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# MMTC Communications – Review

**Vol. 8, No. 6, December 2017**

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# Message from the Review Board Directors

Welcome to the December 2017 issue of the IEEE ComSoc MMTC Communications – Review.

This issue comprises four reviews that cover multiple facets of multimedia communication research including QoE-driven resource allocation for DASH over OFDMA networks, multiview video aware transmission over MIMO wireless systems, content-centric sparse multicast beamforming for cache-enabled cloud RAN, and real-time 3D shape search engine for large datasets. These reviews are briefly introduced below.

The first paper, published in IEEE GLOBECOM 2016 and edited by Xiaohu Ge, investigated the challenging problem of Dynamic Adaptive Streaming over HTTP (DASH) based video delivery over Orthogonal Frequency Division Multiple Access (OFDMA) networks.

The second paper is published in IEEE Transactions on Multimedia and edited by Carl James Debono. This paper exploits the MIMO system to provide content-aware transmission that allows streaming of multiview video.

The third paper, published in IEEE Trans. on Multimedia and edited by Debashis Sen, aims to theoretically model video popularity evolution from a new perspective by modeling major factors driving user views.

The fourth paper published in ACM Multimedia Systems 2017, Taipei, Taiwan as a best paper and edited by Michael Zink. This paper presents OpenFace, a new open-source face recognition system that approaches state-of-the-art accuracy. Integrating OpenFace with inter-frame tracking, they build RTFace, a mechanism for denaturing video streams that selectively blurs faces according to specified policies at full frame rates.

All the authors, nominators, reviewers, editors, and others who contribute to the release of this issue deserve appreciation with thanks.

IEEE ComSoc MMTC Communications – Review Directors

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# A Dual-Timescale Cross-layer Optimization Framework for QoE-driven DASH over OFDMA Networks

*A short review for "QoE-driven resource allocation for DASH over OFDMA networks"*

Edited by Xiaohu Ge

K. Xiao, S. Mao, and J. Tugnait, "QoE-driven resource allocation for DASH over OFDMA networks," in *Proc. IEEE GLOBECOM 2016*, Washington, DC, Dec. 2016, pp.1-6.

This paper [1] investigates the challenging problem of Dynamic Adaptive Streaming over HTTP (DASH) based video delivery over Orthogonal Frequency Division Multiple Access (OFDMA) networks. DASH has been adopted by many Internet video companies, such as Youtube and Netflix for its benefits of flexible adaptation to network congestion levels and quality of experience (QoE) provisioning. In DASH, video content is encoded into multiple versions with different bit rates and quality, and each version is partitioned into multiple non-overlapping chunks. A user uses HTTP/TCP to download the video chunk by chunk. Instead of controlling the transmission rate of video at the server, DASH provides users with high QoE through adaptively choosing a proper version (i.e., a proper bit rate) for different chunks, in reaction to network dynamics. QoE prediction in DASH is an interesting and important problem, since it determines the selection of the data rate for the future chunks. Several recent works [2], [3] indicate that the DASH QoE model should be different from the traditional ones, where additional factors such as rebuffering events and initialization delay should be taken into account.

Orthogonal frequency division mutiplexing (OFDM) has been the core technique for many broadband wireless networks. It has been adopted in major standards such as 3GPP-Long Term Evolution (LTE), Wi-Fi, and will continue to present in future 5th generation wireless networks. With OFDM, a spectrum is partitioned into multiple subcarriers. Orthogonal frequency-division multiple access (OFDMA) is OFDM for multiple users, where multiple access is achieved by assigning subsets of subcarriers to individual users. An important problem in OFDMA networks is how to allocate resource blocks, in the form of a combination of time and frequency/subcarrier, as well as transmit power to multiple users, to achieve high spectral efficiency and guarantee user's quality of service (QoS) and QoE. There have been considerable existing works on resource allocation in OFDMA networks. In [4], [5], the authors propose rate-adaptive (RA) schemes to maximize the throughput of users under transmit power budget constraints. In [6], [7], energy efficiency is the primary goal for resource allocation in the downlink of an OFDMA network, where proportional rates are guaranteed for mobile users.

