

# ee597-assignment2

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Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

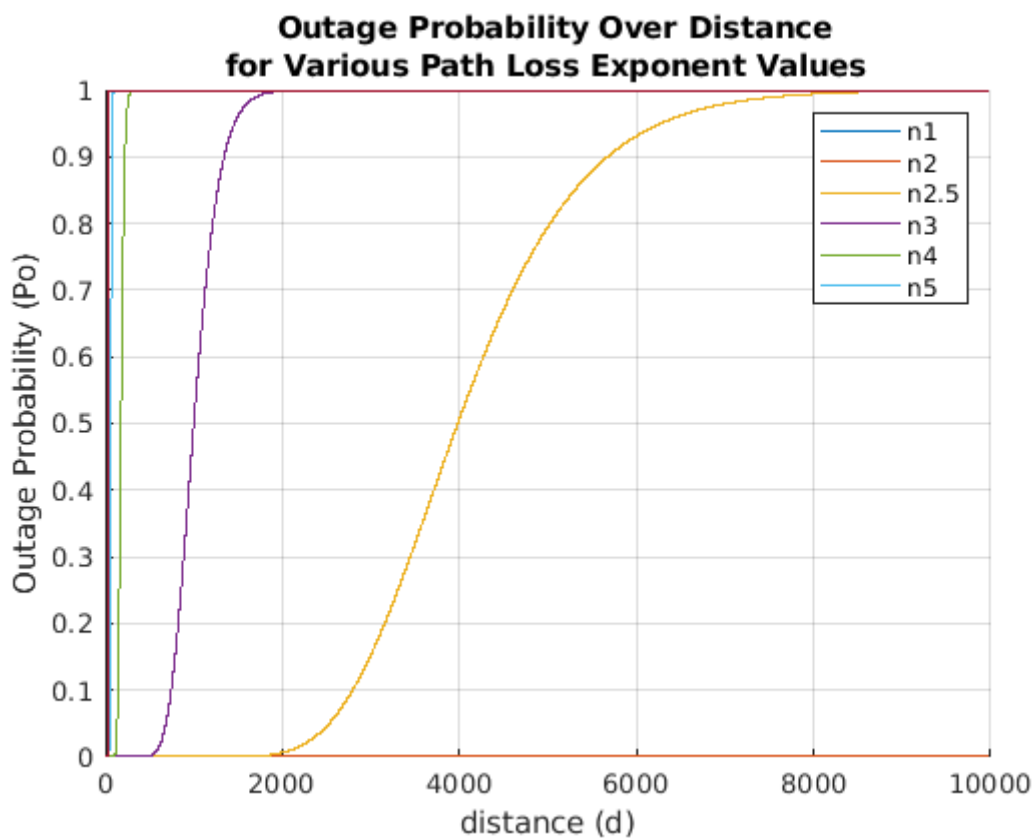
by

Bill Wang student id:

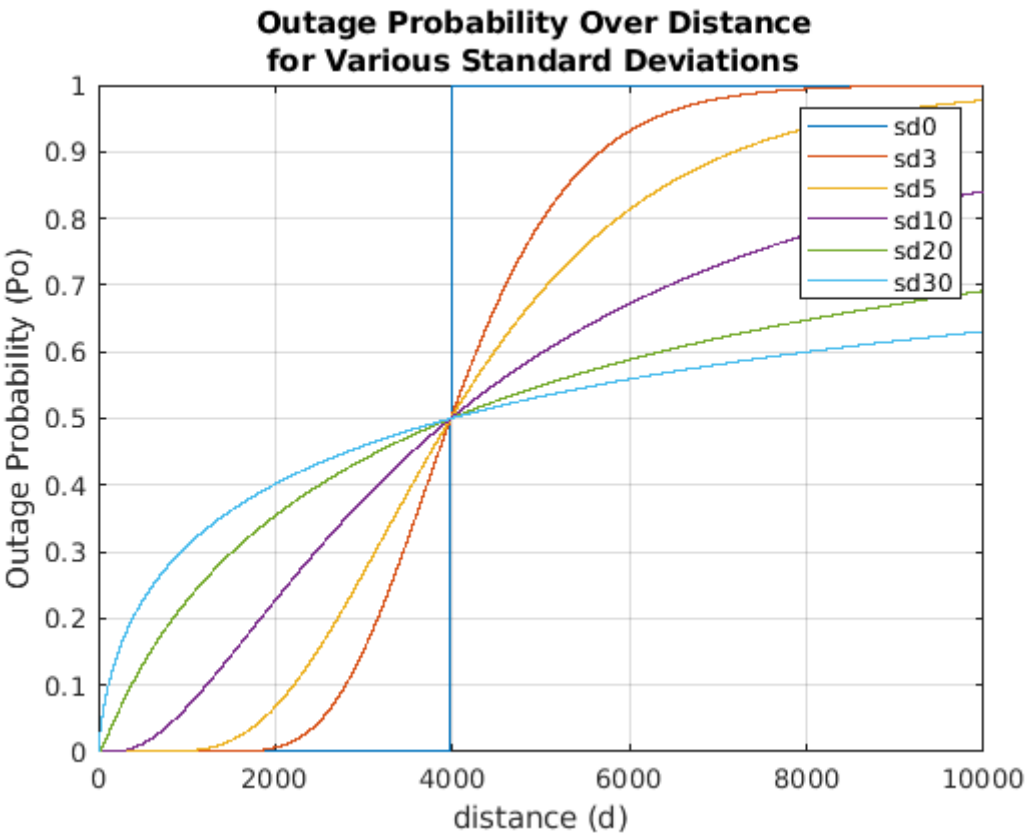
and

Spencer McDonough student id:

## Outage Probability as a function of distance for Log-Normal Shadowing

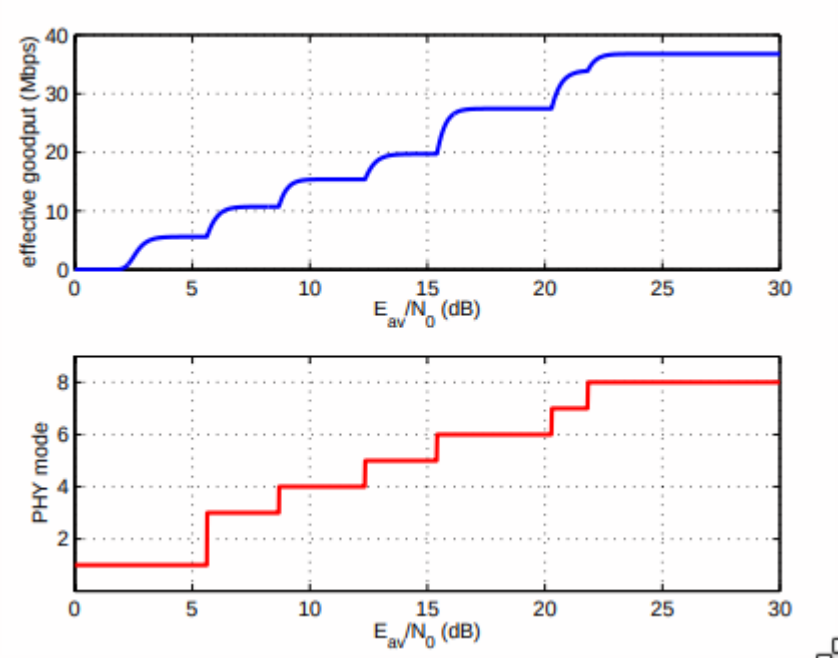


We can see that the probability of outage sigmoid function gets skewed left as we increase the value of the path loss exponent (PLE). This means that the probability of outage increases exponentially by a greater factor when the PLE is increased. This makes sense, as the PLE represents the attenuation due to the nature of the environment ( $\eta > 2$  : loss,  $\eta = 2$  : vacuum, or no loss,  $\eta < 2$  : gain).



We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponent (PLE) increases. This makes sense, as the probability of outage is inversely proportional to the log of the PLE's standard deviation.

Rate Adaptation



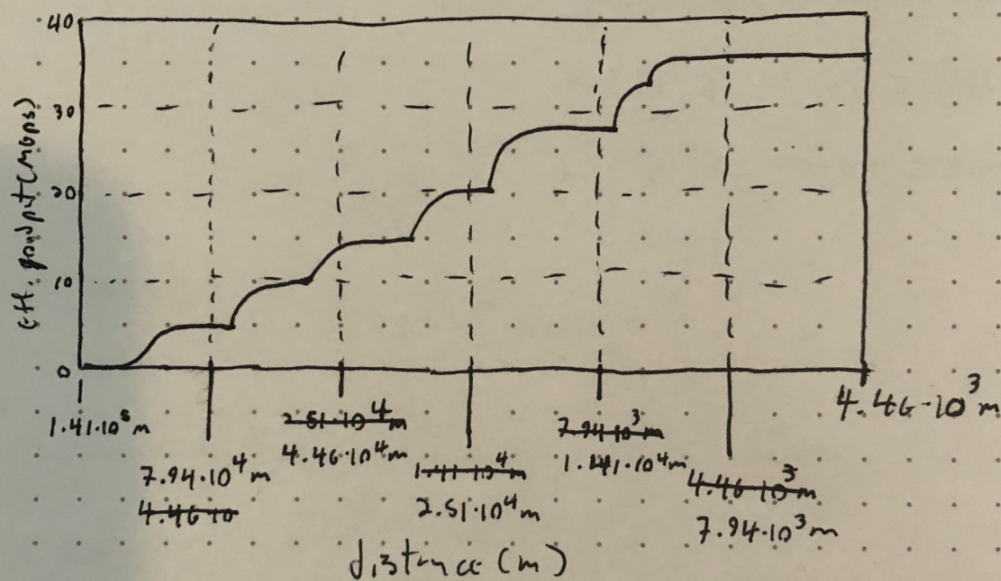
## Effective Goodput as a Function of Distance

$$SNR_{dBm} = P_{TdBm} - N_{dBm}$$

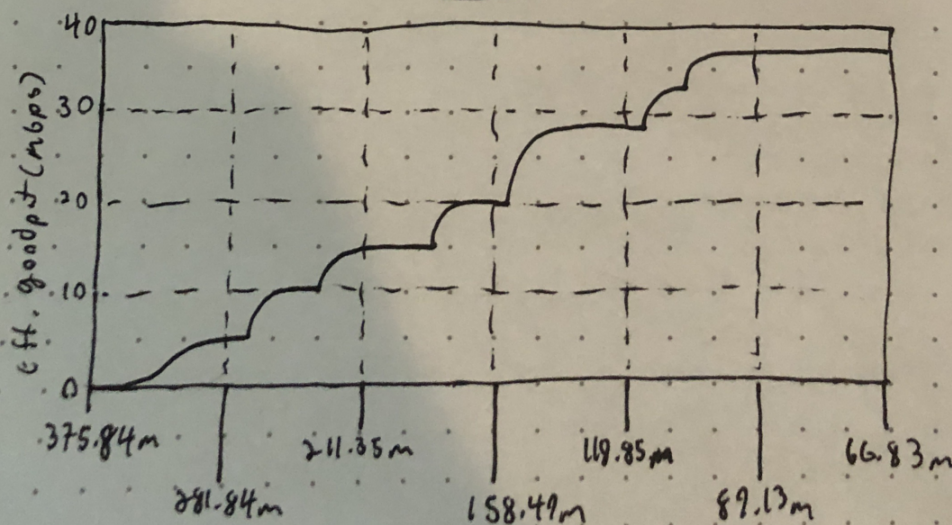
$$P_{dBm} = P_{TdBm} + K_{refdBm} - \eta \cdot 10 \log_{10} \left( \frac{d}{d_0} \right)$$

$$\therefore d = d_0 \cdot 10^{\left[ \frac{P_{TdBm} + K_{refdBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10} \right]}$$

$\therefore$  Effective Goodput (d) for  $\eta = 2$ ,  $P_{TdBm} = 23dBm$ ,  
 $K_{refdBm} = -10dBm$ ,  $N_{dBm} = -90dBm$ .



$\therefore$  Effective Goodput for  $\eta = 4$ :



In this exercise, we converted SNR to distance with a known path loss model.  $P_{TdBm} = 23dBm$ ,  $P_{ref} = -10dBm$ ,  $N_{dBm} = -90dBm$ . We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with eta values 2 and 4. Here is a breakdown of the SNR  $\rightarrow$  d(m) conversions for clarity:

$$d = d_0 \cdot 10^{(P_{TdBm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta \cdot 10)}$$

heta = 2:

d(SNR = 0) = 1.41E5m

d(SNR = 5) = 7.94E4m

d(SNR = 10) = 4.46E4m

d(SNR = 15) = 2.51E4m

d(SNR = 20) = 1.41E4m

d(SNR = 25) = 7.94E3m

d(SNR = 30) = 4.46E3m

heta = 4:

d(SNR = 0) = 375.84m

d(SNR = 5) = 281.84m

d(SNR = 10) = 211.35m

d(SNR = 15) = 158.49m

d(SNR = 20) = 118.85m

d(SNR = 25) = 89.13m

d(SNR = 30) = 66.83m

## Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

*p00 - the probability that we remain in the "outage" state*

*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

p00 = 0.0780

p01 = 0.1400

p10 = 0.1395

p11 = 0.6420

mobile speed = 5:

p00 = 0.0775

p01 = 0.1490

p10 = 0.1490

p11 = 0.6240

mobile speed = 10:

p00 = 0.0715

p01 = 0.1430

p10 = 0.1425

p11 = 0.6425

mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

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(eff\_goodput\_vs\_snr.png)

## ee597-assignment2

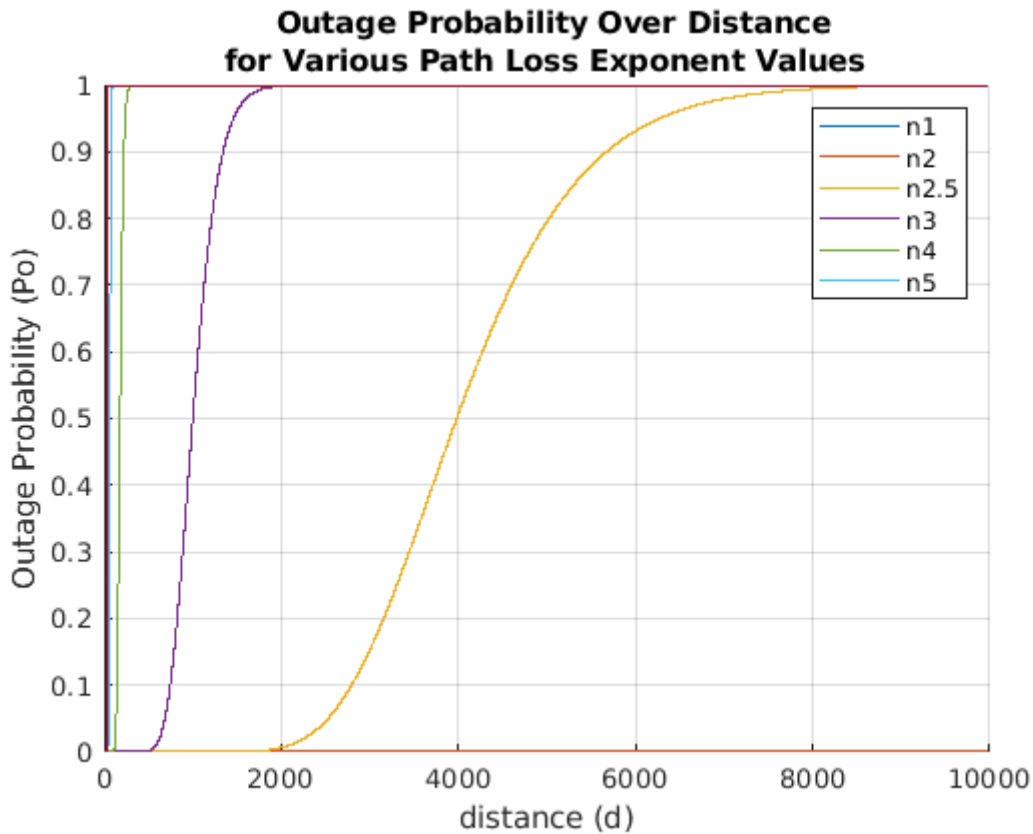
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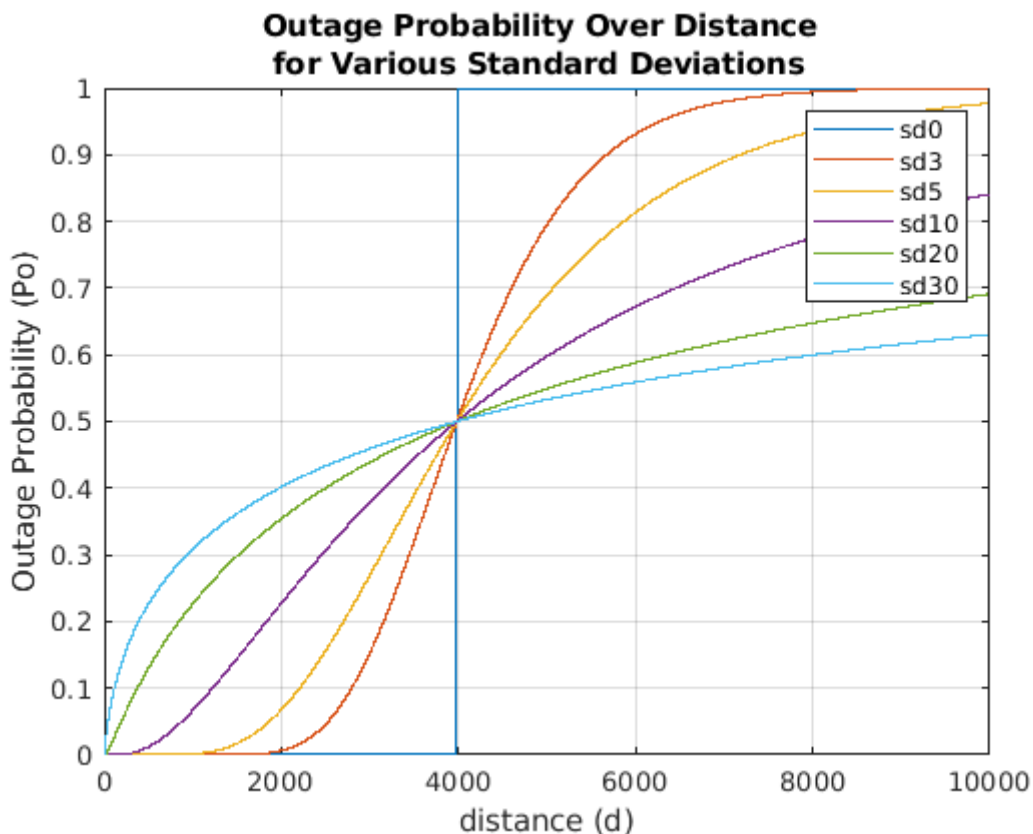
by

Bill Wang student id: and Spencer McDonough student id:

