Can Bluetooth Audio Replace the Wire?

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Abstract

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Introduction

Wireless audio devices are increasingly common in home entertainment systems, and with this the quality of distributed audio and ability to prevent interference is of upmost importance. Bluetooth is a Wireless Personal Area Network (WPAN), developed in 1994 by the Bluetooth Special Interest Group (SIG) with the intention of replacing cables connecting personal computers and peripheral devices [Bluetooth SIG 2001]. It operates in the unlicensed 2.4 GHz ISM (Industrial-Scientific-Medical) band, which is split into 79 1 MHz wide channels [IEEE 802.15.2 2003], and has an operational distance of 10-100m.

A physical radio channel is shared by a group of Bluetooth devices, known as a piconet. Each Piconet compromises of a single master and up to seven slave devices [Bluetooth SIG 2001]. A larger network called a Scatternet can be formed when two or more Piconets connect through a bridge or relay device [Pinkumphi and Phonphoem 2009]. The systems are synchronised to a common clock and use a frequency hopping spread spectrum (FHSS) scheme to combat interference. In a FHSS the 79 frequencies of the ISM band are placed in an algorithmically determined pseudo-random order, based on the device address and master clock [IEEE 802.15.1 2005]. The system hops between these frequencies using a Time Division Duplex (TDD) method dividing each second into 1600 time slots (625µs per slot) [Pinkumphi and Phonphoem 2009]. The pattern is adaptive, whereby frequencies used by interfering devices may be excluded, this is known as advanced frequency hopping [Nagai et al. 2012].

The IEEE Std 802.11 states that the Wireless Local Area Network (WLAN) operational frequency should also be 2.4 GHz [IEEE 802.11 2005]. As both the WLAN and Bluetooth standards operate in the same frequency band, there may be interference between the two systems [IEEE 802.15.2 2003]. There may also be interference from other wireless systems, such as cordless telephones and microwaves, which could result in severe performance degradation [Gehrmann et al. 2004].

Many audio codecs have been developed to improve the audio quality transmitted over Bluetooth piconets, including aptX/aptX HD, Low Complexity Sub Band Coding (SBC) and LDAC. aptX HD claims ‘better than CD’ audio quality, whilst LDAC transfers 3x more data than SBC (990kbps vs 328kbps) plus the ability to ‘maintain maximum bit depth and frequency of 96kHz/24bit audio’ [McClintock 2016; Sony Corporation 2016]. Bluetooth 5 is also due to launch in early 2017, with quadrupled range, doubled speed and a 800% data broadcasting capacity [Washington 2016].

With the immanent launch of Bluetooth 5 and the increasing quality of audio codecs will Bluetooth ever be able to replace the wire?

Network Interference

As both the IEEE 802.11 and IEEE 802.15.1 standards specify an operational frequency of 2.4 GHz, there can often be interference when the two networks coexist in the same physical space. Factors that affect the interference level include; the separation of the wireless devices, the data traffic levels flowing over each network, the power level of each device, and the WLAN’s data. Different information types have varying levels of sensitivity to interference [IEEE 802.15.2 2003].

## Coexisting Networks

Bluetooth uses a FHSS scheme, while IEEE 802.11 either uses FHSS or a direct sequence spread spectrum (DSSS) system [Chiasserini and Rao 2003]. If a Bluetooth system is in the presence of a WLAN system using FHSS then it is susceptible to interference on the channel in use and the two adjacent channels. However, due to the short packet size used in Bluetooth, the packet error rate (PER) for Bluetooth in the presence of IEEE 802.11 is almost insignificant [IEEE 802.15.2 2003].

Bluetooth uses ADP to remove channels that are being used by interfering devices. WLAN can also detect interference and defer transmission on channels when they are used by interfering devices [Nagai et al. 2012]. However, it has been found that these interference avoidance functions do not work effectively [Golmie et al. 2003; Chiasserini and Rao 2003].

# Audio Quality

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