A Novel Channel Interference Identification

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Abstract— **Both direct sequence and frequency hopping spread spectrum communication systems co-exist in unlicensed band such as 2.4 GHz ISM band. In this paper, we propose a novel structure to obtain the channel information so that more robust communication is possible. Both theoretical and numerical results are presented to demonstrate effectiveness.**

I. Introduction

Due to recent blooming wireless applications utilizing the unlicensed band such as Industrial, Scientific, and Medical (ISM) band at 2.4 GHz, it usually requires an effective solution to the coexistence problem. A key step to solve this dilemma is the identification of channel interference, since there were no mechanisms to exchange the mutual channel information among different wireless standards in the past. Once interference from other wireless communication systems is identified, we can avoid the occupied frequency band, or we can provide side information so that powerful signal processing such as Multi-User Detection (MUD) becomes possible.

One good example of recently proposed methods to obtain the channel information is by the packet loss ratio (PLR) [4]. PLR is based on the structure of Adaptive Frequency Hopping (AFH) [1,3,4]. Every receiver maintains a table recording the packet loss ratio of each frequency slot. By comparing the packet loss ratio with a predetermined threshold, the frequency slot is classified as either "Clear" or "Occupied". The receiver makes use of the side information to adjust its hopping sequence. Though this method can easily detect the interference in each frequency slot, it suffers three major drawbacks. First, PLR cannot achieve instantaneous identification to reflect the current channel state. Once the interference disappears after its appearance, it takes longer time to reduce the packet loss ratio beneath the threshold and via versus. Second, it requires the receiver to regularly switch between the adaptive and original hopping sequences. Because once the adaptive hopping sequence is used, the marked frequency slots are not used at that moment and the channel state information is not obtainable hereafter. The third and the critical one is that PLR can only be applied to the FH receiver and it does not intend to identify which kind of interference that exists.

In this paper, we propose a more general structure to identify the channel interference as shown in Fig 1. In our proposed structure, we use the transmission (TX) detector to monitor the frequency slot. Since we are interested only in whether the observed frequency slot is available for transmission or not, the TX detector structure can be as simple as energy detector which measures only the power level of the frequency slot and regardless of other detailed channel information. This eliminates the complexity of TX detector. We can classify each frequency slot as either "Clean" (marked as "0") or "Occupied" (marked as "1") by comparing the received energy with the pre-determined threshold. After monitoring the L frequency slots totally for N times. We then have an observation table $\boldsymbol{R}$. In this paper, our goal is to design a channel identifier to decide whether the wide-band interference (WBI) exists or not and whether the narrow-band interference (NBI) like FH signals exist or not and to further identify the possible active FH hopping sequences based on the observation table $\boldsymbol{R}$.

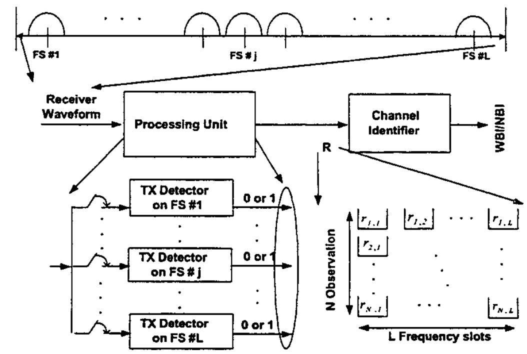

Fig. 1. Identification Structure

The rest of this paper is organized as follows. In Section II, we describe the channel interference model. The theoretical derivation is shown in Section III. We provide one simple example to demonstrate the performance in Section IV. This example can be easily extended to the co-exist problem at the 2.4 GHz ISM band. The conclusion and future work is given in Section V.