### Outage Probability as a function of distance for Log-Normal Shadowing



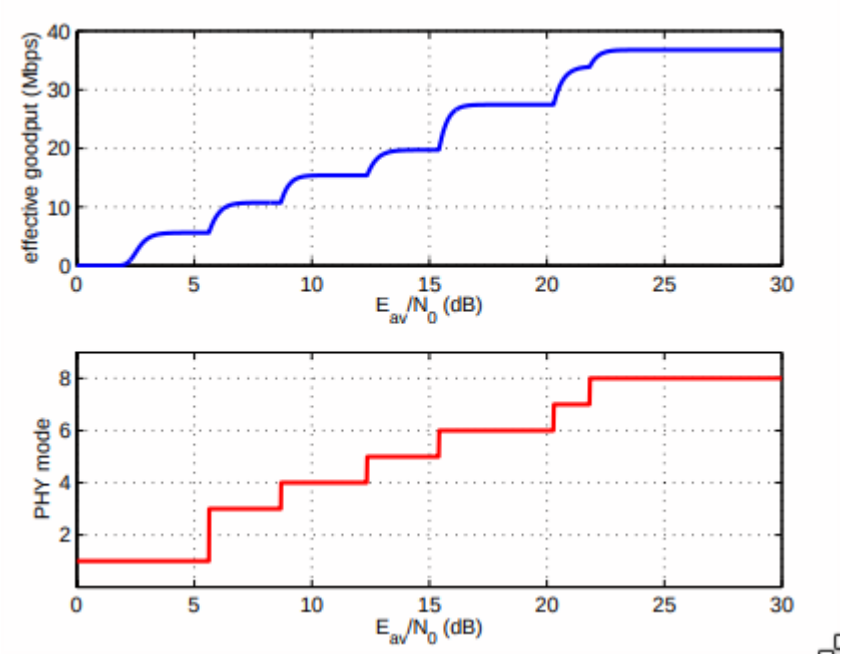
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# Rate Adaptation





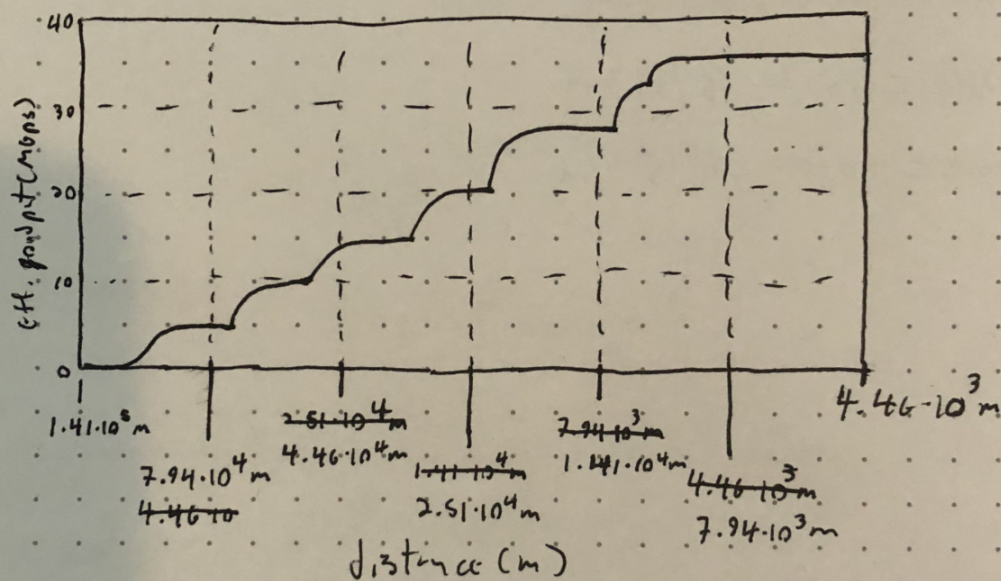
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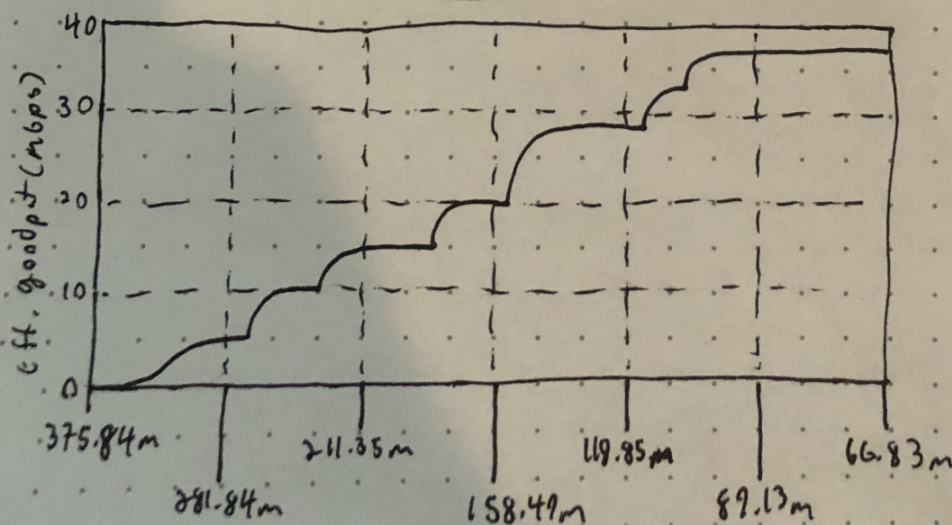
$$P_{dBm} = P_{TdBm} + K_{refdBm} - \eta \cdot 10 \log_{10} \left( \frac{d}{d_0} \right)$$

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heta = 2:

$d(\text{SNR} = 0) = 1.41\text{E}5\text{m}$

$d(\text{SNR} = 5) = 7.94\text{E}4\text{m}$

$d(\text{SNR} = 10) = 4.46\text{E}4\text{m}$

$d(\text{SNR} = 15) = 2.51\text{E}4\text{m}$

$d(\text{SNR} = 20) = 1.41\text{E}4\text{m}$

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heta = 4:

$d(\text{SNR} = 0) = 375.84\text{m}$

$d(\text{SNR} = 5) = 281.84\text{m}$

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$d(\text{SNR} = 20) = 118.85\text{m}$

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*p11 - the probability that we remain in the "receive" state*

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$p00 = 0.0780$

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$p11 = 0.6425$

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p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

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mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

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## ee597-assignment2

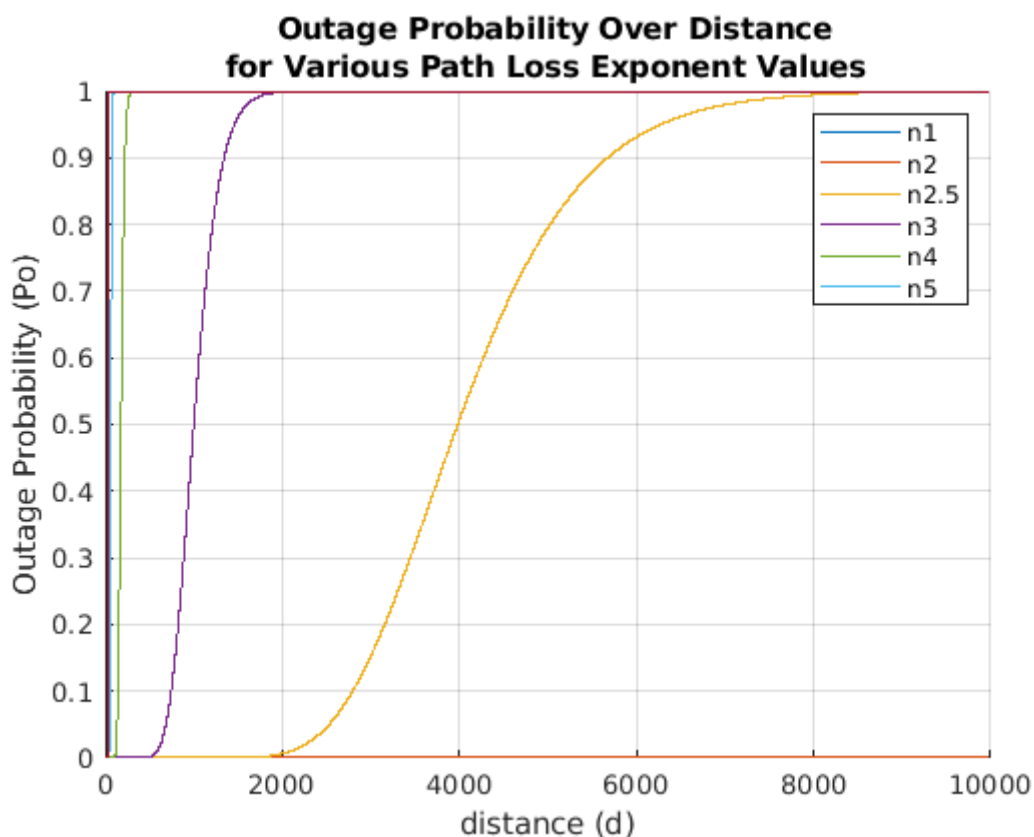
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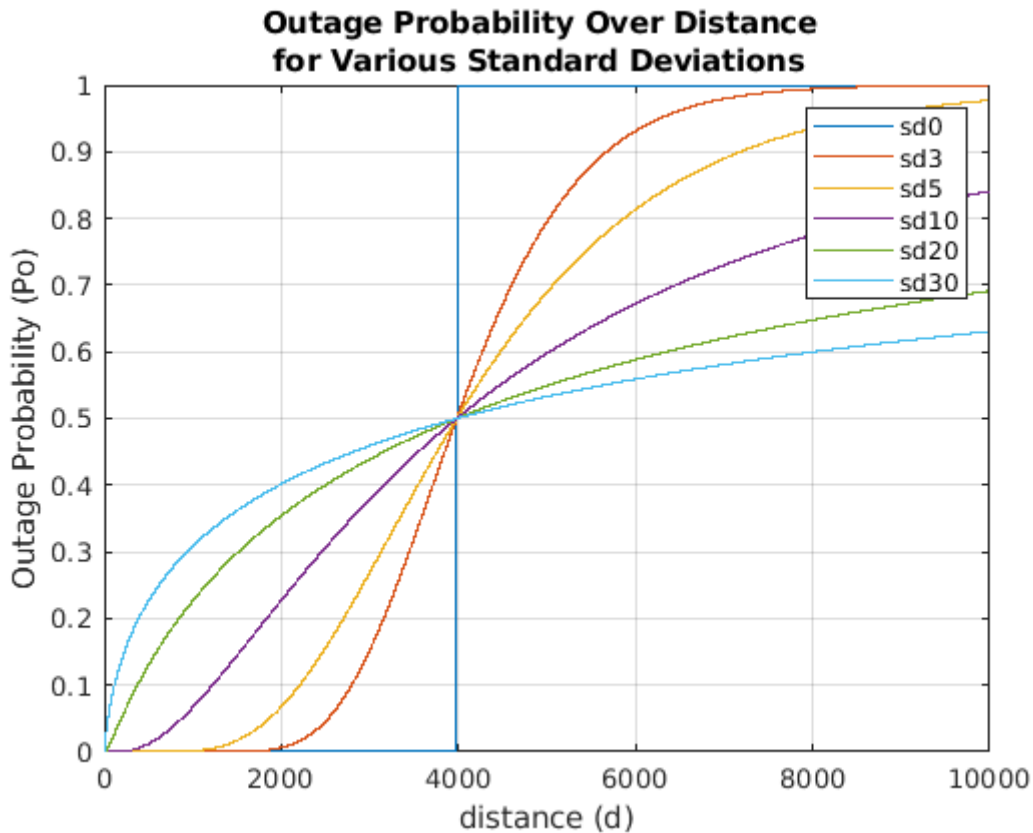
by

Bill Wang student id: and Spencer McDonough student id:

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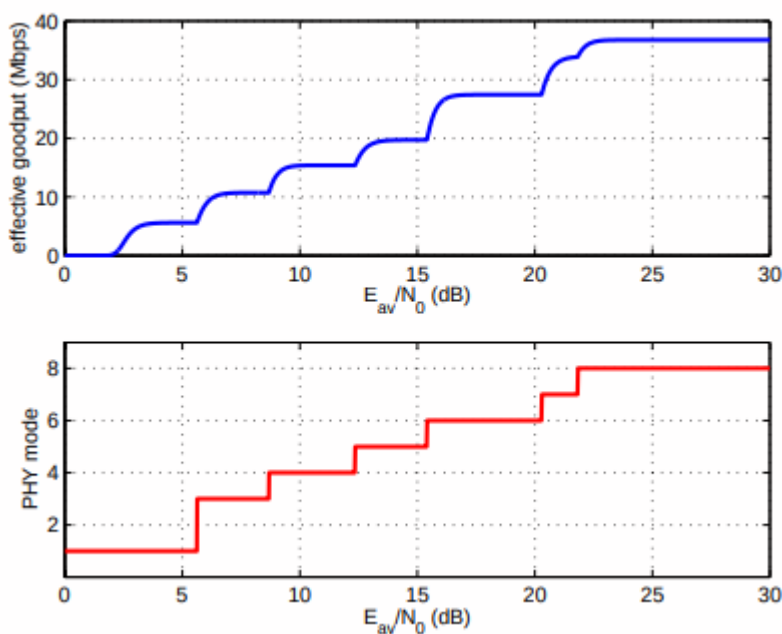


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## Rate Adaptation



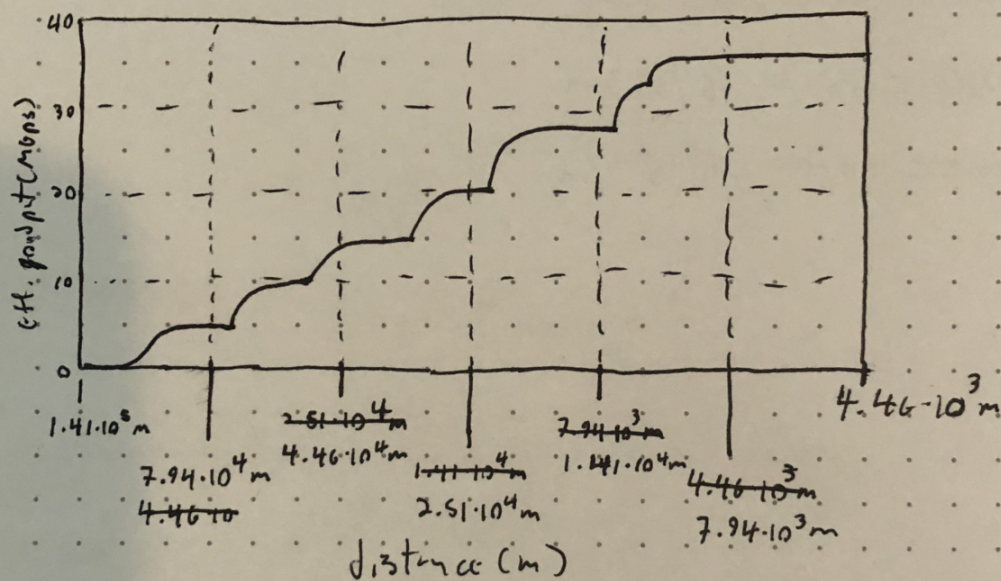
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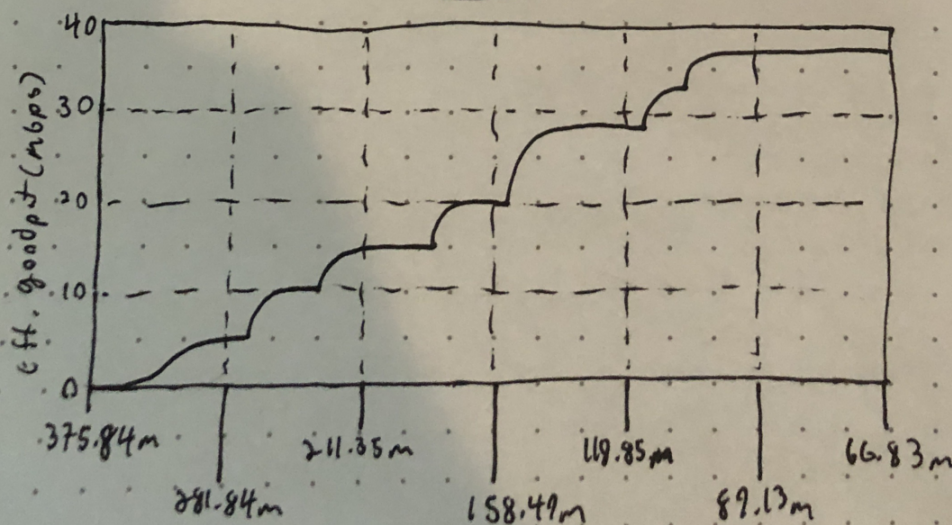
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heta = 2:

$d(\text{SNR} = 0) = 1.41\text{E}5\text{m}$

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$d(\text{SNR} = 10) = 4.46\text{E}4\text{m}$

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heta = 4:

$d(\text{SNR} = 0) = 375.84\text{m}$

$d(\text{SNR} = 5) = 281.84\text{m}$

$d(\text{SNR} = 10) = 211.35\text{m}$

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In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

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*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

$p00 = 0.0780$

$p01 = 0.1400$

$p10 = 0.1395$

$p11 = 0.6420$

mobile speed = 5:

$p00 = 0.0775$

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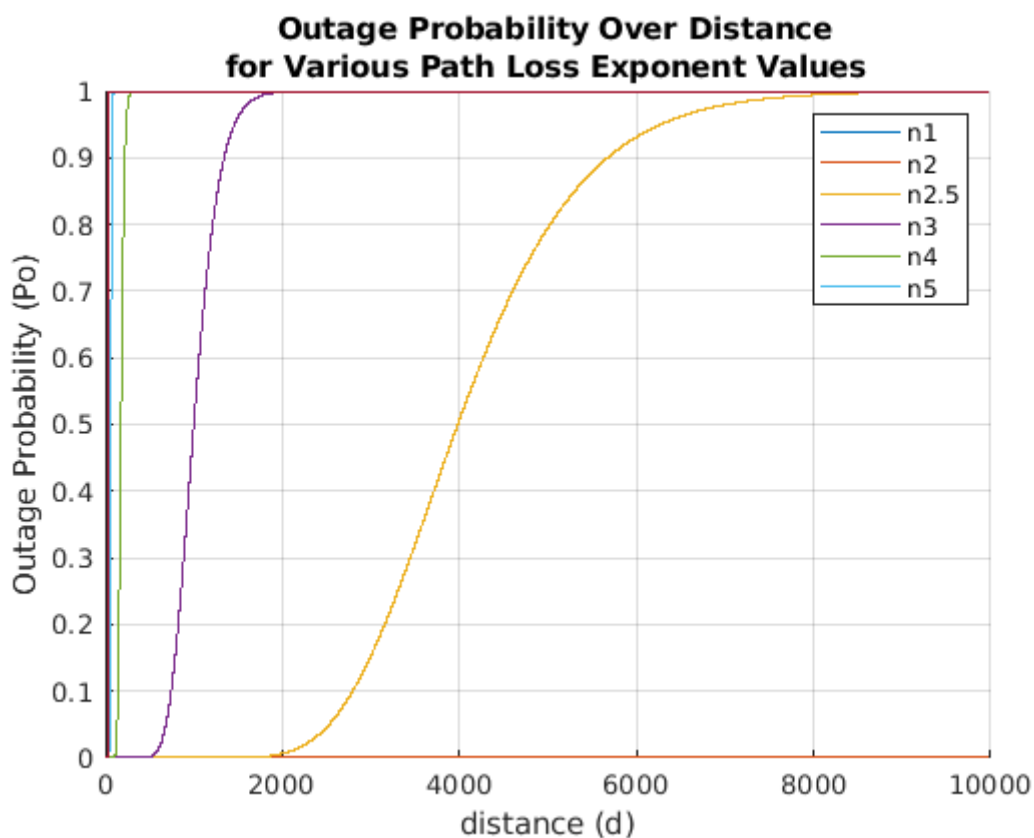
p11 = 0.6215

