Computer Communications Laboratory

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In the AY2017, the Computer Communications Laboratory (CCL) has three faculty members, one visiting scholar, Dr. Ngoc T. Dang, our external research associate from Vietnam Posts and Telecomunications Institute of Technology (PTIT), and ten graduate students (MS/PhD) working as research assistants. We have extensive collaborations with different research groups in Vietnam, Korea, UK and France. Our research sponsors include both Japanese agencies, including Japan Society for Promotion of Science (JSPS), the Japan Science Society (JSS), Telecommunication Advancement Foundation (TAF) etc., and international ones, such as Electronics and Telecommunications Research Institute (ETRI, Korea) and National Foundation for Science and Technology Development (NAFOSTED, Vietnam).

Our research and education focus on the areas of computer networks, multimedia communications and networks, optical/wireless communications and networking technologies, communication engineering, and ubiquitous computing & its applications. Especially, we recently encompass following topics:

1. Visible light communications (VLC) and its Applications in Indoor Positioning. The future of lighting is currently moving in the direction of being multifunctional; modern light sources have the capacity for illumination and concurrent wireless data transmission. The merger of these two applications has been made possible through solid-state high brightness light emitting diode (LED) technology. Short-range optical wireless communication utilizing the visible spectrum emitted from the LEDs, referred to as visible light communication (VLC) transmits data via modulation of the light intensity. So far the VLC capability is above 1 Gbps with a reasonable coverage range that is applicable for home/office environment. The dual functionality required from the LED creates the unique opportunity for indoor localization which is much more precise than RF counter-

part. Our research focuses on development of smart lighting systems that support high-speed, multiuser data transmission and VLC-based indoor localization, which will play a crucial part in the paradigm of the Internet of Things.

2. Quality of Experience (QoE) Modelling. Multimedia contents are increasingly being created in different formats, standards, modalities, and complexities. Meanwhile, the users are consuming the contents through a variety of terminals and network connections. Different users may use a wide variety of terminals with very different capabilities (in terms of screen sizes, processors, etc.) to consume multimedia contents from different sources. This fact results in big challenges for providers to provide good Quality of Experience (QoE) for users today. In this research, we investigate the influence factors and models for the overall QoE perceived by users at their devices. Especially, through the models, we try to reveal the insights into the influence factors of the overall quality, thus leading to suggestions to improve the quality of multimedia contents.

3. Internet Video Streaming. In a recent study, Cisco predicts that 90 percent of the bits carried on the Internet will be video traffic in the near future. Video streaming over IP networks has been conventionally based on the Real-time Transport Protocol (RTP) or some variations of RTP. However, thanks to the abundance of Web platforms (including the Content Delivery Network - CDN) and broadband connections, HTTP (Hypertext Transfer Protocol) has become a cost effective solution for video/audio streaming nowadays. In this research, our purpose is to investigate the use of HTTP streaming for video content over the open Internet. In this context, adaptivity to network fluctuations is the most important feature. Further, we will try to support not only small resolution/bitrate video, but also large resolution (e.g. Full High-Definition) ones.

4. Free-space Optics/Millimeter-Wave Front/Backhaul of the 5G Mobile Networks. In this research, we propose hybrid architecture and enabling technologies for 5G mobile front/backhaul (F/BH) networks. We argue that a single-technology solution, either optical fiber (OF) or radio millimeter wave (mmW), is not sufficient for the 5G F/BH networks due to the requirements of enormous capacity, scalability, energy-efficiency and strict quality of service (QoS). Our contributions include fundamental studies on theoretical limits; development of analytical models and performance evaluation/optimization of novel hybrid architecture for 5G F/BH networks using three technologies of OF, mmW and free-space optics.

