Bringing digital data services to life in North America

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Abstract
In this paper we relate our experiences of bringing digital data services to life in North America. Our focus is on the Total Traffic HD News Service. This News Service is based on the Journaline ETSI standard for relating news and text information to HD Radio™ receivers, e.g. JVC's KW-NT3HDT head-unit.

Through a so-called adaptation layer, transmission on the HD Radio Advanced Application Service (AAS) is specified. A small number of proprietary extensions to the Journaline standard define specific service features in an interoperable way. We also present our practical experiences made during the realisation of a data service addressing mobile users.

Keywords
HD Radio™ Technology, Journaline, adaptation layer, framing, bearer, interoperability.

INTRODUCTION
Digital radio has established a firm foothold in North America, with well over 2000 radio stations broadcasting digital AM/FM as of mid 2010. The HD Radio System has enabled a smooth evolution from analog FM transmission to the digital broadcast, and furthermore offers a much wider bandwidth for digital data services than FM-R(B)DS.

HD Radio™ Technology is iBiquity Digital Corporation's trademark for its In-Band On-Channel (IBOC) system for digital transmissions [6]. The IBOC system enables stations to broadcast both an analog and digital signal on a single AM or FM channel. In North America, this "hybrid" system was selected in part, because it did not require additional spectrum. In addition, IBOC allows for digital transmission with minimal impact on reception of existing analog AM/FM services [7].

The HD Radio System in the United States differs from the Eureka-147 digital radio system (known as DAB/DAB+/DRM [9]) that is used in Europe, Canada and Asia. A key technological difference is that IBOC uses the same band as AM and FM channels, whereas Eureka-147 requires a different spectrum [6][3].

One of the chief benefits of the HD Radio System is improved sound quality for both AM and FM broadcasts [7]. Secondly, compared with traditional analog broadcasts, stations transmitting an HD Radio signal can send multiple audio streams [6], and provide a much larger bandwidth for data services [1].

HD Radio Technology's data bandwidth is readily exploited in support of audio content. Two examples are *Music Tagging* (hear a song you like, "tag" it for subsequent preview and purchase in e.g. the iTunes music store), and *Album Art* (synchronized display of the album cover, song, and CD title and artist name of the currently playing song).

Nonetheless, the available data bandwidth can be utilized in addition for supplying traffic, news and information services to both home and mobile receivers. The migration of FM-TMC (Traffic Message Channel) to HD Radio broadcasting is a first obvious choice to take advantage of the much higher data rates possible with HD Radio Technology.

The gamut of potential data services span from news, weather, sports and general information services, to image-based services (e.g. slide shows), fleet services, customer relationship management services, through mobile-device database (Map, POI) content update services. The localized nature of FM broadcasts enables targeted, hence cost-effective delivery of such data services.

In this paper, we report on our experiences in bringing a news, weather, and sports information service to life in North America for Clear Channel's Total Traffic Network [5] (see Figure 1 for the main menu of this Total Traffic HD News Service). Journaline [3] was chosen as the application protocol for this menu-driven, text-based news service, and the HD Radio Advanced Application Services (AAS) transport [1][2] as the transport bearer.

Figure 1: JVC's KW-NT3HDT showing the main menu of the Total Traffic HD News Service

We discuss our experiences, adaptations, and flexibility in standards for creating this successful news service in North America. Finally, we put these experiences in the context of standards creation and digital radio services in general.

DESIGN FOR A SUITE OF DATA SERVICES

The Journaline-based Total Traffic HD News Service is but one in a suite of data services that is potentially carried in a station's HD Radio broadcast. Data services may come in a variety of guises:

- Program Service Data providing information on audio content.
- Station Information Services to inform on station names (call signs), station location etc.
- Text based services such as Journaline.
- Image based services such as Album Art.
- Binary information services such as TMC or TPEG to pass on machine-interpretable information to in-car devices, e.g. navigation systems.

Furthermore, the commercial nature of data services may differ:

- Basic services, such as Program Service Data.
- Free to air services such as Album Art and Music Tagging.
- Premium, paid-for, content services, such as traffic (TMC/TPEG) services or this Total Traffic HD News Service.
- Closed user group services, e.g. targeting a specific car brand or a specific fleet service.