! [Figure 4: Effective Goodput (Mbps) as a function of Distance (m)]# ee597-assignment2 Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

by

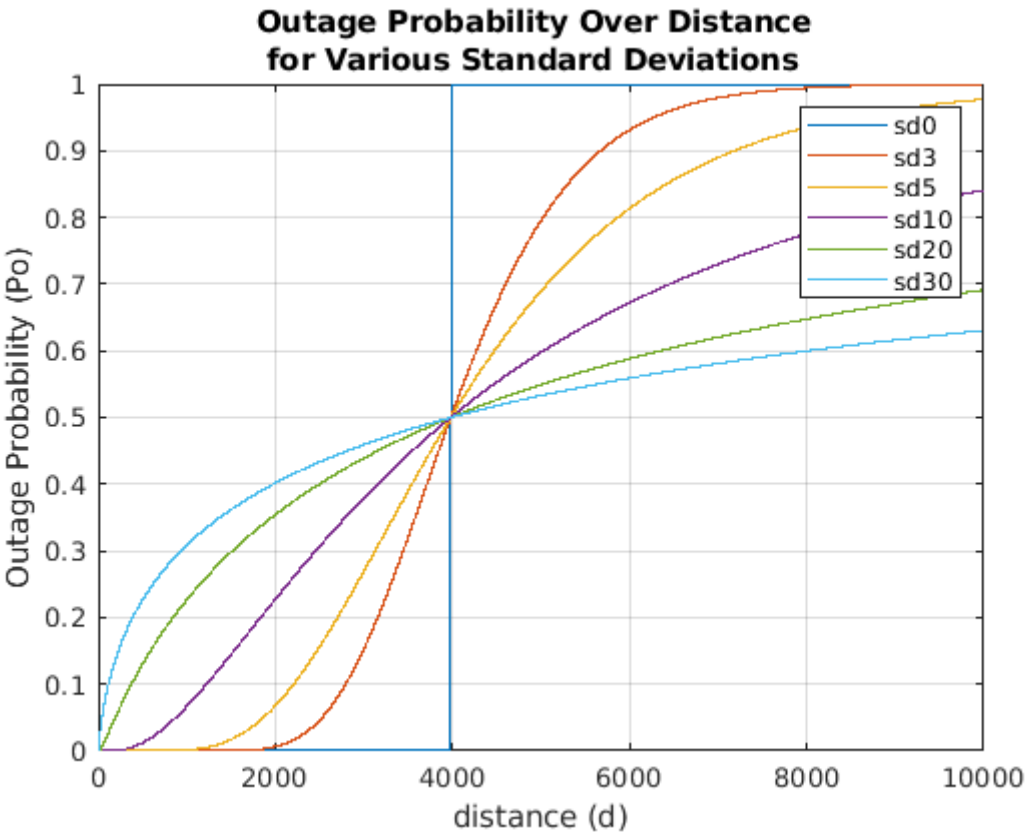
Bill Wang student id: and Spencer McDonough student id:

## Outage Probability as a function of distance for Log-Normal Shadowing



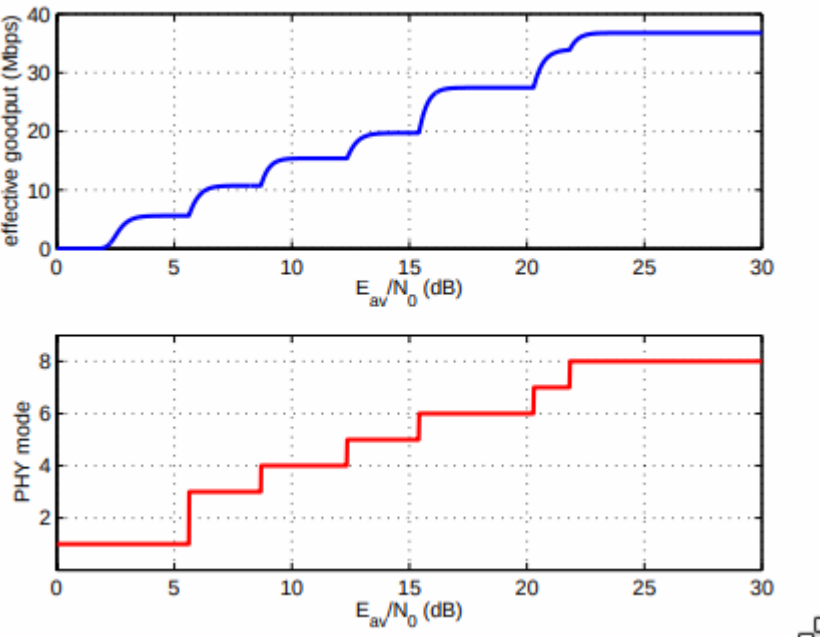
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Rate Adaptation



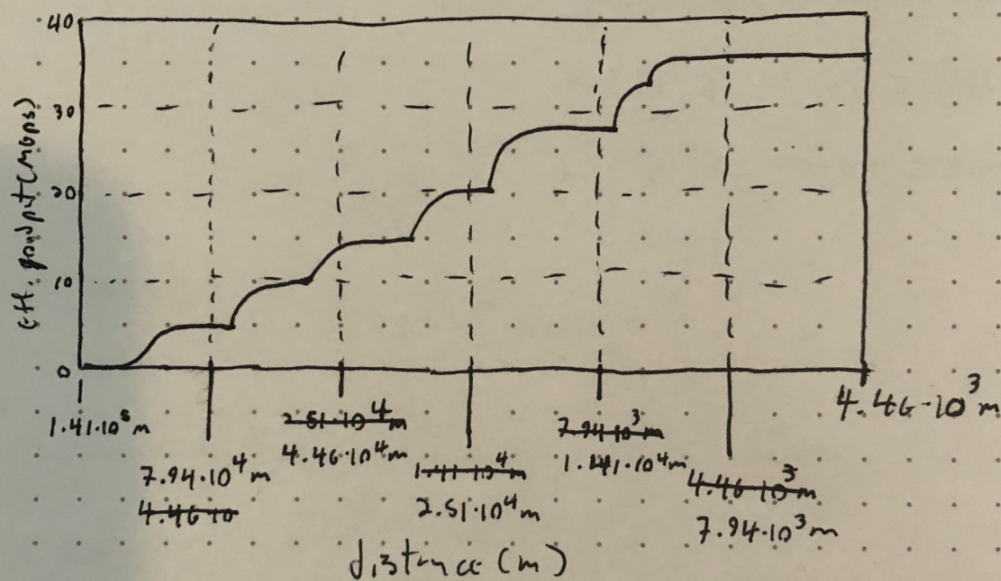
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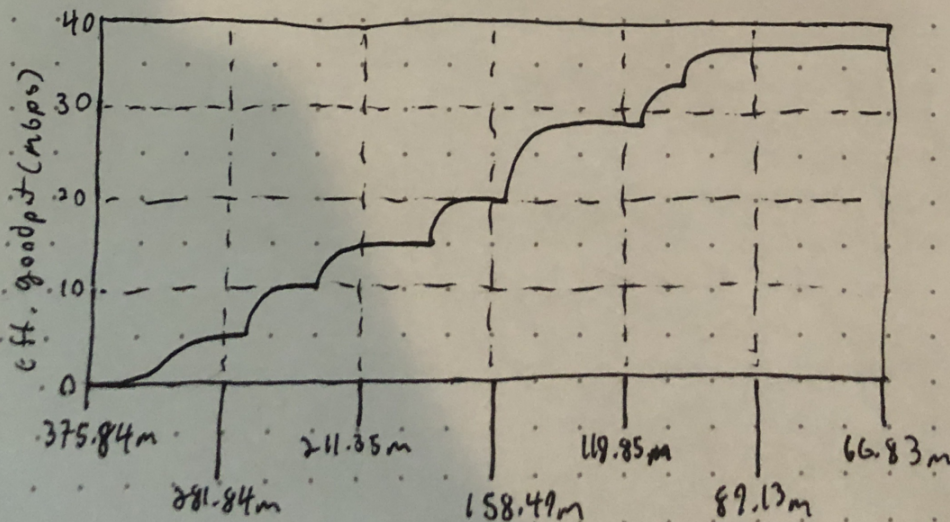
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*p01 - the probability that we move from the "outage" state to the "receive" state*

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*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

$p00 = 0.0780$

$p01 = 0.1400$

$p10 = 0.1395$

$p11 = 0.6420$

mobile speed = 5:

$p00 = 0.0775$

$p01 = 0.1490$

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mobile speed = 20:

p00 = 0.0750

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(eff\_goodput\_vs\_d.png)

## ee597-assignment2

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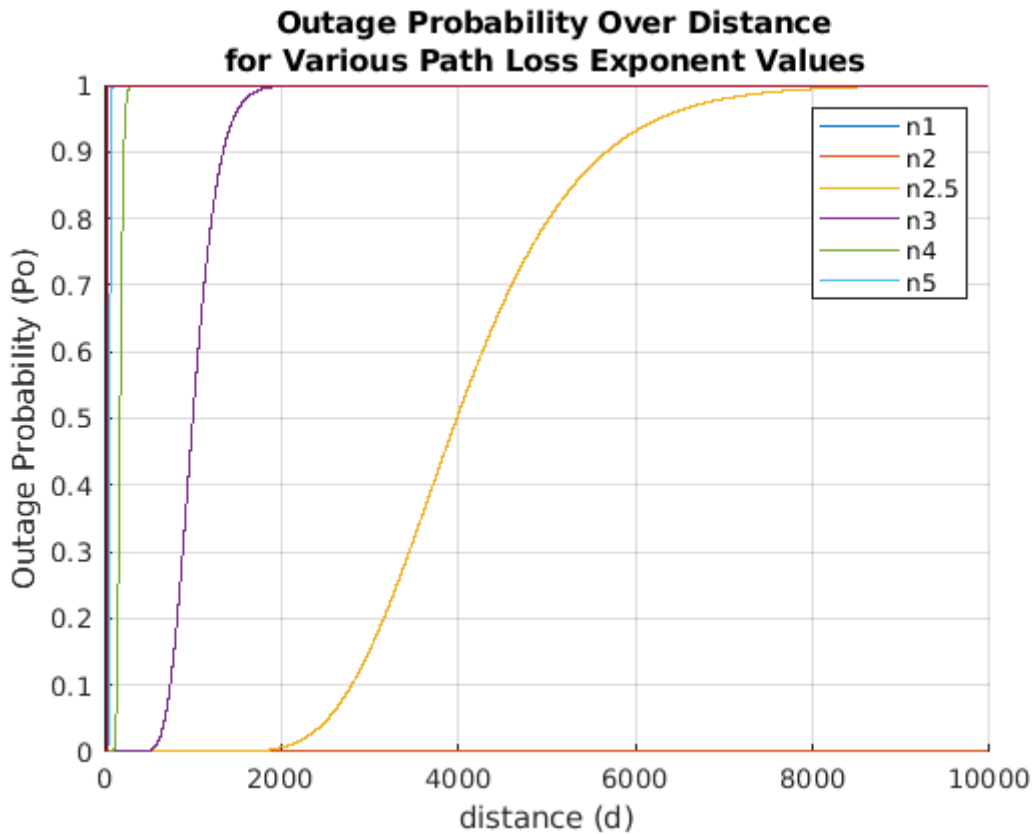
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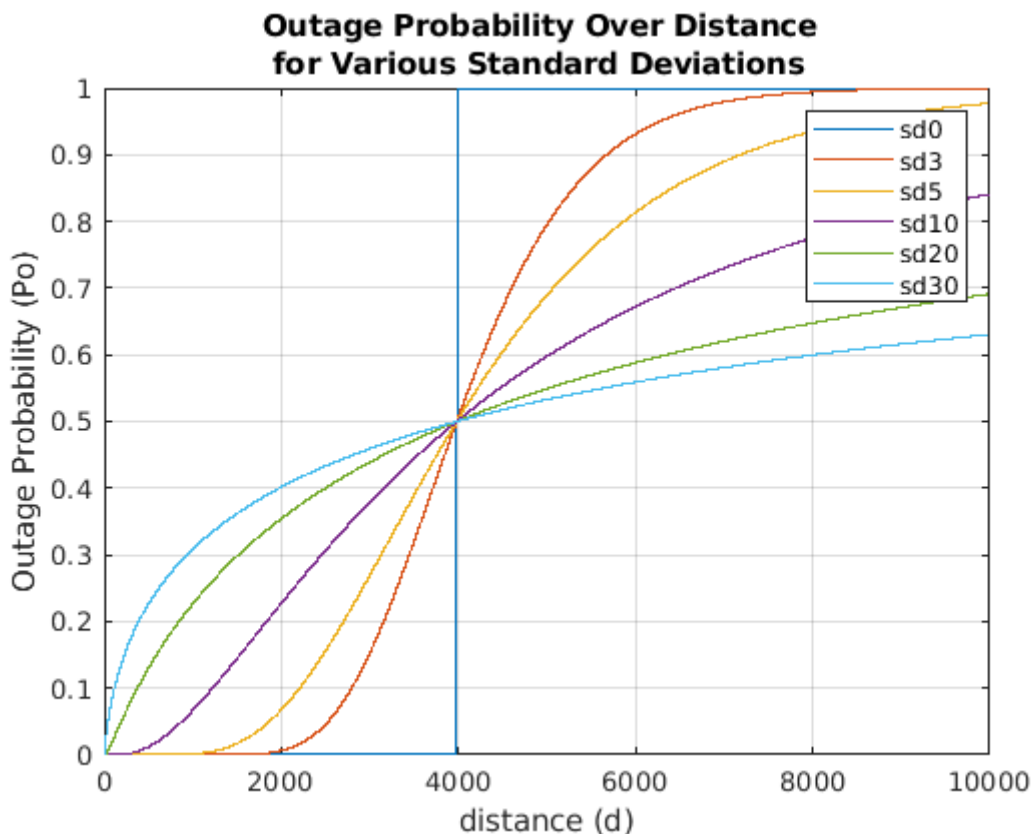
Bill Wang student id: and Spencer McDonough student id:

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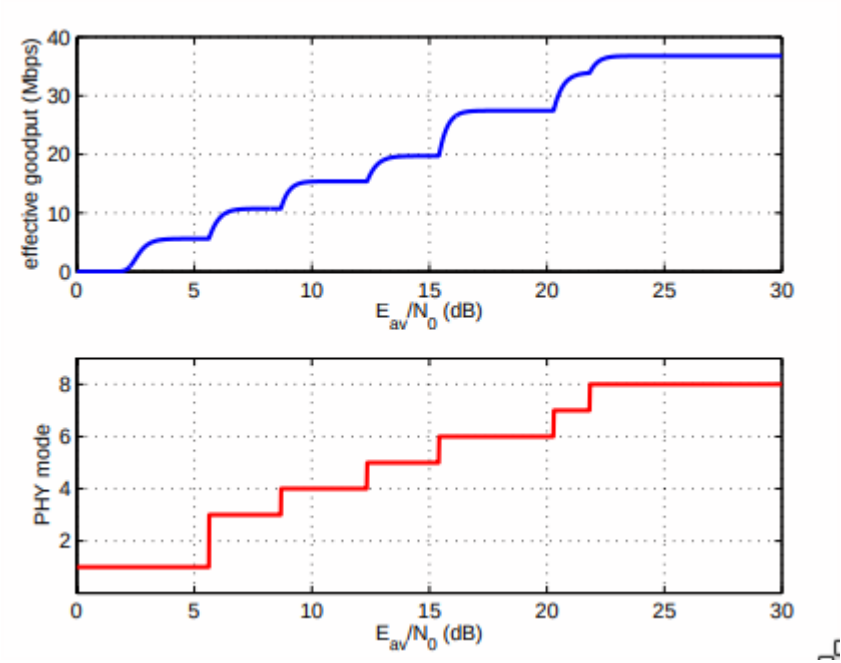
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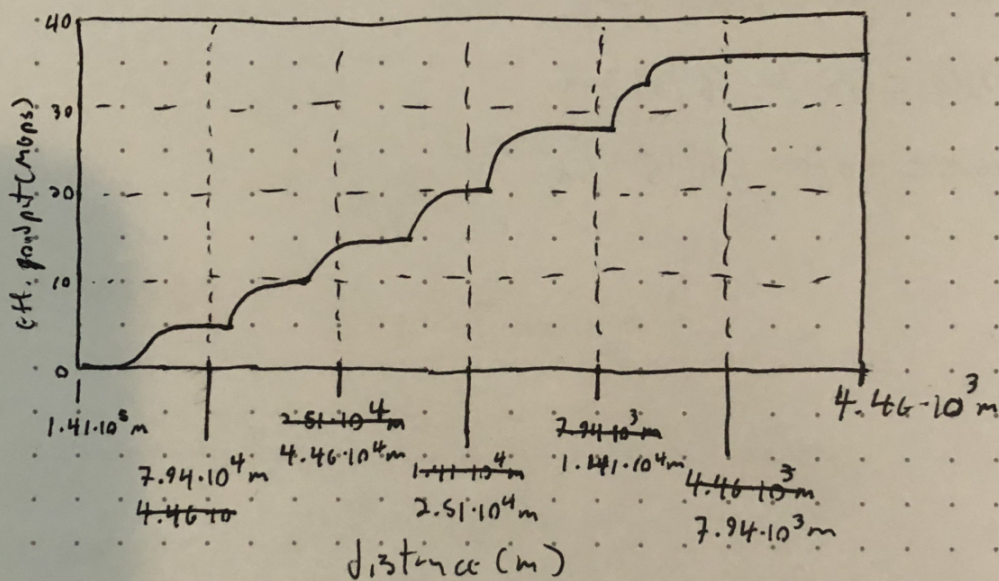
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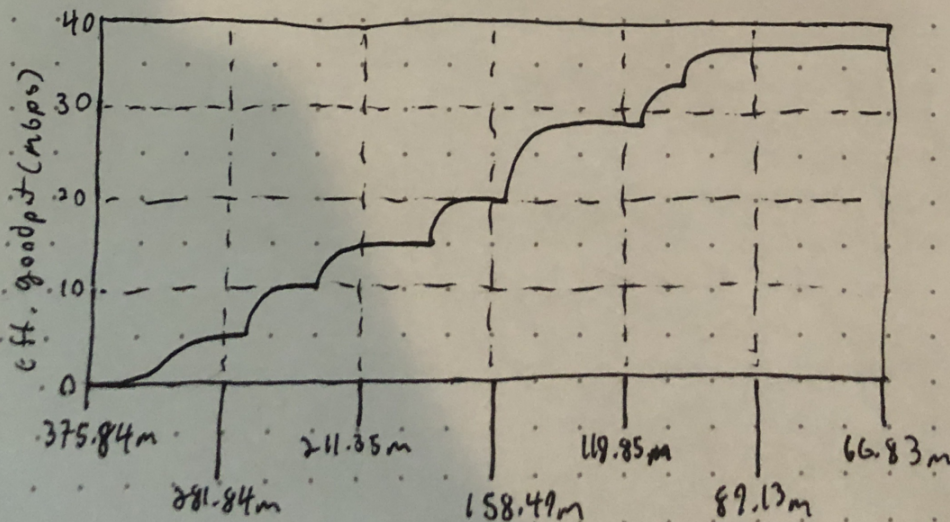
$$P_{dBm} = P_{TdBm} + K_{refdBm} - \eta \cdot 10 \log_{10} \left( \frac{d}{d_0} \right)$$

$$\therefore d = d_0 \cdot 10^{\left[ \frac{P_{TdBm} + K_{refdBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10} \right]}$$

$\therefore$  Effective Goodput (d) for  $\eta = 2$ ,  $P_{TdBm} = 23dBm$ ,  
 $K_{refdBm} = -10dBm$ ,  $N_{dBm} = -90dBm$ .



