Internet of Things Acoustic Emission: Systems and Applications

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Abstract Internet of Things Acoustic Emission (IOT AE) was developed and introduced in hardware, software and network structure. IOT AE transmits the data and analysis results to the network server through the Internet/intranet. The analysis results can go to the end user's smart phones and PCs as alarm info. Users don't need the acoustic emission technicians to operate IOT AE. So IOT AE can be used as remote long-term unattended monitoring and automatic alarm system. Compared with traditional acoustic emission instrument which needs to process the data manually to get the detection and monitoring results, IOT AE control the data acquisition and data analysis by embedded software automatically. Besides the long-term cycle of self-learning correction of artificial intelligence based on big data on the server makes the system have the ability of self-learning, self-improvement and continuous improvement of performance.

This paper introduces the IOT AE systems developed and discusses the application of IOT AE technology of monitoring and alarming for valve leakage, wire rope breakage and tool wear, etc..

Index Terms Acoustic Emission, Internet of Things (IOT), remote monitoring, unattended, alarm

1 IOT AE System Introduction

1.1 Architecture of IOT AE monitoring and alarm system

IOT AE system consist of AE sensor, AE data acquisition and data analysis module (AE module), internet/intranet communication module, server/smart phone/PC. Firstly, the AE sensor installed on the monitoring object (valve pipeline, bridge steel cable broken wire, CNC machine tool, etc.) collects signals, and converts the tiny mechanical vibration signals into voltage signals. Then the AE module processes the voltage signal and outputs the results (alarm info, AE waveform and AE hit parameters). The outputs of the AE module are transmitted to the server/smart phone/PC by internet/intranet communication module.

The system architecture is shown in Figure 1

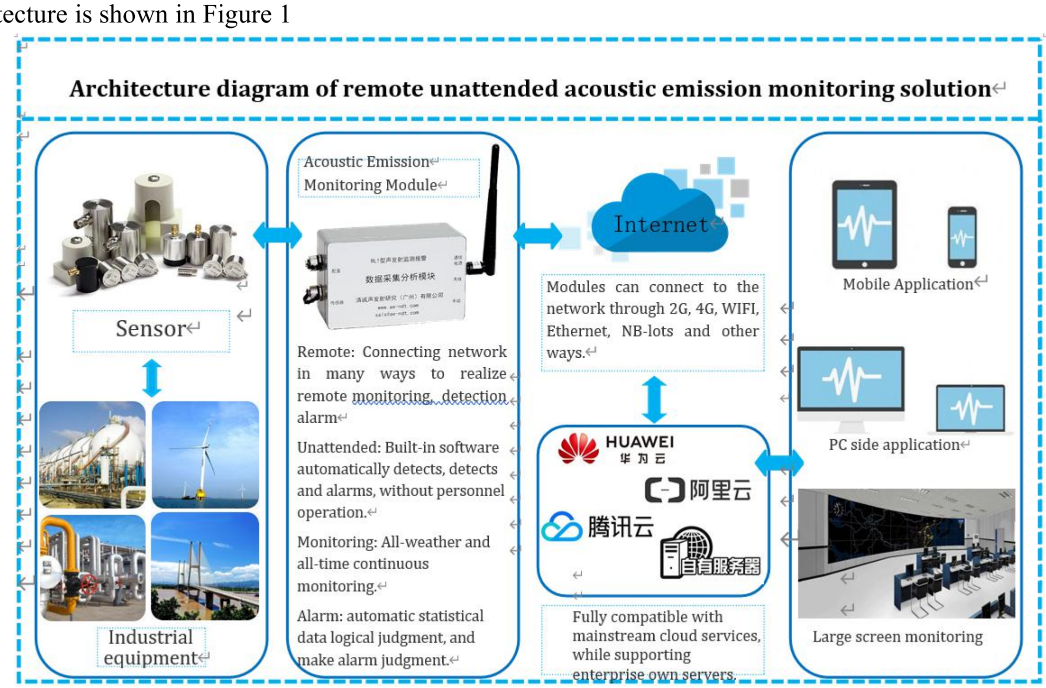

Fig. 1 Architecture of IOT AE monitoring and alarm system

There are many available internet/intranet communication ways such as GPRS, 4G, 5G, NB-IoT, Lora, ZigBee, WiFi, RJ45 Cable, etc. for various applications.

