Mobile 3DTV Content Delivery Optimization over DVB-H System

Mobile 3DTV Content Delivery Optimization over DVB-H System (www.mobile3dtv.eu) is a three-year project partly funded by the European Union 7th RTD Framework Programme in the context of the Information & Communication Technology (ICT) Cooperation Theme and its objective 1.5 Networked Media. The project started on 1 January 2008 and is carried out by a consortium of three universities (Tampere University of Technology, Technical University of Ilmenau, Middle East Technical University), one public research institute (Fraunhofer HHI), and two SMEs (Tamlink Ltd and MM Solutions Ltd).

The project ultimate goal is to develop and demonstrate the viability of the new technology of mobile 3DTV. Mobile 3DTV system is conceptualized by Fig. 1. Stereo video content is suitably created at the transmission side, then effectively encoded and robustly transmitted over DVB-H channel to be received, decoded and played by a DVB-H enabled handheld, equipped with auto-stereoscopic display.

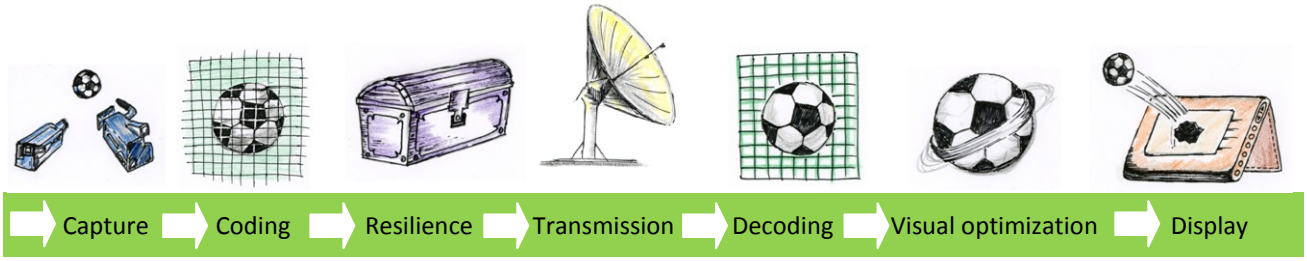


Fig. 1 Mobile 3DTV system.

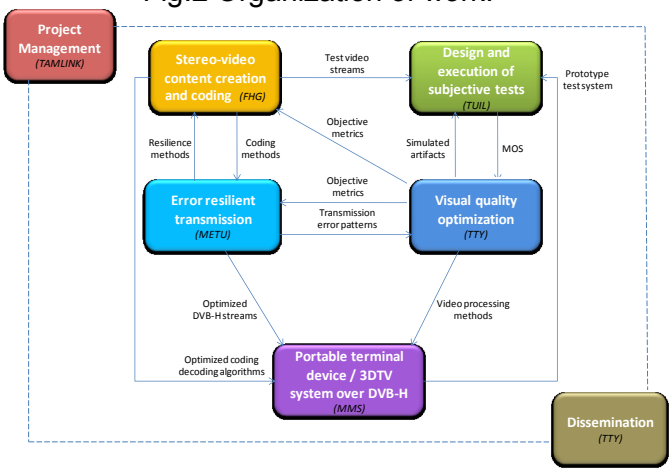
To achieve the project ultimate goal, the following objectives have been specified by the project consortium

1. Develop optimal formats for stereo video content creation for mobile 3DTV in terms of compressibility, efficient rendering and user satisfaction.
2. Develop optimal appropriate codecs for mobile 3DTV in terms of supported spatial and temporal resolution, compression efficiency and decoder complexity.
3. Develop optimal tools for error-resilient transmission of mobile 3DTV content over DVB-H.
4. Gather new knowledge about user experience in terms of acceptance of and satisfaction with mobile 3DTV content, relevant to the artefacts specific to mobile stereo-video compression and transmission and to the purpose for which the user will view such media.
5. Develop novel metric for objective assessment of quality of processed stereo-video streams relevant to the artefacts specific to mobile stereo-video compression and transmission.
6. Develop optimal tools for stereo video quality enhancement so as to appeal to the mobile user.
7. Develop a backward-compatible prototype portable device capable of receiving and displaying 3D video streams.
8. Build an end-to-end system enabling broadcasting of compressed and stored stereo-video content over DVB-H channel.

