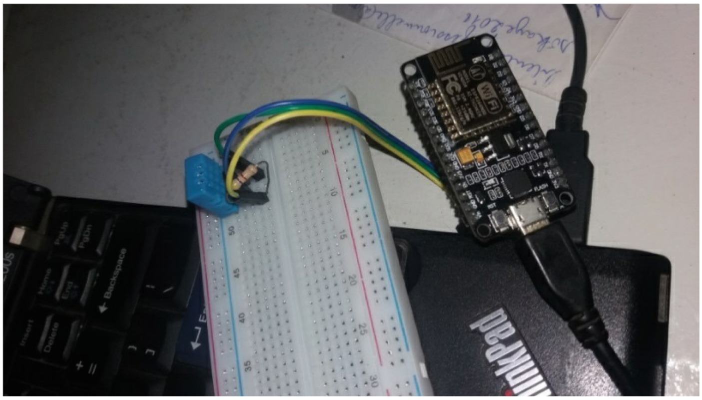


Fig. 4. Wiring the ESP8266 with the DHT11

5.2 API

We have developed a REST API capable of retrieving information collected by sensors and storing it in a MongoDB database. MongoDB belongs to the NoSQL family Document-store, developed in C++. It is based on the concept of a key-value pair. The document is read or written using the key. MongoDB supports dynamic queries on documents. Since this is a document-oriented database, the data is stored as JSON, BSON style [17].

According to recent work [18–20], NoSQL database systems are non-relational databases designed to provide great accessibility, reliability and scalability to huge data. NoSQL databases can store unstructured data such as e-mails and multimedia documents. MongoDB has many security risks that can be overcome by a good, secure cryptographic system [21].

5.3 Web Application

To set up the web application, we use the NodeJs and Kurento Media Server technologies. This platform allows teachers/tutors and students to register and authenticate themselves to access Kurento Media Server features. Once connected, students can view the sensor data and media streams of the tutor in charge of the educational output. Figures 5 and 6 show the authentication principle on the KMS-IoT platform.

The web application can also collect information from the database and display it. Connected users can then view sensor data. Figures 7 and 8 show that actors can access the temperature and humidity sensor information. The same mechanism is applicable to any other sensor.

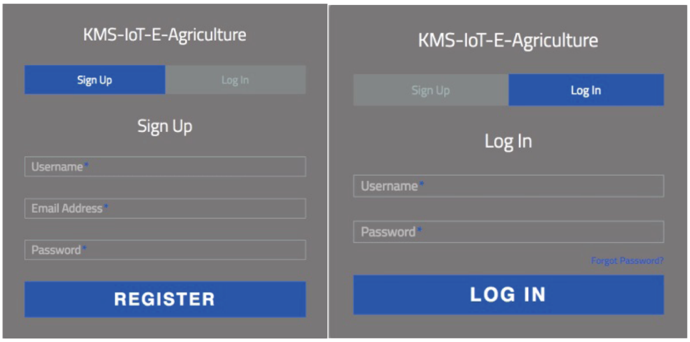
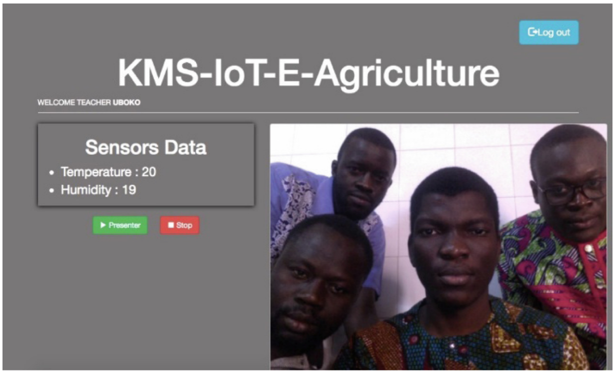