Servers can be Internet cloud servers such as Alibaba cloud Internet of things servers, local LAN servers such as petrochemical plant for valve monitoring and alarm system which only needs to display alarm results in the control room of the plant. Servers can also be local servers + Internet servers and other networking structures according to applications.

2. IOT AE systems developed/developing

2.1 RL1 IOT AE system

RL1 IOT AE is designed and developed/developing for continuous AE signals such as leakage signals. Table 1 is the specification and Fig 2 is the system functional block diagram.

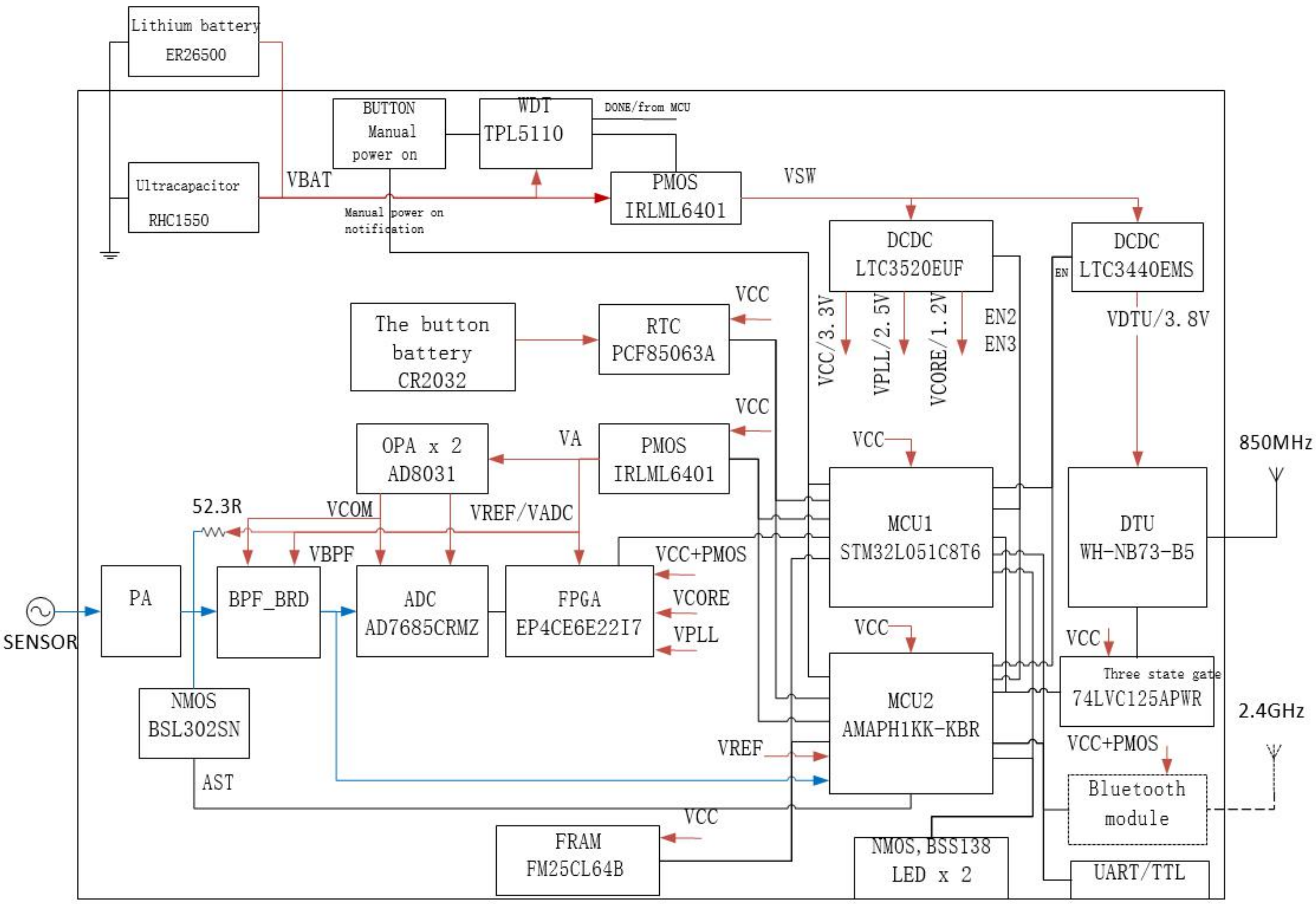

Fig 2 RL1 functional block diagram

Figure 3 shows the AE module， its battery and NB-IOT(Narrow band interenet of Things) chip are in the box, sensor is out off the box.

Fig 3 RL1 IOT AE photo

Table 1 RL1 and RAE1 specifications

IOT AE acquisition system			
RL1 specifications		RAE1 specifications	
Sampling accuracy	16bit	Sampling accuracy	16bit
Sampling frequency	10KHz-200KHz	Maximum sampling rate	2MHz
Input bandwidth	100Hz-70kHz	Input bandwidth	1KHz-2.2MHz
Sampling points	100k, 200k		
Filter	20K-100KHz	Filter	digital filter, high pass filter(KHz): 1 < Fl < 400, low pass filter(KHz): 20 < Fh < 2000
Sampling form	Timing sampling, manual button sampling	Sampling form	Continuous sampling
characteristic parameter	Timing generation time parameter, including RMS, ASL, power, battery voltage	characteristic parameter	Alarm, MaxAmp, MaxEnergy, MaxRing
Preamplifier voltage	5V	Preamplifier voltage	5V
sensor	Can be built-in or external	sensor	Can be built-in or external
IOT module	Can be built-in or external	IOT module	Can be built-in or external
Appearance size	52mm diameter and unequal height metal cylinder structure	Appearance size	52mm diameter and unequal height metal cylinder structure

2.2 RAE1 IOT AE system

RAE1 IOT AE is designed and developed/developing for burst AE signals such as cracking signals. Table 1 is the specification and Fig 4 is the system functional block diagram.

