Link quality decrement and spectrum crowded impacts to wireless local area network performances

S Suherman*, A H Rambe, N Mubarakah
Electrical Engineering Department, Universitas Sumatera Utara, Medan-Indonesia

Email: *suherman@usu.ac.id

Abstract. Wireless local area networks (WLANs) are now preferred for high speed internet connections. Compared to cable network, radio propagations are more prone to errors and interferences. The increasing internet users push more access points (APs) installations. Moreover, mobile devices tethering work at the same channels. Since the networks operate on the free license frequency bands, problems are emerged when many collocating APs work at the same area. As results, network performances may decrease. This article investigates how the radio link quality decrement as well as the crowded APs affect user performances. System modelling in Java and repeating simulation help the investigation. As results, it is proven that network performances, such as delay, throughput and packet collisions are affected by those conditions. Link quality decrement up to 1/10 causes packet transmission delay increasing 2.5 times which causes throughput drops about 30% in unsaturated condition. Meanwhile, crowded APs worsen network performances by leaving only 8% throughputs when collocating APs increase from 2 APs to 10 APs.

1. Introduction
Internet users rapidly grow anywhere in the world, where 802.11 technology is one of the popular end point access networks. This wireless local area network (WLAN) delivers internet data in a free license spectrum, where the connection depending on link quality [1], [2]. The quality varies overtime as multipath propagation, non-light of sight link and interferences exist in radio link. Link quality variations cause transmitting speed changes overtime. These changes are anticipated by using some methods such as adaptive modulations and coding. The higher number of bits per symbol results the higher bit rate and throughput [3].

However, available bandwidth decreases as number of installed access points grows. As the radio channels are limited, competitions among the APs lower network performances [4]. Various works have been carried out to overcome 802.11 dense network problems [4]. Dynamic channel algorithm [7] and many more. Those changes may overcome the problems. Practically, users may consider access point number restriction working in one area. In order to do that, the new installation may be preceded by a performance study based on some performance parameters achieved at current number of access points [8]. Physically, link quality is measured by propagation attenuation, where the received signal level is expected to be higher than the threshold. The noises and interferences are measured in term of signal to noise ratio (S/N) or bit energy per noise (Eb/No). On medium access layer, channel quality is measured by determining the collision rate occurred which is referred to as the probability of collision. On the upper layers, parameters such as delay, throughput and packet losses are employed.
This work proposes crowded access point evaluation model based on carrier sensing multiple access/collision avoidance (CSMA/CA) algorithm by using some input parameters such as maximum and minimum bitrates, a fixed frame length, average transmission rate, and number of competing access points. The crowded access point means that number of access point is higher than the available channel. It is assumed those access point working on the same frequency, as if they work at different frequency likely will impose no major matter. The evaluated parameters are frame transmission delay, overall throughput and collision rates. The work could be used for determining maximum access point working in the same channels within the same area.

2. Research Method

In order to evaluate the performance 802.11 with co-located access points within the same frequency channel, the mathematical approximation proposed by Bianchi model is employed [9]. The collision probability is determined by the Equation 1 [9]. Since each access point is connected to some clients (i) with traffic $\Phi_i$, the streamed traffic related to this access point is approximated by the total number of connected clients traffics ($\sum_{i=0}^{n} \Phi_i$), where access point traffic is $\Phi_0$. This parameter is simplified as the average transmission number, $n = i + 1$.

$$P_{\text{collision}} = 1 - (1 - \Phi)^{n-1}$$  \hspace{1cm} (1)

The successful transmitting access point is determined randomly using Equation 1 and transmit frame size of m bytes. If the available bitrate is r, then the frame delay d, is determined by $d = r / m$. Meanwhile, the queue delay caused by the unsuccessful transmission is not counted. This is held as the counted throughput is measured at fixed time size of T. The unsuccessful transmission is counted towards the collision rate. The maximum bit rate is set 54 Mbps. The available bandwidth is calculated depending upon the signal to noise ratio which is generated randomly and channel capacity which is assumed error free, is calculated by using Shannon formula [10].

![Figure 1. System model and flow](image)

Figure 1 shows the step of model execution in order to determine the performance. Input parameters for the simulation is number of mobile transmissions, n, number of access points N, back off time, frame length and number of iterations. The system is then modelled by using Bianchi equation, collision rate is used as Shannon equation input to ensure available bandwidth, then performances were determined. The following parameters were set. The number of collocated access point N, was set from 2 to 10, the
number of transmission $n$ was set 100, maximum backoff was 1, maximum bit rate was 54 Mbps, the ethernet size $l$, was 2048 and simulation ran for 1000 times.

### 3. Results and Discussion

After running the simulation about a thousand times for many conditions and number of collocated access points, the recorded average frame delay for each channel degradation is shown in Figure 2. Channel degradation is represented in percentage which means the percent degradation to maximum bit rate of 54 Mbps. Figure 2 shows that the more significant the link quality degradation occurs, the higher the time required to send ethernet frames. On the other hand, the higher the number of collocated access points, the bigger the delay. For worst channel quality, delays vary for given number of access point. Generally, delay increases exponentially as the channel poorer.

![Figure 2. Frame delay performances](image)

On the other hand, throughput decreases significantly when channel worsen for number of access point 2, 3 and 4. For higher number of wireless access point, the throughput is low and stagnant (Figure 3). For 10% of network quality is low, 28.84% of transmitted data received successfully. While decreasing link quality to 90% results throughput degradation to 28.84%. Meanwhile, impact number of access point to frame delay can be seen in Figure 4. For number of access point 2 and 3, delay varies.

![Figure 3. Throughput Performances](image)
But for number of access point 3 and higher, the ethernet frame delay consistently increases from 83\(\mu\)s to 89 \(\mu\)s.

![Figure 4. Performance comparisons](image)

Throughput decreases significantly to number of transmitting access point. Throughput achieves 46.6\% for number of access point 2, decreases sharply to only 3.34\% (Figure 5). The throughput decrement is inversely proportional to the collision rate (Figure 6). Collision rate is about 6.76 \% for two access point, decreasing tremendously to 94.25 \% for 10 access points. Unfortunately, model validation by using real experiment is not finished yet. However, delay, throughput and collision characteristics are in line with the mathematic analysis presented by other researchers.

![Figure 5. Throughput performance to number of APs](image)

![Figure 6. Collisions occurs to number of APs](image)
4. Conclusions
This paper models link decrement and crowded access point impacts to 802.11 performance. System modelling was based on Bianchi and Shannon works with some adjustment for collocated access points. The collocated access points are assumed to work at the same frequency. Java based simulation shows that the worse the channel the higher the frame delay and the lower the system throughput. The 10% worse link leads to 2.5 times delay increment. Meanwhile, throughput dropped for more than 40% when link decreases up to 90%. The crowded APs make network performances worsen, achieving only 8% throughputs for 10 APs.

System model proposed in this paper is logically proportional to mathematic analysis. However, model should be validated to real experiment to make sure model be usable and that could be of future work, for instance, by developing MAC and PHY changeable access point. Access points that work at the same frequency as number of channels is lower than the number of activated access points should perform some techniques to avoid performance decrement, this is also of the future work.

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