

Computer Communications Laboratory



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In the AY2015, the Computer Communications Laboratory (CCL) has three faculty members, one visiting scholar, Dr. Nam N. Pham from Hanoi University of Science and Technology, and 15 research assistants, including graduate (PhD, MS) and undergraduate students. 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. Integrated FSO/PON for Next-Generation Access Networks. Free-space optics (FSO) is a wireless line of sight technology that transmits high data rates using a narrow beam light through the air as transmission medium. The

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theory of the FSO transmission is basically the same as that of the fiber optics transmission. The main difference is that the air is used as transmission medium instead of fiber. The transmission rate may reach gigabit-per-second rates over few kilometers. FSO communication has the advantage of ease of setup and tear down, provision of access in difficult locations, and lower cost. Our research exploits the possibility of employing FSO in a part of practical optical access networks. In particular, we consider the integration of FSO and passive optical networks (PONs). Being more flexible, cheaper, easier and faster to install than the conventional PONs, FSO/PON has been viewed as a potential candidate technology for future optical access networks.

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-207-035-01:2015] Vuong V. Mai and Anh T. Pham. Adaptive Multi-Rate Designs and Analysis for Hybrid FSO/RF Systems over Fading Channels. *IEICE Transaction on Communications*, E98-B(8):1660–1671, 8 2015.

This paper proposes the concept of adaptive multi-rate (AMR), which jointly employs switching between two links and adaptive rate on each link, for hybrid free-space optical/radio-frequency (FSO/RF) systems. Moreover, we present the cross-layer design of AMR switching, which is based on both the physical and link layers with an automatic-repeat request (ARQ) scheme. We develop an analytical framework based on a Markov chain model for system performance analysis. System performance metrics, including frame-error rate, goodput and link switching probability, are analytically studied over fading channels. Numerical results quantitatively show how the proposal significantly outperforms conventional ones with physical layer-based design and/or fixed-rate switching operation.

- [pham-207-035-02:2015] Nhan Nguyen-Thanh, Philippe Ciblat, Anh T. Pham, and Van-Tam Nguyen. Surveillance Strategies Against Primary User Emulation Attack in Cognitive Radio Networks. *IEEE Transactions on Wireless Communications*, 14(9):4981–4993, 9 2015.

We investigate the primary user emulation (PUE) attack, which is a serious security problem in cognitive radio (CR) networks. There exist three types of PUE attackers: 1) a selfish one, which aims at maximizing its selfish usage of channel resource; 2) a malicious one, which points for obstructing the operation of CR network; and 3) a mixed one, which is between a selfish and malicious PUE attacker. For combating a selfish PUE attacker, a channel surveillance process has to be implemented in order to determine active user's identification and so selfish PUE attacker. An extra-sensing process has to be implemented for observing new opportunities to access the channel and so for mitigating the malicious PUE attacker's effect. Relevant strategies for deploying the above processes are obtained through a game theory-based analysis and the exhibition of Nash equilibrium (NE). We show the NE strongly depends on the network demand, the availability of the spectrum resource, and the type of the attacker.

- [pham-207-035-03:2015] Hien T. T. Pham, Phuc V. Trinh, Ngoc T. Dang, and Anh T. Pham. Secured Relay-Assisted Atmospheric Optical CDMA

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Systems over Turbulence Channels. *IET Optoelectronics, Special Issue on Optical Wireless Communications*, 9(5):241–248, 2015.

The authors propose a relay-assisted atmospheric optical code-division multiple-access (AO/CDMA) system for secured, multiuser optical communications. Chip detect-and-forward (CDF) scheme is used at relay nodes so that the complex multiuser decoding process can be avoided. The proposed system performance, in terms of bit-error rate (BER) and transmission confidentiality, is analysed over atmospheric turbulence channel taking into account channel loss due to atmospheric attenuation and beam divergence. Multiple-access interference and background noise are also included in the analysis. In addition, a quantitative analysis of data confidentiality is further examined in the study. The numerical results show that the relay transmission is an efficient solution to improve the system performance. Thanks to this solution, AO/CDMA systems can achieve low BER, long distance, and a large number of users. Moreover, high confidentiality can be attained by properly configuring system parameters, such as limiting the transmitted power and/ or reducing the signal beam width.

