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Fast Link Assessment in Wireless Mesh Networks By Using Non-constant Weight Code

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Abstract— **The wireless mesh network is experiencing tremendous growth with the standardization of IEEE 802.11 and IEEE 802.16 technologies. Compared to its wired counterpart, the resource (e.g., capacity) of the wireless mesh network is limited. Worst yet, the wireless link quality is time and space varying, depending on the environment and interference. In order to make efficient use of the scarce channel resource during topology formation, scheduling and routing, it is vital to understand the quality of the links in the wireless mesh network (in terms of, e.g., probability of successful transmission, or signal to noise ratio). The existing approaches for link assessment consume substantial amount of time and thus introduce significant delay and overhead. In this paper, we propose a novel link assessment scheme where the link assessment packets are transmitted efficiently according to a set of non-constant weight codes, which achieves low collision probability within a short link assessment period. In our proposed approach, each node considers the actual nodal degree while choosing the codeword for its link assessment. In this work, we design the link assessment procedure and establish a set of theorems that provide the necessary condition for successful link assessment. Extensive simulations are carried out, showing that our proposed approach reduces link assessment delay by over 70% compared to the orthogonal optical code *OOC*-based approach.**

Index Terms— **Link assessment, non-constant weight code, wireless mesh network.**

I. INTRODUCTION

The Wireless Mesh Network (WMN) consists of a set of stationary wireless routers forming a multi-hop wireless backbone network. Each wireless router relays data packets to/from its neighbors, and at the same time, serves as the access point that provides service to the nearby mobile hosts (MH's). A small number of wireless routers, called gateways, are connected to the wired backbone, while others connect to the gateways through single or multi-hop wireless links. With its "self-configurability", the wireless mesh network does not require manual configuration or maintenance, nor does it involve intricate planning for deployment of the network.

In a WMN the wireless link quality is time and space varying, depending on the environment and interference. Therefore, it is vital to gather related information and understand the quality of the links for making efficient use of the resource. This paper focuses on link assessment, which is a procedure of assessing the quality of all links (in terms of, e.g., probability of successful transmission, signal to noise ratio, distortion rate, or a combination of them) in the wireless mesh network by the exchange of sufficient number of packets between neighboring nodes. The information obtained during this phase is useful for various operations of the wireless mesh network such as topology formation, scheduling, and routing.

Link assessment is not a one-shot process. It needs to be performed periodically. A link is assessed successfully, if and only if the link assessment packets are transmitted in a collision free time slot. The link assessment protocol needs to ensure that all links in the network should have at least one collision-free time slot. Clearly, the link assessment consumes time, and thus introduces delay and overhead to the wireless mesh network. The goal of the link assessment protocol is to assess the quality of all links in the network successfully in the minimal amount of time.

As to be discussed in Sec. II, the traditional approach for link assessment is to sequentially assess each link by having all nodes in the network transmit in a specific order [1], [2]. This simple approach consumes excessive time proportional to the number of nodes in the network and thus prolongs the delay required for network setup and reconfiguration. In [3] two approaches have been proposed for link assessment in sensor networks, with the main objective of optimization energy efficiency. The first approach is probabilistic. While this approach is simple and easy to implement with the ability to scale to large networks, it doesn't guarantee successful assessment of all links within any given time period (no matter how large the period is). The second approach is based on constant weight code. Although it ensures successful link assessment within a confined period and thus has a bounded delay and overhead, the actual link assessment time resulted from this approach in practice is not reduced significantly compared to the probabilistic approach, according to the simulation results given in [3]. This is mainly because the worst case scenario (i.e., each node having the maximum number of neighbors) is always considered in the constant weight code approach. Therefore, the collision probabilities are overestimated, and consequently, a very long codeword is chosen to ensure a collision free time slot for each link.

