Content Management and Control of HD Radio™ Networks via HD Protocol

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INTRODUCING THIRD GENERATION HD RADIO™ BROADCAST SYSTEM ARCHITECTURE

In order to meet the needs of today's diverse broadcast system topologies and enhance the utility of HD Radio, new system architecture has been developed. The Third Generation HD Radio Broadcast System Architecture (BSA) is made up of hardware and software components that have been designed to facilitate the evolution of radio broadcasting from the traditional single analog service to hybrid, In-Band-On-Channel (IBOC), offering multiple services in a more cost effective and reliable system than ever before.

The third generation HD Radio system has evolved as part of the new Embedded Exporter hardware platform and version 4 software developed jointly by iBiquity Digital Corp., leading broadcast equipment manufacturers with funding from the National Association of Broadcasters. The new architecture, shown in Figure 1 implements content and services frameworks as well as command and control functionality built on a common communications protocol between the various HD Radio components.

There is much work yet to be done to provide all of the new functionality that is made possible by the Gen III architecture. It will be left to manufacturers and developers driven by customer demand, to implement these features. The purpose of this paper is to bring to light the many possibilities and stimulate discussion.

Framework Based Architecture

The HD Radio Broadcast System is divided into three distinct frameworks: the Main Program Service (MPS), the Advanced Applications Service (AAS), and the HD Content Management Services (CMS).

The MPS framework contains the hardware and software necessary to supply a Main Program Service and the Station Information Service (SIS). MPS provides the main program audio and basic Program Service Data (PSD, e.g. music title, artist, album name). The SIS is the station information (e.g. call sign, time, GPS position). There are three main