[pham-207-035-04:2015] Phuc V. Trinh, Ngoc T. Dang, and Anh T. Pham. All-Optical Relaying FSO Systems Using EDFA Combined With Optical Hard-Limiter Over Atmospheric Turbulence Channels. *IEEE/OSA Journal of Lightwave Technology*, 33(19):4132–4144, 2015.

In this paper, a novel relaying technique is proposed to improve the bit-error rate (BER) performance and distance coverage of high-speed all-optical free-space optical (FSO) communication systems. Particularly, an optical amplify-and-forward (OAF) relaying technique using erbium-doped fiber amplifier (EDFA) combined with optical hard-limiter (OHL) is introduced. The use of OHL enables EDFA-based OAF relaying FSO systems to prevent the accumulation of amplified background noise, which significantly degrades the system performance, when deploying multiple relays. For performance evaluation, we theoretically analyze the proposed system over atmospheric turbulence channels modeled by Gamma-Gamma distribution. A closed-form expression for the end-to-end BER bounds is, therefore, analytically formulated, taking into account other impacts of atmospheric channels, including atmospheric attenuation and geometric spreading of the optical beam, as well as noises caused by the background light and receiver. The numerical results, which are validated by Monte-Carlo simulations, confirm

the superiority of the proposed system in comparison with the conventional ones.

- [pham-207-035-05:2015] Takafumi Hayashi, Yodai Watanabe, Anh Pham, Toshiaki Miyazaki, Shiya Matsufuji, and Takao Maeda. A Novel Class of Zero-Correlation Zone Sequence Set Having a Low Peak-Factor and a Flat Power Spectrum. *IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences*, E98-A(12):2429–2438, 2015.

The present paper introduces a novel method for the construction of a class of sequences that have a zero-correlation zone. For the proposed sequence set, both the cross-correlation function and the side lobe of the auto-correlation function are zero for phase shifts within the zero-correlation zone.

- [pham-207-035-06:2015] Vuong V. Mai and Anh T. Pham. Cross-Layer Designs and Analysis of Adaptive-Rate Transmission and ARQ for Free-Space Optical Communications. *IEEE Photonics Journal*, 8(1):7901015, 2016.

The impact of atmospheric turbulence is one of the most challenging issues for the widespread deployment of free-space optical (FSO) communication systems. To enhance the systems' performance, adaptive-rate (AR) transmission and automatic repeat request (ARQ) have been separately considered at the physical and data link control layers. This paper introduces a framework of cross-layer design, analysis, and optimization for FSO communication systems, in which ARQ and AR transmission are jointly integrated to further improve the overall system performance over atmospheric turbulence channels. Two cross-layer designs are considered: 1) AR and standard ARQ and 2) AR and ARQ with frame combining. In addition, we newly develop a Markov chain model-based cross-layer analysis to evaluate system performance. System performance metrics, including spectral efficiency, maximum expected number of transmissions, and outage probability, are analytically studied under the presence of atmospheric turbulence. In numerical results, how the cross-layer designs significantly outperform conventional ones is quantitatively shown. Furthermore, we discuss a cross-layer optimization of selecting the ARQ persistence level for the tradeoff between the spectral efficiency and the number of transmissions.

- [thang-207-035-01:2015] DV Nguyen, HT Le, PN Nam, AT Pham, and TC Thang.

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Adaptation method for video streaming over HTTP/2. *IEICE Communications Express*, 5(3):69–73, Mar. 2016.

HTTP streaming, which is currently based on the pull-based HTTP/1.1 protocol, has a tradeoff problem between overhead and adaptivity. We propose an adaptation method for adaptive streaming over the new HTTP/2 protocol, leveraging its server push feature. The method is based on a cost function that takes into account the number of pushed segments and the client buffer level. Experiment results show that the proposed method can improve the balance between the number of requests and buffer stability compared to existing methods.

[thang-207-035-02:2015] HT Le, HN Nguyen, NP Ngoc, AT Pham, and TC Thang. A Novel Adaptation Method for HTTP Streaming of VBR Videos over Mobile Networks (accepted). *Mobile Information Systems*, 2016, Jan. 2016.

