# Virtual Reality Architecture Oriented Wireless Connection For Future Generation Virtual Reality Devices

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***Abstract*** – **In order to enhance the user experience of virtual reality (VR) devices, VR multi-user environments and wireless connections must support as the latest generation of VRdevices. Wireless network-based wireless communication devices (WLANs) are popular consumer devices with high throughput and low cost using incompatible bands. However, the use of WLANs can cause packet delivery delays, due to their distributed nature when accessing channels. In this paper, we carefully discuss wireless VR via WLAN, and we request an efficient wireless multiuser VR communication architecture, as well as providing communication for VR. Because the architecture proposed in this paper uses many WLAN standards, based on the characteristics of each VR traffic chain, it is agreed that it supports the efficient sending of massive uplink data generated by several VR devices, and provides adequate frame rates and video control frames. rate for high-quality VR services. We conduct evaluations that are supported to improve exceptional applications than are supported.**

***Keywords – multiuser, OFDM, Virtual Reality, LAN nirkabel, VR nirkabel***

## I. INTRODUCTION

Network operators and system administrators are interested in the mix of traffic that is carried out on their network for several reasons. Knowledge of the composition of traffic is valuable for network planning, accounting, security, and traffic control. Traffic control includes packet scheduling and intelligent buffer management, to provide the quality of service (QoS) required by the application. You need to determine which application packages are included, but the traditional protocol layering principle limits the network to process only IP packet headers. Virtual reality (VR) devices are novel, and attractive consumer electronics that can provide an immersive VR (UX) user experience [1][2]. To improve UX of VR services, there have been significant efforts to improve not only the quality of video and audio and its interactions, but also the convenience of connecting VR devices to VR consoles, or VR (PC) - computer personal computers. Therefore, consumers at the Market Market ensure high resolution and comfortable devices. To provide a comfortable VR service environment without cables, a low latency wireless communication scheme needs to be used for VR devices. However, the high resolution feature is not only a challenge for imaging equipment, but also for wireless interfaces. Therefore, the wireless interface. Therefore, we need to find a trade-off between these two features, namely a reliable wireless connection. Wireless local network (WLAN) is one of the popular communication interfaces, which has low costs while achieving high data throughput. Because some IEEE 802.11 categories are designed to replace wired video interfaces, including high definition multimedia (HDMI) interfaces, WLAN-based IEEE 802.11 can provide very high data rates. To meet the high data rate requirements of high-resolution video transmission, the IEEE 802.11 working group expanded the IEEE 802.11 standard to support 60-GHz frequency band with wide bandwidth. IEEE 802.11ad is the standard of change, to operate IEEE 802.11 in the 60-GHz frequency band. Specifically, IEEE 802.11ad uses 2.16-GHz bandwidth to achieve high data speeds. However, IEEE 802.11ad has a relatively short communication range, due to the operation of high frequency bands under indoor environments. IEEE 802.11ay is an enhanced version of IEEE 802.11ad, with channel channel support and multiple spatial streams. Although this 60-GHz WLAN standard can be considered a wireless VR interface for high-resolution video transmission, future VR systems will require real-time interactive control between many VR users. Some applications related to the gaming industry have adopted a multiuser augmented reality (AR) system to provide a better playing experience in the living room [6]. Because VR consumers have experienced this multi-user AR system, multi-user VR must also be provided to meet the needs of VR consumers. Sharing VR experiences with the closest users is expected to provide VR UX that is much deeper to VR consumers. Wireless multi-user VR systems based on the IEEE 802.11 standard can be described as shown in Picture 1, which shows elements of a wireless multi-user VR system, VR data flowing, and the VR service delay component. To provide a deep VR interaction experience, each component of the VR system must provide appropriate feedback, based on its sensing data. From the component delay of Picture 1, the delay of the VR interaction of the wireless VR system, Tvr, can be described as follows

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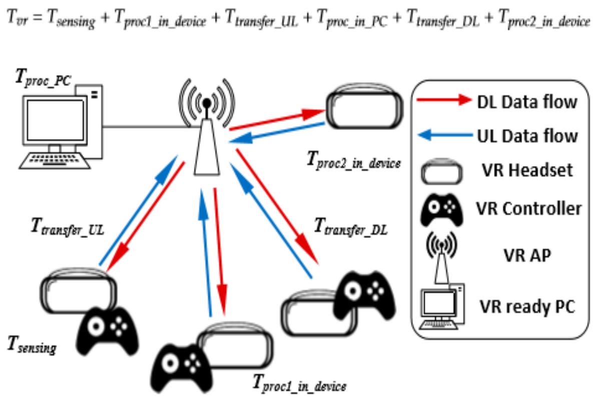


