# Throughput Optimization in a Wireless Link Using AWGN and Rayleigh Channel

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***Abstract:*** **-** In wireless communication throughput is a key factor to measure the quality of wireless data link. Throughput is defined as the number of information bits received without error per second and we would naturally like this quantity as to be high as possible. This thesis looks at the problem of optimizing throughput for a packet based wireless data transmission scheme from a general point of view. The purpose of this work is to show the very nature of throughput and how it can be maximized that means how we can optimize the throughput by observing its certain changing parameter such as transmission rate, packet length, signal-to-noise ratio (SNR) etc. I tried to take a more general look at throughput by considering its definition for a packet-based scheme and how it can be maximized based on the channel model being used.

***Key words:*** Throughput, Optimization, AWGN, Rayleigh channel, Packet length, Transmission rate, Signal-to-Noise Ratio (SNR).

## I. INTRODUCTION

Throughput is defined as the number of information bits received without error per second and we would naturally like this quantity as to be high as possible. In a wireless data system [1] many variables affect the throughput such as the packet size, the transmission rate, the number of overhead bits in each packet, the received signal power, the received noise power spectral density, the modulation technique, and the channel conditions. From these variables, we can calculate other important quantities such as the signal-to-noise ratio, the binary error rate, and the packet success rate. Throughput depends on all of these quantities.

Here I discuss the general look at throughput by considering its definition for a packet-based scheme and how it is maximized based on the channel model being used. As an initial step in a theoretical study, I examine the influence of transmission rate and packet size in a noise-limited transmission environment. The transmitter, operating at R b/s, sends data in packets. Each packet contains L bits including a payload of K bits and a cyclic redundancy check error-detecting code with C bits. A forward error correction encoder produces the remaining L-K-C bits in each packet. The channel adds white noise with power spectral density watts/Hz and the signal arrives at the receiver at a power level of P watts. In this research paper I assume to be the sum of all noise and interference, which can be modeled as Gaussian white noise. The CRC decoder detects transmission errors and generates acknowledgments that cause packets with errors to be retransmitted. Table 1 displays a summary of the variables in our analysis and their notation [2].

| Quantity | Notation | Value |
|---|---|---|
| Signal to Noise Ratio | $\gamma$ | 10 |
| Received signal power | P (watts) | $5*10^{-9}$ W |
| Receiver noise power spectral density | N0 (W/Hz) | $10^{-15}$ W/Hz |
| Binary transmission rate | R bits/s | Varied |
| Packet size | L bits | Varied |
| Cyclic Redundancy Check | C bits | 16 bits |

Table 1: Variables in Analysis

An important objective of data communications systems design and operation is to match the transmission rate to the quality of the channel. A good channel supports a high data rate, and conversely. For a given channel, there is a transmission rate that maximizes throughput. At low rates, transmitted data arrives without error with high probability and an increase in the data rate increases throughput. Above the optimum rate, the error probability is high and it is possible to increase throughput by decreasing the data rate, thereby increasing the probability of correct reception. Recognizing this fact, practical communications systems including facsimile, telephone modems, wireless local area networks, and cellular data systems incorporate rate adaptation to match the transmission rate to the quality of the channel. In some systems (facsimile and telephone modems), the adaptation is static, occurring at the beginning of a communication session only. In others, the adaptation is more dynamic with the rate rising and falling in response to changes in channel conditions.

The research work begins with the analysis by looking at throughput optimization as a function of the packet length with a fixed transmission rate followed by an analysis of throughput as a function of transmission rate with a fixed packet length. Using the optimization equations obtained, the throughput can be jointly optimized with respect to both the packet length and transmission rate, both written in terms of the SNR. These equations can be used to find the optimal signal-to-noise ratio (SNR) that the system should be operated at to achieve the maximum throughput. I have used these equations and simulated those in MATLAB and then observed the results in graphical representation in MATLAB window. I have talked about different variables and how changing certain parameters can yield better throughput performance.

## II. THROUGHPUT ANALYSIS

### A. Throughput Analysis

The amount of data transferred from one place to another or processed in a specified amount of time. Data transfer rates for disk drives and networks are measured in terms of throughput. Typically, throughputs are measured in kbps, Mbps and Gbps, the speed with which data can be transmitted from one device to another. Data rates are often measured in megabits (million bits) or megabytes (million bytes) per second. These are usually abbreviated as Mbps and MBps, respectively.

### B. Assumptions and Definitions

My analysis includes the following simplifying assumptions: [2]

- The CRC decoder detects all errors in the output of the sending decoder channel. That means no matter what kind of data is transmitting and received by the receiving channel we are assuming that the receiving channel decoder will be able to get all the data most accurately. If there is any error in the bit stream then the CRC(Cyclic Redundancy Check) decoder will be able to correct all the errors in the received data.
- Transmission of acknowledgments from the receiver to the transmitter is error free and instantaneous.
- In the presence of errors, the system performs selective repeat ARQ (Adaptive Retransmission Query) retransmissions.
- The received signal power is P watts, either a constant or a random variable with a Rayleigh probability density function, representative of fading wireless channels. In this paper, we consider “fast fading” in which the values of P for the different bits in a packet are independent, identically distributed Rayleigh random variables.