II. System Model

We first aim at wideband interference such as DSSS or the radiation from Microwave Oven. This kind of interference usually co-exists with other narrow-band and short-duration signal such as FHSS transmissions. We can ex-

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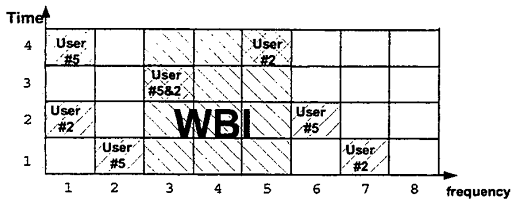

Fig. 2. Example

press the observed matrix $\boldsymbol{R}$ after the processing unit as

$$\boldsymbol{R} = \begin{pmatrix} \underline{R}_1 \\ \underline{R}_2 \\ \vdots \\ \underline{R}_N \end{pmatrix} = \boldsymbol{S} + \widetilde{\boldsymbol{I}} \tag{1}$$

where $\underline{R}_n = (r_{n,1}, r_{n,2}, \cdots, r_{n,L})$, and

$$\underline{R}_n = \underline{S}_n \oplus \widetilde{\underline{I}}_n \tag{2}$$

where $\underline{S} \in \Gamma_s = \{\underline{S}_0, \underline{S}_1, \cdots, \underline{S}_M\}$. $\{\underline{S}_1, \cdots, \underline{S}_M\}$ means the M possible WBIs and we let $\underline{S}_0$ denotes no WBI exists.

$$\begin{aligned} \widetilde{\underline{I}}_n &= \underline{I}_n^{k_1} \oplus \cdots \oplus \underline{I}_n^{k_{u_k}} \\ &= \sum_{k_j \in \Gamma_a} \underline{I}_n^{k_j} \end{aligned} \tag{3}$$

where $\Gamma_a \subset \{0, 1, 2, \cdots, K_{max}\}$ and K_{max} is the maximum possible number of active FH users. Γ_a is the active FH user set and u_k is the size of Γ_a which means the number of active FH users. Here, we define a binary operator $\oplus$ as

$\oplus$	0	1
0	0	1
1	1	1

Once the frequency slot is occupied (the wide-band interference or the FH signal or both exist in this frequency slot), the output of the TX detector is "1". Only when the monitored frequency slot is clean, the output of the TX detector is "0".

For example, as shown in Fig. 2, we can obtain

$$\underline{S}_n = \{0, 0, 1, 1, 1, 0, 0, 0\}$$

$$\Gamma_a = \{k_2, k_5\}$$

$$\widetilde{\boldsymbol{I}} = \boldsymbol{I}^{k_2} \oplus \boldsymbol{I}^{k_5} = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \end{pmatrix} \tag{4}$$

and

$$\boldsymbol{R} = \boldsymbol{S} \oplus \widetilde{\boldsymbol{I}} = \begin{pmatrix} 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \end{pmatrix} \tag{5}$$

In this paper, we consider two kinds of hopping sequences:

A. Embedded Markoff Chain Hopping Sequences

We assume that the hopping sequence of user $\#k_j$ has a transition probability ρ^{k_j} as

$$\rho^{k_j} = \begin{bmatrix} \rho_{11}^{k_j} & \rho_{12}^{k_j} & \cdots & \rho_{1L}^{k_j} \\ \rho_{21}^{k_j} & \rho_{22}^{k_j} & \cdots & \rho_{2L}^{k_j} \\ \cdots & \cdots & \cdots & \cdots \\ \rho_{L1}^{k_j} & \rho_{L2}^{k_j} & \cdots & \rho_{LL}^{k_j} \end{bmatrix} \tag{6}$$

and define $\rho^{k_j}(\underline{I}_i^{k_j}, \underline{I}_{i-1}^{k_j})$ as

$$\rho^{k_j}(\underline{I}_i^{k_j}, \underline{I}_{i-1}^{k_j}) = \begin{cases} \rho_{mn}^{k_j} & \text{if } I_{i,m}^{k_j} = 1,\ I_{i-1,n}^{k_j} = 1 \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

