# Capturing and Transferring of Acoustic Information in a Closed Room via Wireless Acoustic Sensor Network

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*Abstract* – **Recent researches and discoveries in acoustic sensors and acoustic sensor networks provide many opportunities for explorers and engineers to create new sensing systems and to improve the existing ones. There are a lot of applications including noise pollution monitoring, acoustic calibration of closed rooms, search missions, environment monitoring, accident detection etc. But these networks are different from the classical wireless sensor networks because of their characteristics. It is a challenge to combine a low-energy and less complicated protocols for data transfer and processing of acoustic information with the privacy of the data and a secure communication. To find a solution of this issue it is necessary to develop efficient algorithms. The main task of one acoustic sensor node is to detect acoustic signals from different transmission points or in various receiving points and to provide the needed information for an acoustic environment analysis. The aim of the article is to develop a methodology for measuring test audio signals at multiple points in an enclosed space using a wireless acoustic sensor network. The captured test audio signals should be transmitted to a computer (server of the wireless acoustic sensor network) for the purpose of their processing and analysis for determination of the acoustic parameters and the acoustic picture of the closed room.**

*Keywords* – **capturing sound, transferring files, Internet of Things, wireless acoustic sensor network, acoustic sensors**

## I. INTRODUCTION

A several acoustic capturing and processing systems have been developed over the last years, but all of them rely on complicated computing configurations and expensive microphones arrays. The microphone arrays have a better performance than single-microphone networks, but some difficulties arise from the fact that the position of the microphones tend to be fixed, and all the acoustic data processing is performed on a centralized processor. But single-board computers have increased the capabilities of the wireless sensor networks. The focus is on acoustic signal capturing and processing. This makes the sound a useful source of information. In different scientific fields there is a necessity of capturing acoustic information in closed rooms. Such a development is self-deployable indoor localization, where a VA assisted asynchronous acoustic-based localization system is developed [1]. One of the issues is that current approaches have much latency to obtain a location fix, making it infeasible for mobile target tracking. One of the solutions of this problem is registering more acoustic data in many different points. Another area of research is developing an advanced acoustic sensor network for noise monitoring [2]. The main aim in this work is analysis and monitoring of the whole audio signal in the audible bandwidth. There are similar issues in the following three articles too: “Acoustic event localization on an Arduino-based wireless sensor network” [3], “Wireless Sensor Networks and Audio Signal Recognition for Homeland Security” [4] and “A Low-Cost Wireless Acoustic Sensor for Ambient Assisted Living Systems” [5]. Because of that in this thesis it is described an alternative- an acoustic sensor node, which is low-cost and independent in terms of localizing and transferring data. This acoustic sensor node has many advantages- it is wireless, less expensive, energy efficient, with option for battery-powered or wire-powered. It can be placed wherever needed and to be connected in network. That allows using many sensors to cover a large area of interest. In this system are used many methods and algorithms. As described in my previous article “Acoustic Sensor Network for Acoustic Measurements in Closed Rooms”, most of the measuring methods that exist depend on three types of physical variables derived from sensor readings: time delay of arrival (TDOA), direction of arrival (DOA) and received signal strength (RSS). Energy (intensity) based method is an appropriate choice and has been studied intensively in recent years since it can reduce the computation burden as well as communication bandwidth. One controversial concept is the usage of A-weighted measurements. There are studies putting forth the pros and cons of using this weighing. Another important factor is the sonic environment and how to characterize or analyze it. Criteria that should be included are mainly, the ambient noise present in the space, the separate noise sources, the nature of each different source or sound, the number or presence and the weight of sound sources and the history of the sound environment. Such factors should be handled in close contact with the objective factors as both objective and sonic factor guide and give clues about one another [6]. The main objective of the article is to research some methods for measuring test audio signals at multiple points in a closed room via wireless acoustic sensor network. The registered acoustic information needs to be transmitted to the server of the wireless acoustic sensor network in order to be processed for the needs of the study of the acoustic parameters and the acoustic picture of the closed room.

## II. DESCRIPTION OF THE DEVELOPED BLOCK SCHEME OF WIRELESS ACOUSTIC SENSOR NETWORK FOR CAPTURING AND TRANSFERRING OF ACOUSTIC INFORMATION IN A CLOSED ROOM

In figure 1 is presented the block scheme of the experimental staging- wireless acoustic sensor node for acoustic measurements in closed rooms and multiple test sound generators, which were developed for the needs of the experiment.

