Context-aware Greedy Scheduling Algorithm in Wireless Network

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Abstract—In order to measure the link's interference in static heterogeneous wireless networks, we need to know its context information, but the context information can not be informed before the link allocates the time slot. Because of the highly inadequate collection and the use of traditional scheduling algorithms for link interference information, which severely limits their performance, this paper proposes the context-aware greedy scheduling algorithm. This paper analyses the cumulative effect of interference and the sequence detection feature of the serial interference cancellation (SIC, successive interference cancellation). The algorithm researches the strategy of choosing time slot, defines tolerance to measure the saturation of the link set and gives two kinds of new heuristic time slot selection mechanism. Finally, network simulator (NS 2) conducts simulation experiments which adopt performance evaluation as throughput to assess the performance of scheduling algorithm of this paper in the case of a single multi-hop. The experiments show that: the scheduling performance of context-aware greedy scheduling algorithm in heterogeneous static wireless network has been improved.

Index Terms—Greedy Algorithm; Wireless Networks; Weighted Concurrency; Tolerance

I. INTRODUCTION

Communication network in the future is a coexistence of various wireless access networks all IP-based seamless integration of heterogeneous systems. As heterogeneous wireless network resources have differences, therefore, achieving unified management of radio resources, improving the utilization of radio resources has become the focus of radio resource management in the current research [1-3]. Grid technology is an effective means for safe management and sharing a variety of resources on a network, and provides technical services [4]. Grid resource’s dynamics, structural heterogeneity and diversity of features are similar with heterogeneous wireless network environment. The concept is applied to the grid resource management in heterogeneous wireless and it can achieve a reasonable distribution of heterogeneous wireless resources and resistance to interference, which could better meet users’ Qos requirements [5-7].

Serial interference cancellation (SIC, successive interference cancellation) is an effective anti-jamming multi-packet reception (MPR, multiple packet reception) technology. A receiving node with SIC using an iterative function mode to detects multiplexed transmission signal. In each iteration test, the strongest signal is decoded, while the other signal is regarded as an interference [8-10]. If the signal to interference noise ratio (SINR, signal to interference and noise ratio) is not less than a given threshold value, the signal is decoded and then removed from the mixed signal. In subsequent iterative detection, the next strongest signal is decoded [11-13]. This iterative process continues until all the signals are decoded or iteration failed. Such conflicting signals decoded by one process reflects the properties of SIC sequence detection (sequential detection) [14-16].

Processing interference is one of the main challenges of wireless communication system design. Consider the affect of link L1 to the link L2 at the link L2’s receiving node. On the one hand although, if the signal strength of L1 is weaker than that of L2, but both run simultaneously, L2’s signal SINR threshold value is not reached, then the L2 reception will fail, due to the interference of L1. On the other hand, if the signal of L1 strength is stronger enough than that of L2, the SIC can be decoded first and removes L1’s signal from L2, thus eliminating its interference. But at the same time, a third party can prevent L1’s decoding signal to achieve the effect of interference. In addition, the cumulative effect of interference (cumulative effect) also makes a link moderating effect not only decided by it, but also closely related with other concurrent links. Cumulative effect is that when multiple interfering signals coexist, the total interference is cumulative. Thus, in scheduling a link; we need to incorporate all previously scheduled link effects to accurately portray the current link interference effect. Defining these concurrent links to the current link context (context) based on the cumulative interference model, we study context-aware scheduling algorithm.

