Guest Editorial QoE-Aware Wireless Multimedia Systems

Maria G. Martini, Chang Wen Chen, Zhibo Chen, Tasos Dagiuklas, Lingfen Sun, and Xiaoqing Zhu

WITH the evolution towards new multimedia systems and services, user requirements are not limited any more to requirements on connectivity: users now expect services to be delivered according to their demands on quality. At the same time, audiovisual systems are becoming more and more complex and new possibilities of presenting content are available, including augmented reality and immersive environments. However, for wireless systems the possible limitations due to the characteristics of the transmission channel and of the devices can result in perceivable impairments, originated in the different steps of the value chain from content production to display techniques, that influence the user's perception of quality. In recent years, the concept of quality of service (QoS) has been extended to the new concept of quality of experience (QoE), as the first only focuses on the network performance (e.g., packet loss, delay and jitter) without a direct link to the perceived quality, whereas the QoE reflects the overall experience of the consumer accessing and using the provided service. Experience is user- and context-dependent (involving considerations about subjective multimedia quality and users' expectation based on the cost they paid for the service, on their location, on the type of service, on the convenience of using the service, etc.). Subjective QoE evaluation is however time consuming, costly and not suitable for use in closed loop adaptation, hence there is a growing demand for objective QoE evaluation and control: objective, rather than subjective, QoE evaluation enables user centric design of novel multimedia systems, including wireless systems based on recent standards, such as WiMAX and 3GPP LTE, through an optimal use of the available resources based on such objective utility indexes.

Through an open call for papers, this special issue sought submissions on the latest research on QoE-aware wireless multimedia systems, including relevant applications in new areas. We received 44 papers, and 11 papers have finally been selected after a careful and highly competitive review process, consisting of two steps to ensure the best possible quality for the accepted papers based on the revised versions. Due to space and time limitations, a number of high quality contributions could not be accommodated.

The papers in this special issue cover a range of topics and can be logically organized in three groups, focusing on QoE-aware media protection, QoE assessment and modelling, and multi-user QoE management.

The first group includes papers addressing QoE-aware media protection. Quality of experience aspects can indeed be considered as a design factor for forward error correction and in general for the protection strategy adopted for the media content, in a cross-layer design framework.

The paper "A Cross-Layer Design for Perceptual Optimization of H.264/SVC with Unequal Error Protection", by Khalek, Caramanis, and Heath, leverages perceptual metrics in concert with link adaptation to maximize the perceptual quality and satisfy real-time delay constraints. The authors introduce a cross-layer architecture that enables optimizing the perceptual quality for delay-constrained scalable video transmission. The authors propose an online QoS-to-QoE mapping technique to quantify the visibility of the packets lost from each video layer using the ACK history and perceptual metrics. At the physical layer, a link adaptation technique that uses the QoS-to-QoE mapping is proposed, to provide perceptually-optimized unequal error protection per layer according to packet loss visibility. At the application layer, the source rate is adapted by selecting the set of temporal and quality layers to be transmitted based on the channel statistics, source rates, and playback buffer state. The authors demonstrate that the proposed architecture prevents playback buffer starvation, provides immunity against short-term channel fluctuations, regulates the buffer size and achieves an increase in video capacity.

The paper "Channel Coding Optimization Based on Slice Visibility for Transmission of Compressed Video over OFDM Channels", authored by Toni, Cosman, and Milstein, addresses transmission of video sequences over an orthogonal frequency division multiplexing (OFDM) system in a slowly varying Rayleigh faded environment. The authors propose a cross-layer technique, based on an interesting slice loss visibility model used to evaluate the visual importance of each slice. In particular, the mapping of video slices within a 2-D time-frequency resource block and/or the channel code rates is performed by taking into account the visibility scores available from the bitstream, in order to better protect more visually important slices. The proposed algorithm is investigated for several scenarios, with different levels of information about the channel available in the optimization process. Results demonstrate that, for different physical environments and different video sequences, the proposed algorithm outperforms baseline ones which do not take into account either the slice loss visibility or the channel state information in the video transmission.

