Mobile 3DTV content delivery optimization over DVB-H system

Mobile 3DTV Content Delivery Optimization over DVB-H System [1] 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 1st January 2008 and is carried out by a consortium of three universities (Tampere University of Technology, Ilmenau University of Technology, 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 Figure 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 device equipped with auto-stereoscopic display.

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.

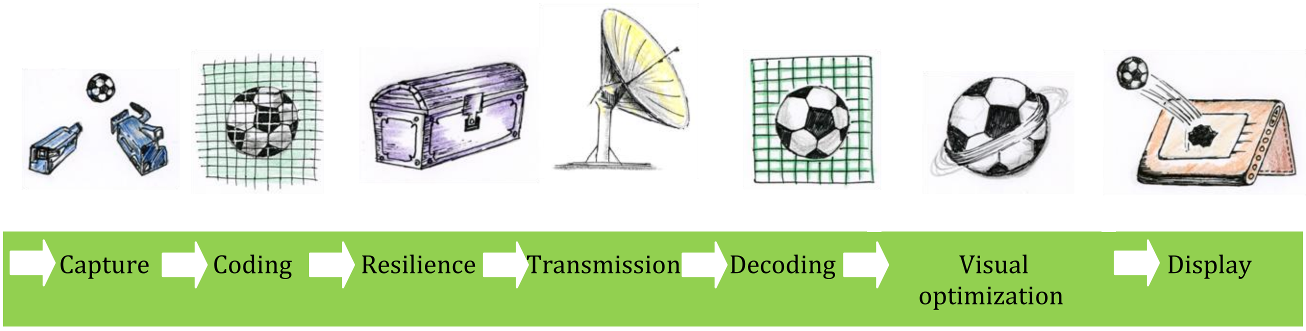

Figure 1 Mobile 3DTV system

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

At the stage of 3D content creation and coding, currently there is no single and generally adopted representation format for stereo video, taking specific mobile channel conditions into account. To study different representation formats, during the first year the research aimed at collecting proper *test data streams*. Two types of representations were considered: *two-channel stereo video* and single video augmented with dense depth information (*video plus depth*). In total, 28 stereo and multiview sequences were collected and are available to the project, which is quite rich data set. The stereo-video database is publicly available [2]. For generation of the video plus depth database, a technique referred to as *Hybrid Recursive Matching* (HRM), previously developed at FHG was applied to each stereo sequence. Temporally and spatially smooth and stable depth maps were generated. The video plus depth database is publicly available [3].

As a starting point and reference for the further research on 3D video coding, during the first project year, available coding standards for 3D video were optimized and evaluated for the specific conditions of mobile 3DTV. Specifically, the optimizations were targeted for the demonstrator device as to be used in the project, i.e. how to use the different 3D video codecs in this specific context. The following 3D video formats and codecs were evaluated: *H.264/AVC simulcast*, *H.264/AVC stereo SEI message*,

