A Case Study of a Virtual Training Environment

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Abstract. Virtual Reality is the most promising technology for providing new learning and education solutions and more efficient opportunities for a revolutionary training environment. Here we introduce a Learning Management System (LMS) for providing users not only with all education material but also supporting experiential learning as well through VR simulations. The presented VR model trains users for managing several threat factors, ensuring data protection and security for the operation of LPWAN in Industry 4.0 environment. The training platform uses virtual reality environment so that to increase user's comprehension of the provided security level of an LPWAN network. In addition to this, users of Virtual Reality training platform can easily discover the security vulnerabilities of the LPWAN deployment. The proposed VR model provides a web based portal that is incorporated with Moodle and OpenSim for providing a user interface for managing Learning activities and for consistent linking of learning activities in e-Learning and OpenSim environments.

Keywords: Virtual reality · Learning Management Systems · VR simulation · VR training · LPWAN

1 Introduction

Over the last years the widespread usage of Internet and accessibility at educational resources; the new technologies and various accessing means have led to the creation of vast amount of open online educational environments. There have been examined and proposed new concepts and methodologies towards the realization of e-participation of students and at the same time aiming to the integral combination of academic and industrial sector [1–6]. Many scientists work on the technologies and methods of adaptive learning (see [7–12]). On the other hand the adoption of new technologies like Virtual Reality in education could offer different more adaptive and attractive learning experience. The development of 3-dimensional Virtual Worlds is a key element in distance learning [13–15] offering a 3-D experience to users interaction and communication [16].

Virtual Reality (VR) has the ability to create and integrate any kind of environment, redesign, retest and refined them in a virtual computer based framework. Thus, Virtual Reality is the most promising technology for providing new learning and education solutions and more efficient opportunities for a revolutionary training environment. The

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use of Virtual reality for training and learning proposes [17–21] is attracted great interest from the research community. Thus various VR use case scenarios are proposed to learning users specific activities [22–26]. Beyond that, VR simulation on a real-time event in industry can investigate poorly understood phenomena and allows companies to decrease design and production costs [17, 18, 21, 23, 27–35]. In one of those scenarios, they created a platform that simulates an actual facility. All buildings and objects were created with the use of 3D CAD. The user with the use of HMD and haptics could perform machining operations. The creation of a method for a risk evaluation is critical for all industries. The VR has been used for evaluation and testing [21, 28]. Furthermore VR simulation of a real-time movement decreases the potential cost and risk of physical implementation thus Virtual Reality is undeniable a unique tool that has many uses [36], from teaching students all around the world to simulate safety scenarios [20, 37, 38]. It is a great substitute for the real life environment and can minimize the safety concerns especially for training users to a new technology. Here our VR model trains users to a new IoT technology.

Here we introduce a Learning Management System (LMS) for providing users not only with all education material but also supporting experiential learning as well through VR simulations. Moreover we implemented a simple user role playing 3D game for delivering Information Security issues in LPWAN networks thought the LMS platform that includes all the learning material for exploiting security parameters in LPWAN. Our proposed training system includes an internet portal that provides to the users an Learning Management System (LMS) that will support the exchange of information on learning activities and uses the possibilities of the 3D virtual world technology to create experiential learning simulations. Finally we evaluate the usage of the developed VR training system by a set of 10 students.

1.1 VR Software Platforms

There are various software application that could be used to create Virtual Environment with specific scenarios usable for training users not only in education sector but in industry sector [39]. Unreal Engine 4 and Unity 3D are VR tools that can be used to develop VR applications for training users in various scenarios but require heavy coding. There is also the solution of Second Life and OpenSim. Those two platforms have been used for years to create virtual worlds for education and learning. Both OpenSim and Second Life are applications that are easy to install and maintain [40]. Unlike those two platforms Linden Lab, the company behind Second Life, they published a new platform named Sansar. In this platform they upgraded the graphics to provide improved immersion but it also raised the PC requirements. The realistic look of a VR application makes the immersion better. Software such as blender and 3DS max has been used to create 3D models. In the presented VR model we use the OpenSimulator because it provides less immersion compared to platforms that have been created from Unity 3D and Unreal Engine 4, it is widely used for educational purposes and in some cases replace the classroom.