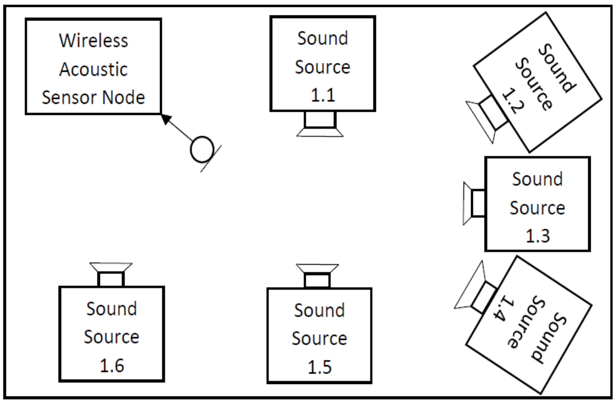


Fig. 1. Block scheme of the experimental staging- wireless acoustic sensor node for acoustic measurements in closed rooms and multiple test sound generators.

This block scheme contains two main parts- “Wireless Acoustic Sensor Node” and a “Sound Source” (Fig. 1). The “Sound Source” produces a test audio signal, which is captured by the “Wireless Acoustic Sensor Node”. There are several sound sources (Sound Source 1.1, Sound Source 1.2, Sound Source 1.3, Sound Source 1.4, Sound Source 1.5, Sound Source 1.6), because the experiment requires recording test signals from different points in the closed room. The acoustic sensor node has a single-board computer, which is connected to a wireless network, and a microphone. The node saves all the received acoustic data in audio files. These files are stored in the memory of the single-board computer. Because of the wireless connectivity, it is possible to access the saved audio files and to transfer them into a wireless acoustic server, where they will be processed. In this article it will be shown how this system works in real conditions. In the next part is presented the capturing of sound signals, created from different sound source in multiple locations.

## III. EXPERIMENTAL RESULTS FROM ACOUSTIC INFORMATION CAPTURING IN A CLOSED ROOM VIA WIRELESS ACOUSTIC SENSOR NETWORK

Based on previous studies, it was established an acoustic sensor node. This node and all the experimental work are done in laboratory 1258- ”Audio Systems”, located in Technical University- Sofia (Fig. 2, 3). The core of this node is a single-board computer- Raspberry Pi 4. It gives the opportunity to run specific programs in “Python” or “C” programming languages and also has a Matlab support.

To proceed the capturing, it is needed a sound source. In this case it is a configuration of RC signal generator and guitar amplifier (Fig. 2). This generator transmits seven test tones from seven different locations in the closed room, while the acoustic sensor node is static. Before every of the seven measurements, the sensor node starts the capturing programme.


Fig. 2. Sound source

The capturing of an audio signal is achieved with the following source code, created on “Python”:

```
import pyaudio
import wave
form_1 = pyaudio.paInt16 # 16-bit
resolution
chans = 1 # 1 channel
samp_rate = 44100 # 44.1kHz sampling
rate
chunk = 4096 # 2^12 samples for buffer
record_secs = 5 # seconds to record
dev_index = 2 # device index found by
p.get_device_info_by_index(ii)
wav_output_filename = 'test1.wav' # name
of .wav file
audio = pyaudio.PyAudio() # create
pyaudio instantiation
# create pyaudio stream
stream = audio.open(format = form_1,rate
=
samp_rate,channels = chans, \
                    input_device_index =
dev_index,input = True, \

frames_per_buffer=chunk)
print("recording")
frames = []
# loop through stream and append audio
chunks to frame
array
for ii in
range(0,int((samp_rate/chunk)*record_secs
)):
    data = stream.read(chunk)
    frames.append(data)
print("finished recording")
# stop the stream, close it, and
terminate the pyaudio
instantiation
stream.stop_stream()
stream.close()
```

```
  audio.terminate()
  # save the audio frames as .wav file
  wavefile = wave.open(wav_output_filename,'wb')
  wavefile.setnchannels(chans)
  wavefile.setsampwidth(audio.get_sample_size(form_1))
  wavefile.setframerate(samp_rate)
  wavefile.writeframes(b''.join(frames))
  wavefile.close()
```

The main features in this code are that it can be set how long to record, how to name the saved file, setting up the sample rate and audio channel.