Picture. 1 Wireless multiuser virtual reality (VR) system, based on the IEEE 802.11 system

VR devices must track the user's movements and commands using sensing components. The sensing component can cause delay, depending on the performance of the sensing. This delay is considered as Tsensing. Tproc1_in_device is a processing delay for the processor unit in the VR device, which handles sensing data and generates data packets. The resulting data packet is transmitted to the related VR computing device via the WLAN link in the proposed system. Sending a one-hop wireless packet over a WLAN link causes a delay, Ttransfer_UL, which can be a relatively large value for the condition of the wireless channel, including channel congestion caused by channel disputes. Ttransfer_UL is the most dominant tdayay component in the proposed multi-user VR system. VR computing devices, which are generally PCs, require a processing delay, Tproc_in_PC. To provide smooth VRUX by minimizing processing delays, high processing performance is preferred. VR computing devices generate VR feedback packages, including VR video data, and send them to related VR devices via WLAN links. The delay caused by this WLAN transmission is considered Ttransfer_DL. Because transmission causes a delay of Ttransfer_DL is from one node (VR computing device) to several nodes (wearable VR devices), and transmission causes a delay of Ttransfer_UL is from several nodes (wearable VR devices) to one node (VR computing device). Ttransfer_DL can be more easily controlled than Ttransfer_UL. The downlink delay, Ttransfer_DL, is the second most important component of delay in the proposed system. The VR device decodes the packet and operates to produce sensory feedback, which causes a processing delay, Tproc2_in_device. For example, a VR headset translates VR video images and performs video enhancement procedures, for smooth and immersive UX. Tproc2_in_device is a delay component for processing this kind of hardware, to provide sensory feedback [1]. To help create interpolation frames, some network characteristics, e.g., the ratio of video frame arrivals and control frame sending rates, must be given to VR devices. When there is a mismatch between the visual and vestibular systems, VR disease can occur. This means that if the VR vision in the VR view cannot reflect the user's real movements, the user experience can be degraded. To prevent VR disease, accurate VR frame interpolation operations are needed. Therefore, in the delivery of the network-based VR framework proposed in this paper, the video framework interpolation procedure is very important, to reduce VR disease. The relationship between received video frames and interpolated video frames is shown in Picture 2. In this paper, interpolated video frames do not refer to video frames produced by the graphics processor of a PC VR or VR console. Here, only the frame that is produced by the VR headset after receiving the video frame from the VR access point (AP) is called an interpolated video frame, which can be generated using the received sand frame motion path information. Picture 2, VR processing unitina headsets will move the last video frame in the opposite direction of the user's motion vector, to produce an interpolated video frame. Interpolated video frames provide direct visual responses that resolve mismatches between the visual and vestibular systems. In a wireless multi-user VR system, because wireless links with inefficient performance of multi-user channel access is bottleneck, which cannot provide data rates high enough for high video frame rates, many interpolation frames are generated. Because of such problems, the next generation wireless multi-user VR system must be designed to be tightly integrated with the wireless system. Next-generation multi-user VR systems, wireless, must optimize VR video images and motion tracking rates, taking into account the status of wireless links. Based on the above observations, to design high-quality multi-user VR systems via WLAN, both wireless link optimization, which improves the efficiency of wireless channel access, and optimizing VR in tight pairs with wireless systems, which prevents unnecessary waste of resources, must be considered. In this research, to provide high-quality VR UX in multi-user VR WLAN services, we consider both the increased efficiency of multi-user wireless connections and the optimization of VR which is tightly integrated with the wireless system. Appl. Sci 2018, 8, 43 4 of 17 processing units in a VR headset will move the last video frame in the opposite direction of the user's motion vector, to produce an interpolated video frame. Interpolated video frames provide direct visual responses that resolve mismatches between the visual and vestibular systems [3]. In a wireless multi-user VR system, because wireless connections with inefficient multi-user channel access performance are bottlenecks, which cannot provide data rates high enough for high video frame rates, many interpolation frames are generated. Because of such problems, the next generation wireless multi-user VR system must be designed to be tightly integrated with the wireless system. Next-generation multi-user VR systems, wireless, must optimize VR video images and motion tracking rates, taking into account the status of wireless links. Based on the above observations, to design high-quality multi-user VR systems via WLAN, both wireless link optimization, which improves the efficiency of wireless channel access, and optimizing VR in tight pairs with wireless systems, which prevents unnecessary waste of resources, must be considered [1].