Recently, HTTP streaming has become very popular for delivering video over the Internet. For adaptivity, a provider should generate multiple versions of a video as well as the related metadata. Various adaptation methods have been proposed to support a streaming client in coping with strong bandwidth variations. However, most of existing methods target at constant bitrate (CBR) videos only. In this paper, we present a new method for quality adaptation in on-demand streaming of variable bitrate (VBR) videos. To cope with strong variations of VBR bitrate, we use a local average bitrate as the representative bitrate of a version. A buffer-based algorithm is then proposed to conservatively adapt video quality. Through experiments, we show that our method can provide quality stability as well as buffer stability even under very strong variations of bandwidth and video bitrates.

Refereed proceedings of an academic conference

[pham-207-035-07:2015] Thanh V. Pham, C-T. Truong, and Anh T. Pham. On the MGF-Based Approximation of the Sum of Independent Gamma-Gamma Random Variables. In *Proc. of the 2015 IEEE 81st Vehicular Technology Conference (VTC Spring)*, pages 1–5, Glasgow, UK, May 2015. IEEE.

We study the use of moment generating function (MGF) method to approximate the distribution of the sum of independent, but not necessarily identi-

cal, Gamma-Gamma variables, which is crucial in performance evaluation of multiple- input multiple-output (MIMO) free-space optical (FSO) systems. We show that the MGF-based approximation method can flexibly provide sufficient accuracy in the upper and lower tails of the cumulative distribution function (CDF) for both identically and non- identically distributed cases. Comparisons to highlight the advantages of the proposed method over existing ones are also presented. We then apply the proposed method to analytically derive closed-form expressions for the outage probability and average bit-error rate of MIMO-FSO systems. Monte-Carlo simulations are also performed to validate analytical results.

- [pham-207-035-08:2015] Vuong V. Mai and Anh T. Pham. Adaptive rate-based MAC Protocols Design and Analysis for Integrated FSO/PON Networks. In *Proc. of the 2015 IEEE International Conference on Communications (ICC)*, pages 5007–5012, London, UK, June 2015. IEEE.

This paper proposes two novel medium access control (MAC) protocols, which jointly employ bandwidth allocation and adaptive rate concepts, to enhance the performance of uplink transmission of the integrated free-space optical/passive optical networks (FSO/PON). System performance metrics, including frame-loss rate, goodput and delay, are analytically studied under the presence of atmospheric turbulence. Numerical results quantitatively show how the proposed protocols significantly outperform the conventional one with fixed bandwidth allocation/fixed rate.

- [pham-207-035-09:2015] Phuc V. Trinh, Ngoc T. Dang, and Anh T. Pham. All-optical AF Relaying FSO Systems using EDFA combined with OHL over Gamma-Gamma Channels. In *Proc. of the 2015 IEEE International Conference on Communications (ICC)*, pages 5098–5103, London, UK, June 2015. IEEE.

In this paper, we newly propose and theoretically analyze the performance of all-optical amplify-and-forward (OAF) relaying free-space optical (FSO) systems using erbium-doped fiber amplifier (EDFA) combined with optical hard-limiter (OHL) over atmospheric turbulence channels. The use of OHL enables OAF relaying FSO systems to remove accumulated background noise, which is one of the main factors that limit the system performance. The performance of proposed systems is analytically studied by which closed-form expression for bit-error rate (BER) is formulated, taking into account the effects of atmospheric turbulence channels and noises caused by background

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radiation and receiver. The numerical results, which are validated by Monte-Carlo (M-C) simulations, confirm the superiority of the proposed systems in comparison with conventional ones.

- [pham-207-035-10:2015] Thanh V. Pham, Hoa Le Minh, Zabih Ghassemlooy, Takafumi Hayashi, and Anh T. Pham. Sum-Rate Maximization of Multi-User MIMO Visible Light Communications. In *Proc. of the 2015 IEEE International Conference on Communication Workshop (ICCW)*, pages 1344–1349, London, UK, June 2015. IEEE.