System throughput (T) is the number of payload bits per second received correctly:

$$T = \frac{K}{L} R \, f(\gamma) \qquad (1)$$

where (KR/L) b/s is the payload transmission rate and f(□) is the packet success rate defined as the probability of receiving a packet correctly. This probability is a function of the signal-to-noise ratio

$$\gamma = \frac{E_b}{N_0} = \frac{P}{N_0 R} \qquad (2)$$

In which $E_b$ = P/R joules is the received energy per bit. We will now look at maximizing the throughput in a Gaussian white noise channel with respect to the transmission rate and packet length.

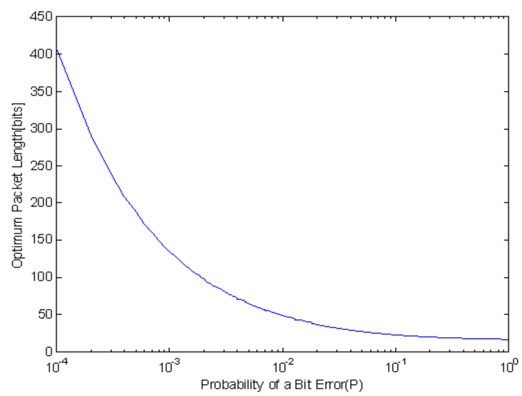


Figure 1: Optimum packet length as a function of P

## III. SIMULATION AND RESULTS

### A. Throughput vs. Transmission Rate: Fixed Packet Length

#### 1. Equation simulation

To find the transmission rate, R=R* b/s, that maximizes the throughput, we differentiate Equation (1) with respect to R to obtain:

$$\frac{dT}{dR} = (K / L)\, f(\gamma) + (K / L)\, R \quad (3)$$

$$\frac{df(\gamma)}{d\gamma}\frac{d\gamma}{dR} = (K / L)$$

$$\left( f(\gamma) + R\frac{df(\gamma)}{d\gamma}(-P/N_0 R^2) \right)$$

Next we set the derivative to zero:

$$f(\gamma) - (P / N_0 R)\frac{df(\gamma)}{d\gamma} = f(\gamma)\gamma \quad (4)$$

$$\frac{df(\gamma)}{d\gamma} = 0,$$

$$f(\gamma) = \gamma \frac{df(\gamma)}{d\gamma}. \quad (5)$$

We adopt the notation $\gamma = \gamma^*$ for a signal-to-noise ratio that satisfies Equation (5). The corresponding transmission rate is

$$R^* = \frac{P}{\gamma^* N_0}. \quad (6)$$

A sufficient condition for a locally maximum throughput at R=R* is:

$$\left.\frac{d^2T}{dR^2}\right|_{R=R^*} < 0 \quad (7)$$

The solution to Equation (5), $\gamma^*$, is the key to maximizing the throughput of a packet data transmission. To operate with maximum throughput, the system should set the transmission rate to R* in Equation (6). $\gamma^*$ is a property of the function, $f(\gamma)$, which is the relationship between packet success rate and signal to interference ratio. This function is a property of the transmission system including the modem, codecs, receiver structure and antennas. Each system has its own ideal signal-to-noise ratio, $\gamma^*$. Depending on the channel quality, reflected in the ratio P/N0, the optimum transmission rate is R* in Equation (6).

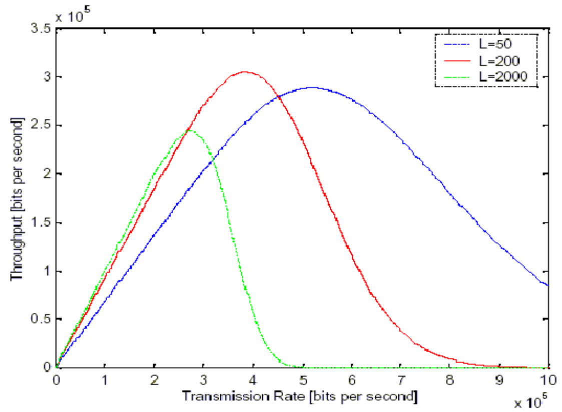


Figure 2: Throughput vs rate for fixed packet length

#### Graphical Analysis

In the figure 2 I have take three Readings. The first one was packet length of 50 bits. We have got the maximum throughput at transmission rate of 0.58 Mbps and the throughput was .27 Mbps. If we increase the transmission rate the throughput was seen to be fallen down and at a certain period it went to at the value zero. In my second assumption I have seen that for packet length of 200 bits the throughput was 0.30 Mbps and at the transmission rate of 0.4 Mbps it has gone its highest pick. After then it has also fallen down to zero. The third assumptions also showed the same. I have noticed that when the packet length size was small then the throughput has reached its highest pick with higher transmission rate and also has fallen in a wide range. But as soon as the packet length has kept higher then the curve of throughput is stepper rather than flat. When we have increased our packet length size then the throughput has reached the maximum pick at a lower transmission rate and also has fallen down quite quickly. So at the end we have come to some several decisions.