$\therefore$  Effective Goodput for  $\eta = 4$ :



In this exercise, we converted SNR to distance with a known path loss model.  $P_{TdBm} = 23dBm$ ,  $P_{ref} = -10dBm$ ,  $N_{dBm} = -90dBm$ . We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with  $\eta$  values 2 and 4. Here is a breakdown of the SNR  $\rightarrow$  d(m) conversions for clarity:  $d = d_0 \cdot 10^{(P_{TdBm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta \cdot 10)}$

heta = 2:

$d(\text{SNR} = 0) = 1.41\text{E}5\text{m}$

$d(\text{SNR} = 5) = 7.94\text{E}4\text{m}$

$d(\text{SNR} = 10) = 4.46\text{E}4\text{m}$

$d(\text{SNR} = 15) = 2.51\text{E}4\text{m}$

$d(\text{SNR} = 20) = 1.41\text{E}4\text{m}$

$d(\text{SNR} = 25) = 7.94\text{E}3\text{m}$

$d(\text{SNR} = 30) = 4.46\text{E}3\text{m}$

heta = 4:

$d(\text{SNR} = 0) = 375.84\text{m}$

$d(\text{SNR} = 5) = 281.84\text{m}$

$d(\text{SNR} = 10) = 211.35\text{m}$

$d(\text{SNR} = 15) = 158.49\text{m}$

$d(\text{SNR} = 20) = 118.85\text{m}$

$d(\text{SNR} = 25) = 89.13\text{m}$

$d(\text{SNR} = 30) = 66.83\text{m}$

## Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

*p00 - the probability that we remain in the "outage" state*

*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

$p00 = 0.0780$

$p01 = 0.1400$

$p10 = 0.1395$

$p11 = 0.6420$

mobile speed = 5:

$p00 = 0.0775$

$p01 = 0.1490$

$p10 = 0.1490$

$p11 = 0.6240$

mobile speed = 10:

$p00 = 0.0715$

$p01 = 0.1430$

$p10 = 0.1425$

$p11 = 0.6425$

mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

p11 = 0.6215

## ee597-assignment2

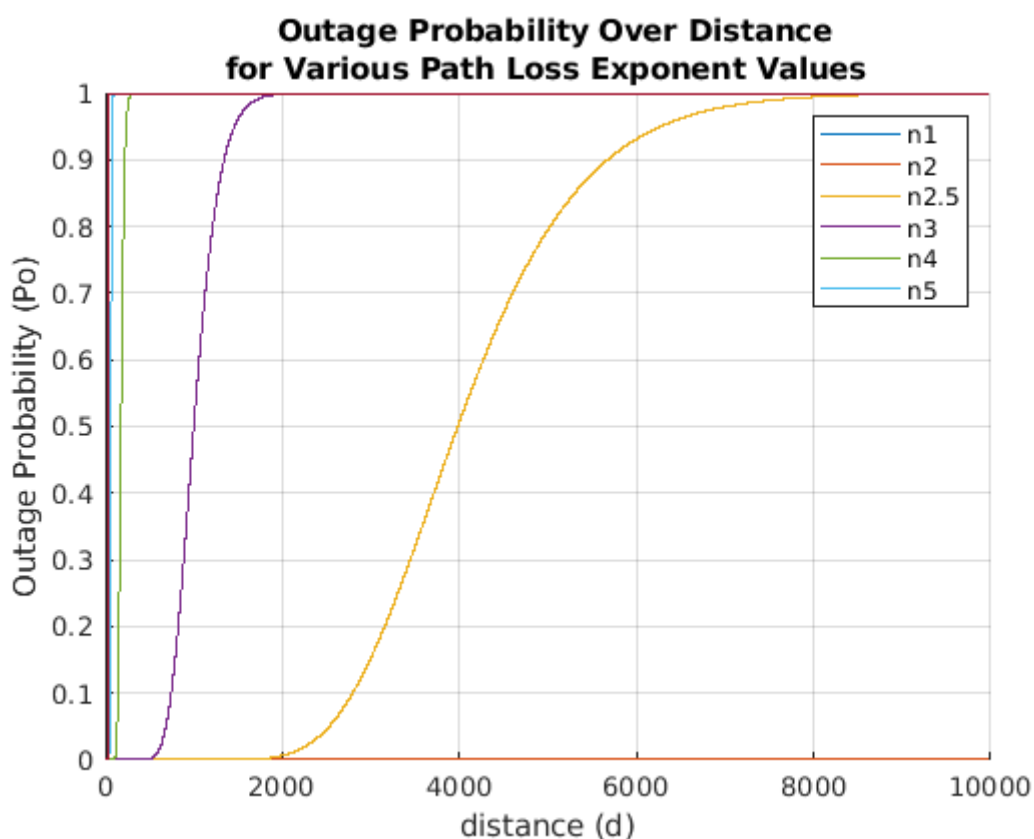
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Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

by

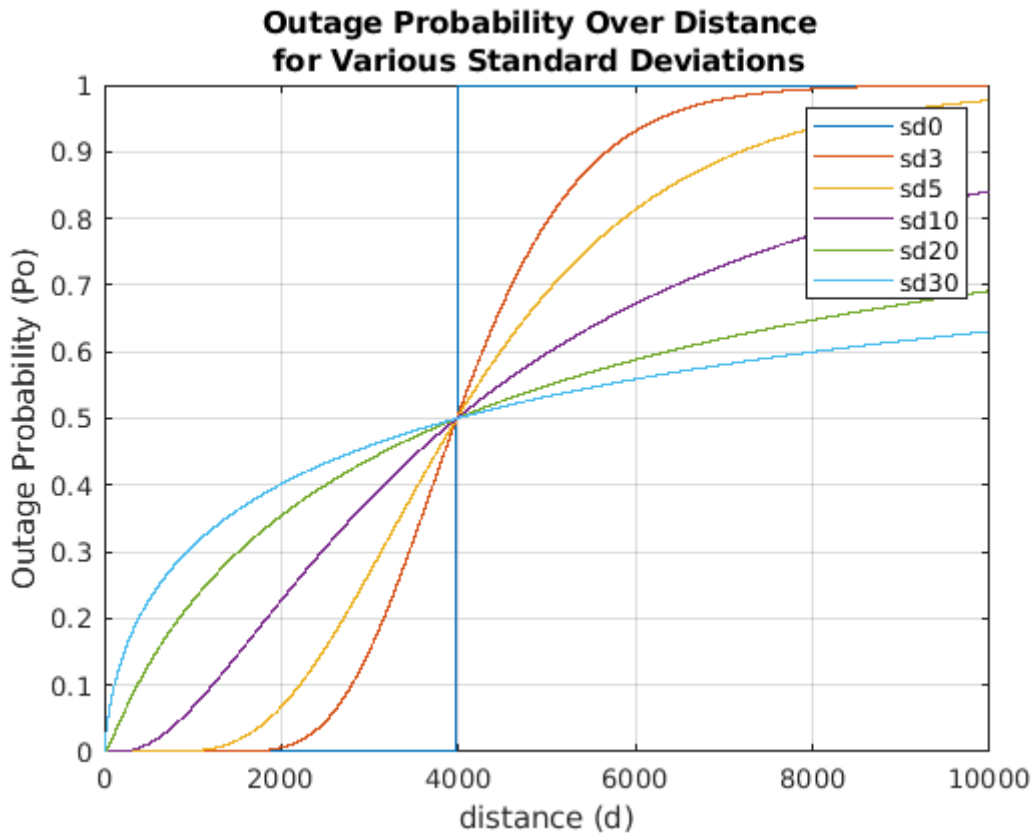
Bill Wang student id: and Spencer McDonough student id:

### Outage Probability as a function of distance for Log-Normal Shadowing



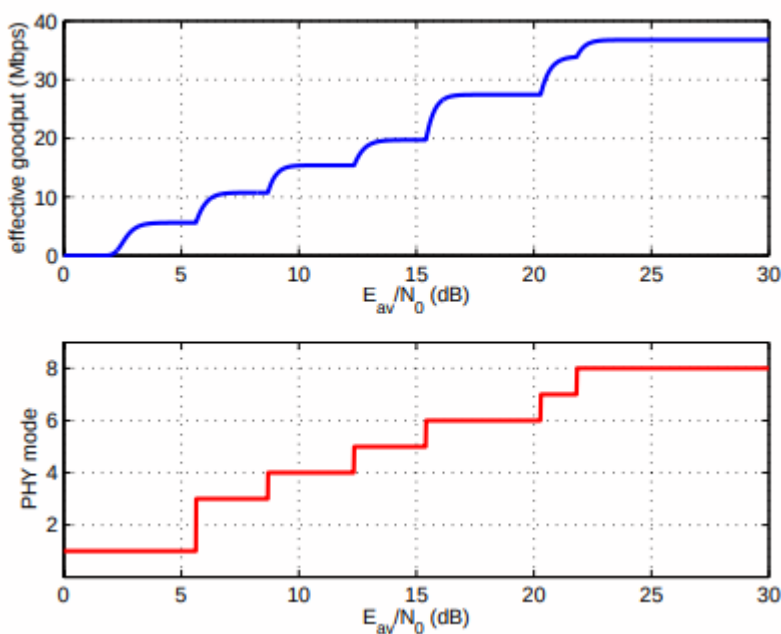


We can see that the probability of outage sigmoid function gets skewed left as we increase the value of the path loss exponent (PLE). This means that the probability of outage increases exponentially by a greater factor when the PLE is increased. This makes sense, as the PLE represents the attenuation due to the nature of the environment ( $\eta > 2$  : loss,  $\eta = 2$  : vacuum, or no loss,  $\eta < 2$  : gain).



We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponent (PLE) increases. This makes sense, as the probability of outage is inversely proportional to the log of the PLE's standard deviation.

## Rate Adaptation



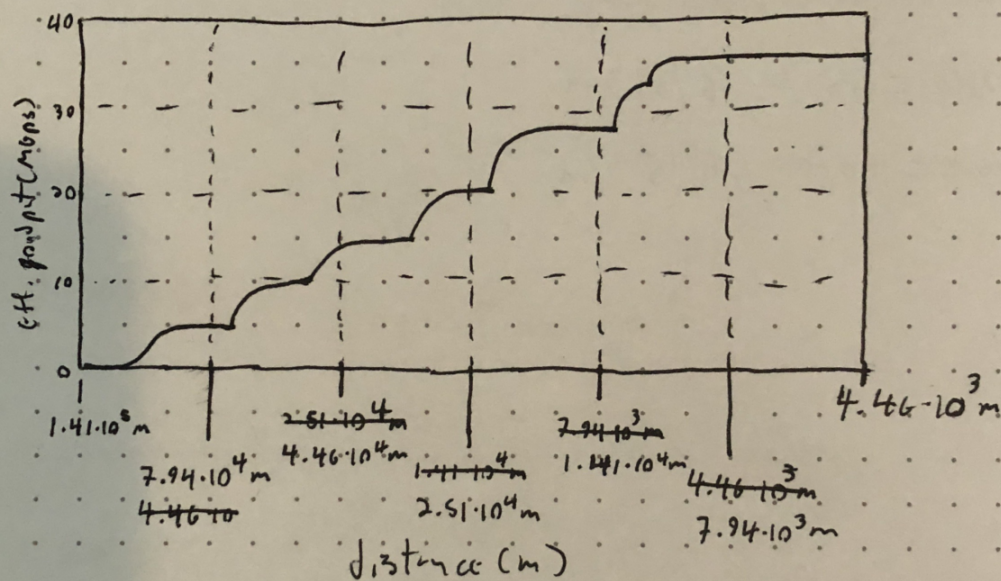
## Effective Goodput as a Function of Distance

$$SNR_{dBm} = P_{TdBm} - N_{dBm}$$

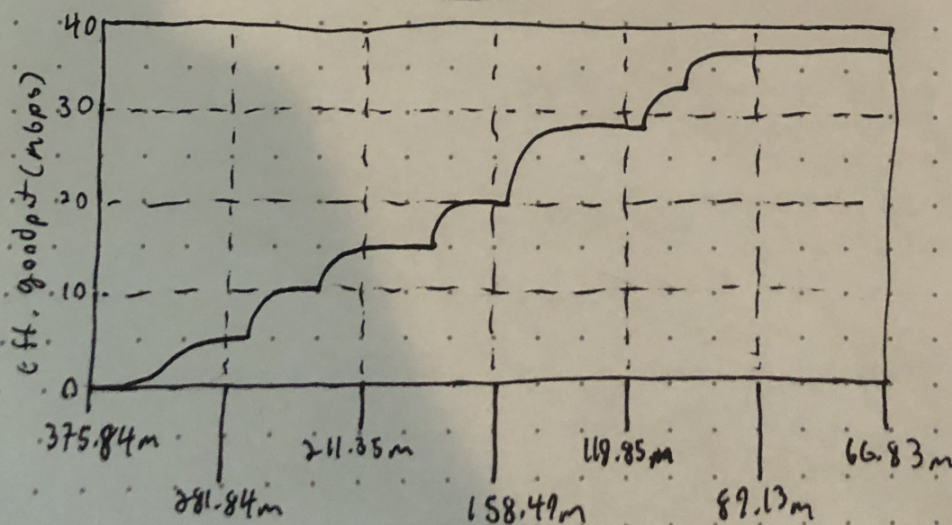
$$P_{dBm} = P_{TdBm} + K_{refdBm} - \eta \cdot 10 \log_{10} \left( \frac{d}{d_0} \right)$$

$$\therefore d = d_0 \cdot 10^{\left[ \frac{P_{TdBm} + K_{refdBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10} \right]}$$

$\therefore$  Effective Goodput (d) for  $\eta = 2$ ,  $P_{TdBm} = 23dBm$ ,  
 $K_{refdBm} = -10dBm$ ,  $N_{dBm} = -90dBm$ .



$\therefore$  Effective Goodput for  $\eta = 4$ :



In this exercise, we converted SNR to distance with a known path loss model.  $P_{TdBm} = 23dBm$ ,  $P_{ref} = -10dBm$ ,  $N_{dBm} = -90dBm$ . We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with  $\eta$  values 2 and 4. Here is a breakdown of the SNR  $\rightarrow$  d(m) conversions for clarity:  $d = d_0 \cdot 10^{(P_{TdBm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta \cdot 10)}$

heta = 2:

$d(\text{SNR} = 0) = 1.41\text{E}5\text{m}$

$d(\text{SNR} = 5) = 7.94\text{E}4\text{m}$

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$d(\text{SNR} = 20) = 1.41\text{E}4\text{m}$

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$d(\text{SNR} = 30) = 4.46\text{E}3\text{m}$

heta = 4:

$d(\text{SNR} = 0) = 375.84\text{m}$

$d(\text{SNR} = 5) = 281.84\text{m}$

$d(\text{SNR} = 10) = 211.35\text{m}$

$d(\text{SNR} = 15) = 158.49\text{m}$

$d(\text{SNR} = 20) = 118.85\text{m}$

$d(\text{SNR} = 25) = 89.13\text{m}$

$d(\text{SNR} = 30) = 66.83\text{m}$

## Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

*p00 - the probability that we remain in the "outage" state*

*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

$p00 = 0.0780$

$p01 = 0.1400$

$p10 = 0.1395$

$p11 = 0.6420$

mobile speed = 5:

$p00 = 0.0775$

$p01 = 0.1490$

$p10 = 0.1490$

$p11 = 0.6240$

mobile speed = 10:

$p00 = 0.0715$

$p01 = 0.1430$

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$p11 = 0.6425$

mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

p11 = 0.6215

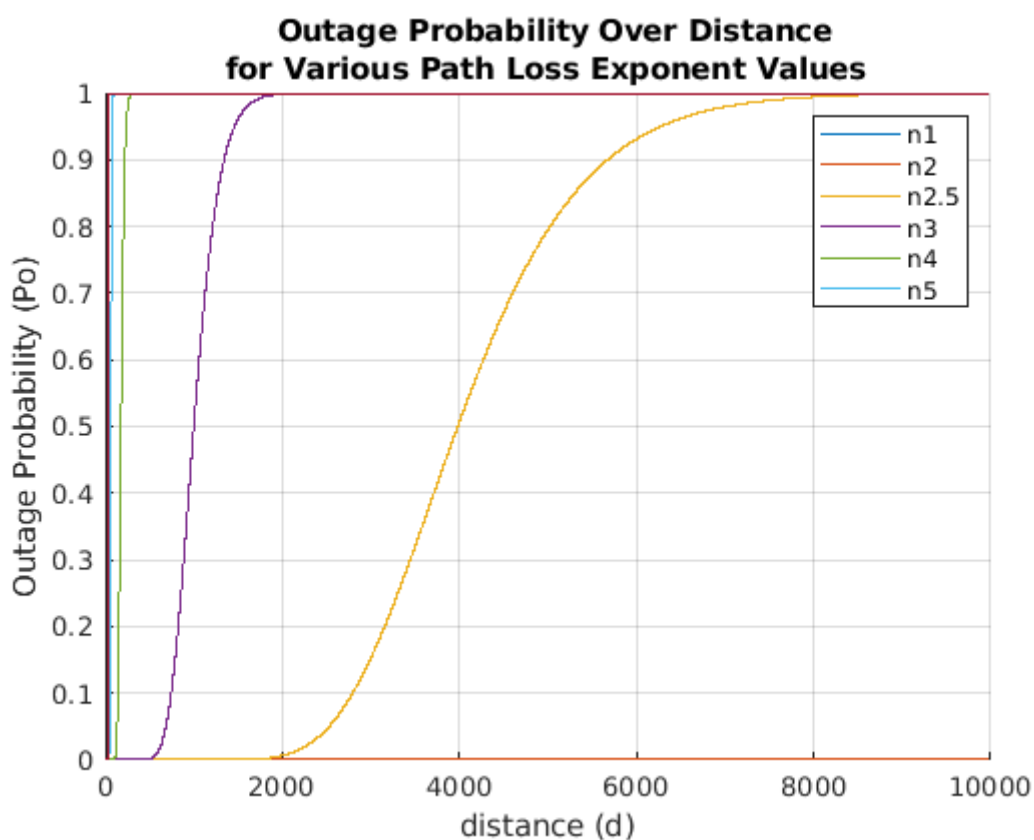
In this exercise, we converted SNR to distance with a known path loss model. # ee597-assignment2

Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

by

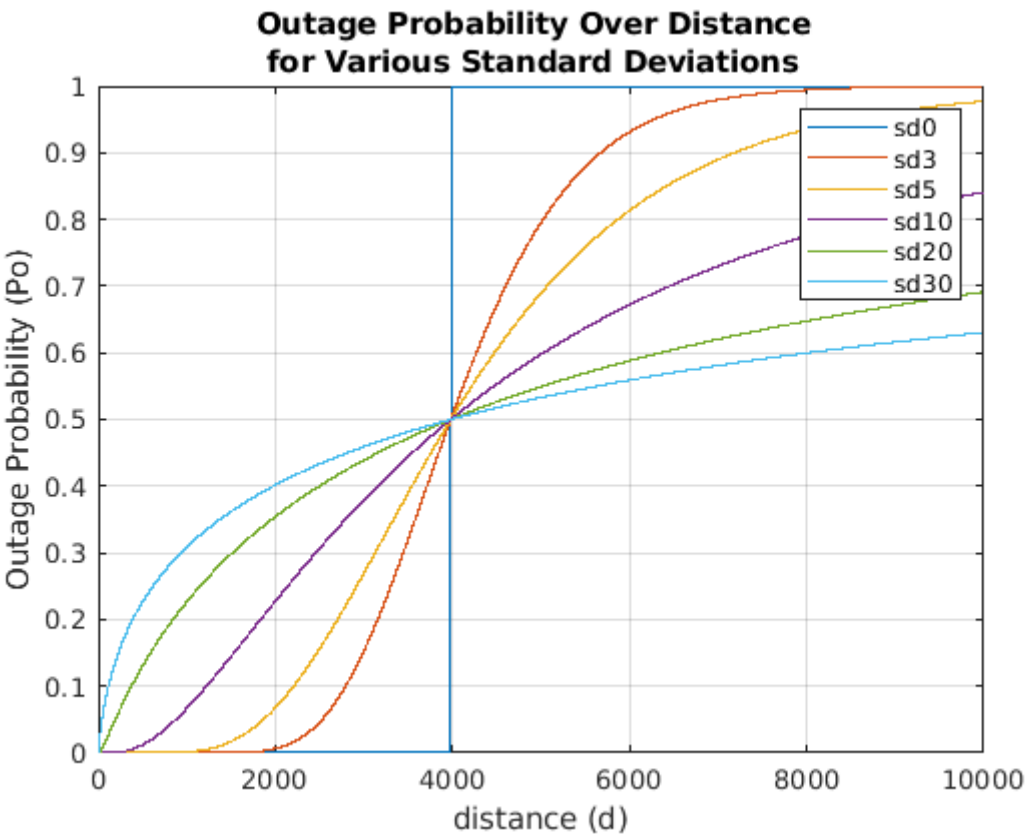
Bill Wang student id: and Spencer McDonough student id:

## Outage Probability as a function of distance for Log-Normal Shadowing



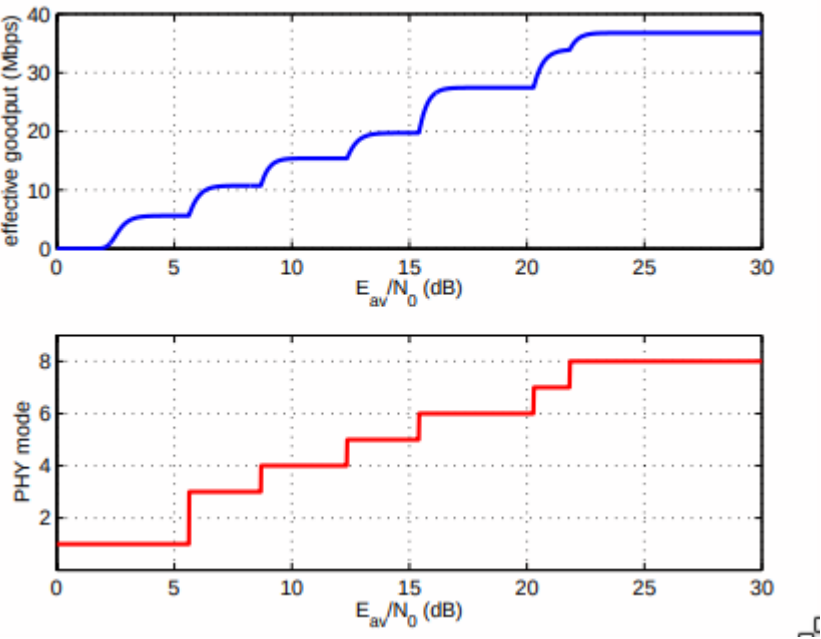
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factor when the PLE is increased. This makes sense, as the PLE represents the attenuation due to the nature of the environment ( $\eta > 2$  : loss,  $\eta = 2$  : vacuum, or no loss,  $\eta < 2$  : gain).



