Emerging Trends in Mobile Communications

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Contents

1 Acoustic data transmission

> I tried to discover, in the rumor of forests and waves, words that other men could not hear, and I pricked up my ears to listen to the revelation of their harmony.
>
> Flaubert, (*November*)

1.1 Introduction

The rise of IoT devices in the home and workplace has created a world where data and connectivity are becoming increasingly complex. Lucero, (*IoT platforms: enabling the Internet of Things*) predicts a staggering 75 billion connected devices by 2025, up from 26 billion in 2019, as shown in Figure 1. As IoT technology advances and the demand for efficient ways of communicating data between these devices grows, the world has witnessed a rise in emerging new data transmission technologies which are looking to provide secure and effective solutions for sharing information. One solution rising to meet these new demands is data-over-sound.

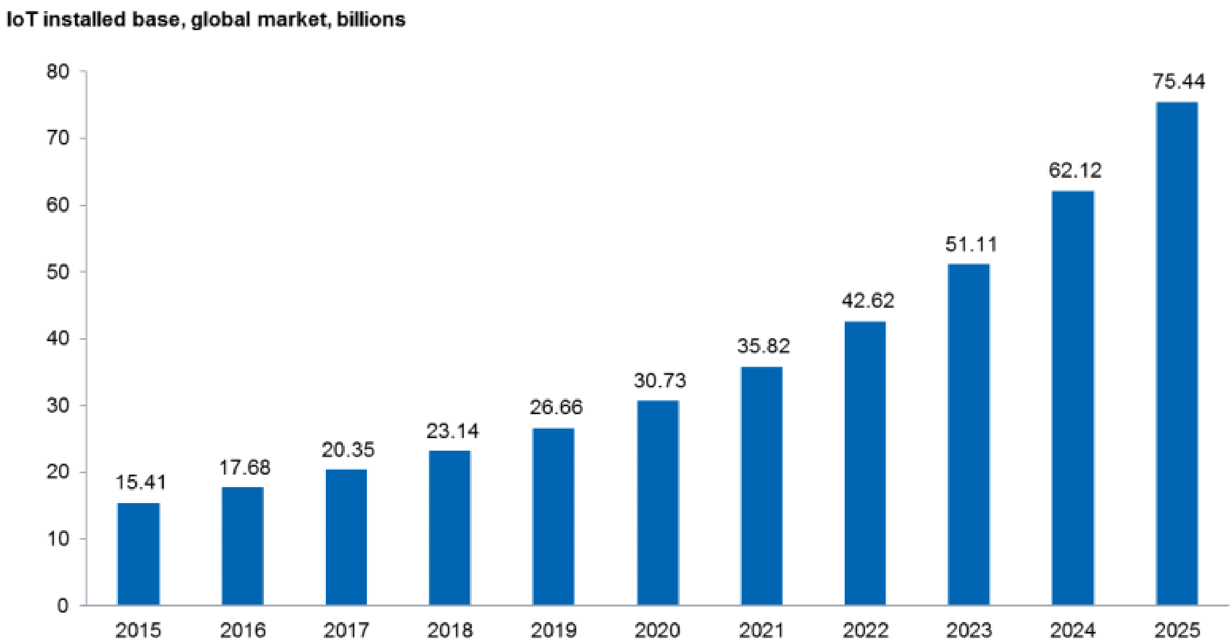

Figure 1: Number of IOT devices that will be installed worldwide from 2019 to 2025 (in billions).

Data-over-sound (DoS) presents a compelling solution for many device-to-device connectivity applications, particularly for use cases that require frictionless, low cost connectivity with nearby devices. DoS harnesses devices existing speakers and microphones to send and receive data over an acoustic channel. Because it doesnt require any additional networking hardware, DoS has captured the interest of companies interested in adding wireless connectivity functionality to existing devices. Some big names such as Google and Cisco already have point-product DoS integrations

There are a number of connectivity technologies available in the market today, including extremely short range (NFC and QR); short range, high bandwidth (Bluetooth and Wi-Fi). Each technology has its advantages which makes it more or less suitable for certain applications. An overview of these considerations are given in Table 1.

1.2 Advantages of Data-over-Sound

According to Table 1 following advantages can be listed.