Due to most problems of link scheduling are NP-hard, greedy algorithm is a commonly used algorithm. There are the characteristics of speediness and easy to implement for solving optimization problems. Although the optimal solution can not be necessarily got, a satisfactory relative optimal solution can be obtained, so the application range is wide. When the greedy algorithm is used to solve this problem, the clue to solve the problem is that the current best element is selected based on greedy criteria, and all the elements, which locate in the same rows and the same columns are modified, that is, the conflicting parts are removed by making difference
sets, until there is no conflict between elements in each row and each column of the entire matrix. The greedy criterion here selects the longest element in the current matrix as the current best elements, because the greater the length of the element, the greater the contribution to the final evaluation value. Typically, greedy link scheduling algorithm mainly includes two stages: link selection and time slot selection. The former will be scheduled to select the next link, while the latter assigns the appropriate time slot for the current link. Existing link scheduling algorithm focuses on research of selection strategy, and in the time slot selection phase uses a simple first-match (first fit) strategy. First matching means for a given link L, starting from the first time slot, can find sequentially x̄l time slots which can be assigned to L ( x̄l is the number of time slots required for L, x̄l ≥ 1).

In the selecting link stage, these algorithms design a reasonable selection strategy through the use of interference information. However, the measure of link interference condition needs its context information, which can not be informed before the link allocates time slot. Therefore, the existing scheduling algorithms for interference information access and use are very inadequate, which severely limits their performance.

Interference model of wireless networks includes cumulative interference model and non-cumulative interference model. It has been demonstrated that in the second model, the wireless network link scheduling is the problem about NP-hard. Therefore, the greedy algorithm is widely used to construct the approximately optimal scheduling, for example, scheduling based on non-cumulative interference model and scheduling based on the cumulative interference model. When a network node with multiple packet reception capability, we need a new interference model to reflect the characteristics of the current interference. SIC's and other works, the cumulative interference model has been expanded. Now, SINR threshold value is set to a value which is less than 1, so that the conflict of the plurality of signals packets can be decoded. The drawback of this model is that it does not consider the difference between the different signals in conflict, and therefore can not describe the feature of SIC sequence detection.

Lv and others, based on non-cumulative interference model, give a interference model portrayed SIC's characteristics. It accurately captures dependence (correlation) exist between the concurrent multiple links when receiving node has the ability of the SIC. The drawback is that it does not consider the cumulative effect of radio interference. In addition, Gelal and others research topology control which supports SIC's multiuser MIMO wireless network. Recently, Lv and others put forward conflicting set graph (conflict set graph) to build a model to support the interference when the wireless network is under SIC. However, in the worst case, the time complexity of this method is exponential.

This paper mainly conducts expanding and innovative work in the following areas:

(a) For heterogeneous static scheduling algorithm for wireless networks link interference has the problem of highly inadequate information collection and use of traditional scheduling algorithm, we propose a new greedy algorithm, namely context-aware scheduling algorithm. Firstly, the weighted support concurrent diagram describes a wireless network interference under SIC. Then, focusing on time slot selection stages of the design, that is, for a given link, if there is more available time slots, whether for the first time must match the time slots for the best, or how to choose the best time slot based on the link- context information, definite tolerance in order to measure the saturation of the link set (i.e. the ability to accept new link) and gives two kinds of heuristic strategy: a) Select the time slot so that the time slot link set maximum tolerance; b) select the time slot so that the time slot link set minimal variation tolerance.

(b) In order to further validate the speediness and effectiveness of the proposed context-aware greedy scheduling algorithm, the thesis uses throughput as the evaluation performance indicators to make simulation experiments. The experiments evaluate the performance of the similar programs through simulation experiments based on network emulator (NS 2), sum up the parameters and protocol settings in the simulation process and evaluate the scheduling algorithm proposed in this thesis under the circumstance of single and multi hop. As to the two efficient strategies in this thesis, LRF, MDF and First-Fit are used to respectively express experimental results of the first match. Under the circumstance of single hop, the advantages of LRF and MDF on throughput can reach up to 30%; under the circumstance of multi-hop, the throughput of LRF and MDF can be grained to 27%. The experiments show that: the performance of two kinds of strategy of context-aware greedy scheduling algorithm is better than the commonly used first-match strategy, and the performance of the proposed algorithm in heterogeneous wireless networks static scheduling has been improved.

II. SYSTEM MODEL

We consider an N-containing static nodes and links of n single-channel wireless network. The link is marked as Li, the transmission node and the receiving node is Si and Ri, where, i = 1, 2, n. Assumed that: a) SIC's removal of the signal is error-free; b) Each node is equipped with an omnidirectional antenna, which operates in half-duplex mode and can not send more packets at the same time.

