FINAL PUBLISHABLE SUMMARY REPORT

Communicating multimedia content such as high-quality images, audio or video streams became a part of everyday life both for the purpose of business and entertainment. However, due to considerable bandwidth consumption and strict quality of service (QoS) requirements, today's multimedia communications usually take place between stationary users such as desktop/laptop PC's connected to high-speed wired/wireless Local Area Network (LAN) connections. On the other hand, as user mobility and need for multimedia content available anytime and anywhere increases, multimedia applications such as video streaming, mobile TV, video-conferencing, multimedia peer-to-peer (P2P) networking, social networking with multimedia content, interactive gaming, etc., are becoming a major bandwidth consumer on small, handheld, mobile devices and are indicated in many recent studies as a major driving factor for the next generation mobile broadband technologies such as Mobile WiMax and 3GPP LTE-Advanced that aim to provide sufficient data rates for comfortable high-quality mobile multimedia services.

Although wireless communication standards that support mobile multimedia applications have been successfully launched, research efforts are focused on improving their performance, expanding possibilities and services, addressing clients' heterogeneity and reducing power requirements. There are number of challenges to ensure reliable high-quality, real-time, low-power communication services in severe error-prone wireless environment. Firstly, to receive multimedia at high quality, high bandwidth is necessary, which is an expensive resource. Secondly, transmission rates are limited by channel noise, interference, fading, multipath, path loss and shadowing on wireless links, calling for high source compression efficiency and strong channel error protection. Thirdly, end user devices have different capabilities and QoS requirements in terms of bandwidth and screen resolution, which calls for scalable video compression schemes simultaneously adaptable to different users. Finally, low-complexity and power-efficient schemes that operate in real time are required for mobile receivers with limited battery life.

The research on Marie Curie FP7-PEOPLE-IEF MMSTREAM addresses one of the hottest topics in today's communications: how to robustly and efficiently transmit scalable multimedia data over the existing wireless infrastructure to handheld devices of mobile users. The project started in June 2009 and, lasting for 18 months, was finished in December 2010. The goal of the project was to address the problem of efficient and robust application layer forward error correcting (AL-FEC) code design for real-time scalable image/video streaming to handheld devices with varying capabilities and transmission channels with varying severity (e.g., wireless channels in urban/rural settings). The project intended to deeply investigate the design of the state-of-the-art channel coding schemes based on Low Density Parity Check (LDPC) and Digital Fountain (DF) codes, jointly optimized with the scalable image/video sources, with the aim of providing increased end-user Quality of Service (QoS) guarantees for the receivers of low capabilities and/or affected by severe channel conditions, and at the same time providing users with higher capabilities and/or better channel conditions with progressively higher QoS guarantees.

Among the project results, numerous benefits of novel Unequal Error Protection (UEP) DF codes called Expanding Window Fountain (EWF) codes over the existing FEC solutions for multimedia streaming are demonstrated. The simplicity, design flexibility and UEP performance make EWF codes ideally suited for scalable multimedia streaming, i.e., EWF codes offer a number of design parameters to be "tuned" at the server side to meet the different reception conditions of heterogeneous receivers. Apart from optimizing EWF code parameters for increased error-protection performance of different data importance classes, EWF codes may be optimized with respect to the end-to-end distortion performance of multimedia transmission for different scalable

multimedia sources. Furthermore, EWF code parameters may be jointly optimized through the cross-layer optimization techniques with the error-protection mechanisms at lower layers, thereby providing overall optimal error-protection for multimedia services. The work on EWF codes served as an inspiration and is extended towards the end of the project to UEP Network Coding (NC) design.

The MMSTREAM project has achieved the following goals:

- The MMSTREAM project was intended to be a highly research-oriented project with its major contribution being high-quality publications in leading international journals or at leading international conferences. To this end, the researcher and scientist in charge have produced 3 journal papers (1 published in IEEE Transactions on Multimedia, and 2 submitted to IEEE Transactions on Communications and IEEE Transactions on Multimedia) and are currently involved in the final preparations for submission of 2 journal papers. They have published 10 papers at the leading IEEE conferences with additional 2 recently accepted for publication. The material presented in these papers represents a major outcome of the MMSTREAM project.
- Apart from the strong research component, MMSTREAM project will establish and further enhance existing collaboration among EU research groups interested in multimedia broadcasting. Building on the researcher's collaboration within the COST 2100 special interest group on Hybrid Broadcast/Cellular Networks, the researcher and the host scientist together with Dr Gomez Barquero and Dr Nybom organized a special session titled "Scalable Video Transmission over Digital Video Broadcast Networks" on a leading IEEE multimedia conference IEEE Int'l Conference on Multimedia and Expo (ICME 2010). Special session presented latest contributions in the field by groups from leading academic and industrial contributors in the field. The special session resulted from collaboration within the MMSTREAM project and can therefore be attributed as its outcome.
- Finally, the MMSTREAM project has its application-oriented component, which is developed throughout the course of the project in collaboration with the host scientist and his research students. This output is a software library comprising encoding and decoding solutions for all relevant state-of-the-art AL-FEC coding schemes: LT codes, Raptor codes including 3GPP standardized DF Raptor encoder/decoder, EWF codes, random linear codes (RLC) and corresponding Gaussian Elimination (GE) decoder and UEP RLC codes. All of these encoders/decoders are successfully integrated with H.264/SVC video coder output including appropriate segmentation and packetization of layered video content. These upper layer processing blocks are adjoined with the packet-level channel models for DVB-H transmission obtained from the real-world measurements.

The aforementioned contributions of the MMSTREAM project will serve as theoretical, collaborative and application developing basis for the future research in the field. More precisely, the work on the MMSTREAM project and its results served as an inspiration for UEP network coding which will be a core topic of the Marie Curie European Reintegration Grant project titled MMCODESTREAM, the start of which is expected in June 2011. In addition, experience obtained from DVB-H system investigation will be extended in the proposed research not only to DVB-NGH, but even more in the direction of LTE-Advanced technology whose multi-hop and relaying aspects serve as a promising arena for integrated research on network coding with UEP property, multimedia streaming services, cooperative communications, energy efficiency, throughput and delay performance and other fundamental communication/information theoretic aspects of reliable and efficient multimedia transmission.