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Audio Steganography using Modified Enhanced Least Significant Bit in 802.11n

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Abstract
Steganography is a technique to improve the security of data, by inserting messages or confidential information using a medium called the host or carrier or cover. A wide variety of digital media can be used as a host, among others audio, image, video, text, header, IP datagram, and so forth. For audio steganography, the embedded audio is called stego-audio. Steganography can be cracked by using steganalysis. By exploit the weaknesses of each steganography method. Many steganography methods has been developed to increase its performance. This work proposed audio steganography scheme called Modified Enhanced Least Significant Bit (MELSB) which is modified version of Enhanced Least Significant Bit (ELSB). This work use Modified Bit Selection Rule to increase SNR and robustness of stego-audio. After applying MELSB scheme SNR of stego-audio is increased due to its Modified Bit Selection Rule. MELSB scheme also increase robustness of stego-audio. MELSB still works fine until amplification level 1.07. MELSB also works against noise addition better than ELSB and LSB. It gives BER and CER with value 0 at SNR 33 dB. MELSB work fine in real-time condition on 802.11n WLAN if there is no transcoding and noise addition between sender's and recipient's computer.

Keywords: 802.11n; Audio; Steganography; Modified Enhanced Least Significant Bit

1. Introduction

Steganography is used to improve the security of data, which is by inserting messages or confidential information using a medium called the host or carrier or cover. A wide variety of digital media can be used as a host, among others audio, image, video, text, header, IP datagram, and so forth. As cryptography that can be solved by cryptanalysis, steganography can be solved by using steganalysis. By exploiting the weaknesses of a steganography method, steganalysis continue to be developed in order to solve steganography for a variety of media and methods of insertion.

For this reason, it is necessary to develop a new steganography method or develop from existing methods. Modified Enhanced Least Significant Bit (MELSB) is a method developed from the Enhanced Least Significant Bit (ELSB) method which is included in the temporal domain insertion method category. The ELSB method is more secure than LSB, but it gives stego-audio lower SNR due to its Bit Selection Rule. The differences that owned by MELSB is the Modified Bit Selection rule making confidential information is not easily detected and gives higher SNR than ELSB. MELSB method will be tested on 802.11n channel to determine the performance and resistance in wireless channel.

2. Related Work

2.1 Steganography

Steganography comes from the Greek Steganos, which means "hidden" and graphein which means "to write" [1]. Media used to hide secret messages referred to as the host and confidential information that would embed into the host called a message. Media used as a host or a message in the form of multimedia files such as images, audio, video, or text. Steganography is used to send a very important message so as not to be stolen in transmission or to give a sign to a file that can contain information about copyright or hidden serial number.

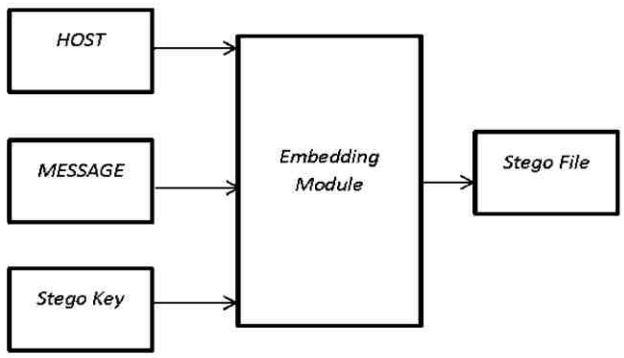

Fig 1. Steganography General Scheme

2.2 Least Significant Bit Steganography (LSB)

Least Significant Bit is a method that works by replacing the least significant bit of the cover with a bit message. Examples of the use of this method are described in the following.

0011001**1** 1010001**0** 1010001**1** 0010011**0** 0101100**1** 0110111**0** 1011010**1** 0001010**1** 1110011**0** 1101101**0**

Above is a row of bits from the host. Suppose the data that we wanted to embed is a message with a row of bits **1110101011**. Rows of the message bits will replace the LSB of the host data. After embedded, a row of bits from the host will be like below

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0011001**1** 1010001**1** 1010001**1** 0010011**0** 0101100**1** 0110111**0** 1011010**1** 0001010**0** 1110011**1** 1101101**1**
Advantages of LSB method is easy to implement and high insertion capacity, but this method have a low resistance. Filtration, amplification, and noise addition can easily damage the data [2]. The attacker can easily find a secret message by taking every LSB of each sample.