5. Quantum Key Distribution (QKD) over FSO. Due to the recent rapid growth of computing technologies, today's encrypted information based on classical computational complexities will soon no longer remain secure. Quantum

cryptography, or quantum key distribution (QKD), relying on the physical laws of quantum mechanics, stands out as a more powerful cryptographic solution that enables the secret key to be shared securely over publicly unsecured communication channels in the presence of eavesdroppers. Conventional QKD systems are implemented over optical fiber. In this research, we focus on the development of QKD over FSO for both terrestrial and satellite channels. Our target is the design and development of QKD over FSO systems and protocols which are affordable to implement, flexible for quick deployment and re-deployment in emergency and wireless networks, and high key rate distribution.

We always welcome undergraduate and graduate students who are interested in the above mentioned research. For further information, visit our website at `http://www.u-aizu.ac.jp/labs/ce-cc/`.

Refereed academic journal

[pham-207-035-01:2017] T. Hayashi, Y. Watanabe, T. Miyazaki, A. T. Pham, T. Maeda, and S. Matsufuju. A Novel Class of Quadriphase Zero-Correlation Zone Sequence Sets. *IEICE Tran. on Fundamentals of Electronics, Communications and Computer Sciences*, E100-A(4):953–960, 2017.

> The present paper introduces the construction of quadriphase sequences having a zero-correlation zone. For a zero-correlation zone sequence set of N sequences, each of length l, the cross-correlation function and the side lobe of the autocorrelation function of the proposed sequence set are zero for the phase shifts τ within the zero-correlation zone z, such that $|\tau| \leq z$ ($\tau \neq 0$ for the autocorrelation function). The ratio $\frac{N(z+1)}{\ell}$ is theoretically limited to one. The proposed zero-correlation zone sequence set can be generated from an arbitrary Hadamard matrix of order n. The length of the proposed sequence set can be extended by sequence interleaving, where m times interleaving can generate $4n$ sequences, each of length $2m + 3n$. The proposed sequence set is optimal for $m = 0, 1$ and almost optimal for $m > 1$

[pham-207-035-02:2017] C. T. Nguyen, A-T H. Bui, V-D Nguyen, and A. T. Pham. Modified Tree-based Identification Protocols for Solving Hidden-Tag Problem in RFID Systems over Fading Channels. *IET Communications*, 11(7):1132–1142, 2017.

> Hidden-tag problem is one of the most important issues in the implementation of radio-frequency identification (RFID) systems. Due to effects of imperfect wireless channels, RFID tags can be hidden during the identification process by either another tag or an unsuccessful detection. The former is known as the capture effect (CE) while the latter is the detection error (DE). This study newly proposes two modified tree-based identification protocols, namely tweaked binary tree (TBT) and tweaked query tree (TQT), which are able to tackle the hidden-tag problem caused by both the CE and DE. The performance of the proposed TBT and TQT protocols, in terms of the average number of slots required to detect a tag, and the tag-loss rate, is evaluated in comparison with that of previously proposed ones. Computer simulations and numerical results confirm the effectiveness of the proposed protocols

[pham-207-035-03:2017] T. V. Pham, H. L. Minh, and A. T. Pham. Multi-User Visible Light Communication Broadcast Channels with Zero-Forcing Precoding. *IEEE Trans. on Communications*, 64(6):2509–2521, 2017.

This paper studies zero-forcing (ZF) precoding designs for multi-user multiple-input single-output visible light communication (VLC) broadcast channels. In such broadcast systems, the main challenging issue arises from the presence of multi-user interference (MUI) among non-coordinated users. In order to completely suppress the MUI, ZF precoding, which is originally designed for radio frequency (RF) communications, is adopted. Different from RF counterpart, VLC signal is inherently non-negative and has a limited linear range, which leads to an amplitude constraint on the input data signal. Unlike the average power constraint, obtaining the exact capacity for an amplitude-constrained channel is more cumbersome. In this paper, we first investigate lower and upper bounds on the capacity of an amplitude-constrained Gaussian channel, which are especially tight in the high signal-to-noise regime. Based on the derived bounds, optimal beamformer designs for the max-min fairness sum-rate and the maximum sum-rate problems are formulated as convex optimization problems, which then can be efficiently solved by using standard optimization packages

[pham-207-035-04:2017] H. V. Nguyen, P. V. Trinh, A. T. Pham, Z. Babar, D. Alanis, P. Botsinis, D. Chandra, S. X. Ng, and L. Hanzo. Network Coding Aided Cooperative Quantum Key Distribution Over Free-Space Optical Channels. *IEEE Access*, 5:12301–12317, 2017.