SIC's sequence detection: Consider two links L1 and L2. When at R1, signal power from the L2 is strong enough, so that even with the interference signals of L1, L2’s signal can still be detected by R1. Then, by removing the signal L2, R1 can complete the L1 signal decoding. Now, we call that L1 is dependent on L2 and the L2 is L1’s related links. The condition is:

$$\frac{R}{K_n + R_1} \geq \omega_L$$  \(1\)
where in, \( R_{ij} \) is the energy at the node \( R_i \) which is received from the signal of node \( K_i \); \( N_0 \) is the noise intensity; \( R_{ij} \) is the minimum required SINR from signal \( R_j \) for decoding data from node \( o_i \).

Ordered cumulative interference model: considering \( L_d \)'s reception. Supposed there is a total of \( J \) \((J \leq n-1)\) lines of the link with \( L_d \) concurrency, where \( D \) \((D \leq J)\) lines of links is related \( L_d \). Without loss of generality, all links in accordance with the received power in \( R_d \) sort of \( L_1, L_2, ..., L_{ij} +1 \), assuming \( ik = d \), then \( P_{k1} \geq P_{k2} \geq ... \geq P_{ij} +1 \), a collection of links is \( \{L_1, L_2, ..., L_{id}\} \). \( L_d \) is successfully detected signals. It requires that:

\[
\frac{R_{ij}}{K_n + \sum_{(i+1) \leq n \leq k+1 w_{ij}}^n} \geq \beta_{ij}\wedge \beta_n \leq U
\]

When a group of links has concurrency, each link's success or failure of the transmission can be accurately determined through the orderly accumulation of interference model. When the link set \( LS \) has concurrency, if any link \( L_v \) transmission is successful, then we call \( LS \) is feasible link set (feasible link set), referred as the feasible set. Link scheduling can be converted to finding problems of multiple feasible set.

III. WEIGHTED CONCURRENT FIGURE

The main challenge of network interference modeling is to deal with the characteristics of SIC sequence detection and interference cumulative effects. The following figure shows the weighted concurrency (WSG, weighted simultaneity graph). Its main idea is to reflect the interference between the links through the weights, while the sum of the weights reflects the cumulative effects of interference.

A. Structure

Specifically, make \( sgw = (V, E, w_e, w_v) \) represents a WSG, where \( V \) is the vertex set, \( E \) is the set of directed edges, \( w_e \) and \( w_v \) right point (vertex weight) and right side (edge weight) collection \( SGW \) contains two class of distinct vertexes.

Common vertex corresponds to a single link. Create OV (\( Li \)) for the link \( Li \). Order \( v_i = p_{i} \) represents the weight of \( Li \).

There are two distinct types of \( SGW \) side.

Establish \( l_i \) to \( Li \)'s side, if \( p_{i} < (p_{i} + r_{i}) \) \((i \neq Li \) and \( l_j \) are not related links). Order \( e_j' = p_{i} \) represents the right side of the edge.

Establish \( l_i \) to \((l_i') \) side, if \((P_{ii} + n0) \) \( p_{i} \) \((i \neq Li \) and \( l_j \) are not relevant links, and \( l_j \) signal is stronger than the \( l_i \) signal at the \( R_i \)). Order \( e_j = p_{j} \) represents the right side of the edge.

