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Reliability-Aware Transmission with Multiple Paths Parallel for Haptic Media Communication

Marisa Lemos[1], Longjiang Li[2]

[1, 2]School of Information and Communication Engineering, University of Electronic Science and Technology of China, Chengdu 611731
Email: *marisalemos[at]yahoo.com, longjiangli[at]uestc.edu.cn*

Abstract: ***Haptic media is a kind of media involving a sense of touch. The main network conditions issues that occur in haptic media are packet loss, delay, and jitter as degraded the quality of experience (QoE). However, haptic media is required to attain high reliability, low latency, and minimum overhead in real-time applications.*** **This paper proposes a reliability-aware transmission with multiple paths parallel scheme for haptic media communication.** ***Furthermore, this paper aims to call into question how to transmit packet one by one over these paths with reliability guarantee as efficiently as possible, thus, the proposed scheme is simulated by Matlab.***

Keywords: Haptic Media Communication, Reliability, Multiple Paths Parallel

1. Introduction

Recently, haptic media communication has drawn a lot of researcher's attention. The term haptic is originated from the Greek word "haptesthai" which means the sense of touch [2]. It relates to the capacity and senses to manipulate objects in real-time (or virtual) environment employing haptic devices. Generally speaking, haptic media can be tactile and kinesthetic information, while tactile information relates to a sense of touch, pressure, temperature, and pain, and kinesthetic information relates to a sense of muscle movements, joints, and tendons [4]. Potential innovative applications enabled by haptic media are virtual reality, augmented reality, robotics, teleoperation, real-time gaming, autonomous driving, medicine, education, learning, design, mobile, e-commerce rehabilitation, etc. Haptic media is a kind of media involving a sense of touch and need to be delivered in addition to video and audio in multimedia services. Its should be mentioned that a video and audio involving a sense of vision and audition. In addition, haptic media is considered bidirectional data while video and audio are considered unilaterally data. There are three distinct domains in haptic media namely a master, network, and slave domains. The master domain consists of a human system interface (HSI), while the HSI is a haptic device (i.e., PHANToM Omni), which converts the human input into haptic input. The haptic device enables a user to touch and manipulate objects in a real or virtual environment. Further, the master domain has provided video and audio. The video and audio play a crucial role in improving perceptual performance as the human brain naturally integrates distinct sensory modalities. The slave domain normally consists of a teleoperator, which is directly managed through the master domain, and the network domain aids the medium for haptic media between master and slave domains [2] [3]. When haptic media is delivered over a network, which does not guarantee the quality of service (QoS), the output quality of haptic media is deteriorating by packet loss, delay, and jitter. Hence, the QoE may seriously be degraded. Notably that, for haptic media, the maximum delay shouldn't exceed 50ms, the jitter should be less than 10ms, and the packet loss less than 10%. Nevertheless, the main challenges in haptic media are required to achieve high reliability with a maximum packet loss probability of 0.001% (99.999%), low latency (i.e., end-to-end delay) at 1ms, and minimum overhead in real-time applications [5]. The approach is to uses multiple paths parallel simultaneously for the same data packet to improve reliability for haptic media communication. Furthermore, this paper intends to call into question how to transmit packet one by one over these paths with a reliability guaranteed as efficiently as possible. This paper is organized as follows. Section II gives a brief overview of haptic devices, section III discusses the related work, the proposed scheme is given in section IV, the simulation result is presented in section V and the conclusions of the paper are given in Section VI.

2. Haptic for devices

Haptic devices enable users to sense and manipulate the object in the virtual environment via touch as shown in figure 1. Moreover, haptic devices are small robots that substitute mechanical energy for users [3]. The haptic devices have one or more input sensors and one output actuator. The sensors include the contact forces or positions of any part of the human body, and the actuator display contact forces or positions to the users. There are distinct types of haptic devices namely, PHANToM Omni, SensAble's Phantom haptic device, and CyberForce as shown in figure 2 [4]. The advantages of haptic devices are small size, low price, and high performance for human-machine interaction. There are two characteristics of haptic devices namely update rate and degree of freedom (DoF) [5]. The update rate relates to the maximum speed at that the device can generate force to the user. Haptic devices require an update rate at 1kHz and the degree of freedom (DoF) relates to the number of independent axes down that the device can exert force. As we have known, haptic devices give users the ability to sense of touch and produce a high date rate. Hence, haptic devices are sensitive to packet loss, delay, and jitter as degenerating the quality of services (QoS) metrics [1].