I have seen that if I keep my packet length less than 400 bits and greater than 50 bits, then I will be able to get the maximum throughput and the transmission rate shouldn't be so high. It has to be in a range of 0.3 Mbps to 0.8 mbps. So using the general equations for calculating throughput in respect of transmission rate and keeping the packet length fixed the throughput can be optimized in a certain range.

**B. Throughput vs. Packet Length: Fixed Transmission Rate**

**Equation simulation**

Each packet, of length L bits, is a combination of a payload (K bits) and overhead (L-K bits). Because the packet success rate, $f(\gamma)$ is a decreasing function of L, there is an optimum packet length, L*. When L<L*, excessive overhead in each packet limits the throughput. When L>L*, packet errors limit the throughput. When there is no forward error correction coding, which we shall assume for the entirety of this chapter, (K=L-C, where C bits is the length of the cyclic redundancy check), there is a simple derivation of L*. In this case,

$$f(\gamma) = (1 - P(\gamma))^{L} \qquad (8)$$

Where $P_e(\gamma)$ is the binary error rate of the modem. Therefore, in a system without FEC, the throughput as a function of L is

$$T = f(\gamma) = \frac{L-C}{C} R(1 - P_e(\gamma))^{L} \qquad (9)$$

To maximize T with respect to L, we consider L to be a continuous variable and differentiate Equation (9) to obtain

$$\frac{dT}{dL} = R\frac{L-C}{L}(1-P_e(\gamma))^{L}\ln(1-P_e(\gamma)) + R\frac{C}{L^2}(1-P(\gamma))^{L} \qquad (10)$$

Setting the derivative equal to zero produces a quadratic equation in L with the positive root:

$$L^* = \frac{1}{2}C + \frac{1}{2}\sqrt{C^2 - \frac{4C}{\ln(1-P_e(\gamma))}} \qquad (11)$$

As shown in Figure 3, 4 and 5 (in which C=16), the optimum packet size is a decreasing function of $P_e(\gamma)$. As the binary error rate goes to zero, the packet error rate also approaches zero and the optimum packet size increases without bound. Because $P_e(\gamma)$ decreases with $\gamma$, L* increases monotonically with signal-to-noise ratio. Better channels support longer packets. Of course, in practice L is an integer and the optimum number of bits in a packet is either the greatest integer less than L* or the smallest integer greater than L*.

Equations (5) and (11) can be viewed as a pair of simultaneous equations in variables L and $\gamma$. Their simultaneous solution produces the jointly optimum packet size and Signal - to- noise ratio of a particular transmission system. We will use the notation, L** and $\gamma$**, respectively for the jointly optimized variables.

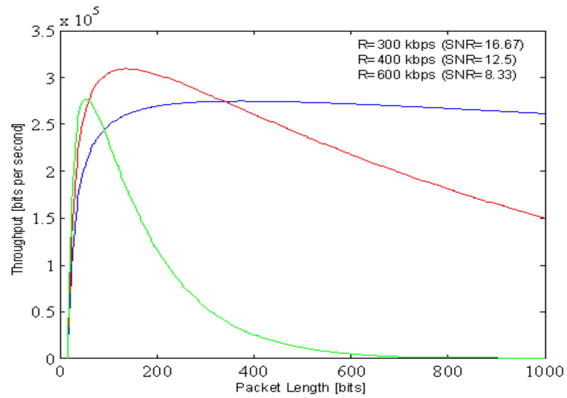


Figure 3: Throughput vs L for a fixed transmission rate (1)

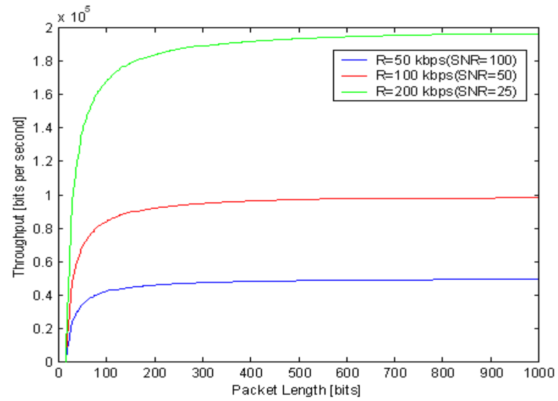


Figure 4: Throughput vs L for a fixed transmission rate (2)