1.2 LPWANs

There is a wide applied approach of exploiting sub-GHz bands in order to increase the transmission range of nodes by trading-off data transmission rate while keeping at the same time power consumption at low levels [41]. This so-called Low-Power Wide Area Networks (LPWANs) are in contrast to high-frequency communication. In fact, low frequency signals are not as attenuated by obstacles, thick walls or multipath propagation and they are contributing in this way to robustness and reliability of the signal [42].

LPWAN technologies allow IoT devices to connect to gateways (also called collectors or concentrators) over distances in the range of several kilometers. Overall, LPWANs are promising candidates for IoT applications in Industry 4.0, since they allow high energy autonomy of the connected devices, low device and deployment costs, high coverage capabilities and support a large number of devices [43].

1.3 Security in LPWANs

Security is a major concern for novel Industrial IoT environments, since primitively industrial systems are not designed to deal into an internet not secure connected environment. One major concern about the security threats in industrial IoT ecosystems is the possibility to disclosure critical data and information. Exposure of critical data is essential such as revealing the design of a new product, which could cause substantial financial and reputation loss. Industrial competitors spend a lot of effort to gain some inside information about products, suppliers, production procedures and methodologies. The disclosure of critical business data may allow access to the critical know-how of a company and might result in a very high business risk.

Regardless of the technology used to connect the smart devices with the Internet in the industrial environment, during the interaction within the IoT ecosystem, huge amounts of data are being recorded, shared, aggregated, annotated, stored and processed. If an external have access to these collected data may use it to extract or infer sensitive information about the industrial process and so violate company's and customers' privacy [21, 44].

It is essential that any IoT system must guarantee the confidentiality and integrity of the information and the privacy and anonymity especially for industrial users. Moreover, it is important to guarantee the confidentiality of the end nodes data, especially when these end node devices operate in open and uncontrolled environments. Inherently, IoT framework suffers from several security issues which are more challenging than any other case because of the complex and resources-constrained IoT devices environment. There are initiated a lot of research efforts in order to investigate and provide efficient security solutions for IoT environment, particularly to address resources constraints and scalability issues. A comprehensive top-down survey of the most recent proposed security and privacy solutions in IoT is provided in [45].

Recently some technical papers have concentrated on the security vulnerabilities in LPWANs [46–48] providing alternative solutions for the cryptographic primitives (see [49] and [50]). Authors in [10] focus on application server vulnerabilities and in [51] introduced an alternative key management scheme. However, to the best of our knowledge, there are no approaches that analyze the trust from a technological, policy and public awareness point of view, based on a trust life cycle of a system that includes the operation phases.

1.4 Our VR Model

In the present study is designed and implemented a Learning Management System (LMS) that supports Virtual Reality technology for training purposes. The designed system includes an LMS platform includes various learning and assessment activities and implements educational activities in Virtual Reality environments. The implemented system utilizes a Virtual training model that helps users to investigate the security issues and tools in LPWAN protocols and to better understand new risks and vulnerabilities that they should consider and address when they use LPWAN protocol.

The presented VR model utilizes the designed use case scenarios that were introduced in [36, 52] for training users for managing several threat factors, ensuring data protection and security for the operation of LPWAN in Industry 4.0 environment. The training platform uses virtual reality environment so that to increase user's comprehension of the provided security level of an LPWAN network. In addition to this, users of Virtual Reality training platform can easily discover the security vulnerabilities of the LPWAN deployment. The proposed VR model provides a web based portal that is incorporated with Moodle, Sloodle and OpenSim for providing a user interface for managing Learning activities and for consistent linking of learning activities in e-Learning and OpenSim environments. Finally we evaluated the usage of the developed VR training system by a set of 10 students.