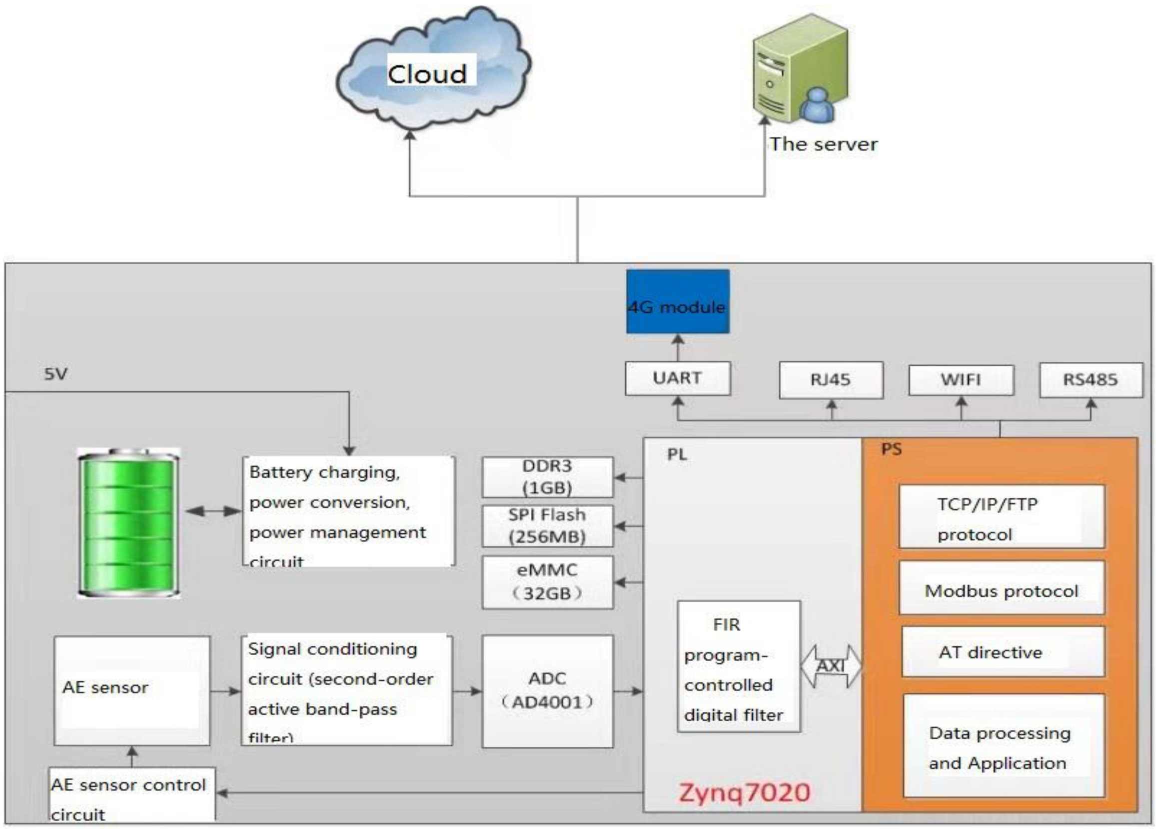

Fig 4 RAE1 functional block diagram

New RL1/RAE1 IOT AE systems are in developing and can be the integrate structure or separate structures as shown in Fig 5 for various applications.

Fig 5 shows the integrate and separate RL1/RAE1: Above right: integrate of sensor/battery/AE module/4Gmodule; Above left: DC power and sensor are out of metal cylinder with AE module and 4G module; Above center: 4G module out of cylinder; Below left: DC power out of the cylinder; Below right: Different cylinders holding different parts inside.

Fig 5. Integrate and separate RL1/RAE1

3 Testing of RAE1 and RL1 IOT AE system

3.1 Testing layout and procedures

The water tap and water pipeline are used for generating water leakages. The sensors are placed on the water tap to monitor the water leakages of the tap. The water leakages are generated by operate the tap at the positions of close, open a little, open large, corresponding to no leakage, small leakage and large leakages. Fig 6 shows the testing layout and the RAE1 and RL1.

Fig 6 Layout of testing on tap and RAE1/RL1

3.2 The RL1Testing data

The setting of RL1 in this experiment: 16bit sampling accuracy; 200kHz sampling rate; filter 20khz-100khz; manual sampling once every 5 minutes; ls35 sensor, resonance frequency 15khz-70khz, central resonance frequency 35kHz. The operation process of faucet controlling water flow is shown in Table 3.

Access the server through the laptop, and the historical data is shown in Table 2. It can be clearly distinguished from the historical RMS data of the five stages.