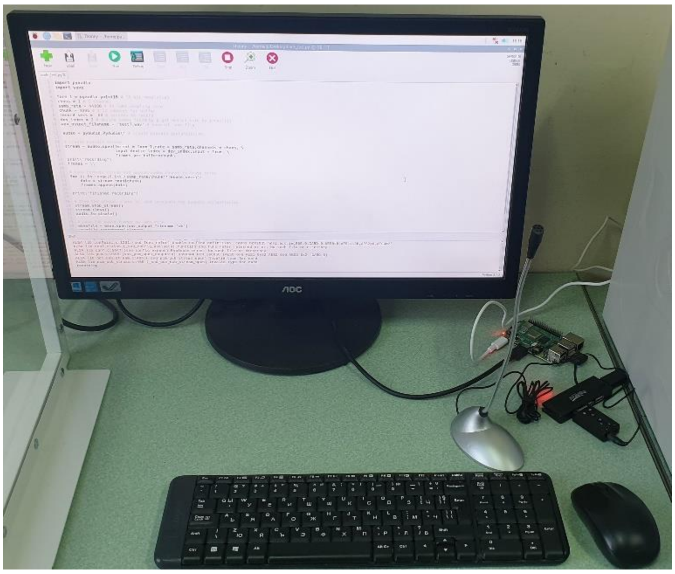

Fig. 3. Experimental staging

When the code starts running, it turns on the microphone of the acoustic sensor node and starts recording (Fig. 3). After the program ends, it turns off the microphone and saves the audio file in the memory of Raspberry Pi 4 (Fig. 4). The saved audio files are in format "WAV". This is useful for the future work of processing the acoustic information in these audio files in our next article.

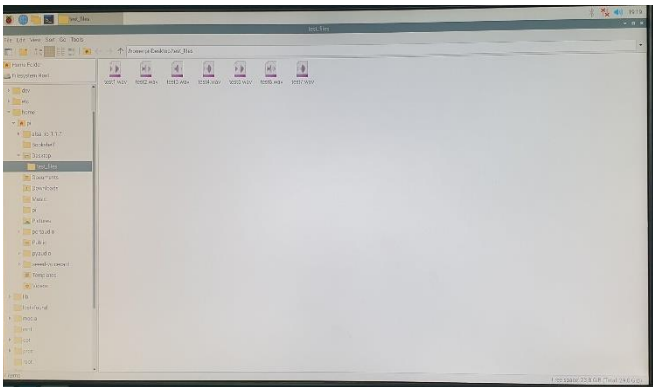

Fig. 4. Saving the captured acoustic signals

In the next section it is shown the transfer of acoustic information in a closed room via wireless acoustic sensor network.

## IV. EXPERIMENTAL RESULTS FROM ACOUSTIC INFORMATION TRANSFER IN A CLOSED ROOM VIA WIRELESS ACOUSTIC SENSOR NETWORK

The transfer of sound files from Raspberry Pi 4 to the Acoustic server is done with the help of a program called "WinSCP". This software is an open-source FTP, SFTP, SCP, WebDAV client for Windows. Its main use is file transferring between a remote computer (Raspberry Pi 4) and a local computer (Server). WinSCP has also scripting option and a file manager functionality [7].

WinSCP is installed on the server. It connects to acoustic sensor node after filling the login dialog with the correct for the node host name, user name, password and port number (Fig. 5).

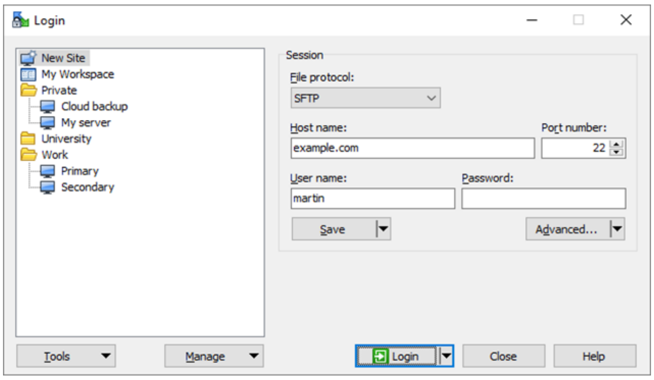


Fig. 5. Login Dialog

After the connection between the Server and the acoustic sensor node is ready, WinSCP opens a new window with the directories of the two devices (Fig. 6).