Realistic public wireless channels and quantum key distribution (QKD) systems are amalgamated. Explicitly, we conceive network coding aided cooperative QKD over free space optical systems for improving the bit error ratio and either the key rate or the reliable operational distance. Our system has provided a 55% key rate improvement against the state-of-the-art benchmarker

[pham-207-035-05:2017] T. V. Pham and A. T. Pham. Secrecy Sum-Rate of Multi-User MISO Visible Light Communication Systems with Confidential Messages. *Elsevier's OPTIK (Int. Journal for Light and Electron Optics)*, 151:65–76, 2017.

This paper studies the information theoretic secrecy sum-rate for multi-user multiple-input single-output (MU-MISO) visible light communication (VLC) systems with confidential messages. The well-known zero-forcing (ZF) precoding technique is employed to ensure confidentiality among legitimate users and, at the same time, to prevent eavesdropper(s) from obtaining any information. Different from radio frequency (RF) counterpart where the average input power constraint is usually imposed on the derivation of channel capacity, the input data signal of VLC systems is amplitude constrained, leading to a peak

input power constraint. The amplitude constraint gives rise to the complexity in obtaining an analytical expression for the capacity. In this paper, we analytically investigate a novel bound on the secrecy sum-rate of all legitimate users in MU-MISO VLC systems, which is valid in high signal-to-noise ratio (SNR) regime. The secrecy sum-rate performance is then derived for two scenarios: known and unknown eavesdropper's channel state information (CSI) at the transmitter.

[pham-207-035-06:2017] A-T H. Bui, C. T. Nguyen, T. C. Thang, and A. T. Pham. Design and Performance Analysis of a Novel Distributed Queue Access Protocol for Cellular-based Massive M2M Communications. *IEEE Access*, 6:3008–3019, 2018.

This paper proposes a novel access protocol based on the distributed queue (DQ) mechanism to effectively tackle the massive access issue in the cellular-based machine-to-machine (M2M) communications. To fully take the advantage of the DQ mechanism, we newly propose a method to avoid the DQ's inherent over-division problem by letting the base station first roughly probes the number of colliding devices in a random access opportunity. Based on the probing result, the base station then randomly divides these devices into a determined number of groups and "pushes" these groups to the end of a logical access queue. In addition, we develop an analytic model to accurately estimate the average access delay of the proposed protocol in the massive scenarios. Computer simulations are also performed to validate the correctness of the analytic model as well as the effectiveness of the proposed protocol in comparison with the LTE standard and conventional DQ access schemes.

[pham-207-035-07:2017] P. V. Trinh, T. V. Pham, N. T. Dang, H. V. Nguyen, S. X. Ng., and A. T. Pham. Design and Security Analysis of Quantum Key Distribution Protocol over Free-Space Optics Using Dual-Threshold Direct-Detection Receiver. *IEEE Access*, 6:4159–4175, 2018.

This paper proposes a novel design and analyzes security performance of quantum key distribution (QKD) protocol over free-space optics (FSO). Unlike conventional QKD protocols based on physical characteristics of quantum mechanics, the proposed QKD protocol can be implemented on standard FSO systems using subcarrier intensity modulation binary phase shift keying and direct detection with a dual-threshold receiver. Under security constraints, the design criteria for FSO transmitter and receiver, in particular, the modulation depth and the selection of dual-threshold detection, respectively, is analytically investigated. For the security analysis, quantum bit error rate,

ergodic secret-key rate, and final key-creation rate are concisely derived in novel closed-form expressions in terms of finite power series, taking into account the channel loss, atmospheric turbulence-induced fading, and receiver noises. Furthermore, Monte-Carlo simulations are performed to verify analytical results and the feasibility of the proposed QKD protocol

[thang-207-035-01:2017] Nam Pham Ngoc Anh T Pham Truong Cong Thang Huyen TT Tran, Cuong T Pham. A Study on Quality Metrics for 360 Video Communications. *IEICE TRANSACTIONS on Information and Systems*, 101(1):28–36, Jan. 2018.