where $I_{i,m}^{k_j}$ and $I_{i-1,n}^{k_j}$ are the m-th and the n-th element of vector $\underline{I}_i^{k_j}$ and $\underline{I}_{i-1}^{k_j}$. Then the p.d.f. of the hopping sequence of user $\#k_j$, $\boldsymbol{I}^{k_j}$, is

$$\begin{aligned} P(\boldsymbol{I}^{k_j}) &= P(\underline{I}_{N-1}^{k_j}) \cdot \rho^{k_j}(\underline{I}_N^{k_j}, \underline{I}_{N-1}^{k_j}) \\ &= P(\underline{I}_{N-2}^{k_j}) \cdot \rho^{k_j}(\underline{I}_N^{k_j}, \underline{I}_{N-1}^{k_j}) \cdot \rho^{k_j}(\underline{I}_{N-1}^{k_j}, \underline{I}_{N-2}^{k_j}) \\ &= \cdots \\ &= P(\underline{I}_1^{k_j}) \cdot \prod_{i=2}^{N} \rho^{k_j}(\underline{I}_i^{k_j}, \underline{I}_{i-1}^{k_j}) \end{aligned} \tag{8}$$

B. Finite State Hopping Sequences

If we view the hopping sequence of each FH user as a finite state sequence, which can be expressed as

$$\underline{I}_p^{k_j} = \underline{I}_{p+F}^{k_j} \tag{9}$$

where F is the length of the finite state sequence. Then, the probability, $P(\boldsymbol{I}_j^k)$, given in (8) becomes

$$P(\boldsymbol{I}^{k_j}) = \begin{cases} 1 & \text{if } \boldsymbol{I}^{k_j} = \bar{\boldsymbol{I}}_{p,(p+N) mod F}^{k_j} \\ 0 & \text{otherwise} \end{cases} \tag{10}$$

where $p \in \{0, 1, \cdots, F-1\}$.

III. Channel Interference Identification

Our goal is to design a channel identifier to provide the channel information that whether the WBI, $\underline{S}$, exists or not and to identify the possible hopping sequences, $\widetilde{\boldsymbol{I}}$, the FH users currenly use based on the observation table $\boldsymbol{R}$.

A. The Optimal Channel Interference Identification

The optimal *maximum a posteriori* (MAP) is

$$(\widehat{\underline{S}}, \widehat{\boldsymbol{I}}) = \max_{\underline{S} \in \Gamma_s; \widetilde{\boldsymbol{I}}} P(\underline{S}, \widetilde{\boldsymbol{I}} | \boldsymbol{R}) \tag{11}$$

From (11), we know that the optimal solution to this problem is the exhaustive search of the possible combinations of $(S, \widetilde{\boldsymbol{I}})$. If the Markoff chain hopping sequences are used, the computation required for the search of the optimal solution will be

$$M \cdot [C_0^{K_{max}} + C_1^{K_{max}} \cdots + C_{K_{max}}^{K_{max}}] \cdot L^N = M \cdot 2^{K_{max}} \cdot L^N \tag{12}$$

where M is the n unber of possible WBI signals, L is the total observed frequency slots, N is the observation times and K_{max} is the maximum possible FH users. If the finite state hopping sequences are used, the computation required for the search of the optimal solution will be

$$M \cdot [C_0^{K_{max}} + C_1^{K_{max}} \cdot F + \cdots C_{K_{max}}^{K_{max}} \cdot F^{K_{max}}] = M \cdot (1+F)^{K_{max}} \tag{13}$$

where F is the length of the finite state hopping sequence. How ever, the complexity concerning to these two cases is tantamount for us to implement the hardware of this channel identifier because F and L are a large number in most situations.

