Chapter 3

Simulation and Numerical Results

3.1 Simulation Results

There are three parts in the simulations. The first 2 parts compare the original PCF with the PCF which applies the static partner choosing algorithm and the dynamic partner choosing algorithm about the performance, like throughput, delay and packet loss. The PCF which applies the static partner choosing algorithm is named ***Static Cooperative PCF***, while the PCF which applies the dynamic partner choosing algorithm is named ***Dynamic Cooperative PCF***. In the first part, we try to simulate how the packet error rate affects the overall performance when the number of the stations is fixed. In the second part how the increase of the number of the stations affects the overall performance when the packet error rate is fixed. In the third part, we prove that after applying the dynamic partner choosing scheme, the load of help other error stations is distributed among all the stations.

The simulation topology is shown in Fig. 3.1. There is only one destination connecting to the AP via wired link. The destination acts as a sink receiving all the traffic flows sent by the wireless stations attaching to the AP. The wireless medium is *802.11b DSSS* with bandwidth of 11Mbps. And the relative parameters are listed in Table 3.1. In order to

Table 3.1: Simulation parameters

Parameter	Value
PHY	DSSS
bandwidth	11Mbps
slot time	20us
SIFS	10us
PIFS	30us

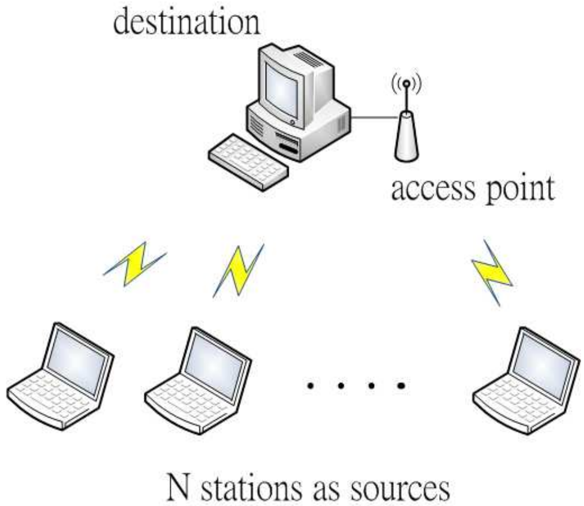

Figure 3.1: The Simulation Topology

emulate the fluctuant radio link in the wireless environment, we adopted the simplified two-state Gilbert-Elliott error modelSGE. The two-state Markov model is concentrated because Zorzi *et al* [10] investigated the error characteristics in a wireless channel and claimed that two-state Markov model is a good approximation of wireless channel. Fig. 3.2 illustrates a state diagram for the two-state Markov model of Gilbert-Elliott channel. The wireless link may be in the "*GOOD*" or "*BAD*" states. In the "*GOOD*" state losses occur with low probability p_G while in the "*BAD*" state they happen with high probability p_B. But we use the simplified Gilbert model that the p_G and p_B are set to be 0 and 1 respectively. The transition probabilities, P_{GB}, P_{BG}, P_{GG} and P_{BB}, mark the probabilities that the radio link will transit from one state to the other. The steady state probabilities of being in state "*GOOD*" and

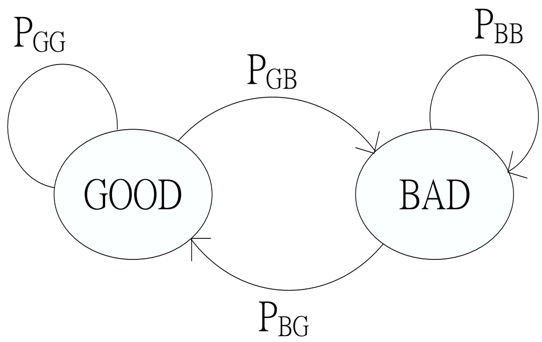

Figure 3.2: The Error Model

"*BAD*" are

$$\Pi_G = \frac{P_{BG}}{P_{BG} + P_{GB}}$$

and

$$\Pi_B = \frac{P_{GB}}{P_{BG} + P_{GB}}$$

The average packet loss rate produced by the Gilbert channel is

$$p = p_G \Pi_G + p_B \Pi_B$$

which is

$$p = \Pi_B$$

in this case since we set p_G to 0. The error model is applied to every link between every two terminals. Simulations is run based on the NS-2 [11] network simulator. In the simulations, the association process is neglected. Because we want to simulate the effects of putting cooperative network into PC, we focus on the *Uplink* traffic and *constant bit rate (CBR)* traffic type. And we assume all the stations always are *backlogged* and have data frames to send, so the data arrival rate is set large enough. The packet size are all 1000*bytes*.