At the service provider, these data services need to be managed in terms of bandwidth allocation, allowable data latency, and finally multiplexed on the digital broadcast.

The latter two classes of services may be unrelated to the station's audio content. Dual tuners (e.g. NXP's SAF3560 'Cayman' [11]) allow independent reception of audio on one tuner and data on a second one, tuned to a different station/frequency. With such support, premium or closed user group services do not require a broadcast on all stations in an area to benefit the user.

Adding Journaline to a suite of data services

When adding Journaline to Clear Channel's HD Radio stations, we were faced with the choice on how to embed its transmission in the HD Radio broadcast. The AAS transport mechanism [2] still left a number of options open:

- *Transport mode:* AAS transport supports both packet and byte streaming mode
- *Channel allocation*; Journaline could be allocated a specific AAS channel (i.e., a specific AAS port) or be multiplexed with other data services on a higher, bearer-independent level.

Our choices to these options are provided in the next section.

Transport mode

On HD Radio System bearer level, the basic unit for data services multiplexing is an AAS packet. The elemental size of such a unit is fixed, but bandwidth dependent.

The variety of JML (Journaline Markup Language) object sizes (cf. Figure 3) would make a synchronized packet transport less effective. Full JML object transmission would cause padding at the end of a packet, reducing transmission efficiency. The alternative option for synchronized package transport, JML object fragmentation to fit AAS packet size, would mean adjustment of the data service's transport packaging to individual station transmissions and bandwidth allocations. In principle this is possible, but with several hundreds of stations broadcasting the service, content generation and distribution would be more complex and error-prone due to an undesired coupling with transmission parameters.

In contrast, the byte streaming mode effectively eliminates packet size as a variable (except for reception reliability considerations). Synchronization then needs to be provided by the adaptation layer, through a framing construction. As the framing overhead proved rather small, the transport mode chosen was byte streaming, forming the basis of the design of the adaptation layer.

Channel allocation

Channel allocation decisions in general depend on content, protocol, transmission efficiency, and service discovery and conditional access considerations.

For the HD Radio system, we decided to rely on the multiplexing at the bearer level. The AAS transport mechanism offers a high level of flexibility, while being generic enough to allow for a variety of data services. The transport mechanism is integrated with a service discovery scheme, enabling receivers to freely access all parts of the service multiplex.

This enables Clear Channel to provide a real-time news service based on Journaline alongside a real-time traffic information service based on TPEG. At the same time the transport mechanism allows for a mix of free and subscription based service components.

INTRODUCING A JOURNALINE BASED NEWS SERVICE IN NORTH AMERICA

When we were tasked to define a new kind of data service for the HD Radio System, a set of commercial requirements helped us to bring together two existing technologies: the HD Radio system [2] and the Journaline [3] standard. These requirements were the following:

- Create a specification framework and a receiver implementation for a Journaline news service over HD Radio broadcasting
- Provide suitable mechanisms for the provision of general news in text form, weather information and sports scores in table format.
- Define a hierarchy of menus and pages to allow for a nation-wide service with regional sub-pages.

- Define the transport layer such that a free service can be amended with premium content.
- Define the transport layer such that reception robustness is maximized for mobile users at typical highway speeds and in urban environments.
- Define the transport layer such that frequent updates of real-time information pages can take place.

It took largely three steps to implement these requirements. Firstly, we had to identify and adapt the transport mechanism to fit Journaline objects. Secondly, we adapted and extended the Journaline object specification to make an attractive service suitable for the US American audience. Finally, a set of guidelines for the service implementation were defined to specify regionalization of the service.

ADAPTATION LAYER

As outlined above, considerations for a business model brought us to select the Advanced Application Services (AAS) as the bearer for the Total Traffic HD New Service.

However, AAS provides a transparent data channel without any framing or signaling. In order to transport JML binary objects in byte streaming mode, a suitable adaptation layer had to be developed. The following conceptual considerations helped us translate the commercial requirements into a technical concept.