Figure 1: User interacts with the virtual environment through a haptic Device [3]

Figure 2: Distinct types of haptic devices

3. Related Work

First, it reviews the related work in the haptic media communication, then followed by reliability, and finally with multiple paths parallel. J. Cha et al. [6] defined haptic media as sensations, applicable to a broad series of devices and divided haptic media into linear and nonlinear. A linear haptic media relates to a haptic sensation that progresses sequentially in time, for instance, displayed movements or tactile patterns of touches that generate experiences of passive haptic playback, and non-linear haptic media allows users to touch haptically displayed object and experience texture information with a force that creates a compelling, active, and haptic interaction. The characteristics of haptic media can be comparing it with video. Haptic media deal with the sense of touch and video deal with a sense of vision. Video requires exact spatial resolution and operates with a rough of a time. The human user reacts with slow response time for a sense of vision since the brain processes all information. For instance, 30Hz is the frame rate for a HD video, and a frame contains several hundred-kilo bytes of data. It usually uses a MPEG-1 to transmit such a video. characteristic results in around 10+Mbit/s bit rate for a video. On the other hand, haptic media requires high resolution for the time but the less special resolution. The human user nerve system reacts instantly without the intervention of the brain, so the reaction time in haptic media is shorter than the video. To order these requirements, the PHANToM Omni haptic device generates 100bytes to 1kbytes of data for each sense but it requires around 1000Hz update rate for haptic media. This implies it produces around a few Mbit/s constant bit rate haptic media, which is a comparative bit rate with the video.

Haptic media is available in sampled forms to be transmitted through the network. Haptic media compression is the process of removing spatial and temporal redundancy from the haptic media for the goal of reducing the size of the haptic media to be transmitted over the network and reduces the required bandwidth (data rate) for haptic media. Furthermore, haptic media can be compressed by MPEG-4 BIFS [6]. However, in this work, haptic media is compressed by MPEG-1, which is converted into a sequence of packets (or frames) such as Intra (I), Inter (P), and Bidirectional (B) packet. The authors in papers [6][7] proposed haptic media compression techniques such as perceptual deadband (PD), prediction, down sampling, and quantization technique. PD technique is used to reduce non-noticeable data by human perception. Prediction technique is used to improve the compression ratio and reduce the errors between the uncompressed and the reconstructed haptic media, and the downsampling technique is applied to reduces the update rate, data size, and data rate of haptic media, and quantization technique is applied to evaluate lossy compression of haptic media. Tatematsu et al. [8] investigated the influence of network latency on the quality of experience in haptic media, sound, and video transmission in the case that delay and jitter exist. Research in [10], [11], [12] listed many protocols used for transfer haptic media over the network. Theses protocols are TCP, UDP, SCTP, S-SCTP, Light TCP, ETP, RTP, RTP/I, ALPHAN, Admux, and HoIP. Research in [10], [11], [12] listed many protocols used for transfer haptic media over the network. These protocols are TCP, UDP, SCTP, S-SCTP, Light TCP, ETP, RTP, RTP/I, ALPHAN, Admux, and HoIP. All these protocols attempt to transmit a haptic media of packets with a packet rate of 1000 packets/s, and haptic media packet size at 64 bytes of data payload plus an overhead. With the focus set on reliability, Suzuki and Katsura [13] proposed a multiple-routes method for the reliability of haptic media. This paper focused on the packet loss issue to lose the reliability of haptic media transfer. The authors also emphasize the methods such as retransmission control, packet pass diversity, and forward error correction (FEC) to deal with packet loss issue and to improve reliability in haptic media. It is well-known that reliability is a characteristic that requires be supported by haptic media. A small part of the data packets, for instance, the last update data packet feedback channel and control should be sent reliably. The authors of papers [14], [15], [16] investigated two techniques to improve reliability for haptic media such as Negative Acknowledgement (NACK) and Selective Acknowledgment (SACK). Lee and Payandeh [17] proposed the forward error correction (FEC) method for haptic media to improve the reliability of network-based bilateral teleoperation systems or haptic interfaces based on the digitization of haptic media. With the focus set on improving reliability, N. Higo et al. [1] proposed multiple paths and compressed data transmission for haptic media with a goal to improve the transmission of haptic media emitted from a haptic device in high frequency. Multiple paths are available for each pair of source and destination

