VRFiWall
Virtual Reality Edutainment for Firewall Security Concepts

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***Abstract*— Network security is an important topic in the security class for computer science students. Unfortunately, the network security concept is moderately abstract and challenging when students learn in the traditional lecture-based class. The knowledge can be delivered to students better in the form of edutainment, i.e. the combination between education and entertainment. This edutainment technology will help students to learn difficult topics more enjoyably and more efficient. This paper discusses the development of a novel virtual reality (VR) application called VRFiWall, destined to educating the Firewall concept, which is one of important topics in network security class. Our edutainment game is designed for university-level students and can be alternatively used to support in lecture-based class. Moreover, our game also supports both the desktop and mobile platforms, thus students can practice the game and review the security concepts easily via their mobile phones anywhere and anytime as well.**

Keywords*— *Firewall, network security, virtual reality, educational entertainment

I. INTRODUCTION

Computer and network security is an important topic in the computer science education. It helps students to realize the importance of security, how to protect the systems from hackers and intruders, and how to prevent from the potential attacks. Firewall is a network security system that is usually deployed at the first line on the organization's gateway in order to filter malicious packets. It monitors and manipulates the incoming and outgoing network traffic based on predetermined security rules [1]. Most of the computer science curricula in universities and institutes of higher education provide this knowledge in a course focused on network security.

Although universities provide these classes, the abstract nature of firewall security concepts require perception and imagination, but not all students learn in the same way. Therefore, the traditional lecture-based teaching techniques have often been considered insufficient to accomplish these learning objectives [2]. In this digital era where people are familiar with digital media, a better mechanism to stimulate student interest and engagement in such a course is required.

Educational entertainment or edutainment is a method that combines the entertainment with the education in order to make learning more enjoyable and engaging [3]. The entertainment can be any kind of audios, videos, films, games, and toys. The recent interest in virtual reality (VR), which is a technology that immerses a user's physical presence in a virtual environment through a head mounted display, is making VR a viable platform for the creation of entertainment games.

In this paper, we explore the use of VR technology to develop a fantasy role-playing game (RPG) called "VRFiWall" or "Virtual Reality Edutainment for Firewall" for educating students about firewall concepts. The virtual environments in the application are created to be analogous to the real firewall scenario, such as the packet filtering firewall or the stateless firewall. This game was developed using the Unity game engine [4], which gives it flexibility to be run either on a desktop or a mobile device.

The rest of the paper investigates as follows. The next section provides briefly addresses related works on the learning security based on game methodology. Section III details on VRFiWall application, game story, the implementation, mechanisms in application, problems and limitations. The last section concludes the current status and discusses future work.

II. RELATED WORK

Traditional lecture-based teaching techniques are commonly using to provide knowledge of network security, but they are well known to lack student engagement [5]. As a result, many alternatives have been created, especially game-based learning, to help students study network security. However, none of these alternatives focus deeply on the specific topic of Firewall security.

A. CyberAware

The authors in [6] developed "CyberAware" it is a mobile game-based application for cybersecurity education and awareness. They are aiming to deliver the knowledge of in the form of a digital game-based activity to K-6 aged children. Moreover, they are composed with the ARCS motivational model; the systematic design process for

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promoting and spurring motivation during the learning process.

B. CyberCIEGE

"CyberCIEGE" [7] this one is the resource management simulation in which the player assumes the role of a decision maker for an IT dependent organization. The objective is to maintain the users in virtual organization happy and productive while providing the necessary security to them.

C. Control-Alt-Hack

Another example of computer security game based learning is the "Control-Alt-Hack" [8] it is a board game in which players will be assigned a role as employees of a computer security company and have missions to be completed about computer security. The concept of this game is similar to CyberCIEGE.

D. Anti-Phishing Phil

This game is an online game that teaches players good habits to notice uncommon URLs to avoid phishing attacks [9]. It was implemented in 2D using Flash 8. The contents for the game, including URLs and training messages, are loaded from a data file at the start of the game. Thus, the developer can quickly update the contents.

III. Design of VRFiWall

Firewall security is one solution in computer science to manage threats in the network. This is the reason that most information and communication technologies universities and institutes of higher education publish firewall security as part of network security education and include traditional lecture-based security classes. In this context, the VRFiWall application was designed to support learners with an alternative, engaging, and more efficient way for learning firewall security. The overall aim of the application is to help computer science students learn about firewall security, definition, types, mechanisms, capabilities, and limitations.