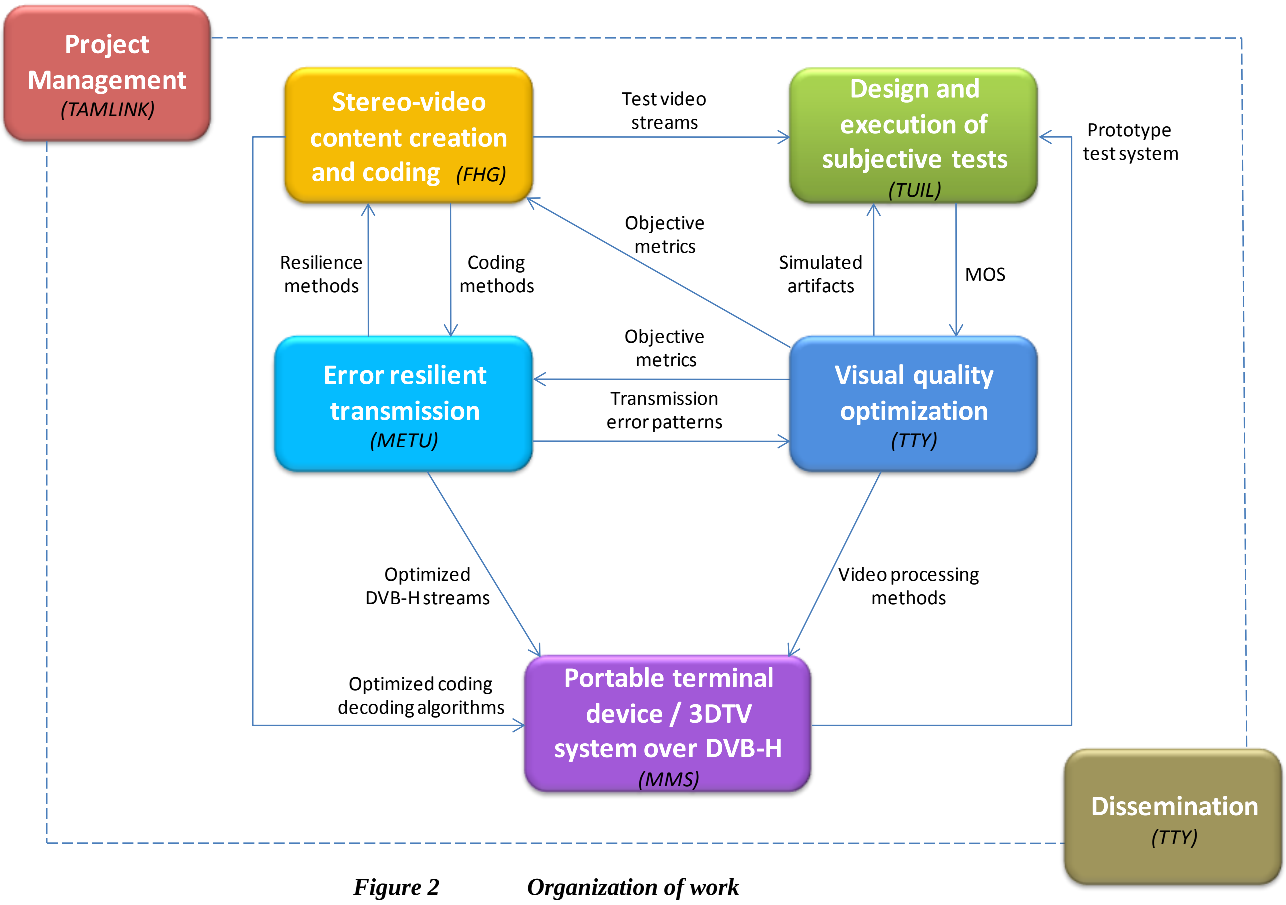

Figure 2 Organization of work

H.264/AVC for both video and depth, and *H.264 Auxiliary Pictures*. These coding approaches and comparative results are described and summarized in detail in a technical report [4]. A detailed comparison of V+V and V+D approaches is still to be done. This will include formal subjective tests and novel objective quality metrics especially tailored for stereo video. Further, the concept of mixed resolution stereo video coding will be studied in detail, as an extension of available 3D video formats.

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. During the first year, the project focused on setting up real and simulated communication channels including the required hardware and software components. These tools enabled the research teams to observe typical transmission errors and the effects of system parameters on these errors.

A full-featured transmitter setup using proprietary broadcasting equipment has been set up at TTY [5]. For laboratory experiments and demonstrations, a PC-based transmitter configuration was setup up at the research sites of TTY, METU, and MMS. A set of open-source software tools has been adapted and modified with the purpose to create a full set of tools for simulating the application, link and physical later of the DVB-H channel [5]. These are available for download [6]. Channel error traces for different channel models and operational parameters have been generated and made publicly available [7]. Figure 3 illustrates both DVB-H