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and can be used to carry data packets parallel [18]. There are three types of multiple paths such as node disjoint, link disjoint, and general. In node disjoint type, paths are independent of each other and don't have common nodes and links. The paths are deemed independent and parallel. Therefore, if transmission failure on one of these paths does not affect others. In link disjoint type, paths have common nodes, and the paths are deemed parallel. Failure on one of the common nodes can result in failure transmission on multiple paths and even failure of the transmission process between the source and destination and in general type, paths share both nodes and links in common, which can improve the reliability in haptic media [6]. The authors of papers [22], [23], [24] proposed techniques in multiple paths parallel to improve reliability and reduce latency such as packet duplication. While packet duplication improves reliability by using multiple paths parallel redundant and reducing latency by using short path transmission.

4. Proposed Scheme

In this section, the author formulates the reliability problem, presents the proposed scheme, and provides the benefits of a proposed scheme.

a) Problem Formulation

Reliability is defined as the probability that a data packet is successfully transmitted within a time. The reliability of the system is improved by multiple paths parallel redundant subsystems, each is configured to work independently in parallel [23] [25]. Given the reliability required for a sequence of packets [p_1, p_2,...p_i] and [q_1, q_2,...q_i],the reliability system can be calculated as:

$$p = 1 - \prod_{i=1}^{n} (1 - p_i) \quad (1)$$

$$q = 1 - \prod_{i=1}^{m} (1 - q_i) \quad (2)$$

Where p_i and q_i represents the reliability of the i^{th} path n and m are the number of independent paths. The reliability system is measured in percentage (%). It should be mentioned that, in a wireless network, to improve the reliability system it is necessary to improve either reliability of each path (link) or the number of paths (links) carrying the same data packet.

b) Multiple Paths Parallel Scheme

It considers multiple paths parallel scheme as a connected directed graph $G(N, L)$, where N is the set of nodes (A, B) and L is the set of links. For each link $l \in L$, there is a delay $d_l > 0$ and bandwidth capacity $c_l > 0$ in link as shown in figure 3. Without error transmission, the delay d_l in the multiple paths parallel is the lowest delay on each path, which d_l can be calculated as:

$$d_l = \min_{i \in \Lambda} d_i \quad (3)$$

Where Λ represent set of paths with successful transmission. d_i represent the delay of the i^{th} path, measured in millisecond (ms).The bandwidth capacity c_l is the highest capacity of each path, which c_l can be calculated as:

$$c_l = \max_{i \in \Lambda} c_i \quad (4)$$

Where c_l represent the capacity of the i^{th} path. c_l is measured in kilobits per second (kbps).

It is well known that multiple paths parallel allows two or more paths to transmitted simultaneously data packets from the node(A) to the destination node (B). However, it establishes reliability-aware transmission with multiple paths parallel for haptic media delivers a sequence of packets over different paths independently. Furthermore, the multiple parallel paths scheme work is described as follows: fixed the size of the compressed haptic media packet (i.e., in byte), and transmitted haptic media packet one by one over these paths, the successive haptic media packet has the same value as the previous one. Note that, the goal of multiple paths parallel scheme is to improve reliability in haptic media.

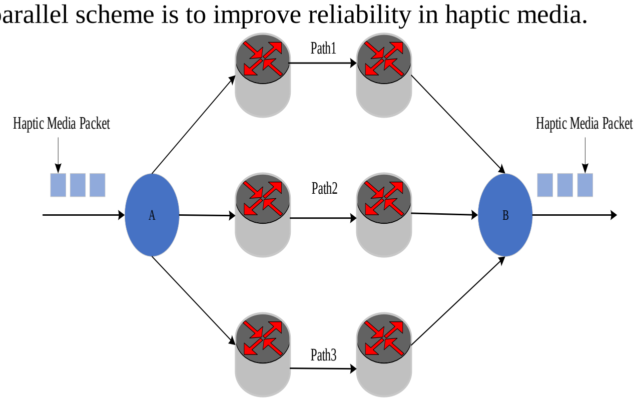

Figure 3: Proposed scheme

c) Benefits of Multiple Paths Parallel

Multiple paths parallel in haptic media provides a number of benefits which are described as follows [13], [19], [20].