In this research, we propose a novel approach for link assessment by addressing the above problem. More specifically, a set of hamming codes are generated, which satisfy the constraints in weight and hamming distance to be discussed in Sec. III. Each node employs a perfect hash function to choose a unique code, with the consideration of the nodal degree of itself and /or its neighbors (in contrast to the approach in [3] that assumes all nodes with the maximum degree),

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which determines its transmission pattern in corresponding time slots. Due to the difference in codeword generation, the theories developed in [3] for determining the link assessment delay bound cannot be applied in our proposed approach. In this paper, we design the link assessment procedure and establish a set of theorems that provide the necessary condition for successful link assessment within a bounded period and give a deep insight into the use of non-constant weight code in wireless mesh networks. Extensive simulations are carried out to evaluate our proposed approach. The results show that our approach reduces the link assessment delay by over 60% compared with the optical orthogonal code (*OOC*)-based scheme employed in [3] that is the best known approach in the literature.

The rest of this paper is organized as follows. Sec. II discusses the related work in the literature. Sec. III introduces our proposed approach including the network model and assumptions, a set of theorems and lemmas that establish the necessary conditions for successful link assessment, and a description of the proposed link assessment procedure. Sec. IV presents the simulation results, comparison, and discussion. Finally, Sec. V concludes the paper.

II. RELATED WORK

The traditional approach for link assessment is to sequentially assess each link by having all nodes in the network transmit in a specific order [1], [2]. The major drawback of this approach is excessive time consumption that is proportional to the number of nodes in the network. For instance, consider a scenario where there are 10,000 nodes in the network (a similar example is also illustrated in [3]). Let us assume that each link requires a time slot equivalent to 4 seconds. Then the total time required for link assessment is $10,000 \times 4 = 40,000$ seconds, equal to 11 hours and 7 minutes. It is clearly too expensive to allocate so much time for link assessment.

In [3] two methods have been proposed for link assessment in wireless sensor networks. One is the probabilistic approach, where each node may be in one of the three states in any particular time slot: "transmit," "receive," or "sleep". A node chooses its state (i.e., one of the above three states) randomly. The choice of the state is independent of its previous states and is selected based upon the predetermined probabilities. The sum of the probabilities of a node going into "transmit," "receive," and "sleep" mode is one. The total number of successful time slots for link assessment is modeled as a binomial random variable. It has been shown in [3] that the best performance of this protocol is achieved when the probability of transmission is the inverse of the maximum nodal degree and the probability of node going into "sleep" state is zero. The main drawback of this approach is the lack of guarantee for successful assessment of all links within any bounded time period. Neither does it minimize the time required for the link assessment. Thus this approach is not desirable even though it is easy to implement and scales to large networks.

The second approach proposed in [3] is a deterministic approach that ensures successful link assessment within a bounded period. Each node in the network is assigned a binary constant weight code and the transmission or the reception pattern is based on this code. The code assignment is not discussed in [3]. But it is assumed that each node has a unique codeword. A node would be in "transmit" state if the bit corresponding to the time slot is 1 and the node would be in "receive" mode if it is 0. All of the codewords have the same weight W with a minimum hamming distance d. For successful link assessment, the weight of the codeword W_i should satisfy $C \leq W_i \leq \left(\frac{n_{max}\frac{d}{2}-C}{n_{max}-1}\right)$, where n_{max} is the maximum nodal degree (which is indeed the number of nodes in the network) and C is the total time slots for the assessment of each link. C is equal to 1 under our assumption that one time slot is sufficient for transmitting the assessment packets over a link if there is no collision. In [3], the authors adopt the optical orthogonal code (*OOC*) that is a special class of constant weight code for their implementation. The special property of OOC is that the codes are cyclically permutable. It has been shown in [3] that the time required for link assessment is approximately equal to $(C+n_{max})^2$.

While the constant weight code approach provides an insight into the design of link assessment protocol, it doesn't reduce the link assessment time significantly, compared to the probabilistic approach. For instance, with $n_{max} = 25$ its yields only 17% improvement. This is because that the worst case scenario of each node having n_{max} neighbors is always considered in the constant weight code approach, and thus the collision probabilities is far overestimated. In general, however, only a few nodes in the network would have n_{max} degree and all other nodes may have much less number of neighbors. Therefore, the protocol doesn't yield significant performance gain compared with other simple approaches. This problem has motivated our research and is solved by our proposed approach to be discussed next.

