Ubiquitous Text Transfer Using Sound a Zero-Infrastructure Alternative for Simple Text Communication

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Abstract

Even in these days where data networks has increased much in terms of speed, bandwidth and penetration, the need for a low power, low bandwidth, ubiquitous networks is more pronounced than ever before. As the devices get smaller, their power supply is also limited, in according to the definition of "dust", "skin" and "clay" in the ubiquitous computing paradigm. The possibility of these devices to be present in real world depends a lot on the key capability they must possess, which is to be network enabled, ubiquitously. This paper looks at the possibility of using the ever present signal "sound" as a ubiquitous medium of communication. We are currently experimenting on various possibilities and protocols that can make use of sound for text transmission between two electronic devices and this paper looks at some attempts in this direction. The initial phase of the experiment was conducted using a very large spectrum and encoding the entire ASCII text over audible sound spectrum. This gave a very large spectrum spread requirement which a very narrow frequency gap. The experimental results showed good improvement when the frequency gap was increased.

Keywords

Ubiquitous computing • Network • Text transmission over sound

Introduction

The presence and developments the world is witnessing to the IEEE 802.15.4/Zigbee protocols are clear indications to the direction in which the future of mass-computing is headed. While the power of computing keeps increasing on the desktop PC front more or less in tune with the Moore's law for many decades now, the increase in the scale of VLSM is also allowing devices to be smaller. This allows the concept of "ubiquitous computing" [1] to be a reality whereby it allows the devices to be as small and unobtrusive as required. The concept however shares that this will definitely allow much greater penetration in the market.

This paper looks at using some ubiquitous signal for data transmission. Sound was identified as a very common, easy to generate, low power signal and the attempt is to transfer data using sound frequency encoding [2]. Combining this with the fact that in the modern day environment almost all average (urban) population is exposed to some device that generates or receives sound (the mobile phone being a classic example), makes it an ideal ubiquitous signal.

The first round of the experiment directly converted text into audible frequency with a 3, 5, 7 and 10 Hz gap. Increasing the frequency gap gives very good results, but this caused the spectrum used to be much wider. The paper identifies the capability of using sound for

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T. Sobh and K. Elleithy (eds.), *Innovations and Advances in Computing, Informatics, Systems Sciences, Networking and Engineering*, Lecture Notes in Electrical Engineering 313,
DOI 10.1007/978-3-319-06773-5_32,

simple text transmission between two devices, leveraging the large spectrum of available spectrum of sound frequencies.

The paper is organized as follows. Second section is related works, third section looks at the need and possibilities, fourth section shows the idea and experiments done, fifth section is evaluation and summary and the last section is conclusion.

Related Works

M. Weiser, in 1991 proposed ubiquitous or pervasive computing as technologies those that disappear as they weave themselves into the fabric of everyday life until they are indistinguishable from it [1]. He introduced concepts called tabs, pads and boards which we see in common use in today. Weiser also opens up the networking challenge the nature of the devices will present.

Anil Madhavapeddy, David Scott, and Alastair Tse looked at audio networking as a forgotten technology [2]. They used audio in order to send and receive data and were also able to make use of common computing platforms to achieve high frequency (ultrasonic) communication at low bandwidth.

Chen, T. T., & Lee, M presented a bibliographic study of the Ubiquitous Computing prospect looking at the major research themes and in ubiquitous computing and their inter-relationships [3]. This paper reveals that the majority of the studies relate to basic foundational studies of ubiquitous computing, power aware computing, context aware computing etc.

Jurdak, R., Lopes, C. V., & Baldi, P. discussed an acoustic identification scheme for location systems [4]. The paper looks at the design of using acoustic signals to uniquely identify and locate a user.

Madhavapeddy, A., Scott, D., & Sharp, R. presented context aware computing with sound [5]. The paper presents a variety of location- and context-aware applications that use audio networking including a location system, a pick-and-drop interface and a framework for embedding digital attachments in voice notes or telephone conversations.

Luo, H., Wang, J., Sun, Y., Ma, H., & Li, X.-Y discussed wireless audio sensor networks (WASN) that can provide event detection, object tracking audio stream monitoring etc. the proposed scheme works on improving signal recovering fidelity with low energy costs [6].

Shah, R., & Yarvis, M. presents experiments carried out over on-body networks or body area networks and experiments on how the node location (on the knee, heel etc.) as well as body position (sitting, standing, lying down etc.) affect the connectivity properties in the network [7]. The system looks at the IEEE 802.15.4 radios for the low power networking technology.