- Improve Reliability: The multiple paths parallel provides a simple solution to fulfill the stringent requirements of haptic media. It improves reliability by providing additional paths that can keep the connection alive in case of a failure path or link. Haptic media requires high reliability of 99.999%
- Reduce Delay: Multiple paths parallel allows haptic media to be split among two or more disjoint paths to reduce delay and jitter.
- Reduce burst loss: The packet loss has a high probability to occur continuously, which is called a burst loss. The packet loss deteriorates haptic media. Using multiple paths parallel can reduce the impact of burst loss.
- Increase Throughput: Throughput is a measure of the quantity of data that can be transmitted over the network per unit time by aggregating bandwidth and sharing haptic media over multiple paths parallel networks faster transmission can be achieved. Haptic media requires high throughput of 500kbps-1Mbps
- Load balancing: When a link becomes over-utilized and produces congestion, multiple paths parallel decides to

distribute haptic media traffic through alternative paths to reduce the load of the congested link.

5. Analysis and Simulation Result

It evaluates the performance of the proposed scheme in a typical scenario through simulation. The simulation was implemented in the MATLAB, which is an efficient network simulator [25] and using and Windows 10 environment (8GB RAM, Intel Core i7). It evaluated the proposed scheme in terms of reliability. The analysis mathematically of reliability is given above. It is set the overall required throughput in haptic media to 500kbps, 1Mbps, and 2Mbps, respectively. The fixed size of the compressed haptic media packet is 32byte.Figure 4 shows the result of the multiple paths parallel. It observed that reliability aware transmission with multiple paths parallel for haptic media attends to improved.

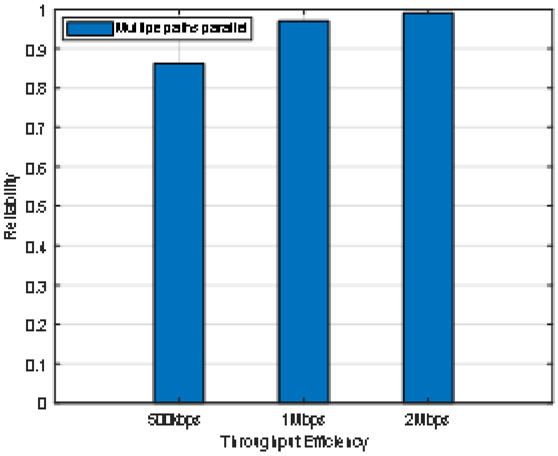

Figure 4: Performance of multiple paths parallel

6. Conclusion

In this paper, the reliability problem was investigated, along side with the proposed scheme. It established reliability-aware transmission by transmitting a haptic media packet to multiple parallel paths independently. The simulation result shows that the multiple path parallel scheme can provide a sample solution to improve reliability efficiently and to increase throughput in haptic media.

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References

[1] N. Higo, T. Tsubaki, Y. Sueda, T. Kuwahara and A. Koike, "Multi-path and Compressed Data Transmission for Haptics Media Communication in Robotic System," *2018 IEEE International Symposium on Local and Metropolitan Area Networks (LANMAN)*, Washington, DC, 2018, pp. 127-128.

[2] El Saddik, Abdulmotaleb, et al. Haptics technologies: bringing touch to multimedia. Springer Science & Business Media, 2011.H. Poor, *An Introduction to Signal Detection and Estimation*. New York: Springer-Verlag, 1985, ch. 4.

[3] Touch[online] Available https://thinglab.com.au/geomagic-haptic-devices/

[4] Bermejo, Carlos, and Pan Hui. "A survey on haptic technologies for mobile augmented reality." arXiv preprint arXiv:1709.00698 (2017).

[5] K. Salisbury, F. Conti and F. Barbagli, "Haptic rendering: introductory concepts," in *IEEE Computer Graphics and Applications*, vol. 24, no. 2, pp. 24-32, March-April 2004.