We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponent (PLE) increases. This makes sense, as the probability of outage is inversely proportional to the log of the PLE's standard deviation.

Rate Adaptation





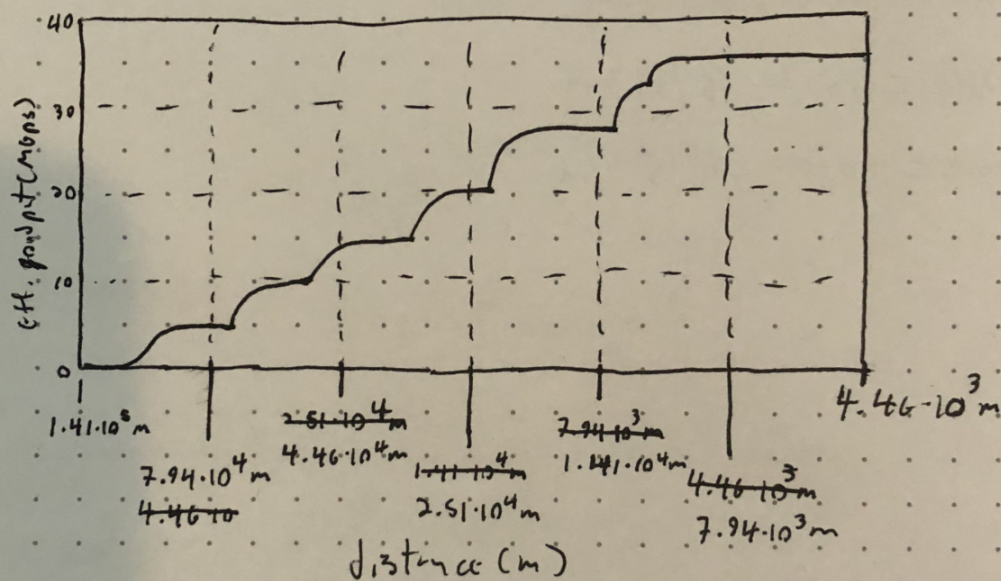
## Effective Goodput as a Function of Distance

$$SNR_{dBm} = P_{TdBm} - N_{dBm}$$

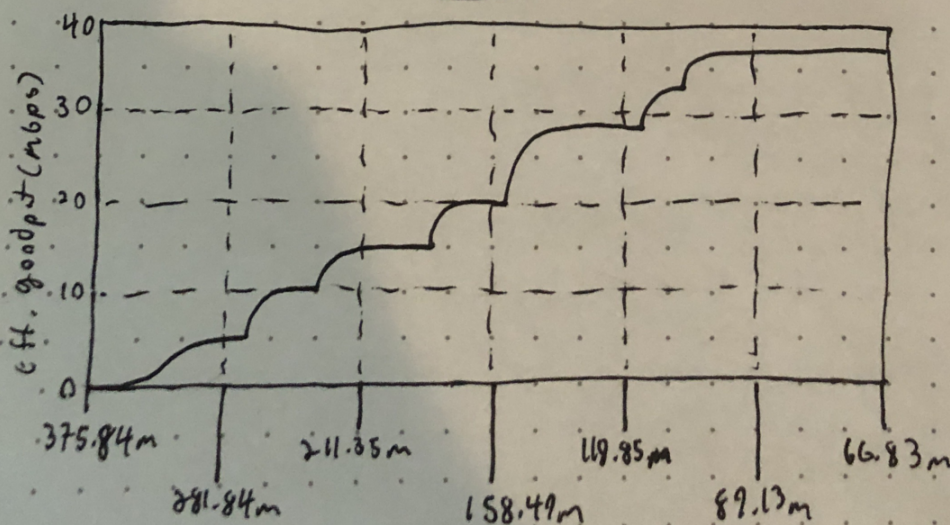
$$P_{dBm} = P_{TdBm} + K_{refdBm} - \eta \cdot 10 \log_{10} \left( \frac{d}{d_0} \right)$$

$$\therefore d = d_0 \cdot 10^{\left[ \frac{P_{TdBm} + K_{refdBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10} \right]}$$

$\therefore$  Effective Goodput (d) for  $\eta = 2$ ,  $P_{TdBm} = 23dBm$ ,  
 $K_{refdBm} = -10dBm$ ,  $N_{dBm} = -90dBm$ .



$\therefore$  Effective Goodput for  $\eta = 4$ :



In this exercise, we converted SNR to distance with a known path loss model.  $P_{TdBm} = 23dBm$ ,  $P_{ref} = -10dBm$ ,  $N_{dBm} = -90dBm$ . We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with  $\eta$  values 2 and 4. Here is a breakdown of the SNR  $\rightarrow$  d(m) conversions for clarity:  $d = d_0 \cdot 10^{(P_{TdBm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta \cdot 10)}$

heta = 2:

$d(\text{SNR} = 0) = 1.41\text{E}5\text{m}$

$d(\text{SNR} = 5) = 7.94\text{E}4\text{m}$

$d(\text{SNR} = 10) = 4.46\text{E}4\text{m}$

$d(\text{SNR} = 15) = 2.51\text{E}4\text{m}$

$d(\text{SNR} = 20) = 1.41\text{E}4\text{m}$

$d(\text{SNR} = 25) = 7.94\text{E}3\text{m}$

$d(\text{SNR} = 30) = 4.46\text{E}3\text{m}$

heta = 4:

$d(\text{SNR} = 0) = 375.84\text{m}$

$d(\text{SNR} = 5) = 281.84\text{m}$

$d(\text{SNR} = 10) = 211.35\text{m}$

$d(\text{SNR} = 15) = 158.49\text{m}$

$d(\text{SNR} = 20) = 118.85\text{m}$

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*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

$p00 = 0.0780$

$p01 = 0.1400$

$p10 = 0.1395$

$p11 = 0.6420$

mobile speed = 5:

$p00 = 0.0775$

$p01 = 0.1490$

$p10 = 0.1490$

$p11 = 0.6240$

mobile speed = 10:

$p00 = 0.0715$

$p01 = 0.1430$

$p10 = 0.1425$

$p11 = 0.6425$

mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

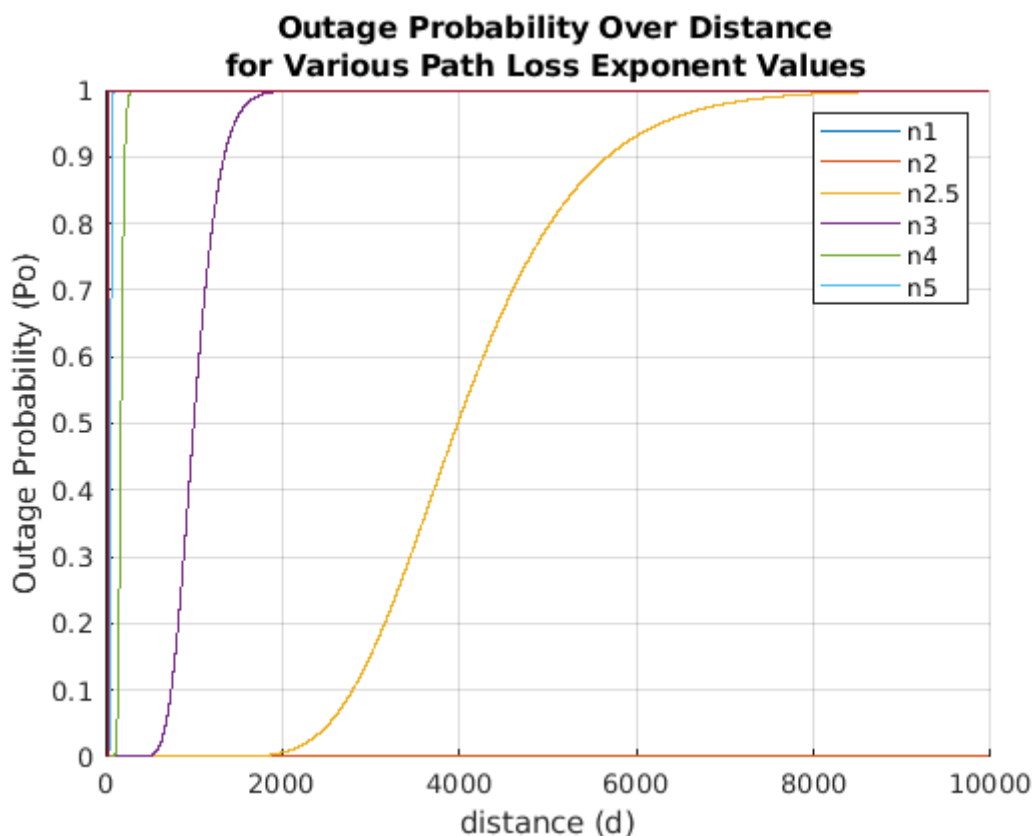
p11 = 0.6215

$P_T$  dBm = 23dBm,  $P_{ref}$  = -10dBm,  $N$  dBm = -90dBm. We took # ee597-assignment2 Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

by

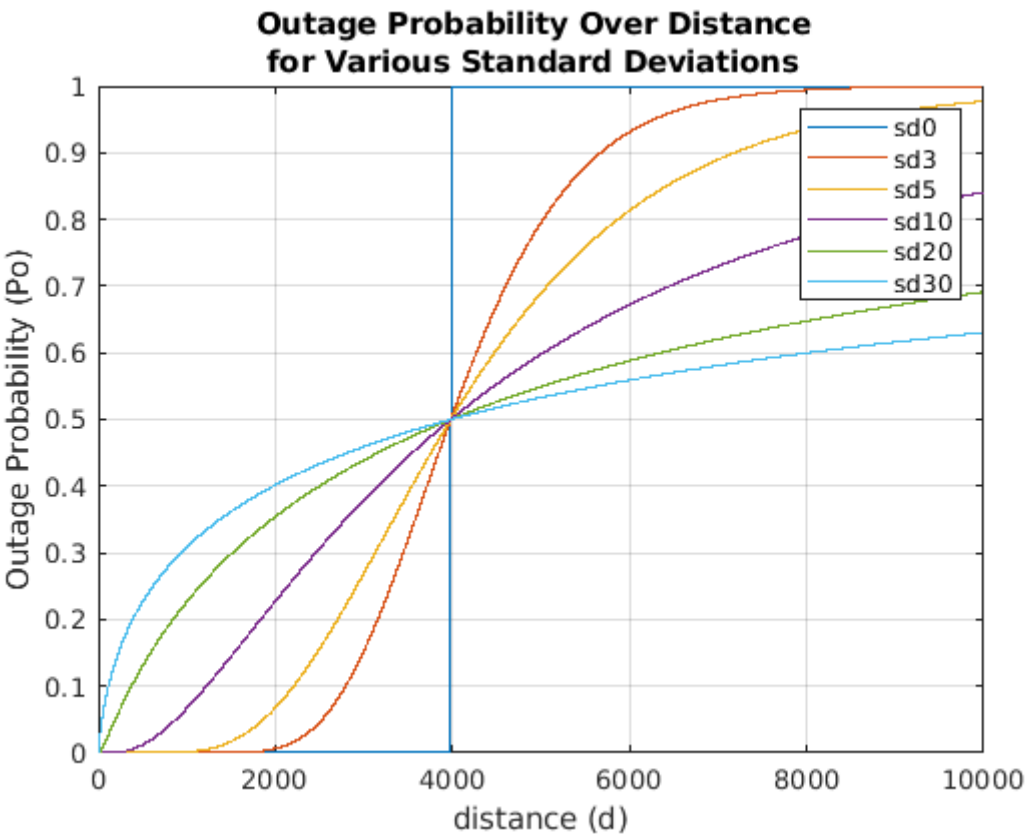
Bill Wang student id: and Spencer McDonough student id:

## Outage Probability as a function of distance for Log-Normal Shadowing



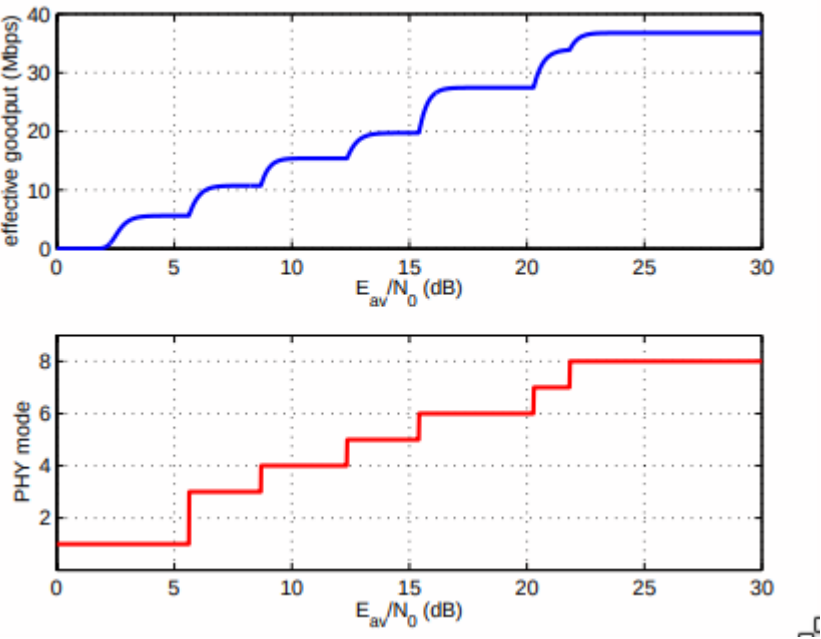
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factor when the PLE is increased. This makes sense, as the PLE represents the attenuation due to the nature of the environment ( $\eta > 2$  : loss,  $\eta = 2$  : vacuum, or no loss,  $\eta < 2$  : gain).



We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponent (PLE) increases. This makes sense, as the probability of outage is inversely proportional to the log of the PLE's standard deviation.

Rate Adaptation





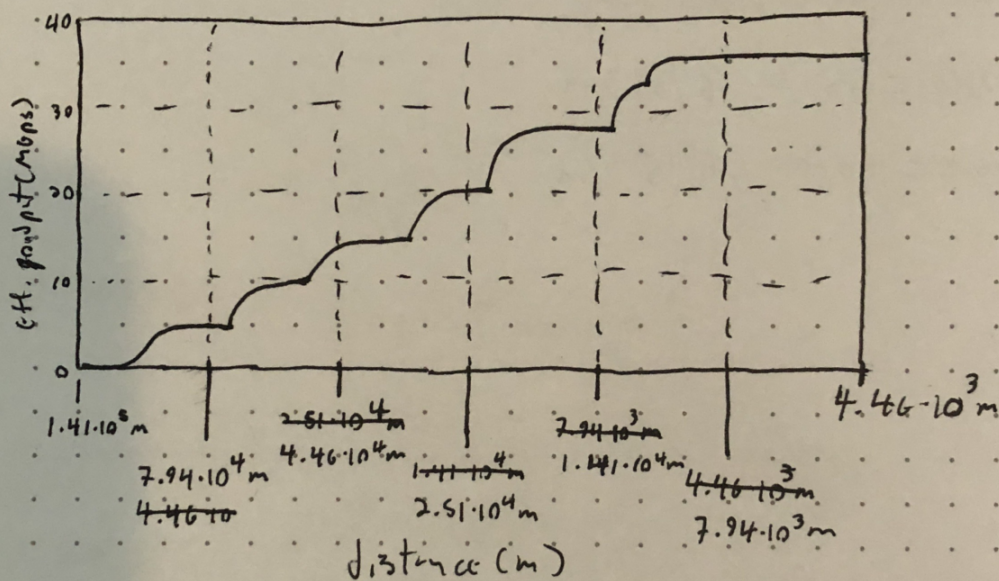
## Effective Goodput as a Function of Distance

$$SNR_{dBm} = P_{TdBm} - N_{dBm}$$

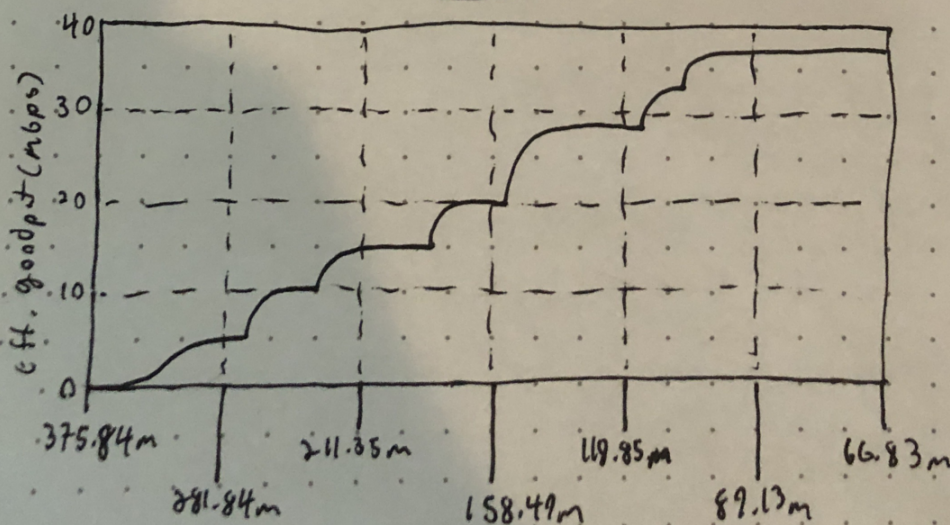
$$P_{dBm} = P_{TdBm} + K_{refdBm} - \eta \cdot 10 \log_{10} \left( \frac{d}{d_0} \right)$$

$$\therefore d = d_0 \cdot 10^{\left[ \frac{P_{TdBm} + K_{refdBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10} \right]}$$

$\therefore$  Effective Goodput (d) for  $\eta = 2$ ,  $P_{TdBm} = 23dBm$ ,  
 $K_{refdBm} = -10dBm$ ,  $N_{dBm} = -90dBm$ .