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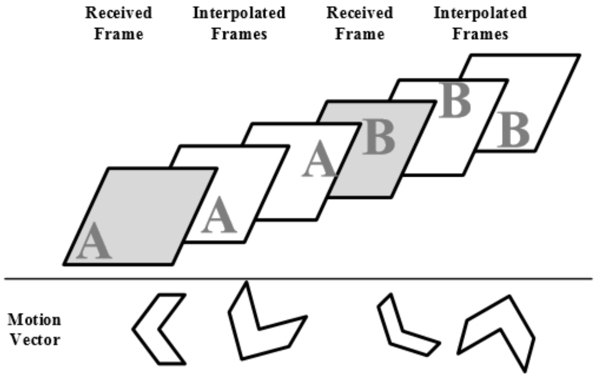



Picture. 2 Sensing-based video interpolation on a VR headset.

## II. RESEARCH METHODOLOGY

### A. *Virtual Reality Features*

**Immersion** is a sense of being present in a virtual environment (not real). The environment is produced by the synthesis of 3D images, sounds and other stimuli, which surround users and make them feel physically present in the nonphysical world. The extent to which the user believes that is present in a virtual environment (immersion) is different in various systems ranging from fully immersive to nonmermersive, depending on the capabilities of the system.

**Interaction** is the power of users to modify the virtual environment. This feature is the main difference between 3D movies and virtual environments. In a VR system, users can interact with cyberspace, move around it, view it from various angles, grab it, grab it, and reshape it. This kind of interaction is made possible by using head-mounted video glasses, wired clothing, and optical fiber data gloves. Position tracking devices and real-time updates from the visual and hearing display systems are also needed

### B. *Types of VR Systems*

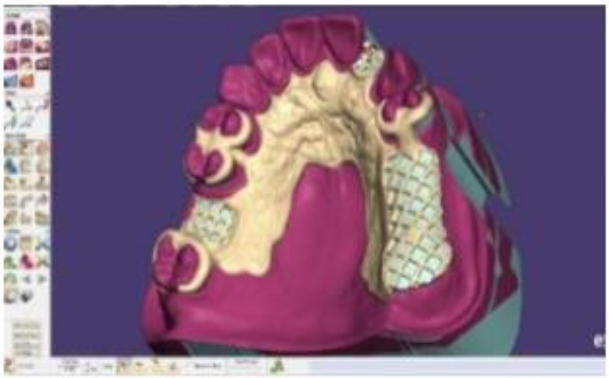
**Immersive VR simulation** is a technology that gives users a psychophysical experience surrounded completely by virtual computer-generated environments (Picture. 2) using hardware, software, and interaction devices. Full immersion is the highest level of immersion, which is produced by a head-mounted device that displays three-dimensional images through a process known as stereoscopy. In this process, the user sees two images - one by eye - and the brain combines them into one 3D image. Another component is the data glove, which allows people to interact with objects, for example, pulling, rotating or gripping them and might also provide style feedback to the user, known as haptic. There is also a tracking device, which tracks the user's head, hands, fingers, eyes and feet to enable interaction with cyberspace. Sound is displayed too. In a fully immersive virtual environment, users are completely separated from the real world.

**Semi-immersive VR simulation** is a system where the user stands in a room with a rear projection wall, lower projection floor, speakers at different angles, wall tracking sensors and sound / music devices (Picture. 3). By wearing eye glasses, users see all three dimensions. Because users can still see themselves, this system is not considered a fully immersive simulator. Cave Automatic Virtual Environment is an example of this system.