2.3 Enhanced Least Significant Bit Steganography (ELSB)

Enhanced Least Significant Bit [3] is a modification of the method of Least Significant Bit method. This method can be done in two ways. The first way is to randomize the number of bits of the host file that is used for embedding secret messages, this is called bit selection rule. The second way by using selective host sample to embed message bits, this is called sample selection rule. These two rules are used to confuse the intruder and providing more security.

Table 1. Bit Selection Rule [3]

1st MSB	2nd MSB	Secret Message Bit
0	0	3rd LSB
0	1	2nd LSB
1	0	1st LSB
1	1	1st LSB

Table 2.Sample Selection Rule [3]

1st MSB	2nd MSB	3rd MSB	Sample containing next secret message bit
0	0	0	i + 1
0	0	1	i + 2
0	1	0	i + 3
0	1	1	i + 4
1	0	0	i + 5
1	0	1	i + 6
1	1	0	i + 7
1	1	1	i + 8

3. Modified Enhanced Least Significant Bit Steganography

3.1 Modified Bit Selection Rule

Because value with first two MSB “00” is smaller than value with first two MSB “10” and “11”, bit selection rule from ELSB method will be changed. This is done in order to make changed value on the host are not too visible when message insertion process is done Changes made when 1st MSB and 2nd MSB are 0 and 0. In ELSB, 3rd LSB is used to embed message bit, but in MELSB when first two MSB is 0 and 0, 1st LSB is used to embed message bit. The sample selection rule in MELSB is still the same as in ELSB

Table 3.Modified Bit Selection Rule

1st MSB	2nd MSB	Secret Message Bit
0	0	1st LSB
0	1	2nd LSB
1	0	3rd LSB
1	1	3rd LSB

With combination of modified bit selection rule and sample selection rule, MELSB can provide more security than LSB method and give higher stego-audio SNR than ELSB. TABLE IV show the comparison between LSB, ELSB, and MELSB insertion method.

Table 4.Comparison of LSB, ELSB, and MELSB insertion method[1]

Method	Strong Points	Weak Points
Least Significant Bit (LSB)	• Low computational complexity • High bit rate • Easier implementation	• Less prone to attacks • Amplifying, noise addition and compression of audio will destroy the data • Extraction is easy
Enhanced Least Significant Bit (ELSB) [3]	Randomness in the bit selection and sample selection providing more security.	Compression will destroy the data
Modified Enhanced Least Significant Bit (MELSB)	Modified Bit Selection give higher SNR to stego-audio.	Compression will destroy the data

3.2 Robustness Test

This test is conducted to measure MELSB robustness compared with LSB and ELSB method. Bit Error Rate (BER) of inserted message bits and

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Character Error Rate (CER) will be calculated in this test. The message that will be inserted to host audio in robustness test is '**The quick brown fox jumps over a lazy dog 1234567890**.' which has total 53 character or 424 bits in 8 bits binary form. Robustness test including:

- *SNR Test*

This test was conducted to prove that the SNR of audio after embedding messages is larger when using the MELSB scheme (ELSB with modified bits selection rules). This test was conducted using LSB, ELSB, and MELSB scheme. SNR is obtained by using this equation [4].

$$\mathrm{SNR} = 10\log_{10}\frac{\sum_0^N Host(n)^2}{\sum_0^N [Stego(n)^2 - Host(n)^2]} \quad (1)$$

- *Amplification Test*

Amplification test conducted to determine the robustness of the MELSB methods against amplification compared with ELSB and LSB. Amplification here is enlarging the amplitude of the audio signal that had been inserted by a message (stego-audio).