The research work has been properly organized and focused around five research topics as given in Fig. 2. The project co-ordination has been appointed jointly to Tamlink Ltd (Co-ordinator) and Tampere University of Technology (in Finnish - Tampereen Teknillinen Yliopisto –TTY, Scientific Co-ordinator). The Fraunhofer (FhG) research team has brought in its comprehensive experience in developing multi-view content creation and coding methods, while Middle East Technical University's team has concentrated on developing error resilience techniques for streaming 3D video content over error-prone channels. The research team of Department of Signal Processing, Tampere University of Technology has focused on developing advanced image and video processing methods to achieve the best possible visual quality at the receiver side. Teams from Technical University of Ilmenau (TUIL) and the Unit of Human-Centered Technology, Tampere

University of Technology have been designing and carrying out subjective tests to support the optimization of critical parts of the system. MM Solution's activity has focused on the design of a technology demonstrator, i.e. a prototype handheld device capable of receiving, decoding and playing stereoscopic video-streams.

Fig.2 Organization of work.



At the stage of 3D content creation and coding, different representation formats have been studied for their applicability in mobile 3DTV scenarios. Three types of representations have been considered: *two-channel stereo video,* single video augmented with dense depth information (*video plus depth*), and *mixed resolution stereo.* Corresponding databases of test video streams have been created or collected and constantly updated. At the end of the second project year there are 32 stereo and multi-view sequences described at the project web site at www.mobile3dtv.eu/stereo-video/. More than half of the material is available for free use from the server of the project. Video plus depth database, providing temporally and spatially smooth and stable depth maps has been generated by FHG-HHI and made available at www.mobile3dtv.eu/video-plus-depth/. In addition, a database of mixed-resolution stereo video has been created by down-sampling one of the views. Two subsets of gathered and newly created content, reflecting the user's needs on mobile 3DTV content and representative for coding and transmission studies, have been selected as the project official sets for psychometric subjective tests. They are also available at http://sp.cs.tut.fi/mobile3dtv/test-sequences/.

Research on 3D video coding is an important direction in the project. Available coding standards for 3D video have been optimized and evaluated for the specific conditions of mobile 3DTV. After comparing *H.264/AVC simulcast*, *H.264/AVC stereo SEI message*, *MVC*, *MPEG-C Part 3* (V+D using H.264/AVC), and *H.264 Auxiliary Pictures* for their applicability in mobile scenarios, MVC and V+D have been selected to be further optimized in terms of proper bitrate allocation and modified to enable error resilience. More specifically, slice modes have been added and their performance evaluated. Furthermore, the concept of mixed resolution stereo coding (MRSC) has been studied and Advanced MRSC has been developed as an extension of MVC. These coding approaches have been compared both objectively and by extensive subjective tests. Comparative results are described and summarized in details in a series of technical reports available at www.mobile3dtv.eu/results/#technical-reports. At the end of second year, MVC has been selected as the representation and coding format to be supported by the end-to-end system and terminal device, while further research on V+D and MRSC will be carried out during the third year.

In our concept, DVB-H is considered to be the broadcast media of future mobile 3DTV. We especially addressed the specific error protection of stereo-video content over such a channel. A full-featured transmitter setup using proprietary broadcasting equipment has been set up at TTY and PC-based transmitter configurations have been setup up at the research sites of TTY, METU, and MMS. A full set of tools for simulation of the application, link, and physical layers of the DVB-H channel have been developed. These are described at www.mobile3dtv.eu/technology and available for download at www.mobile3dtv.eu/download. Channel error traces for different channel models and operational parameters have been generated and made available at www.mobile3dtv.eu/download/error-traces/. Fig. 3 illustrates the broadcast system over DVB-H.

Using the developed tools, the effect of transmission errors on different 3D video representations has been studied for different MPE-FEC code rates, mobility speeds and carrier to noise ratios and for different channel parameters. Furthermore, error resilience has been implemented in two modes: as the slice mode of the encoder and as forward error correction existing in the link-layer of

DVB-H. The effect of content and source and channel coding has been analysed through numerous transmission tests. The results of these simulations are available in a series of technical reports at www.mobile3dtv.eu,fi/results/#technical-reports. The results demonstrated the superiority of MVC as a coding approach and showed a clear improvement when using its slice mode. Equal link-layer error protection seems to be more beneficial at the current stage however more comprehensive unequal protection schemes are to be studied during the third project year.

