

Enabling Mobile Coverage for DVB-T

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Vision

Consumer adoption of mobile TV has been slowed to a crawl because of the need to finance and build-out wholly new networks. Especially in today's economic environment, this is a nonstarter. Operators cannot afford the financial risks and consumers are unwilling to make a subscription commitment to unproven and largely unknown services. On the other hand, if existing free-to-air digital terrestrial TV broadcasts could be inexpensively and reliably extended to the mobile environment, then operator financial risks would be removed and consumers would be enticed to get their familiar TV experience on their mobile device for the one-time cost of a capable handset.

This is an attractive vision but one with a well-known technical holdup: Current digital terrestrial TV infrastructures do not provide a good user experience in mobile environments.

Digital Fountain, a leader in entertainment-grade media delivery over dynamic networks, has identified a means to reliably and inexpensively extend current digital terrestrial TV broadcasts to the mobile environment. Critically, the method provides legacy compatibility, meaning that while it enhances the reception experience on mobile devices, it does not disrupt the operation of existing devices like home TVs.

This paper outlines how this system would be implemented over DVB-T networks and provides simulation results carried out with our European research partners that demonstrate the effectiveness of the method. Trial deployments of this system will be initiated by the end of 2008.

Background

As the prevailing digital terrestrial television standard in Europe, it would be very appealing if DVB-T were usable in the mobile environment. Content and business models have been established, consumers are already familiar with the services, and no new infrastructure would need to be built. Unfortunately, DVB-T was not designed to meet the requirements of mobile handset reception. Therefore, DVB-H was established to provide two key enhancements over existing DVB-T: extension of battery life and coverage extensions.

However, LG Electronics and others have recently (May 2008) opened the market's eyes by offering DVB-T capable mobile handsets in Germany and have already sold hundreds of thousands of handsets to consumers looking to enjoy their favorite content on their mobile devices. The devices have subsequently become available in the Czech Republic, Austria, France, and Spain. A healthy and growing market for mobile DVB-T also exists in the laptop and UMPC markets, where DVB-T USB extensions and other modules achieve varying degrees of user experience quality.

Even without DVB-H's power management capabilities, the battery life question is one that customer experience, education, and technology have already alleviated. Consumers understand that battery life varies based on device activity—battery talk time is far lower than battery stand-by time. Just as listening to an iPod is not as battery intensive as watching video on an iPod, consumers will understand that watching 2 hours of video

will require more battery resources than talking on their handsets. The Germany experience and the success of LG demonstrate this point with fact.

This paper addresses the other obstacle: coverage extensions. The solution proposed herein meets and can exceed DVB-H coverage range and user experience. Recent innovations from Digital Fountain can provide a backwards-compatible enhancement to DVB-T to serve the needs of the mobile environment, allowing for robust mobile TV services that represent what customers expect while leveraging the existing ecosystem, investment, and business model. As a backwards-compatible solution, all existing DVB-T receivers can continue to operate as they do today with existing terrestrial broadcasts, but new DVB-T receivers would have enhanced functionality allowing for viable services in the mobile environment.

The proposed extensions are at the same time able to handle impulse noise interference in stationary and mobile reception conditions which may originate from switching processes, radiating electrical devices, or car ignitions. This is not only of interest for portable and mobile DVB-T reception but also for stationary reception with indoor aerials.

DVB-T to Mobile TV Service Solves Adoption Obstacles

Enhancing DVB-T to extend the existing services to mobile use cases provides an opportunity to take mobile TV services forward. DVB-T was initially ruled out by mobile operators, as it was not devised to send a signal robust enough to deliver content to mobile receivers, in particular handsets. Studies conducted in the WingTV project [3], for example, have shown that, in mobile environments and at ground level, the DVB-T television experience breaks down, resulting in a poor QoE. DVB-H was initially set as the mobile implementation of DVB-T, but uptake has been slowed by the high initial investment required. However, using Digital Fountain's ToughStream solution in the ways set forth below to overcome these limitations achieves viability for mobile TV services to be delivered by DVB-T. The enabling of DVB-T to provide services to mobile receivers has a number of compelling benefits for the marketplace:

- *Minimal required infrastructure investment by all ecosystem members.* Rather than necessitating investments exceeding hundreds of millions of euros, nominal investments are required to add software to the video encoders (or other device that processes the streams) or adding a single transparent server component at the multiplexer and to bring supporting mobile devices into the market. Existing physical infrastructure can be used, and the updated solution is fully backwards compatible so there is no impact with existing DVB-T receivers, creating a truly unique opportunity—broadcasters can expand their markets to include the fast-growing mobile market with a minimal investment.
- *Time to market.* Since only software updates are required on the broadcasting side, and because handsets enabled with DVB-T reception capability are available to all operators and are already present in the market, time to commercial deployment with a complete service is months rather than years.
- *Customer content experience.* Customers expect that linear mobile TV will reflect the traditional TV experience. Studies have shown that made-for-mobile linear TV channels that do not reflect traditional linear television are not what consumers expect.