- *Noise Addition*

Testing is conducted by add AWGN in the audio signal that had been inserted with a message (stego-audio) using LSB, ELSB, and MELSB insertion method. SNR of stego-audio continuously increased from 1 dB to 50 dB.

- *Compression / Transcoding Test*

Stego-audio is compressed from 64 Kbps to ADPCM 32 Kbps based on algorithm in [5]. After stego-audio is compressed, message in stego-audio will be extracted, then BER and CER of extracted message is calculated.

3.3 Implementation in 802.11n

This method will be implemented in WLAN 801.11n with 1 spatial stream and 20 MHz channel (MCS 7) in real-time condition. Input host data is speech signal with sampling frequency 8000 Hz and each sample is encoded to 8 bits. Block diagram of MELSB steganography implementation in 802.11n is shown in Fig 2. The message that will be inserted into the host is prepared beforehand. Decimal ASCII value of each character is obtained. Then the decimal ASCII value of each character is converted into 8 bits binary number. While user talk through a microphone each voice samples are converted into 8 bits binary form and embedding process will be carried out simultaneously following the pattern in Table 2 and Table 3. The voice that already contains the message will be sent directly to the recipient without being at the same time. The stego-audio will be send trough TCP/IP. The message that will be inserted into the host is prepared beforehand. Decimal ASCII value of each character is obtained.

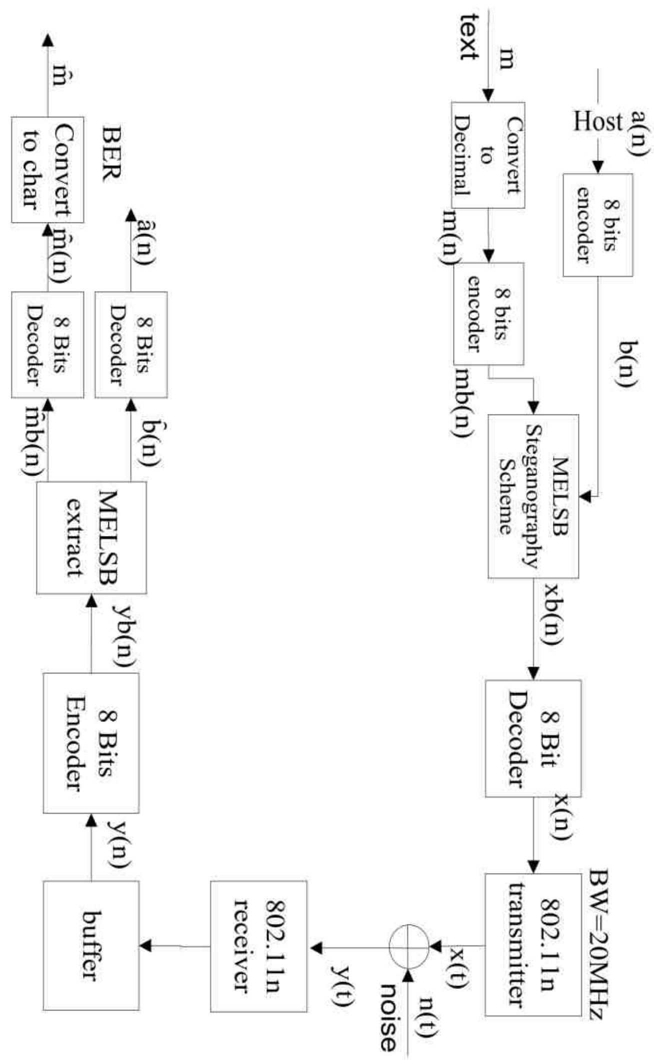

Fig 2. MELSB Steganography Block Diagram in 802.11n

Then the decimal ASCII value of each character is converted into 8 bits binary number. While user talk through a microphone each voice samples are converted into 8 bits binary form and embedding process will be carried out simultaneously following the pattern in Table 2 and Table 3. The voice that already contains the message will be sent directly to the recipient without being at the same time. The stego-audio will be send trough TCP/IP. Figure 3 shows the real-time implementation of MELSB in 802.11n Wireless-LAN.