	DoS	QR	NFC	Bluetooth	Wi-Fi	Li-Fi
Two-way communication	1	0	0	1	1	1
One-to-many broadcast	1	0	0	0	0	1
Non line-of-sight communication	1	0	0	1	1	0
Zero pairing/set-up procedure	1	1	1	0	0	0
Low power operation	1	1	1	1	0	0
max data rate	1 kb/s	3 kb	424 kb/s	25 mb/s	70 mb/s	1 gb/s
max range	100m	10:1	20/cm	100/cm	50m	10m

Table 1: Feature comparison for DoS vs alternative technologies

Device interoperability The simple hardware requirement of a speaker and/ or microphone make data-over-sound arguably the most wide-reaching wireless communication technology in terms of device compatibility. Mobile phones, voice controlled devices, and any device with an alarm speaker are able to communicate using data-over-sound. This includes many legacy devices. Data can also be transmitted over media channels such as radio and TV, and over existing telephone lines.

Frictionless UX Data-over-sound requires no pairing or configuration, making data transfer as simple as pressing a button.

Physically Bounded Because sound waves respect room boundaries, particularly in the near-ultrasonic range commonly used in data-over-sound, transmissions do not pass between neighbouring rooms. This means that it can be used for detecting the presence of a device with room-level granularity.

Zero power The advent of wake-on-sound MEMs microphones such as the Vesper VM1010 enables devices to communicate using data-over-sound, whilst draining virtually no battery power in between communications (< 10 A).

1.3 Applications of DoS

Based on these advantages, four key use cases for Chirp (a DoS implementation) are emerging, which are identified here.

IoT device provisioning Configuring a new smart device with network credentials and functional configuration remains a disproportionately complex task, particularly for headless devices. Chirp offers an approach to provisioning which is offline, locally-bounded, and does not require any infrastructure modifications. Credentials are encoded as audio, optionally layered with cryptography for secure scenarios, and broadcast over-the-air to nearby smart devices.

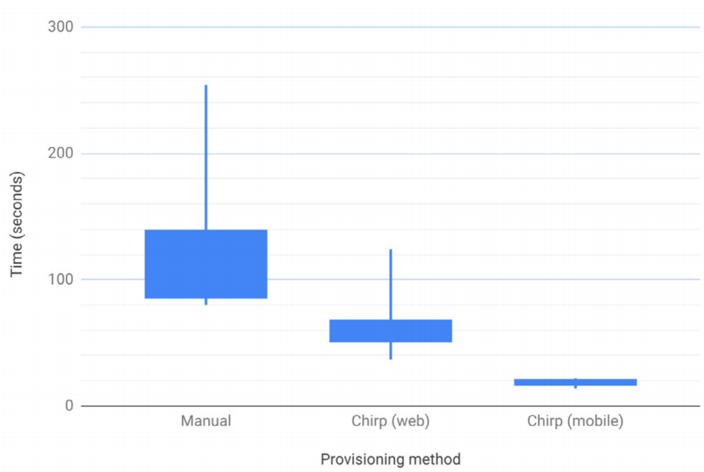

Figure 2: Time taken to provision a smart device.

Figure 2 shows the result of a study in which some experience of IoT were asked to provision a headless smart device using three methods:

1. Manually, by creating a temporary Wi-Fi hotspot on the device, connecting to the hotspot with a web browser, and entering credentials;
2. Using a Chirp-enabled web interface which asks the user to enter credentials and transmits them to the device via data-over-sound;
3. Using a Chirp-enabled mobile app which was able to use the devices existing knowledge of the credentials

The Chirp-enabled solutions reduced the provisioning time by 48% with the web-based scenario, and 86% with the mobile scenario.

Proximity Detection A key property of acoustic signals is that their propagation respects room boundaries, particularly in the near-ultrasonic range. As a consequence, there is a growing uptake for near-ultrasonic acoustic beacons for presence sensing at room-level granularity

Two way acoustic NFC Data-over-sound also supports near-field communication scenarios whilst offering a two-way full-duplex mode of communication, thus addressing a critical limitation of NFC. Enabling two-way data exchange means that devices can perform challenge-and-response dialogues - for example, Diffie-Hellman key exchange for secure financial transactions, or securely sending un-spoofable receipts to a merchant or buyer.