Conceptual considerations

In the adaptation layer we had to address primarily the mobile environment. While the transport bearer is virtually error free within the coverage area, it remains prone to burst errors.

The framing must provide for a reliable synchronization, so that start and length of the received frame can be identified. An error detection technique needs to ensure the received block of data is free of errors.

A second consideration was to provide some flexibility for future extensions. The service frame type field allows a way to convey data other than Journaline content, e.g. meta-data such as service names or identifiers.

Object fragmentation helps alleviate scheduling issues, which allows real-time updates of small objects in the presence of large objects on narrow band channels. An optional time-stamp field provides high resolution time information, so that JML objects can be reliably versioned with frequent updates.

In order to avoid duplication of work and to benefit from solutions elsewhere we tried to adopt existing concepts where possible. This brought us to reuse several protocol elements from TPEG framing and from Journaline's DAB/DRM adaptation layer for the HD Radio System's version.

Framing Structure

The framing we defined, implements a two-fold frame structure (see Figure 2) and a data component which holds payload data, i.e. JML objects.

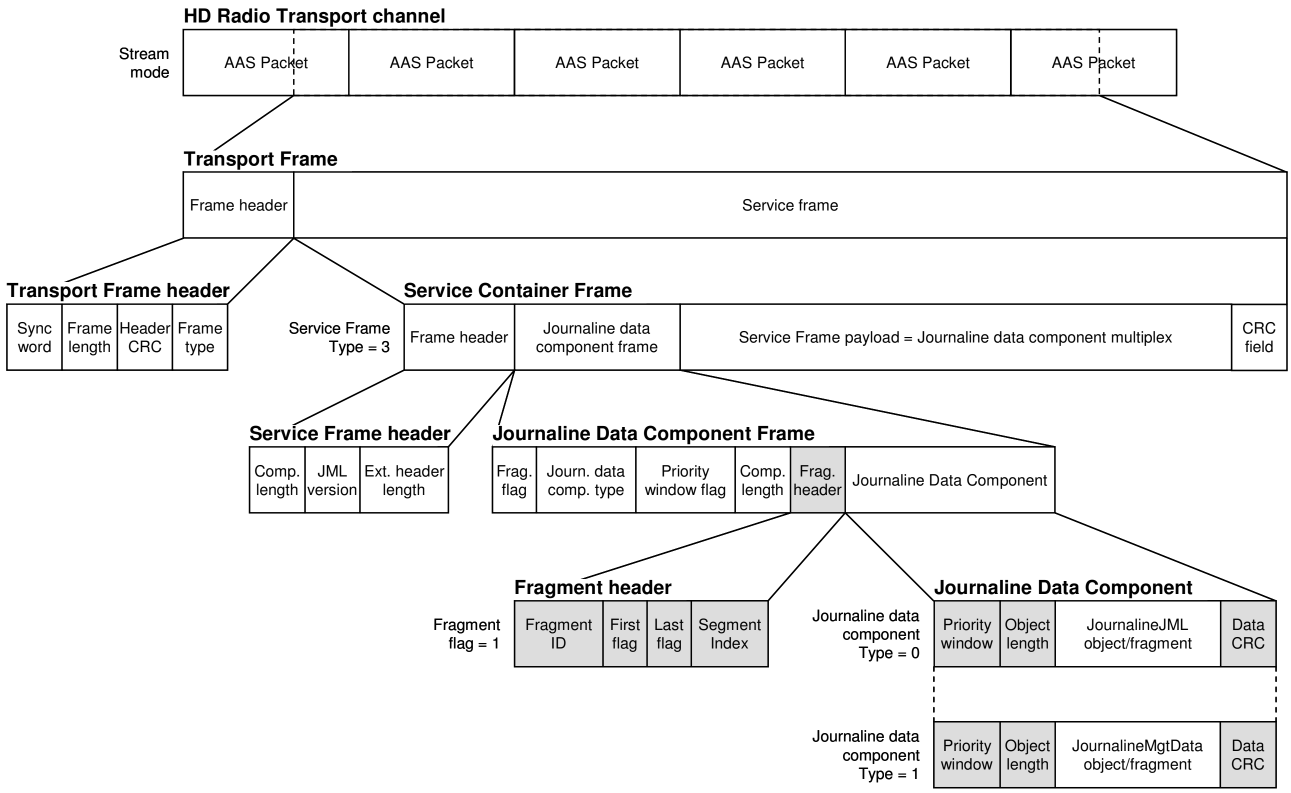

Figure 2: Protocol stack of Journaline adaptation layer over the HD Radio system.