1.5 Structure

The rest of the paper is organized as follows. Section 2 presents system's architecture and its components. Section 3 presents the unifying training environment and Sect. 4 summarizes its usage evaluation by a small set of users. The paper concludes in Sec. 5 along directions for future work.

2 System's Architecture

The architecture of VR training system is consisted on the following main components:

- Link to the home page
- Template of courses
- Learning Activities
- Learning Assessment Tasks
- The Forum
- Help links to users' manual, training course, and video on the use of the portal
- Professors' and Students' user interface
- The VR training Environment.

System's architecture is consisted of various components that have different and complementary functionalities and roles. In the following, we will give a detailed description of the portal:

Home Page: This is the main informational web page. Through this web page, the Users are informed about the system's functionality and how it operates. It provides to the users the necessary links to the other components of the system. Every time a user desires to interact with the system, the first action to take is to visit the url of the portal and then he can perform various actions (e.g. evaluate a competence, browse a Course etc.). Home Page is accessible through http://www.tiphys.eu/moodle/ (see Fig. 1).

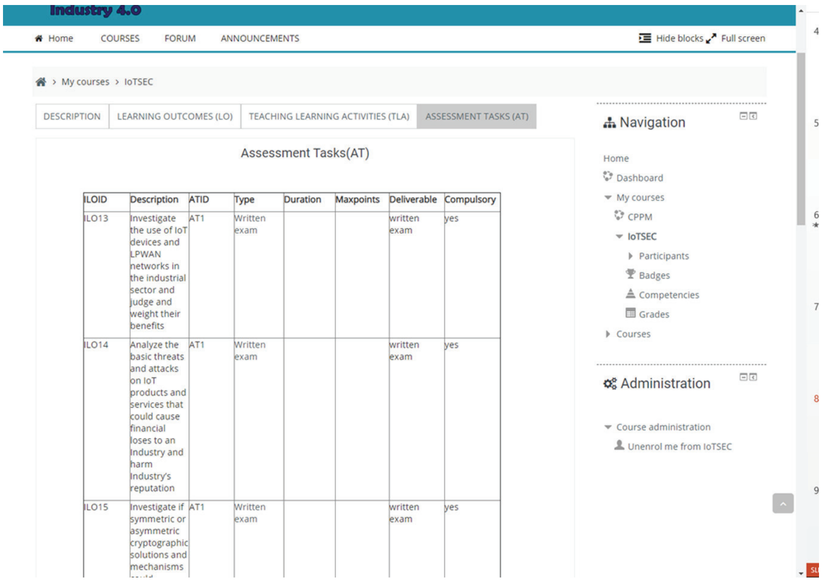

Fig. 1. Home page.

Professors Interface: A professor could log into the portal and access the interface in order to:

- Edit/Insert data in a specific Course
- View a Course
- Add Announcements
- Insert/edit an Learning Activity
- Edit an VR environment of the uploaded learning activities and assessment tasks

Student Interface: A student could log into the portal and access the interface in order to:

- View a Course
- View Announcements
- Access the list of Learning Activities/Assessment Tasks
- Participate in VR simulation for a of Learning Activity or Assessment Task
- View a Virtual Presentation
- Participate to a virtual exam

List of Courses: This component includes the index of all the provided Courses and their links. Students could browse part or/all the provided Courses through this web page.

Course Components
Each Course component consists of the following subcomponents:

1. *Course's Description:* This component includes a detailed description for each Course.
2. *Announcements:* This component includes and presents all the uploaded announcements from professors for the specific Course.
3. *Teaching Learning Activities:* This component describes the Teaching Learning Activities for each Course for learning Industry 4.0.
4. *Assessment Tasks:* This component helps students to understand what actual assessment tasks.
5. Must be delivered by a specific Course. Professors are responsible for constructing these tables.
6. *VR simulation:* This component is responsible for the realization of virtual training environment for a specific assessment task or learning activity (see Fig. 2).
7. *VR components:* This component uses VR representation for participating a VR class attendance or a VR exam (see Fig. 3).