Chen, W., Hou, J., & Sha, L. presented a fully decentralized, light-weight, dynamic clustering algorithm for target tracking in wireless sensor networks [8]. The paper's proposed dynamic clustering algorithm effectively eliminates contention among sensors and renders more accurate estimates of target locations as a result of better quality data collected and less collision incurred.

Mandal et al. attempted to makes use of audible sound for indoor positioning based on standard 3D multilateration algorithms [9]. It is able to work with an accuracy of about 2 ft in almost 97 % of the cases using standard cheap consumer use hardware.

Ubiquitous Computing Networks: The Need and Possibilities

Ubiquitous definition makes some devices very small with very limited power supply [12]. The devices may be too small to allow a physical communication interface or ports. Hence it is desirable, even necessary, that each of these devices should be able to connect and communicate with its neighboring devices and/or central concentrators using some wireless technology. The device communication requirements may be limited, ranging from as simple as transmitting its own id to notify the presence of an attached resource to some basic data transfer to begin with. Since the present capability of the communication devices is assumed to be limited, transmission of very large data is not an expectation from the system.

Such a system can be very useful in conditions where a large infrastructure is either not available, not feasible due to economic or technical limitations, or simply for the sake of convenience. Some possible application of the system is in remote locations where large scale infrastructure with very large power requirements may have its own practical limitations. It may also be employed in a crowd to push transfer messages ubiquitously to a selected group of users who may be carrying a decoding device and hence can be useful in large conference type of events. It can be used by shopping malls desiring to advertise the presence of various stores within it along with special offers. They can be employed in hazardous environments [13] like underground mines, expanding it as a zero infrastructure ubiquitous sensor network, can provide much more than life saving critical system, it can be a communication tool for administration and management and even for social networking.

Current wireless networking technologies rely on either microwaves or light as the medium for signal transmission. Microwave technology works by modulating the signals to be transmitted over high speed and high frequency microwaves, which are then relayed between the sender and receiver devices with the help of transponders. This usually requires some amount of infrastructure setup ranging from small Wi-Fi networks to Wi-Max, which can cover major metropolitan areas, and also requires lots of battery power which is required to create the high strength signals. Optics or use of light has been in use for a good amount of time. Classic examples of low bandwidth data transfer using light is the infrared. Infrared is capable of making low bandwidth data transfer in short distances, however with the requirement of a clear line of sight as light only travels in straight lines. This bottleneck imposes serious restrictions in the use of light as a signal for wireless data transmission. This also imposes that the devices are equipped with infrared signal generators and sensors.

Using sound as an alternative can provide us with a low bandwidth, low power alternative to the current signals in use, eliminating the need of any specialized components to be included either generate or receive the signal. The category of devices we are looking to consider is already expected to be equipped with both the speaker and the microphone as essential accessories of the devices. The generation of sound is also not as power consuming as the higher power signals are thus making them more power efficient, but this also restricts the distance the signal can travel. The speed of sound is much slower in comparison to both microwaves and light but this can prove to be sufficient for low-bandwidth solutions requiring the transfer of plain textual character data as experimented in this paper. Current common communications generally does not make use of sound as a signal carrier and hence specific security and reliability considerations needs to be evaluated.

However, one issue to be expected when using ubiquitous signal is the fact that the signals are already present in the environment. This multiplies the effect of noise and interference [11] on the communication. However, the bandwidth being quite high, we can always shift the frequency to a different range to find a quieter band. In any environment we should be able to apply some kind of noise gate to filter out the noises. This will be a major challenge in the presence of "white noise" which contains all frequencies in relatively equal levels. Another issue in using sound is that it creates humanly perceivable signals. This can be disturbing, even unacceptable for some communities. We may be able to work around this by exploring the possibilities of using the sub-sonic and ultrasonic frequencies. Sound on the other hand comes with zero radiation and hence should be a much safer signal for society.

Networking Using Sound: Idea and Experiments

The Idea

The current networking technologies work on microwaves, which are both, high power consuming and non-ubiquitous. More often they require a good amount of infrastructure setup before they can start functioning. In this paper, we are looking at achieving low bandwidth data transfer using sound signals. Sound signals can usually work on very low power, allows a very good control on range by controlling amplitude, and meets the ubiquitous constraints.

The initial attempt is to send plain ASCII text as beeps of varying frequencies. If the frequencies are sufficiently spaced, then any standard microphone can pick up the frequencies. These can then be decoded using standard algorithms such as the Fast Fourier Transform (FFT), which is what we have tried for our experiment [10].