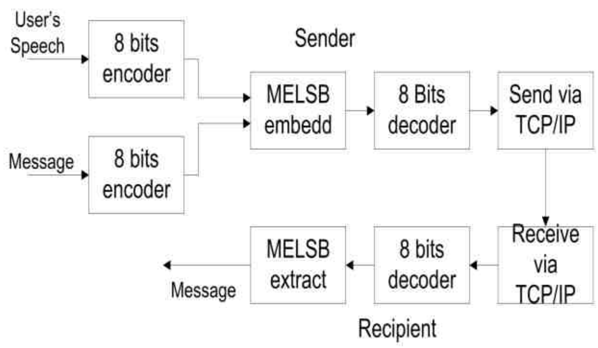

Fig 3. Real-time Implementation Block Diagram

4. Robustness Test Result

This test is conducted to measure MELSB robustness compared with LSB and ELSB method. Bit Error Rate (BER) and Character Error Rate (CER) will be calculated in this test. BER is obtained by comparing extracted message bits before testing with extracted message bits after testing. Figure 4 illustrated how BER is obtained. As seen in figure 4, 1st bit, 3th bit, 4th bit of the message after tested is different with the message bits before tested. After test there are 3 different message bits from total 8 message bits, so the BER is 3/8 or 0.375.

	1st bit	2nd bit	3rd bit	4th bit	5th bit	6th bit	7th bit	8th bit
Before test	1	1	1	0	0	1	0	1
After test	0	1	0	1	0	1	0	1

Fig 4. Illustration of Message Bits before Test and after Test

CER is obtained by comparing extracted message characters before testing with extracted message characters after testing. Figure 5 illustrated how CER is obtained. As seen in figure 5, 1st, 2nd, 3rd and 6th characters of the message after tested is different with the message characters before tested. After test there are 4 different message characters from total 8 message characters, so the CER is 4/8 or 0.5.

	1st char	2nd char	3rd char	4th char	5th char	6th char	7th char	8th char
Before test	a	b	c	d	e	f	g	h
After test	b	k	s	d	e	c	g	h

Fig 5. Illustration of Message Characters before Test and after Test

4.1 SNR Test Result

Average SNR after embedding using MELSB scheme is smaller than LSB scheme but larger than ELSB. Modified Bit Selection Rule in MELSB method replace 1st LSB of host-audio when the first two MSB is “00”, while Bit Selection Rule in ELSB replace 3rd LSB. So the difference value between host-audio and stego-audio is smaller when using MELSB, with the result that MELSB scheme give larger SNR than ELSB.

4.2 Amplification Test Result

MELSB method still works fine until amplification 1.07, which means amplitude value is enlarged by 7% from previous value. It means amplification mostly affecting 1st LSB of stego-audio. When the amplitude value of stego-audio is enlarged by amplification 1st LSB of stego-audio is mostly changed.

Table 5.SNR Testing Result Using ELSB, MELSB, and LSB

Attempt	SNR (dB)		
	LSB	ELSB	MELSB
1	44.36173	35.99525	40.63282
2	46.65434	33.80618	40.15372
3	40.87727	36.28362	44.21818
4	43.2815	37.17845	40.86791
5	41.99188	34.13527	41.3105
6	38.92647	33.24726	39.17588
7	41.01622	33.14977	40.84485
8	43.90634	37.20582	42.06382
9	37.84235	34.53976	40.69677
10	39.4386	35.54426	42.48434
11	38.70683	37.42117	40.53558
12	47.17619	39.3466	42.74927
13	43.26216	33.07516	41.107
14	41.38815	38.06389	38.62263
15	41.50903	41.08978	38.74961
16	44.02229	36.82805	44.90617
17	41.01958	37.15722	39.32776
18	40.61701	36.71136	41.71994
19	40.16404	47.53137	42.00134
20	39.40574	34.52373	42.4399
21	42.13484	34.77714	42.42505
22	44.81598	33.63326	39.55485
23	38.88055	34.71129	40.29103
24	40.32901	34.43852	42.49332
25	40.51863	38.9727	39.04027
26	38.34437	32.67965	41.21652
27	40.05223	45.22093	44.81666
28	40.73492	37.20063	42.3634
29	42.29691	34.49359	39.68386
30	49.53513	43.07145	45.23205
Average	41.77368	36.73444	41.39083

Modified Bit Selection Rule in MELSB have better robustness against amplification, because it replace 3rd LSB when first two MSB is “10” or ”11”, while ELSB while Bit Selection Rule in ELSB replace 1st LSB.