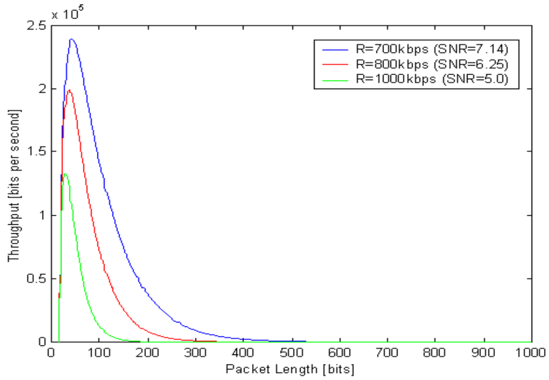


Figure 5: Throughput vs. L for a fixed transmission rate (3)

**Graphical Analysis**

Figure 3 shows and throughput optimization for fixed transmission rate varying the value of the packet length. I have taken three different assumptions for figure 3. In the first assumption I have taken the transmission rate as 300 kbps and for this value the SNR came as 16.67. I have got the value of SNR from the Equation 2. Where P (Received Signal Power) is Watts, (Received noise power spectral density) is W/Hz. Those values are constant here. In the second assumption I have taken the value of transmission rate as 400kbps and SNR as 12.5. In the third we have taken the transmission rate as 600kbps and SNR as 8.33. I have always kept the value of C (cyclic redundancy check) as 16bits.
Figure 4 shows the same work as 3. The only difference is I have changed the value of transmission rates. The first value is 50 kbps, SNR is 100. Second one is 100kbps, SNR is 50 and the third one is 200kbps, SNR is 25.

In the figure 5 we have increased the transmission rate like 700, 800 and 1000 kbps. From those rates I have got the value of SNR 7.14, 6.25 and 5.0 respectively. In every assumption I have also kept the value of C as 16bits as a constant.

One very important thing has also been observed. If I keep my transmission rate in the range of 0.2mbps to 0.4 mbps we will be able to get the maximum throughput. And for the maximum throughput the packet has come in the range of 200bits to 400 bits. So, this observation has proved my decision when I observed throughput in terms of transmission rate for certain fixed packet length. In this observation I have also seen that when I have taken the transmission rate higher than the throughput curve is going to be more stepper rather than flatter.

**C. White Gaussian Noise Channel**

The channel model is used to approximate the way errors are introduced in a data stream when it is transmitted over a noisy medium. The model we may use in the Workshop is the Additive White Gaussian Noise channel (AWGN). This channel [3] model is memory less, meaning that the distortion of one bit is independent of all other bits in the data stream. Here one noise is added with the original transmitted signal, called white noise.

The AWGN channel models the distortion incurred by transmission over a noisy medium as the addition of a zero-mean Gaussian random value to each bit. Decoders can take advantage of the added information of "how close" a received value is to a valid bit value (0 or 1 for our purposes). This type of decoding is called soft decision decoding. Because decoders that use soft decision decoding take advantage of information that the BSC throws away, soft decision decoders often have better error correcting capability.For the AWGN model, the parameters are noise variance values so they must be greater than or equal to 0

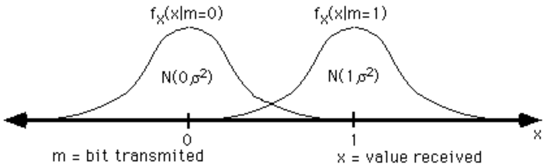


Figure 6: AWGN Channel

The design [4] of efficient signal sets for transmission over channels which are contaminated by Gaussian noise has been an active area of research for many years. Signal set that is more efficient than another will typically result in a comparable savings in transmitted energy. Hence the determination of optimal signal sets is an important problem from a practical communication perspective as well as from a theoretical standpoint. However, the optimal selection of signal vectors embedded in even the most fundamental type of noise, white Gaussian noise, is not known in general. In 1948, it was conjectured that, with finite energy constraints but without constraint on dimension of signal space, the M optimal signal vectors are vertices of a regular simplex in (M−1)-dimensional signal space. This conjecture is referred to as the strong simplex conjecture (SSC) when the signal vectors are constrained only by an average energy limitation and as the weak simplex conjecture (WSC when the signal vectors are equal-energy-constrained. Under assumption that signal vectors have equal energy, Bal Krishnan proved that the regular simplex is optimal (in the sense of maximizing the detection probability) as λ goes to infinity, optimal as λ goes to zero, and locally optimal at all λ, where λ2 is the signal-to-noise ratio. Dun bridge proved further that under an average energy constraint the regular simplex is the optimal signal set as λ goes to infinity and a local ex tremism at all λ. For the case of M=2 , the reg ular simplex has been proved to be optimal at all λ for both the average and equal energy constraint. Dun bridge proved, under an average energy constraint, that the regular simplex with M=3 is optimal as λ goes to zero. Work on the weak simplex conjecture in was shown by Farber in to prove this conjecture for M<5.