As mobile TV sees its highest tune-in rates during live events, customers expect to have their traditional television experience replicated on their mobile device.

- Interoperability among the 67 countries (and growing) that use DVB-T and the terrestrial television standard today, avoiding costly consumer confusion and giving consumers confidence to adopt the services and avoiding market fragmentation.

As with other mobile TV systems, once DVB-T is proven as a viable concept, an ecosystem will coalesce around it, enabling value added services for mobile operators, and supplemental services to complete a strong value chain.

Ultimately, driving adoption of a free mobile TV service will pave the way for supplemental fee-based premium mobile TV services. Devices equipped with ToughStream would get free over-the-air TV. Think of this as basic television or freeview service that is free as long as a compatible phone has been purchased. Having consumers engaged in the experience and receiving the true TV that they expect at a high QoS creates the opportunity to offer premium or pay TV that offers sports, news, business, and other specialized channels that are not available for free over the air. As a first step to driving consumer adoption of mobile TV, extending DVB-T to mobile establishes a two-part strategy that also drives premium mobile television with accelerated revenue potential.

Digital Fountain ToughStream

Digital Fountain's ToughStream is an advanced application-layer software solution that eliminates video and audio degradation caused by network impairments, including packet loss. The DF ToughStream¹ solution features Digital Fountain's Raptor Forward Error Correction (FEC) technology, which has been adopted by several mobile and IPTV standards including 3GPP (MBMS) and DVB-IPTV, among others.

The ToughStream™ solution consists of a software Server Client pair. The Server software, which can be installed on most standard hardware platforms, is placed in a Video Headend, and the Client is ported as a library in a mobile handset or Set Top Box (STB).

Digital Fountain's ToughStream applied to DVB-T

The fundamental aim of ToughStream in DVB-T is to employ advanced FEC protection directly into the MPEG-2 TS to protect transmissions against fading, impulse noises and other disturbances. The objective is to adapt the DVB-T MPEG-2 TS distribution to mobile reception in a way that it is backwards compatible with traditional fixed reception.

The proposed architecture for FEC protection employs ToughStream in order to protect the PES packets of the programs being transmitted in a MPEG-2 TS. Figure 1 sketches a robust DVB-T architecture with a backwards-compatible ToughStream integration. The Packetized Elementary Streams (PESs) carrying the video and audio information are generally multiplexed into an MPEG-2 TS stream along with additional signalling and data information. In the extension, the packets are also processed by the ToughStream server to produce a FEC elementary stream (ES), which is multiplexed in the MPEG-2 TS together with the original media elementary streams. ToughStream not only incorporates

¹ For details refer to <http://www.digitalfountain.com/iptv-solution-toughstream-datasheet.html>

Raptor FEC codes, but also all relevant functions to add FEC packets in a backward compatible manner. The original multimedia stream is *not modified* as the association between the source data and the FEC data is provided by ToughStream. The generated FEC parity data are multiplexed into the MPEG-2 TS along with the original data stream by applying data piping [1]. The MPEG-2 TS is then transmitted over the DVB-T network. The FEC parity data of each program is signalled as another elementary stream in the Program Map Table (PMT) using user private codes.

A legacy receiver receives the DVB-T stream and de-multiplexes the elementary streams. As the MPEG-2 TS packets carrying FEC information are marked as private data, the legacy receiver does not de-multiplex the FEC packets. In contrast, robust receivers that incorporate ToughStream de-multiplex and make use of the FEC packets; in case of losses of MPEG-2 TS packets, ToughStream can recover the original audio and video streams.