Telemetry in RF-restricted environments In many sensitive environments, RF-based communications are prohibited due to the risk of sparks or interference with equipment that pre-dates RF regulation. Chirp overcomes these limitations, allowing the industrial IoT to harness the benefits of wireless communication without limitation.

1.4 How it all works?

The basic idea of data-over-sound is no more complex than a traditional telephone modem. Data is encoded into an acoustic signal - either audibly as bleeps and tones inaudibly above human hearing range or hidden as imperceptible modifications of existing speech or music - which is then played through a medium (typically the air, although it could equally be a wired telephone line or VoIP stream), and received and demodulated by a listening device. The listening device then decodes the acoustic signal and returns the original data. This process is described in Figure 3.

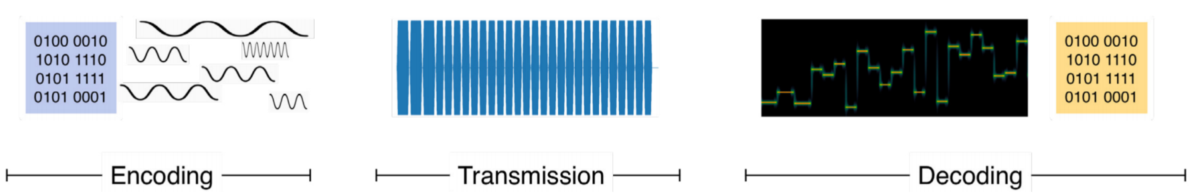

Figure 3: life-cycle of data-over-sound

As with other data transmission protocols, the entire message can include specific sequences to indicate the start and expected length of a message, as well as additional bytes for error detection and correction, as shown in Figure 4. Messages are typically encoded using frequency-shift keying (FSK) modulation, which is robust to background noise and distortion from acoustic effects such as reverberation. Following extensive testing of a large range of consumer devices, Chirp considers the safe range to be between 1kHz-20kHz. This enables the production of audible messages, or near ultrasonic when limited to 17kHz-20kHz, which is imperceptible to most adult humans.

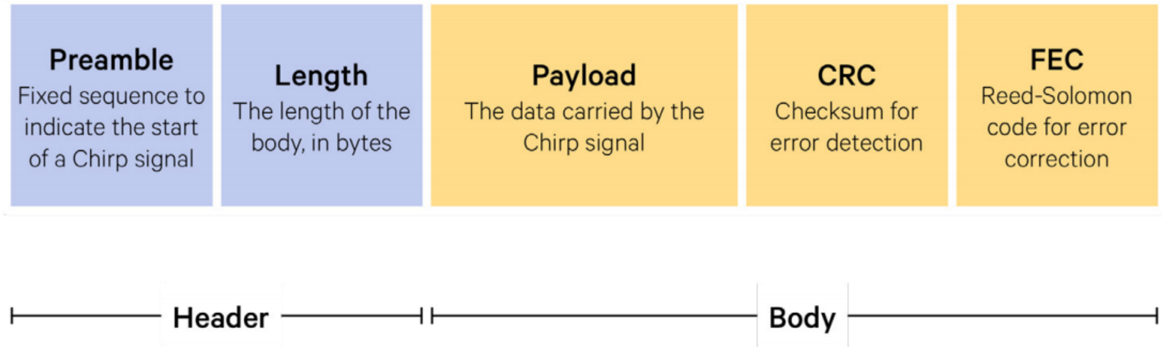

Figure 4: Makeup of the message

All of Chirps standard profiles are tested to perform at ¿99under normal operating conditions. Of the existing data-over-sound solutions on the market, the main differentiator for Chirp is this reliability and robustness of the internal decoding technology. This has been demonstrated and stress-tested in acoustically extreme environments, including nuclear power stations with upwards of 100dB(A) of background noise, across ranges exceeding 100m.

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2 Li-Fi

There is a crack in everything. That's how the light gets in.