Figure 1 shows a graph of the weighting of concurrent example, Figure 1 (a) is a network which contains four links \( L_1, ..., L_4 \), wherein, \( L_2 \) and \( L_3 \) are \( L_1 \)'s associated links, and the distance of \( S_2, S_3, S_1 \) and \( S_4 \) to \( R_1 \) progressively increase. Take link \( L_1 \) as an example to explain the tectonic processes of \( SGW \). First, establish four common vertexes \((L_1 \sim L_4)\) for the four links; since, \( L_2 \) and \( L_3 \) are related links of \( L_1 \), thus we create hyperlinks vertex \( L_1L_2 \) and \( L_1L_3 \). Secondly, because the link \( L_4 \) is not \( L_1 \)'s related links, we establish a side from \( L_4 \) to \( L_1 \) and the right side is \( P14 \); since \( L_2 \) and \( L_3 \) are \( L_1 \)'s associated links, creating side from \( L_2 \) and \( L_3 \) to \( L_1 \) is not needed. Since \( P13 \wedge P12 \), we establish a side from \( L_3 \) to \( L_1L_2 \)'s edge and the right edge as \( P13 \); without creating \( L_2 \) to \( L_1L_3 \) side. The resulting weighted concurrent is like what the Figure 1 (b) shows (for clarity, the weight of each vertex is not given).

![Weighting example of a graph of concurrent](image)

B. Analysis and Discussion

The key of concurrent weighted graph structure is to receive \( p_{ij} \)'s energy access. In this regard, Qiu L and Reis c e.t. give a measurement-based approach, the basic idea is: when there is no link transmission, the receiving node can measure the noise intensity \( N_0 \); the link \( l_i \), at a certain time slot, allows only \( s_j \) send packets. At the moment, for any receiving node \( R_i \), the energy it received is measured as \((N_0 + p_{ij})\); every link performs this procedure then it can get all the \( p_{ij} \) \((1 \leq i, j \leq n)\). Obviously, this method is effective for static wireless networks, but once network topology’s dynamic changes occur, we need to re-execute the above measurement process. When a network has a strong dynamic, the method and timeliness of the cost have become far from ideal. For dynamic wireless networks, how to get timely access to information about its status remains a challenging problem. On link scheduling, when the network frequently changes dynamically, the existing scheduling policy may not apply. At this point, we need some mechanism to track, analyze and forecast the network dynamics. This is beyond the scope of this paper.

SIC is very simple, but it's complexity of computation, control logic’s achieving should not be underestimated. The progress of hardware design technology and software radio (SDR, software-defined radio) and other new technology, helps overcome this problem Recently, Halperin D, etc. realize SIC with the SDR platform and experimentally analyzed the impact of SIC on network performance. As a complex signal processing algorithms,
The most critical key of SIC’s realization is to make a choice between performance and cost. Weber B, etc. points out that SIC will be able to greatly improve network performance only needs less than 2 iterative decoding; at the same time, continue increase of the number of iterative decoding does not significantly improve network performance. Accordingly, SIC’s realization can be greatly simplified. By avoiding the complex high-level iteration, SIC will be able to exchange for a reduced implementation difficulty with little performance loss.

IV. CONTEXT-AWARE GREEDY SCHEDULING ALGORITHM

Due to the cumulative effects of interference and the features of SIC sequence detection, it is difficult to accurately assess the link interference, unless the context of the link has been fully specified. This makes available interference information extremely limited at the link selection stage. For this reason, we research the use of interference information of time slot selection phase and put forward a new scheduling algorithm.

A. Greedy Algorithm

Supposed that each link requires only one time slot, the link scheduling problem is: to give a weighted concurrent chart, find a set of link sets which meet the following conditions: a) each link is included in a particular link set; b) Each link sets are feasible set; c) minimum number of link set.

Theorem 1 in wireless network which supports SIC, link scheduling problem based on the cumulative interference model is NP-hard.

Proof For any link Li and each \( j \neq i \), order the threshold value \( \beta_j \rightarrow 0 \). Then, Li can not decode any signal except the signals it needs. The question naturally degenerate into a non-SIC link scheduling problem, which is NP-hard problem. Therefore, as a more general case, the issue of this paper is NP-hard.

As there is yet no polynomial time optimal solution of NP-hard problem, greedy algorithm as an effective approximation scheme has been widely studied. Greedy scheduling mainly contains link selection and time slot selection phases. Figure 2 shows the general process of greedy scheduling: a) link selection: chose a link in the set of links which is not scheduled according to given indicators, make Li represent this link; b) time slot options: look for time slot which is available for Li in the assigned time slot. A time slot available for Li is scheduled to be after that time slot and all scheduled links including Li can be successfully transferred. If there are no available time slots, then assign a new time slot and if there are several available time slots, the algorithm will select the best time slot for Li. Above process is repeated until all links are scheduled.