III. PROPOSED APPROACH

In this section, we discuss our proposed approach, which achieves a significant shorter time for link assessment. The basic idea of our proposed approach is to consider the degree of the sender and/or the receiver when designing and choosing the codeword, in contrast to the approach in [3] that assumes all nodes with the degree of n_{max}. Due to such difference in codeword generation, the theories developed in [3] for determining the link assessment delay bound cannot be applied here. In the rest of this section, we will first introduce the network model and assumptions used in our research. Then, we present a set of theorems and lemmas that establish the necessary conditions for successful link assessment and give a deep insight into the use of non-constant weight code in wireless mesh networks, followed by a description of the complete link assessment procedure.

A. Network Model and Problem Description

The wireless mesh network can be represented by a directional connectivity graph $G(V,E)$, where V denotes the set of nodes and E denotes the set of edges in the network. The total number of nodes is denoted by $N = | V |$. The maximum and minimum degrees of the vertices in the graph are denoted by n_{max} and n_{min}, respectively. A node x is adjacent to node y if there is an edge joining them. However, the forward and reverse edges between a pair of nodes are considered as two separate links for assessment, due to the possible asymmetric wireless transmissions. Let Φ_i denote the set of neighbors of node i and let $D_i = |\Phi_i|$ denote the number of nodes in Φ_i, i.e., the degree of node i.

The quality of the links in the network is graded by the exchange of sufficient number of packets between the neighboring nodes. Parameters like probability of successful transmission, signal distortion rate, signal to noise ratio, and so on can be calculated during link assessment. The number of packets to be exchanged in order to evaluate a link depends on the parameters to be estimated. We make the following assumptions.

1) Each node in the network has a unique identification number, and the link assessment packet includes the sender's ID. The readers are referred to [1] for distributed ID assignment.
2) All nodes are synchronized (by using the available approaches such as [4], [5]. Time is divided into slots, where one time slot is sufficient for transmitting all packets on a link for its assessment (if no collision occurs).
3) The nodes can be in one of the two states, i.e., "transmit" or "receive", at any point of time. If a node is in "transmit" state, it broadcasts the packets to all of its neighbors. If a node is in "receive" state it continuously monitors the channel for receiving possible link assessment packets from its neighbors.
4) The link assessment packet sent out from a sender is not specific to a particular receiver. Thus it can be used by *any* of the neighboring nodes for link assessment if the packet is received without collision.
5) A node cannot switch between the two states in the middle of a time slot.
6) It is also assumed that the network topology is static during each round of link assessment procedure.

If two or more nodes transmit to the same receiver simultaneously, collision occurs and the assessment of the links to this receiver is failed in this time slot. A link is assessed successfully, if and only if the link assessment packets are transmitted in a collision free time slot. Note that the packet loss or errors due to the error-prone wireless channel does not affect the link assessment, as it is one of the parameters we would like to measure. The goal of the link assessment protocol is to assess the quality of all links in the network successfully in the minimal amount of time.

B. Principles of Proposed Link Assessment Scheme

The proposed link assessment scheme is based on the non-constant weight codes with the consideration of actual nodal degree in code generation and selection.

Let's assume a set of codewords, each of which has a length of F bits and a minimum hamming distance of d, are shared by all nodes in the network. A node, e.g., node i, is associated with a codeword, denoted by C_i. The weight of the C_i is W_i. Let W_{max} denote the maximum weight of the set of codewords. The F bits of the codeword correspond to F time slot during which the link assessment is performed. In a given time slot, a node will be in "transmit" state (i.e., to transmit link assessment packets to its neighbors) if the bit corresponding to the time slot is 1; otherwise, it will be in "receive" state and listen to the channel. The notations used in our discussion are summarized in Table I.

TABLE I

LIST OF NOTATIONS

N	Number of nodes in the network
F	Number of bits in the codeword
d	Hamming distance
C_i	Codeword of node i
Φ_i	The set of neighboring nodes of node i
W_i	Weight of C_i
W_{max}	Maximum weight of the codewords
D_i	Degree of node i
n_{max}	Maximum nodal degree
n_{min}	Minimum nodal degree

We first derive the necessary condition for the assessment of a single link from a node i to a node j, and then extend it to entire network. To facilitate our discussion, we assume every node knows the degrees of its neighbors in the following Theorem 1 and its proof. This assumption will be nullified later in Theorem 3 to obtain more general solutions. Formally, we establish Theorem 1 as below.

