Wireless Product Applications, Technologies & Performance Testing

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I. Introduction

Manufacturers looking to succeed in the wireless CE marketplace need to focus on wireless connection Quality of Experience (QoE) as the key value proposition that will differentiate their products from the competition. In order to ensure a high QoE, wireless CE equipment must be rigorously tested to ensure that it performs at least on a par with wired devices. Determining the component factors of wireless CE QoE is the first step to measuring it, and validating the capabilities of new wireless CE products, while difficult, is of vital importance.

For consumers to truly embrace wireless CE entertainment, it must meet or exceed their existing QoE standards for wired CE devices. The Simplay Labs Wireless CE performance testing program encompasses many QoE factors, including customer expectations concerning interoperability, performance, and usability. The Simplay HD Wireless performance testing program maps these factors into metrics that can be objectively evaluated, and has developed test requirements and scenarios for each metric. Now and going forward, the Simplay HD mark takes the guesswork out of shopping for wireless HD CE equipment, promising the perfect performance that consumers demand. It ensures that consumers will enjoy the performance of a lifetime from their wireless home entertainment equipment.

This paper discusses the requirements for wireless entertainment networks and an approach for testing them. An understanding of key technical requirements and features will also serve to increase testing effectiveness.

II. Clarifying Wireless Applications

The first order of business with wireless technologies is to clearly define the consumer applications of content distribution versus content rendering. The two terms are often confused or conflated, and need to be distinguished as separate applications with different requirements.

HD Content Wireless Distribution Application

The distribution application focuses on transferring content across a home and through many walls and obstructions. Distribution is a problem common to both wireless video and wireless computer networking, so many solutions will use the same technology for both usage scenarios. The video distribution application requires the ability to reliably deliver a highly compressed multi-megabit video stream. *See Figure 1.*

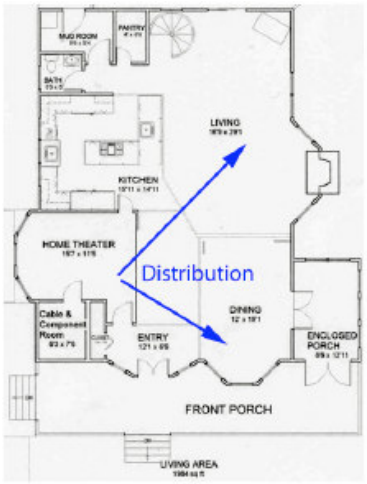

Figure 1. HD Content Wireless Distribution Concept

The wireless distribution of HD content around a home at multi-megabit levels requires access to and distribution of content in a highly compressed form. This requires access to either the raw compressed content (e.g., an MPEG stream from a CATV decoder or a Blu-ray Disc player), or upstream compression of HD content (e.g., video from a gaming console or HD camcorder). Once distributed, some downstream component within the system must decompress and render the content in HD format. Electronic program guides and menus must also be rendered and distributed at the end component, and a content protection system must be approved for use in compressed HD content distribution environments. Innovative companies such as Silicon Image are developing complementary networking technology solutions for this application.

HD Content Wireless Rendering Application

The HD content rendering application focuses on transferring content within a single room, though not necessarily with line of sight. HD content rendering should not be treated as a short-range version of the HD content distribution application. By treating

rendering as a separate application, HD wireless products can make use of technologies optimized for extremely low error rates, low latencies, contention-free media access protocols, and asymmetric communications channels. Supporting the HD content rendering application without the additional burden of whole-house distribution enables high QoE factors in products designed to provide wireless rendering only. *See Figure 2.*

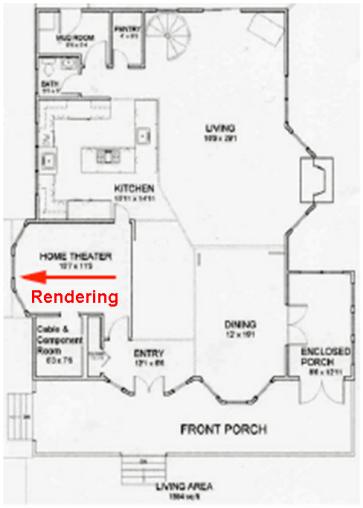

Figure 2. HD Content Wireless Rendering Concept

This HD content wireless rendering application is also complementary to existing HDMI based products that incorporate HDCP content protection. The wireless interface can simply be an external module that bridges two wired HDMI links with an HDMI-wireless-HDMI connection. The key requirement is to manage the HDCP repeater function properly.