Table 2 Data of RL1 for tap water leakages

Equipment number	Instrument Name	Data point ID	Time	characteristic parameter	numerical value	characteristic parameter	numerical value
356566078314267	RL1-099	29907	2019-11-02 07:14:23	RMS	20.0	ASL	23.7
356566078314267	RL1-099	29907	2019-11-02 07:14:59	RMS	21.8	ASL	24.7
356566078314267	RL1-099	29907	2019-11-02 07:23:35	RMS	21.2	ASL	24.7
356566078314267	RL1-099	29907	2019-11-02 07:30:11	RMS	19.4	ASL	23.7
356566078314267	RL1-099	29907	2019-11-02 07:38:51	RMS	18.2	ASL	22.5
356566078314267	RL1-099	29907	2019-11-02 07:40:31	RMS	2008.5	ASL	64.1
356566078314267	RL1-099	29907	2019-11-02 07:46:18	RMS	1791.6	ASL	63.1
356566078314267	RL1-099	29907	2019-11-02 07:52:11	RMS	1764.6	ASL	63.0
356566078314267	RL1-099	29907	2019-11-02 07:57:23	RMS	2194.5	ASL	64.8
356566078314267	RL1-099	29907	2019-11-02 08:03:36	RMS	1488.3	ASL	61.5
356566078314267	RL1-099	29907	2019-11-02 08:08:43	RMS	1918.8	ASL	63.7
356566078314267	RL1-099	29907	2019-11-02 08:16:03	RMS	1596.9	ASL	62.1
356566078314267	RL1-099	29907	2019-11-02 08:19:47	RMS	1855.5	ASL	63.4
356566078314267	RL1-099	29907	2019-11-02 08:22:05	RMS	17.3	ASL	21.2
356566078314267	RL1-099	29907	2019-11-02 08:28:06	RMS	17.8	ASL	22.5
356566078314267	RL1-099	29907	2019-11-02 08:34:39	RMS	17.1	ASL	21.2
356566078314267	RL1-099	29907	2019-11-02 08:35:58	RMS	8734.8	ASL	76.8
356566078314267	RL1-099	29907	2019-11-02 08:37:24	RMS	9026.6	ASL	77.1
356566078314267	RL1-099	29907	2019-11-02 08:43:44	RMS	10345.4	ASL	78.3
356566078314267	RL1-099	29907	2019-11-02 08:49:17	RMS	10229.3	ASL	78.2
356566078314267	RL1-099	29907	2019-11-02 08:54:56	RMS	9178.0	ASL	77.3
356566078314267	RL1-099	29907	2019-11-02 09:01:36	RMS	10299.0	ASL	78.3
356566078314267	RL1-099	29907	2019-11-02 09:06:47	RMS	10191.2	ASL	78.2
356566078314267	RL1-099	29907	2019-11-02 09:08:23	RMS	15.3	ASL	19.6
356566078314267	RL1-099	29907	2019-11-02 09:13:58	RMS	13.0	ASL	17.7
356566078314267	RL1-099	29907	2019-11-02 09:17:58	RMS	10.8	ASL	15.2
356566078314267	RL1-099	29907	2019-11-02 09:24:48	RMS	11.0	ASL	17.7
356566078314267	RL1-099	29907	2019-11-02 09:34:36	RMS	11.5	ASL	17.7

Figure 7 shows that alarm data can be notified to users through WeChat official account, e-mail, text message, etc.

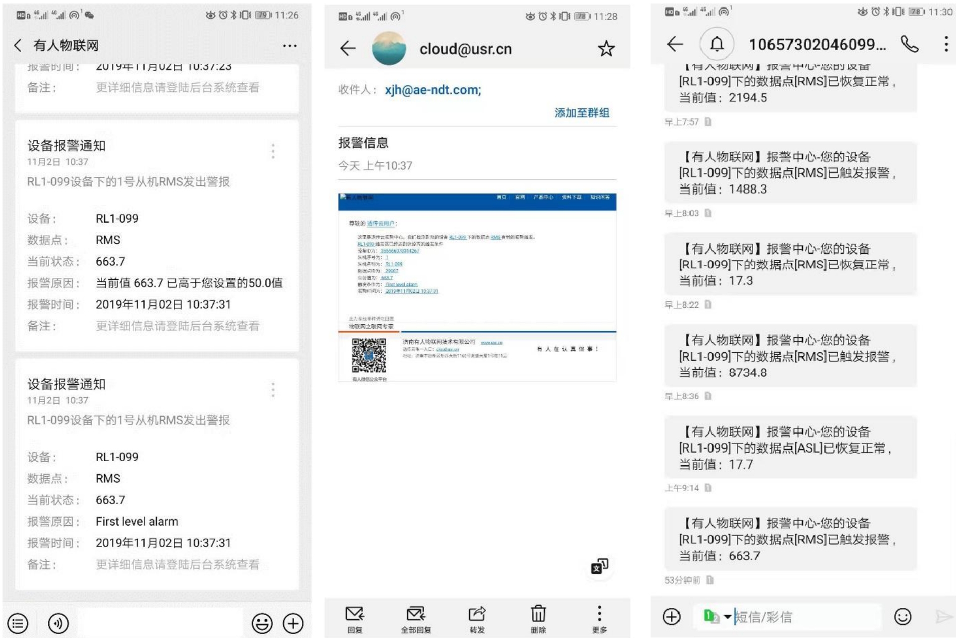

Fig 7 smart phone displays of RL1 for tap water leakage monitoring and alarm

Figure 8 and Figure 9 show the history data from server of RL1 AE IOT system. RMS and ASL have useful references. When the water out, no water out and different effluent, the differences are obvious, as shown in the figure.