B. 2-stage Channel Interference Identification

By the Bayesian rule, we know that

$$\max_{\underline{S} \in \Gamma_s, \widetilde{I}} P(\underline{S}, \widetilde{\boldsymbol{I}} | \boldsymbol{R}) = \max_{\underline{S} \in \Gamma_s, \boldsymbol{I}} P(\boldsymbol{R} | \underline{S}, \widetilde{\boldsymbol{I}}) \cdot P(\underline{S}) \cdot P(\widetilde{\boldsymbol{I}}) = \max_{\underline{S} \in \Gamma_s, \boldsymbol{I} \in \{\boldsymbol{S} \oplus \widetilde{\boldsymbol{I}} = \boldsymbol{R}\}} P(\widetilde{\boldsymbol{I}}) \tag{14}$$

The first equality follo ws from $\underline{S}$, $\widetilde{\boldsymbol{I}}$ are independent. Here, w e assume that the probability that $\underline{S} = \underline{S}_i$, $i \in \{0,1,2,\cdots,M\}$, is equally probable which is given below.

$$P(\underline{S}) = \frac{1}{M+1} \tag{15}$$

and $P(\widetilde{\boldsymbol{I}})$ given in (14) is

$$P(\widetilde{\boldsymbol{I}}) = \sum_{\Gamma_a} P(\widetilde{\boldsymbol{I}} | \Gamma_a) \cdot P(\Gamma_a) = \sum_{\Gamma_a} \left[\prod_{j=1}^{u_k} P(\boldsymbol{I}^{k_j}) \right] \cdot P(\Gamma_a) \tag{16}$$

where $P(\Gamma_a)$ is assumed as

$$P(\Gamma_a) = \frac{1}{2^{K_{max}}} \tag{17}$$

and $P(\boldsymbol{I}^{k_j})$ is given in (8) or (10) depending on the hopping sequence. The second equality follo ws from

$$P(\boldsymbol{R} | \underline{S}, \widetilde{I}) = \begin{cases} 1 & \text{if } \boldsymbol{I} \in \{\widetilde{\boldsymbol{I}}; \widetilde{\boldsymbol{I}} \oplus \boldsymbol{S} = \boldsymbol{R}\} \\ 0 & \text{otherwise} \end{cases} \tag{18}$$

Then we can first identify whether the WBI, $\underline{S}$, exists or not by

$$\widehat{\underline{S}} = \max_{\underline{S} \in \Gamma_s} \sum_{\boldsymbol{I} \in \{\widetilde{\boldsymbol{I}}; \widetilde{\boldsymbol{I}} \oplus \boldsymbol{S} = \boldsymbol{R}\}} P(\widetilde{\boldsymbol{I}}) \tag{19}$$

where $P(\widetilde{\boldsymbol{I}})$ is giv en in (16). Then we can obtain the hopping sequences, $\widehat{\boldsymbol{I}}$, by

$$\widehat{\boldsymbol{I}} = \max_{\boldsymbol{I}} P(\widehat{\underline{S}}, \widetilde{\boldsymbol{I}} | \boldsymbol{R}) = \max_{\boldsymbol{I}} P(\boldsymbol{R} | \widehat{\underline{S}}, \widetilde{\boldsymbol{I}}) \cdot P(\widetilde{\boldsymbol{I}}) = \max_{\boldsymbol{I} \in \{\widetilde{\boldsymbol{I}}; \widetilde{\boldsymbol{I}} \oplus \widehat{\boldsymbol{S}} = \boldsymbol{R}\}} P(\widetilde{\boldsymbol{I}}) \tag{20}$$

The complexity of this 2-stage channel interference identifier then reduces to $O(M + L^N 2^{K_{max}})$ if the Markoff c hain hopping sequence is used, and $O(M + (1+F)^{K_{max}})$ if the finite state hopping sequence is used.