Existing schedule in time slot selection phase commonly adopts first-match strategy, hat is they always choose the first available time slot. They try to obtain good performance through the interference information in the link selection stage. The rationality of this design comes from the study of graph coloring (graph coloring). Graph coloring is a classic problem of graph theory. Its research results indicate that sorting through the rational vertexes, the greedy algorithm which based on the first match can obtain optimal or near-optimal solution. However, FIG models only consider the interference between each two links, which also is feasible under the non-cumulative interference model. However, under the cumulative interference model, the affect of link interference is also closely related to its concurrent links. In the link selection stage, these concurrent links, that is the context, can not be determined, and they severely limit the scheduling algorithm.

![Figure 2. Process of Greedy Scheduling Algorithm](image)

Accordingly, we propose design of context-aware scheduling which focuses on the time slot selection phase. The basic idea of the new program is that even if the link orders in any sort of way, a good schedule can be achieved by designing an appropriate time slot selection strategy. At this point, the main task of algorithm design is to reasonably assess the suitability of each time slot for scheduling current link. The key of the assessment is to accurately portray the current link is dispatched after the interference generated. In this case, each scheduled links of time slot provides the context information which is needed to assess the current link.

B. Link Set Saturation

We may note \( R'_i \) as the link set which is dispatched to time slots \( t_i \) before dispatching \( L_i \). Then the interference generated from the dispatch of \( L_i \) to \( t_i \) embodied as the difference in saturation \( (i, \text{ the ability to accept a new link}) \) between \( R'_i u \{ L_i \} \) and \( R'_i \). As for LS link set and link \( L_i \), if \( L_i u \{ L \} \) is not feasible set, we call link set LS saturated for \( L \). Obviously, the empty set has minimum saturation. Adding any new links are likely to increase the saturation of the link set. However, if a new link interference can be eliminated by the SIC, adding it does not change the link set saturation. Link set
LS saturation can be reflect through the link LS immunity.

Definition 1 Link \( L_i \in L \) tolerance means maximum interference the link L can tolerate when the LS all links.

Given weighting concurrently diagram, algorithm 1 shows the tolerance calculation. The tolerance value is the smaller one of the following disturbances: a) necessary minimum interference for any one of links associated with L decoding the signals; b) necessary minimum interference that disturb L signal decoding after all relevant signals are removed. Algorithm 2) ~3) calculate the part a), and line 4) to line 10) calculate the part b). Link tolerance and feasibility have the following relationships, whose correctness is not difficult to be proved.

Theorem 2 the link L of link set LS is feasible, if and only if L tolerance is greater than 0.

Theorem 3 algorithm 1’s time complexity is \( o(|LS|^2) \), wherein \(|LS|\) is the number of links that LS contains.

Proof First of all, the first two lines need to traverse all edges between vertex \( L_i \) and \( L_j \), and its complexity does not exceed O (|LS|). Secondly, 4) ~ 10) lines need to traverse all super-vertexes which are shaped like \( L_i L_j \) and sides between \( L_i L_j \) and \( L_j L_i \). The number of edges of each super-vertex does not exceed O (|LS|), while the number of super-vertex does not exceed O (|LS|). Thus, the algorithm’s time complexity is O (|LS|^2). QED

Algorithm 1 Calculation of tolerance
Input: SGW = (V, E, WW, WE): Weighted concurrent
Figure
LS: link set; \( L_i \) : is output of the LS link:
Output: Li’s tolerance
a) SG, WW←SGW;
b) \( M_0 \leftarrow v_i / \beta_i - N_0 - I_0 \);
c) For each link Ly in LS do
\( M_y \leftarrow v_y / \beta_y - N_0 - I_0 - v_i \);
d) End
h) Return \( M_y \)