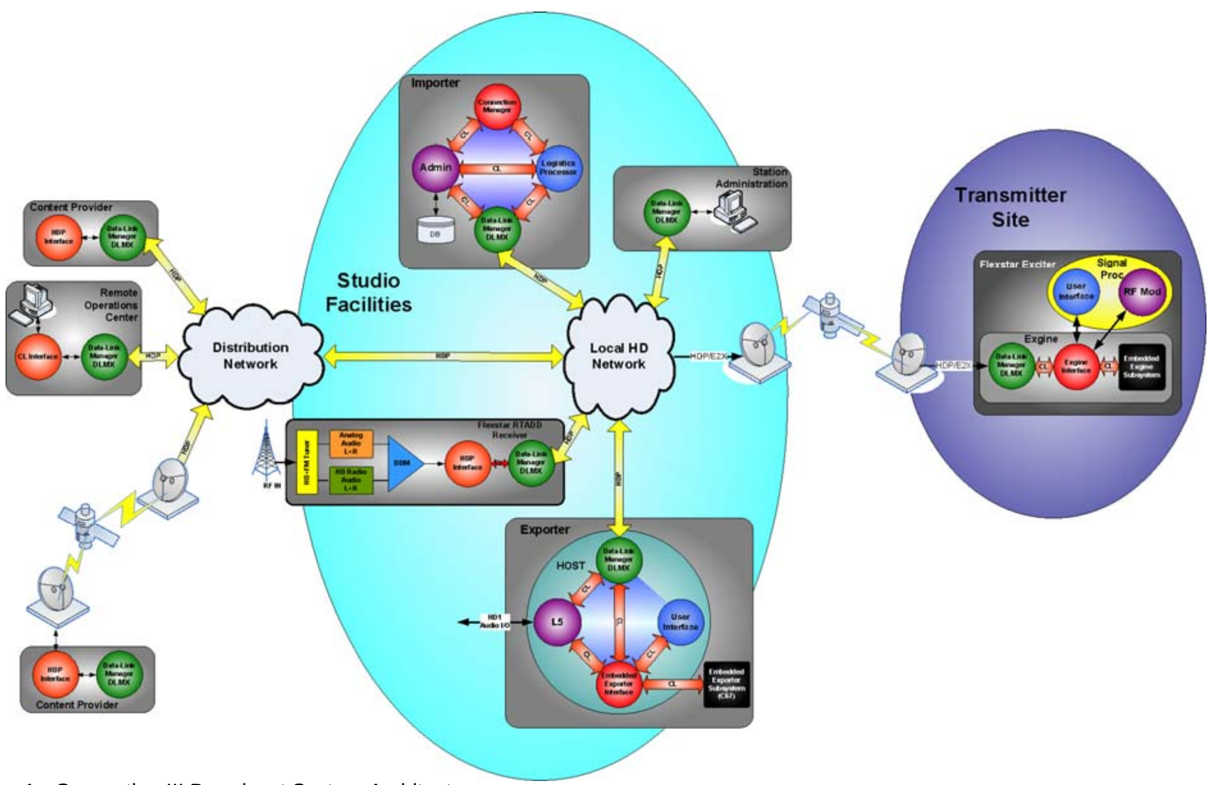

Figure 1 - Generation III Broadcast System Architecture

system components within the MPS framework: The Exciter, the Exgine and the Exporter.

The AAS framework provides the software and hardware necessary to deliver the AAS such as Suplemental Program Services (SPS) and any data services such as weather, traffic information, navigational maps, digital signage data, electronic program guides, multimedia programming and other content.

The AAS framework also contains the infrastructure to support bandwidth management and broadcast system administration.

The three main components within the AAS framework are the Core Importer Software, the Importer API and the Client Software. Typically, these components are assembled into a single physical unit collectively known as the "Importer".

The HD Content Management framework deals with the delivery of content into the HD Radio broadcast system, regardless of whether it is MPS or SPS audio or AAS data. This framework provides the foundation for future development of applications for content creation, management, distribution, and delivery.

The Embedded Exporter

The second generation HD Radio BSA introduced the concept of physically separating the two main HD Radio components; the Exporter and second generation, Exgine-based Exciter. The first generation Exporter was an application running on a Linux-based PC platform modified with specialized hardware for control and system synchronization. The Exporter application contained the iBiquity proprietary HD Radio compression and data encoding algorithms along with the necessary control and interface applications.

Introduced in 2008, the second generation, solid-state "Embedded Exporter" provides a powerful hardware/software platform that offers improved reliability and ease of use at a significantly lower cost over the first generation system. This is accomplished by "*embedding*" the proprietary compression and data encoding algorithms as software libraries onto a T.I.-C67 DSP platform with APIs to an embedded microcontroller host. This eliminates the cost and inherent liabilities of the PC based system.

HD PROTOCOL

At the heart of the advanced HD Radio functionality and capabilities is the new HD Protocol (HDP). HDP began as a development effort by iBiquity to unify the MPS and SPS Program Service Data (PSD) into a single application. Prior to unification, the MPS and SPS data formats were of significantly different structure, requiring separate APIs on the Importer and Exporter. As development proceeded, the purpose and scope of the HDP implementation within the BSA expanded to enhance and unify communications between all of the various HD Radio components, not just PSD. The scope was further expanded to consider support for content creation and distribution as well as command and control across the entire HD Radio system from local, centralized and/or remote locations.

Implementing HDP necessitated rebuilding virtually every component of the HD Radio system. For this reason, all components of the HD radio system, i.e. the Importer, Exporter and Exciter were required to be updated together beginning with the new Exporter and version 4.2 software. With the release of the Gen. III architecture, HDP is now the standard protocol used throughout the HD Radio broadcast system.

The HDP protocol stack shown in Figure 2 is very similar to the Distribution and Communications Protocol (DCP) used by Digital Radio Mondiale (DRM). In order to make use of the features of the DCP standard, add security enhancements, and make it more suitable for use in the HD Radio broadcast architecture, HDP has been defined as the DCP standard with additional information at the Application Framing Layer (AFL) and a redefinition of the TAG Layer (now the TAL).