C. 3-stage Channel Interference Identification

We find that the complexity of the channel interference iden tification mainly comes from the attempt to trak the hopping sequences of the active FH users. Due to the unknown number of active FH users, w eneed to join tly estimate the most lik ely number of FH users and the best hopping sequence concerning to each users. How ever, if we can know the number of the active FH users, it is easier to estimate the hopping sequences. Following from (20), w e can estimate u_k b y

$$\widehat{u_k} = \max_{u_k} P(\widehat{\underline{S}}, \widetilde{\boldsymbol{I}} | \boldsymbol{R}) = \max_{u_k} \sum_{\boldsymbol{I} \in \{\widetilde{\boldsymbol{I}}; \widetilde{\boldsymbol{I}} \oplus \widehat{\boldsymbol{S}} = \boldsymbol{R}\}} P(\widetilde{\boldsymbol{I}}) = \max_{u_k} \sum_{\boldsymbol{I} \in \{\widetilde{\boldsymbol{I}}; \widetilde{\boldsymbol{I}} \oplus \widehat{\boldsymbol{S}} = \boldsymbol{R}\}} \sum_{\Gamma_a} \left[\prod_{j=1}^{u_k} P(\boldsymbol{I}^{k_j}) \right] \cdot P(\Gamma_a) \tag{21}$$

and then estimate the active FH user set Γ_a b y

$$\widehat{\Gamma}_a = \max_{\Gamma_a} \sum_{\boldsymbol{I} \in \{\widetilde{\boldsymbol{I}}; \widetilde{\boldsymbol{I}} \oplus \widehat{\boldsymbol{S}} = \boldsymbol{R}\}} P(\widetilde{\boldsymbol{I}} | \widehat{u_k}) = \max_{\Gamma_a} \sum_{\boldsymbol{I} \in \{\widetilde{\boldsymbol{I}}; \widetilde{\boldsymbol{I}} \oplus \widehat{\boldsymbol{S}} = \boldsymbol{R}\}} \left[\prod_{j=1}^{\widehat{u_k}} P(\boldsymbol{I}^{k_j}) \right] \tag{22}$$

The complexity of this 3-stage channel interference identifier is less than $O(M + K_{max} + L^N)$ if the Markoff chain hopping sequence is used, and less than $O(M + K_{max} + F^{K_{max}})$ if the finite state hopping sequence is used.

D. The Binary Channel of TX Detector

The observed matrix $\boldsymbol{R}$ given in (1) makes one critical assumption that the TX detector is perfect. The assumption is not realistic. Instead, the TX detector possibly misses or falsely alarms the existence of signals due to the channel effect. Thus, w ecan model the TX detector as a binary channel with cross error probability λ_0 and λ_1 shown in Fig. 3.

Each element in observed table $\boldsymbol{Y}$ is a Bernoulli random variable with parameter

$$P(y_{i,j} = 1) = (1 - \lambda_1) P(r_{i,j} = 1) + \lambda_0 P(r_{i,j} = 0) \tag{23}$$

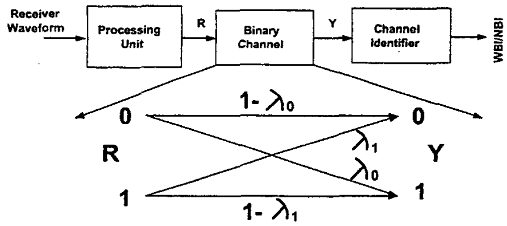

Fig. 3. Binary c hannel model for TX detector

Then the MAP given in (11) becomes

$$(\hat{\underline{S}}, \hat{\boldsymbol{I}}) = \max_{\underline{S}\in\Gamma_s;\tilde{\boldsymbol{I}}} P(\underline{S}, \tilde{\boldsymbol{I}}|\boldsymbol{Y}) \quad (24)$$

IV. Example

Consider one simplified example: There are 10 frequency slots under mointering and 4 different kind of WBIs which are given below

$$\begin{aligned} \underline{S}_1 &= [1\ 1\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0] \\ \underline{S}_2 &= [0\ 0\ 0\ 1\ 1\ 1\ 0\ 0\ 0\ 0] \\ \underline{S}_3 &= [0\ 0\ 0\ 0\ 0\ 0\ 1\ 1\ 1\ 0] \\ \underline{S}_4 &= [0\ 0\ 1\ 1\ 1\ 1\ 1\ 1\ 0\ 0] \end{aligned} \quad (25)$$

and suppose that the hopping sequence of eac h FH user is finite-state hopping sequence with hop length $F = 10$. Each hopping sequence makes use of the 10 frequence slots uniformly.