Take figure 1’s link L1 as an example to demonstrate the calculation of tolerance. First, after removing the relevant link signal, L1’s suffered interference is the signal and noise of L4. Thus interference that L1 can withstand is \( M^1 = P_{11}/\beta_{11} - N_0 - P_{14} \). Secondly, considering R1’s signal decoding for relevant links. For link L2, when link L1 and another one related link L3 suffer signals interference, the interference which its signal decoding can withstand is \( M^2 = P_{12}/\beta_{12} - N_0 - P_{14} - P_{13} - P_{11} \). Similarly, for link L3, the interference which its signal decoding can withstand is \( M^3 = P_{13}/\beta_{13} - N_0 - P_{14} - P_{13} - P_{11} \). Finally, the tolerance of links L1 is the minimum among \( \{ M^1, M^2, M^3 \} \).

Definition 2 Link set \( L_i \)'s tolerance is denoted as MLS, which means the maximum interference it can tolerate when it is under a feasible premise.

Tolerance of set is the minimum tolerance of each link. Link set tolerance is calculated as follows: For each link of set link, algorithm is applied, and then take the minimum of all the results. For \( L_i \in L_S \), if \( M_{L_i} \mu \{ L \} \geq 0 \), then we say that LS is feasible for L. Tolerance measures the saturation of the link set. Empty tolerance is infinite. Adding a new link may lead to reduction of tolerance and increase of saturation. Eventually, when tolerance is reduced to a critical point, any unscheduled link’s joining will make the link set unsafe, and link set is said to reach saturation. Similarly, for tolerance and feasibility of the link set, the following relationship exists.

Theorem 4 Link set LS is feasible, if and only if LS tolerance is greater than 0.

Sub optimality of first matching strategy is that it simply chooses the first feasible time slot, while ignore the scheduled link set tolerance on the time slots. Consider that two links L1 and L2, assuming that \( P_{12} / P_0 + P_{11} = \beta_{11} \). Since signal L2 can be removed by SIC in the receiving node of L1, so L1 and L2 can be complicated. However, if they are complicated, because \( M \{L_1, L_2\} = 0 \), any other link can no longer dispatched to the time slot. From the perspective of the whole network optimization, it might be able to get better results if the two are assigned to different time slots. Therefore, choosing a time slot in any manner may increase the final number of necessary time slots.

C. Context-aware Scheduling

Now the context-aware scheduling algorithm CONG is given, its processes is shown as algorithm two below. First, arbitrarily order all links as the \( L_1 L_2...L_n \). Before Li is scheduled, make Ni as the number of time slot that has been used. \( s_j \) is the scheduled link set at j time slot. CONG processes each link from L1 in the following ways: a) For each \( 1 \leq j \leq N_i \), calculate the tolerance of \( \{ L_i \} \); b) If \( N_i = 0 \) or when \( 1 \leq j \leq N_i \), Li is not feasible for \( s_j \), then reassign a new time slot to schedule L. Otherwise, it selects a schedule Li among all the available time slots. After processing all links, CONG return the total number of time slots and the scheduled link set of each time slot. Obviously, all the link sets are feasible.

Algorithm 2 Context-aware greedy scheduling algorithm CONG
Input: SGW = (V, E, WW, WE): Weighted concurrent
Figure
Output: The number of time slots M and dispatch \( s_1 ,..., s_m \)
a) N←0;
b) Order links arbitrarily as \( l_1 ...l_m \);
c) For \( i =1 \) to n do
\( d) For k=1 to M do
\( e) Calculate tolerance of \( s_k \) and \( s_i \cup \{ l_k \} \)
f) End  
g) If no available time slots for $l_i$  then  
h) Assign time slot (M +1) and let $S_{l_i+1} \leftarrow \{l_i\}$  
i) Else  
j) Chose a best time slot (such as $t$ ($1 \leq t \leq M$) time  slot)  
k) $S_i \leftarrow s_i \cup \{l_i\}$  
l) End  
m) End  
n) Return $M$ and $s_1,...,s_m$.

