Audio Analysis Using Edge Computing for Road Side Assistance Systems

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***Abstract*—Although Cloud Computing remains de-facto solution for IoT data processing, Edge Computing (EC) has started to gain its ground. EC systems are closer to devices generating various data types (audio, video, text etc.) and have capabilities to provide quick data validation and analysis. This paper explores one such application of EC for audio analysis in road side assistance services. A noise cancellation algorithm running in the EC system is described. A prototype of the overall scenario is developed and reported.**

***Keywords*-Audio Analysis; Edge Computing; Internet of Things; Road Side Assistance.**

I. Introduction

The current Cloud centric IoT paradigm is challenged when diverse and real time applications and services need to be supported [1]. Edge Computing [2], [3] is becoming popular in this context since it offers IoT data processing capabilities at the edge of the networks. This is due to several reasons including - (i) no round trip delay for IoT data processing, (ii) saving network bandwidth and (iii) quicker reaction through actuator communications.

In our previous work [4], we introduced an IoT architecture for road side assistance services. Following research and engineering problems were addressed - (i) current road infrastructure centric approach, (ii) cloud based services, (iii) lack of consumer centric design and (iv) seamless interoperability of consumer devices & software platforms. We presented an IoT architecture that is data centric and can solve the mentioned challenges. This paper extends the architecture enabling audio analysis at the Processing and Storage Layer which is the actual Edge Computing component in Fig. 1 It also extends the capabilities of our IoT architecture.

The EC implementation is based on a decentralized implementation and deployment of nodes placed very close to the Road Side devices. These nodes are heterogeneous in nature and can include routers, access points, IoT gateways among others. The heterogeneity is actually hidden from Road Side devices and client seeking assistance through a unified EC abstraction layer. It exposes a set of interfaces for discovery, resource monitoring, security, data processing etc.

II. Noise Cancellation and Audio Analysis

For the Edge Computing system used in road side (RS) assistance, the speech signal is acquired at the RS by one

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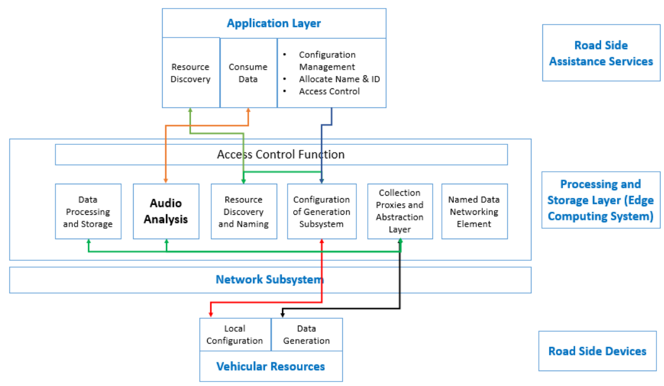

Fig. 1. Edge Computing architecture.

or two directional microphones. The noise reference (7th column), when estimated, that means is the actual noise, is acquired at the RS by one omni-directional microphone. The first two microphones are oriented towards the speaker and away from the road. The latter is oriented away from the speaker and towards the road. In this work, noise cancellation for audio analysis is done based on the Least Mean Square (LMS) algorithm.

The LMS adaptive filter uses the noise signal on the reference input port and the clean speech signal on the primary input port to automatically match the adaptive filter response [5]. As convergence of the adaptive filter, the noise is subtracted and the error signal should contain only the clean speech signal. Fig. 2 illustrates the basic principles of adaptive noise canceling. The input to the adaptive filter is a noise signal n_0 that is highly correlated with the additive disturbance, n, but is uncorrelated with the clean signal s. The reference signal n_0 is filtered to produce the output n̂ that is an estimate of the additive noise n. This output is then subtracted from the noisy signal s+n to produce the system output ŝ. Adaptive noise cancellation using LMS algorithm with two microphones is performed in this project and is depicted in Fig. 3.

III. Use Case and Prototyping Experience

The audio analysis at the Edge Computing system is used in a road side assistance service use case. It is drawn in Fig. 4.