**6.3 Equation Derivation**

For non-coherent FSK in a white Gaussian noise channel, the probability of a bit error is given by:

$$P(\gamma) = \frac{1}{2} e^{\frac{\gamma}{2}} \qquad (12)$$

and so from (11) above, we can get the length to maximize the throughput by plugging in (12) for $P_e(\gamma)$. We illustrate how this graph changes with different values of R by showing three different plots on Figure 3. The solid line uses a transmission rate of 300 kbps ($\gamma$ □= 16.67) which, from (11), yields a length of L*(16.67) = 373 bits to maximize the throughput. The small dotted line uses a transmission rate of 400 kbps ($\gamma$ = 12.5) which yields a length of L*(12.5) = 137 bits to maximum the throughput. The large dotted line uses a transmission rate of 600 kbps ($\gamma$ = 8.33) which yields a length of L*(8.33) = 54 bits to maximize the throughput. The relationship between the SNR, $\gamma$, and the transmission rate, R, is derived from (2).

Some important conclusions can be drawn from this information. We first notice that at high SNR values (low transmission rates) the packet length used to maximize the throughput must be large. When the transmission rate increases and the SNR drops, the packet length to maximize the throughput must also decrease. Another observation we make is how the throughput curve behaves for increasing values of L when different SNR values are used. From Figure 3 we can see that at high bit rates (low SNR) the choice of packet size is more critical (i.e. the peak is very localized). On the contrary, at low bit rates (high SNR) the packet length doesn't have much of an effect on the throughput. Also, it can be seen that the maximum throughput increases with decreasing SNR, up to a point. When the SNR gets too low, the maximum throughput begins to decrease. This suggests that the optimum SNR value to give the maximum throughput ($\gamma$**) is between 8.33 and 16.67. This observation is confirmed when the throughput is optimized jointly with both the packet length and the SNR.

From (5) we cannot obtain an explicit solution for the rate (or SNR) that optimizes throughput directly as was done for the length, but the following result is obtained:

$$e^{\frac{\gamma^*}{2}} = \frac{4}{2 + L\gamma^*} \qquad (13)$$

This solution results from substituting (8) for $f(\gamma)$ and (12) for $P_e(\gamma)$. For any value of L, there is a $\gamma$* that maximizes the throughput. To see the effects of varying the transmission rate we choose a fixed value of L and graph the throughput (9) as a function of R. To illustrate how this graph changes with different values of L we have shown three plots on Figure 4. The solid line uses a packet length of 50 bits. If we use this value of L in (13) we obtain as a solution $\gamma$* = 9.58, which from (6) corresponds to a rate of R* = 521.9 kbps to maximize the throughput. The small dotted line uses a packet length of 200 bits. If we use this value of L in (13) we obtain as a solution $\gamma$* = 12.95, or a rate of R* = 386.1 kbps to maximize the throughput. The large dotted line uses a packet length of 2000 bits. If we use this value of L in (13) we obtain as a solution $\gamma^*$ = 18.24, or a rate of R* = 274.1 kbps to maximize the throughput.

We can see from Figure 4 that as the packet length increases the rate necessary to maximize the throughput decreases. Unlike Figure 4, however, the slope at which the throughput decays remains approximately constant for the different packet lengths. For rates less than the optimal rate, the throughput increases linearly with a slope of (LC)/ L. We can also make a general conclusion based on the shapes of the plots in Figures 3 and 4 by saying that the throughput is more sensitive to changes in the transmission rate than it is to changes in the packet length. Also, it can be seen that the maximum throughput achieved increases with increasing packet length, up to a point. If the packet length gets too large, then the maximum throughput begins to decrease. Based on the graphs in Figure 3, we can say that the optimum length to achieve the maximum throughput (L**) is somewhere between 50 and 2000 bits. This observation is confirmed when we optimize the throughput with respect to both SNR and packet length.

To maximize the throughput with respect to both the packet length and the transmission rate, we can write the throughput solely as a function of the SNR by graphing (4.2) and substituting L* (4.4) for the length, and R* (3.4) for the rate. In Figures 3 through 5 we have assumed a constant value (5*106) for P/No. In reality, this value can change as a result of a number of different situations. P depends on the location of the mobile in relation to the base station and N0 depends on the level of interference present at the mobile. To illustrate how the throughput is affected by these different values of P/No we put three different plots in Figure 7. The solid line uses a value of 106, the small dotted line uses a value of 5*106, and the large dotted line uses a value of 107. A very important conclusion can be drawn from this. The actual value of P/No only determines the value of the maximum throughput. A high value of P/No indicates a high maximum throughput, and a low value indicates a low maximum throughput. The important thing to note from Figure 7 is that the value of the SNR to maximize the throughput is independent of the value of P/No. We can see that the SNR to maximize throughput for a Gaussian Channel is γ**=11.47. This is indicated by the vertical line in Figure 7. We can now use this value in (11) to find that the packet length to achieve maximum throughput is L** (γ**)=108 bits. This packet length is also independent of P/No