VRFiWall is developed for multiple platforms for virtual reality on PC and Android using the Unity3D Game Engine with C# language complied on Microsoft Visual Studio Community 2015. The concept of game is based on the fantasy role-playing game (RPG) that the player can interact with non-player characters (NPCs), get items, and battle with a monster.

We took advantage of the cross-platform compatability of Unity to develop two versions of the game. One was suitable for desktop computers, composed of high-resolution graphics and environment rendering. The second was composed with lower resolution polygon models in order to prevent VR induced motion sickness when playing on mobile devices. One major design consideration for mobile devices is that typically the users do not have hand controllers. This also helps to lower the barrier to entry when deploying the VR application to a large number of students. Because of this, our versions of the game were implemented using the Cardboard, from the Google VR Software Development Kit (SDK) for Unity; obviating the need for hand controllers. Fig. 1 illustrates the system architecture of VRFiWall. Other than Unity framework, Google's Cardboard, and Visual Studio's C#, we also use Blender for developing some 3D models.

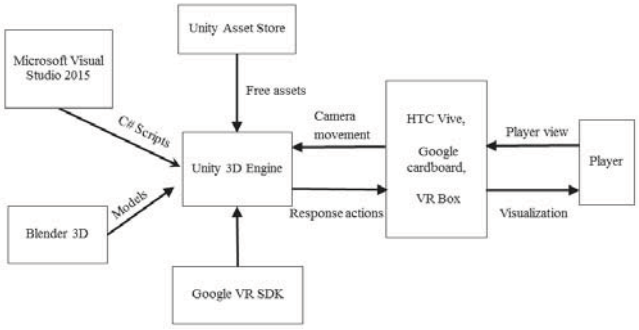

Fig. 1. System architecture of VRFiWall

Only two types of interaction mechanisms were implemented within the game. Pointing is used as the main function to control almost every action of a player including player movement, picking up objects, selection, and combat. Head gestures is used to control interactions with non-player characters (NPC) in the game. Fig. 2 shows a user playing VRFiWall by using the head gesture.

Fig. 2. Playing VRFiWall by using the head gesture

IV. Game Implementation

A. Game Story

The game currently covers only one type of firewall, which is the packet-filtering firewall or stateless firewall. The firewall inspects each packet that is transferred over the Internet. In the stateless firewall, there are normally four fields of packet headers that the firewall has to inspect: (1) source IP address, (2) source port, (3) destination IP address, and (4) destination port. The packet that matches a firewall rule will be forwarded to the destination host, or will be discarded, based on the ACTION that is assigned to each rule. In most deployments, the administrator normally discards all incoming packets and forward only packets that match the forwarding rules. If the header of the packet does not match any filtering rules, the packet will be "discarded".

Conversely, if the header of packet matches one of the rules, the packet will be "forwarded".

In the game scenario, the player will be assigned as a "packet" named Paragon that must pass through the firewall. Paragon was given a secret mission from his kingdom (a source IP address) to go to another kingdom (a destination IP address). The player must learn about filtering rules and make himself (i.e. the packet) match with a rule in order to successfully pass the firewall gate.

In addition, according to [10], a firewall can be considered to be similar to immigration, or frontier control. At the immigration gate of airport in real life, when people want to move from a country to another, there must be a passport and a visa for identifying the origin country of people and permission to go that country. Therefore, the idea to represent the source and destination ports as game items to show identification and permission is adopted from this concept.

Thus in our game, the player must possess two items from two kingdoms. These items represent the source port, which is analogous to a passport where the kingdom the player originates from, and the destination port, which is analogous to a visa to the destination kingdom beyond the firewall. There are four conditions that match a firewall rule in the game. These conditions are *Primitive kingdom, Primitive kingdom's item, Terminal kingdom,* and *Terminal's item.* Each rule has its own values on this stateless firewall as shown in Table I.

TABLE I. LIST OF ITEMS AND THEIR TYPES DEFINED IN VRFIWALL

Item Types	Item Name
Primitive kingdom (Source address)	DoSa, Spoofia, Tinya, Flager
Primitive kingdom's item (Source port)	Telnetar Rune (23), Simail Rune (25), Dominia Rune (53), Hyper Rune (80)
Terminal kingdom (Destination address)	Honey, Demitar, Interia
Terminal's item (Destination port)	Telnetar Ring (23), Dominia Ring (53), Hyper Ring (80)

As shown in Fig. 3, there are four other important non-player characters (NPC) in the game.