This paper investigates the problem of DASH-based video delivery in OFDMA networks, aiming to integrate these two principal technologies to enable effective wireless video delivery. In particular, the authors consider the downlink of an OFDM network, where the BS transmits multiple video streams to mobile users. The videos are encoded in the DASH format, i.e., multiple versions, while each partitioned into multiple chunks. The multiple video sessions share the downlink capacity. The BS dynamically allocates the downlink resource, in terms of time, subcarrier, and transmit power, to the mobile users, based on feedback on channel state information (CSI) and users' playout buffer occupancy. After downloading a chunk, each user also dynamically adjusts its data rate for the next chunk, based on its buffer level and CSI. The overall goal is to maximize the user QoE through joint BS and client side optimization.

Compared to the prior work on DASH (e.g., [8]), this paper considers a more realistic wireless network model. This paper also jointly optimizes the operation of the underlying wireless network and the DASH system with a cross-layer optimization framework by incorporating a novel and more general QoE model for DASH videos. The following contributions are made in this paper. First, the authors propose a comprehensive QoE model that incorporates several key factors, including average and variance of the video quality, rebuffering ratio, and startup delay. The QoE model is quite general, and does not depend on any specific assumptions on the network or video traffic models. Second, the authors develop a global offline formulation to maximize the sum QoE of all users through resource allocation and DASH rate adaptation. This cross-layer optimization framework captures the key design factors in DASH and OFDMA networks, and is also a very general model. Third, to avoid the use of future information, the authors break down the offline problem into a BS resource allocation problem, where the BS optimizes a weighted sum of user rates by allocating time, subcarrier, and transmit power, and a user rate adaptation problem, where each user chooses a data rate for the next chunk to maximize its own QoE. Effective solution algorithms are developed to derive optimal solution to both problems. In addition, the two optimization mechanisms are executed at different timescales: the rate adaptation is executed at a much larger timescale than the BS resource allocation. Finally, through a thorough simulation study, the authors validate the performance of the proposal scheme with a realistic network/video setting and comparison with a representative benchmark scheme, where considerable gains are observed.

Overall this is a well-written paper on a timely topic. The proposed QoE model and the cross-layer optimization framework, as well as the dual-timescale solution could be useful for practical DASH over OFDMA systems.

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## Transmission of Multiview Video on MIMO Wireless Systems

*A short review for "MuVi: Multiview Video Aware Transmission over MIMO Wireless Systems"*

Edited by Carl James Debono

*Z. Chen, X. Zhang, Y. Xu, J.Xiong, Y. Zhu and X. Wang, "MuVi: Multiview Video Aware Transmission over MIMO Wireless Systems," IEEE Transactions on Multimedia, vol. 19, no. 12, pp. 2788 – 2803, December 2017.*

Multiview video provides opportunities to enhance the way video is consumed, including personal scene view selection, 3D video and immersive applications. This is done through the transmission of multiple views of a scene captured by cameras positioned at different locations. However, such transmission demands huge amounts of bandwidth which are not readily available in most channels. Moreover, the wireless channel quality varies drastically causing fluctuations in the available bandwidth due to the modulation and coding scheme switching in response to these channel quality variations.

Multiview streaming services have also low latency and high video quality requirements to ensure a good quality of experience. Meeting these requirements is challenging in the limited bandwidth and time varying channel conditions experienced in wireless networks. Multiple input multiple output (MIMO) solutions offer the possibility of simultaneous transmission of data through multiple antennas. This spatial multiplexing provides higher data throughput and can lay the infrastructure necessary to support multiview services. Resource allocation schemes have been designed for MIMO Wi-Fi networks to maximize the throughput [1, 2] and thus allow services and applications that need more bandwidth.

Unequal power allocation schemes for the transmission of video have been developed in literature. Adaptive channel selection for scalable H.264 content over MIMO was presented in [3] while [4] uses loss visibility side information. Minimization of distortion in layered video over MIMO was studied in [5]. Moreover, space-time coding was employed in [6]. Cross-layer schemes, such as [7, 8] exploit unequal error protection (UEP) to support better multiview video quality when delivered on wireless networks.

