Local Packet Detection in SDR based IoT Gateways

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***Abstract*—The aim of the first deliverable is to understand the devices and to receive the sampled signal into a file using RTL-SDR. Implement the Energy based detection and Correlation based approach in C Language to detect the actual signal.**

I. Introduction

Software Defined Radios (SDRs) are the devices that can be tuned to retrieve wireless signals from a particular frequency band. SDRs have the flexibility to retrieve any wireless signal arriving at a particular frequency, irrespective of its technology, modulation scheme, bandwidth etc.

The project envisages to make a gateway radio receiver using SDR and Raspberry Pi and forward the received data to its connected network. Wherein the RTL-SDR can be made to tune in to any given frequency/signal and send the signal to the network. This will enable it to act as a one-for-all receiver device that can be used to detect any signal.

The first part of the project was to implement the C Code to detect the signal using two different methods that are effective in their own domain. Retrieving the entire bit stream and forwarding them as it is to the network is not an efficient way and will have network overheads. Hence the signal has to be detected in the Raspberry Pi device and only the signal part should be sent to the network. In addition, RTL-SDR enables us to get the sampled signal to be saved into a local file, from which the signal can be detected using appropriate technique. The final outcome is to detect the signal in real-time and send the same to the network.

Every signal has got its specific characteristics and the detection techniques must customize the approach to effectively detect them. For the first deliverable, LoRa transmitter was used and the detection algorithms were tweaked to get the desired results.

The signal detection methods used are Energy based detection and the other is Correlation based detection. In energy-based detection, the entire signal stream is monitored against varying power levels. The points where the power is higher is considered to be signal while the rest is discarded as noise. The more efficient method which shows better noise resilience is correlation based approach. Here the entire signal is correlated with the preamble of the wireless packet to identify the signal position. The correlation is done by comparing the sum of products of the received signal and the original preamble.

II. First Deliverable

A. Aim

Implement a basic signal file retrieval over the RTL-SDR and send it to laptop. Implement a C-code that can perform energy-based detection on the file retrieved. Find the preamble of the transmitted signal and implement a correlation based detection in C.

B. Outcomes Expected

Show the performance of the two algorithms across varying levels of transmit power from the transmitter device. Compare the efficiency of the detection algorithms in terms of error in detection.

III. Procedure And Steps Followed

A. Preparation

First hand understanding of the signal characteristics is important to start with the signal detection. The team studied the signal characteristics using the following devices and software:

- LoRa Transmitter (SX1276)
- RTL-SDR Radio Receiver (RTL2832U)
- MATLAB 2018a

Fig. 1. LoRa Transmitter Module

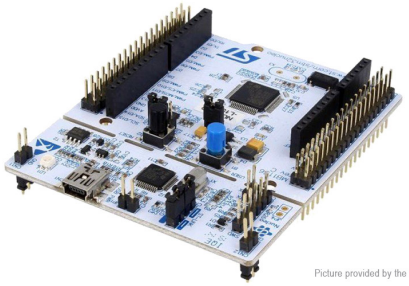
LoRa is the signal transmitter used in this project. The RTL-SDR device was used to receive the LoRa signal, sample the received signal and save it in a .bin file. For this, the SDR has to be provided with the frequency, bandwidth of the signal and the number of samples to be taken. Sampled signal file can be plotted using MATLAB thereby enabling us to view the signal in time domain.

B. Set-Up

The transmitter device was set to transmit signal at minimal power as the detected signals were getting clipped off due to the high power. Online embedded compiler (mbed) was used to make changes to the transmitter device settings. The preamble of the signal was also changed as per project requirement. The preamble to be detected will have 14 symbols with each symbol of 2048 sample size. Out of the 14, 10 symbols will be up chirps and the last four symbols are the start delimiter. The start delimiter has 2 x Up chirps and 2 x down chirps.

Fig. 2. Raspberry Pi Device

Fig. 3. Nucleo Module



C. Energy Based Detection

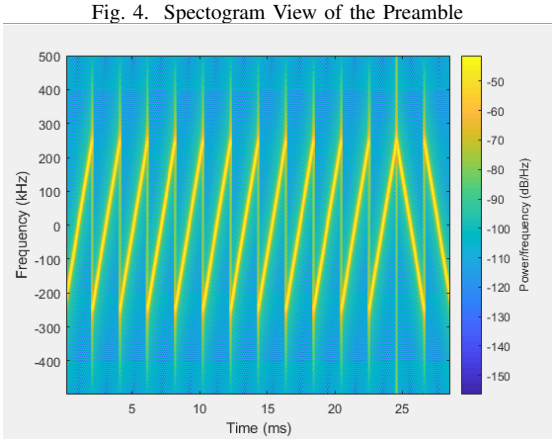
The sampled signal data by the SDR is a raw data in binary format which has to be read and converted into complex number format by reading 8bits at a time. First eight bits represent the real component and next eight bits represent the imaginary component of the complex number. The real numbers of the sampled data can be easily plotted in MATLAB to study the signal characteristics.