1) Uni-chan

She is the one of the NPCs that the player can interact with if help is needed. She will give clues about the filtering rules that the firewall accepts. Clues will be embedded in the character dialogue.

2) Lion

This is a second NPC that the player can query for help and will give player different clues about the filtering rules similar to Uni-chan.

3) Feena

Feena is the fairy that lives in the Black Forest. Her duty is to protect the heart of Statelessa; the item that allows a player to pass through stateless firewall without needing to satisfy the rules. A player can obtain this item by answering her questions.

4) Statelessa

Statelessa is the name of the stateless firewall in this game. It is a wall that will inspect a player to see if he/she satisfies the filtering rules or not.

Fig. 3. Other four main characters in game
(1) Uni-chan, (2) Lion, (3) Feena, (4) Statelessa

B. Game Mechanism

This initial prototype of VRFiWall game contains only one level focusing on the packet filtering or stateless firewall. In this level, we use a simple script to randomly generate the firewall rules from four conditions mentioned in Table I.

TABLE II. EXAMPLES OF RANDOM GENERATED RUELS FOR PACKET FILTERING

Rule No.	Source IP Address	Source Port	Destination IP Address	Destination Port
1	DoSa	23 Rune	Honey	23 Ring
2	Spoofia	25 Rune	Demitar	53 Ring
3	DoSa	53 Rune	Honey	53 Ring
4	Tinya	80 Rune	Interia	80 Ring
5	Spoofia	25 Rune	Demitar	53 Ring
6	Flager	23 Rune	Interia	23 Ring

Each time the user starts playing the game, two rules that will be accepted by the firewall are randomly generated.

Examples of rules randomly generated are displayed in Table II. Two randomly selected firewall rules will be passed to Uni-chan and Lion NPCs who can provide appropriate clues to players for guidance. For instance, rule 1 will be the clue that the player can receive from Uni-chan and rule 2 can be received from Lion.

In the main scene of the game, there is a navigation menu above the player's view to provide further step-by-step guidance when the player desires. Navigations will be updated when the player completes each task. The sequence of navigation are ordered as shown in Table III.

TABLE III. NAVIGATION LIST FOR PLAYERS

Navigation	Message
1	"Talk with NPC and follow the clues"
2	"Get source port item and destination port item"
3	"Go to Statelessa magic barrier"
4	"Answer Statelessa's questions"

The player has to answer the question by correctly selecting a choice that is provided by Statelessa. As we do not have the hand controller, the player must point at a desired choice for 3 seconds in order to select it. There are four or three choices depending on the type of rule, as in Fig. 7. A selected choice must correspond to one of the generated two firewall rules. If the answer is wrong, the player will be teleported to the starting point (i.e. discarded the packet). Therefore, the player must answer every question correctly.

Fig. 4. Environment of VRFiWall in "Main scene"

There are four scenes in the current prototype: *Starting*, *How to* P*lay*, *Main*, and *Black Forest*. *Starting* is the first scene of the game that uses two head gestures: nodding to play and shaking to quit. The *How to Play* scene consists of the description of the game objectives, how to win, and basic functions in the game. The *Main* scene is the beginning location of the game. The *Black Forest* scene is a scene composed of mystical things, such as a monster, book of Firewall, and a fairy.

Fig. 5. Screen Output of "Starting scene"

The end of the game can be achieved by two ways: normal ending and special ending. For the normal ending, the player must successfully match the filtering rules. At the beginning of the game, the player must find the clues about the filtering rules by interacting with NPCs and remembering the keywords. Then, the player searches for the items that are mentioned in the clues. Once obtaining the items, the player will be directed to the Firewall for inspection to see if the player, who is analogous to a packet, matches a filtering rule or not. Fig. 7 illustrates the screen output of the normal ending.

Fig. 7. VRFiWall's Screen output of "Normal ending"

Fig. 6 "Book of Firewall", which is a hidden book that contains the basic information of Firewall security

For the special ending, the game will allow the player to pass through the firewall without inspection, by obtaining a special item. In order to obtain that item, the player must answer five questions about a firewall correctly. This requires the player to have knowledge of firewall security before attempting to answer. This knowledge is provided in a hidden book that contains basic information of firewall security, written as a mythical tale that corresponds to the overall story of the game. The player must search the virtual world to find this information and learn about firewall in

detail. Fig. 6 and 7 illustrates the screen outputs of "Book of Firewall" and "Special Ending" scenes, respectively.