Theorem 5 the time complexity of Algorithm 2 does not exceed $o(n_i)$, wherein $n$ is the number of links included in the network.

Proof first, calculate any link set $S_i$’s tolerance, time costs no more than $o(s_i[2])$. At the same time, $x_1^2 + x_2^2 +... + x_n^2 \leq (x_1 + x_2 +... + x_n) \leq 2$, and all the number of links $s_i$ does not exceed O (n). Thus, the total time cost of 4- 6) line does not exceed $o(n_i)$. Secondly, the time cost of (7) to 10) line is a constant, the 11) line’s required tolerance information has been calculated, the cost of selection process is O (M) $\leq$ O (n). In short, a cycle (4) to (11) line) time requires O (n2). The number of times that loop is executed does not exceed O (n). Thus, the total time cost is no more than O (n3). QED. Here are two kinds of strategy for selection time slot.

Maximum residual priority (LRF, largest residue first): In all the available Time slots chose the first time slot which has the most tolerance. For the link $l_i$, the condition for selecting k time slot: k is the minimum of $R^i_k$.

$$ R^i_k = \{A[T_i \cup \{l_i\}]\} \forall \{S_i\} $$

Among this:

$$ \Omega_i = \min 1 \leq R \leq |S_i [T_i \cup \{l_i\}]| $$

Minimum reduction priority (MDF, minimum decrease first): In all the available time slots, choose the smallest tolerance reduces the first time slot. The link $l_i$, the $k_{th}$ time slot selected condition: k is the minimum of $R^i_k$.

$$ R^i_k = \{A[k_{t=1}\max_{S_i[k]} \{A^t_i\}]\} $$

Among this:

$$ \lambda^t_i = R^i_{\lambda_i} \leq R^i_{\lambda+1} \cup \{l_i\} $$

Li is the time slot tolerance variation when it is dispatched to the j time slot. The common goal of the two kinds of strategies is to dispatch more links to the selected time slot. In general, the greater the tolerance, the stronger ability of a link set receiving a new link. LRF $s$ selection balance the tolerance on different time slots, avoiding a lot of link set on time slot reaching saturation in the early scheduling stage. The MDF is more focused on minimizing the interference which generates from the current link’s scheduling. The example in figure 3 shows the difference between LRF and MDF, assuming three time slots are used before $l_i$ is scheduled. Since

$$ M_{\omega[1]} > M_{\omega[2]} > M_{\omega[3]} $$

LRF selects $t_1$ time slot. However, since $s_1$ $\{l_i\}$ $s_1$ $\{l_i\}$ MDF selects $t_3$ time slot. We can investigate the performance of two strategies by the following simulation.

![Figure 3. Example of difference between LRF and MDF](image)

V. EXPERIMENTAL RESULTS

The performance of approximate solutions is evaluated through a network simulator’s (NS 2, network simulator 2) simulation experiments. Table 1 summarizes the simulation process’s parameters and protocol settings. Evaluating performance index is the throughput, wherein the average throughput is the average of the total throughput (aggregate throughput), the average throughput of a single link chain is the average throughput obtained by each link. Each data point is obtained through average of the repeated results. By comparison with the first matching strategy to examine the performance of the new scheduling mechanism, two kinds of new strategies and the first match of the experimental results are represented by LRF, MDF and First-Fit.

<table>
<thead>
<tr>
<th>Parameter / Value</th>
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</thead>
<tbody>
<tr>
<td>Protocol / protocol</td>
<td>Value / mechanism</td>
<td>Parameter / protocol</td>
<td>Value / mechanism</td>
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<tr>
<td>The number of nodes</td>
<td>15-100</td>
<td>Packet size</td>
<td>1600 byte</td>
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<td>transmission speed</td>
<td>255 m</td>
<td>MAC protocol</td>
<td>TDMA</td>
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<td>transmission range</td>
<td>2.1 Mb/s</td>
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<td>SINR rate</td>
<td>11</td>
<td>Route protocol</td>
<td>Shortest path</td>
</tr>
</tbody>
</table>

NS 2 does not provide a model based on SINR the packets receipt and SIC functionality. First, adding new modules to support the cumulative interference model and SIC, the transmission range in Table 1 refers to the normal maximum distance where the communication link can work when there is no other concurrent transmission. Unless otherwise noted, at the beginning of each time slot, each source node sends a packet according
to the probability of $\eta$. The probability is the same for all the source nodes.