(Cohen, *Anthem*)

2.1 Introduction

Today, when the world is exploring 5G technology, and smart devices are connecting to the cloud for fluid communication and IOT. Daily data traffic is increasing at the steepest rate. According to cisco, (*Global Mobile Data Traffic Forecast Update, 2017-2022*) it has been estimated that, mobile data traffic will reach to 77 exabytes per month by 2022. It is not hidden from the industry that current transmission system is under pressure.

Figure 5: Mobile data traffic. Source: (cisco, *Global Mobile Data Traffic Forecast Update, 2017-2022*)

To revive the radio-wave spectrum from high traffic concentration, a new technology is attracting scientists, it's Visible light communication using the concept of Orthogonal Frequency Division Multiplexing(OFDM) or simply termed as Li-Fi(Light Fidelity).
Li-Fi was first introduced to the world by Prof. Herald Haas during a TEDGLobal Talk in July 2011. In that talk, Harald Haas, (*Wireless data from every light buld*), showcased the potential of the technology to be integrated in the future communication system. From then, scientists from various parts of world started studying for various ways to improve the transmission method.

The technology uses visible-light spectrum as a medium for data transmission. It comprises of a huge bandwidth of 400THz as compared to radio-waves in GHz. Moreover, visible light does not have any adverse effect on our body as that of radio-waves. LEDs are perfect candidates for light transmission as they have the property that their intensity can be changed at a very high speed.

2.2 Working of Li-Fi

2.2.1 Modulation-Demodulation

According to Dimitrov et al., (*Clipping Noise in OFDM-Based Optical Wireless Communication Systems*), the system uses Orthogonal Frequency Division Multiplexing(OFDM) for modulating the signals. As shown in the figure, first the transmitting data is mapped to complex symbols X(l) by some modulation scheme

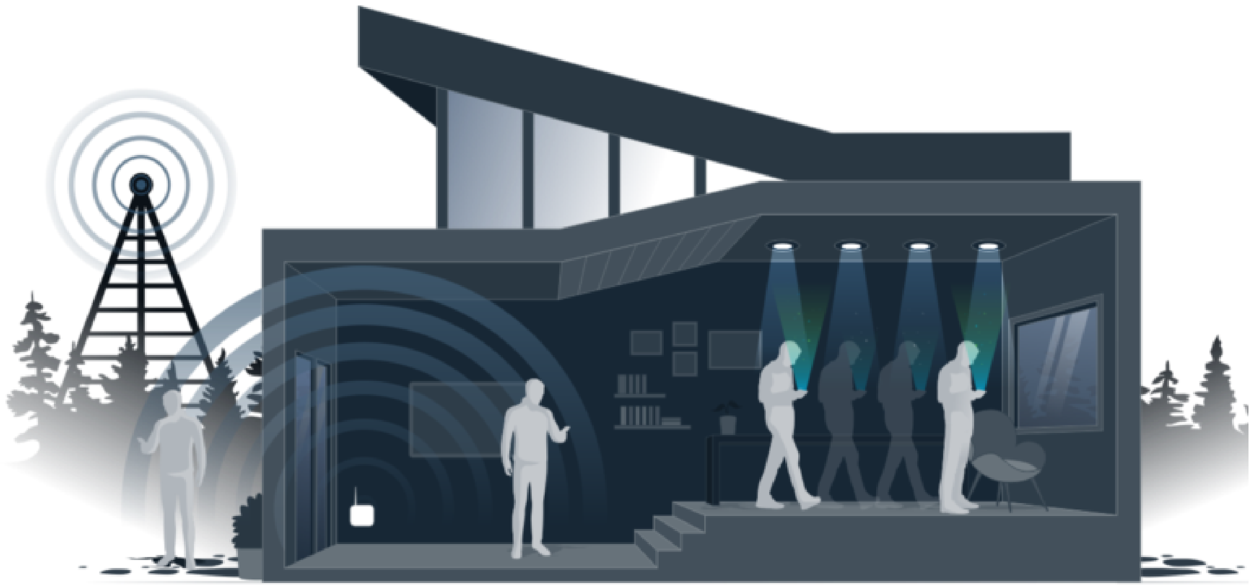

Figure 6: Li-Fi. Source: (pureLiFi, *Light becomes data*)

