On the (In)Feasibility of Fine Grained Transmit Power Control

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1. INTRODUCTION

Spectral efficiency has been a major focus of research in wireless networks. Recent theoretical work has shown that ideal medium access protocol using optimal power control can improve channel utilization by up to a factor of $\sqrt{\rho}$, where ρ is the density of nodes in the region [2] . Although power control mechanisms have been extensively studied in theory and simulations, their practical evaluation has not been done throughly. Most of the power control mechanisms proposed in literature [4, 6, 5] assume a very fine grained handle on transmit power of wireless nodes and exercise this control to provide sophisticated mechanisms of sharing wireless medium among competing flows. In this work, we investigate the (in)feasibility of fine-grained power control in wireless networks using real testbed experiments. We perform detailed experiments to highlight fundamental issues with power control mechanisms, that cannot be captured by using a network simulator. Our experiments indicate that fine grained power control may not be a viable solution for indoor wireless networks and most power control mechanisms may need to be adapted to be suitable for practical settings.

2. LIMITATIONS OF FINE GRAINED TRANSMIT POWER CONTROL

Implementation of fine grained power control mechanisms has been limited by the hardware support in current 802.11 wireless cards which have only limited number of discrete power levels. As shown in [1] , most of the wireless cards support only 4 to 5 power levels at the hardware, which is in stark contrast to the fine grained power control assumed by most power control schemes. This being a limitation of current state of the art hardware, can be resolved in future wireless cards that may support fine grained power levels. However we argue that there are fundamental limitations to power control mechanism in wireless networks, which limits the number of feasible power levels that can be used in such mechanisms.

Multipath and fading effects of the wireless medium are well studied [3]. Due to such multipath and fading effects, received signal strength (RSS) can vary significantly in an indoor environment, even in the absence of explicit interference from other flows. A difference of an order of wavelength in the paths taken by the wireless signals from the transmitter, can lead to the two signals being out of phase [3], resulting in variations in the signal strength at the receiver. In addition to multipath and fading effects, external interference from other flows in the network can also contribute considerably towards RSSI variations. We also study the variations in RSSI values due to the orientation of the wireless cards of the transmitter and the receiver. We perform detailed experiments on real testbed to evaluate the effect of the aforementioned factors on RSSI variations. Here we present a subset of our experimental results which indicates that variations in RSSI values can be significant, especially for indoor wireless networks and multipath, fading, interference and orientation are important factors that determine the extent of RSSI variations. Such fluctuations in the RSSI values limits the number of feasible power levels at the transmitter and makes fine-grained power control unattractive for practical purposes.

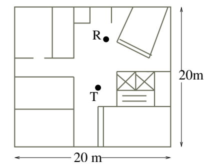

Figure 1: Floor Plan of the Indoor Environment. Transmitter(T) and Receiver(R) are shown in the figure

Experimental Setup. Figure 1 shows the placement of the transmitter receiver pair for our indoor experiments performed in the computer science building. The experiment used 2 IBM thinkpad laptops with atheros chipset based 802.11a/g linksys wireless card and used madwifi drivers.[1] In order to evaluate the effect of multipath and fading on RSSI values, the laptops were configured to use the 802.11a frequency band, so that there is no external interference from the department WLAN that operates on 802.11g. Later in the poster, we also analyze the effects of external interference on RSSI by repeating these experiments on 802.11 b/g. Further, the laptops were separated by a distance of 40 feet from each other in the line of sight. We used *netperf 2.2* to generate UDP flows between the two laptops.

Figure 2(a) shows the probability density function of RSSI observed in our experiments over 802.11a. The figure shows the probability density function of RSSI values for various power levels at the transmitter. The power levels are increased from 1mW to 60mW,in steps of 10mW, where 60mW is the maximum transmit power for the linksys card used by the transmitter. For the sake of clarity, these power levels are chosen so that there is minimal overlap between their respective RSSI distributions. For example at a power level of 60mW, the RSSI values vary from 35dBm to 45dBm, with 40 percent of the packets being received at 41dBm. The average variation in RSSI value over all power levels is approximately 7.5 dBm.

These overlaps can be attributed to the multipath and fading effects, due to which the packets transmitted at the same power level, may be received with varied signal strength at the receiver. Although the exact shape of the RSSI distribution may depend on the exact indoor environment and other interference effects, but the general nature remains similar to Figure 2(a)-(b), which has been confirmed by our extensive experimentation in multiple indoor environments.