Transport and Service frame

The transport frame represents the low level protocol unit and maps directly onto AAS packets. The AAS transport mode determines whether frames are aligned with packet boundaries (packet mode) or freely segmented (byte stream mode).

The transport frame provides all information to establish synchronization. A sync word together with a cyclic redundancy check (CRC) on header data allows for frame start detection. A length field and a data CRC over the entire frame data provide for a data integrity check. The transport frame is shared with the TPEG protocol stack [4].

The service frame represents the data specific structure and holds an object multiplex. A very simple frame header holds meta-data fields common to all objects within the frame. So far only the service container frame is defined, which holds a multiplex of Journaline objects. Other frame types may hold meta-data or other services.

Journaline data component frame

The Journaline Data Component (JDC) frame encapsulates JML objects and management data or fragments thereof. Flag fields in the JDC frame header signal payload structure.

Object encapsulation. The JDC frame encapsulates entire JML object or management data objects. The frame size implicitly gives the object size. The Priority Window provides an optional 16-bit second counter (time-stamp), which gives a relative time-out value for the object. An explicit protocol defines the update rules between objects with and without time-stamp. This facilitates time critical information to supersede basic information, i.e. for real-time sports news.

Object segmentation. The JDC frame also provides for object segmentation. A JML object may be conveyed in an arbitrary number of segments. The optional header fields provide the necessary signaling. A fragmented object holds a size field and a CRC to facilitate buffering and data integrity verification.

Object segmentation is the key mechanism to allow for real-time information services, which interrupt transmission of large JML objects with frequent 'real-time' objects, e.g. for news ticker applications, primarily on narrow-band channels.

Protocol efficiency

The transport framing brings largely two overhead components. The frame headers for transport and service frame combine to a per-frame overhead (12 Byte typ). And the per object headers (3 Byte typ.) which combine the Journaline Data Component frame header, not considering the optional object header fields.

Given a typical frame-size in the range of kB, frame overhead diminishes, while per-object overhead scales with number of objects. The object size is given by the content conveyed.

Table 1 gives typical relative overhead figures of the adaptation layer as described. Very small objects face a overhead penalty, i.e. the overhead goes down mainly with object size. It does not scale as strongly with the number of objects per frame.

Table 1: Protocol overhead (typ.) exemplified

		Objects per Frame			
		6	8	10	12
Object Size [Byte]	50	9,1%	8,3%	7,7%	7,4%
	100	4,8%	4,3%	4,0%	3,8%
	200	2,4%	2,2%	2,1%	2,0%
	400	1,2%	1,1%	1,0%	1,0%

Object compression therefore increases the relative overhead. It has a good effect on the channel capacity though. A compression ratio of little more than 60% is realistic using the standard 'deflate' method.

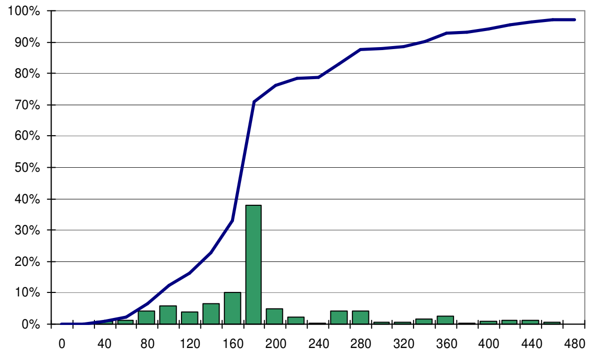

Figure 3: Distribution of object size (typ.)

Object sizes vary with content but not by a large amount, 80% of all objects are smaller than 240 Byte, with almost 40% of all objects in the 180-200 Byte bracket alone.

