# Broadcasting in 4G mobile broadband networks and its evolution towards 5G

## Abstract

One of the challenges of the mobile industry is to cope with the growth of mobile traffic demand expected for the next years, primarily driven by the increasing usage of mobile video services. Indeed, the existence of increasingly powerful terminals is encouraging the consumption of high-quality video content. Usually, video services are identified with linear Television (TV) and scheduled broadcast (point-to-multipoint (p-t-m)) distribution. However, the consumption of video content over mobile networks is different from traditional fixed TV because contents are mainly consumed on-demand with unicast point-to-point (p-t-p) connections. Then, the convergence of linear TV and on-demand content delivery represents a challenge that requires a combined broadcast/unicast transmission model.

This dissertation addresses the use of broadcasting technologies for the provision of mobile multimedia services in Fourth Generation (4G) mobile broadband networks and beyond. Specifically, the dissertation focuses on the broadcast technology included in 4G Long Term Evolution (LTE) and LTE Advanced (LTE-A) networks, known as Enhanced Multicast Broadcast Multimedia Services (eMBMS). It analyses the benefits of the eMBMS physical layer aspects regarding Multimedia Broadcast Multicast Services over a Single Frequency Network (MBSFN) deployments and identifies the current limitations of eMBMS at physical layer by comparing with the broadcast technology of the other 4G mobile system, the Institute of Electrical and Electronics Engineers (IEEE) 802.16m standard. Those limitations are the use of a dedicated carrier and Multiple-Input Multiple-Output (MIMO) techniques for broadcast transmissions. Our investigations employ a complete simulation platform including link-level and system-level simulations to evaluate the performance of broadcast transmissions in these real technologies.

The research on eMBMS services is aimed at finding the optimum delivery of streaming and file download services focusing on the Radio Resource Management (RRM) problem and trade-off between Physical layer – Forward Error Correction (PHY-FEC) and Application Layer - Forward Error Correction (AL-FEC). Concerning streaming services, results show that the use of AL-FEC increases the coverage level and, then, the maximum service data rate. The gain due to AL-FEC is greater in scenarios with high mobility users, although, this gain is limited if low zapping times are desired. Regarding file delivery services, this dissertation analyses the duration of the transmission required to guarantee the correct file reception and the reduction in the mean throughput of unicast users with different delivery modes. They are the unicast delivery, the eMBMS delivery and a hybrid approach, which combines a first eMBMS delivery with a post-delivery error repair phase with unicast transmissions. Our results show that the hybrid delivery is the most efficient configuration in terms of file download time, although it further reduces unicast performance.

On the other hand, as an exemplary use case, this dissertation also investigates the use of LTE networks for the provision of vehicular safety services comparing both unicast and eMBMS delivery modes. Results highlight the significant benefits in terms of resource usage, end-to-end latency and cost delivery saving that can be achieved by using eMBMS for the delivery of road safety applications. In addition, research also addresses the problem associated with the support of road safety applications over the current eMBMS architecture, the configuration of the Intelligent Transportation Systems (ITS) server in charge of distributing safety messages as well as on its interaction with the mobile network operator.

Finally, this dissertation analyzes feasible options of convergence between mobile and broadcast industry to ensure the success of the mobile broadcasting deployments in the future. A separated evolution of the broadcast technologies of both industries would lead to a scenario with two complete different industries, with different network infrastructures and business models competing for market and spectrum. This dissertation proposes an approach by which the definition of the future Fifth Generation (5G) mobile broadband communication system could bring together the cellular and broadcast industries to form a single fixed and mobile converged network and offer a full alternative to terrestrial TV broadcasting as a universal service.