The paper "Perceptually Coded Transmission of Arbitrary 3D Objects over Burst Packet Loss Channels Enhanced with

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a Generic JND Formulation" introduces a quite interesting research topic on perception based transmission for 3D objects over burst packet loss channels, due to the rapid growth of online applications with 3D computer graphic media content, such as games, virtual reality, augmented reality and immersive experience. The authors propose a novel approach to reliably transmit 3D mesh content without retransmission including applying stripification on a 3D mesh following the valence-driven algorithm and distributing the nearby vertices into different packets, combined with a probabilistic mesh-dependent interleaving technique. A 3D JND metric is also proposed. The paper presents promising performance with different levels of mesh content in the simulation experiments.

The second topic of QoE assessment and modelling is represented by the paper "Managing Quality of Experience for Wireless VOIP Using Noncooperative Games" from J Hassan, M Hassan, Das and Ramer. It presents a QoE model as a function of the amount of human effort (or user irritation) to continue a VoIP call in mobile VoIP services. The user irritation threshold leading to quit a call and the quitting probability during VoIP calls are analysed. A non-cooperative game between a service provider and a VoIP user is formulated. The paper demonstrates how, by applying game theory for resource management, VoIP service providers can reduce the irritation of a VoIP user and increase their revenues.

Finally the last large group of papers focuses on multi-user QoE management. Addressing jointly the Quality of Experience of multiple users is not an easy task when limited resources have to be shared among the users. In this scenario, pricing approaches can be adopted, as well as approaches derived from game theory and learning algorithms. Methodologies such as interference shaping also appear interesting.

The paper "A Novel QoE-Aware Multicast Mechanism for Video Communications over IEEE 802.11 WLANs", from Santos, Villalón, and Orozco-Barbosa, introduces a novel multicast service for the IEEE 802.11 WLAN standard. The proposed architecture combines a novel MAC scheme and layered video, guaranteeing a minimum acceptable video quality to all the members of the multicast group through the base layer. The enhancement layers are transmitted using a higher transmission rate. The authors show that by properly coupling the video and multicast control mechanisms, the QoS as well as the QoE requirements of the end-user can be guaranteed. In particular, results show that the real-time video streaming quality of the total system can be greatly improved while keeping downward compatibility with the IEEE 802.11 multicast mechanism.

The paper "QoE-Driven Channel Allocation Schemes for Multimedia Transmission of Priority-Based SUs over Cognitive Radio Networks", from Jiang, Wang, and Vasilakos, addresses cognitive radio networks as a means to provide high wireless bandwidth and support for quality-driven wireless multimedia services. The authors observe that the unstable channels allocated to the multimedia secondary users (SUs) can be re-occupied by the primary users at any time, which makes it difficult to meet the QoE requirements. To cope with this possible limitation, this paper proposes a novel QoE-driven channel allocation scheme for SUs and cognitive radio networks base stations. The historical QoE data under different primary channels are collected by the SUs and delivered to a Cognitive Radio Base Station (CRBS). The CRBS will allocate available channel resources to the SUs based on their QoE expectations and maintain a service queue. The proposed channel allocationapproach is able to significantly improve the QoE of the priority-based SUs over the cognitive radio networks.

The paper "MOS-Based Congestion Control for Conversational Services", from Oussama, Hu, van der Schaar, Hayel and Wu, proposes a Quality-centric Mean Opinion Score based congestion control that determines an optimal congestion window updating policy for multimedia transmission. Unlike standard congestion control algorithms, the proposed approach defines a new Additive Increase Multiplicative Decrease algorithm taking into account the multimedia application and the transmission characteristics. In order to get the optimal congestion policy in practice, the sender requires complete statistical knowledge of both multimedia traffic and the network environment, which may not be available in wireless systems. Hence, the paper proposes a Partially Observable Markov Decision Process framework in order to determine an optimal congestion control policy which maximizes the long term expected Quality of Experience of the receiver. Moreover, the computation of an optimal policy is usually time/process consuming and as wireless devices are computationally limited, optimal solutions based on temporal difference online learning algorithms are considered. Experiments are performed on a Microsoft Lync test-bed with unidirectional and bidirectional communications over a wireless network.