This paper studies multi-user multiple-input multiple-output (MU-MIMO) visible light communications (VLC) for indoor broadcast systems. Transmitters, configured as multiple LED arrays, and multiple users equipped with multiple photodetectors (PD) are considered. The main challenge in such broadcast systems is the multi-user interference (MUI). In order to completely suppress the MUI, the block diagonalization (BD) precoding technique, originally utilized for radio frequency (RF) communications, will be adopted. Unlike RF counterpart the VLC signal is positive only leading to the modification of the precoding matrix, thus affecting the overall performance. The paper will investigate the lower bound for the sum-rate maximization of all users in the room scale scenario. Furthermore, the findings show that user's positions and PD's rotations considerably impact on the VLC system performance.

- [pham-207-035-11:2015] Hoa Le Minh, Zabih Ghassemlooy, Andrew Burton, Farag Mousa, Suparna Biswas, Anh T. Pham, Tien Dat Pham, and Shien-Kuei Liaw. Self-Correcting MIMO Visible Light Communications System Using Localisation. In *Proc. of the 2015 IEEE International Conference on Communication Workshop (ICCW)*, pages 1362–1367, London, UK, June 2015. IEEE.

Multiple-input-multiple-output (MIMO) technique for visible light communications (VLC) facilitates higher data rate thanks to parallel data transmission. However, full channel-state information (CSI) is a requirement in a MIMO system at all times for successful data recovery, which is a major challenging factor in mobility and shadowing scenarios. In this paper we introduce a novel approach for a self-correcting MIMO system's CSI that enables robustness against channel blocking and overcomes the reduced rank of the CSI matrix thanks to the self-estimation of the MIMO receiver position. This approach is designed to provide seamless MIMO VLC operation. The paper presents the theoretical modelling and numerical evaluation. We show that

the system can achieve data recovery for all channels even though one channel (or more) loses the pilot signal, which are used for determining the CSI.

- [pham-207-035-12:2015] Anh T. Pham, Phuc V. Trinh, Vuong V. Mai, Ngoc T. Dang, and Cong-Thang Truong. Hybrid Free-Space Optics/Millimeter-Wave Architecture for 5G Cellular Backhaul Networks. In *Proc. of the Opto-Electronics and Communications Conference (OECC), 2015*, pages 1–3, Shanghai, China, June 2015. IEEE.

This paper proposes a cost-effective, scalable network architecture, which combines millimeter-wave (MMW) and free space optics (FSO) technologies that can be employed as a complementary solution for pre-deployed optical fiber based 5G cellular backhaul networks.

- [pham-207-035-13:2015] Anh T. Pham, Phuc V. Trinh, Vuong V. Mai, Ngoc T. Dang, and Cong-Thang Truong. Hybrid Free-Space Optics/Millimeter-Wave Architecture for 5G Cellular Backhaul Networks (Invited Paper). In *Proc. of the Opto-Electronics and Communications Conference (OECC), 2015*, pages 1–3, Shanghai, China, July 2015. IEEE.

This paper proposes a cost-effective, scalable network architecture, which combines millimeter-wave (MMW) and free space optics (FSO) technologies that can be employed as a complementary solution for pre-deployed optical fiber based 5G cellular backhaul networks.

- [pham-207-035-14:2015] Chuyen T. Nguyen, Cong-Thang Truong, and Anh T. Pham. Performance Analysis of Hybrid ALOHA/CDMA Anti-collision Scheme for RFID Systems over Fading Channels. In *Proc. of the 2015 Seventh International Conference on Ubiquitous and Future Networks*, pages 657–661, Sapporo, Japan, July 2015. IEEE.

This paper proposes and theoretically investigates the efficiency of a hybrid ALOHA/CDMA anti-collision scheme for passive radio frequency identification (RFID) systems. The decorrelating detector is supposed to be used at RFID reader, while each tag is assumed to assign with a Gold code and responds to the reader in a randomly selected time slot. The tag identification is performed considering the influence of both code collisions and detection errors due to fading channels. The system efficiency, which is defined as the average number of successfully detected tags over a slot, is theoretically derived. Computer simulations are also performed to validate the theoretical analysis. In the numerical results, we evaluate the performance of the tag identification procedure with system parameters that maximize the system

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efficiency. We also confirm the superiority of the proposed system in comparison with conventional ALOHA-based ones.