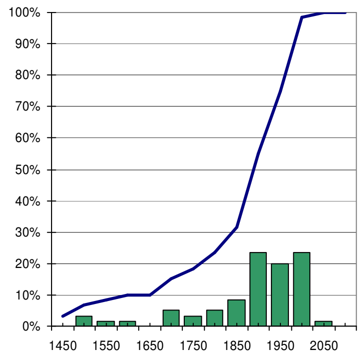

Figure 4: Distribution of frame size (typ.)

The need to maximize frame-sizes for minimal overhead faces a trade-off in terms of error robustness. At a given data rate, larger frames are more likely subject to data loss. The carousel cycle time until a receiver has received all objects in field conditions cannot be ignored by the object scheduling and frame assembly.

The mix of content in the Total Traffic HD News Service has body text objects and list objects to hold the information, news and weather. A large proportion in the carousel is occupied by menu objects, many of them require frequent repetition to support fast service uptake in the receiver.

In practice, frame sizes of below 2kB represent a good compromise between protocol efficiency and transport robustness. The object scheduling of the Total Traffic HD News Service produces frame sizes of about 2kB, which translates to an average overhead of around 2%.

JOURNALINE OBJECT ENHANCEMENTS

While the development of an adaptation layer was a technical necessity, the enhancement of the standard Journaline object was driven by commercial and cultural demand.

Usability considerations

The Journaline service confronts the user with a hierarchical tree of JML objects. In the receiver UI implementation, a minimum of operational controls should provide for the maximum of usability. JVC's application uses the basic paradigm of 1 object equals 1 page.

Figure 5: Example screen-shot, menu screen.

We have found that the direct activation of menu items, on a touch screen, allows very quick navigation down the hierarchy. As additional controls 'Up'/'Down' keys for page scrolling are needed to allow the content to overflow the screen size. A single step 'Return' key navigates 1 step up the navigation history, i.e. to the previously shown object.

Figure 6: Example screen shot, Los Angeles weather report.

Journaline, being a text-only based service, seems to struggle a bit in providing information 'at a glance'. Here the addition of graphical elements can bring a significant improvement. Using proprietary data sections, an icon index references a pre-installed graphical image.

Providing icons on menu items results in a very comprehensive listing as shown in Figure 5. The example uses weather icons to show a city's daily weather status at a glance. Using the link to open the associated object gives the detailed weather information with a short term forecast (see Figure 6). The title icon repeats the status information.

Weather Icons

Within the array of information of the Total Traffic HD News Service, we identified the weather information as most valuable for an enhancement by adding graphical information. Additionally, we had considered sports scores too, but finally, issues with legal rights to sports team's logos, amongst others, made the idea not yet practical for a first version.

From various existing services, users have wide-ranging daily experiences with weather information services. Accordingly, expectations are as demanding as requirements are well established. For representation of weather conditions the National Oceanic and Atmospheric Administration (NOAA) has standardized a list of terms with associated icons for day and night-time use [10].

Using this pre-defined list of weather conditions, the service signals only an index to reference a given icon/status. Receiver makers provide their factory installed own icon graphics for screen display. The encoding uses proprietary data-sections (see [3], section 5.3.2.2) to convey an icon reference. So far, the service specification foresees icons in menu items, object titles and list items.

As the reader may see from Figure 5, the provided weather information is very comprehensible and easily accessible as on-screen information of an in-car receiver.

List Structuring

To illustrate cultural differences that inherently have impact on service design, Figure 7 shows the European-style sports-score formatting. In this European style, the home team is listed first, away team second (after the dash), and the score is shown on the same line.

```
Soccer - Bundesliga 32nd Round (16:15)
TSV 1860 - Cottbus     3:0
Dortmund - Nürnberg    4:1
Hertha - Bayern        3:6
Stuttgart - Bremen     0:1
```

Figure 7: European-style team sports scores (from [3])

In contrast, the North American style listing (see Figure 8) is a dual-line listing with the away team on top, the home team below, with the score to the right.