The developed system includes an open LMS website. The LMS was developed using the Moodle technology. Moodle is installed in a Linux server that operates Linux Ubuntu 16.04.4 and it uses mysqli as a database. Moodle provide the users with tools to create their own courses, communicate via messages with other users and post questions in dedicated forums for each course.

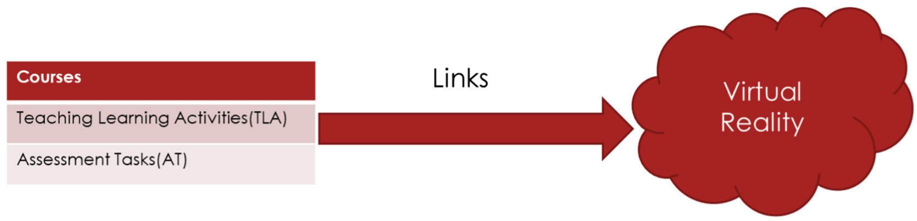

Fig. 2. VR simulation.

Each course includes a list of Learning Activities and Assessment tasks and some of them are connected with the VR training environment.

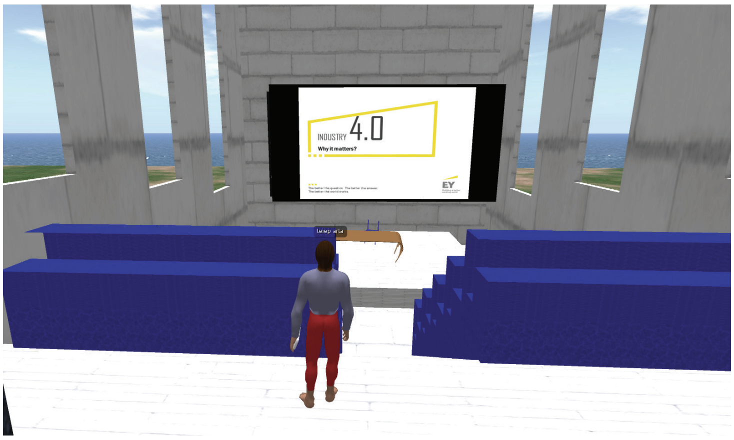

Fig. 3. VR presentation and VR exam.

3 The VR Training Environment

Virtual Reality training environment operates via OpenSimulator server and user's client uses the Firestorm viewer. The LMS system is connected with the VR training environment via the HOP technology. The learning activities and assessment tasks (Fig. 1) are connected with a set of URLs in the virtual reality server and when users from the browser click on the link he will be teleported to the specific locations of training (Fig. 2).

The creation of the included 3D objects in the implemented VR training environment was made via OpenSimulator's native tool and via creating collada files by using blender or any other software for 3D object creation.

The developed scripts in VR Training environment are created in server by using the Linden Script Language for short LSL. LSL is a native scripted language developed and used in the OpenSimulator server.

The users in the VR Training Environment can navigate in Virtual World and interact with it. They can view lectures, do exams and participate in quiz questions. They can also use the chat function or the voice chat to communicate with others.

VR presentation was created as an object using the OpenSimulator's native tools. VR presentations are uploaded in server, by creating an image for each slide, and imported them in its object. The developed scripts in the LSL language provide VR view function of presentation's object.

The VR exams and quizzes were created as a small object and it is added a small image. A notecard with the questions was created and imported to their object. The developed scripts in the LSL language provide a VR read function of the notecard and a small dialog box that opens on the top right side of the user for answering them. All the answers are recorded and can be seen by other users in the chat.

We implemented a "*Security in LPWAN*" course in the presented training environment for evaluating user's comprehension of the security parameters of an LPWAN network by a small set of ten students. The presented training environment implements a 3D game where the specific tools and approaches ensuring that users know the basic security tools of LPWAN protocol and understand the potential security flaws for their actions. Therefore the course "*Security in LPWAN*" includes the following set of learning activities and assessment tasks that are linked to a VR training environment where the user has to pass through different rooms/areas for concluding a 3D game.