Picture. 3 Immersive virtual reality, head mounted displays (HMD) and data gloves

Picture. 4 Semi-immersive virtual reality; Cave Automatic Virtual Environment (CAVE)

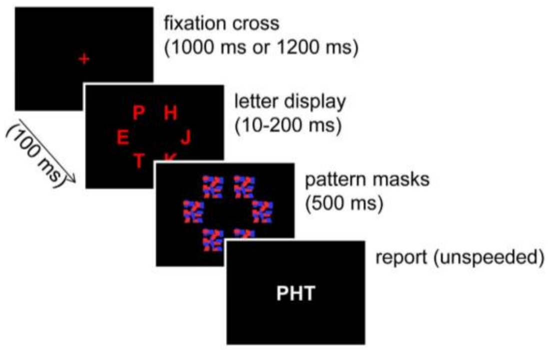
**Non-immersive VR simulation** is the most immersive and the cheapest of all. This allows users to engage with the 3D environment by simply inserting a stereo screen monitor and glasses. They can be run on a standard desktop computer using a mouse and joystick (Picture. 4). This is mostly used in designing and CAD systems [2].



Picture. 5 Computer aided design system

C. *Augmented* Reality

Augmented reality refers to the superim position of a computer-generated graph in the real world. In contrast to VR simulators, in AR real environments are not fully suppressed and even play a dominant role in this process. Augmented reality aims to add synthetic additives to the real world (or to live video from the real world) rather than involving someone in the world, which is entirely computer generated. This is widely used in guided image operations, where real and virtual objects need to be arranged, integrated, presented or manipulated simultaneously in one scene. It is also applied in dental implantation, maxillofacial surgery, temporomandibular joint motion analysis and prosthetic surgery. One of the main uses of AR in oral and maxillofacial surgery is in the visualization of deep masking structures. Before surgery, the surgeon will be able to map out the surgical plan on a 3D image of the site and consider the necessary modifications. During the operation, the surgeon sees and follows a mapped image that is affixed to the surgical site using special glasses. This system can be developed for root canal therapy as well. In some systems, AR and VR technology are used together to increase the system's training capacity. The system developer believes that this integration improves user performance [2]. One way to judge the speed of visual processing without messing up because of variations in motor performance is to give unlimited time for individuals to respond, but to limit the duration of presentation of visual objects. In this case, the key dependent variable is report accuracy rather than reaction time20. Such an approach to assessing visuals

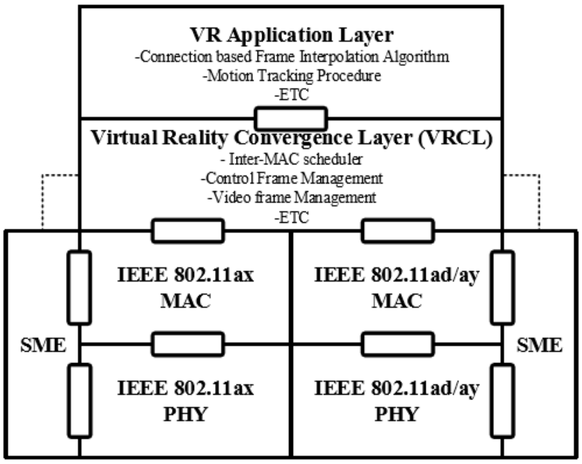



Picture. 6 Trial sequence of the TVA-based assessment

Processing speed 9,10,19 has been realized in diagnostic assessments based on Bundesen's "visual attention theory" (TVA). In this assessment procedure (Picture. 6), the individual briefly sees letters, the presentation ends with a mask pattern. After that, the letters must be reported, but without the speed requirements. Presentation duration varies to allow assessing how letter recognition increases with increasing presentation duration. If the speed of visual processing is high, individuals must be able to recognize letters even at short presentation times (provided the minimum required presentation duration is given). Conversely, if the processing speed is low, a longer presentation duration must be required before letters can be recognized. Therefore, the rate at which performance increases over the duration of the presentation can be used as a measure of visual processing speed that is not confused by motor ability. In addition to visual processing speed, two additional components of visual processing not available in reaction-based time-based assessments can be obtained using TVA1,9,10 based diagnostic assessments. The first component is the threshold of conscious perception. It measures the minimum time an object must be presented to allow visual processing for object recognition1. The second component is the capacity of visual working memory. Information about visual objects is maintained in visual working memory for a short period of time. This enables their online perception, their use in action control, and their later recognition 21-24. Thus, after processing an object has been completed, it is coded into visual working memory and can be followed up on, but only if the visual working memory has sufficient remaining retention capacity1. It is important to note that the TVA-based visual processing component is firmly rooted in cognitive neuroscience and experimental psychology research25. Therefore, they provide content validity in the sense that measurements are readily interpreted in terms of the psychological processes of the human brain19.