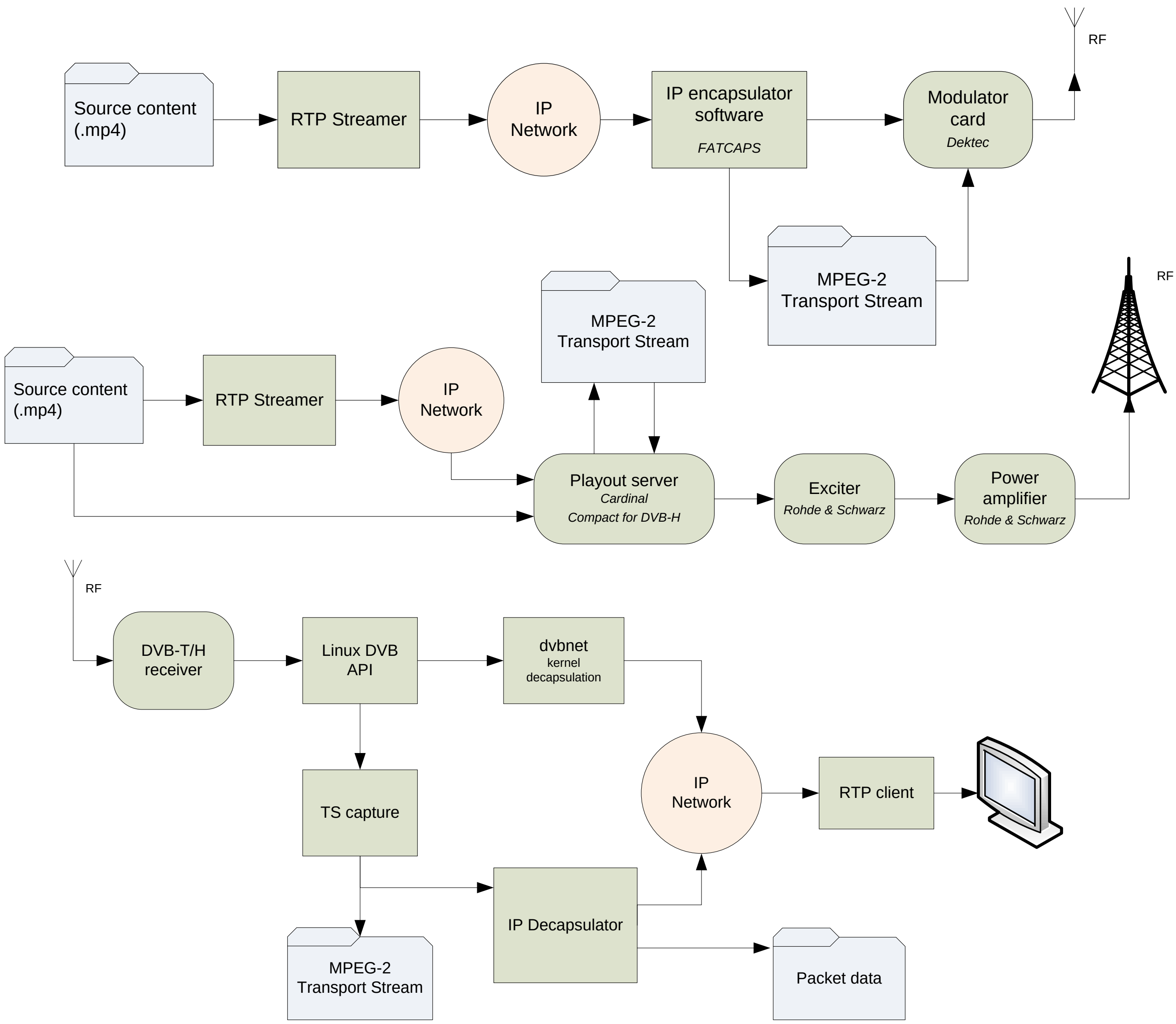

Figure 3 ***DVB-H channel setup. Up: full-featured and PC-based transmitter; Below: Linux-based receiver.***

physical channel and simulation tools available.

Using the developed simulation 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. The results of this simulation are available in a technical report [8]. The results showed a clear improvement of quality when the received MPE-FEC data is used especially in low channel SNR cases. In representations involving dependencies between the right and left views, the joint coding was found less robust to errors. Future research will target Unequal Error Protection (UEP) techniques in order to tackle this problem and improve the robustness for this specific type of data.

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. A specific triangulation approach was applied. An *online survey* was conducted in Germany and Finland with 342 participants to elicit user requirements. The survey helped to identify current practices and needs for mobile 3DTV systems. Then, *focus groups* helped in generating new ideas and usage scenarios through the group discussion process. Finally, *probe studies* targeted the more implicit requirements of users which are normally not expressed in discussions or interviews. As a result, the project issued a detailed (90+ pages) "Report on user needs and expectations for mobile stereo-video" [9]. In the report, user requirements have been formulated as guidelines for designing user experience for mobile 3D television and video. To the best of our knowledge, this is the first study on the topic. The research activities in this area continued with developing a framework for user-centered user studies including the main aspects of user experience – *user, system, and context.* Plan for psychoperceptual assessment tests, user-centered quality evaluation experiments, and prototype tests, was drawn to help in the optimization of the critical parts of the system. The framework is publicly available as a technical report [10].