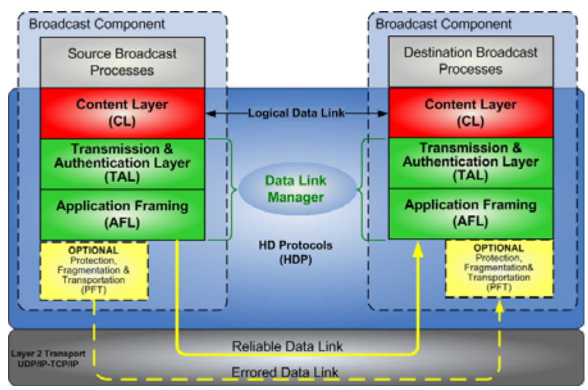

Figure 2 - HD Protocol Stack

HDP is an extensible, general purpose protocol that may be used over either unidirectional or bi-directional links. The protocol supports both multicast and unicast delivery of all forms of HD Radio content. HDP also affords options to improve the data link's robustness and security by providing error correction and the ability to authenticate messages being received from other broadcast components and systems. The DLMX, which must exist on all participating broadcast components, is responsible for processing the AFL and TAL portions of the HDP messages and routing the payload with the CL header to the appropriate process based on the Destination ID in the TAL header. Any information or content transmitted by HDP is called application data.

The entire HDP stack requires an additional 28 to 44 bytes depending on the HDP functions that are implemented. The use of message authentication codes, cyclical redundancy checks, packet numbering and reordering should be unnecessary on a Layer 2 network, and may be expensive in terms of bandwidth resources.

The Content Layer (CL) header is the first header appended to the payload message and is 12 bytes long. The CL header consists of information about the payload needed by the destination process such as HDP version, message identifier, message sequence number, and message length. The message ID is unique to the specific destination process for which the message is intended.

The Transmission & Authentication Layer (TAL) header is between 4 and 20 bytes long depending on whether or not authentication is used. The first 4 bytes set the HDP version, the source and destination process IDs and the message authentication hash length and type. The ability to direct source and destination IDs is what gives the protocol its ability to operate from a single exporter to many Exgine-Exciters. The TAL is appended to the CL header + message payload. If the TAL message digest length is set to 0 then authentication is not available and the additional 16 bytes for the authentication hash are not used. The TAL authenticates data received from the AFL and handles routing to different processes within the same broadcast component.

The Application Framing Layer (AFL) header uses 10 bytes of additional data. This is the link layer, that together with the AFL footer creates the completed data application package. The AFL combines the elementary data into a cohesive block of related data and moves the packets between broadcast system component.

The AF footer may include a CRC check that allows for detection of transmission errors due to noise and dropouts at the destination. Currently, the CRC is not calculated and the 2 byte CRC is set to null.

Protection, Fragmentation and Transportation (PFT) Layer This is an optional layer that may be implemented to provide additional functionality such as Forward Error Correction (FEC) and packet fragmentation to accommodate data links with reduced Maximum Transmit Units (MTUs). These are normally functions of network layers 2, 3 and 4 and not of the application.

Message Authentication

Delivering content and control data over switched networks may expose stations and service providers to unauthorized access and other vulnerabilities. The optional message authentication functionality may be used to verify both the data integrity and the authenticity of messages sent across the BSA.

The TAL header is used to authenticate the identity of the source of the HDP message and also determines which process should digest the message.

A “hash” value, identified by the Message Authentication Code (MAC) type, is computed on the payload. This hash value is then encrypted using a private key of a public key encryption method and placed in the MAC field. The length of the MAC is specified by the MAC length field. To verify the identity of the message, the receiver of the message decodes the MAC using the public key of the public key encryption method then computes the hash using the appropriate method (identified by MAC type) and compares the two values. If they are the same the message has not been compromised. A recipient of a message can choose not to perform the authentication step and just pass the payload to the appropriate application based on the payload type. Authentication (if used) will require up to 16 additional bytes per message.

Error Detection and Correction

The AFL footer provides for the inclusion of Cyclic Redundancy Check (CRC) codes to allow the detection of errors at the destination caused by noise or other impairments during transmission. FEC may also be added to the HDP architecture, by embedding Reed-Solomon codes or some other low-density parity-check (LDPC) codes into the optional PFT layer. While this might be desirable on some unidirectional links, virtually all Studio Transmitter Link (STL) network transport systems have error correction or mitigation as part of their protocol.

Sequence Numbering

Two different sequence numbers are generated with each message within the HDP. In the AFL a sequence number is incremented with each AF packet transmitted. In the CL a separate sequence number is incremented with each unique message. These incrementing sequence numbers may be useful for detecting missed packets and for reordering out of sequence packets. However, this type of detection and reordering is usually accomplished by the layer 2 network transport architecture and not be done at the application level. 4 bytes are added to the message overhead by the two sequence numbers. The current implementation of DLMX does not check sequence numbering or perform any packet reordering.