1. In the first part of simulations, we want to see how the packet error rate enhance the performance when applying the static and dynamic partner choosing algorithms in the PCF, under the fixed number of stations environment. Every single experiment

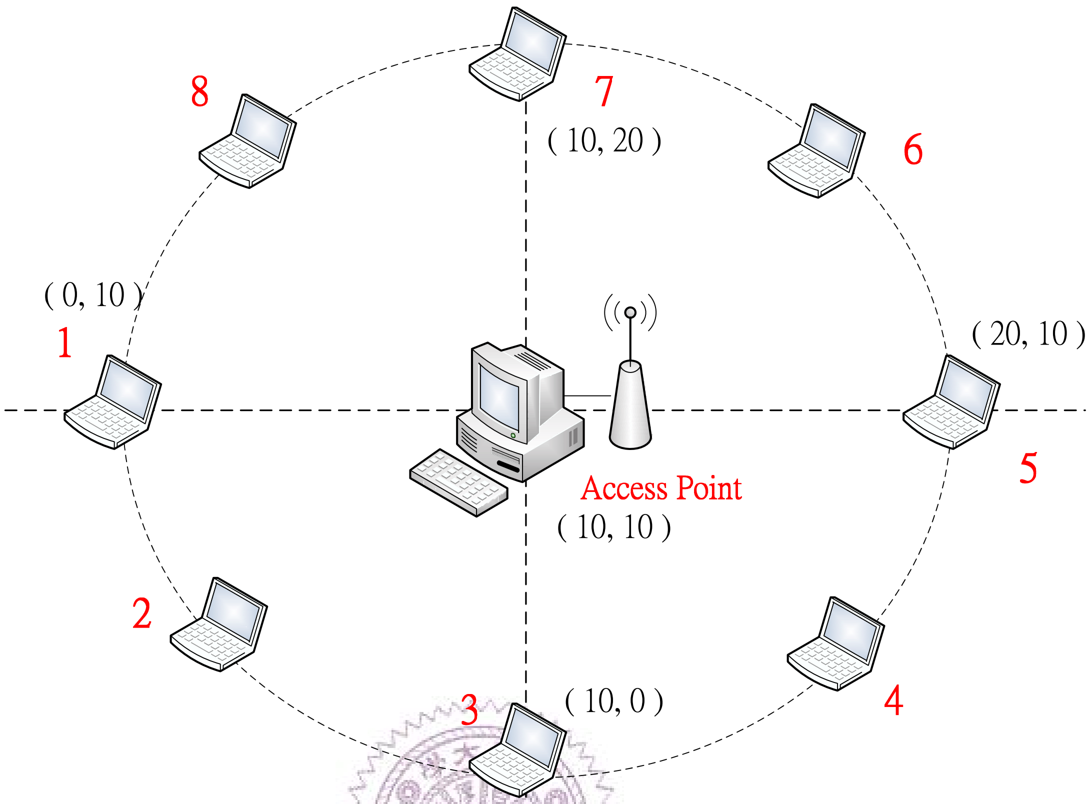

Figure 3.3: The Topology of The First Part Simulations

takes 100 seconds of simulations time. The number of stations is set to be 8 and the simulation scenario is illustrated like Fig. 3.3. The destination is in the center and 8 stations is spread with equal distance in a circle, which radius is 10, around the destination. Refer to [12], the P_{GB} and P_{BG} are set as the formulas indicate. We consider the packet error rate from *0.01*, *0.1* to *0.9*. We compare the original PCF, the Static Cooperative PCF, and the Dynamic Cooperative PCF. The simulation results are shown in Fig. 3.4, Fig. 3.5 and Fig. 3.6.