Energy based detection uses a sliding window checking of the sampled received signal to locate the desired signal. In every iteration, the average amplitude of all samples of the window is maintained and the same is compared with the next window. If the ratio of two consecutive window crosses a particular threshold then it can be assumed that the signal is present in that particular window. Setting a threshold for this detection requires repeated testing of the various samples of the signal. Though the energy-based detection was able to detect the signal in the samples where the power of the signal is higher than the noise level, the same was prone to errors when the noise levels were high and equal to the signal power. The output of the energy-based detection is given in succeeding paras.

D. Correlation Based Detection

A more advanced and better way to detect the signal is to correlate the original preamble of the signal with the data of the received signal. The LoRa transmitter was programmed using the mbed online compiler to transmit using a preamble of 14 symbols length with each symbol of 2048 sample size. Each preamble has 10 up chirps and a start delimiter. The start delimiter has two up chirps and two down chirps. Visualization of the preamble was seen using the spectogram package in Matlab. The same was compared with the original signal to identify the difference. Screenshot of spectogram view of the preamble is given below.

Fig. 4. Spectogram View of the Preamble



The received is signal is correlated with the original preamble of the signal to detect the starting point of the signal. Whenever a preamble is detected then the following sequence of data before the next preamble is the data. Here a window size of the size of the preamble (2048 x 48 symbols) was used. For every iteration the correlation value (sum of products of both the signal and the preamble values) is calculated and the ratio is checked for a threshold. If it crosses the threshold then signal starting point is identified. Otherwise the window is shifted by one sample to repeat the same procedure. The received signal was normalized and demean was calculated to make the correlation work effectively.

IV. Trials and Observations

A. Efficiency of Detection Algorithms

The efficiency of both energy based detection and correlation based approach was tested using various signals samples of various power outputs. Distance of the transmitter and the receiver were also altered to test both the methods. Though the energy based detection was fast enough to detect the signal in the sample were the signal power was higher than the noise. But it was facing issues in detecting signal in a

noisy environment/low power signal. On the other hand, the correlation based approach was able to exactly identify the starting point of the signal in all the environment. The details of the results of the algorithms is given below:-

TABLE I
SIGNAL DETECTED BY BOTH ALGORITHMS

S.No	Actual Number of Signals Present	Detected	
		Energy Based	Correlation
High SNR			
1	2	2	2
2	2	2	2
3	3	3	3
4	2	2	2
5	3	3	3
Low SNR			
1	3	3	3
2	2	2	2
3	3	5	3
4	3	6	3
5	2	6	2

Fig. 5. Signals Detected in High SNR Condition

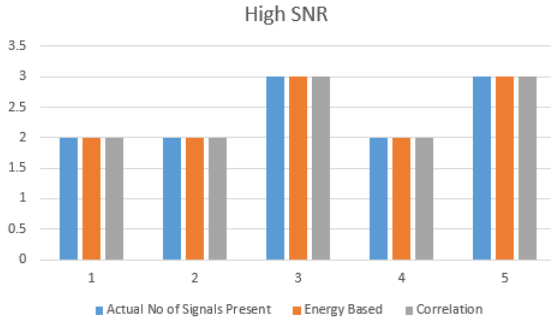
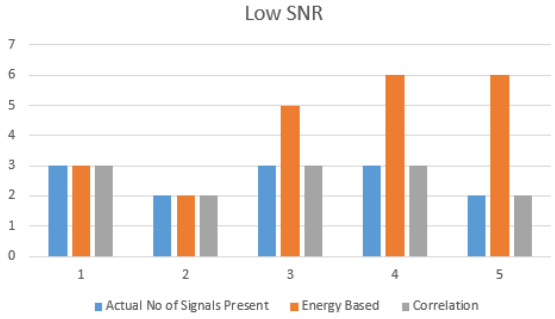


Fig. 6. Signals Detected in Low SNR Condition



B. Observations

1. The energy based detection was able to detect the signals in a low noise environment and it has become erratic in noisy environment. However, the correlation based approach was able to detect the signal presence in both the environments.

2. The starting point of the signal detected by energy based detection was off-shoot from the actual starting position by around 500-700 samples. However, the correlation method was able to detect the correct starting point of the signal.

3. Due to the large number of computations involved in the correlation based approach, the program took more time than energy based method. The same has to be improved to make it work in a real-time environment.

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