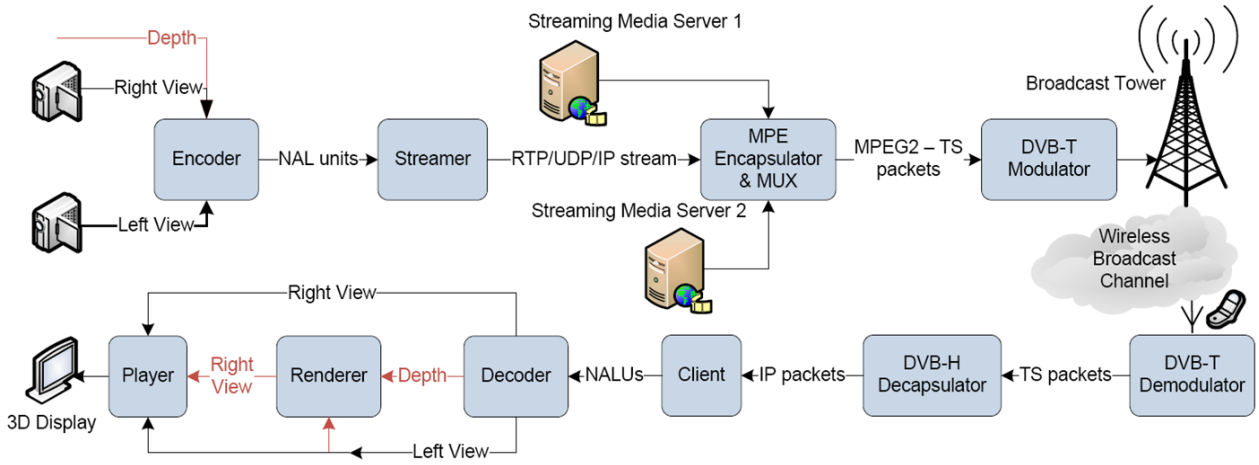


Fig. 3. Stereo-video broadcast over DVB-H channel

In our approach, we put the mobile user in focus since little is known about the user experience of 3D video content visualized on a portable screen. During the first project year, the user studies focused on studying user expectations and requirements for mobile stereo video. In a combination of an *online survey, focus groups and probe studies*, conducted in Germany and Finland, current practices and needs for mobile 3DTV systems have been identified, and more implicit requirements of users have been revealed. A detailed report on user needs and expectations for mobile stereo-video has been issued at www.mobile3dtv.eu/results/#technical-reports. A framework for user-centered user studies including the main aspects of user experience – *user, system, and context* has been developed to help in the optimization of the critical parts of the system. Open Profiling of Quality has been selected as the main research method to combine quantitative quality preference evaluation according to existing standards with sensory profiling for elicitation of individual quality factors. During the second project year three extensive subjective tests have been conducted: the first study included 87 participants and evaluated the subjective quality of different coding methods. The second follow-up study investigated the impact of channel parameters and transmission errors on the perceived quality involving 66 participants. The third study evaluated the quality in real usage context. It also studied the impact of multimodality (stereo video / audio) on quality requirements. The obtained results, available at www.mobile3dtv.eu/results/#technical-reports, are very instructive for the selection of source and channel coding methods and operational modes. Most importantly, MVC and V+D have been identified as the best accepted coding formats, while MVC in slice mode has been the most preferred for channel coding. Artefact perception strongly influenced participants' perceived quality and hindered the depth perception added value. For certain displays, display-specific artefacts may mask all other effects. The display quality has been found central for the acceptance of the new technology.

