Can Bluetooth Audio Replace the Wire?

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Abstract

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Introduction

Millions of users around the world use networking daily to communicate with friends, family, and colleagues. Computers are able to connect in more ways than ever before, and with technology improving day by day, almost all consumer electronic devices have network capabilities.

Fixed connection networks are less susceptible to interference and are consequently more reliable than their wireless counterparts. However, wireless communications enable users to seamlessly connect personal computers to peripheral devices, without the constraints associated with wired connections.

Bluetooth and Wi-Fi are widely used wireless communications networks. The operational speed and distance of Wi-Fi is ten times faster than Bluetooth and both have similar costs. However, Bluetooth consumes much less energy than Wi-Fi, making it ideal for use in portable devices such as headphones, hard drives, wearables and cars, where batteries need to be kept as small as possible.

ZigBee is another low power wireless communications network, with a range 30 times greater than Bluetooth, however with just a quarter of the data speed it isn’t suitable for file transfers [Abinayaa and Jayan 2014]. It is mainly used for home automation systems, and is often found in remote controls.

Bluetooth audio devices such as speakers and headphones are increasingly common in the consumer electronics market, and with this the quality of distributed audio and ability to prevent interference is of upmost importance. With manufacturers continuously developing ways of improving the system, will Bluetooth ever be able to replace the wire?

## Bluetooth Audio

Bluetooth is a Wireless Personal Area Network (WPAN), developed in 1994, by the Swedish mobile phone company Ericsson, with the intention of replacing cables connecting personal computers and peripheral devices [Bluetooth SIG 2001]. In 1998 IBM, Intel, Nokia and Toshiba joined the study forming the Bluetooth Special Interest Group (SIG), which now has over 30,000 member companies [Bluetooth SIG 2016b]. It is robust, has low power, low complexity and low cost [Bluetooth SIG 2001]. Bluetooth enables numerous devices such as personal computers, mobile phones and entertainment systems to communicate using low power, short distance wireless links [Verma et al. 2015].

Since its creation the development of Bluetooth has been continuous, allowing new capabilities such as stereo audio to be introduced [McClintock 2016]. It was one of the main technologies behind the audio steaming revolution, disconnecting inconvenient wires from between headsets and speakers, and phones and computers, giving users reliable, convenient access to their music anywhere [Bluetooth SIG 2016a].

Consumer demand for devices with the ability to receive transmitted audio via Bluetooth is increasing [GfK Global 2015]. A total of €1.6 billion was spent on Bluetooth enabled docking speakers in 2014. In the same year the Western European market purchased 7.6 million Bluetooth speakers. Sales of these devices continue to grow, up by 40 percent in the first six months of 2015, compared with the same period in 2014.

Advantages of Bluetooth Audio

**Universal**

Bluetooth is universal, making previously impossible connections between devices with various proprietary connectors and pin arrangements possible [Bisdikian 2001]. Devices such as headphones can connect to a mobile phone with the same ease as connecting to a laptop or tablet, irrelevant of manufacturer. Likewise, computer peripherals including keyboards, hard drives, printers and speakers can be easily connected, reducing the stress and cost of sourcing and utilising potentially expensive interconnect cables.

**Low power**

Battery technology isn’t advancing in line with other technologies as it is still poorly understood [Bullis 2015]. There have been improvements over the last decade, but they’ve largely come from frequent small advances.

Bluetooth’s power consumption is around 100mW, whilst WiFi consumes 700mW [Lee et al. 2007]. This makes it ideal for portable devices with limited battery power.

**Mobility**

With the removal of cables, wireless devices give users the ability to move freely without disrupting connections. Bluetooth headphones have become a popular sports accessory, especially amongst runners.

**Quick easy installation**

**Increased personal safety (phones emit radiowaves)**

**Easy integration of new devices into networks**

**Inexpenseve**

**In most personal computers**

**Can locate and connect to devices without user input**

**Psychological studies showing wireless is better?**

# Disadvantages of Bluetooth

They are convenient for those who don’t want to be constrained to physical spaces such as desks, however wireless networks are noisier and less reliable than fixed connection networks due to interference that occurs during transmission.

## Network Interference

Bluetooth 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].

### Coexisting Networks

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 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 [IEEE 802.15.2 2003]. 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. 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].

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

Bluetooth uses the Advanced Audio Distribution Profile (A2DP), to stream stereo audio from a source device to headphones or speakers [Bluetooth SIG 2015]. The A2DP uses the low complexity subband codec (SBC) to ensure the interoperability [Bluetooth SIG 2015]. The device may also support Optional codecs to maximize its usability. When both SRC and SNK support the same Optional codec, this codec may be used instead of Mandatory codec. The device may support other codecs as Vendor Specific A2DP codecs. A user of a Vendor Specific A2DP codec (hereafter the Vendor) will need to define parameters and other information necessary for use of the codec in A2DP.

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 [Bluetooth SIG 2016b].

# Conclusions

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