Fast Fourier Transform or the FFT algorithm is a discrete Fourier Transform algorithm that can be used to determine the fundamental frequency of a captured signal. This audio signal is recorded and the FFT algorithm is applied to find the frequencies encoded in the signal. It is used to transform the original audio data into the original text. The FFT exploits the fact that a periodic signal will be similar from one period to the next. FFT algorithm has two sections, first section sorts data in bit reversed order. The second section has an outer loop that is executed log2 N times and calculates, transforms of length 2; 4; 8; ...; N. For each stage of this process, two nested inner loops range over the sub-transforms already computed and the elements of each transform, implementing the Danielson-Lanczos theorem [10]. FFT transform source code by Aleksey Surkov was used in our experiments.

For the first attempt we are looking at encoding ASCII data as sound frequencies. This gives us an effective range of values from 0 to 127. The audible range of sound that can be picked up by a microphone is quite large and hence gives us a good range of frequencies to work with. To keep things simple to start off, we picked up a frequency gap of 5 Hz starting from 500 Hz. The text was encoded using a simple encoding scheme, given as follows:

$$f = (a + sh) * g \tag{1}$$

f: frequency in Hz,
a: value in ascii,
sh: Freq Shift
g: frequency gap between two ASCII codes

"a" is the code in ASCII which we intent to transmit. "f" is the frequency of the encoded data. We apply a frequency shift parameter to be able to move the data transmission band up or down on the audible spectrum. “g” is the frequency step gap, which forms the gap between two consecutive codes.

According to this scheme, the character “A” will be sent as a beep of (65 + 100)*5 = 825 Hz, assuming a 5 Hz gap between each consecutive code. This will use a spectrum ranging from (0 + 100)*5 = 500 Hz to (127 + 100)*5 = 1,135 Hz. If we increase the gap factor, it is expected to give a better accuracy, but will use a larger bandwidth, between 1,000–2,270 Hz.

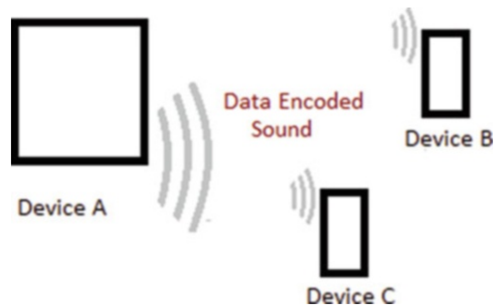

Fig. 1 Block diagram of the experiment setup

Experiment Setup

We used some very commonly available devices for the experiment, some Smartphones and tablet PCs, all running the Android OS. The hardware used included the Samsung Galaxy Nexus running Android 4.1.1 (Jelly Bean), Samsung Galaxy SII running Android 2.3.3 (Gingerbread), Samsung Galaxy tab 10.1 running Android 3.2 (Honeycomb), Toshiba Thrive running Android 4.0 (Ice cream Sandwich) and a very old HTC Magic running Android 1.6 (Donut). All devices were able to participate in the communication dealing with the audio signals with more or less equal clarity.

An application to send text and another one to receive text was created. The send text application will receive plain text user input and convert it first to ASCII, use the function (1) to convert it to the frequency code and then generate the tone as a beep. The receiver application will listen actively and when it receives a tone, it will apply the Fast Fourier Transform (FFT) algorithm to identify the frequency of the tone. The reverse of function (1) is then applied to decode the actual ASCII value, which is then converted to plain text and displayed on the UI screen.

Figure 1 shows the block diagram of the experiment setup where data is encoded as sound and sent from device A using its in-built speakers and received using devices B, C etc. The signal in use is data encoded as sound signals, medium of transmission is air at room temperature. Sound is generated using standard speakers build into the devices and received using standard microphone, also built into the devices. The devices are expected to always ship with these components as standard accessories.

Figure 2 shows the devices used for the experiment, each of them showing the application in the foreground. The data transfer is more of the broadcast nature and therefore when one device transmits data, all listening devices can receive the data.

Figure 3 shows the successful data transfer between the transmitting device and one of the receiving device. The text “TEST” is sent with a 5 Hz frequency step gap and frequency shift of 100. The text is transmitted from Samsung Galaxy Nexus running Android Jelly Bean and received on a Samsung Galaxy SII running Android Gingerbread.