Fig. 5. Authentication and login on the KMS-IoT-E-Agriculture

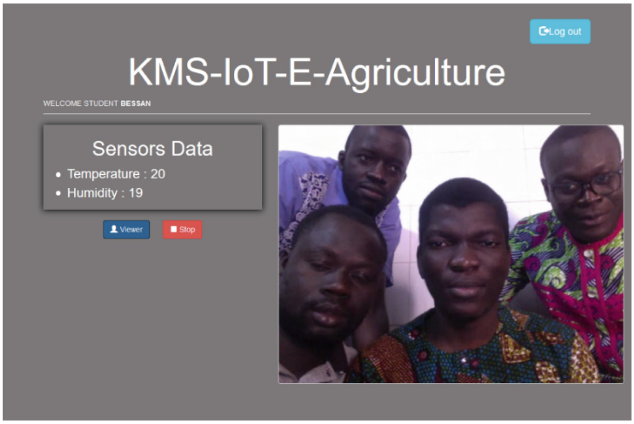


WELCOME TEACHER **UBOKO**

Sensors Data

- Temperature : 20
- Humidity : 19

Fig. 6. Communication between teacher and students: teacher side



WELCOME STUDENT **BESSAN**

Sensors Data

- Temperature : 20
- Humidity : 19

Fig. 7. Communication between teacher and students: student side

Figures 8 and 9 show the authentication and communication steps between the students and the teacher on the KMS-IoT-E-Agriculture platform.

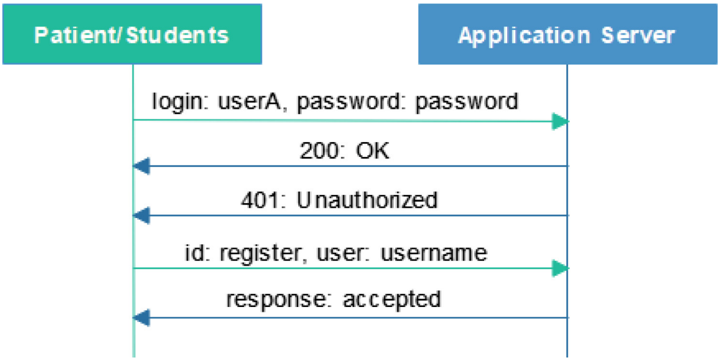


Fig. 8. Authentication flow

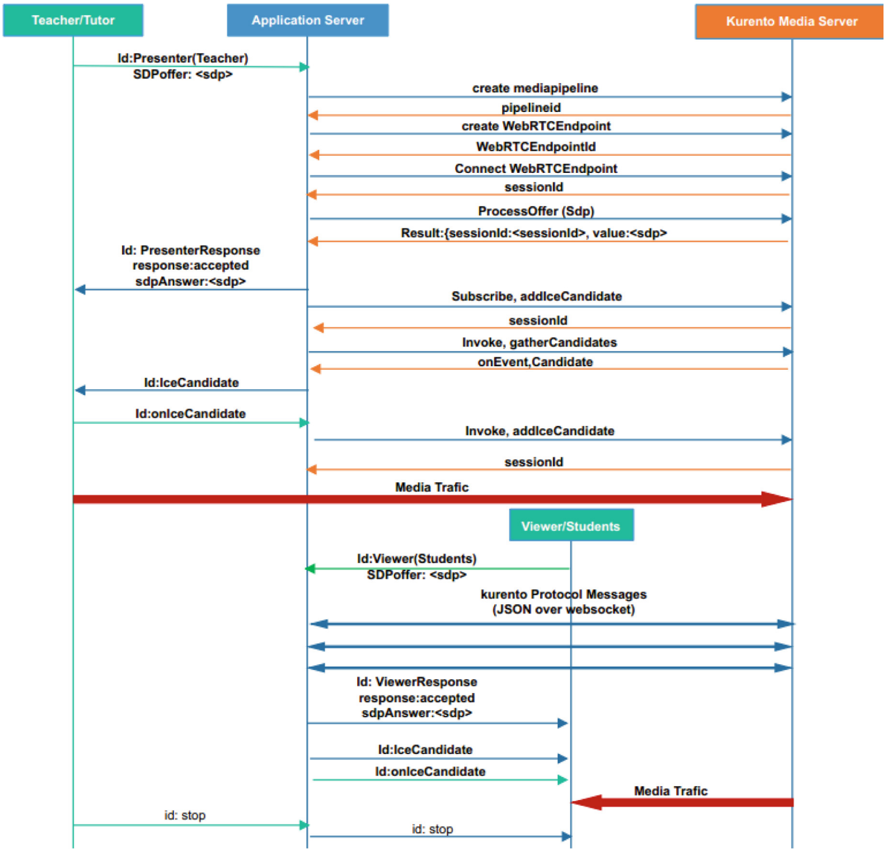


Fig. 9. Communication flow between students and the teacher on the KMS-IoT platform.

6 Conclusion

In this article, we propose the platform KMS-IoT-Agriculture which allows to do practical work in the distance education of agriculture. This platform is built around a WebRTC Kurento multimedia server, an API, a Web application and connected objects. It allows distance learning students at ENSA Thiès to undertake a virtual tour to study the biodiversity of southern Senegal. The adoption of the proposed approach could contribute to the improvement of distance education in agriculture.

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