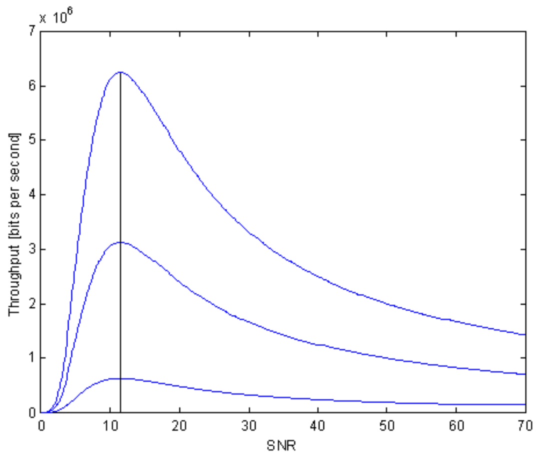


Figure 7: Throughput vs SNR using joint optimization (1)

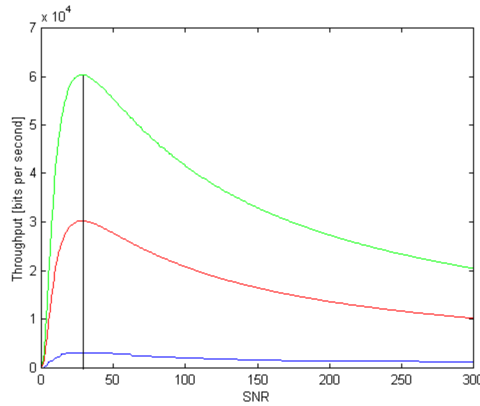


Figure 8: Throughput vs SNR using joint optimization (2)

### 6.4 Graphical analysis

Figure 7 and figure 8 has shown the throughput optimization with respect to joint optimization in terms of SNR(Signal to Noise Ratio) in White Gaussian Noise channel. We have analyze throughput with respect to SNR and has kept some fixes values for P/ $N_0$. Here P is the received signal power and $N_0$ is the received noise power. In generalized form the value of P is $5*10^{-9}\,watts$ and the value of $N_0$ is $10^{-15}$ watts/Hz. So, the value of $\frac{P}{N_0}$ is $5*10^5$ Hz. In figure 6.1 we have taken three value of $\frac{P}{N_0}$, like $10^6$, $5*10^6\,and 10^7$. We have seen that for each assumption the throughput has reached in maximum peak in a certain term and then has fallen down. For different value each curve has reached its maximum peak in different level but there was one thing common. That was the value of SNR. In our Experiment we have seen that all the three curves has the maximum peak in the same value of SNR. Figure 7 has showed that with a vertical line between all the curves. Figure 8 was an extension of Figure 8. Here we have analyzed throughput with different value of $\frac{P}{N_0}$, and we have got the same result. So, we have come to the decision that in White Gaussian Noise Channel the joint optimization in terms of SNR has no impact on the throughput.

### D. Rayleigh Fading Channel

For a model that corresponds to mobile radio communications, we can perform the same analysis for a fast fading Rayleigh channel. For non-coherent FSK in a Rayleigh fading channel, the probability of a bit error is given by:

$$\overline{P_e}(G) = \frac{1}{2+G} \qquad (14)$$

We can see how a changing packet length affects the throughput by choosing a fixed transmission rate and graphing (4), with Pe(G) replacing Pe(□), as a function of the packet length. To illustrate the effects of changing the transmission rate on the throughput graph, we have three plots on Figure 6. The solid line uses a transmission rate of 10 kbps corresponding to G = 500 from (6) which from (11) yields a packet length of L*(500) = 98 bits to maximize the throughput. The small dotted line uses a transmission rate of 100 kbps corresponding to G = 50 which yields a packet length of L*(50) = 38 bits to maximize the throughput. The large dotted line uses a transmission rate of 500 kbps corresponding to G = 10 which yields a packet length of L*(10) = 24 bits to maximize the throughput. The same conclusions and observations can be made from Figure 6, 7 and 8 as those made from Figure 3, 4 and 5. The only real difference is the scale of the numbers used. Because a fading channel imposes more rigorous conditions on a transmission system, the achievable throughput will be lower than a Gaussian channel. Consequently, the system will have to operate at higher average SNR values and smaller average packet lengths.