The simplified example can be easily extended to the co-exist problem at 2.4 GHz ISM band which arises great interest in IEEE 802.15.2 TG2 now. As sho wn in Fig. 4 (a)(b)(c), IEEE 802.11b WLAN uses one of three frequency band, and another possible WBI is the radiation from Microw ae Oven shown in (d). Bluetooth seperates the ISM band into 79 frequency slots sho wn in (e). Then w e can express these WBIs as

$$\begin{aligned} [\underline{S}_1]_i &= \begin{cases} 1 & i \in \{1, 2, \cdots, 24\} \\ 0 & \text{otherwise} \end{cases} \\ [\underline{S}_2]_i &= \begin{cases} 1 & i \in \{25, 26, \cdots, 49\} \\ 0 & \text{otherwise} \end{cases} \\ [\underline{S}_3]_i &= \begin{cases} 1 & i \in \{50, 51, \cdots, 74\} \\ 0 & \text{otherwise} \end{cases} \\ [\underline{S}_4]_i &= \begin{cases} 1 & i \in \{15, 16, \cdots, 65\} \\ 0 & \text{otherwise} \end{cases} \end{aligned} \quad (26)$$

A. Performance of the Optimal Channel Interference Identific ation

The performance of detection of WBI when the optimal channel interference iden tificationis used is given below. Here, we let the cross error probability $\lambda_0 = \lambda_1 = \lambda$.

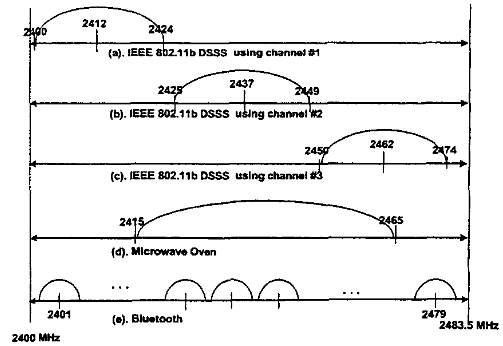

Fig. 4. Channel Interference in ISM band

WBI detection error during 100 tests when $K_{max} = 2$					
$N\backslash\lambda$	$\lambda = 0$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
$N = 3$	0	0	6	24	40
$N = 4$	0	0	0	13	37
$N = 5$	0	0	1	9	34
$N = 6$	0	0	0	6	31
$N = 7$	0	0	1	3	34

WBI detection error during 100 tests when $K_{max} = 3$					
$N\backslash\lambda$	$\lambda = 0$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
$N = 3$	0	1	10	34	40
$N = 4$	0	0	2	14	36
$N = 5$	0	0	3	12	38
$N = 6$	0	0	0	10	44
$N = 7$	0	0	1	1	29

The above tw otables are given according to the maximum possible FH users, K_{max}. We find that the detection error decreases if the observation times N is large and the detection error increases if the cross error probability λ is large. How ev er, the performance of detection of WBI is satisfactory. The identification error is extremely low when λ is small. Besides, the performance becomes better when N gets larger even though λ is large.

The performance of the identification of the hopping sequences of the active FH users is given below.

NBI detection error during 100 tests when $K_{max} = 2$					
$N\backslash\lambda$	$\lambda = 0$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
$N = 3$	5	53	67	79	96
$N = 4$	5	31	54	90	81
$N = 5$	0	23	59	71	83
$N = 6$	0	15	48	75	82
$N = 7$	0	13	44	67	86

NBI detection error during 100 tests when $K_{max} = 3$					
$N\backslash\lambda$	$\lambda = 0$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
$N = 3$	13	60	84	82	89
$N = 4$	5	52	68	89	91
$N = 5$	1	35	66	88	85
$N = 6$	1	21	49	83	88
$N = 7$	0	22	62	85	86

We find that the identification of the hopping sequences of the active FH users becomes uneffective when $K_{max} \geq 3$.