The degradations caused by channel errors or compression artefacts will be investigated at the receiver side in terms of user acceptance of quality and acceptance and satisfaction scores will be obtained through the planned subjective tests. To advance in this process, a unified artefact classification system was developed within the project. The main stages of mobile 3DTV content delivery were considered as potential sources of artefacts, and matched against the different "layers" of the human 3D vision. In the resulting multidimensional space, all the artefacts found in the overview were properly mapped [11]. Based on artefact grouping, an artefact simulation channel was designed and a framework for introducing mobile 3dtv artefacts to a 3D video was developed. The framework is implemented in Matlab, and can simulate around 30 different artefact types. The framework is modular and the available artefact simulation functions can be easily extended. The final version of the framework is available for download on the project website [6]. User's guide, covering installation and usage, is included.

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 and important results of the MOBILE3DTV project. During the first year, RTD activities were concentrated on selecting the most suitable development platform, integrating auto-stereoscopic display and developing first version of the prototype capable of playing stereo video. The selected development platform is OMAP 3430 manufactured by Texas Instruments. Reasons for choosing it are given in a technical report [12].

Two different displays designed and produced by two different auto-stereoscopic display technologies were integrated to the chosen platform. The first display, procured from MasterImage, Korea, is developed by the parallax barrier technology, which makes it suitable for backward compatible applications. It is a 4.3"WVGA (800px x 480px) transmissive LCD display. The following set of resolutions is available: 800x480 in 2D mode, 400x480 in landscape 3D mode, and 240x800 in portrait 3D mode. To integrate the display, a special interface daughter card, containing all needed logic and level translation was developed. The second display, developed by NEC LCD, is based on lenticular technology. In contrast to other known displays of this class, the pixels in the NEC's design are twice as dense in horizontal than as in vertical direction, an arrangement called Horizontal Douple Density Pixel (HDDP) arrangement. The display is able to work both in transmissive or reflective mode, which ensures 3D operation in wide range or lighting condition. The HDDP display is not yet commercially available. NEC kindly provided a pre-production sample to the project [13]. It is a 3.1 inch size, with 427x240 resolution both in 2D and 3D mode. The display was interfaced to the OMAP platform through DVI interface.

The work on the platform continued with the design of an embedded mobile stereo-video player to be used in the subjective tests. To this end, the H.264 simulcast encoding approach was implemented. The simulcast approach has been chosen due to the purpose of that version, i.e. to be used in the subjective tests. Simulcast allows manipulating and experimenting with videos of different quality (varying quality factors such as bitrate, framerate, transmission modes, etc.). Display support was added for the selected displays. This support was developed as OMAP 3430 TI Linux baseline display drivers. It combines left and right views from the output of the H.264 decoder to produce the format required for driving the respective auto-stereoscopic LCD display.

An end-to-end DVB-H channel, featuring transmission of stereo-video streams encoded by MVC and simulcast and their reception by portable devices, either equipped with 3D display or legacy ones, was demonstrated at the NEM Summit, held in Saint-Malo, France in October 2008 and at the ICT Event, held in Lyon, France in November 2008. The first version of the handheld technology demonstrator is to be demonstrated at the World Mobile Congress, 16-19 February 2009. These events are addressed by posts in the project blog [14]. In addition, eighteen conferences were attended by project participants and twelve conference papers on project topics were presented. Conference papers are available at the project website [15].

The first project year was quite successful and full of events and research achievements. The results set up a solid foundation for further research. 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, 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. Based on what is seen at commercial shows, such as IBC in Amsterdam and CES in Las Vegas, one can confidently claim that 3D is going to be the next big thing in audio-video entertainment. MOBILE3DTV project addresses this trend from the point of view of the mobile (i.e. most dynamic) user. The 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 also allow for playing conventional 2D content. Encoding and playing will be supported by our project outcomes. As of broadcasting, services based on specific content to be delivered in 3D will be expected. Examples vary from weather forecast and geographical/navigation information to full-length nature feature documentaries (in the style of National Geographic, Animal Planet, etc.).The channel and error-protection outcomes from our project will play a role in the successful deployment of such services.

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