In Fig. 3.4, the x-axis represents the set *packet error rate* [13] from 0.01 to 0.9, while the y-axis stands for the overall system throughput in *Mbps*. As the plot shows, the throughput decreases as the packet error rate increases. It is because when packet error rate increases, the probability that PC is unable to send out correct polling frames or

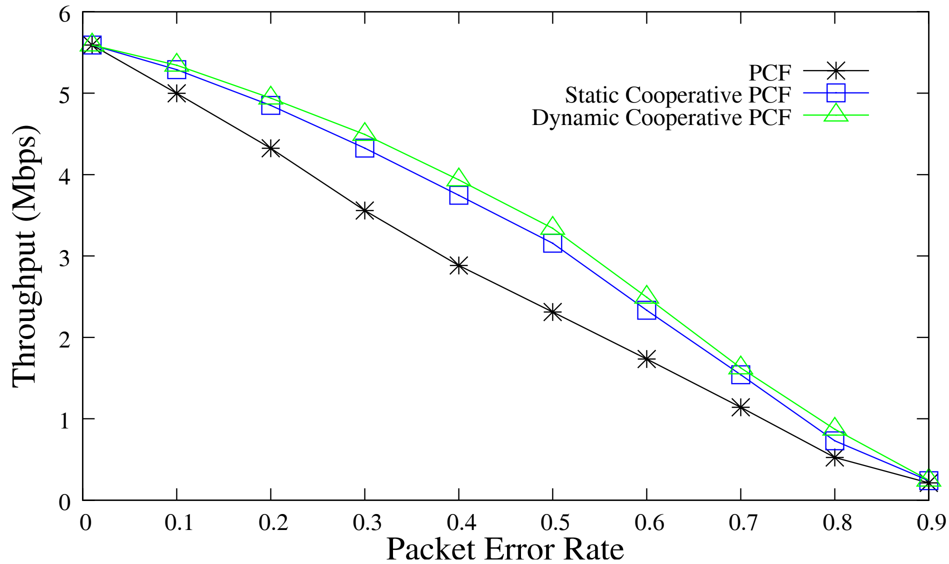

Figure 3.4: The Throughput Results of PCF, Static Cooperative PCF, and Dynamic Cooperative PCF

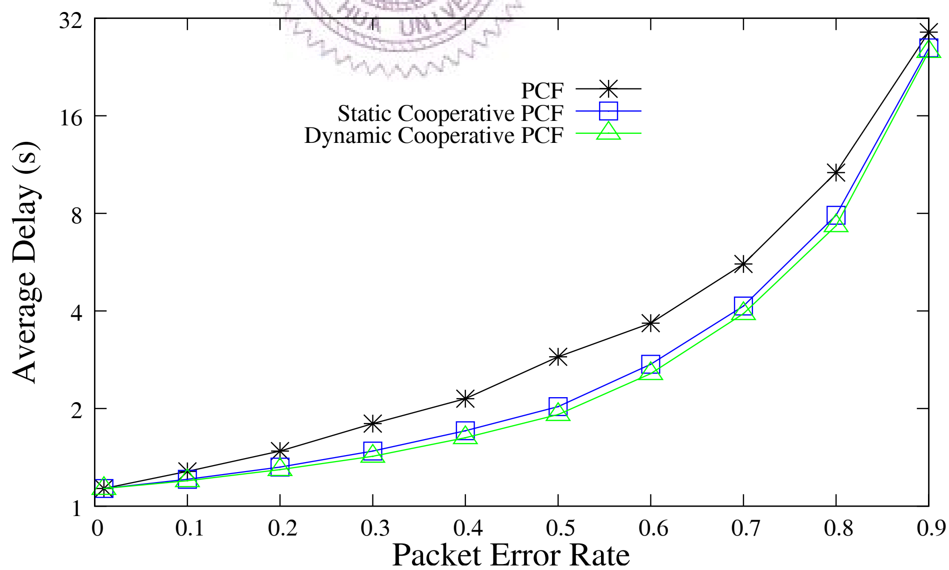

Figure 3.5: The Delay Results of PCF, Static Cooperative PCF, and Dynamic Cooperative PCF