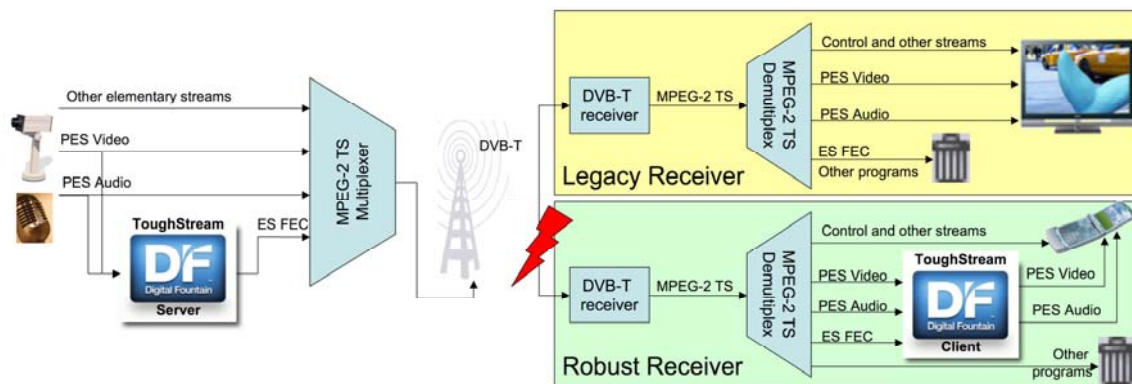


Figure 1 Robust DVB-T Architecture with backwards-compatible ToughStream integration.

ToughStream allows configuration of both the protection period (duration of source stream packets that are incorporated in one source block) as well as the protection amount (the amount of FEC overhead, usually expressed in % relative to the original streams). The information to be protected in one ToughStream operation process can be selected on an elementary stream basis, in a similar way as applied in 3GPP MBMS streaming framework for different flows [3]. Information such as Teletext and supplementary data may be left with no protection in order to maximize the efficiency of the FEC protection for the more important data, such as popular video data. Also, one may consider protecting only the I- and P-frames to maximize the use of available bandwidth for the highest-priority data elements.

ToughStream is unique due to its high coding efficiency, low software decoding complexity of the client, as well as flexibility in terms of media bitrates, protection periods and protection amount. ToughStream is a professional client-server solution that has been tested and integrated in many IPTV set-top boxes and mobile device platforms.

The FEC parity data to be transmitted along with the original MPEG-2 TS must be minimized. Therefore, lowest overhead FEC codes are of paramount importance. The bandwidth to deliver this additional FEC data may for example be obtained by the use non-occupied capacity in DVB-T, replacement of null packets in MPEG-2 TS streams with

FEC data, or by protecting the perceptually most important data (e.g. I and P frames but not B-frames) or the most important programs only. Interestingly, preliminary studies on the deployed German DVB-T system show that approximately 4% of the total capacity is filled with null data, indicating that 4% of the MPEG-2 TS is available “for free” for FEC parity data.

Selected Simulation Results

For the verification of the DVB-H specifications, the Wing TV project has created a simulation framework including channel models based on measurements, quality criteria and reference results [3], [4]. DVB-H and DVB-T physical layers are identical and the Wing TV project has also included typical DVB-T configurations in their modelling and simulation campaigns. We have made use of this framework for the assessment of mobile DVB-T performance and have collaborated with Wing TV members to assess the performance gains of our proposed solutions. The simulator was implemented according to the architecture in Figure 1. Furthermore we recorded a DVB-T stream and applied a demultiplexer in order to extract the necessary information of a transport stream. For one specific program with a bitrate of approximately 3 Mbps we applied ToughStream protection jointly for the video and audio PES packets.

The performance of the solution is evaluated in different Wing TV mobile channel environments mainly focusing on effects resulting from mobility and fast fading (i.e. Doppler effects). For this purpose, a well-established and widely-used DVB-H physical layer performance model for TU6 channels developed by the University of Turku [2] is employed in the simulations. This performance model covers a range of Carrier-to-Noise Ratio (CNR) between 1 and 30 dB and a range of Doppler frequencies between 5 and 80 Hz. Note that at the operational frequency of 600MHz the Doppler frequency is converted to a velocity by multiplying it by 1.8 (km/h)/Hz. Apart from the TU6 model several 12-tap channel models had been proposed [3] for different channels: *Motorway 100km/h (MW100)*, *Vehicular Urban 30km/h (VU30)*, *Pedestrian Outdoor 3km/h (PO3)* and *Pedestrian Indoor 3km/h (PI3)*. The Wing TV report also discusses suitable performance measures, in particular the IP packet loss rate is proposed. To align with this, we target a PES packet loss ratio of at most 1%.