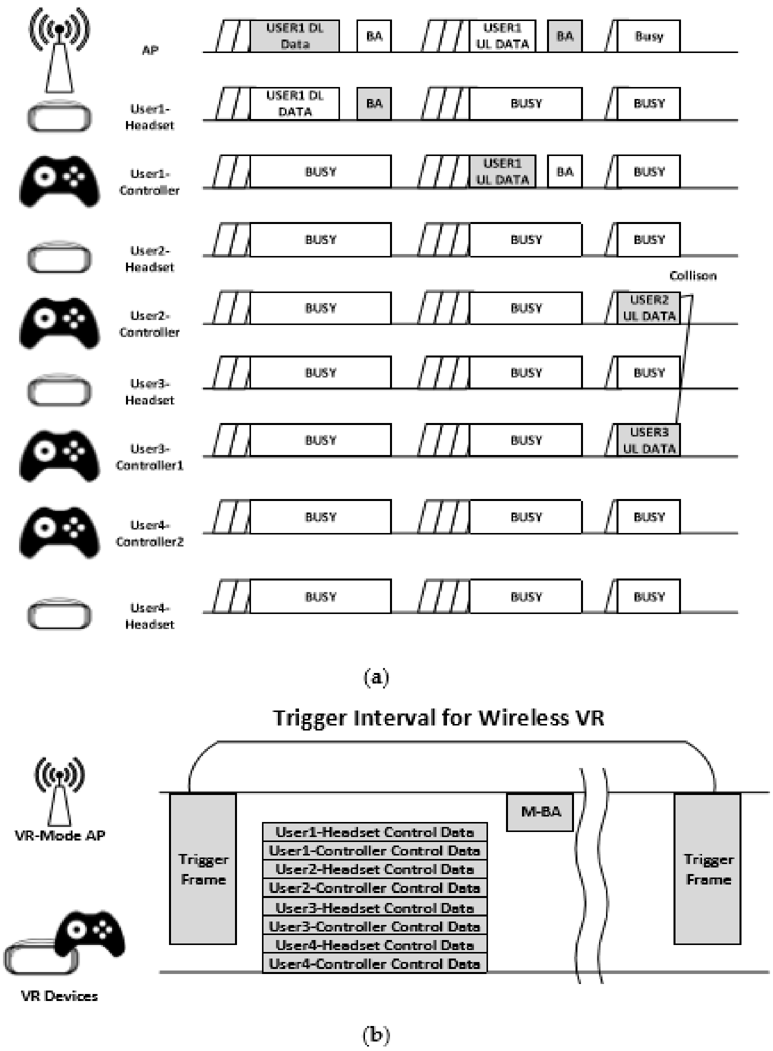
*D. Architecture and Protocol*

The network architecture for multi-user VR systems must meet the very requirements. The network architecture for multi-user VR systems must meet the requirements of very high high throughput and low latency. To meet the needs of high data throughput of low throughput and latency. To meet the high data throughput requirements of high resolution high resolution video images, we can use the 60-GHz standard, IEEE 802.11ad / ay. The images of this video, we can use the 60-GHz standard, IEEE 802.11ad / ay. This amendment standard standard is designed for wireless high resolution image devices. Because it is immersive designed for wireless high resolution image devices. Because immersive VR UX can become VR UX achieved by this high-resolution video image, the use of the 60-GHz standard is achieved by this high-resolution video image, the use of the 60-GHz standard is inevitable in various VR user scenarios. However, despite the standard multi-user VR standard scenario high-throughput. However, even though this high throughput wireless standard is used, it is used, with the combination of UL and DL transmissions in multi-user scenarios, which is effective with the combination of UL and DL transmissions in multi-user scenarios, effective throughput and throughput and delayed performance will deteriorate. This means that the performance of basic inter-service delays (BSS) will deteriorate. This means that the collection of intra-basic channel contention channels (BSS) must be controlled by the wireless VR protocol. Without such controls the algorithm must be controlled by the wireless VR protocol. Without such control algorithms, additional channels and additional channel resources, VR experience cannot be guaranteed in a wireless network. As a result, VR devices including VR APs must have a special multi-standard protocol architecture, described in Picture 3, to support VR connections based on WLAN. IEEE 802.11ax is a change standard for WLAN that is very efficient in a multi-device scenario. IEEE 802.11ax defines a trigger frame to accommodate multiple uplink frames from several devices simultaneously [1]. In many scenarios, it can be used in parallel with conventional single frame transmissions. If the trigger frame asks the station to send its UL data, each station transmits the data without delaying additional channel access. This trigger framework can reduce the delay of WLAN system delays significantly [5].