Theorem 1: Consider a set of codewords with a length of F bits and a minimum hamming distance of d, in which a unique codeword is assigned to each node for link assessment. Given $d - W_{max} \geq 1$, the link from node i to node $j \in \Phi_i$ can be assessed successfully within F time slots if

$$\begin{cases} 1 \leq W_i \leq \left(\frac{D_j \frac{d}{2} - D_j \frac{W_{max}}{2} - 1}{\frac{D_j}{2} - 1} \right), & D_j > 2 \\ 1 \leq W_i, & D_j \leq 2 \end{cases} \tag{1}$$

Proof: As we have discussed earlier, node i transmits link assessment packets in the time slots corresponding to the bits of 1's in its codeword. The link assessment from node i to node $j \in \Phi_i$ will be successful if at least one of these transmissions are collision-free. Let's assume the position of "1"'s in the codeword is randomly and uniformly distributed. Thus, for a given time slot in which node i transmits, the collision probability at node j is

$$1 - (1 - \frac{W_j}{F}) \prod_{k \in \Phi_j,\ k \neq i} (1 - \frac{W_k}{F}). \tag{2}$$

Clearly, given the codeword C_i assigned to node i, the collision probability is higher if node j and its neighbors use codewords with higher weight. Consider the worst case scenario where the weight of C_j is the maximum weight (i.e., $W_j = W_{max}$), which results in the maximum possible collision probability

$$1 - (1 - \frac{W_{max}}{F})^{D_j}. \tag{3}$$

Then $W_i + W_{max}$ is the maximum total number of "1"s in C_i and C_j. Since the codewords have a hamming distance of d, the maximum number of "1"s *at the same bit positions* in these two codewords is $W_i + W_{max} - d$. In other words, the maximum number of overlapped "1"s in C_i and C_j is given by

$$\left(\frac{W_i + W_{max} - d}{2}\right). \tag{4}$$

The above discussion applies not only for the codewords C_i and C_j but also for C_i and any C_k where $k \in \Phi_j$. Similarly, let's consider the worst scenario for the neighbors of node j by assuming all neighbors of node j have the codewords with the maximum weight (i.e., $W_k = W_{max}$, $\forall k \in \Phi_j$). Since node j has D_j neighbors (see Fig. 1), the maximum number of overlapped "1"s between C_i and C_j or the codewords of j's neighbors is given by

$$D_j \left(\frac{W_i + W_{max} - d}{2}\right). \tag{5}$$

This is also the maximum number of time slots in which node j may experience possible collisions.

In order to ensure successful link assessment from node i to node j, W_i should be larger than the maximum number of possible collisions given in Equation 5, leading to at least one time slot for clear transmission of link assessment packets. Thus we arrive at

$$W_i \ge 1 + D_j \left(\frac{W_i + W_{max} - d}{2}\right). \tag{6}$$

When $D_j > 2$, Inequation 6 can be written as

$$W_i \le \left(\frac{D_j\frac{d}{2} - D_j\frac{W_{max}}{2} - 1}{\frac{D_j}{2} - 1}\right). \tag{7}$$

When $D_j = 1$, we have

$$W_i \ge 1 + \left(\frac{W_i + W_{max} - d}{2}\right), \tag{8}$$

which is equivalent to

$$W_i \ge 2 + W_{max} - d. \tag{9}$$

Since $d - W_{max} \ge 1$, Inequation 9 always holds as long as $W_i \ge 1$, which is clearly true.

When $D_j = 2$, we arrive at

$$W_i \ge 1 + 2\left(\frac{W_i + W_{max} - d}{2}\right), \tag{10}$$

which is obvious if $W_i \ge 1$, given $d - W_{max} \ge 1$. Thus, Theorem 1 is proven. ■

Theorem 1 gives the necessary condition for successfully assessing a link. Based on the above results, we can also derive the bounds of W_{max} and d. More specifically, we establish the following lemmas.