360 videos have recently become a popular virtual reality content type. However, a good quality metric for 360 videos is still an open issue. In this work, our goal is to identify appropriate objective quality metrics for 360 video communications. Especially, fourteen objective quality measures at different processing phases are considered. Also, a subjective test is conducted in this study. The relationship between objective quality and subjective quality is investigated. It is found that most of the PSNR-related quality measures are well correlated with subjective quality. However, for evaluating video quality across different contents, a content-based quality metric is needed.

[thang-207-035-02:2017] Duc V Nguyen Huyen T Tran Truong Cong Thang, Pham Ngoc Nam. An Evaluation of Screen Content Casting over Mobile and Wireless Networks. *Wireless Personal Communications*, 97(3):4877–4895, 2017.

Thanks to the availability of many smart devices, displays, and broadband connections, screen casting/sharing has become an important functionality for user devices. Meanwhile, a new video standard called screen content coding (SCC) is going to be issued to support this trend. This paper presents a standard-compliant implementation and evaluation of SCC streaming to mobile devices. The study is targeted at a feasible design and settings for customer devices, supporting both content-generating side and content-consuming side. The evaluation results help to answer how a sending device should generate screen content videos, and how a receiving device could be implemented and adjusted in time-varying environments of mobile networks and wireless home networks. To the best of our knowledge, this is the first evaluation study for SCC casting.

[thang-207-035-03:2017] Nam Pham Ngoc Anh T Pham Truong Cong Thang Hung T Le, Thang Vu. Seamless mobile video streaming over HTTP/2 with

gradual quality transitions. *IEICE Transactions on Communications*, 100(5):901–909, May 2017.

HTTP Adaptive Streaming (HAS) has become a popular solution for media delivery over the mobile Internet. However, existing HAS systems are based on the pull-based HTTP/1.1 protocol, leading to high overheads (e.g., in terms of energy, processing, bandwidth) for clients, servers, as well as network nodes. The new HTTP/2 protocol provides a server push feature, which allows the client to receive more than one video segment for each request in order to reduce request-related overheads. In this study, we propose an adaptation method to leverage the push feature of HTTP/2. Our method takes into account not only the request-related overhead but also buffer stability and gradual transitions. The experimental results show that our proposed method performs well under strong throughput variations of mobile networks.

Refereed proceedings of an academic conference

[pham-207-035-08:2017] P. V. Trinh and A. T. Pham. Design and Secrecy Performance of Novel Two-Way Free-Space QKD Protocol using Standard FSO Systems. In *Proc. of the 2017 IEEE International Conference on Communications (ICC'17)*. IEEE COMSOC, IEEE Press, May 2017.

This paper proposes a novel two-way free-space quantum key distribution (QKD) protocol, which can be implemented using standard free-space optical (FSO) systems with subcarrier intensity-modulation (SIM) binary phase-shift-keying (BPSK) and direct-detection (DD) receiver. Different eavesdropping threats, including unauthorized receiver, beam-splitting, and intercept-resend attacks, are considered in the security analysis of the proposed protocol. Under the constraints on security requirements, we analytically investigate the design criteria for transmitter and receiver, in particular, the intensity modulation depth at the transmitter and the dual-threshold setting of the receiver in two-way free-space QKD systems. Quantum bit error rate (QBER), the ergodic secret-key rate, and the probability of detecting eavesdropper of the proposed system are analytically derived in closed-form expressions, considering the atmospheric loss, turbulence, and receiver noises.