The course "*Security in LPWAN*" includes the following list of Learning Activities and Assessment Tasks that are connected with the VR training environment:

1. LPWAN Network Architecture
2. Keys' Security Parameters
3. How does the Joining Procedure work
4. How to send a packet

In all implemented VR environments user's avatar could make specific actions like navigation, interaction with objects, communication, objects creation and avatars configuration within the virtual world. The main 3D experience of the Learning activities and assessment tasks and how it helped the end-users are described in following subsections.

3.1 LPWAN Network Architecture

The designed training environment includes specific visualizations and steps so that the user to be able to understand the basic security parameters of LPWAN network. Initially users navigate thought a LPWAN network where the avatar can select the connection links from different components as shown in Fig. 4. One of the basic

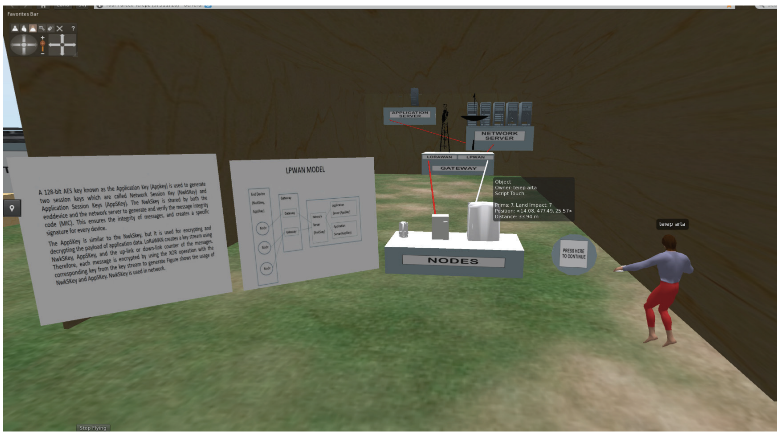

Fig. 4. LPWAN components.

characteristics that LPWAN introduces in order to perform all its provided security mechanisms is that the user interacts through various concentrators to an application server that forwards the encrypted package to Network Server. The 90% of all end-users stated that 3D virtual environment helped them to understand LPWAN components and their functionality.

The assessment task for this learning activity includes a 3D game where the Avatar has to select and connect an IoT device and thought its navigation is able to assess the knowledge about the basic security factors of LPWAN by answering specific questions in different parts of its navigation based on the acquired Virtual experience it possess.

3.2 How Does the Joining Procedure Work?

Here the VR environments simulates the learning activity by informing the user about LPWAN joining procedures via a VR presentation as shown in Fig. 3. The user after concluding the presentation he must be able to understand that the LPWAN network provides two different procedures for connecting an IoT device with different security requirements. All the users stated that the VR presentation has minor benefits compared with the uploaded 2D presentation on LMS portal.

The assessment task for this learning activity is utilized by a quiz (see Fig. 5). Based on user's answers the user could follow two different joining scenarios. Here the majority of users do not understood all the security parameters of the joining procedures.

Fig. 5. Knowledge assessment

3.3 Keys' Security Parameters

In this VR experience the user will learn how the corresponding keys are used by constructing package information, encrypting and signing it.

This VR experience implements the learning activity by a more experiential way and users stated that got deeper knowledge on this environment compared to the previous ones.

The packet construction VR experience helps the user to understand how an IoT device is connected in LPWAN. User's avatar can create its packet by selecting packet's component by a stack of objects. The packet construction VR experience helps the user to understand what information is broadcasting by LPWAN protocol for joining the network. Figure 6 shows the packet construction phase and how it helps the avatar to be informed:

- for its actions.
- that the initial secret symmetric is known to both end-device and the network server.
- that the IoT device is equipped with an application identifier and a global unique identifier.