Lemma 1: The bound of the maximum weight the codewords is given below:

$$W_{max} \quad \le \quad \left(\frac{n_{max}\,\frac{d}{2} - 1}{n_{max} - 1}\right). \tag{11}$$

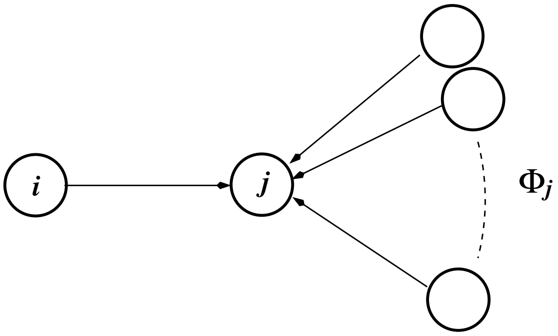

Fig. 1. Successful link assessment from node i to j.

Proof: Let W_i= W_{max}. From Theorem 1, we have

$$W_{max} \ge 1 + D_j\left(W_{max} - \frac{d}{2}\right), \tag{12}$$

i.e.,

$$W_{max} \quad \le \quad \left(\frac{D_j\,\frac{d}{2} - 1}{D_j - 1}\right). \tag{13}$$

$\left(\frac{D_j\,\frac{d}{2} - 1}{D_j - 1}\right)$ is a function of D_j. Differentiating it, we find that

$$\left(\frac{D_j\,\frac{d}{2} - 1}{D_j - 1}\right)' = \frac{1 - \frac{d}{2}}{(D_j - 1)^2}, \tag{14}$$

which is negative. Hence $\left(\frac{D_j\,\frac{d}{2} - 1}{D_j - 1}\right)$ is a decreasing function that attains the minimal value when D_j is maximum. Since $D_j \le n_{max}$, we arrive at $W_{max} \quad \le \quad \left(\frac{n_{max}\,\frac{d}{2} - 1}{n_{max} - 1}\right)$. ■

Following similar argument, we can obtain the bound for d, as stated in Lemma 2.

Lemma 2:

$$d \ge 2\left(\frac{(1 + n_{min})(n_{max} - 1) + 1}{n_{max}}\right). \tag{15}$$

Proof: Omitted. ■

Theorem 1 gives the necessary condition to ensure successful assessment of a link from node i to node j. In order to assess the links from node i to all of its neighbors, Inequation 1 should hold for all $j \in \Phi_i$. Furthermore, we can extend this result and establish Theorem 2 below for the link assessment of the entire wireless mesh network.

Theorem 2: All links in the wireless mesh network can be assessed successfully within F time slots if Inequation 1 holds for every pair of neighboring nodes.

Proof: It is straightforward based on the proof for Theorem 1. ■

In the above discussions, we have assumed that any node in the network knows the degrees of its neighbors (i.e., D_j in Inequation 1). In certain scenarios, however, a node may not have such information (e.g., at very initial stage of network setup). To address this problem, we propose a two-phase method, where each phase has F time slots. We assume a node always knows its own degree (i.e., D_i for node i). Similar to Theorem 1, a set of codewords with F bits and $d - W_{max} \geq 1$ are available. In phase one, node i chooses a unique codeword that satisfies the following constraint,

$$W_i \geq 1 + D_i \left(\frac{W_i + W_{max} - d}{2} \right). \tag{16}$$

Similar to our discussion in the proof of Theorem 1, Inequation 16 leads to

$$W_i \leq \left(\frac{D_i \frac{d}{2} - D_i \frac{W_{max}}{2} - 1}{\frac{D_i}{2} - 1} \right), \tag{17}$$

when $D_i > 2$. Node i transmits link assessment packets in the time slots that correspond to the "1"s in its codeword. In addition to the typical information for link assessment, these packets carry an extra byte to contain D_i. Thus, if a link is assessed successfully, the receiver also knows the degree of the sender.