Picture. 7 Architecture and Protocol

The distributed coordination function (DCF) and the delayed mode VR operation are proposed for wireless VR systems. (a) Wireless multiuser VR with conventional wireless local area networks (WLAN); (b) Wireless multiuser VR with delay-oriented WLAN mode (Kadam et al., 2013). Each MAC and PHY layer follows its own standards. The convergence layer controls and schedules all frames into several MAC layers correctly. For example, DL data frames can be scheduled on IEEE 802.11ad / ay MAC and UL data frames can be scheduled on IEEE 802.11ax MAC. 11ax can accommodate multiple frames, using orthogonal frequency-division multiple access (OFDMA). The trigger frame is transmitted by the AP, to instruct stations that have UL frames when and where to send their UL frames. In the usual IEEE 802.11ax scenario, the trigger framework will compete with other UL frames to guarantee the opportunity for all stations to access the channel. However, VR APs require very strict delay properties, and traffic patterns are very regular - this is a special purpose AP for VR devices. This means that for related devices, channel conflict is not required to guarantee opportunities for channel access. In other words, to make full use of UL OFDMA from IEEE802.11 max multi-user VR services, single-user ULt ransmissions must apply. Single-user UL transmissions can be set by multi-user EDCA procedures in 802.11ax [1]. By using a new set of EDCA parameters, which are used by STA in multi-user BSS, the AP can set STA to have low priority EDCA parameters. Such low-priority EDCA parameters make STA access time.