$\therefore$  Effective Goodput for  $\eta = 4$ :



In this exercise, we converted SNR to distance with a known path loss model.  $P_{TdBm} = 23dBm$ ,  $P_{ref} = -10dBm$ ,  $N_{dBm} = -90dBm$ . We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with  $\eta$  values 2 and 4. Here is a breakdown of the SNR  $\rightarrow$  d(m) conversions for clarity:  $d = d_0 \cdot 10^{(P_{TdBm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta \cdot 10)}$



heta = 2:

d(SNR = 0) = 1.41E5m

d(SNR = 5) = 7.94E4m

d(SNR = 10) = 4.46E4m

d(SNR = 15) = 2.51E4m

d(SNR = 20) = 1.41E4m

d(SNR = 25) = 7.94E3m

d(SNR = 30) = 4.46E3m

heta = 4:

d(SNR = 0) = 375.84m

d(SNR = 5) = 281.84m

d(SNR = 10) = 211.35m

d(SNR = 15) = 158.49m

d(SNR = 20) = 118.85m

d(SNR = 25) = 89.13m

d(SNR = 30) = 66.83m

## Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

*p00 - the probability that we remain in the "outage" state*

*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

p00 = 0.0780

p01 = 0.1400

p10 = 0.1395

p11 = 0.6420

mobile speed = 5:

p00 = 0.0775

p01 = 0.1490

p10 = 0.1490

p11 = 0.6240

mobile speed = 10:

p00 = 0.0715

p01 = 0.1430

p10 = 0.1425

p11 = 0.6425

mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

p11 = 0.6215

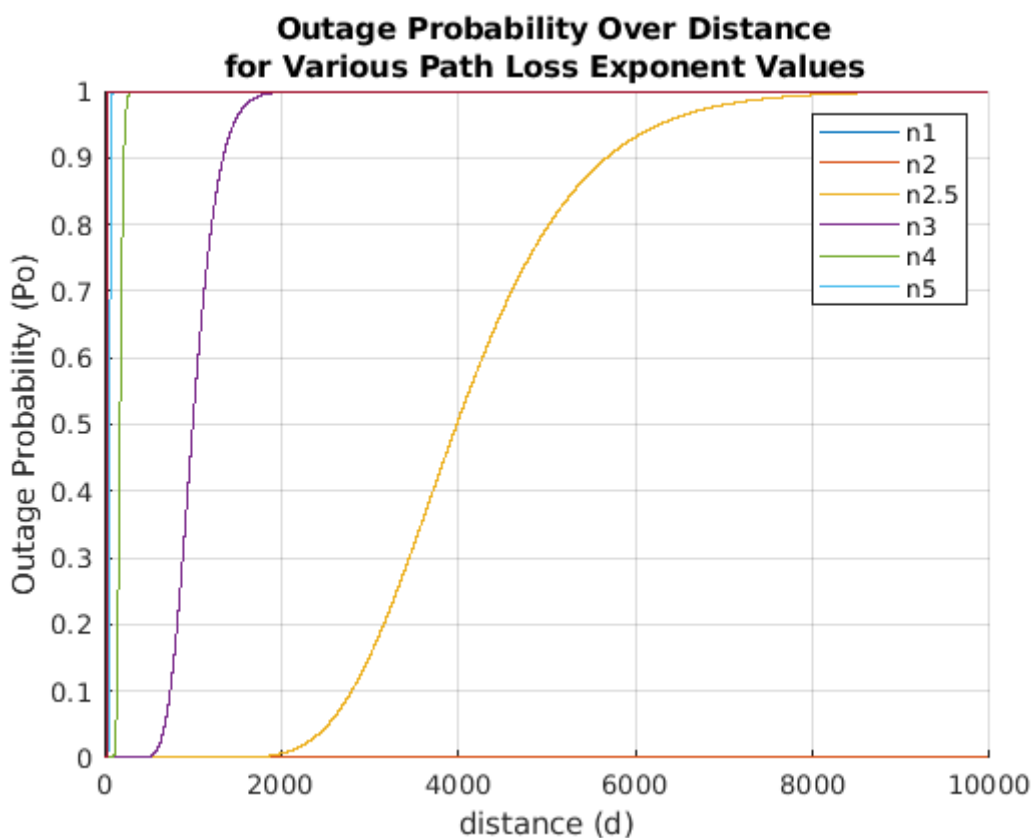
figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance # ee597-assignment2

Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

by

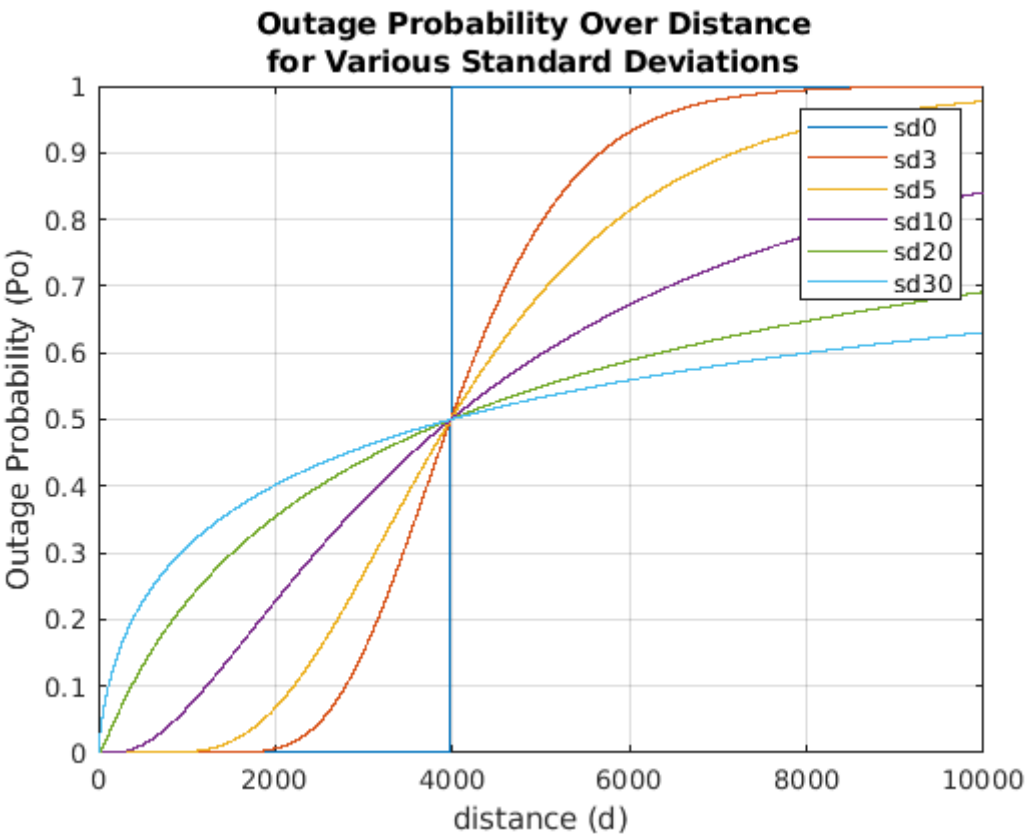
Bill Wang student id: and Spencer McDonough student id:

## Outage Probability as a function of distance for Log-Normal Shadowing



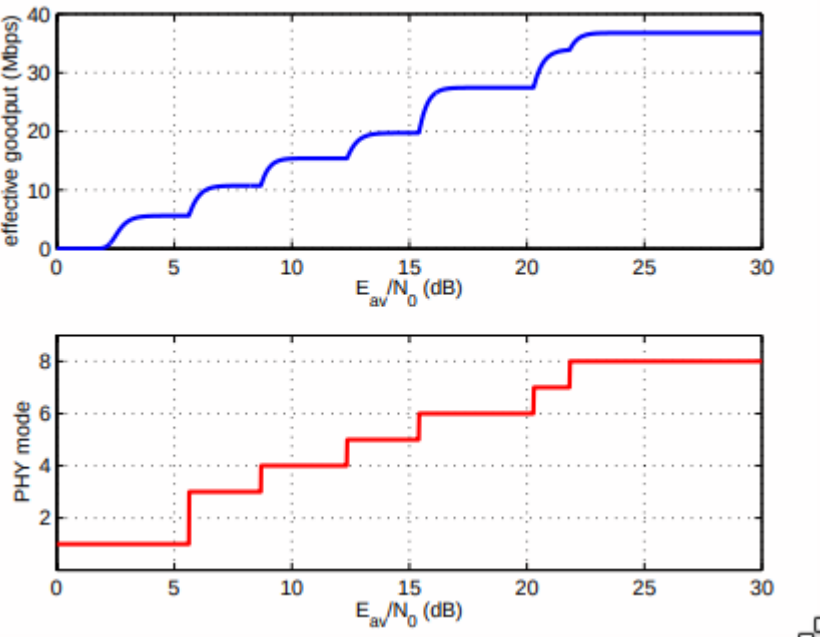
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Rate Adaptation



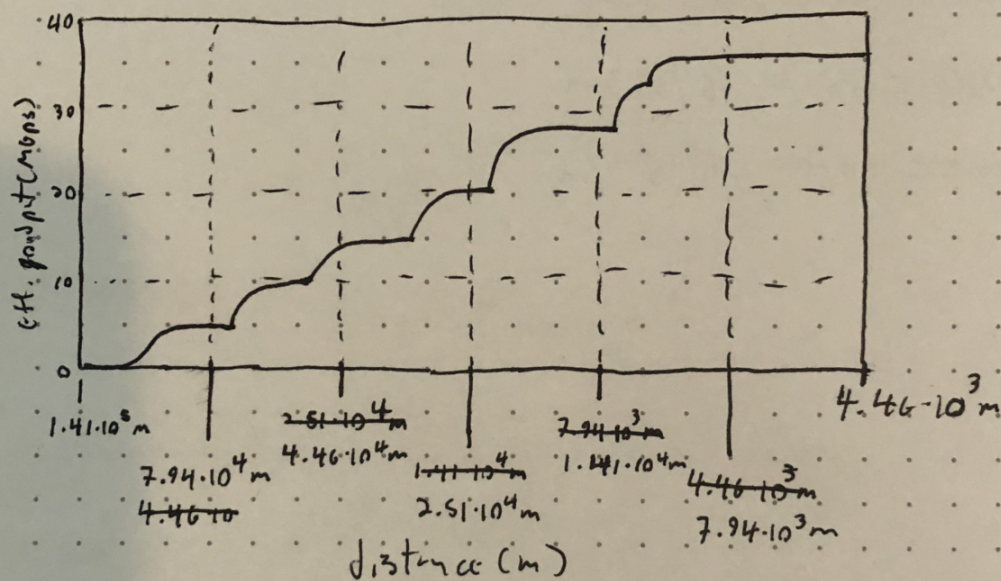
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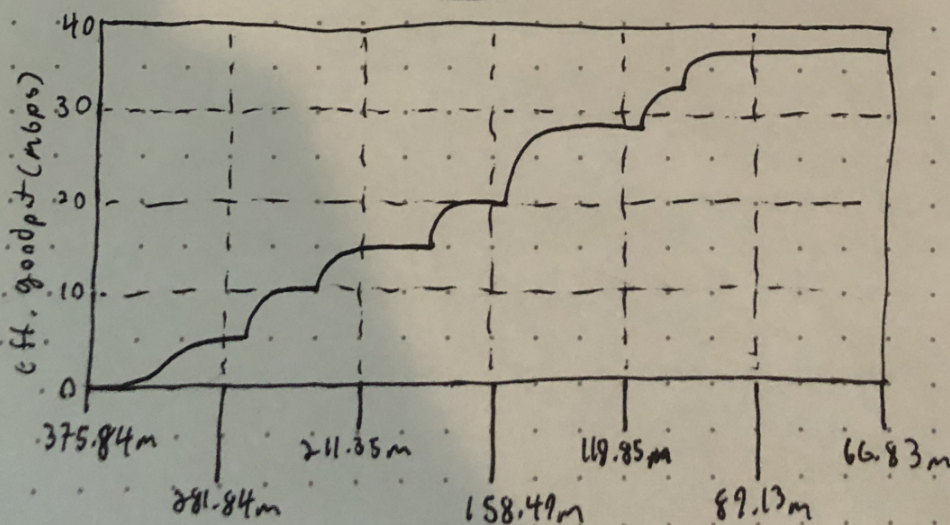
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$$\therefore d = d_0 \cdot 10^{\left[ \frac{P_{TdBm} + K_{refdBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10} \right]}$$

$\therefore$  Effective Goodput (d) for  $\eta = 2$ ,  $P_{TdBm} = 23dBm$ ,  
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In this exercise, we converted SNR to distance with a known path loss model.  $P_{TdBm} = 23dBm$ ,  $P_{ref} = -10dBm$ ,  $N_{dBm} = -90dBm$ . We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with  $\eta$  values 2 and 4. Here is a breakdown of the SNR  $\rightarrow$  d(m) conversions for clarity:  $d = d_0 \cdot 10^{(P_{TdBm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta \cdot 10)}$

heta = 2:

$d(\text{SNR} = 0) = 1.41\text{E}5\text{m}$

$d(\text{SNR} = 5) = 7.94\text{E}4\text{m}$

$d(\text{SNR} = 10) = 4.46\text{E}4\text{m}$

$d(\text{SNR} = 15) = 2.51\text{E}4\text{m}$

$d(\text{SNR} = 20) = 1.41\text{E}4\text{m}$

$d(\text{SNR} = 25) = 7.94\text{E}3\text{m}$

$d(\text{SNR} = 30) = 4.46\text{E}3\text{m}$

heta = 4:

$d(\text{SNR} = 0) = 375.84\text{m}$

$d(\text{SNR} = 5) = 281.84\text{m}$

$d(\text{SNR} = 10) = 211.35\text{m}$

$d(\text{SNR} = 15) = 158.49\text{m}$

$d(\text{SNR} = 20) = 118.85\text{m}$

$d(\text{SNR} = 25) = 89.13\text{m}$

$d(\text{SNR} = 30) = 66.83\text{m}$

## Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

*p00 - the probability that we remain in the "outage" state*

*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

$p00 = 0.0780$

$p01 = 0.1400$

$p10 = 0.1395$

$p11 = 0.6420$

mobile speed = 5:

$p00 = 0.0775$

$p01 = 0.1490$

$p10 = 0.1490$

$p11 = 0.6240$

mobile speed = 10:

$p00 = 0.0715$

$p01 = 0.1430$

$p10 = 0.1425$

$p11 = 0.6425$



mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

p11 = 0.6215

(m) with heta values 2 and 4.

## ee597-assignment2

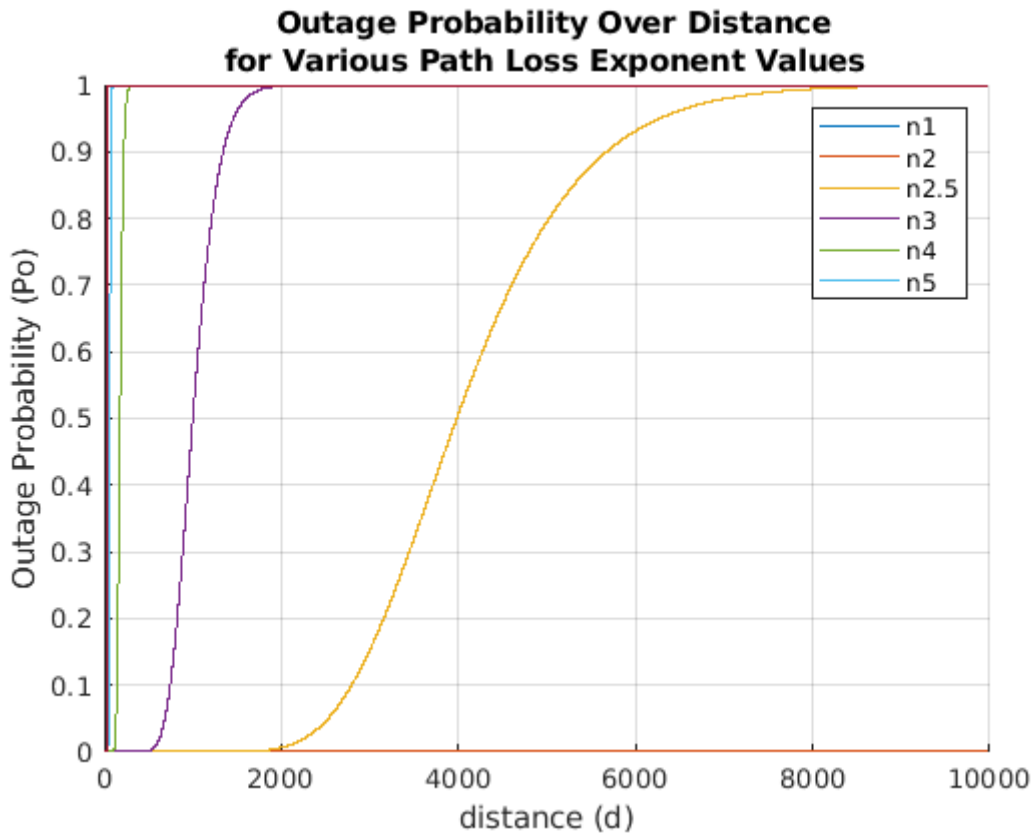
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Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

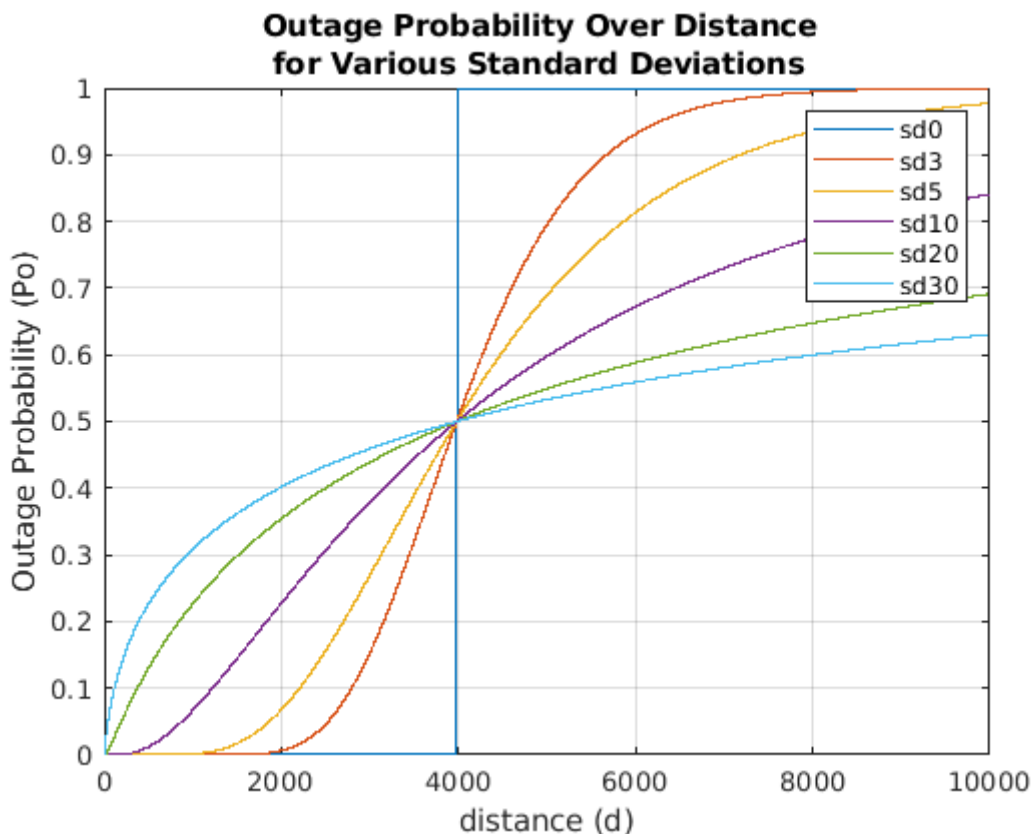
by

Bill Wang student id: and Spencer McDonough student id:

### Outage Probability as a function of distance for Log-Normal Shadowing



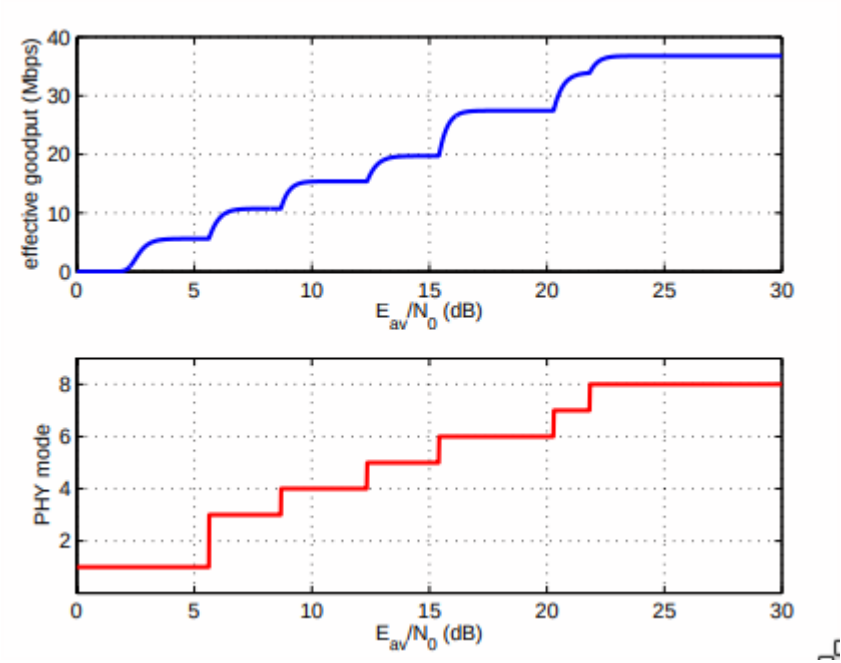
We can see that the probability of outage sigmoid function gets skewed left as we increase the value of the path loss exponent (PLE). This means that the probability of outage increases exponentially by a greater factor when the PLE is increased. This makes sense, as the PLE represents the attenuation due to the nature of the environment ( $\eta > 2$  : loss,  $\eta = 2$  : vacuum, or no loss,  $\eta < 2$  : gain).