- [pham-207-035-15:2015] Phuc V. Trinh and Anh T. Pham. Outage Performance of Dual-Hop AF Relaying Systems with Mixed MMW RF and FSO Links. In *Proc. of the IEEE 82nd Vehicular Technology Conference (VTC Fall), 2015*, pages 1–5, Boston, MA, September 2015. IEEE.

In this paper, we theoretically analyze the performance of a dual-hop fixed-gain amplify-and-forward (AF) system with mixed millimeter-wave radio-frequency (MMW RF) and free-space optics (FSO) links. The system is considered as a high-capacity, scalable and cost-effective backhaul solution for the 5G cellular- based vehicular networks. MMW RF and FSO channels are respectively modeled by the Ricean and Gamma-Gamma fading channels. Novel closed-form expressions for the end-to-end outage probabilities of the proposed system under various impacts of the transmission channels are analytically derived. Numerical results validate the mathematical analysis by Monte-Carlo (M-C) simulations and perform a comprehensive outage performance analysis of the proposed system.

- [pham-207-035-16:2015] Takafumi Hayashi, Yodai Watanabe, Anh T. Pham, Toshiaki Miyazaki, Shinya Matsufuji, and Takao Maeda. A Novel Class of QPSK Zero-Correlation Zone Sequence Sets. In *Proc. of the 2015 Seventh International Workshop on Signal Design and its Applications in Communications (IWSDA)*, pages 205–208, Bengaluru, India, September 2015. IEEE.

The present paper introduces the construction of Quadrature Phase Shift Keying (QPSK) modulation based 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 is 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 $N(z + 1)$ over l is theoretically limited to one. When the ratio of a sequence set is equal to one, the sequence set is called an optimal zero-correlation sequence set. The proposed zero-correlation zone sequence set can be generated from an arbitrary Hadamard matrix of order n . First, the proposed sequence set is generated as a set of $4n$ sequences of length $8n$ with the zero-correlation zone $z = 1$. The length of the proposed sequence set can be extended by sequence interleaving, where m times interleaving can

generate the $4n$ sequences, each of length $2m + 3n$. The proposed sequence set is optimal for $m = 0, 1$ and almost optimal for $m > 1$.

- [pham-207-035-17:2015] Vuong V. Mai and Anh T. Pham. Performance Analysis of Parallel Free-Space Optics/Millimeter-Wave Systems with Adaptive Rate under Weather Effects. In *Proc. of the 2015 21st Asia-Pacific Conference on Communications (APCC)*, pages 193–198, Kyoto, Japan, October 2015. IEEE.

This paper presents a concept of parallel Free-Space Optics/Millimeter-Wave (FSO/MMW) systems, in which adaptive rate is employed in both FSO and MMW links. We newly propose an analytical framework based on Markov chain model for system performance analysis. System performance metrics, including throughput and reliability rate, are analytically studied under the presence of various weather conditions. Numerical results quantitatively show how the adaptive-rate FSO/MMW significantly outperform conventional ones, and how weather conditions affect on the systems performance.

- [pham-207-035-18:2015] Chuyen T. Nguyen, Anh Tuan H. Bui, Vuong V. Mai, and Anh T. Pham. Tweaked Binary Tree Algorithm to Cope with Capture Effect and Detection Error in RFID Systems. In *Proc. of the 2015 21st Asia-Pacific Conference on Communications (APCC)*, pages 674–679, Kyoto, Japan, October 2015. IEEE.

This paper proposes a new RFID binary tree-based identification protocol, namely Tweaked Binary Tree (TBT), to cope with hidden tag problem caused by capture effect and detection error phenomena. In TBT, the whole identification process is divided into multiple binary tree cycles, and the hidden tags in a cycle are checked and re-transmitted in the first slot of the next one. The average number of slots for a successful detection of a tag, and the tag loss rate, defined as a ratio between the number of missing tags and the whole tag cardinality, are theoretically analyzed. Computer simulations are also performed to validate the theoretical analysis. We also confirm the superiority of the proposed method in comparison with a conventional General Binary Tree (GBT) one.

