Using Genetic Algorithms based on Neighbor List Mechanism to Reduce Handover Latency for IEEE 802.11 WLAN

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ABSTRACT

In IEEE 802.11 Wireless Local Area Network (WLAN), the mobile stations (STAs) have to perform handover to keep network connections when they move out of the range of an access point (AP). However, the STAs collect the information of surrounding APs by channel scanning, which will cause high handover latency and degrade the quality of mobility. Therefore, minimizing the scanning delay is key to enabling seamless communications over WLAN. In this paper, we propose a genetic algorithm (GA) algorithm combined with neighbor list mechanism to reduce handover latency. Using this proposed approach, the handover latency is minimized by reducing both the number of scanned channels and the waiting time for each channel. Simulation results demonstrate that our approach improves throughput up to 9.5% and reduces handover delay up to 74% compared to standard IEEE 802.11.

CCS CONCEPTS

• **Computing methodologies → Genetic algorithms**; • **Networks → Network management**;

KEYWORDS

Genetic Algorithms, IEEE 802.11 WLAN, NLM

ACM Reference Format:
Lina Hao and Bryan Ng. 2018. Using Genetic Algorithms based on Neighbor List Mechanism to Reduce Handover Latency for IEEE 802.11 WLAN. In *GECCO '18 Companion: Genetic and Evolutionary Computation Conference Companion, July 15–19, 2018, Kyoto, Japan.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3205651.3205704

1 INTRODUCTION

IEEE 802.11 WLAN handover consists of three phases: scanning, re-authentication and re-association. The 802.11 scanning takes more than 300ms to scan all the channels and accounts for more than 90% of the overall handover latency [3]. Therefore, reducing scanning delay can improve overall handover latency. In our previous work [2], we proposed a neighbor list mechanism (NLM) to reduce handover latency. In NLM, an up-to-date sorted neighbor list is stored in an access point controller (APC). All APs are linked to the APC. Each STA is made aware of the neighboring APs and their channels by APC. Therefore, the STA only probe a reduced set of channels and APs and the scanning delay is reduced.

In this paper, a genetic algorithm based on neighbor list mechanism (GA-NLM) is proposed. We use GA to find a solution for the optimal values of scanning timers. These timers are $MinChannelTime$ and $MaxChannelTime$ whereby the $MinChannelTime$ is the minimum waiting time that a STA spends before considering the channel is empty and $MaxChannelTime$ is the maximum waiting time after a probe response has been successfully received. The scanning timers optimized by GA are stored in the APC. They will be sent to a STA combined with the neighbor list when scanning is initiated. The GA-NLM is a pre-handover plan mechanism. After the fist full scan obtaining the neighbor list and GA optimized scanning timers, the following scans with the known neighbor information and optimized scanning timers can significantly reduce the scanning delay. This reduction occurs because the GA-NLM reduces the number of scanned channels, probed access points and unneccessary waiting time of probe responses of non-adjacent APs or APs with poor Quality of Service (QoS).

2 PROPOSED GA-NLM OPTIMIZATION

In this section, our proposed GA-NLM handover scheme is presented. We articulate the problem of handover latency and present the GA-NLM solutions.

2.1 Problem formulation

The scanning delay can be calculated using Equation 1 as follows,

$$T_{scanning} = T_{P_{req}} + T_{switching} + T_{waiting} = \sum_{i=1}^{N}\{T_{P_{req}}(i) + p_{empty} * MinCT(i)) + (1 - p_{empty}) * MaxCT(i) + T_{switching}(i)\}, \quad (1)$$

where $T_{P_{req}}$ is probe request time and $T_{switching}$ is the channel switching time. $T_{P_{req}}$ and $T_{switching}$ are assumed as constant in this paper. Therefore, the problem reduces to minimize $T_{waiting}$, which denotes the probe response waiting time. It turns out that $T_{waiting}$ is a function of $MinCT(i)$ and $MaxCT(i)$. The number of channels is denoted by N. p_{empty} denotes the probability that the ith channel is empty. The value of p_{empty} is calculated based on the entries in the neighbor list.

In the neighbor list mechanism, there is no empty channel on the neighbor list. Therefore, we assume the probability of finding an AP (over the duration $MaxCT(i)$) follows a Uniform distribution. The probability of AP discovery from t=0 to t= $MaxChannelTime$ is 1. Therefore, we have the probability density function as follows:

$$f(t) = \frac{1}{MaxCT(i)}. \quad (2)$$

GECCO '18 Companion, July 15–19, 2018, Kyoto, Japan

ACM ISBN 978-1-4503-5764-7/18/07.
https://doi.org/10.1145/3205651.3205704

Using the Probability Density Function (PDF) in Eq.2, the probability of AP discovery within $MinCT(i)$ is defined as follows:

$$P_{min}(t) = \int_{0}^{MinCT(i)} \frac{1}{MaxCT(i)} dt. \tag{3}$$

The average discovery rate of APs over a duration of $MaxCT(i)$ is expressed as follows:

$$\begin{aligned} D &= \frac{N_{Min}}{MinCT(i)} + \frac{N_{ap} - N_{Min}}{MaxCT(i) - MinCT(i)} \\ &= \frac{P_{min}(t) * N_{ap}}{MinCT(i)} + \frac{(1 - P_{min}(t)) * N_{ap}}{MaxCT(i) - MinCT(i)}, \end{aligned} \tag{4}$$

where N_{ap} denotes the total discovery number of APs over each scanning time $MaxCT(i)$ on channel i. N_{Min} denotes the average discovery number of APs within $MinCT(i)$ scanning time and $P_{min}(t)$ is defined in Eq.3. The threshold of the average discovered rate of APs over $MaxCT(i)$ on channel i is defined as follows.