Now let's exam a particular link from node i to node j. If $D_i \geq D_j$, Inequation 16 ensures Inequation 6. Therefore, the link can be assessed successfully in phase one, according to Theorem 1. If $D_i < D_j$, the assessment of the link from node i to node j is not necessary to be successful in phase one. Note that, however, since $D_j \geq D_i$, the link from node j to node i must have a successful assessment. In order words, node i must receive the link assessment packets from node j in at least one time slot without collision. As a result, node i now has the degree of node j (i.e., D_j). Consequently, in phase two, node i can choose an appropriate codeword according to Theorem 1, which ensures a successful link assessment for the link from node i to node j. Therefore, we have the third theorem below.

Theorem 3: Given the set of codewords with F bits and $d - W_{max} \geq 1$, in which a unique codeword is assigned to each node for link assessment, all links in the network can be assessed successfully within $2F$ time slots, if the following condition is satisfied,

$$\begin{cases} 1 \leq W_i \leq \left(\frac{D_i \frac{d}{2} - D_i \frac{W_{max}}{2} - 1}{\frac{D_i}{2} - 1} \right), & D_i > 2 \\ 1 \leq W_i, & D_i \leq 2 \end{cases}, \forall i \in V. \tag{18}$$

Proof: The proof is straightforward based on the above discussions, and thus omitted. ■

C. Link Assessment Procedure

Based on the principles discussed in the previous subsection (Sec. III-B), we design the following steps for the link assessment procedure. Note that, this is a distributed approach, where every node performs these steps independently.

- **Step 1: choosing parameter** F. The minimum value of F is chosen such that enough number of codewords can be generated, one for each node in the network. Figure 2 depicts the impact of the codeword length (i.e., F) on the maximum number of codewords that can be generated. As can be seen, the total number of codewords increases drastically with the increase of the length of the codewords. To ensure successful link assessment, the number of codewords must be no less than the number of nodes in the network. This figure can be used as guideline for choosing appropriate F for a given network. In our implementation, a table is created based on this result, from which one can easily look up the minimum F needed for a given network size.

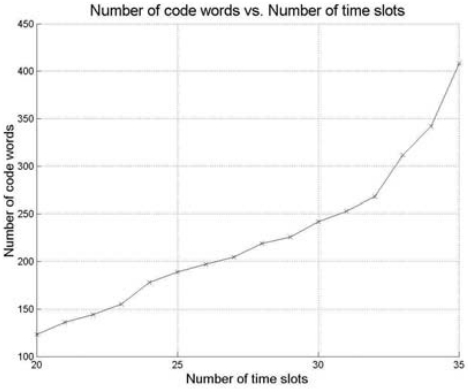

Fig. 2. Number of codewords vs. F.

- **Step 2: determining parameter** W_{max}. Lemma 1 has shown that $W_{max} \leq \left(\frac{n_{max} \frac{d}{2} - 1}{n_{max} - 1} \right)$. For given length ($F$) of the codewords, larger W_{max} results in more codewords that can be generated. Thus we choose W_{max} to be its upper bound.
- **Step 3: determining parameter** d. The impact of d on the total codewords is shown in Figure 3. As can be seen, the number of codewords first increases and then decreases with the increase of d. When d is very small, the total number of hamming codes generated is large. However, since $W_{max} < d - 1$, only a small subset of the codes can be used by the nodes for link assessment. A very large d also results in small number of codewords because only a small set of hamming codes can be generated for a given code length F in order to keep such large hamming distance. We have observed that the peak value is achieved when d is around $2\left(\frac{(1+n_{min})(n_{max}-1)+1}{n_{max}} \right)$, which is the lower bound given in Lemma 2. Hence we let $d = 2\left(\frac{(1+n_{min})(n_{max}-1)+1}{n_{max}} \right)$ for generating the set of codewords.
- **Step 4: generating the set of codewords**. Each node runs standard hamming code generation module by using the above parameters. Note that, all nodes run the same algorithm with the same parameters, and thus yield the same set of codewords.
- **Step 5: choosing codeword**. Each node employs a perfect hashing function (e.g., [6] that performs a one-to-one map from the set of nodal ID's to the set of codewords generated above) and follows Theorems 1-3 to choose an appropriate and unique codeword.
- **Step 6: assessing links**. Each node transmits link assessment packets according to it codeword, i.e., to transmit