- [pham-207-035-19:2015] Tuan Bui, Chuyen T. Nguyen, Thang M. Hoang, and Anh T. Pham. Tweaked Query Tree Algorithm to Cope with Capture Effect and Detection Error in RFID Systems. In *Proc. of the 2015 International Conference on Communications, Management and*

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Telecommunications (ComManTel), pages 46–51, Danang, Vietnam, December 2015. IEEE.

In this paper, we propose a new Query Tree-based identification algorithm, namely, Tweaked Query Tree (TQT), to cope with hidden or missing tags caused by both Capture Effect and Detection Error phenomena in RFID systems. The whole identification process is divided into several query cycles, where hidden tags in a cycle re-transmit in the first query of the next one. The average number of time slots to successfully detect one tag and the tag loss rate defined as the ratio between the number of missing tags and the total number of tags, are evaluated by computer simulations. Obtained results show that the proposed TQT much more effectively solves the hidden tags problem in comparison with conventional methods.

[pham-207-035-20:2015] Thanh V. Pham and Anh T. Pham. Max-Min Fairness and Sum-Rate Maximization of MU-VLC Local Networks. In *Proc. of the 2015 IEEE Globecom Workshops (GC Wkshps)*, pages 1–6, San Diego, CA, December 2015. IEEE.

In this paper, we study multi-user multiple-input single-output (MU-MISO) visible light communications (VLC) for indoor broadcast systems. Multiple LED arrays are deployed as transmitters to serve multiple users simultaneously. In such broadcast systems, the main challenging issue is the presence of multi-user interference (MUI) among users. In order to completely cancel the MUI, the zero forcing (ZF) precoding technique which is originally designed for radio frequency (RF) communications, is adopted due to its low computational complexity. However, different from RF counterpart the VLC signal is inherently non-negative leading to the necessity of modifying the design of ZF precoding matrix. The paper investigates the maxmin fairness and the lower bound for the sum-rate maximization of all users in the room scale scenario taken into account the non-negativity signal constraint imposing on precoding matrix. Furthermore, numerical results show that relative user's positions has a considerable impact on the system performance.

[pham-207-035-21:2015] Vuong Mai and Anh T. Pham. Integrated FSO/PON for Broadband Access Networks: A Comprehensive Protocol Stack Design and Analysis. In *Proc. of the 2015 IEEE Global Communications Conference (GLOBECOM)*, pages 1–7, San Diego, CA, December 2015. IEEE.

In integrated free-space optical/passive optical networks (FSO/PON), provid-

ing efficient media access control (MAC) protocol and ensuring high reliable transmission are two major challenging issues. This paper comprehensively addresses these issues through a protocol stack design, which jointly considers the dynamic bandwidth allocation (DBA), adaptive rate (AR) transmission, and automatic repeat request (ARQ) with different retransmission strategies. A 2-D Markov chain model is developed to qualify quality-of-service (QoS) performance metrics in terms of frame loss probability, throughput and delay. Selected numerical results show that the proposed protocol stack design can offer considerable performance improvement over conventional ones.

[thang-207-035-03:2015] HT Le, DV Nguyen, NP Ngoc, AT Pham, and TC Thang. Quality-energy aware adaptation for mobile streaming clients. In *in Proc. IEEE International Conference on Consumer Electronics (ICCE)*, Las Vegas, US, January 2016.

Energy saving is an important requirement for any mobile devices. Meanwhile, streaming is one of the most popular services via mobile devices now. In this paper, we study the dependence of consumed power on adapted video bitrates. A novel adaptation method is then presented to balance the requirements for high video quality and low power consumption.

[thang-207-035-04:2015] T Nguyen, T Vu, DV Nguyen, NP Ngoc, and TC Thang. QoE optimization for adaptive streaming with multiple VBR videos. In *in Proc. IEEE International Conference on Communications, Management and Telecommunications (ComManTel)*, Danang, Vietnam, Dec. 2015.