REMOTE COMMAND AND CONTROL

Remote command and control will allow station personnel to monitor and control operational parameters of the of the HD Radio system locally or across a large network of systems from a central administration location. This will provide groups with multiple stations the ability to monitor and configure system parameters group-wide. Configurations may be scripted and deployed across the entire group simultaneously allowing greater consistency of operation and listener experience.

As currently envisioned, RCC will be accomplished over the network IP interface between the various HD Radio components using HDP. These functions may be managed through a Remote Operations Center (ROC) application currently under development

RCC also affords closed-loop, off-air monitoring with automated alignment and maintenance of transmission system parameters such as analog to digital diversity delay and level alignment

The following RCC functions are being considered for support in the Exporter in future releases:

FCC ID
Country Code
Call Sign
Station Slogan
Station Message
Date & Local Time Settings
GPS Location
SIS Schedule
HD1 Program Type
HD1 Audio Processing
PSD Message
Audio Diversity Delay
Audio Blend Control
Alarm Status
Operational Status
System Configuration

Remote Audio Diversity Delay Alignment

One of the first RCC applications developed has been Harris' Real-Time Diversity Delay Alignment or RTADD™ system.

Proper diversity delay synchronization between the HD Radio MPS and the legacy analog audio program are critical to the successful implementation of any HD Radio installation and ultimately, the listener's experience. While many tools exist to assist the engineer in obtaining optimal initial alignment, inherent network flaws can cause continual drift or sudden shifts in the otherwise perfectly aligned installation. It becomes a constant battle to detect and correct slight misalignments before they become noticeable to listeners. It was determined that method of automatically detecting, correlating and correcting these misalignments at a regular interval is necessary.

Diversity slip and misalignment are caused by the loss of synchronization between the Exporter and the Exgine and/or buffer underflow or overflow in the Exgine. There are three methods currently used to provide synchronization:

- Local synchronization
- GPS referenced remote synchronization
- Synchronization with the Exporter over Ethernet.

The first two methods of synchronization are preferred because of their immunity to network jitter induced error in the Exporter/Exgine clock synchronization. In order to maintain synchronization over the Ethernet network, jitter must be maintained as low as possible to avoid noticeable blending artifacts due to instantaneous phase differences between the Exporter and Exgine clocks. Network dropouts are also very destructive to the HD Radio system. While the stream can recover from the occasional dropped packet, the loss of a single bit in transport will invalidate the entire HD Radio message frame. IP networks are not well-suited to the real-time transport of streaming data. IP transport in and of itself cannot guarantee packet delivery at all. When used with TCP we can guarantee delivery, but not the timeliness of that delivery. In fact, TCP can exacerbate the problem by delaying the re-transmission of an errored packet to the point where it arrives too late for transmission in the sequence and so it must discarded. When packets are lost, the Exgine buffers must make up the difference. The buffers hold up to (32) 92 ms packets. The loss of a single packet will cause the apparent latency of the digital system to be reduced by 92 ms. This loss is not recovered and the diversity delay will now be permanently skewed and will continue to skew further as additional packets are dropped.

In order to provide flawless synchronization the network would need to have jitter figures of less than 25 us and BER performance of better than 10^{-12}. Most networks cannot approach this on a consistent basis. It was determined, that the best approach to maintaining diversity delay alignment is to apply a real-time correction to the analog delay to compensate for the variations in the digital stream's latency and buffer variations.

With RTADD, a specially designed HD Radio + FM tuner shown in Figure 3, operating in "Split" analog/digital mode monitors the signals continuously and presents the received analog and digital audio signals to a Diversity Delay Measurement (DDM) comparator circuit. The DDM algorithm determines the delay differential between the analog and HD digital audio signals and calculates the number of audio samples that must be added to or subtracted from the analog audio delay in order to synchronize the two audio streams. A correction message is generated and formatted into an HDP control message that is sent to the Exporter via the Ethernet network connection. Within the Exporter, the diversity delay control makes the