The audio device placed at road side (RS) is affected by quasi-stationary traffic noise and the speech intelligibility

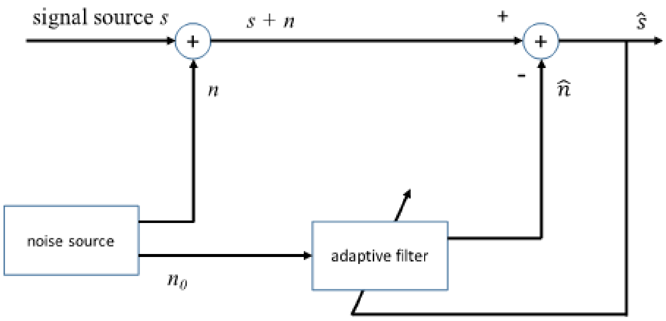

Fig. 2. Adaptive noise cancellation.

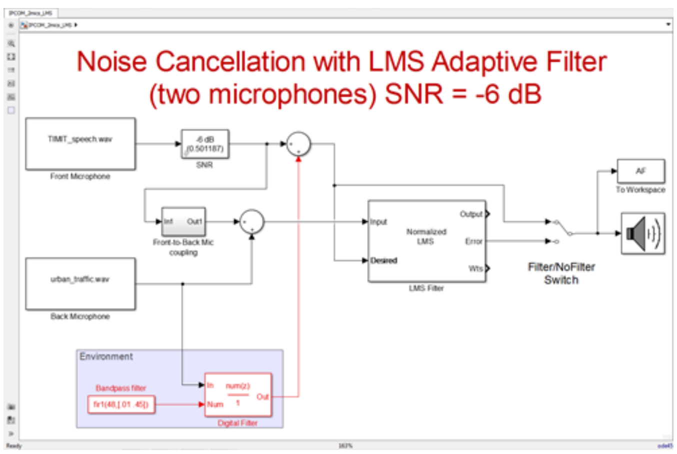

Fig. 3. Noise cancellation LMS algorithm with two microphones.

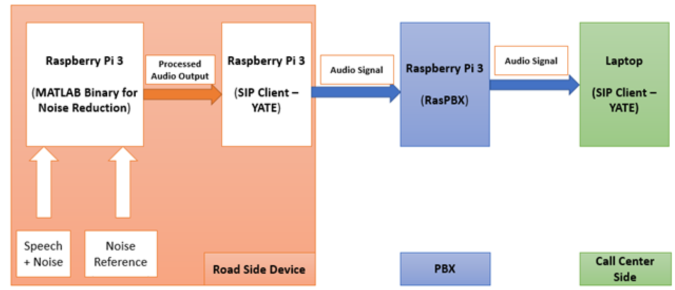

Fig. 5. Road side assistance service prototype.

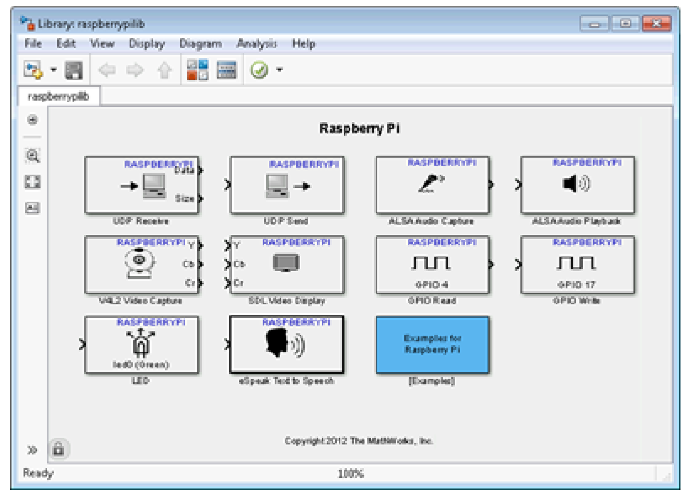

Fig. 6. Simulink open block library for Raspberry Pi.

(from a client seeking assistance) can be worsened. The Audio signal that is transmitted to the call center (CC) can be entirely or partly degraded. Therefore audio analysis in the form of noise reduction or speech enhancement is necessary to safeguard all such communications.