[pham-207-035-09:2017] V. V. Mai, T. C. Thang, and A. T. Pham. CSMA/CA-based Uplink MAC Protocol Design and Analysis for Hybrid VLC/Wifi Networks. In *Proc. of the IEEE International Conference on Commu-*

nications (ICC'17), Workshop on Optical Wireless Communications. IEEE COMSOC, IEEE Press, May 2017.

This paper proposes a multi-channel medium access control (MAC) protocol for hybrid VLC/Wifi networks. The proposed MAC protocol is based on an integration of two standards, IEEE 802.15.7 VLC and IEEE 802.11 Wifi CSMA/CA(s) (Carrier Sense Multiple Access/Collision Avoidance). We newly add on top of current MAC protocols a sub-layer that runs dynamic channel selection by taking intelligent control decisions, regarding channel aware and traffic aware. System performance metrics are analytically studied based on a combination of queuing and Markov chain theories. Numerical results quantitatively show how the proposed protocols significantly outperform the conventional ones.

[pham-207-035-10:2017] T. V. Pham, H. L. Minh, and A. T. Pham. Multi-Cell VLC: Multi-User Downlink Capacity with Coordinated Precoding. In *Proc. of the IEEE International Conference on Communications (ICC'17), Workshop on Optical Wireless Communications.* IEEE COMSOC, IEEE Press, May 2017.

This paper studies the multi-user performance of multi-cell visible light communication (VLC) systems with coordinated precoding among cells. Practically, separated LED arrays are employed to properly illuminate a large room/office. This configuration enables a multi-cell VLC system, which is analogous to that in mobile cellular networks. In such multi-cell systems supporting multiple users, the received signal at a user can severely be degraded not only by the interference caused by the signals that are intended to other users within the cell (intra-cell interference) but also by interference from signals of the other cells (inter-cell interference). In order to remove these interferences, we propose a coordinated precoding technique which allows coordination between VLC cells. We then investigate the optimal precoding matrix design to maximize the achievable sum capacity of users. The maximization problem is formulated as a convex optimization problem which can be solved efficiently by using standard software packages. Numerical results show that the proposed coordinated precoding outperforms the non-coordinated one.

[pham-207-035-11:2017] A. T. Pham, T. C. Thang, J. Villegas, and M. Cohen. VLC-based Smart Supermarket (SMARTKet): Concepts and Enabling Technologies. In *Proc. of the IEEE 6th Globe Conference on Consumer Electronics (GCCE).* IEEE Consumer Electronics Society, IEEE Press, Oct. 2017.

We present the key concepts and design of our proposed framework for a smart supermarket (SMARTKet). We briefly introduce the infrastructure, smart functions, and enabling technologies of the SMARTKet implementation. We especially focus on the basic principles, performance evaluation in terms of localization accuracy, and proof-of-concept implementation of the indoor navigation system using visible light communications (VLC) localization technology in the context of SMARTKet.

[pham-207-035-12:2017] A-T H. Bui, C. T. Nguyen, T. C. Thang, and A. T. Pham. An Improved DQ Access Protocol for Cellular-based Massive M2M Communications. In *Proc. of the IEEE/CIC ICC China 2017*. IEEE/CIC, IEEE Press, Oct. 2017.

This paper proposes an improved multiple access protocol based on the Distributed Queue (DQ) mechanism for cellular-based massive Machine-to-Machine (M2M) communications. The key concept of our protocol is to initially employ a subsets division step before starting the DQ mechanism. To validate the effectiveness of the proposal, we evaluate the performance of the proposed protocol over present Long-Term Evolution (LTE) networks with ultra-dense scenarios. Simulation results confirm that in the low load region, the proposed scheme offers comparable performance to the conventional DQ-based protocol and outperforms the standard Access Class Barring (ACB) scheme. In dense scenarios with high traffic, however, the proposed protocol outperforms both conventional DQ and the ACB in terms of delay.

[pham-207-035-13:2017] H. D. Le, C. T. Nguyen, V. V. Mai, N. T. Dang, and Anh T. Pham. On the Performance of TCP Cubic over Fading Channels with AMC Schemes. In *Proc. of the International Conference on Advanced Technologies for Communications (ATC) 2017*. Radio & Electronics Association of Vietnam and IEEE COMSOC, IEEE Press, Oct. 2017.