Interoperability considerations brought us to define invisible marker elements to implement a number of usability enhancements.

Such markers are to be used as optional layout 'hints' by the receiver, to enable more sophisticated layout of lists and tables. These markers are defined as extended escape sequences and will be included in the next revision of the Journaline standard.

Multi-line marker indicates a 'binding' of a table row with the following. Such markers may be used to reduce the line spacing and/or to suppress a potential line separator. They might also indicate a page break to appear preferably above the marked line.

Line separator marker introduces an explicit separator, either as a graphical element or as an additional empty line or increased line spacing.

Headline marker suggests a line to be highlighted as a headline for the table: e.g. as to indicate column headers. A headline may be represented in a bold font and different color.

Figure 8: Example screen shot, sports score page.

Figure 8 shows how multi-line markers and line-separators may play together for a presentation of score board for basketball. Two lines representing one game are visually packed by a multi-line marker. Games are separated by a line separator. The bottom line is an inserted blank line, so as to not 'tear apart' the two lines of the next game on different screen pages.

REGIONALIZATION AND MOBILE RECEIVERS

One of the beneficial side effects of the limited coverage of AM/FM transmissions (analog or digital) is the induced regionalization of reception areas. This offers an advantage of providing local content effectively, since only information for the local region inside the transmission coverage area needs to be provided.

For the Total Traffic HD News Service, this meant that depending on the coverage area ('market') content could be suitably regionalized easily, e.g. for weather reports and local news or interest information

Service regionalization

Nonetheless, the service needed to be set-up as nation-wide service with regionalized content mixed in with nation-wide content. This turned out to need thought for mobile receiver support.

Mobile receivers should be able to switch seamlessly from one region to the next by (invisibly to the user) switching to the next region's station when reception conditions would warrant so. When e.g. traveling from New York through Philadelphia onto Baltimore, a mobile receiver would encounters three regions consecutively, each with their own regionalized content.

When switching from one region to the next, inside the mobile receiver's cache of objects, the new region's local content objects need to replace the old region's local content objects.

Journaline was found to offer little support for this use case. We considered a few 'brute force' methods, e.g. different identification for the main menu and subsequent menu/object tree, or even a different AAS port per region, but quickly discarded those.

Rather, the main objective was to maintain all the nation-wide content inside the receiver's cache (to avoid temporary service blackouts when switching), and only switch in and out the regional content as appropriate. This meant we had to work around the Journaline object identification and versioning.

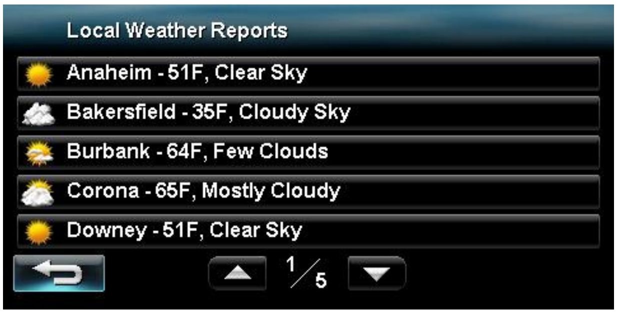

Figure 9: Example of regionalized content: local weather reports

Journaline object identification and versioning

In Journaline, a particular object is identified by an *object ID*, a number in the range 0-61139 (a further ~4000 numbers are reserved for future use). Objects are linked by their object IDs to menu pages/objects.

In addition, each object is assigned a *revision index* in the range 0-7. The purpose of this revision index is to provide a means for the receiver to detect a transmission of a duplicate of the object (same object ID with same revision index) or a new version of an object (same object ID with different revision index).

In case of the same version, as a matter of efficiency, the newly received object can be discarded, which eliminates the need for decompressing and overwriting the prior received object.

Versioning versus regionalization

This efficiency worked against us for regionalization. A local weather reports menu (see Figure 9) needed a nation-wide object ID, to link into the main menu (see Figure 1).

Yet the contents of this local weather reports menu needed to be regionalized and always updated in mobile receivers when switching regions. Also, the linked pages containing the individual local weather reports (e.g. as shown in Figure 10) needed to be tailored for the proper region.