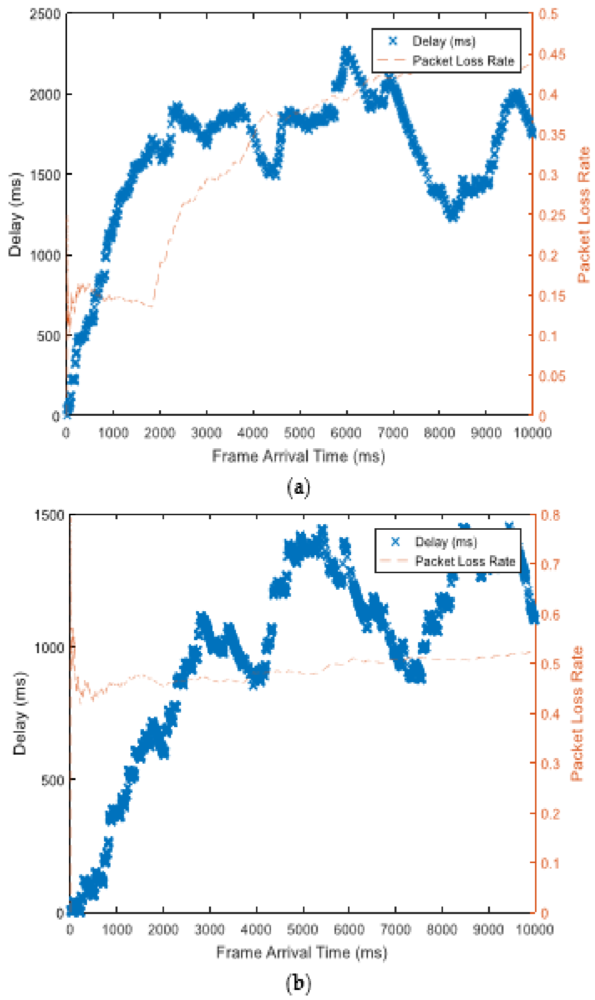

Picture. 8 Protocol Design

### *E. Protocol Design*

VRCL must encapsulate interpolation and frame rate information, using VR video frames in a combined MAC protocol data unit (A-MPDU). VRCL will control the UL and DL frame arrival rates for WLAN systems based on the frame rate of the original VR video rate and wireless environment. Because of VRCL, VR AP and VR devices can use the IEEE 802.11 family standard which provides MAC and PHY layers without standard modification. VRCL is the only additional layer for multi-user VR network interfaces. The VR application does not require additional network control features, and requires donations to produce VR video frames, based on information submitted by VRCL. VRCL provides the level of UL control and DL video frame information needed to the VR application layer. Because VRCL will discard VR frames which can cause large network delays on VR devices, VR applications don't need to waste resources on unnecessary video frames. For this reason, VRCL and VR AP must perform the VR system controller functions. Not only does VRCL provide information that can be used to control VR video frames to the VR application layer, but VRCL also controls its network operations based on information provided from SMEs. The level of packet loss, an indication of the strength of the received signal (RSSI), and modulation and encoding index information (MCS) are representative information observed by VRCL. Based on the observed information, VRCL can control the level of MCS, channel bandwidth, frame arrival rate, number of users supported by VR AP, and so on. The 60-GHz and 5-GHz standards can be used by VRCL, due to efficient multi-user VR operations. The main goal of a 60-GHz wireless link, in this paper, is the delivery of high-resolution VR video frames. Because delivery requires a large bandwidth, the use of the 60-GHz standard is unavoidable. The 5-GHz standard is used to accommodate multi-user UL frames, utilizing multi-user UL OFDMA procedures [1].

## III. RESULTS AND DISCUSSION

Virtual reality technology is defined as a method in which a three-dimensional environment is simulated or replicated, giving users a sense of being in it, controlling it, and personally interacting with it. Virtual environments are almost completely generated by computers. Technology has various possible benefits in many aspects of life such as building construction by providing a highly detailed virtual three-dimensional (3D) model of a building to verify each part of the plan, cost and layout. Likewise, in designing new products, virtual prototypes can be used instead of physical prototypes to evaluate designs from various aspects. In the medical field, VR is used for surgical procedure instruction, patient education and training students. It also helps in the treatment of psychological disorders by providing a valid virtual controlled environment for assessing behavior objectively and rehabilitating cognitive and functional abilities. This is used successfully for the treatment of complex regional pain syndromes as well. 3D virtual scenery helps improve dental experience through interference interventions [2]. In the case of conventional EDCA, nine devices produce their UL frame that contains motion sensing information every 1ms. For the case of conventional EDCA, the packet loss rate and Ttransfer_UL appear in Pictureure 7. Because the VR system requires real-time processing, the maximum number of retransmissions does not need to be set to a large number. If set to 2, as shown in Pictureure 7a, it will decrease PLR for a short time, but then increase to 0.4 PLR shortly thereafter. From the start, the PLR observed in conventional EDCA cases could not be used for consumer VR devices.




Picture 8. Delay and packet loss rate (PLR)

In the case of no-retransmission, as shown in Pictureure 7b, even though there is a large PLR and a relatively small delay, not only does the PLR damage, but the delay cannot be used either. After 8 seconds, the delay value increases by more than 1 second for sending motion-sensing data. From the results of Pictureure 7, we can observe that conventional EDCA procedures cannot afford a wireless multi-user VR system. At a minimum, wireless VR systems require very low ms-level and PLR delays for a reasonable user experience [1]. For proposed WLAN structures with improved conventional distributed channel access (EDCA). (a) 9 VR devices with retx max amount = 2; (b) 9 VR devices without retx. The proposed VR AP deactivates conventional EDCA procedures, which can cause tragic delays and PLR results as shown in Pictureure 7. If there is no interference device, which is usually called an OBSS device, VR AP is the only wireless device that starts the procedure channel access. In this case, VR AP always gets transmission opportunities without contention channels and back-off procedures, because the channel is idle during each period of channel access. This means that VR AP does not require additional contention delays caused by back-off procedures.

## IV. CONCLUSION

The proposed architecture, schema, and rate control algorithm can substantially improve the performance of delays in a wireless multi-user VR system. We show that conventional EDCA WLAN cannot fully support multi-user VR systems, because delays and PLR are not affordable for multi-user VR systems. We need to consider the proposed multi-user VR system for next-generation consumer VR devices, to support multi-user VR services. Unless there is an OBSS, the proposed multi-user VR system achieves very low delays and PLR, which can guarantee a smooth UX VR. We observed that the retransmission procedure did not provide significant PLR improvements in the proposed wireless multi-user VR system. Without the need for retransmission, by setting the maximum number of retransmissions to 0, we can significantly increase the delay performance. In addition, because the proposed wireless multi-user VR system does not require modification to the standard, the proposed scheme can easily be used with commercial WLAN chipsets available on the market, by adding the VRCL layer proposed in this paper.

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