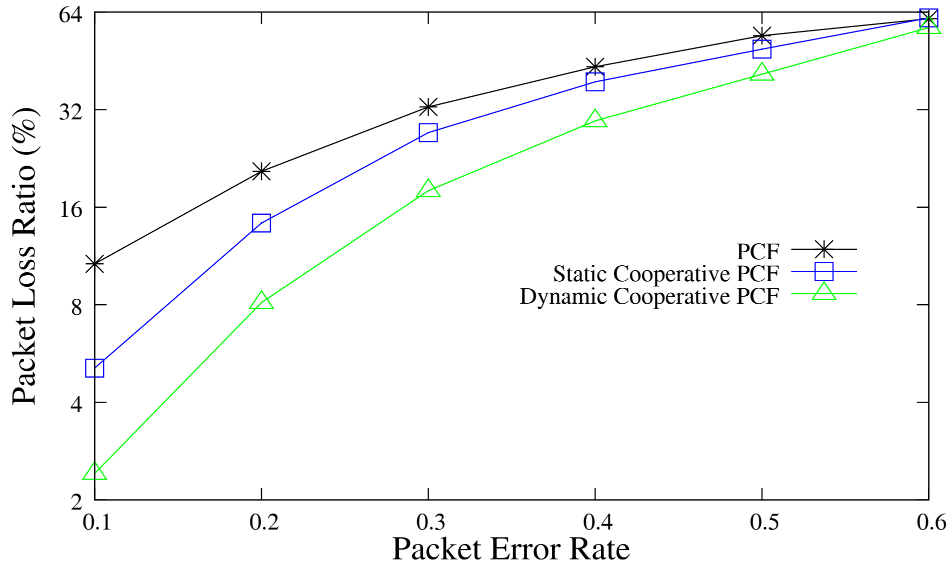

Figure 3.6: The Packet Loss Ratio Results of PCF, Static Cooperative PCF, and Dynamic Cooperative PCF

the stations are unable to reply to PC arises. For PCF, the throughput can achieve 5.59 *Mbps* when packet error rate is very low, but fall to 0.21*Mbps* when packet error rate increases to 0.9. As to the *Cooperative PCF*, because of the dynamic partner choosing scheme effects, the throughput can be improved up to 44% when packet error rate is 0.5. When the packet error rate arises, there will be more and more channel error problems that can be fixed by the dynamic partner choosing scheme. But when the packet error rate increases to some extent, although there are more and more the channel error problems, the percentage of the *Helpers* having a bad channel is high too. So high packet error rate will decrease the profit from the cooperative operations. Overall, the throughput is enlarged no matter how the packet error rate changes. The enhancement compared to the original PCF is from 7% (packet error rate = 0.1) to 44% (packet error rate = 0.5), and will be 15% even when packet error rate = 0.9. Thus, the *Dynamic Cooperative PCF* which applies the dynamic partner choosing algorithm has better performance than the PCF.

In Fig. 3.5, the x-axis represents the set *packet error rate* from 0.01 to 0.9 and the y-axis stands for the *average delay* in seconds. The traffic is *TCP* in this simulation. As the plot shows, since the overall throughput decreases as the packet error rate increases, the average delay of the TCP packets are sure to increase as the packet error rate arising. In the beginning, the packet error rate is set to be very small,which means the channel error seldom occurs. That is, there is little space that the dynamic partner choosing scheme can make progress. As the packet error rate arises, the possibilities that the station have troubles communicating with the PC become higher and the dynamic partner choosing is helpful. The *Dynamic Cooperative PCF* can reduce the average delay of every packet at least 6% and up to 33%. Just like the throughput cannot be enhanced much as the packet error rate is high, the average delay cannot be reduced much. The error station will not have other station to help it, therefore the transmission packets will be delayed in queue. But the *Dynamic Cooperative PCF* still can reduce the packet delay by 10% even when the packet error rate is 0.9.