4.3 Noise Addition Test Result

The test results of noise addition test can be seen in the figure below. All of method work fine if SNR is above 30 dB.

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Table 6.BER after Amplification Testing Result

Amplification	Message BER		
	LSB	ELSB	MELSB
1	0	0	0
1.01	0	0	0
1.02	0	0	0
1.03	0	0	0
1.04	0	0	0
1.05	0	0	0
1.06	0.018868	0.023585	0
1.07	0.044811	0.051887	0
1.08	0.153302	0.134434	0.113208
1.09	0.283019	0.20283	0.113208
1.1	0.384434	0.264151	0.113208

Table 7.CER after Amplification Testing Result

Amplification	Message CER		
	LSB	ELSB	MELSB
1	0	0	0
1.01	0	0	0
1.02	0	0	0
1.03	0	0	0
1.04	0	0	0
1.05	0	0	0
1.06	0.056604	0.113208	0
1.07	0.056604	0.150943	0
1.08	0.301887	0.245283	0.528302
1.09	0.320755	0.264151	0.528302
1.1	0.566038	0.471698	0.528302

MELSB produce BER and CER with value 0 at SNR 33 dB, ELSB at SNR 34 dB and LSB at SNR 35 dB. Sample Selection Rule combined with Modified Bit Selection Rule in MELSB method increase the robustness against noise addition.

4.4 Compression/Transcoding Test Result

All of embedding method is weak against compression / transcoding because the amplitude value is changed after compression, so when it encoded into 8 bits binary form, the binary value of amplitude and embedded messages are changed as well.

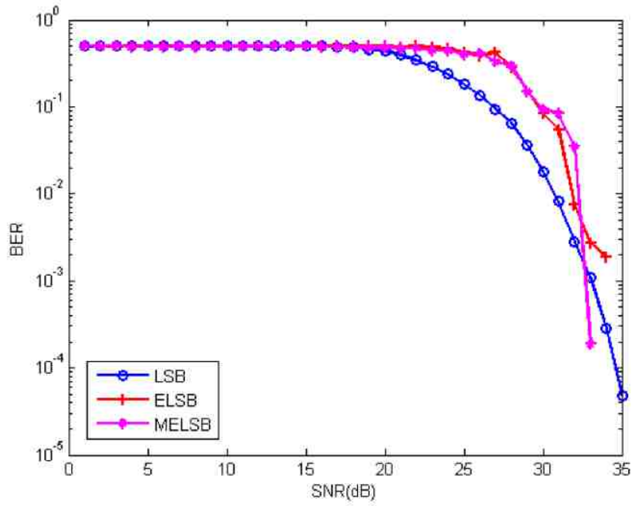

Fig 6. BER Result after Noise Addition

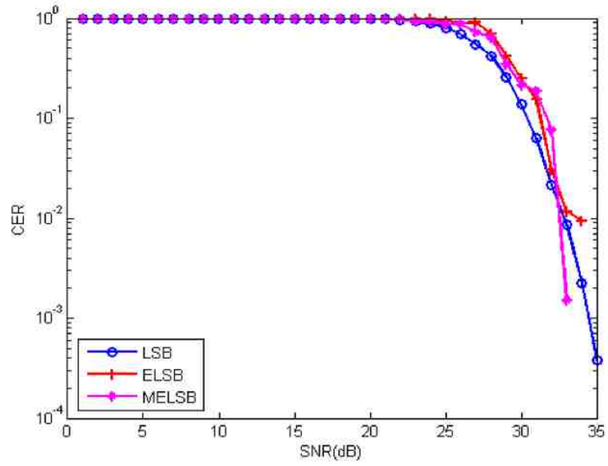

Fig 7. CER Result after Noise Addition

Table 8.Message BER and CER after Compression Result for file 'rekamanlagi.wav'