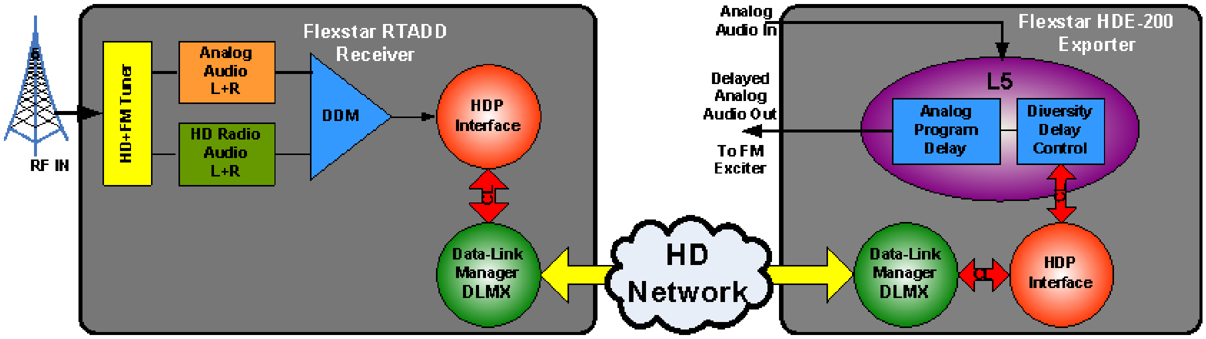

Figure 3 - Real-Time Audio Diversity Delay Control (RTADD™)

necessary correction. This process is repeated at a regular, frequent interval, assuring that the two audio streams are always optimally synchronized.

CONTENT DELIVERY

Content creation, distribution and delivery processes are enhanced and facilitated by the Gen III architecture. Stations and content providers have identified the need for distributed content creation, centralized storage and content management to enable them to operate efficiently in today's dynamic media environment.

Content may be anything that is sent over the HD Radio system such as a video or audio clip, graphics, or a script. It could be streaming data or data files such as album art, digital signage files, map files or traffic data, just to name a few.

While still in the early stages of development, the current Content Management framework is envisioned as having two main components; The HD Radio Registry and the HD Radio Content Management Software

The HD Radio Registry will be a central repository for the creation, management and distribution of all information pertaining to HD Radio services world-wide. The Registry will be a clearing house to manage, disseminate and control access between service providers, the HD Radio stations, content services and the consumer/listener. Details of the ownership and management of the Registry are still to be determined.

Some of the functions of the Registry are expected to be:

- Registration and tracking for all data service providers and their associated services
- Registration and tracking of all CA equipped HD Radio's Electronic Serial Numbers (ESN) and service authorizations.
- Management of conditional access services
- On-line payment for international Importer licenses
- Management of Importer license keys
- Management of all HD Radio specific parameters such as Mime Types and Audio/Data Types (Genres)

The HD Registry will connect the various HD Radio system components through a series of standard applications including Importers, conditional access equipment, station administration equipment and consumer access portal systems.

Content Management Software tools will need to be created to assist broadcasters or content providers the means to compose, package, and delivery all types of content destine for the HD Radio system. Among other things, these tools, will allow third parties the ability to create multi-component (e.g. audio, text, images) programs that can be ingested, broadcast, and rendered in a consistent synchronized manor that will optimize the user experience.

SUMMARY

What we have discussed here are the beginnings of an advanced radio system that will, in time fundamentally shift the paradigm as we know it. While radio will continue to bring familiar local program content and serve its communities' interests as it has for nearly 100 years, it will also have the ability to become a centralized and ubiquitous supplier of low-cost bandwidth for every imaginable purpose. By leveraging the content distribution and system control capabilities throughout the vast network of HD Radio stations, it will be possible to trade on the one to many distribution of bandwidth as a commodity.

ACKNOWLEDGEMENTS:

HD Radio™ is a trademark of IBiquity Digital Corporation, Columbia, Maryland

The author wishes to knowledge the following individuals for the contributions:

Monica Collins, Administrative Assistant, Harris Broadcast Systems

Jeff Detweiler, Director, Broadcast Business Development, iBiquity Digital Corporation

Geoffrey Mendenhall, V.P Transmission Research & Technology, Harris Broadcast Systems

Richard Redmond, Director, Strategic Marketing
Harris Broadcast Systems

Ted Staros, Director, Pacific Design Center
Harris Broadcast Systems

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