As strongly emphasized by the subjective tests, the degradations caused by channel errors or compression artefacts are quite critical for the acceptance of the new technology. To study the role of artefacts in objective quality measurements, a unified artefact classification system has been developed within the project. The main stages of mobile 3DTV content delivery, considered as potential sources of artefacts, have been matched against the different “layers” of the human 3D vision and thus mapped in a multidimensional ‘artefact’ space. An artefact simulation framework for introducing typical mobile 3dtv artefacts to a 3D video has been developed and made available for download on the project website: www.mobile3dtv.eu/download. During the second project year,

this knowledge was extended toward extensive modelling of the human visual system and designing a suitable signal processing chain to reflect the selected model. In addition, advanced signal processing methods have been developed to properly pre- and post-process 3D video for enhancing its quality. The set of methods include image resizing, video denoising and depth map sequence restoration, as reported at www.mobile3dtv.eu/results/#technical-reports.

A purposely designed backward-compatible handheld device equipped with auto-stereoscopic display and capable of receiving, decoding and playing stereo video streams is one of the expected most important results of the MOBILE3DTV project. Research activities have included selection of development platform, integration of DVB-H stack and auto-stereoscopic display. At the end of second year, the technology demonstrator is in its third version. It is based on TI OMAP 3621, put in a proper form factor, with all HW and SW support for a mobile device. Specific HW and SW components for 3D support, such as daughter cards for 3D display and corresponding drivers have been designed. Three different 3D displays, based on different display technologies (parallax-barrier, lenticular Horizontal Double Density Pixel (HDDP) arrangement, and LED light-guided 3D film) have been integrated. The current demo device can receive DVB-H broadcasts, decapsulate and decode 3D video encoded in MVC and play it on the auto-stereoscopic display.

The project partners have devoted considerable efforts to publicise their work. Demonstrations of the end-to-end DVB-H channel, featuring coding and transmission of stereo-video and its reception by portable devices, either equipped with 3D display or legacy ones, were carried out at the NEM Summit 2008 and 2009 in Saint-Malo, the ICT Event 2008 in Lyon, and Dimension 3 Expo 2009 in Paris. The first and third versions of the handheld technology demonstrator were demonstrated at the Mobile World Congress 2009 and 2010, respectively. Invited talks about the project were given at the EU-Korea forum 2008 in Brussels, Japan-EU symposium 2009 in Tokyo, Dimension 3 Forum 2009 in Paris, 3D Stereo Media Festival in Liege and DVB 3DTV workshop 2010 in Geneva. Most of the events have been addressed by posts in the project blog at: http://mobile3dtv.blogspot.com/. 19 conferences have been attended by project participants and 25 scientific publications on project topics have been made. Publications are available at www.mobile3dtv.eu/2/results/#conference-papers. The project has also actively participated in the activities of the 3D Media Cluster – an umbrella gathering of EC-funded projects in the area of 3D media. The project assumed a leading role in summarizing the user studies within the cluster.

The first two project years have been quite successful and full of events and research achievements. The main outcome of the MOBILE3DTV will be a working system for the capture and coding of 3D video content and its delivery and display on a mobile device. Today, no such system exists. However, the technologies that enable the development of such a system are at a good stage of maturity. The scope of the MOBILE3DTV project is to pool various technologies, adapt, optimize and extend them, and to evaluate their acceptance by the users in order to make them work together efficiently within a single system.

As of the impact of the developed technology, it is determined by the current hype regarding 3D Media technologies. 3D has gathered incredible attention due to current success of 3D digital cinema and has become a central and most spectacular topic at commercial shows, such as IBC in Amsterdam and CES in Las Vegas. 3D standardization initiatives have emerged in bodies such as MPEG, DVB, ITU, and SMPTE. MOBILE3DTV project addresses this trend from the point of view of the most dynamic that is the *mobile* user. A key issue of our technology is its scalability and flexibility. It will give users the freedom to choose and switch between 2D and 3D viewing mode, depending on their preferences and service availability. 3D video layers will be backward compatible to allow for playing conventional 2D content too. Encoding and playing will be supported by our project outcomes. As of broadcasting, services based on specific content to be delivered in 3D should be expected. Examples vary from weather forecast and geographical/navigation information to full-length nature feature documentaries. The channel and error-protection outcomes from our project will play a role in the successful deployment of such services. New knowledge about user expectations, and the acceptance and satisfaction of mobile 3D video content shall help in the development of most suitable and appealing novel 3D applications and services.