The authors of the original paper exploit the MIMO system to provide content-aware transmission that allows streaming of multiview video. Streaming of multiview content can achieve acceptable quality of experience if transmitted over 802.11ac MIMO systems. Yet, if the wireless system is resource-limited, then the streaming quality can degrade if all the video frames are treated equally. Thus, if more important packets are better protected, the overall quality of experience can be improved.

In multiview video coding (MVC), one of the views, referred to as the base view, is encoded in the same way as single view coding, while the rest present a different structure with the increased complexity of interview coding. Given these dependencies, it is clear that some frames are more important than others. The video frames are normally transmitted in a number of packets and therefore errors on the channel will impact on parts of a frame and not the entire frame as assumed in [9]. These factors imply that multiview streaming is different from single view streaming.

The gains of the channel vary with time and are different for each antenna pair. Therefore, appropriate selection of the antennas for transmission can achieve gains in throughput. This must be done jointly with power allocation such that more important packets are transmitted over more reliable links. This provides additional challenges that need adequate attentions.

The simulation scenario is not always enough to understand the quality of the transmitted video over wireless networks. Real channels are more complex than the models that can be used. Thus, a prototype can help to better understand and evaluate such solutions. The authors of the original paper develop a software-defined radio (SDR) system built on an 802.11 MIMO-OFDM (orthogonal frequency-division multiplexing) module they call MuVi to evaluate their proposed solution.

The authors of the original paper developed a content-aware scheme for the streaming of 3D multiview video in a MIMO wireless network. They do measurements to evaluate the average peak-signal-to-noise ratio (PSNR) of the multiview frames such that optimization for transmission can be done. UEP is then employed through the use of the diversity gain of the MIMO system to offer more resources to protect the important packets against errors on the channel. A mixed-integer programming framework is applied to reduce the mean distortion of the video content. Moreover, a joint two stage antenna selection and power allocation algorithm is used to exploit the diversity of the transmission paths offered by the MIMO system. A proof-of-concept prototype is also implemented to determine the performance of the resource allocation solution proposed. The prototype is compatible with the MAC (medium access control) and physical layers of 802.11ac specifications. The results reported in the paper for H.264/MVC video show improvements in PSNR over a standard resource allocation scheme.

MIMO systems offer additional parameters that can be exploited to improve video transmission, including multiview, over wireless channels. Resource allocation plays an important role in distributing fairness amongst users while providing enough resources that allow adequate video quality. Channel quality estimation is also an important research topic to provide more accurate estimates that ensure maximization of the available resources in real time.

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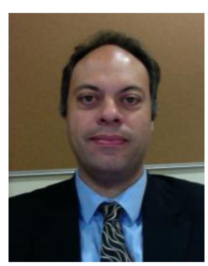

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Prof. Debono is a senior member of the IEEE and served as chair of the IEEE Malta Section between 2007 and 2010. He was the IEEE Region 8 Vice-Chair of Technical Activities between 2013 and 2014. He currently chairs the IEEE MMTC Media Processing for Communications Interest Group (MPCIG). He has served on various technical program committees of international conferences and as a reviewer in journals and conferences. His research interests are in wireless systems design and applications, multi-view video coding, resilient multimedia transmission, and modeling of communication systems.

# Popularity Evolution of Internet Video Content

*A short review for "Modeling Dynamics of Online Video Popularity"*

Edited by Debashis Sen

*J. Wu, Y. Zhou, D. Chiu and Z. Zhu, "Modeling Dynamics of Online Video Popularity," IEEE Transactions on Multimedia, vol. 18, no. 9, September 2016.*

Video streaming serves a fast increasing number of Internet users. The number of user views taken by a particular video can be regarded as the video's popularity. Online video providers seek to optimize their operations such as load generation, content caching and video recommendation based on popularity [1]. However, the challenge is that popularity is not a static value, but a variable changing with time for even an individual video. Modeling evolution of internet video popularity will therefore be very helpful for improving service quality and providers' operating efficiency. In reality, evolution of popularity with time is not a stationary process resulting in the challenge to precisely model video popularity dynamics. We can take a snapshot of a whole online video system to investigate the popularity of all videos at a particular moment [2]. However, it is difficult to use such snapshot captures to model how popularity is evolving with time, as an appropriate sampling rate is not known. Hence, some empirical work has led to certain video popularity expressions, without much emphasis on theoretical modeling [3].