In Fig. 3.6, the x-axis represents the packet error rate from 0.1 to 0.6, and the y-axis stands for the *packet loss ratio*. The traffic type is *UDP* this time. And we want to know the effects of using dynamic partner choosing algorithm about packet loss ratio when the traffic is UDP. As the plot shown, the *Dynamic Cooperative PCF* can reduce the number of packet loss a lot compared to the PCF. The reducing can be up to 77% when packet error rate is not that high. But as the packet error rate risen, the range that the *Cooperative PCF* can make progress from the PCF is limited. Overall, the *Dynamic Cooperative PCF* can reduce the UDP packet loss ratio even when the packet error rate up to 0.9.

2. In the second part of simulations, we try to see how much the static and dynamic partner choosing algorithm can help the original PCF as the number of the stations increases. The simulation scenario is in a *20*20* area. The location of PC is in the center, *(10, 10)*, and the stations are randomly placed in this area. In this simulation, the packet error rate is fixed to be 0.3. We consider the performance when the number of stations increases from 5, 10, 15... to 50. Comparing the performance of the original

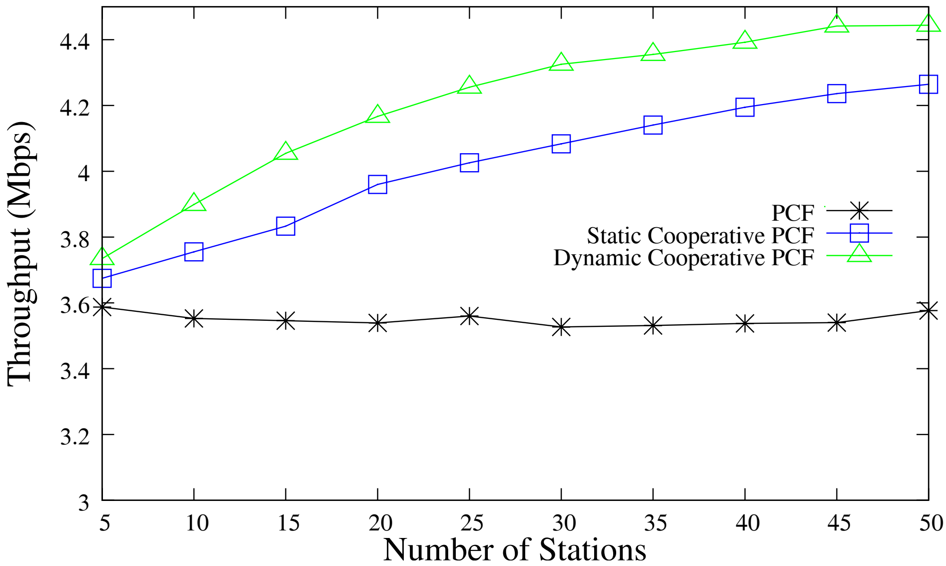

Figure 3.7: The Throughput Results of PCF, Static Cooperative PCF, and Dynamic Cooperative PCF With Packet Error Rate 0.3

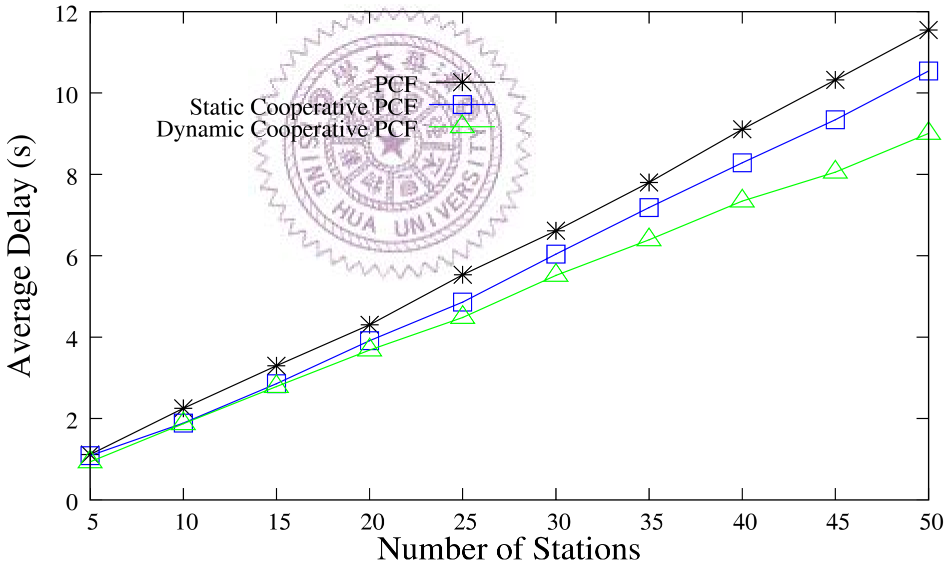

Figure 3.8: The Delay Results of PCF, Static Cooperative PCF, and Dynamic Cooperative PCF With Packet Error Rate 0.3