[6] J. Cha, Y. Ho, Y. Kim, J. Ryu and I. Oakley, "A Framework for Haptic Broadcasting," in *IEEE MultiMedia*, vol. 16, no. 3, pp. 16-27, July-Sept. 2009.

[7] E. Steinbach, S. Hirche, J. Kammerl, I. Vittorias, and R. Chaudhari. Haptic data compression and communication for telepresence and teleaction. IEEE Signal Processing Magazine, 28(1):87-96, Jan. 2011.

[8] C. Shahabi, A. Ortega, and M.R. Kolahdouzan. A comparison of different haptic compression techniques. In Proc. of IEEE International Conference on Multimedia and Expo, pages 657-660, Aug. 2002.

[9] A. Tatematsu, Y. Ishibashi, N. Fukushima and S. Sugawara, "QoE assessment in haptic media, sound and video transmission: Influences of network latency," *2010 IEEE International Workshop Technical Committee on Communications Quality and Reliability (CQR 2010)*, Vancouver, BC, 2010, pp. 1-6.

[10] G. Kokkonis, K. Psannis, M. Roumeliotis and S. Kontogiannis, "A Survey of Transport Protocols for Haptic Applications," 2012 16th Panhellenic Conference on Informatics, Piraeus, 2012, pp. 192-197.

[11] M. Eid, J. Cha and A. El Saddik, "Admux: An Adaptive Multiplexer for Haptic–Audio–Visual Data Communication," in IEEE Transactions on Instrumentation and Measurement, vol. 60, no. 1, pp. 21-31, Jan. 2011.

[12] Kokkonis, George, et al. "Evaluating transport and application layer protocols for haptic applications." 2012 IEEE International Workshop on Haptic Audio-Visual Environments and Games (HAVE 2012) Proceedings. IEEE, 2012.

[13] N. Suzuki and S. Katsura, "Haptic communication using multiple-routes in data transmission," *SICE Annual Conference 2011*, Tokyo, 2011, pp. 1361-1366.

[14] A. Roach. A negative acknowledgement mechanism for signaling compression. IETF Network Working Group Std., May 2005.

[15] M. A. Smith and K. K. Ramakrishnan. Formal specification and verification of safety and performance of TCP selective acknowledgment. In IEEE/ACM Transactions on Networking, vol. 10, no. 2, pp. 193-207, April 2002.

[16] S. Shirmohammadi and N. D. Georganas, "An end-to-end communication architecture for collaborative virtual environments," Computer Networks, vol. 35, no. 3, pp. 351 - 367, 2001.

[17] J. Lee and S. Payandeh, "Forward error correction for reliable teleoperation systems based on haptic data digitization," *2013 IEEE/RSJ International*

Conference on Intelligent Robots and Systems, Tokyo, 2013, pp. 5871-5877.

[18] Fiore, M., Casetti, C. and Galante, G., 2007. Concurrent multipath communication for real-time traffic. Computer Communications, 30(17), pp.3307-3320.

[19] K. Qin, C. Huang, N. Ganesan, K. Liu and X. Chen, "Minimum cost multi-path parallel transmission with delay constraint by extending openflow," in *China Communications*, vol. 15, no. 3, pp. 15-26, March 2018.

[20] Li, S., Sun, W. and Hua, C., 2016. Optimal resource allocation for heterogeneous traffic in multipath networks. International Journal of Communication Systems, 29(1), pp.84-98.

[21] Gabriel, Frank, et al. "Multipath communication with finite sliding window network coding for ultra-reliability and low latency." 2018 IEEE International Conference on Communications Workshops (ICC Workshops). IEEE, 2018.

[22] Rao, Jaya, and Sophie Vrzic. "Packet duplication for URLLC in 5G: Architectural enhancements and performance analysis." IEEE Network 32.2 (2018): 32-40.

[23] Aijaz, Adnan. "Packet duplication in dual connectivity enabled 5g wireless networks: Overview and challenges." arXiv preprint arXiv:1804.01058 (2018).

[24] Leemis, Lawrence M. Reliability: probabilistic models and statistical methods. New Jersey: Prentice Hall, 1995.

[25] Le, Dac-Nhuong, et al. *Network Modeling, Simulation and Analysis in Matlab: Theory and Practices*. John Wiley & Sons, 2019.