One (slightly less brute force) solution would be to synchronize versioning of such objects across regions and regional transmissions. When traveling in each adjacent region such objects are guaranteed to have a different revision index, then receivers are guaranteed to be updated always too. We rejected this solution for its complexity and rigidity, since it meant that content update rates in all regions had to be the same, and tightly synchronized too.

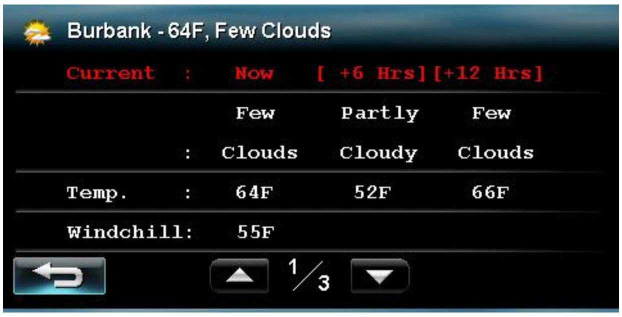

Figure 10: Local weather report for Burbank, CA.

In the end, we settled on a compromise, where such ‘linking’ objects (linking nation-wide and regional content) would be transmitted with two revision indices consecutively in the carousel. This always causes a revision index change, hence always providing an update in the receiver.

This solution loses some efficiency, but only for those few objects linking nation-wide and regional content. This compromise was deemed acceptable.

REFLECTIONS

Invariably, the initially considered bearers and markets implicitly influence design decisions. When bringing an existing application protocol (Journaline) to a new bearer (the HD Radio System) and a new market (North America) we needed to respond to various technical, cultural, and business differences.

Bridging differences

The new bearer, with different characteristics, required a new style of adaptation layer. In this adaptation layer, we built in support for a number of additional business models.

In terms of usability, we had to adapt to cultural differences. The introduction of icons is the most eye-catching example, yet the formatting of sports scores to match North American convention was more subtle but equally needed.

We adapted formatting and structure of the News Service to such differences. Where needed, we added extensions to Journaline to support such formatting cleanly.

Types of standards

In general, one could classify application protocol standards in three classes:

- ***Bearer-dependent standards*** have intricate relations with the underlying bearer format. With small bandwidth bearers such as e.g. RDS, efficiency considerations sometimes force such dependencies.
- ***Bearer-agnostic standards*** do not have a relation with any particular bearer for the content formatting and packaging. Bearer-agnostic standards focus solely on relaying application content, but do not have built in support for service discovery, service identification, or service regionalization.
- ***Bearer-independent standards*** do also avoid any relation with any particular bearer for the content formatting and packaging. Bearer-independent standards do however have built in support for service discovery, service identification, service following.

In our observation, Journaline [3] falls in the class of bearer-agnostic standards. TPEG [4] would fall in the class of bearer-independent standards, as it has specific support for service identification, service partitioning, and (cross-bearer) network information

Given our experiences with Journaline, we would advocate for any application protocol to have a minimal set of network support constructs as present in bearer independent standards. Service identification parameters, but also service scope or partitioning constructs are highly desirable. Support of the various use cases, service target groups, and embedding in a service provider’s suite of data services is made much easier and much more clearly comprehensible with such constructs.

In hindsight, we observe that the regionalization issue that we encountered would have benefitted most significantly from more network support in Journaline. Now we had to settle for a compromise. It worked out satisfactorily, but only thanks to the specific context of this premium, paid for, service setting.

SUMMARY

In this paper, we have described our experiences in bringing digital data services to life in North America. We have focused on the introduction of the Total Traffic HD News Service.

In doing so, we needed to generate additional technical conventions, both for transmissions and display support. As Journaline is largely a “bearer-agnostic” standard, we had to fall back on a number of constructs from the HD Radio bearer to realize this service.

The adaptation flexibility and extensibility of both the HD Radio system and Journaline standard proved immensely valuable. It enabled us to bring this news service to life well inside the span of a year; have it prepared for future extensions, and have it fit into a suite of data services, some already present and some yet to come.

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