PCF, the Static Cooperative PCF, and the Dynamic Cooperative PCF. The simulation results are illustrated in Fig. 3.7 to Fig. 3.9.

In Fig. 3.7, the x-axis represents the number of stations and the y-axis stands for the

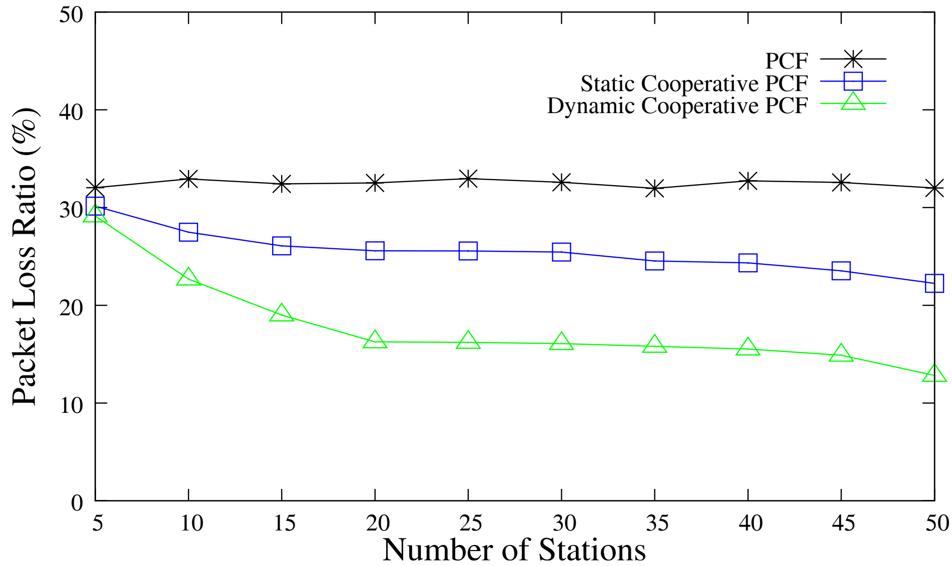

Figure 3.9: The Packet Loss Ratio Results of PCF, Static Cooperative PCF, and Dynamic Cooperative PCF With Packet Error Rate 0.3

throughput in *Mbps*. As the plot shows, *Dynamic Cooperative PCF* can improve the throughput from the PCF up to about 26%. Under the same packet error rate condition, the probability that a bad state station has a good state station to help it increases as the number of randomly placed stations increases. When the number of stations arises, a station suffering from poor channel will have more stations around that might help it during the running time. Since the packet error rate is fixed to 0.3, that means the range the *Dynamic Cooperative PCF* can make progress is limited. So as the plot illustrated, the throughput of the *Dynamic Cooperative PCF* comes to a limitation when the number of stations is big enough.

In Fig. 3.8, the x-axis represents the number of stations and the y-axis stands for the *average delay* in seconds. The traffic type is set to be *TCP* so that the average delay could be meaningful. The average delay of *Dynamic Cooperative PCF* can be reduced up to 22% when the number of stations is 50. When the number of stations increases, the error stations will have more chances to choose good state stations for help. Thus, the average delay is surely to be reduced.

In Fig. 3.9, the relationship between the number of stations and *packet loss ratio* is illustrated. The x-axis represents the number of stations and the y-axis stands for the *packet loss ratio*. The *UDP* traffic is used. As the plot shown, the *Dynamic Cooperative PCF* can reduce packet loss ratio by 30% to 60%. The packet sent to the *Helpers* counted as a packet loss if the cooperation process does not succeed. The reason why the *Dynamic Cooperative PCF* can reduce the packet loss ratio is a error station can easily ask someone for help when the number of *Helper* candidates become larger.