The paper discussed here aims to theoretically model video popularity evolution from a new perspective by modeling major factors driving user views. Video viewing process is considered to be driven by: a) the video information diffusion process and b) the user reaction process. This can be interpreted as follows. The video information should be distributed to a user before the user decides whether or not to view the video based on his personal interests. Once the user decides to view the video, he/she will find an appropriate time slot to play it depending on the video type, duration and the extent the user likes it. For example, if it is an interesting short video, it may be played immediately by the user. However, if it is a long documentary, the user may prefer to watch it in weekend.

In practice, there are a various number of ways to distribute video information, such as video frontpage recommendation, movie posters and word-of-mouth recommendation from friends. It is unrealistic to separately model each way of video information spread. Instead, all information diffusion methods are classified as either direct recommendation representing recommendations made by video markers and video providers who recommend videos based on operation necessities, or word-of-mouth (WOM) recommendation representing recommendations made by users who like the video.

A video popularity model is designed for each individual video considering four parameters. The model created is essentially a stochastic fluid model, and is referred to as EvoModel. The factors considered for the modeling are:
(a) The rate of direct recommendation,
(b) The rate of word-of-mouth recommendation,
(c) The video's intrinsic popularity, and
(d) The users' reaction rate.
The said parameters are fixed from the view count trace data collected through a real system based on [4]. Use of these four factors alone provides a rich model of evolution dynamics that can match the common evolution patterns observed. The advantage with theoretically modeling popularity like the above is that one can investigate and search all possible popularity evolution patterns by searching parameter space.

Tencent Video is a famous online video streaming system in China, providing millions of videos out of more than 20 video categories to Internet users. The number of monthly active users is more than 20 million and the number of users during peak hours is about 2 million. This is the real system that provides the trace data required to design and validate the theoretical model. Through curve fitting by minimizing normalized mean square error (NMSE), the paper arrives at the following conclusions:
a) The model can works for most popular videos except for a small number of unpopular videos with a lot of casual views, which is better than existing models;

b) Parameter study shows that only one recommendation, either direct recommendation or WOM recommendation, plays the major role for video information diffusion, and user reaction is very fast for all popular videos;
c) The recommendation strategy of video providers and users can be visualized through scatter plots by fitting parameters;
d) A popularity prediction algorithm can be designed accordingly that can improve prediction precision [5].

The technical contributions of this paper can be extensively applied to online video streaming systems to improve all operations relying on the knowledge and prediction results of video popularity. Specifically, one can use the model to generate video view loads to estimate required network resources. Personal video recommendation systems can incorporate the knowledge of video popularity before the final video list is generated and presented to each user [6]. Based on video popularity, the video content cached on edge servers and other end devices with limited storage space can be adjusted accordingly to improve hit rate for the cached content improving service quality [7].

**Acknowledgement:**

The editor would like to thank the authors for providing a preliminary draft of this review.

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## RTFace: A System for Denaturing Video Streams

*A short review for "*A Scalable and Privacy-Aware IoT Service for Live Video Analytics"
Edited by Michael Zink

*Junjue Wang, Brandon Amos, Anupam Das, Padmanabhan Pillai, Norman Sadeh, Mahadev Satyanarayanan, " A Scalable and Privacy-Aware IoT Service for Live Video Analytics," Best Paper at ACM Multimedia Systems 2017, Taipei, Taiwan.*

In this paper, the authors present and approach for scalable and privacy-aware live video analytics that is supported by Edge Clouds (a.k.a. Cloudlets). This work is motivated by the deployment of a huge number of surveillance cameras, which generate and abundance of video material. Visually analyzing these data by humans is impossible and face detection and recognition algorithms are required. Obviously distributing video data taken by surveillance cameras raises privacy issues, since individuals can be recognized in these streams. The system presented in this paper tackles these issues by denaturing faces in images before making them public. Since the system is designed for live video analytics, this denaturing has to be performed in real time.