$$D_{threshold} = \frac{N_{ap}}{MinCT_L}. \tag{5}$$

Therefore, the scanning delay problem can be formulated as follows:

$$\arg_{\{MinCT(i), MaxCT(i)\}} \min\{T_{scanning}\}, \tag{6}$$

constraints:

$$D \leq D_{threshold}, a \leq MinCT(i) \leq b, c \leq MaxCT(i) \leq d \tag{7}$$

where D and $D_{threshold}$ are expressed in Eq.4 and 5, the constraint 7 means that if available APs can be found only within last $MinChannelTime$ duration denoted by $MinCT_L$, the STAs will stop searching for more APs. The constraints expressed in Eq.7 are set the boundary values for $a = 0s, b = 1s, c = 0s, d = 1s$.

2.2 GA-NLM: GA optimization procedures

In the GA-NLM approach, two strategies are used to set the values of scanning timers. These are fixed values and GA optimized values. The first stage is to set the fixed pre-defined timers with the same values for all channels. The STA does a full scan to obtain all neighbor APs' information and a sorted neighbor list will be stored in APC. In the second stage, GA is adopted to optimize the scanning timers for each channel. Finally, the neighbor list combined with GA optimized timers are used for the following scans.

In the GA procedures, a set of scanning timers of $MinCT(i)$ and $MaxCT(i)$ are considered as genes of a chromosome. If the number of scanning channels is N, the size of each chromosome is a string of length $N * 2$, which is shown in Fig. 1. The inital population is a randomly generated set of chromosomes by Pseudorandom Numbers Generators. Our fitness function is the objective function in Eq.6 subject to Eq.7. After evaluation, the parents with better fitness values are selected to create new children. The new children can be generated by a uniform crossover and a random uniform mutation. The GA process will be terminated when the maximum generation is reached.

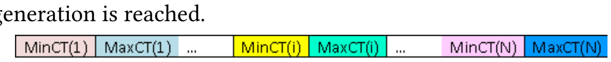

Figure 1: Chromosome representation

3 RESULTS AND ANALYSIS

We implemented the GA-NLM algorithm in ns-3 and collected the throughput and handover delay over 30 running times with a confidence interval of 95%. We evaluates the handover performance of the standard 802.11[1], the NLM [2] and the proposed GA-NLM.

As we can see in Fig. 2, the GA-NLM significantly improves the handover delay compared to 802.11 standard, with an average reduction of 74% by approximately 0.12s (averaged over handovers). In Fig. 3, the trend of throughput decreases with the moving speed increasing in these three mechanisms. However, in the case of proposed GA-NLM handover scheme, throughput is less affected by the speed increasing compared with IEEE 802.11 standard and the NLM. The throughput has been improved by around 9.5% (speed at 6m/s) using GA-NLM method.

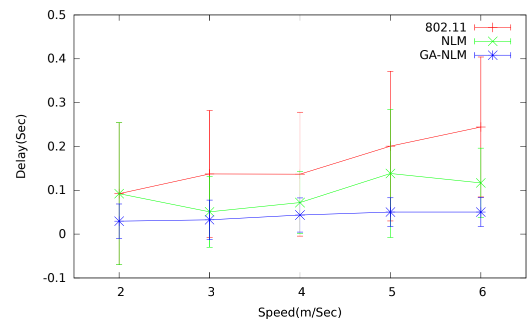

Figure 2: Handover delay of various STA speed

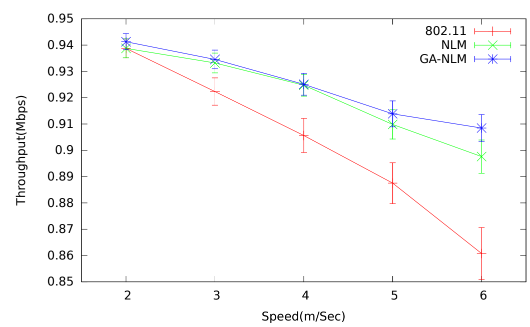

Figure 3: Throughput of various STA speed

4 CONCLUSION

The main contribution of this paper is to introduce a GA method to optimize the scanning parameters based on the neighbor list mechanism. GA-NLM dynamically optimizes the scanning timers using GA algorithm and significantly reduces handover latency by 74% compared with standard 802.11. The throughput is improved up to 9.5%.

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