The DVB-T physical layer configurations considered for the simulations are shown in Table 1.

Table 1 DVB-T Physical Layer Configurations

Configuration	FFT	Modulation	Code Rate	GI	Comment
16-QAM 1/2	8k	16-QAM	1/2	1/4	DVB-H, DVB-T Taiwan, ...
16-QAM 2/3	8k	16-QAM	2/3	1/4	DVB-T Germany, etc.
64-QAM 1/2	8k	64-QAM	1/2	1/8	DVB-H, DVB-T
64-QAM 2/3 ²	8k	64-QAM	2/3	1/8	DVB-T Spain, France, etc.

² 64-QAM 2/3 is currently carried out with our partners, as no data has been available from DVB-H simulation campaigns. The preliminary data strongly indicates that the observed relative gains of different

The mobile performance of DVB-T transmissions with and without DF ToughStream FEC are evaluated. For the TU6 channel model, 16-QAM and code rate $\frac{1}{2}$, Figure 2 shows the required Carrier-to-Noise Ratio (CNR) for different Doppler values in order to obtain a PES packet error ratio value of 1%. Different FEC overheads $A=0\%$, 5%, 10%, and 20% are shown. The case of $A=0\%$ only uses the available null packets. The observed gains for a suitable protection period of $\Delta=1s$ are between 4-10 dB, depending on the Doppler and the applied protection amount. Interestingly, it is observed that by the use of ToughStream protection, the required CNR is almost independent of the Doppler frequency and therefore the velocity.