Fig8 RMS to time, The displays of monitoring data on the laptop by visiting the servers to get the data.

Fig 9 ASL to time, The displays of monitoring data on the laptop by visiting the servers to get the data.

Table 3 records the experimental process and the statistical results of RMS and ASL.

Table 3 results of the testing of RL1 IOT AE for tap water leakages

Experimental process			Water leakage	RL1	
				RMS	ASL
07:14-07:39	25min	Tap off	0 ml/s	18.2-21.3	22.5-24.7
07:40-08:19	40min	Tap small angle on	11ml/s	1488.3-2194.5	61.5-64.8
08:20-08:34	14min	Tap off	0 ml/s	17.1-17.8	21.2-22.5
08:35-09:07	32min	Tap large angle on	30ml/s	8734.8-10345.4	76.8-78.3
09:08-09:35	27min	Tap off	0 ml/s	10.8-15.3	15.2-19.6

3.3 The RAE1 Testing data

The setting of RAE1 in this experiment: Digital filter 20khz-100khz; Hit threshold 60dB; HDT = 5us, PDT = 3us, HLT = 5us; ls35 sensor, resonance frequency 15khz-70khz, central resonance frequency 35kHz. The operation process of faucet controlling water flow is shown in Table 4.

Fig 11 shows the history data from server of RL1 AE IOT system. RMS and ASL have useful references, and the difference between water out and no water out is obvious, as shown in the figure. Fig 12 shows the leakage alarm display on the smart phone for RAE1.

Fig 11 Check historical data through laptop access server

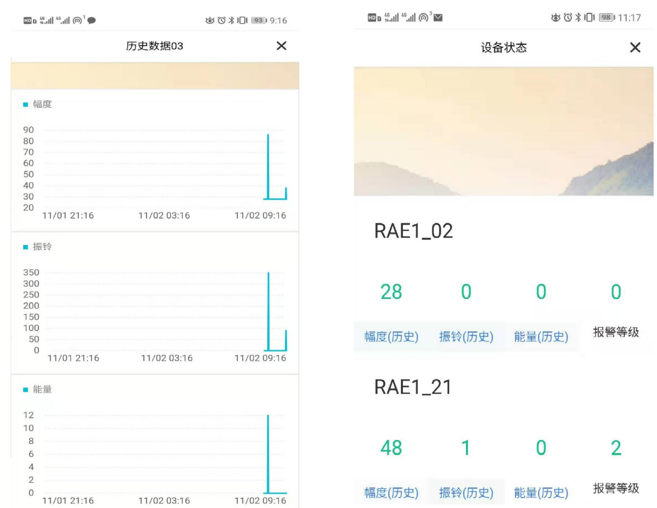

Fig 12 smart phone displays of RAE1 for tap water leakage monitoring and alarm

Table 4 results of the testing of RAE1 IOT AE for tap water leakages

Time	Experimental content	MaxAmp	Conclusion
21:14-9:29	Tap off	45 dB -55dB	1. Background noise 45 db-55db; 2. Accurate acquisition of lead breaking signal;
21:30-22:00	Tap small angle on（12.5ml/s）+ Lead breaks at 21:40	45 dB -70dB	
22:00-22:12	Tap off	45 dB -60dB	
22:12-22:21	Tap large angle on（70ml/s）+ Lead breaks at 22:20	45 dB -78dB	
22:21-22:26	Tap off	0 dB -55 dB	

3.4 Discussion

It is very clear that both RAE1 and RL1 IOT AE systems can correct monitoring and alarms the leakages of the water tap. It can be concluded that valve leakages can be success monitored and alarm report by RL1 and RAE1 IOT AE systems if just use the valves instead of tap for the same testing.

4 Conclusions

From above jobs it can be concluded that IOT AE systems are technically available now and IOT AE are useful for remote unattended monitoring and alarm report.

In future the long-term cycle of self-learning correction of artificial intelligence based on big data on the server makes the system have the ability of self-learning, self-improvement and continuous improvement of performance.