From (9) the bit rate to maximize throughput is found to be:

$$R^* = \frac{P}{N_0}\left[\frac{L-3-\sqrt{L^2-6L+1}}{4}\right] \ldots (15)$$

This solution results from substituting (11) for $\overline{f}(G)$ and (14) for $\overline{P_e}(G)$. To see how throughput changes as a function of the transmission rate we graph the throughput as a function of R with L fixed. To illustrate the effects of changing the packet length we have three plots on Figure 9. The solid line uses a packet length of 20 bits. We can use this value in (15) to tell us that the transmission rate to maximize the throughput is R* = 296.2 kbps (G* = 16.88). The small dotted line uses a packet length of 40 bits. From (15), the transmission rate to maximize throughput is R* = 135.3 kbps (G* = 36.95). The large dotted line uses a packet length of 100 bits. From (15), the transmission rate to maximize throughput is R* = 51.6 kbps (G* = 96.98). The same conclusions and observations can be made from Figure 12, 13 and 14 as those made from Figure 2, 3 and 4. Again, the only real difference is the numbers used. The transmission rate and throughput values are much smaller and the G values are much larger. An interesting result that follows from (13) is:

$$G^* = \frac{4}{L-3-\sqrt{L^2-6L+1}} = \frac{1}{2}(L-3+\sqrt{L^2-6L+1} \qquad (14)$$

This allows us to determine the value of the SNR to achieve maximum throughput for a given packet length in a Rayleigh fading channel.

To maximize the throughput with respect to both the packet length and transmission rate we can write the throughput as a function of SNR by using equation (9) and substituting L* (14) for the length, and R* (6) for the rate. The result is in Figure 13, 14. The same changes are made in P/No as were made in Figure 9 and 10 and the same conclusions can be drawn. The SNR value that maximizes throughput for a Rayleigh fading channel is G** = 28.12 and is independent of the value of P/No. This can be seen by the vertical line in Figure 13. We can now use this value in (11) to find that the packet length to achieve maximum throughput is L**(G**) = 31 bits. This value is also independent of P/No. The rate to maximize throughput R** is dependent on P/No from (6).

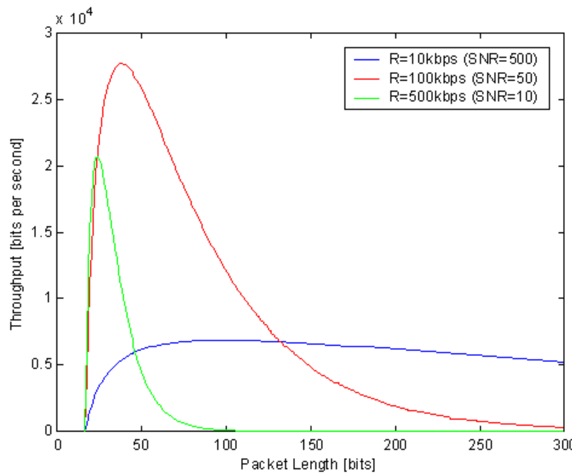


Figure 9:Throughput vs L for a Fixed Transmission Rate(Rayleigh Fading Channel) (1)

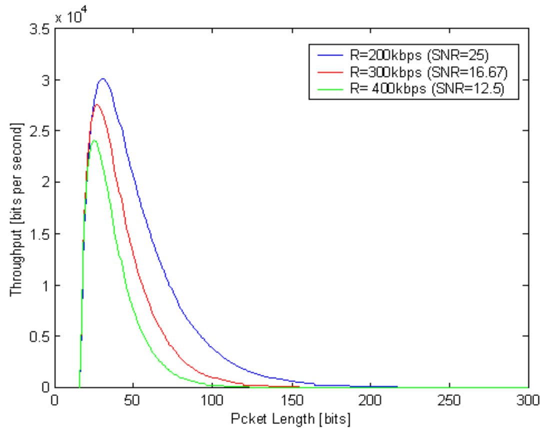


Figure 10: Throughput vs L for a Fixed Transmission Rate(Rayleigh Fading Channel) (2)

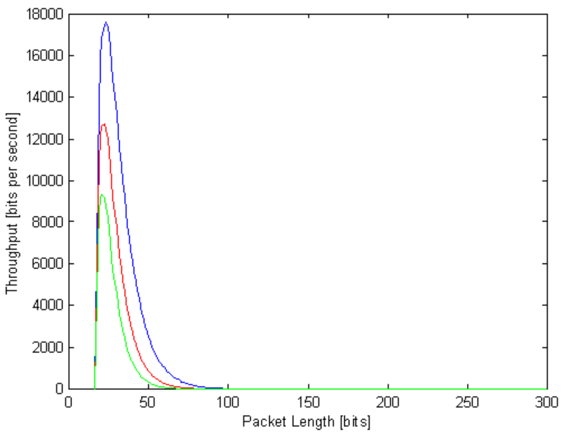


Figure 11: Throughput vs L for a Fixed Transmission Rate(Rayleigh Fading Channel) (3)