Multi-bitrate streaming, especially HTTP adaptive streaming (HAS), is becoming popular for video delivery in multimedia network. In this trend, a video is encoded into different versions with different quality levels. Based on the current conditions, a client can adaptively choose the most suitable encoded version. However, the adoption of HAS in managed network (e.g. IPTV) has many challenges because of the purely client-driven approach of current HAS which causes competing behavior, excessive quality oscillations, and thus negatively impacting quality of experience (QoE). Some recent studies have proposed network-based solutions to overcome these problems; however, they just target at constant bitrate (CBR) videos. In this paper, we propose a new method that allows components inside the network to select an adapted version for each HAS client. To the best of our knowledge, this is the first study on the quality optimization when streaming multiple variable bitrate (VBR) videos. The experimental result show that our method can provide

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in real-time the optimal version for each client with the best possible quality while meeting the constraints of overall bandwidth and delay.

- [thang-207-035-05:2015] AH Duong, T Nguyen, T Vu, TT Do, NP Ngoc, and TC Thang. SDP-based adaptation for quality control in adaptive streaming. In *in Proc. IEEE Vehicular Networking Conference (VNC)*, Danang, Vietnam, Dec. 2015.

HTTP Streaming has been a new trend for video delivering via IP. Currently, most of the adaptation algorithms developed for HTTP Streaming are qualitative, which means the performance metrics could only be shown after the streaming session. In this paper, we embark on this problem by discretizing the whole system. We then formulate an infinite horizon problem (IHP) and solve it by Stochastic Dynamic Programming (SDP). To deal with the time-varying characteristics of video bitrate, we estimate the instant bitrate from the previous bitrate. We also develop mathematical models that predict the average performance of the adaptation policy, which helps adjust the settings before a streaming session. In the evaluation, we compare our method with a previous work which applies bitrate estimation and another method which only applies SDP.

- [thang-207-035-06:2015] T Vu, HT Le, DV Nguyen, NP Ngoc, and TC Thang. Future buffer based adaptation for VBR video streaming over HTTP. In *in the Proc. IEEE 17th International Workshop on Multimedia Signal Processing (MMSP)*., pages 1–5, Xiamen, China, Oct. 2015.

HTTP streaming has become a cost effective means for video delivery nowadays. To enable adaptivity to networks and terminals, a provider should generate multiple representations of an original video as well as the related signaling metadata. So far, most previous studies have just focused on the case of CBR (constant bit rate) video. In this paper, we propose a novel adaptation method for VBR (variable bitrate) video streaming. Based on a trellis representation to estimate future buffer levels, the proposed method can provide smooth video quality while avoiding buffer underflows. The experimental results show that our approach can perform effectively under drastic changes of both connection throughput and video bitrate.

- [thang-207-035-07:2015] HT Le, HN Nguyen, NP Ngoc, AT Pham, H Le Minh, and TC Thang. Quality-driven bitrate adaptation method for HTTP live-streaming. In *in the Proc. 2015 IEEE International Conference on*

Communication Workshop (ICCW), pages 1771–1776, London, UK, Jun. 2015.

In this paper, we focus on the bitrate adaptation issue of HTTP live video streaming. We first present a systematic approach that enables the client to choose the best video quality when deciding video bitrate for next several segments. After that, based on the concept of JND (Just Noticeable Difference), an adaptation method is proposed to meet the tradeoff between the requirements of buffer stability and smooth video quality. The experiment results show that our proposed method can provide smooth videos in terms of perceptual quality even under a small buffer size (i.e. 10s). To the best of our knowledge, this paper presents for the first time the way to use a perceptual quality metric for adaptivity in HTTP streaming.

Writing a textbook or technical book

[pham-207-035-22:2015] Hoa Le Minh, Zabih Ghassemlooy, and Anh T. Pham. *Guest Editorial: Special Issue on Optical-Wireless Communications, IET Optoelectronics*. Number 5. Institution of Engineering and Technology (IET), London, UK, 2015.

Research grants from scientific research funds and public organizations

[pham-207-035-23:2015] Anh T. Pham (PI) et al. Study and development of smart supermarket by using visible light communication (VLC) and smartphone technologies (funded by Japan Society for Promotion of Science (JSPS), Kakenhi 15K00134), 2015-2017.

[pham-207-035-24:2015] Anh T. Pham (Main Researcher) et al. Performance Evaluation and Improvement Methods For Relay-Assisted Free-Space Optical Communication Systems (funded by Grants-in-Aid awarded by Vietnam National Foundation for Science and Technology Development (Nafosted)), 2014–2015.