All of the existing content protection, menu composition, and video enhancement features of HD sources and displays are used in the same way they would be in an HDMI system. By distributing, authenticating, and authorizing the same HDCP system, existing performance standards and test environments are easily extendable to support the wireless application.

III. Wireless Technologies Overview

The consumer allure of wireless CE devices will result in applications using some or all of the above approaches. Challenges remain, however, in ensuring the quality, reliability, and content protection necessary for extending the HD entertainment experience into the wireless space. Increasingly, CE products based on wireless technologies are emerging in the marketplace, making use of various RF technologies, including:

- IEEE 802.11 (WiFi)
- Ultra-Wideband (UWB)
- 60 GHz.

Each of the above technology approaches presents a unique set of QoE challenges. While each of these technologies has its performance advantages, each also has its own unique limitations.

WiFi based products make use of the 5GHz frequency spectrum. This is also the frequency band used by many other consumer products such as cordless phones. The IEEE is investigating the possibility of increasing the bandwidth in the 5-GHz WiFi band. Supporting the maximum data rates of over 500 Mbps provided by the 802.11n standard without accessing significant new amounts of frequency spectrum requires pushing the limits of Shannon's Law. This and the potential spectrum contention problems with other devices will constrain the range and acceptable error rates of WiFi products in the HD content wireless distribution application.

UWB designs hold some promise, but are severely limited by regulatory restrictions on usage and wireless link transmit power levels that severely compromise the link budget available to maintain an acceptable error rate. UWB is allowed by the FCC to transmit a very low power signal over the 7 GHz of spectrum between 3GHz -10 GHz, which is also shared with other consumer devices. The extremely low transmission power provides a severe range limitation if gigabit/second links are required for an application. While efforts are in progress to relax regulations, and while this technology is strongly supported by many companies, UWB is usable only in the United States, and only for very short-range connections.

Wireless technology using the 60 GHz band is capable of combining uncompressed high-definition video, multi-channel audio, intelligent format and control data, and Hollywood approved content protection. The 60 GHz band is an attractive candidate for in-room rendering of HD content because it has high atmospheric loss. The 60 GHz band is also of great interest due to the massive amount of spectral space that has been allocated worldwide for *unlicensed* dense wireless local communications. However, 60 GHz measurement equipment requires a large investment of capital, training, and engineering to make precise testing measurements.

The bandwidth and reach of 60 GHz systems make them ideal for HD content rendering applications. To fully support HD content rendering, any wireless system must preserve the integrity of the existing HDCP security system. HDCP is already approved by Hollywood and is currently in use in HDMI systems. These systems must therefore be interoperable with other HDMI-based systems, and other wired and wireless HDCP-based systems.

IV. Factors Affecting Performance Testing

High-quality rendering of HD audio and video content is the obvious monster challenge for wireless CE QoE expectations. At its core, HDTV provides visual and audio entertainment for consumers, and consumer perception of QoE quality is highly sensitive to wireless impairments including packet loss, latency, jitter, and sequence errors. Video problems created by these impairments such as blocking, blurring, edge distortion, judder, and visual noise will degrade the QoE factor. Audio is the other dimension of QoE quality. Noisy or unsynchronized sound is not acceptable to the discriminating consumer.

Technical factors of wireless QoE are closely related to technologies that are being used to distribute and/or render the HD content. The wireless devices must avoid performance degradation when exposed to interfering signals, and cause no degradation to other communication devices. The reason is that in some wireless distribution applications, wireless devices must coexist with other WiFi (all 802.11 versions a/b/g/n), cellular, cordless phones, and microwave ovens in a range as close as ½ meter.

Wireless QoE platforms must ensure that the percentage of time a wireless link is available for error-free transmission is 98% or better. Wireless QoE requirements also include:

- **Data Throughput:** The wireless products guarantee sustained bandwidth to support multiple high-definition content streams with error free delivery.
- **Error Rate:** For example, only a single data packet could be lost for every two hours of digital content delivered. The packet error rate must be 10^{-8} or better.
- **Quality of Service:** Products support a wired equivalent performance.
- **Interoperability**

How quickly and correctly the consumer can change channels is also an important part of wireless QoE factors. Acceptable channel surfing delay is generally considered to be around 1 second end-to-end. A channel surfing time of 100~200 ms is considered by viewers to be instantaneous.

