







```
byte URL_location;
}
```

We also defined a new stream type for our DASH timeline stream, called DASHTime, and defined its payload as shown in Table 1. This fixed payload is designed to fit in a TS packet, including PES header and optional adaptation fields of the TS packet. It carries the presentation time of all streams in the program, by associating this value with the PTS value given in the PES header of the packet. The DASH packet may be sent at any time, but our implementation only sends them at the beginning of each frame or after every packet containing a PCR. The packet also indicates the location of the DASH MPD as well as the current period id in order to properly handle period changes; it is preferred to send this information in-band with the timestamps rather than using application descriptors such as the AIT in order to avoid synchronization issues when a stream is remultiplexed. Finally, the packet includes an activation countdown announcing that the given URL will not be valid until the indicated time, allowing a client to fetch media data before the actual period switch occurs. Once the broadcasted content can be identified in the MPD, the client can process the MPD as usual, following DASH rules for representation selection and MPD updates, and a regular DASH session can, then take place for broadband media, as shown in Figure 1.

Our solution provides a generic mechanism allowing broadband add-ons to be synchronized with MPEG-2 TS broadcast, regardless of the add-on type; MPEG DASH is of course a main use case for our solution, but other enhancements such as plain files, RTP streams or MMT content could be synchronized with this proposal. This solution is very close to timeline streaming approaches used in DVB, except for the countdown indication, which is not present in existing approaches.

## 5 LIMITATIONS

We have tested this design using multicast TS as a broadcast simulator and an HTTP server, using [11] as the underlying platform for content generation (DASH and TS) and playback, using timeline streaming to achieve frame-accurate synchronization. However, we only used non-live content: broadband data was available for retrieval a few seconds before broadcast data arrived at the receiver, giving the player the ability to fetch broadband data ahead of broadcast time through dynamic construction of URLs using DASH template mechanisms. The hybrid setup delay is obviously increased by the buffering time of the player on the broadband link, but we did not want to consider the pausing of the broadcast stream. Future work will investigate the possibilities to perform this experiment in live conditions, within the typical production delay found in broadcast systems..

Another limitation of our system is the live-only design; we still have to investigate how performing trick-modes on recorded or time-shifted broadcast could be enhanced with the tools that DASH provides.

## 6 CONCLUSION

In this paper, we have presented some use cases for hybrid broadcasting, reviewed the different approaches towards solving these scenarios and explained how the MPEG-DASH standard provides most of the tools needed to fulfill them. We have proposed a light solution compatible with existing infrastructure ensuring a frame-accurate synchronization between broadcast and broadband stream. This work is under investigation for standardization by the MPEG committee, with a work plan targeting both explicit technical tools for the MPEG-2 transport stream and generic transport guidelines for achieving multi-container synchronization. In future work, we will investigate usage of DASH trick modes for broadcasted content as well as low delay live hybrid broadcasting.

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