In this paper, we analyze the TCP Cubic throughput performance over a Nakagami-m slow-fading wireless channel with impacts of adaptive modulation and coding (AMC) schemes. The loss event, which includes a transport-layer congestion loss and physical-layer random packet loss is first analyzed thanks to corresponding finite-state Markov models. The average normalized throughput can be, thus, calculated taking both the losses into consideration. Computer simulations are performed to validate our analysis. The results show that the TCP throughput can be maximized by optimally setting system parameters.

[pham-207-035-14:2017] T. V. Pham and A. T. Pham. Cooperation Strategies and Optimal Precoding Design for Multi-User Multi-Cell VLC Networks. In *Proc. of the IEEE GLOBECOM '17*. IEEE COMSOC, IEEE Press, Dec. 2017.

This paper investigated the comparative performance of different cell cooperation strategies for multi-cell multi-user visible light communications (VLC) networks. In practical deployment of VLC, multiple LED arrays are deployed to provide sufficient illumination for large rooms/offices. As a consequence, multi-cell configurations are a natural progression for indoor VLC networks. In this study, to support multiple users simultaneously by means of precoding technique, each VLC cell is formed by 4 separated LED arrays. In such multi-cell networks, a user can be severely interfered not only by the signals that are intended to other users within the cell (intra-cell interference) but also by the signals for users of the other cells (inter-cell interference). In order to suppress these interferences, cell cooperation can be applied for precoder designs. We consider several strategies of cell cooperation and investigate the design of optimal precoding matrix corresponding to each cooperative strategy to maximize the achievable sum capacity of users. Comprehensive numerical results are shown to compare the performance of the considered cooperation strategies.

[pham-207-035-15:2017] A-T H. Bui, C. T. Nguyen, T. C. Thang, and A. T. Pham. A Novel Effective DQ-Based Access Protocol with Load Estimation for Massive M2M Communications. In *Proc of the IEEE GLOBECOM'17, Workshop on Emerging Technologies for 5G and Beyond Wireless Mobile Networks*. IEEE COMSOC, IEEE Press, Dec. 2017.

This paper proposes a novel effective protocol based on the Distributed Queue (DQ) mechanism to tackle the massive access issue in the cellular-based Machine-to-Machine (M2M) communications. To fully take the advantage of the DQ mechanism, we propose a novel method to avoid the inherent over-division problem by letting the base station first roughly probes the number of colliding devices in a Random Access Opportunity. Based on the probing result, the base station then randomly divides these devices into a determined number of groups and "pushes" these groups to the end of a logical access queue. In addition, we develop an analytical model to accurately estimate the average access delay of the proposed protocol in the massive scenarios. Computer simulations are also performed to validate the correctness of the

analytical model as well as the effectiveness of the proposed protocol in comparison with the LTE standard and conventional DQ access schemes.

[thang-207-035-04:2017] Truong Cong Thang Duc V Nguyen, Huyen TT Tran. Impact of delays on 360-degree video communications. In *in Proc. TRON Symposium (TRONSHOW), 2017*, Tokyo, Dec. 2017.

Internet of Things (IoT) and Virtual/Augmented Reality (VR/AR) are shaping our future by merging the digital and the physical words. In this trend, 360-degree video which is a key component of VR/AR is becoming increasingly popular nowadays. For effective transmission of bandwidth-intensive 360-degree videos over the network, viewport-adaptive streaming has been introduced. In this paper, we study the impact of the response delay on viewport-adaptive streaming of 360-degree videos. Specifically, we focus on two key components of the response delay which are 1) adaptation interval and 2) client buffering delay. Experiment results show that viewport-adaptive streaming is only effective under short adaptation intervals and buffering delays. Under long response delay such as in HTTP Adaptive Streaming, it is found that viewport-adaptive methods are even worse than viewport-independent one.