In my opinion it represents a very good systems paper that identifies several issues in the intersecting area between Multimedia and IoT. The major contribution of this work is its privacy-aware aspects that perform in real time to enable live video analytics. It is a novel application that has the potential to gain some traction since surveillance cameras become more and more ubiquitous and individuals are often concerned about their privacy. The most interesting component of the proposed approach is the Privacy Mediator that will give trusted authorities (e.g., law enforcement) unrestricted access to the video data.

The paper is well written and easy to follow. One reason for its good presentation quality is the initial example given by the authors which is used to motivate the need for a privacy-aware IoT service. Based on this example, it is easy for the reader to understand the overall system architecture and the individual components of the system.

As made clear in the example scenario, real time capabilities are of highest importance to the RTFace system. For that reason, the authors focus on the design, implementation and analysis of a system that can perform face recognition and denaturing in real time. An analysis of face recognition and detection reveals that performing these algorithms on each individual frame does not allow real time processing. To increase the processing speed the authors make two significant contributions. First of all, they develop an approach that tracks faces that have been detect. With this approach, face detection and recognition does not have to be applied to each frame. This results in a significant reduction in processing time. On the downside, performing tracking and recognition only on a subset of frames can lead to the miss of new faces that might appear in the stream. To tackle this issue, the authors introduce a Frame Revisit Buffer (FRB) that allows to jump back a certain number of frames if the denaturing algorithm should have to be applied to frames in the past. E.g., a new individual might appear in a frame on which the algorithm was not executed and the face might only be detected after several frames leading to breach of privacy. With the aid of the FRB, this can be prevented for all the frames that are currently in the frame (up to 30).

A second important contribution of this paper is the controlled reversal of denaturing that would allow specific entities like law enforcement to reverse the process such that they can identify actual faces. This feature is helpful in cases where, e.g., a robbery is recorded by one or more cameras. Through an elaborate key management process trusted authorities have the ability to decrypt formerly encoded bounding boxes to fully reconstruct a face.

The paper finishes with a scenario that describes the components of RTFace at enterprise scale that have been implemented by the authors. In addition, scalability and design choices with respect to users, quantity and quality of cameras, and Cloudlet and LAN are discussed.

Finally, I would like to mention that this paper gives a very good motivation for Edge Clouds/Cloudlets that is not driven by ultra-low latency applications. In the case of RTFace, Cloudlets make the system scalable since they satisfy the application's demand for high bandwidth and compute power.

Professor Michael Zink in the Computer Science Department at the University of Massachusetts in Amherst. He received his PhD in 2003 from the Multimedia Communications Laboratory at Darmstadt University of Technology. He works in the fields of sense-and-response sensor networks, distribution of high-bandwidth, high-volume data, and the design and analysis of long-distance wireless networks and Systems Engineering. Further research interests are in wide-area multimedia distribution for wired and wireless environments and network protocols. He is one of the developers of the KOMSSYS streaming platform. He received his Diploma (M.Sc.) from Darmstadt University of Technology in 1997. From 1997 to 1998 he was employed as a guest researcher at the National Institutes of Standards and Technology (NIST), where he developed an MPLS testbed. In 2003 he received his Ph.D. degree (Dr.-Ing) from Darmstadt University of Technology; his thesis was on Scalable Internet Video-on-Demand Systems.

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Following the direction of MMTC, the Communications – Review platform aims at providing research exchange, which includes examining systems, applications, services and techniques where multiple media are used to deliver results. Multimedia includes, but is not restricted to, voice, video, image, music, data and executable code. The scope covers not only the underlying networking systems, but also visual, gesture, signal and other aspects of communication. Any HIGH QUALITY paper published in Communications Society journals/magazine, MMTC sponsored conferences, IEEE proceedings, or other distinguished journals/conferences within the last two years is eligible for nomination.

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Members of the IEEE MMTC Review Board will review each nominated paper. In order to avoid potential conflict of interest, guest editors external to the Board will review nominated papers co-authored by a Review Board member. The reviewers' names will be kept confidential. If two reviewers agree that the paper is of Review quality, a board editor will be assigned to complete the review (partially based on the nomination supporting document) for publication. The review result will be final (no multiple nomination of the same paper). Nominators external to the board will be acknowledged in the review.

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