Academic society activities

Summary of Achievement

[pham-207-035-25:2015] Anh T. Pham, 2015.

IEEE Senior member: Communications, Photonics and Vehicular Technology societies

[pham-207-035-26:2015] Anh T. Pham, 2015.

Member of Optical Society of America (OSA)

[pham-207-035-27:2015] Anh T. Pham, 2015.

IEICE Member: Communications, Engineering societies

[pham-207-035-28:2015] Anh T. Pham, July 2015.

Organising Committee Co-Chair for the 3rd International Workshop on Optical-Wireless LED Communication Networks (OWLED 2015) Sapporo, Japan

[pham-207-035-29:2015] Anh T. Pham, 2014.

Member of TPC for many other international conferences, including ATC2015, ICTC2015, ICUFN2015 and GC2015 - Workshop - OWC etc.

[pham-207-035-30:2015] Anh T. Pham, 2015.

Peer Reviewer for many Transactions and Journals of IEEE, OSA and IEICE, 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.

Advisor for undergraduate research and graduate research

[pham-207-035-31:2015] Vu Trong Bach. Master Thesis: Theoretical Study and Implementation of Transceiver for FSO Communication Systems, University of Aizu, 2015.

Thesis Advisor: Anh T. Pham

[pham-207-035-32:2015] Luong Anh Duy. Master Thesis: Spatial Diversity in Multihop Coherent FSO Systems over Correlated Gamma-Gamma Turbulence Channels, University of Aizu, 2015.

Thesis Advisor: Anh T. Pham

[pham-207-035-33:2015] Trinh Viet Phuc. Master Thesis: Performance analysis of optical amplify-and-forward (OAF) relaying free-space optical (FSO) communication systems using erbium-doped fiber amplifier (EDFA) combined with optical hard limiter (OHL) over atmospheric turbulence channels, University of Aizu, 2015.

Thesis Advisor: Anh T. Pham

[pham-207-035-34:2015] Sari Yamaguchi. Master Thesis: Design, Analysis and Simple Implementation for VLC Indoor Positioning System using Optical Orthogonal Codes, University of Aizu, 2015.

Thesis Advisor: Anh T. Pham

Others

[pham-207-035-35:2015] won the IEEE ComSoc Sendai Chapter Student Excellent Research Award 2015. Vuong Mai, PhD student.

[pham-207-035-36:2015] won the IEEE ComSoc Sendai Chapter Student Excellent Research Award 2015. Phuc Trinh, PhD student.

[pham-207-035-37:2015] won the IEEE VTS Japan 2015 Young Researcher's Encouragement Award at IEEE VTC2015-Fall in Boston USA in Sep. 2015. Phuc Trinh, PhD student.

[pham-207-035-38:2015] won the IEEE VTS Japan 2015 Young Researcher's Encouragement Award at IEEE VTC2015-Spring in Glasgow Scotland on May 12 2015. Thanh Pham, Master student.

[pham-207-035-39:2015] won the Student Travel Grant for IEEE GLOBE-COM 2015 Vuong Mai, PhD student.

[pham-207-035-40:2015] is award the Publishing Support grant of 120 000 Yen by the Research Foundation for the Electro-technology of Chubbu. Vuong Mai, PhD student.

[pham-207-035-41:2015] is awarded the travel grant of 250 000 Yen by the Telecommunications Advancement Foundation (TAF) to attend the 82nd IEEE Vehicular Technology Conference (VTC2015-Fall) in Boston USA. Phuc Trinh, PhD student.

Summary of Achievement

[pham-207-035-42:2015] is awarded the travel grant award of 250 000 Yen by NEC C&C Foundation to attend 81st IEEE VTC Spring in Glasgow UK. Thanh Pham, master student.

[pham-207-035-43:2015] is awarded the travel grant award of 250 000 Yen by NEC C&C Foundation to attend IEEE ICC in London UK. Vuong Mai, PhD student.

[pham-207-035-44:2015] is awarded the travel grant award of 250 000 Yen by NEC C&C Foundation to attend IEEE ICC in London UK. Vuong Mai, PhD student.