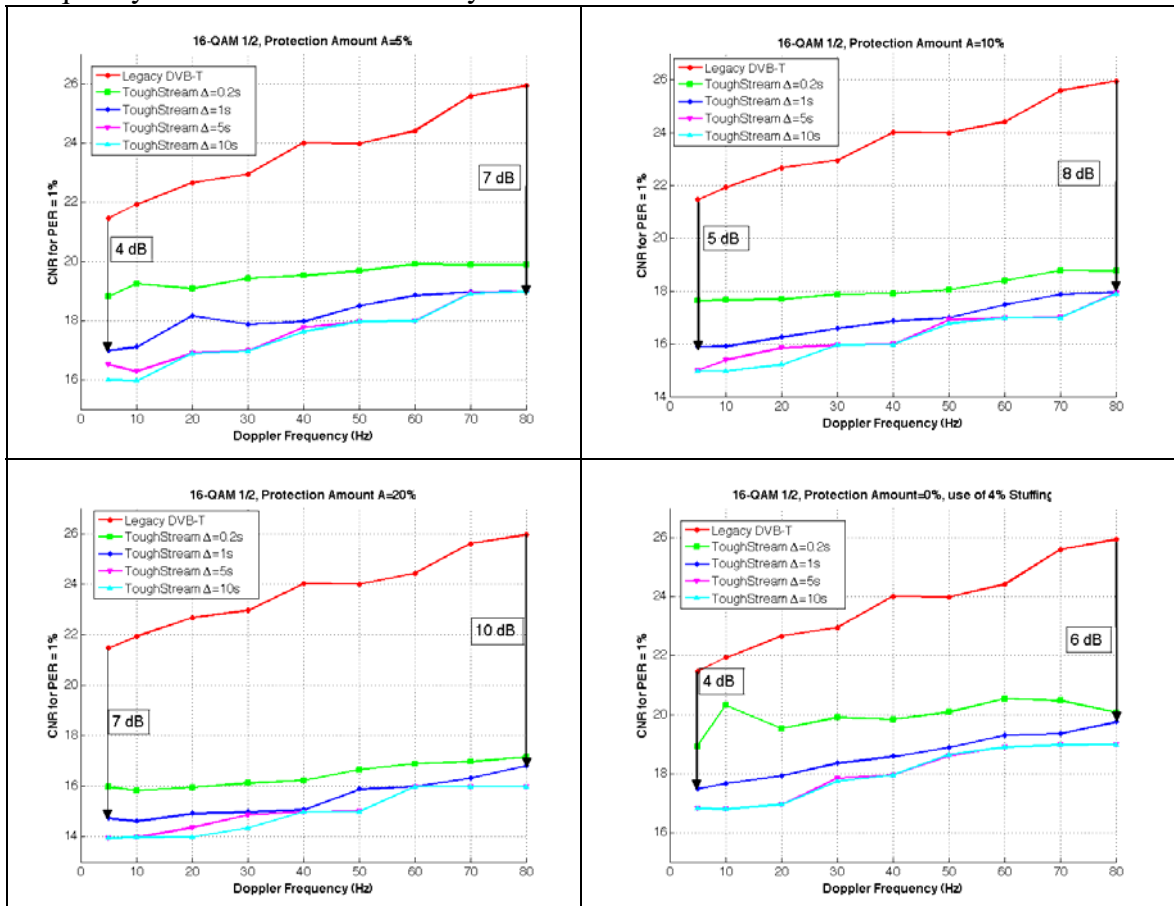


Figure 2 Average CNR required for different Doppler values in order to obtain a PES packet error ratio (PER) of 1% in a *TU6* channel. Protection amount A is set to 5%, 10%, 20% overhead and 0% using only the available null packets.

In a second set of experiments, we have applied the 12-tap channel models. For different configurations of the physical layer according to Table 1, different ToughStream configurations have been tested and the gains in dB compared to physical layer only configuration have been determined. For a selected set of experiments, the gains are reported in

modes in dB compared to the legacy DVB-T system and the usage of a certain ToughStream configuration mode are at least as high, independent of the physical layer configuration.

Table 2. Typical gains between 3 to 10 dB for protection periods of $\Delta=1$ s and beyond are observed. A more comprehensive simulation campaign is currently ongoing with a variety of different channel models, physical layer settings and ToughStream configurations.

**Table 2 Expected Gains in CNR
for different configurations and 12-tap channel models.**

Phy Layer	Δ	A	MW100	VU30	PO3	PI3
16-QAM 2/3	200ms	10%	4 dB	2 dB	0.5 dB	0 dB
16-QAM 2/3	1 sec	10%	5 dB	3 dB	2 dB	1 dB
16-QAM 2/3	5 sec	10%	6 dB	3 dB	2 dB	1 dB
16-QAM 2/3	200ms	20%	6 dB	3 dB	1 dB	0.5 dB
16-QAM 2/3	1 sec	20%	7 dB	4 dB	2 dB	1 dB
16-QAM 2/3	5 sec	20%	8 dB	4 dB	3 dB	2 dB
64-QAM 1/2	200ms	20%	7 dB	3 dB	1 dB	1 dB
64-QAM 1/2	1 sec	20%	9 dB	4 dB	2 dB	2 dB
64-QAM 1/2	5 sec	20%	10 dB	5 dB	4 dB	3 dB

Beyond DVB-T for Mobile

Discussing the proposed solution with broadcasters, content providers, operators and device manufacturers yielded the concept that the impact of the solution can be greater than “DVB-T to handhelds.” Existing DVB-T deployments for stationary reception face issues due to impulse noises, below-roof antenna positions and environmental disturbances. The proposed solution can overcome these problems and improve the stationary TV reception with the same configuration that enables mobile coverage. Furthermore, DVB-T is suitable not only for handsets, but also for laptops, notebooks, in-car receivers and PDAs, as the video quality is full TV resolution, resulting in a superior QoS.

Finally, despite the initial focus on DVB-T, there is no reason why the presented solution would not apply to any MPEG-2 Transport Stream based system, in particular to other terrestrial systems such as ATSC deployed in the US and throughout the Americas and parts of Asia, and ISDB-T as deployed in Japan and Brazil.

Summary

Digital Fountain believes that DVB-T extensions allow a fundamental shift in thinking about mobile TV by overcoming the economic and QoE obstacles that have slowed mobile TV operator deployments and customer adoption to date. Mobile-specific media broadcast networks require focus on new network investment and content acquisition in addition to other facets, all of which strongly impact business models. Since consumers have not shown a willingness to pay for mobile-specific TV services en masse, operators have not been able to justify the investment. The application of ToughStream to DVB-T overcomes the obstacles facing widespread mobile broadcast deployments today: By merely implementing a software solution, requiring nominal operator investment, the terrestrial television service that consumers know can be extended to mobile with a high QoS and provide coverage gains to fixed receivers. In offering the service and content that customers expect, and with a business model that works for consumers and operators

alike, the door will be open for widespread consumer adoption and success for mobile TV.

References

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