We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponent (PLE) increases. This makes sense, as the probability of outage is inversely

proportional to the log of the PLE's standard deviation.

# Rate Adaptation



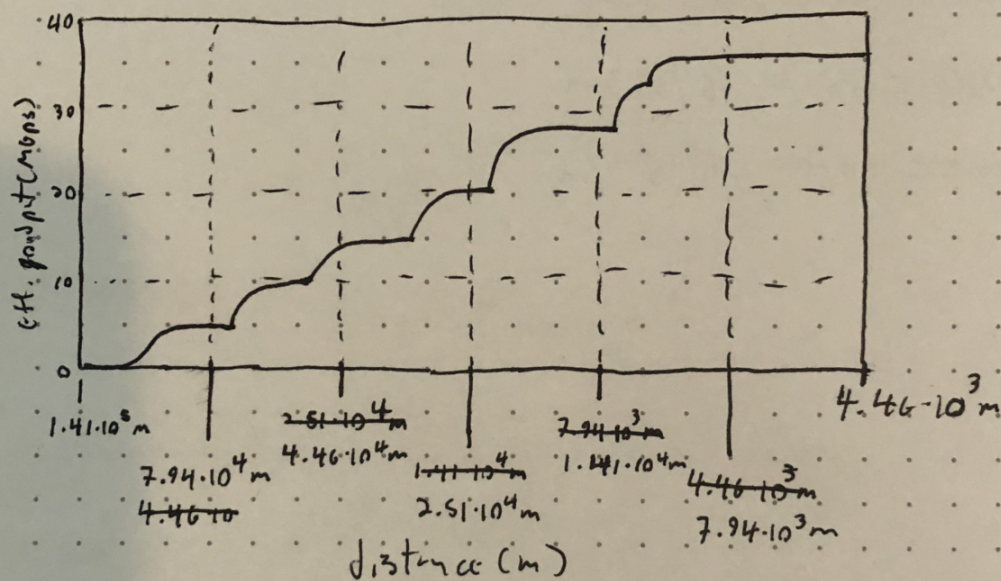
## Effective Goodput as a Function of Distance

$$SNR_{dBm} = P_{TdBm} - N_{dBm}$$

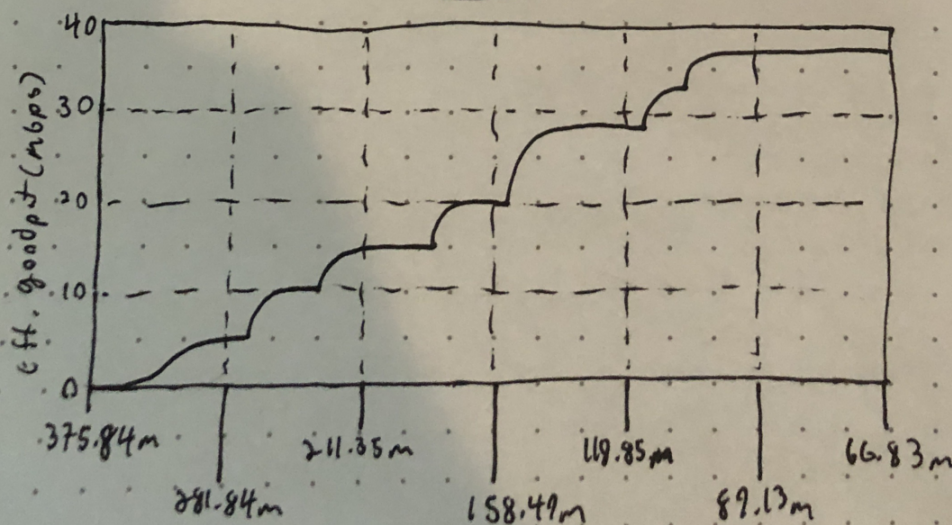
$$P_{dBm} = P_{TdBm} + K_{refdBm} - \eta \cdot 10 \log_{10} \left( \frac{d}{d_0} \right)$$

$$\therefore d = d_0 \cdot 10^{\left[ \frac{P_{TdBm} + K_{refdBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10} \right]}$$

$\therefore$  Effective Goodput (d) for  $\eta = 2$ ,  $P_{TdBm} = 23dBm$ ,  
 $K_{refdBm} = -10dBm$ ,  $N_{dBm} = -90dBm$ .



$\therefore$  Effective Goodput for  $\eta = 4$ :



In this exercise, we converted SNR to distance with a known path loss model.  $P_{TdBm} = 23dBm$ ,  $P_{ref} = -10dBm$ ,  $N_{dBm} = -90dBm$ . We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with  $\eta$  values 2 and 4. Here is a breakdown of the SNR  $\rightarrow$  d(m) conversions for clarity:  $d = d_0 \cdot 10^{(P_{TdBm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta \cdot 10)}$

heta = 2:

$d(\text{SNR} = 0) = 1.41\text{E}5\text{m}$

$d(\text{SNR} = 5) = 7.94\text{E}4\text{m}$

$d(\text{SNR} = 10) = 4.46\text{E}4\text{m}$

$d(\text{SNR} = 15) = 2.51\text{E}4\text{m}$

$d(\text{SNR} = 20) = 1.41\text{E}4\text{m}$

$d(\text{SNR} = 25) = 7.94\text{E}3\text{m}$

$d(\text{SNR} = 30) = 4.46\text{E}3\text{m}$

heta = 4:

$d(\text{SNR} = 0) = 375.84\text{m}$

$d(\text{SNR} = 5) = 281.84\text{m}$

$d(\text{SNR} = 10) = 211.35\text{m}$

$d(\text{SNR} = 15) = 158.49\text{m}$

$d(\text{SNR} = 20) = 118.85\text{m}$

$d(\text{SNR} = 25) = 89.13\text{m}$

$d(\text{SNR} = 30) = 66.83\text{m}$

## Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

*p00 - the probability that we remain in the "outage" state*

*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

$p00 = 0.0780$

$p01 = 0.1400$

$p10 = 0.1395$

$p11 = 0.6420$

mobile speed = 5:

$p00 = 0.0775$

$p01 = 0.1490$

$p10 = 0.1490$

$p11 = 0.6240$

mobile speed = 10:

$p00 = 0.0715$

$p01 = 0.1430$

$p10 = 0.1425$

$p11 = 0.6425$



mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

p11 = 0.6215

Here is a breakdown of the SNR --> d(m) conversions for clarity:

## ee597-assignment2

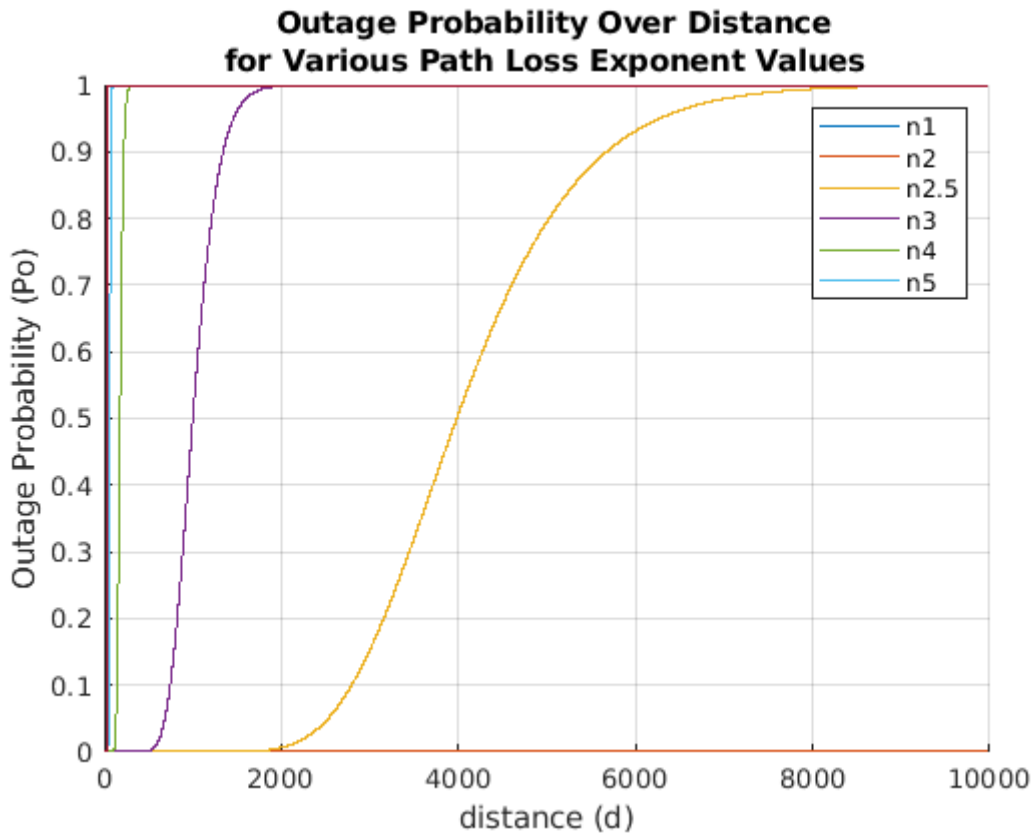
---

Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

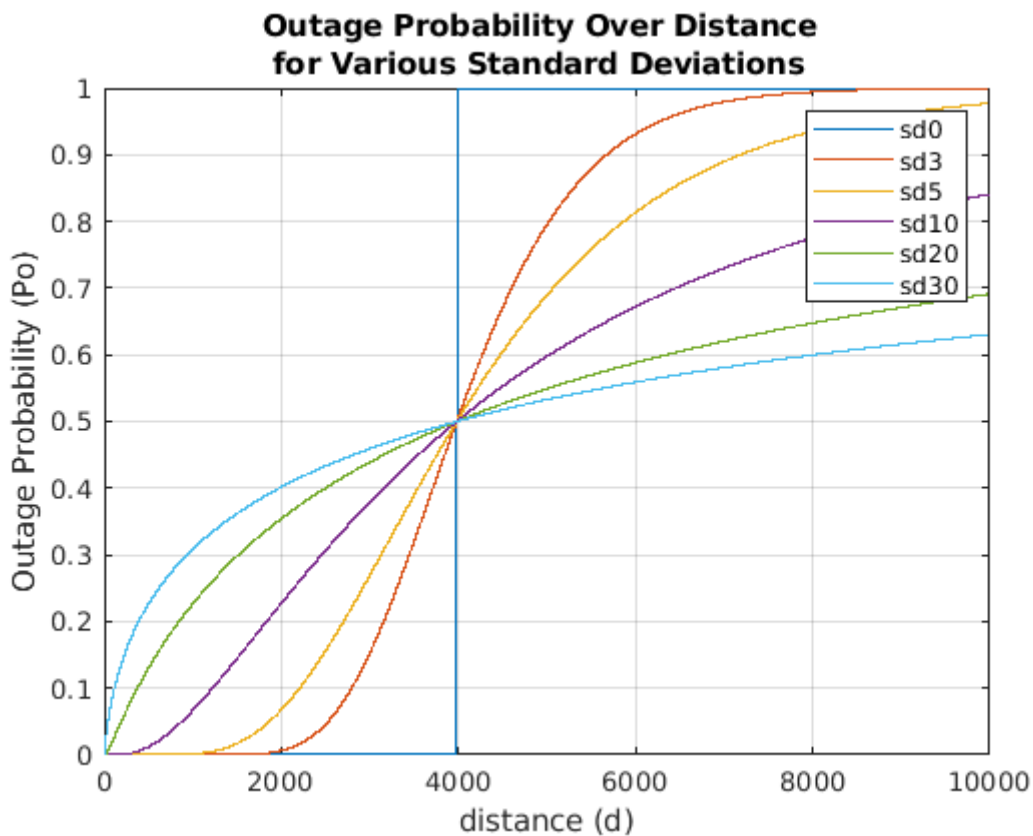
by

Bill Wang student id: and Spencer McDonough student id:

## Outage Probability as a function of distance for Log-Normal Shadowing



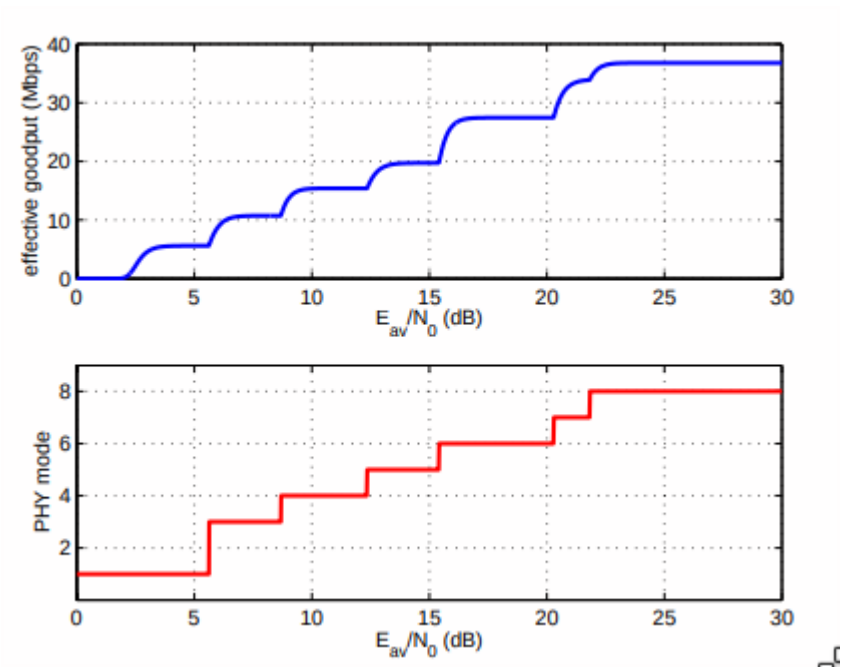
We can see that the probability of outage sigmoid function gets skewed left as we increase the value of the path loss exponent (PLE). This means that the probability of outage increases exponentially by a greater factor when the PLE is increased. This makes sense, as the PLE represents the attenuation due to the nature of the environment ( $\eta > 2$  : loss,  $\eta = 2$  : vacuum, or no loss,  $\eta < 2$  : gain).



We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponent (PLE) increases. This makes sense, as the probability of outage is inversely

proportional to the log of the PLE's standard deviation.

# Rate Adaptation



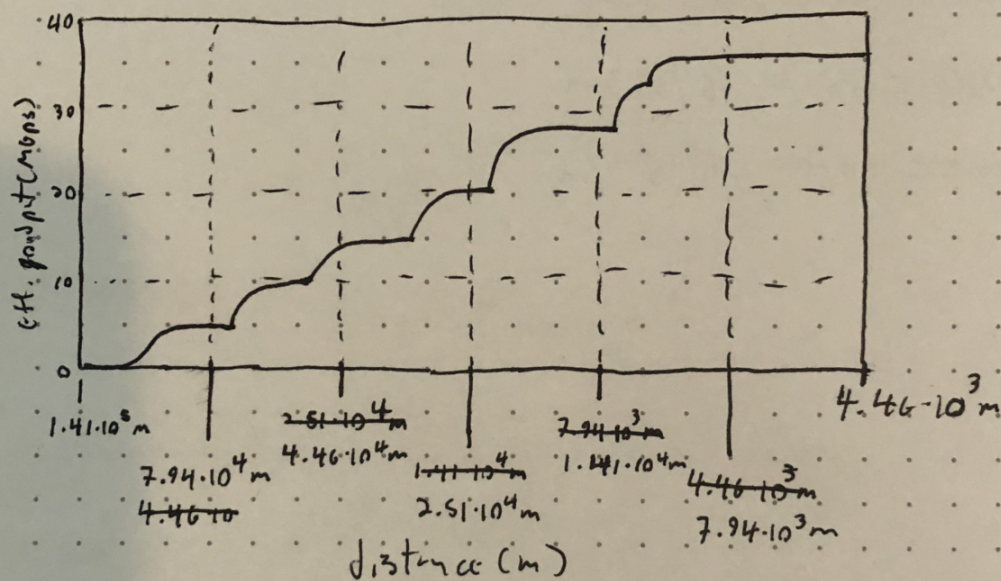
## Effective Goodput as a Function of Distance

$$SNR_{dBm} = P_{TdBm} - N_{dBm}$$

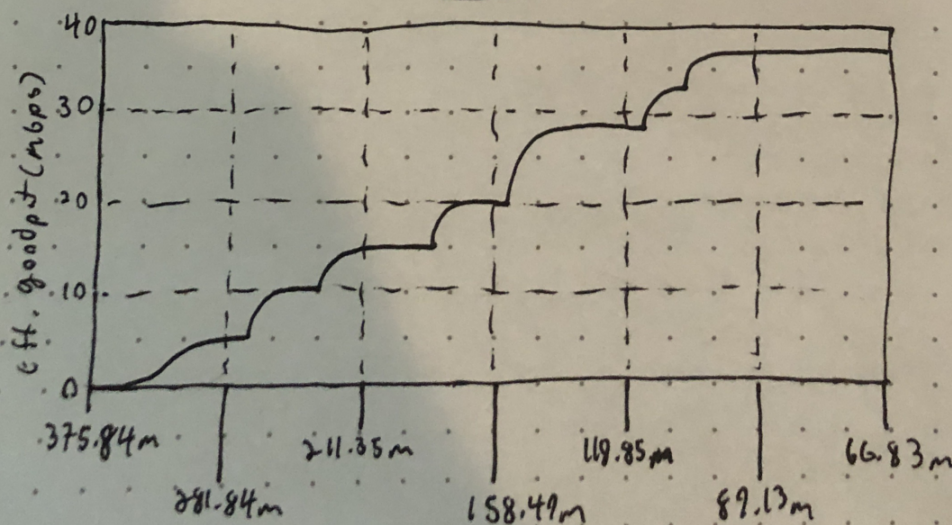
$$P_{dBm} = P_{TdBm} + K_{refdBm} - \eta \cdot 10 \log_{10} \left( \frac{d}{d_0} \right)$$

$$\therefore d = d_0 \cdot 10^{\left[ \frac{P_{TdBm} + K_{refdBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10} \right]}$$

$\therefore$  Effective Goodput (d) for  $\eta = 2$ ,  $P_{TdBm} = 23dBm$ ,  
 $K_{refdBm} = -10dBm$ ,  $N_{dBm} = -90dBm$ .