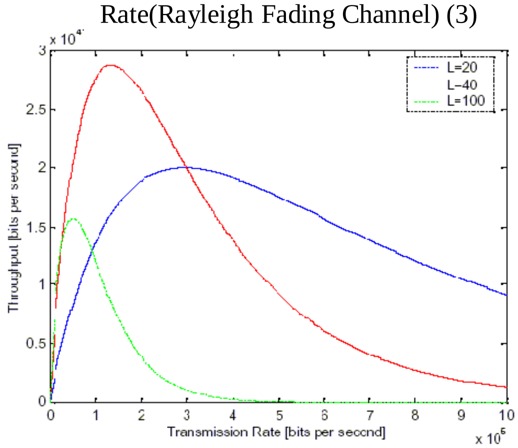


Figure 12: Throughput vs Rate for a Fixed Packet Length(Rayleigh Fading Channel)

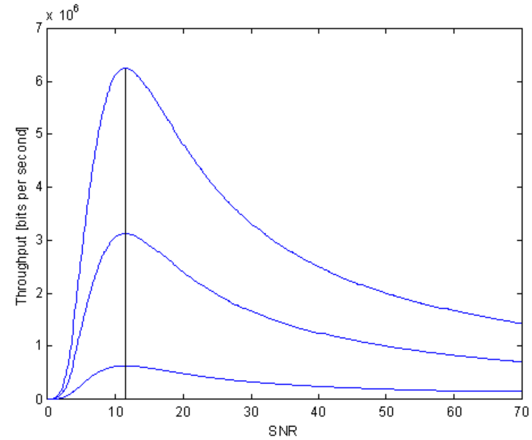


Figure 13: Throughput vs SNR Using Joint Optimization (Rayleigh Fading Channel) (1)

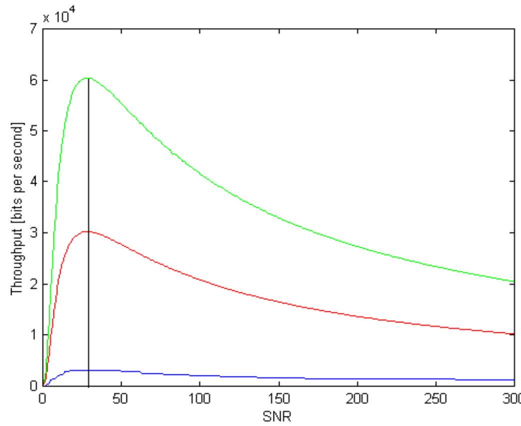


Figure 14: Throughput vs SNR Using Joint Optimization(Rayleigh Fading Channel) (2)

**Graphical analysis**

In rayleigh fading channel we have observed all the possibilities that we have done in the previous chapters. That means in this chapter we have analyzed throughput in terms of transmission rate keeping packet length fixed, packet length keeping the transmission rate fixed. Also in this chapter we have observed throughput in terms SNR using joint optimization under the Rayleigh fading channel.

Figure 9, 10 and 11 is the analysis of throughput in terms of packet length where the transmission rate is kept fixed. From those graphs we have observed that for transmission rate of 150 Kbps to 300 kbps we have got the maximum throughput of 300Kbps. If we go further, then the throughput has dropped toward zero.
Figure 12 is the representation of throughput with the function of transmission rate and fixed packet length. We have also observed that for transmission rate of 100 to

300 Kbps we have got the highest peak of throughput and the packet size was within 100 to 200 bits, which has matched with our previous observations.

Figure 13 and 14 has done with the throughput analysis in terms of SNR where we have used joint optimization. In our observations we have noticed that the throughput has no effect on the value of SNR in Rayleigh fading channel. For different assumption the throughput is different but the highest pick of each throughput is at the same value of SNR. In our observation we have got the value of SNR is 38 db.

## IV. CONCLUSION

Maximizing throughput in a wireless channel is a very important aspect in the quality of a voice or data transmission. In this chapter, we have shown that factors such as the optimum packet length and optimum transmission rate are all functions of the signal to noise ratio. These equations can be used to find the optimum signal to noise ratio that the system should be operated at to achieve the maximum throughput. The key concept behind this research is that for each particular channel (AWGN or Rayleigh) and transmission scheme ( ), there exists a specific value for the signal to noise ratio to maximize the throughput. Once the probability of error, is known, this optimal SNR value can be obtained.

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## Author Biography

**Md. Taslim Arefin** received his B.Sc. in Computer Engineering from American International University –Bangladesh (AIUB) in 2005. He obtained his M.Sc. in Electrical Engineering – Specialization Telecommunications from Blekinge Institute of Technology (BTH), Sweden in 2008. At the present time he is working as Senior Lecturer in the Dept. of ETE at Daffodil International University, Dhaka, Bangladesh. Recently he got chance to work as a research engineer at Institute of Telecommunication, Portugal in a Project named " DRIVE-IN – Distributed Routing and Infotainment Through Vehicular Inter-Networking jointly cooperated by university of Porto and CMU.