First, evaluate the performance of single-hop scheduling algorithm in the case. In the region $150m \times 150m$, randomly distribute 100 nodes among them randomly select 25 nodes as the source nodes. Figure 4 shows the throughput of three algorithms. As a reference, a maximum throughput can be obtained by the use of mathematical programming which is represented as Optimal. LRF and MDF perform well. Compared to the First-fit strategy, LRF and MDF’s throughput is up to 30% on the edge. In addition, with the increase of transmission probability, First-fit throughput dramatically drops. This is because the experiment link orders in any sort of way and when there are a large number of links, each link’s time slots is chosen arbitrarily in the way of First-fit, leading to the final scheduling performance far from ideal. LRF and MDF’s performance roughly equal. However, it must be noted that three kinds of approximation algorithms and optimized values have a certain distance, to design a better time slot selection mechanism still needs further study.

In order to investigate the large-scale network SIC effect, in a $500m \times 500m$ region, uniform deployment of 81 nodes and randomly select 30 nodes as the source nodes. For each source node, in its range of communication randomly select a node as the target node. Figure 5 shows the relations between the average throughput and transmission probability. Consider another flow pattern, so that $(x, y) \ (1 \leq x \leq 9, 1 \leq y \leq 9)$ represent positions of different nodes, considering the three following modes of flow: (1) $P_1: (x, 1) \rightarrow (x, 9)$; (2) $X_1: (x, 2) \rightarrow ((x+7) \mod 9, 7)$; (3) $X_2: (x, 9) \rightarrow ((x+7) \mod 9, 7)$. In order to model to operate, it returns the remainder of $v_1$ dividing $v_2$. Each stream mode has nine different data streams. These data streams may require multi-hop transmission. Different stream mode, the required number of forwarding link is also different. Wherein, $P_1$ requires minimum number of links, $X_1$ second, and $X_2$ needs most. Figure 6 shows the throughput of three kinds of flow patterns.

In the scene of figure 5, the number of active links will gradually increase along with the growth of $\eta$. In the scene of figure 6, from the $P_1$, $X_1$ to $X_2$, the total number of links is also increasing. With the network containing more links in the network it will be expected there are more opportunities for multiplexing. In these scenarios, LRF and MDF demonstrate significantly better than First-fit.

Finally, in an area of $500m \times 500m$ randomly deploy 100 nodes. Then randomly select 30 nodes of the 100 nodes as the source nodes. For each source node, randomly select nodes as the target nodes. At this time, some nodes need the multi-hop transmission and the total number of all active links is from 30 to 48. Figure 7 shows the relation between average throughput and the number of links when $\eta = 0.84$. Compared with First-fit, LRF and MDF’s throughput gain is up to 27%.

VI. CONCLUSION

This paper studies link scheduling based on the cumulative interference model in static wireless network which supports the SIC. First, giving a weighting figure
to describe concurrent network interference, and points out that the link scheduling problem is NP-hard; then, the main research is about greedy scheduling algorithm. Because of SIC’s sequence detection characteristics and the cumulative effects of interference, accurately measuring the link interference becomes a major challenge of the research. Existing greedy scheduling method does not fully understand and use the interference information, resulting in that their performance is not ideal. This paper defines the tolerance to measure the saturation of the link set, and then gives two efficient strategy to let given link choose the best time slot. In the simulation experiment, the performance two kinds of strategy are better than that of the commonly used first-match strategy, and their scheduling performance has been improved in heterogeneous static wireless networks.

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