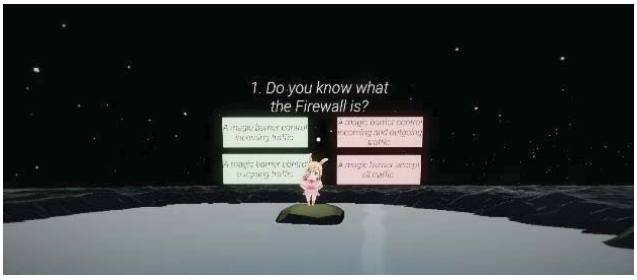

Fig. 8. VRFiWall's Screen output of "Special ending"

The reason we chose two alternative endings is because this game is designed based on the RPG and semi-open world game concept. Therefore, the player can independently explore the world we created and select the ending based on the player's decision. Moreover, two endings have their own effectiveness to teach player firewall concept. For the normal ending, player follows the different concepts step-by-step, before attempting to pass through the stateless firewall. On the other hand, the special ending will give the player the opportunity to self-teach the basic knowledge about the firewall in details by learning from the Book of Firewall. In order to achieve the special ending, the player must have this knowledge to answer all five firewall questions correctly from NPC named "Feena" in the Black Forest scene in order to obtain the key item for this ending.

C. Game Installation

The installation of this game varies depending on which platform is desired: desktop or mobile device. A desktop can run the game directly through the Unity 3D engine or can be used to create different versions of the game for different hardware platforms, increasing the portability of the game. The mobile device platform leverages on the Android application package (APK) file first, then installs the application on an Android device. Note that, in the Unity3d game engine, the color space in the rendering session of player setting must be Gamma. Moreover, the "How to Play" scene could not be built in the Android platform due to lack of video format (Movie Textures) supported on mobile devices [11]. Thus, every scene except "How to Play" were built and installed on Android mobile devices. In the future, we plan to include the game instructions on mobile devices in another format.

V. Problems and Limitations

There are four types of firewall that students have to learn: Stateless, Stateful, Application, and Circuit. Currently in the first prototype of VRFiWall, only the stateless firewall was deployed.

During the game development, one limitation was discovered on the mobile platform that was used to run the VRFiWall application. The mobile device we used was a Samsung Galaxy Note 3, running Android version 5.0 Lollipop with the performance of (A15 1.9 GHz + A7 1.3 GHz) Octa Core, RAM 3GB. The preliminary testing results indicated that more powerful specifications of the hardware than the Samsung Galaxy Note 3 are needed in order for the application to run smoothly. On the Note 3 device, the frame per second (FPS) dropped dramatically when the application was running. This is due to the fact that the game contains many assets, resulting in the high consumption of many mobile device resources. The solution to this problem will be reducing the number of assets in each scene. Moreover, this resource consumption also caused excessive heat generation of the mobile device and should be avoided to prevent additional hardware problems. For the PC desktop platform, we ran the application on the powerful Alienware desktop with CPU Intel® Core™ i7 7800X, 16GB Dual Channel DDR4 at 2400MHz, and NVIDIA® GeForce® GTX 1060 with 6GB GDDR5 connected with HTC Vive virtual reality hardware. The game could perform smoothly as expected with no issues on our Alienware desktop.

VI. Conclusion and Future Work

This paper details the development of a VR application on two platforms for teaching the concepts of firewall security to computer science students at the university level. The contribution of this paper focuses on the balance between the education and entertainment. This edutainment game design is an alternative to the traditional learning techniques that require the students read textbooks and/or lectures, which is considered to be less engaging for students. Furthermore, this approach has a higher entertainment factor because the player must self-discover firewall knowledge through the gameplay independently.

For the future work, a qualitative user study will be conducted to assess the effectiveness of VRFiWall to teach firewall security concepts by a group of computer science students using a pre- and post-use survey. Five questions about Firewall were designed for pre-questionnaire. At the beginning of this study, all participating computer science students will have the same level of firewall security knowledge through their regular network security curriculum. The students will be assigned to answer five questions before using VRFiWall. The student will then be allowed to play VRFiWall, which will be followed by a post-use questionnaire about firewall security that will be designed similar to the pre-use questions. A control group will be tested in the same manner, but will not use the VRFiWall application. A second survey will be used to assess the overall usability, quality, and satisfaction level of all VRFiWall users. The implementation will also continue developing the other three types of firewalls and add more challenges to be completed in the game. This prototype application will serve as a foundation for new learning techniques for firewall security concepts on the VR platform.

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