[thang-207-035-05:2017] Anh T Pham Truong Cong Thang Duc V Nguyen, Huyen TT Tran. A New Adaptation Approach for Viewport-adaptive 360-degree Video Streaming. In *in Proc. IEEE International Symposium on Multimedia (ISM)*, Taichung, Taiwan, Dec. 2017.

In this paper, we propose a new adaptation approach for viewport-adaptive streaming of 360-degree videos over the Internet. The proposed approach is able to systematically decide quality levels of tiles according to user head movements and network conditions by taking into account not only prediction errors but also user head movements in each adaptation interval. Experimental results show that the proposed approach can effectively adapt 360-degree videos to both varying network conditions and user head movements. Compared to existing approaches, the proposed approach can improve the average viewport quality by up to 3.9dB and reduce the standard deviation of the viewport quality by up to 50

[thang-207-035-06:2017] Truong Cong Thang Tien-Dung Pham, Phuong Luu Vo. Improving DASH Performance in a Network with Caching. In *in Proc. ACM Eighth International Symposium on Information and Communication Technology*, Nha Trang, Vietnam, Dec. 2017.

Dynamic Adaptive Streaming over HTTP (DASH) has been widely used in online video streaming nowadays. To reduce network congestion, popular videos are replicated in the intermediate cache nodes. However, with DASH, the intermediate cache node may lead to bitrate oscillations due to the difference in the throughputs from the end user to the cache node and from that to the origin server. In this paper, we develop an adaptation logic for DASH that can reduce bitrate oscillations. Our proposed adaptation logic combines both throughput-based and buffer-based adaptation methods. Extensive simulations show the efficiency of our proposed method.

[thang-207-035-07:2017] Cuong T Pham Nam Pham Ngoc Duc V Nguyen Truong Cong Thang Minh Nguyen, Dang H Nguyen. An adaptive streaming method of 360 videos over HTTP/2 protocol. In *in Proc. IEEE NICS2017*, Hanoi, Vietnam, Nov. 2017.

Nowadays, 360-degree video has become an important component of virtual reality (VR) technology. Unfortunately, this state-of-the-art content type requires a huge bandwidth from a server to a client. In order to solve the bandwidth problem in streaming VR videos over HTTP/2, a dynamic adaptation method is crucial. In this paper, we propose a novel adaptive streaming method based on tiled streaming. By using H.265 standard, a video at the server is divided into spatial tiles, each of which is subdivided into multiple temporal segments. In order to support adaptive streaming method from client, each tile is also encoded into different versions. The priority of tiles is defined based on the user's viewport. Then, the priority feature of HTTP/2 is used to request the server to push the tiles of higher priority first. This ensures that the visible tiles will arrive at the client and be decoded first. Besides, in the case of bandwidth fluctuation, we use the stream termination feature to cancel pushing the tiles that would arrive at the client after their playout deadlines.

[thang-207-035-08:2017] Cuong T Pham Yong Ju Jung Truong Cong Thang Huyen TT Tran, Nam Pham Ngoc. A subjective study on QoE of 360 video for VR communication. In *in Proc. IEEE 19th International Workshop on Multimedia Signal Processing (MMSP)*, Luton, UK, Oct. 2017.

Currently, more and more 360-degree videos (or 360 videos for short) are being provided via the Internet. This kind of videos can render a virtual reality (VR) environment via a head-mounted display (HMD). However, understanding the quality of experience (QoE) of 360 videos is a big challenge because user experience in VR is a very complex phenomenon. In this paper, the QoE

of 360 videos is considered in terms of four aspects, namely perceptual quality, presence, acceptability, and cybersickness. Subjective tests are designed to investigate the influences of important factors including encoding parameters, content characteristics, and device types on QoE aspects. In addition, a comparison of perceptual quality and acceptability between VR and non-VR rendering modes, which refer to watching 360 videos with and without using an HMD respectively, is also made in this study. To the best of our knowledge, this is the first study that covers these four QoE aspects and a large number of influence factors.