Testing for sustained data throughput and packet error rates help determine the appropriateness of a specific wireless technology and/or product for the task.

V. Wireless System Level Testing

HD content wireless distribution and rendering networks, unlike data networks, are only as good as their worst case performance. For data networks, long latency, not transferring data, or losing a connection due to link fading, high-packet error rate or interference is rarely noticeable. For HD content distribution and rendering networks, these same issues result in audio glitches, loss of lip sync, pixilation, and completely lost frames.

The different natures of entertainment systems and data networks result in the need for different test procedures. For a data network the recommended test procedure is to run the same test sequence multiple times and average the performance, thereby eliminating the impact of link fading or interference. For an entertainment content network the recommended test procedure is to run the same test sequence multiple times and take the worst performing result, making the test representative of what the viewer may experience in a real world environment.

To accurately test real-world wireless applications conditions, a test environment that reproduces these conditions is required. Applications conditions are constantly changing due to many variables, including device movement, the environment, people, pets etc. Application emulation approaches should utilize sophisticated application models to replicate conditions that occur in real-world wireless environments.

Standards bodies and industry forums define channel models to represent certain classes of channel conditions, which serve as statistical characterizations of specific environments. The conditions provided by the channel model are based on random processes that create a specific instance of a channel condition due to fading, multipath, and correlations. The models are dynamic in the sense that the conditions are constantly changing. To accurately represent a sufficient variety of conditions, the application emulator must also be dynamic in order to change in time, and to provide long intervals of non-repeating channel conditions. This provides the devices under test with a very large number of unique channel instantiations similar to real-world conditions, resulting in broader test coverage.

There are a number of emulation models that are defined by standards organizations to create a baseline. For example, IEEE 802.11n channel models A through F form the baseline of Wi-Fi testing. Table 1 provides key parameters of IEEE 802.11n channel models A through F.

	Models					
Parameters	A	B	C	D	E	F
Avg 1st Wall Distance (m)	5	5	5	10	20	30
RMS Delay Spread (ns)	0	15	30	50	100	150
Maximum Delay (ns)	0	80	200	390	730	1050
Number of Taps	1	9	14	18	18	18
Number of Clusters	N/A	2	2	3	4	6
Rx and Tx Antenna Spacing	1/2,1, 4 λ					

Table 1. Parameters of IEEE 802.11n channel models

The value of any device performance testing is maximized when test results are both accurate and repeatable. Accurate and repeatable testing of wireless equipment is achieved in a controlled RF environment that is not subjected to external RF interference.

Effective application emulation in a controlled RF testing environment must use RF isolated enclosures for the devices under test.

The areas requiring test specifications and tools include:

- Link fading testing
- Packet error rate performance
- Link reliability performance (e.g., pixilated video, lost frames, etc.)
- Interference resistance performance & recovery (e.g., microwave ovens, cell phones, etc.)
- Through-wall transmission performance
- Security: HDCP support & robustness
- Latency performance.

When determining the suitability of wireless technologies for the distribution of HD content, it's important to focus on three key metrics – sustained data rate, packet error rate, and Quality of Service. By determining how well any given technology performs using these criteria, we can project its performance in a real-world home entertainment distribution network.

VI. The Simplay Labs HD Wireless Performance Testing

Simplay Labs is committed to enabling optimal performance of HD products, facilitating a high Quality of Experience (QoE) factor for consumers. We collaborate with retailers, content providers, and broadcast electronics professionals to enable consumers' passion for the HD lifestyle. We also work with manufacturers to ensure QoE above and beyond simple protocol specifications, by delivering the best possible HD experience to the consumer.

Evaluating the performance of HD content wireless systems requires a repeatable procedure for presenting the system with a stimulus and quantitatively measuring its output relative to an ideal response, given the appropriate application. To meet this goal Simplay Labs is developing a complete wireless test environment, optimized against appropriate applications of HD content *distribution* and *rendering*.

Leveraging this branding component, the Simplay HD Testing Program is educating retail channels on the importance of lip sync performance and how to identify high QoE devices. Now and going forward, the Simplay HD mark takes the guesswork out of shopping for HD, promising the perfect performance that consumers demand. Consumers will enjoy the performance of a lifetime from their home entertainment equipment.