Fig. 6. Packet construction

The avatar could also encrypt its constructed packet by throwing a dice for generating a random number and by locking the packets by using a secret key for encrypting the transmitted packet (see Figs. 7 and 8).

Finally the assessment task for this learning activity includes several quizzes that are placed on different scenes of the VR environment (Fig. 9). The majority of the end users stated that this VR experience helped them to increase their comprehension about how the provided keys are used.

3.4 How to Send a Packet

The VR environment that implements this learning activity simulates the generation of all the basic keys of LPWAN and visualizes where they are used. In this VR scenario the avatar generates its secret keys by using an 128 bit key and the user has to select at

Fig. 7. Generating a nonce

Fig. 8. Encrypting and sign

a panel either the Network Secret Key or Application Secret Key (Fig. 10). Moreover this training phase visualize when the encryption is performed with the Application Secret Key or the Network Secret Session Key and inform the user about the usage of Application Secret Key and Network Secret Session Key and their relation to packet's content.

Fig. 9. Assessment quizzes

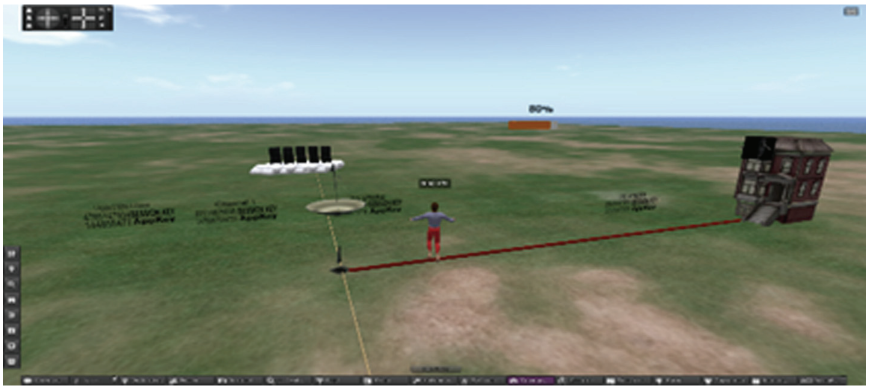

Fig. 10. Getting secret keys

The assessment task checks user's knowledge about the use of the generated session keys (Application Secret Key and Network Secret Session Key) for encrypting all further message payloads between the node and the application server during the lifetime of the session (Fig. 11). The 80% present of users stated that this VR environment mainly was helped them to understand how the application server could not be able to decrypt their packet.

Fig. 11. Sending a packet

4 End-Users Results

The most important result obtained from the evaluation of our VR training environment from all of ten end users is the general perception that a training system that provides all the education material and also supports VR learning simulations provides a very convenient training experience. The majority of users are confident that 3D virtual worlds can provide learners with a full understanding of a situation using experiential 3D use case scenarios.

Users in general prefer a VR use case scenario that simulates several real life actions in order to obtain the sense of purpose of the simulating action, thus the VR use case scenarios that only include 3D navigations and quizzes do not provide good conceptual understanding.

Thus use case scenarios that simulates the learning activities must include several interactions with virtual objects in order to enhance learners' interest and engagement to the learning tasks and help them to develop a stronger conceptual understanding.

5 Future Work

Here we proposed a VR training system that includes an internet portal that provides to the users an Learning Management System (LMS) that will support the exchange of information on learning activities and uses the possibilities of the 3D virtual world technology to create experiential learning simulations. Moreover we implemented a simple user role playing 3D game for delivering Information Security issues in LPWAN networks thought the LMS platform that includes all the learning material for exploiting security parameters in LPWAN and we evaluated its usage to a small set of users.

Although Sloodle (Simulation Linked Object Oriented Dynamic Learning Environment) provides various tools for integrating the Moodle with Second Life it is outdated and all the virtual tools except presenter were encountered various compatibility problems and errors. We plan to evaluate the usage of the developed VR training system by using a bigger set of students in Computer Security theme. Based on the evaluation, we will further update the environment so that to be able to successfully educate the interested parties.

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