A prototype (depicted in Fig. 5) is developed for the above use case. In the prototype, the Road Side device is composed of two Raspberry Pies, another Raspberry Pi is used as a PBX and a laptop computer is used as a Call Center Side device that receives the call from client. The Edge Computing System is the RS device where desired noise cancellation and audio analysis takes place. The first Raspberry Pi includes two microphones that capture (i) speech (originating from a client making a request) and road side noise and (ii) noise reference. A MATLAB code is developed for noise reduction. The MATLAB binary produces a processed audio output that is fed to the audio input of second Raspberry Pi.

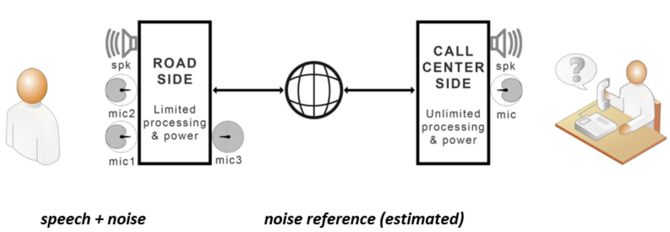

Fig. 4. Road side assistance service use case.

A. Simulink Support Package for Raspberry Pi

A Simulink Support Package for Raspberry Pi supports algorithm development in Simulink, a block diagram environment for modeling dynamic systems and developing algorithms, and running them standalone on a Raspberry Pi. The support package extends Simulink with blocks for configuring the Raspberry Pi, sending and receiving UDP packets, and reading and writing data from sensors. A Simulink model, can be used for algorithm simulation and parameters tuning and also allows completed algorithms to be downloaded for standalone execution on the device. Fig. 6 shows the Open Block Library for the Raspberry Pi. This block library provides support for protocols and APIs available through Raspberry Pi hardware. In particular, Advanced Linux Sound Architecture (ALSA) drivers are ready-to-use to enable audio analysis on the board.

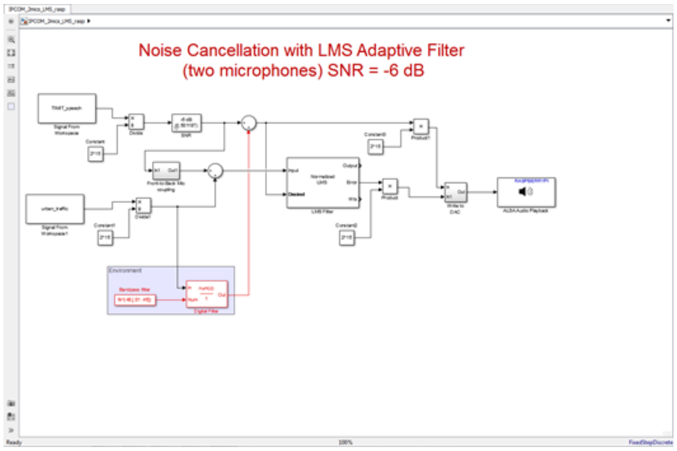

Fig. 7. LMS adaptive filter system on Raspberry Pi.

B. Deploy and run LMS adaptive filter system on Raspberry Pi

To deploy and run the LMS adaptive filter system (depicted in Fig. 7) on a Raspberry Pi we have to replace the internal audio block with the loudspeaker symbol, with the on-board Raspberry Pi audio (ALSA Audio Playback). Moreover, to write to DAC, we must convert the sample from double to int16. The LMS algorithm works well on this board. The CPU load average is in the value of 60%.

A SIP Client, YATE is used to communicate the audio signal to the Call Center. A Raspberry Pi is configured as PBX to transmit the client voice signal using (i.e. the processed audio) Asterisk. For the Call Center Side, a laptop computer running MS Windows is used. The same SIP client (YATE) is used to receive the call. For prototyping, the Road Side & Call Center Side devices and the PBX are configured to be in the same network.

We have experimented the prototype with the noise reduction MATLAB binary and without that. Audio quality is significantly higher in the first case validating the overall system.

IV. Conclusion

This paper explains that audio analysis is possible on Edge devices. We have described a noise reduction mechanism applicable for a road side assistance system. A prototype of the overall use case scenario is developed to validate the noise cancellation algorithm. As for future work, we will measure the power consumption of the hardware systems and measure real time aspects of the prototype.

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