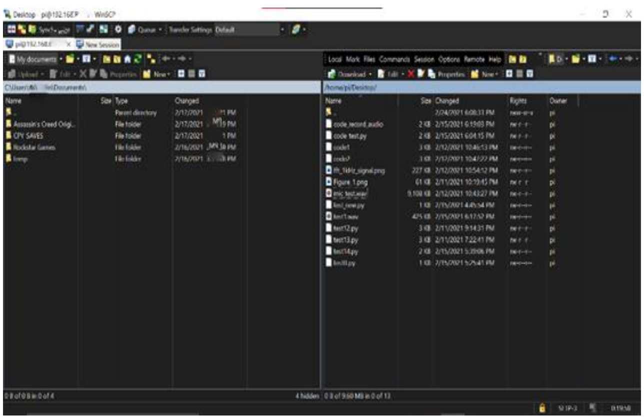

Fig. 6. User interface of WinSCP software, installed on the server, connected to Rasp berry Pi 4.

In Fig. 6 is presented a user interface window of WinSCP. On the left side is the directory of the Server and on the right is the one of Raspberry Pi 4.

It is very easy to change or copy the needed files from the remote computer to the Server. It is only necessary to set the transfer option from the transfer option window of WinSCP (Fig. 7).

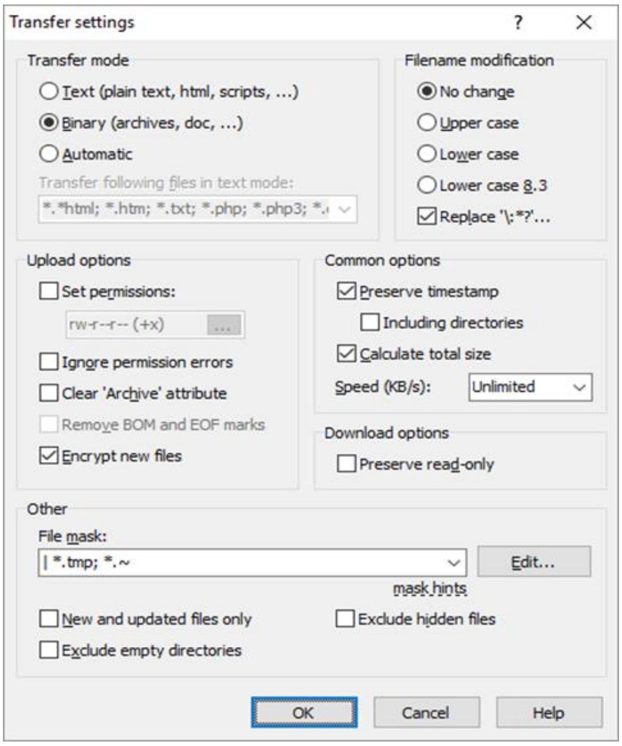


Fig. 7. Window for Setting Transfer Options.

In this window we can set "Transfer mode"- what type of file to transfer (text, binary or auto), "File name modification"- how to change the name of the file, "Upload options"- to set permissions, encrypt or not new files or to clear the "Archive", etc.

After setting up the "Transfer mode", the files are ready to copy and transfer.

## V. CONCLUSION

The following conclusion can be listed: the developed wireless acoustic sensor network for capturing and transferring of acoustic information in a closed room works good as it seems from the experimental work. The communication between the devices is stable and secured. The program for the recording works without errors and the transfer is easy. The captured acoustic signals are saved in "WAV" format and will be used for generating an acoustic 3D picture of a closed room- the laboratory. In next papers it will be shown how to process the audio information using different audio processing algorithms and filters. This part will be done in Matlab because this software has the necessary libraries for the study. It will be used spectrum analyzer, array plotting, measuring average power, attenuation and variance of the test signal and some of the signal processing algorithms like FIR (Finite Impulse Response), FFT (Fast Fourier Transform), LMS (Least Mean Square), etc. After all the processing an acoustic 3D picture of a closed room can be done. The proposed methodology for measuring test audio signals at multiple points in an enclosed space using a wireless acoustic sensor network has been experimented for a small number of points (seven) of measurement of test audio signals in order to demonstrate its proper operation and to create opportunities for the use of the transmitted test audio signals to a computer (server of the wireless acoustic sensor network) as a basis for experiments in their processing and analysis to determine the acoustic parameters and the acoustic picture of the enclosed space. In actual use of the proposed methodology for measuring test audio signals at multiple points in a closed room using a wireless acoustic sensor network, it is recommended that the number of test audio measurement points be significantly higher to ensure sufficient accuracy of determining the acoustic parameters and the acoustic picture of the closed room. The topic of the article is not related to quantitative assessment. The experimental results are presented in graphical form.

## ACKNOWLEDGEMENT

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