[thang-207-035-09:2017] Cuong Manh Bui Minh Hong Pham Truong Cong Thang Huyen TT Tran, Nam Pham Ngoc. An evaluation of quality metrics for 360 videos. In *in Proc. IEEE Ninth International Conference on Ubiquitous and Future Networks (ICUFN)*, Milan, Italy, Jul. 2017.

360 videos are becoming more and more popular on video streaming platforms. However, a good quality metric for 360 videos is still an open issue. In this work, we investigate both objective and subjective quality metrics for 360 videos. The goals are to understand the perceived quality range provided by existing mobile 360 videos and, especially, to identify appropriate objective quality metrics for 360 video communications. To that end, a subjective test is conducted in this study. Then, the relationship between objective quality and subjective quality is investigated. Especially, ten objective quality measures are computed, considering the coding distortion measurement, cross-format distortion measurement, and end-to-end distortion measurement. It is found that most of the objective quality measures are well correlated with subjective quality. Also, among the evaluated quality measures, PSNR is shown to be the most appropriate for 360 video communications.

Research grants from scientific research funds and public organizations

[pham-207-035-16:2017] Anh T. Pham (PI). Japan Telecommunication Advancement Foundation (TAF) Research Grant, 2016-2018.

[pham-207-035-17:2017] Anh T. Pham (PI). Japan Society for Promotion of Science (JSPS), KAKENHI 15K00134, 2015-2017.

[pham-207-035-18:2017] Anh T. Pham (Main Researcher). National Foundation

for Science and Technology Development (NAFOSTED, Vietnam), 2016-2018.

Academic society activities

[pham-207-035-19:2017] Anh T. Pham, 2017.

>Senior member

[pham-207-035-20:2017] Anh T. Pham, 2017.

>Member

[pham-207-035-21:2017] Anh T. Pham, 2017.

>Member

[pham-207-035-22:2017] Anh T. Pham, 2017.

>Member of TPC for many other international conferences, including Globe-com'17 OWC-WS, ATC'17, ICUFN'17, NICS'17

[pham-207-035-23:2017] Anh T. Pham, 2017.

>Peer Reviewer for many Transactions and Journals of IEEE, OSA and IE-ICE, including IEEE Transactions on Communications, IEEE/OSA Journal of lightwave Technology, IEEE/OSA Journal of Optical Communications and Networks, OSA Optics Express, IEEE Communications Letters etc.

Patent

[pham-207-035-24:2017] Julian Villegas and Anh Pham. Indoor localization system using near-ultrasound signals, August 2017.

Advisor for undergraduate research and graduate research

[pham-207-035-25:2017] Vuong V. Mai. PhD Thesis: Cross-layer Design, Analysis, and Optimization for Optical Wireless Communication Networks, University of Aizu, 2017.

>Thesis Advisor: Anh T. Pham

Summary of Achievement

[pham-207-035-26:2017] Phuc V. Trinh. PhD Thesis: Hybrid Architecture and Performance Improvement for Fifth-Generation (5G) Mobile Backhaul Networks, University of Aizu, 2017.

Thesis Advisor: Anh T. Pham

[pham-207-035-27:2017] Le Van Cong. Master Thesis: Modeling and Performance Analysis of Multi-rate FSO Networks using Multi-state Markov Chain, University of Aizu, 2017.

Thesis Advisor: Anh T. Pham

[pham-207-035-28:2017] Nguyen Ngoc Tu. Master Thesis: Performance Analysis of FSO Systems using SIM-MPSK Modulations over Atmospheric Turbulence, University of Aizu, 2017.

Thesis Advisor: Anh T. Pham

[t-huang-207-035-01:2017] Paul Aguirre. Graduation thesis, School of Computer Science and Engineering, 2018.

Thesis Advisor: T. Huang

[t-huang-207-035-02:2017] Satoru Chimoto. Graduation thesis, School of Computer Science and Engineering, 2018.

Thesis Advisor: T. Huang

Contribution related to student management(for example, solution of a student-related problem)

[t-huang-207-035-03:2017] I served as C6 class mentor