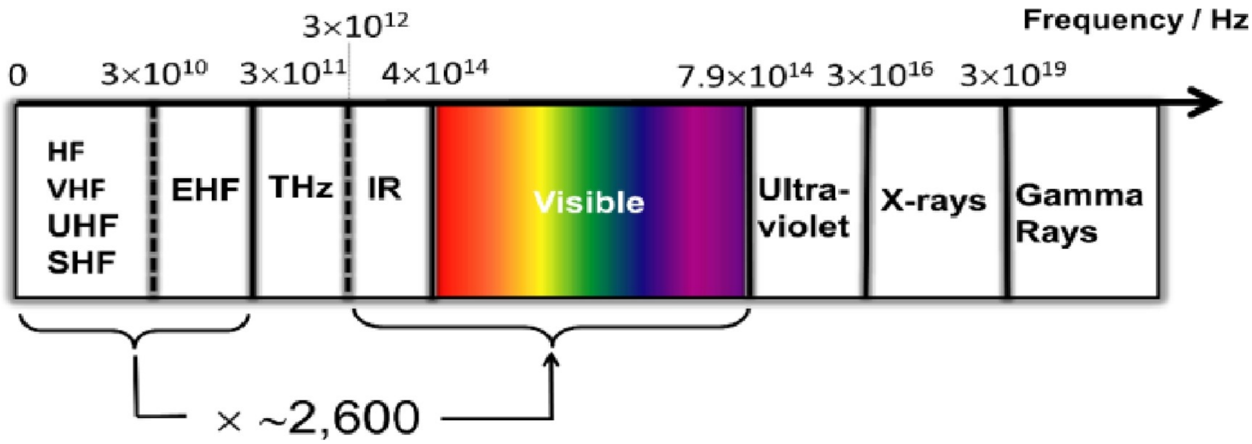

Figure 7: spectrum comparison. Source: (Herald Haas, *LiFi is a paradigm-shifting 5G technology*)

like M-QAM. Then signals are summed using IFFT(Inverse Fast Fourier Transformation). Then signal is guarded after P/S conversion and transmitted through light source.

At the receiver's end, the signals are converted from serial to parallel and individual signals are extracted using FFT(Fast Fourier Transformation). Signals are then demodulated and send to the receiver.

2.2.2 Hardware Requirements

Elgala et al., (*Indoor Broadcasting via White LEDs and OFDM*) states that LiFi requires two DSP(Digital Signal Processor) boards, at transmitter and receiver ends respectively, one LED bulb and a Photo-Diode reciever.
The Electric Signal from the transmitter are first modulated using OFDM by the DSP board, installed between transmitter and the LED. The intensity of the LED to generate the signal is controlled by this DSP.

At the other end, Photo-Diode receiver detects the high speed fluctuations of the intensity of LED. DSP connected to Photo-Diode receiver decodes the OFDM signals and transmits it to the receiver. The fluctuations caused in LED are so fast that it's impossible to detect them by naked eye, and hence serves

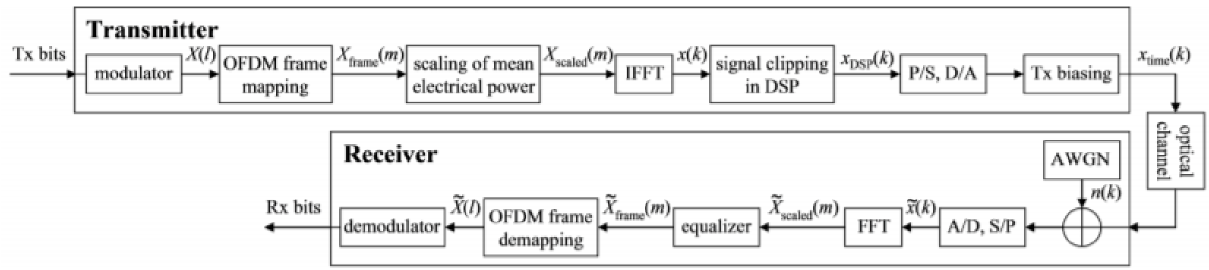

Figure 8: General OFDM. Source: (Dimitrov et al., *Clipping Noise in OFDM-Based Optical Wireless Communication Systems*)

the purpose of normal LED.