Fig. 2 Experiment setup—the devices

Fig. 3 Experiment setup—data transfer

The success rate in using a larger gap was much higher than if using smaller gap. However this used a much larger

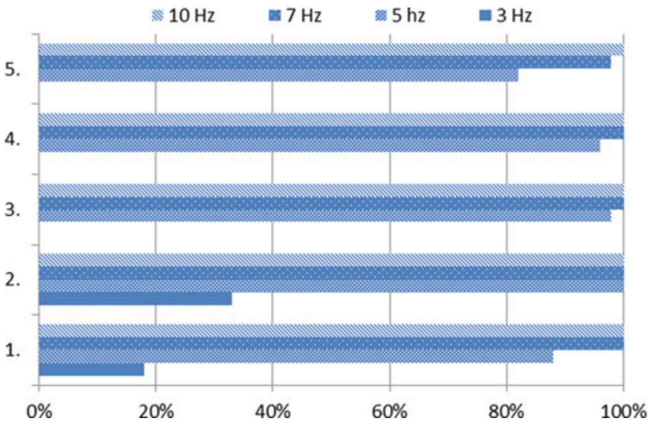

Fig. 4 Chart—comparison of the test experiments

Table 1 Test character transmission results

		Success rate with steps of			
No	Test condition	3 Hz (%)	5 Hz (%)	7 Hz (%)	10 Hz (%)
1.	'A', 'E', 'J', 'O', 'T', 'Z'	18	88	100	100
2.	'0', '5', '9'	33	100	100	100
3.	'A' to 'Z'	–	98	100	100
4.	'0' to '9'	–	96	100	100
5.	Random characters	–	82	98	100

spectrum, making it more susceptible to ambient noise. This was not an issue in the test environment in the lab and will become more prominent in "noisy" environments. This may also be considered as a risk in using a ubiquitous signal, as by definition, the signals are present in the environment and hence more susceptible to noise.

Elementary testing for the data transfer using 3Hz gap caused too many errors to even do an acceptable testing. However, the 5Hz gap gave fairly acceptable success rates to perform a reasonable testing. When the gap was increased to both 7 % and 10 % the errors in transmission of text characters were drastically reduced. The test transmission the above cases are showcased in the following chart.

Figure 4 shows the chart comparing the success for each of the cases in Table 1 in transmission of characters. We can see the success increases when the gap also increases. 7 Hz gap gives very high success. If a good error detection and feedback mechanism can be implemented, then a frequency gap of 5 Hz may also be acceptable, as applicable to the context.

Evaluation and Summary

The experiments effectively establish that it is possible to make use of sound as signal for communication, thought there is a lot of room for precision and improvement. This brings forward sound as a potential ubiquitous signal for low bandwidth communication. The signal also allows fine grained control over distance since the amplitude or strength of the signal determines the travel distance. Furthermore, rooms can be designed to be soundproof to contain the audio signals within defined premises [2].

One possible negative effect of this signal is the noise pollution that widespread use of this technology may create. However, this may be considered far less dangerous than the radiation levels the currently existing mobile infrastructure brings with it to the society. The effect of noise may also be very well addressed using either ultrasonic or infrasonic (sub-harmonic) frequencies, but this may require more specialized hardware which can produce and respond to frequencies in this supersonic or sub-sonic ranges.

The possibility of using this signal in high noise environments still needs to be experimented. As in any signal, presence of noise can cause interference. This is definitely one issue to be anticipated when using signals of the ubiquitous nature as similar signal are expected to be present in the ambient environment. One possible method to circumvent this is by making use the very large range of frequencies that is available in the audio spectrum, wherein we may be able to find a frequency band which is relatively quiet and make use of this band for the communication. This dynamic band for transmission can be identified by the transmitting device and setup between all participating devices.

Sound is therefore a positive candidate as a network communication signal. Some more refinement needs to be brought in before this can be introduced into widespread use.

Conclusion and Future Works

The attempt for a ubiquitous signal for use within a ubiquitous network is still in a very early stage. The current experiments help us understand the capability of sound as a signal for communication. We were able to successfully send out a text encoded sound. This data was received by all capable devices used for the experiment. The devices were all running on the Android platform, but were all of different capacities and form factors ranging from a smart phone more than 3 years old to the latest and relatively much faster 10.1 in. tablet pc, from an old version (Donut) to the latest version (Jellybean) of the Android OS. Each of these devices were able to handle the text transfer with ease, proving that the technology can be deployed with relative ease, subject to good development and establishment of the communication protocol.

This work still requires more experimentation, evaluation and establishment of a workable and practical protocol. Future work in this area will focus on experimenting further to identify efficient communication strategy. The performance for this in various ambient conditions, including "noisy" environments, will vary and detailed study in this realm is called for before this can emerge as a workable practical protocol for everyday use. Once established, this has the potential to emerge as a low cost, low bandwidth, short distance communication medium.

Acknowledgments We thank Aleksey Surkov for the source code which uses FT for pitch detection. The source code was available at http://code.google.com/p/android-guitar-tuner/source/browse/#svn%2Ftrunk%2Ffft_jni

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