3. In the third part of the simulations, we want to show how the *dynamic partner choosing algorithm* can distribute the load of helping other stations averagely to all the stations. The simulation must run under a scenario that the placement of all stations is distributed enough. The randomly placing station scenario might not be so distributed if the number of stations is not big enough. The distribution like Fig. 3.3 is the best because the stations are equal-distance and equal-angle placed in the circle around the PC. So we choose this kind of scenario to prove the distribution of the *load of help*. We simulate by the number of stations from 8 to 14. The number of the packet every station helps other stations send to the PC is counted. And we observe the distribution degree by the mean and deviation computed.

   The simulation results are shown in Fig. 3.10. The x-axis represents the number of stations in the cycle, while the y-axis represents the *Percent Relative Standard Deviation*. In this experiment, the number of the packets that a station helps other station send to the PC is memorized. In the end, the PC will compute the mean and deviation value from those numbers. And we can get the *Percent Relative Standard Deviation* from

$$Percent\ Relative\ Standard\ Deviation = \frac{Deviation}{Mean} * 100\%$$

   We found that not only every station would help other stations send packets to the PC, but also the differences of the load of help between every two station is small. The *Percent Relative Standard Deviation* is around 7.5% to 8.5%, which means the load of help is kindly fairly distributed to all the stations about $Mean \pm 8\%$. Therefore,

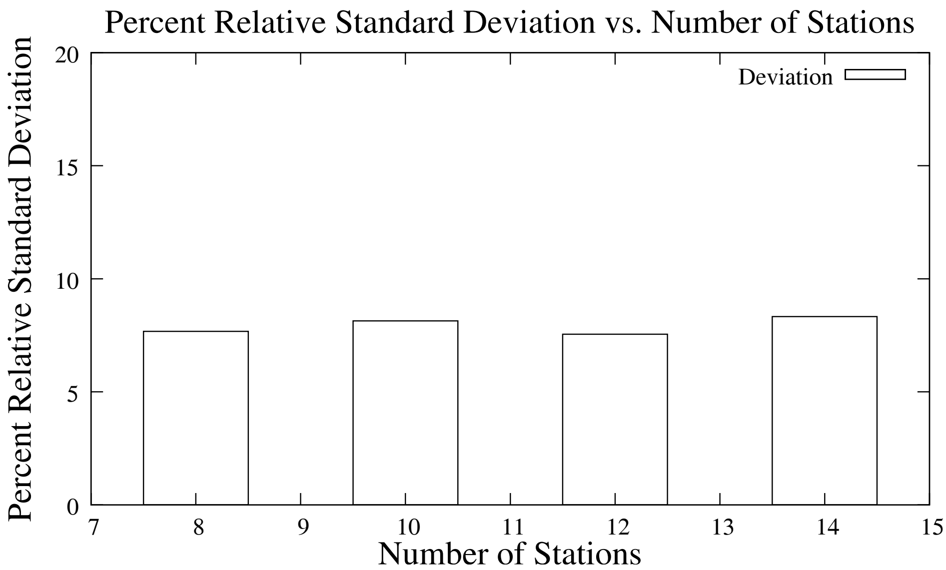

Figure 3.10: The Distribution of The Load of Help Among All The Stations

besides improving the performance of the PCF, the dynamic partner choosing algorithm promises to distribute the assistance load to all the stations when the topology is placed distributedly enough.

3.2 Summary

PCF is a centralized method for medium dispatch in IEEE 802.11. Due to the fluctuation of radio conditions, the wireless stations experience severe service variations. Some forms of diversity are mentioned to alleviate the problems especially the spatial diversity. But most of the literature work focus on the solutions in physical layer. The proposed partner choosing algorithms exploit the advantage of spatial diversity into PCF. In this method focus on uplink traffic, PC gathers location information of all stations and assigns partners to help when they are in poor channel. Besides, PC assigns the chances to allow the stations to ask for help to their partners. Their partners will send packets for them when they are polled.

The simulation results demonstrate the mechanism improve the performance of PCF.

The *Static and Dynamic Cooperative PCF* can outperform because of station cooperations. Thus, it leads to not only throughput increment, but also a more robust system.