This is because that information is lost after our processing unit. The more possible activ eusers exist, the more information gets lost.

B. Performance of the 2-stage Channel Interferenc e Identific ation

The following two tables show the performance of detection of WBI when the 2-stage channel interference identification is used.

WBI detection error during 100 tests when $K_{max} = 2$					
$N\backslash\lambda$	$\lambda = 0$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
$N = 3$	0	0	4	21	46
$N = 4$	0	0	2	13	41
$N = 5$	0	0	2	7	41
$N = 6$	0	0	0	8	30
$N = 7$	0	0	0	5	39

WBI detection error during 100 tests when $K_{max} = 3$					
$N\backslash\lambda$	$\lambda = 0$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
$N = 3$	1	3	5	27	47
$N = 4$	1	0	5	18	39
$N = 5$	0	0	0	19	43
$N = 6$	0	1	0	15	46
$N = 7$	0	0	2	11	28

Compare the results of the detection of WBI between the optimal and the 2-stage channel interference identification. We find that the performance is almost the same.

The performance of detection fo NBI when we seperate the jointly search of WBI and NBI is given below.

NBI detection error during 100 tests when $K_{max} = 2$					
$N\backslash\lambda$	$\lambda = 0$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
$N = 3$	24	67	75	82	99
$N = 4$	5	31	54	88	79
$N = 5$	0	23	58	72	85
$N = 6$	0	15	48	74	81
$N = 7$	0	13	45	67	85

NBI detection error during 100 tests when $K_{max} = 3$					
$N\backslash\lambda$	$\lambda = 0$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
$N = 3$	26	70	96	99	100
$N = 4$	5	55	70	96	99
$N = 5$	1	37	69	99	99
$N = 6$	1	22	52	93	99
$N = 7$	0	22	65	89	99

However, the performace of the detection of NBI of the 2-stage channel interference identification is less than the optimal channel interference identification.

C. Performance of the 3-stage Channel Interferenc e Identific ation

The performance of detection of WBI when the 3-stage channel interference identification is used is given below.

WBI detection error during 100 tests when $K_{max} = 2$					
$N\backslash\lambda$	$\lambda = 0$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
$N = 3$	0	1	7	29	48
$N = 4$	0	0	5	24	43
$N = 5$	0	0	4	14	35
$N = 6$	0	0	1	10	33
$N = 7$	0	0	0	8	33

WBI detection error during 100 tests when $K_{max} = 3$					
$N\backslash\lambda$	$\lambda = 0$	$\lambda = 0.1$	$\lambda = 0.2$	$\lambda = 0.3$	$\lambda = 0.4$
$N = 3$	3	6	7	33	48
$N = 4$	1	3	6	24	43
$N = 5$	0	1	2	16	38
$N = 6$	0	0	0	16	33
$N = 7$	0	1	0	14	26

From these tw o tables,the performace of the detection of WBI when the 3-stage channel interference identification is used is still good. How ever, we find that the detection of the hopping sequences of the active FH users becomes very uneffective according to our simulations which are not sho wn here. This result might come from the sequential estimation of the hopping sequences.

V. Conclusion and Discussion

In this paper, both the optimal and the simplified sequential identification structure are provided and the simulation results of these structures are presented. We find a trade-off betw een the iden tifier structure and its performance. The strategy to adopt which kind of structure depends on the requirement of the channel information needed. If the identification of only WBI is sufficient, the 3-stage channel interference identification is a satisfactory choise. If the pow erful signal processing suc h as MUD is used, then more detailed interference information is required. We need to adopt the optimal channel interference iden tification.

VI. Acknowledgement

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