Method	BER	CER	Extracted message
LSB	0.466981	0.981132	'^|• '
ELSB	0.436321	0.981132	"
MELSB	0.474057	1	"

5. MELSB Steganography Result In 802.11n WLAN

MELSB scheme work fine in 802.11n WLAN in real time condition. It gives CER with value 0, if there's no transcoding and noise addition between sender and recipient. Total average latency in real time condition on 802.11n is between 900 milliseconds to 1200 milliseconds, while WLAN latency is between 0.8 milliseconds to 5.8 milliseconds. This means MELSB scheme (embedding and extracting process) takes more time be processed. Latency also affected by speech data

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retrieval process from microphone and 8 bit encoder/decoder in sender and recipient side.

Table 9. Steganography Testing Result on 802.11n Network

Place	DSP Research Lab, Telkom University	B Building, Telkom University	Graduate School G206, Telkom University
WLAN Bit Rate	65 Mbps	72.2 Mbps	21 Mbps
Number of User	49	9	6
Sender-recipient distance	± 3m	± 3m	±7m
Result	Voice is clean, CER = 0	Voice is clean, CER = 0	Voice is clean, CER = 0
Average total Latency (second)	0.968906574	1.147673246	1.149752728
WLAN latency (second)	0.000984625	0.000886437	0.003047642

6. Conclusions

The conclusion that can be obtained from this work is as follows:

a) Modified bit selection rule in MELSB can increase SNR of stego-audio better than ELSB. Because it replace 1st LSB of host-audio when the first two MSB is “00”, while Bit Selection Rule in ELSB replace 3rd LSB. So the difference value between host-audio and stego-audio is smaller when using MELSB, with the result that MELSB scheme give larger SNR than ELSB.

b) MELSB is stronger than ELSB against amplification. Amplification mostly affecting 1st LSB of stego-audio. When the amplitude value of stego-audio is enlarged by amplification 1st LSB of stego-audio is mostly changed .Modified Bit Selection Rule in MELSB have better robustness against amplification, because it replace 3rd LSB when first two MSB is “10” or ”11”.

c) MELSB is stronger than ELSB and LSB against noise addition due to combination of Sample Selection rule and Modified Bit Selection rule.

d) LSB, ELSB, and MELSB method is cannot work against transcoding. Transcoding changed the amplitude value of stego-audio. When amplitude value is encoded into 8 bits binary form, the binary value of amplitude and embedded messages bits is changed as well

e) MELSB can work fine in real time transmission using 802.11n Network if there is no transcoding and noise addition between sender and recipient.

f) MELSB scheme takes more times to be processed in real-time condition. As seen in Table 5.9, total average latency is larger than WLAN latency.

Reference

[1] Jayaram P, Ranganatha H R, Anupama H S. 2011. *Information Hiding Using Audio Steganography – A Survey*. The International Journal of Multimedia & Its Applications (IJMA) Vol.3, No.3

[2] Fatiha Djebbar, Beghdad Ayad Karim, Abed Meraim and Habib Hamam. 2012. ” Comparative Study of Digital Audio Steganography Techniques,” EURASIP journal on audio, speech and music processing 2012, 2012:25

[3] Muhammad Asad, Junaid Gilani, Adnan Khalid. 2011. An Enhanced Least Significant Bit Modification Technique for Audio Steganography, International Conference on Computer Networks and Information Technology (ICCNIT), pages 143-147

[4] M.Baritha Beguma, Y.Venkataramanib. 2012. LSB Based Audio Steganography Based On Text Compression. International Conference on Communication Technology and System Design. Volume 30, pages 703–710

[5] Richey, Rodger. 1997. Adaptive Differential Pulse Code Modulation using PICmicro™ Microcontrollers. Microchip Technology Inc.

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