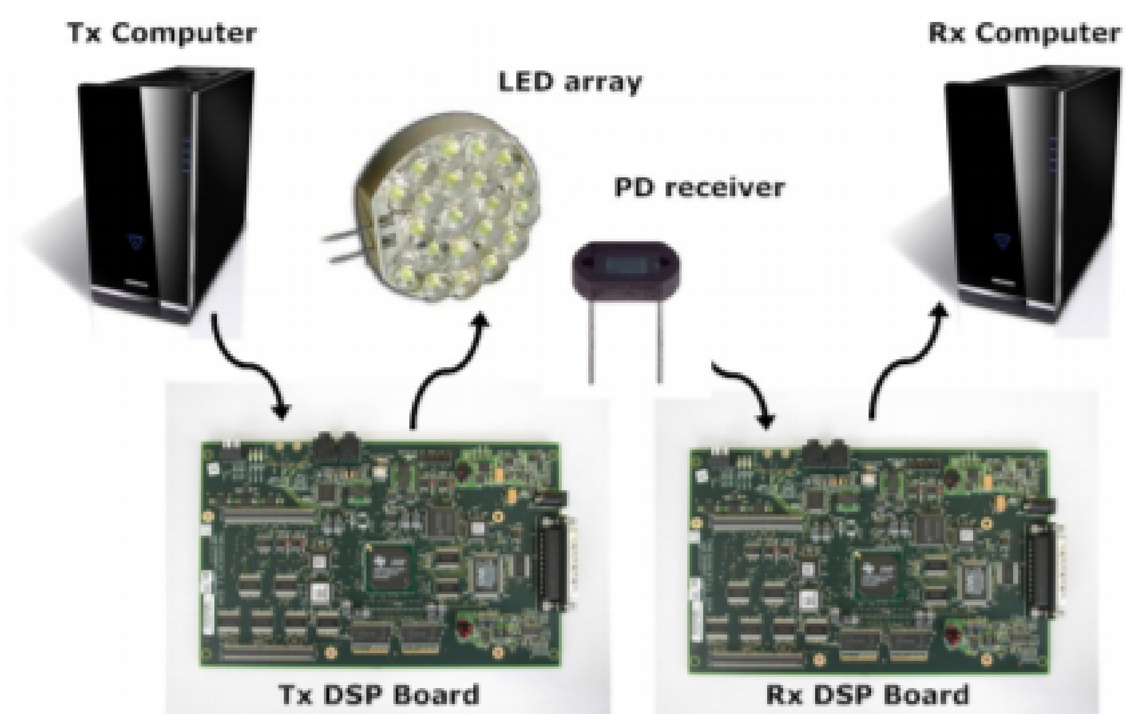

Figure 9: simple OW system. Source: (Elgala et al., *Indoor Broadcasting via White LEDs and OFDM*)

2.3 Advantages

Speed Data transmission speed can reach as high as 224 gigabits per second under light transmission.

Bandwidth The unused bandwidth of 400THz in Visible Light Spectrum can be exploit for transmission.

Cost and Availability There is no issue of initial setup and availability, the LEDs are much cheaper and can be used in place of fluorescent bulbs easily.

Security Light cannot penetrate through walls, and can be localized to the area of operation. Hence, provide secure environment for data transmission.

Efficiency Energy consumption of LED is much less than other artificial light source and there is not much addition energy required for data transmission making it much efficient.

2.4 Misconceptions

It won't work in dark As data is transmitted through light, one can think that we have to switch on the LED always, and we cannot keep the room dark. But these LEDs can be dimmed low enough that it will not be visible to human eye and still can be used for transmission.

It won't work in fog The PD receiver can detect the mere fluctuations from the light source even if there is fog in-between.

It's not bidirectional Li-Fi is a Fully duplex system and networked, hence handover as you move around in space.

Li-Fi doesn't work in sunlight Li-Fi relies on fast change in light intensity, and not on slowly changing natural sources. Various filters can be used to decrease the interference from other sources.

2.5 Global light communication standards

In 2019, IEEE announced formation of 802.11 bb task group which will develop and ratify the Global standard for Li-Fi, opening the doors for the use of technology at global level. The team aims to deliver the standards by mid 2021.

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3 test

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