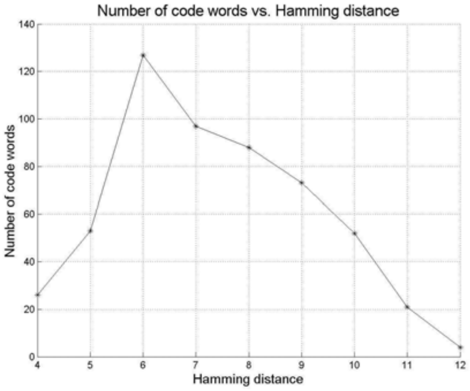

Fig. 3. Number of codewords vs. d.

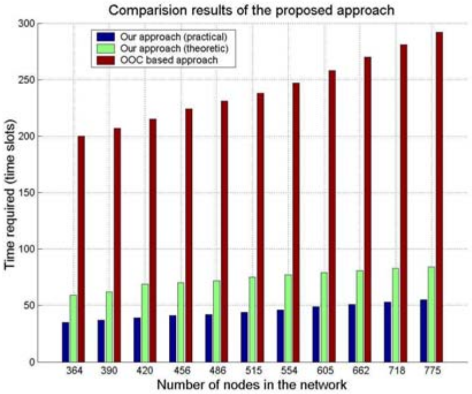

Fig. 4. Comparison of link assessment time.

link assessment packets in the time slots that correspond to 1's in its codeword and listen to channel in the time slots that correspond to 0's.

As we have proved in Sec. III-B, the assessment of all links in the network will be completed successfully within F time slots by following the above six steps.

IV. SIMULATIONS

Simulations have been carried out to compare our proposed approach with the best known approach in the literature [3] that is based on orthogonal optical code (OOC). We simulate the wireless mesh network with N nodes where N varies from 364 to 775. n_{max} and n_{min} are set to be 15 and 3, respectively. Two variations of our proposed approach are simulated. The "theoretic" version follows exactly the method discussed in Sec. III, where a node uses its codeword for the transmission of all link assessment packets and finishes all F time slots. In the practical implementation of our proposed scheme (labelled as "practical" version in our simulation results), once a node has assessed all its adjacent links, it may stop transmitting in the later time slots even though it has "1"s in the later bit positions of the codeword. This will reduce collision probability and consequently shorten the total time for link assessment of the entire network. To implement this approach, the receiver needs to piggyback an acknowledgement for successful link assessment to the sender.

Figure 4 contrasts the total link assessment time of our proposed approach to that of the OOC-based approach. As can be seen, the time for link assessment increases in general with the increase of number of nodes. This is because we fix the network deployment area. With more nodes in the network, the nodal density increases, consequently increasing nodal degree and the collision probability. Thus a larger F has to be used for code generation, resulting in longer link assessment time. Given a network size of N, the OOC-based approach needs about $N/2$ time slots for assessing all links in the network. Our proposed approach can significantly reduce link assessment time by about more than 70%. This is because we avoid the pessimistic assumption that each node has n_{max} neighbors while designing the codeword, and thus our approach results in more codewords for a given code length of F. In other words, we can design the codewords with a smaller F in order to produce enough number of codewords, one for each node. With additional optimization in practical implementation (i.e., that a node stops transmission as soon as it receives the piggybacked acknowledgement for successful link assessment from all of its neighbors), the link assessment time can be further reduced by about 40%. Therefore, our proposed method can complete the link assessment by using only 20% of the time of the original OOC-based approach.

V. CONCLUSION

In this paper we have addressed the link assessment problem in wireless mesh networks, which is crucial for making efficient use of the scarce channel resource during topology formation, scheduling and routing. We have proposed a novel approach based on non-constant weight codes. In contrast to the constant weight code approach which assumes each node to have the maximum number of neighbors, the nodes in our proposed approach considers the actual nodal degree while choosing the codewords. Extensive simulations have been carried out, showing that our proposed approach reduces link assessment delay by over 70% compared to the OOC-based approach.

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