As evident from figure 2(a,b), the rssi distributions of existing discrete power levels cover the entire range of practical RSSI values for power levels upto 60mW. The introduction of fine grained

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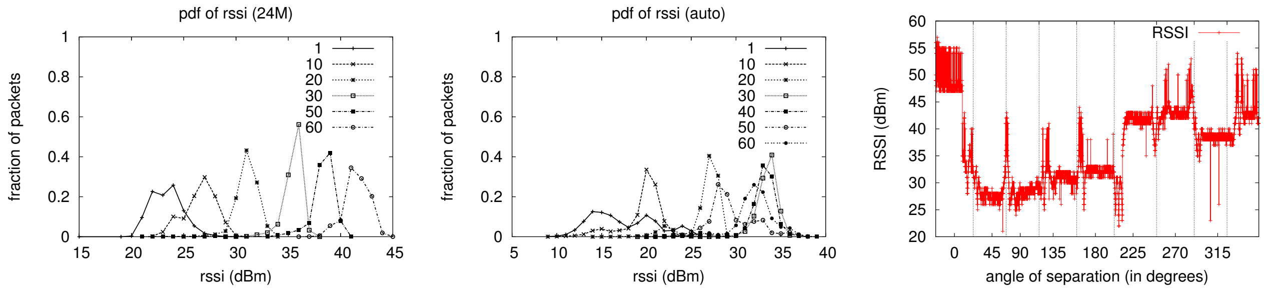
[1] Same experiments were repeated with other wireless cards (Cisco Aironet, Dlink, Netgear) and similar results were obtained.



(a) Pdf of RSSI values on 802.11a (no interference). 6 distinct power levels can be observed

(b) Pdf of RSSI values on 802.11g (interference with department WLAN). 4 distinct power levels can be observed

(c) Effect of wireless card orientation on RSSI values

Figure 2: RSSI variations in the indoor environment.

power levels at the hardware will imply significant overlap between the rssi distributions of existing power levels (1,10,20,30,40,50,60)mW and the new power levels. Such significant overlap between rssi distributions will make most the power levels practically inditinguishable for the receiver. This can be considered analogous to the concept of channels in 802.11 band, where there are 11 channels available but only 3 channels are non overlapping and hence useful. Similarly, fine grained power levels cannot be distinguished easily at the receiver due to RSSI variations and hence may not be useful.

3. EFFECTS OF INTERFERENCE

Recent studies have reported high interference between access points in wireless deployments. Here we analyze the effect of external interference on RSSI variations. We repeat the experiments of Section 2 on 802.11g, so that the transmitter receiver pair experience interference from the department WLAN also operating on 802.11g. The transmitter-receiver pair operates on the same channel as being used by the access points of the department WLAN. The resulting distribution of RSSI values is shown in Figure 2(b). As expected the RSSI variations increase, thereby increasing the overlap between RSSI of neighboring power levels. This observation indicates that in the presence of interference, the number of power levels having non overlapping RSSI distributions are further reduced, thereby making fine grained transmit power control even less effective. These experiments further reinforce our claim that transmit power control mechanism may not be feasible in practical deployments where external interference is substantial.

4. EFFECT OF ORIENTATION

The variation in RSSI with the distance between the transmitter and the receiver is well studied and is given by various propagation models according to the wireless environment (two ray ground and friis propagation model). Power control schemes typically account for such large scale mobility of the wireless nodes and change the transmit power to maintain connectivity. However, most schemes ignore "micro mobility" of the wireless node like slightly changing the orientation of the laptop etc. Such changes are not categorized as explicit node mobility but nevertheless have a considerable impact on the RSSI values observed at the receiver. For practical applications, the wireless users cannot be expected to be absolutely static and hence such small variations in the orientation of wireless cards are expected. We quantify the impact of the change in orientation of the wireless card of the receiver on the RSSI values. Figure 2(c) show the impact of orientation of the wireless card on RSSI. In this experiment, the laptop which is being used as a wireless receiver is rotated by an angle of 45 degree every 10 seconds and the corresponding RSSI values are plotted. The angle in degrees on top of the graph denotes the angle of separation from the line of sight of the transmitter wireless card. Clearly RSSI values are highest when the receiver card is in exact line as the transmitter card and the value decreases as the angle of separation from the transmitter line of sight increases. The variation in RSSI values for the same client location (but varying orientation) is upto 30dBm. This simple experiment shows that very subtle repositioning of the wireless device by the end user can significantly impact the RSSI values. Clearly fine-grained power control may not be necessary to adapt to such considerable variations in RSSI ($\sim 10dBm$) and transmit power at the receiver should be increased substantially to sustain the same RSSI.

5. FUTURE DIRECTIONS

In this poster, we identify some practical challenges that make fine grained power control practically infeasible for indoor environments. We are currently working towards some realistic power control mechanisms, that can be successfully deployed in current off the shelf wireless cards. Traditionally, power control mechanism have focused on reducing the floor space acquired by each flow, so that the maximum number of flows that coexist is maximized. However such mechanism fail to account for the dependency between RSSI and achievable data rates. Our initial experiments show that there is a considerable drop in sustainable data rates with the reduction in transmit power. In the future we want to tackle the joint problem of data rate adaptation and transmit power control and devise a scheme that is practical and easy to implement.

6. REFERENCES

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