The paper "Revenue Maximization in Time-Varying Multi-Hop Wireless Networks: A Dynamic Pricing Approach", from Song, Zhang, Fang, and Lin, addresses a wireless multi-hop network where multiple flows co-exist and share the network resource collectively. Each flow is associated with a user which has specific requirements on its trade-off between cost and quality. To support heterogeneous transmissions efficiently, the article proposes a quality-aware dynamic pricing algorithm, which provably maximizes the overall network revenue while maintaining the stability of the network. The proposed scheme enjoys the merit of self-adaptability due to its online nature.

The paper "Efficient Resource Utilization for Multi-Flow Wireless Multicasting Transmissions", from Tu, studies the efficient utilization of network resources for increasing the number of concurrent multimedia flows when a channel becomes saturated. In particular, the author presents a theoretical study of the flow scheduling policy and the channel aggregation policy in both single-hop and multi-hop wireless networks with the motivation of ameliorating the trade-off between limited channel resources and multiple flow transmission. In order to increase the number of performance guaranteed multimedia flows, based on the dynamic states of wireless channels and the profiles of multimedia flows, the two policies fully utilize the performance gap to schedule concurrent flows for transmission in turn and aggregate multiple channels' residual capacities for useful flow transmissions. A novel algorithm - efficient multiflow multicast transmission is then proposed, to apply the proposed policies to practical wireless multimedia multicast applications.

The paper "Interference Shaping for Improved Quality of Experience for Real-Time Video Streaming", from Singh,

Andrews, and de Veciana, addresses bursty co-channel interference, a prominent cause of wireless throughput variability, leading to video QoE degradation even for a fixed average channel quality. The authors propose and analyze a network-level resource management algorithm termed interference shaping, aiming at smoothing out the throughput variations (and hence improve the QoE) of video users by decreasing the peak rate of co-channel best effort users. Wireless link capacity variations are mapped to the real-time video packet loss rate, and the interference shaping QoE gain for video users is quantified by benchmarking against a perceptual video quality metric, i.e., modified multi-scale structural similarity (H-MS-SSIM) index. The proposed technique increases the mean QoE and reduces the QoE variability over time, while incurring insignificant decrease in the QoE for co-channel best effort users. The proposed approach can be implemented in both unicast and multicast real-time video streaming, although it offers much higher potential gains for multicast.

The paper "Speeding Multicast by Acknowledgment Reduction Technique (SMART) Enabling Robustness of QoE to the Number of Users", authored by Rezaee, du Pin Calmon, Zeger, and Médard, presents a novel feedback protocol for wireless broadcast networks that use linear network coding. The work considers transmission of packets from a single source to many receivers over a single-hop broadcast erasure channel with heterogeneous links. The authors propose a predictive model to minimize feedback as well as extraneous data transmissions by the source. They provide a lower bound for the expected total transmission time, and show that the proposed protocol operates close to this lower bound. The proposed scheme is robust to uncertainty in the number of receiving nodes, to packet erasure probability, and to partial loss of the feedback.

Finally, the paper "GestureFlow: QoE-Aware Streaming of Multi-Touch Gestures in Interactive Multimedia Applications" from Feng, Liu and Li, presents the design of GestureFlow, a broadcast protocol for concurrent gesture streaming in multiple broadcast sessions with the objective of minimizing gesture recognition delay. Inter-session network coding is applied and challenges introduced by linear dependence of coded packets are addressed. The work is evaluated by an experimental test bed based on mobile devices (iPad) and a specifically developed application called "MusicScore". With the aid of user experience tests, the paper demonstrates that GestureFlow achieves higher QoE, when compared with the TCP Relay scheme, over Wi-Fi/3G networks.

The guest editorial team wishes to express their appreciation to all the authors of the papers submitted to this special issue. We received the valuable support of 128 reviewers and we would like to thank them all for their hard work and expert contributions.

Finally, special thanks go to the IEEE JSAC team (the Editor in Chief Martha Steenstrup, the Board representative Pamela Cosman, and the Executive Director Laurel Greenidge) and the IEEE publications staff (Sue Lange in particular) for their cooperation in the preparation of this JSAC special issue.

We hope you will enjoy reading the high quality papers presented in this issue.

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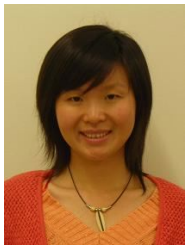

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