$\therefore$  Effective Goodput for  $\eta = 4$ :



In this exercise, we converted SNR to distance with a known path loss model.  $P_{TdBm} = 23dBm$ ,  $P_{ref} = -10dBm$ ,  $N_{dBm} = -90dBm$ . We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with  $\eta$  values 2 and 4. Here is a breakdown of the SNR  $\rightarrow$  d(m) conversions for clarity:  $d = d_0 \cdot 10^{(P_{TdBm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta \cdot 10)}$

heta = 2:

$d(\text{SNR} = 0) = 1.41\text{E}5\text{m}$

$d(\text{SNR} = 5) = 7.94\text{E}4\text{m}$

$d(\text{SNR} = 10) = 4.46\text{E}4\text{m}$

$d(\text{SNR} = 15) = 2.51\text{E}4\text{m}$

$d(\text{SNR} = 20) = 1.41\text{E}4\text{m}$

$d(\text{SNR} = 25) = 7.94\text{E}3\text{m}$

$d(\text{SNR} = 30) = 4.46\text{E}3\text{m}$

heta = 4:

$d(\text{SNR} = 0) = 375.84\text{m}$

$d(\text{SNR} = 5) = 281.84\text{m}$

$d(\text{SNR} = 10) = 211.35\text{m}$

$d(\text{SNR} = 15) = 158.49\text{m}$

$d(\text{SNR} = 20) = 118.85\text{m}$

$d(\text{SNR} = 25) = 89.13\text{m}$

$d(\text{SNR} = 30) = 66.83\text{m}$

## Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

*p00 - the probability that we remain in the "outage" state*

*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

$p00 = 0.0780$

$p01 = 0.1400$

$p10 = 0.1395$

$p11 = 0.6420$

mobile speed = 5:

$p00 = 0.0775$

$p01 = 0.1490$

$p10 = 0.1490$

$p11 = 0.6240$

mobile speed = 10:

$p00 = 0.0715$

$p01 = 0.1430$

$p10 = 0.1425$

$p11 = 0.6425$



mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

p11 = 0.6215

$d = d_0 * 10^{(P_{Tdbm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta * 10)}$

## ee597-assignment2

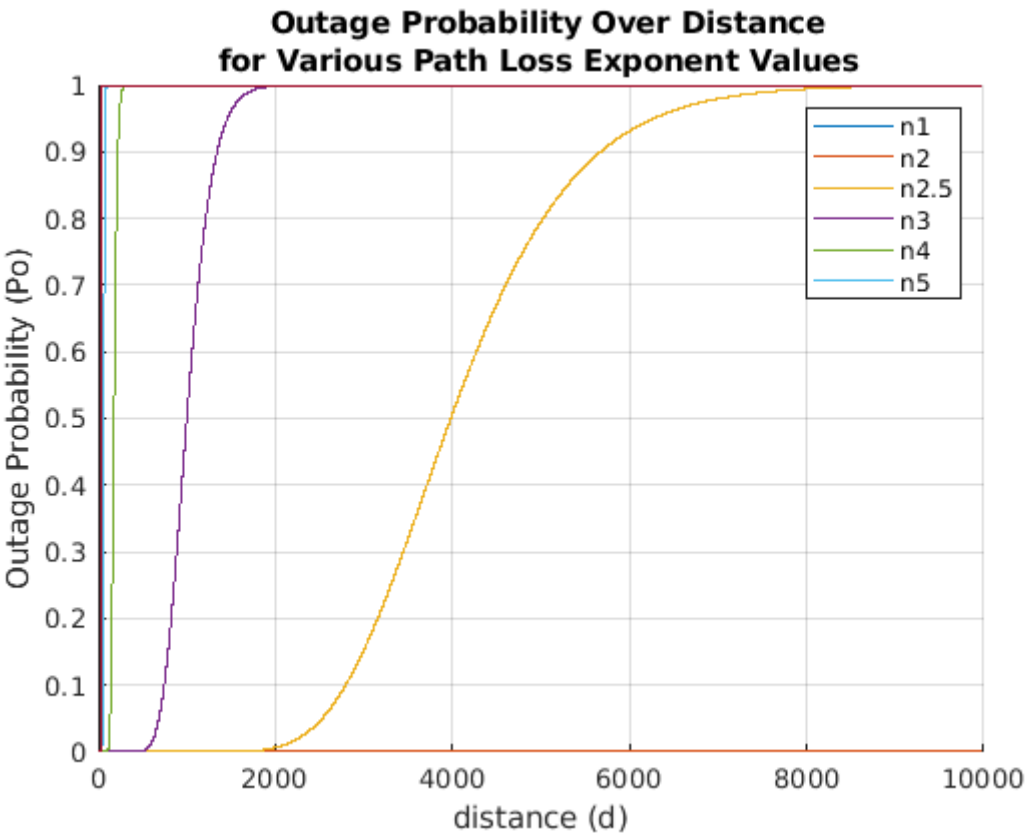
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Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

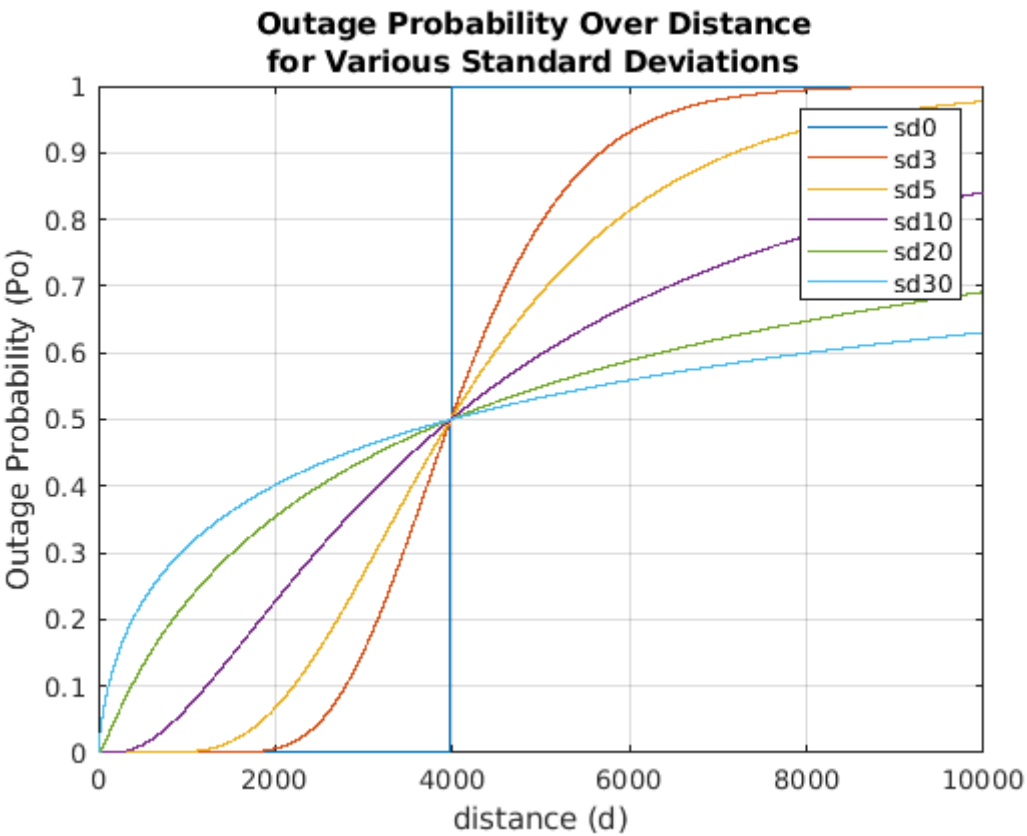
by

Bill Wang student id: and Spencer McDonough student id:

### Outage Probability as a function of distance for Log-Normal Shadowing



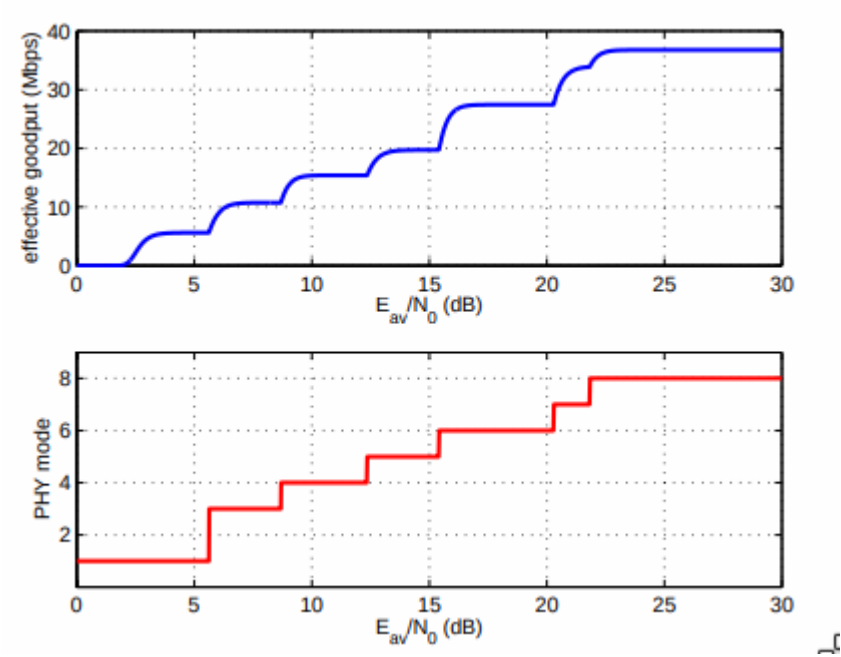
We can see that the probability of outage sigmoid function gets skewed left as we increase the value of the path loss exponent (PLE). This means that the probability of outage increases exponentially by a greater factor when the PLE is increased. This makes sense, as the PLE represents the attenuation due to the nature of the environment ( $\eta > 2$  : loss,  $\eta = 2$  : vacuum, or no loss,  $\eta < 2$  : gain).



We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponent (PLE) increases. This makes sense, as the probability of outage is inversely

proportional to the log of the PLE's standard deviation.

# Rate Adaptation



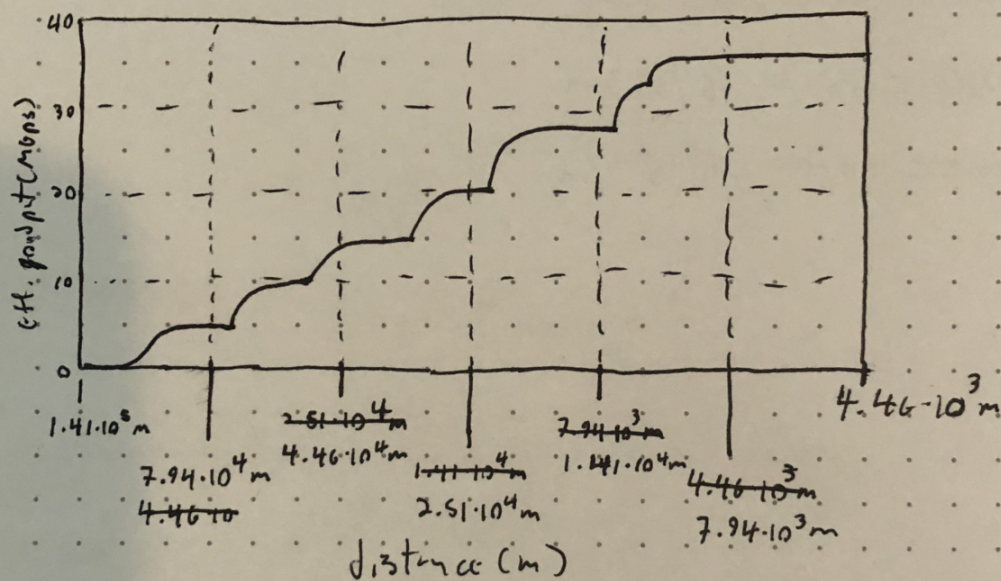
## Effective Goodput as a Function of Distance

$$SNR_{dBm} = P_{TdBm} - N_{dBm}$$

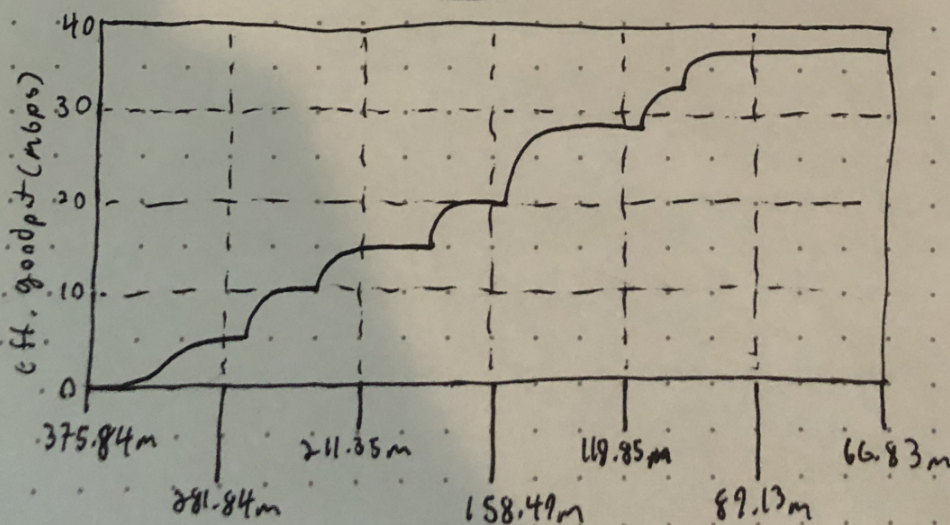
$$P_{dBm} = P_{TdBm} + K_{refdBm} - \eta \cdot 10 \log_{10} \left( \frac{d}{d_0} \right)$$

$$\therefore d = d_0 \cdot 10^{\left[ \frac{P_{TdBm} + K_{refdBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10} \right]}$$

$\therefore$  Effective Goodput (d) for  $\eta = 2$ ,  $P_{TdBm} = 23dBm$ ,  
 $K_{refdBm} = -10dBm$ ,  $N_{dBm} = -90dBm$ .



$\therefore$  Effective Goodput for  $\eta = 4$ :



In this exercise, we converted SNR to distance with a known path loss model.  $P_{TdBm} = 23dBm$ ,  $P_{ref} = -10dBm$ ,  $N_{dBm} = -90dBm$ . We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with  $\eta$  values 2 and 4. Here is a breakdown of the SNR  $\rightarrow$  d(m) conversions for clarity:  $d = d_0 \cdot 10^{(P_{TdBm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta \cdot 10)}$

heta = 2:

$d(\text{SNR} = 0) = 1.41\text{E}5\text{m}$

$d(\text{SNR} = 5) = 7.94\text{E}4\text{m}$

$d(\text{SNR} = 10) = 4.46\text{E}4\text{m}$

$d(\text{SNR} = 15) = 2.51\text{E}4\text{m}$

$d(\text{SNR} = 20) = 1.41\text{E}4\text{m}$

$d(\text{SNR} = 25) = 7.94\text{E}3\text{m}$

$d(\text{SNR} = 30) = 4.46\text{E}3\text{m}$

heta = 4:

$d(\text{SNR} = 0) = 375.84\text{m}$

$d(\text{SNR} = 5) = 281.84\text{m}$

$d(\text{SNR} = 10) = 211.35\text{m}$

$d(\text{SNR} = 15) = 158.49\text{m}$

$d(\text{SNR} = 20) = 118.85\text{m}$

$d(\text{SNR} = 25) = 89.13\text{m}$

$d(\text{SNR} = 30) = 66.83\text{m}$

## Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

*p00 - the probability that we remain in the "outage" state*

*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

$p00 = 0.0780$

$p01 = 0.1400$

$p10 = 0.1395$

$p11 = 0.6420$

mobile speed = 5:

$p00 = 0.0775$

$p01 = 0.1490$

$p10 = 0.1490$

$p11 = 0.6240$

mobile speed = 10:

$p00 = 0.0715$

$p01 = 0.1430$

$p10 = 0.1425$

$p11 = 0.6425$



mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

p11 = 0.6215

## ee597-assignment2

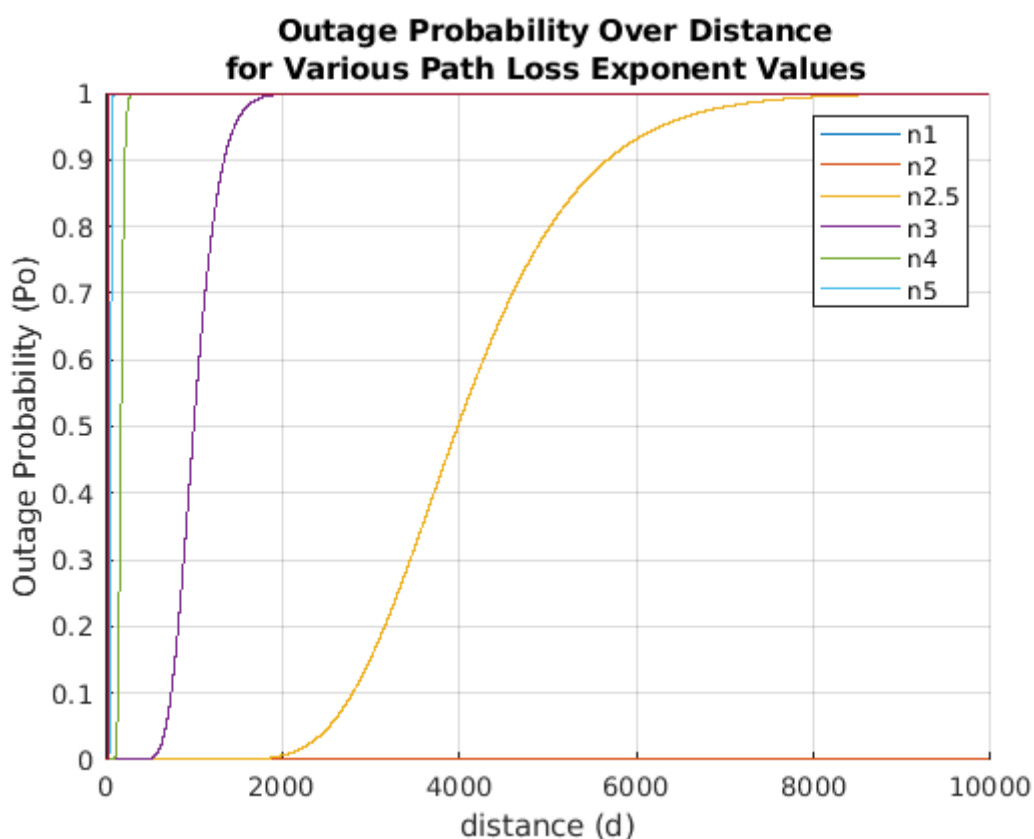
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Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

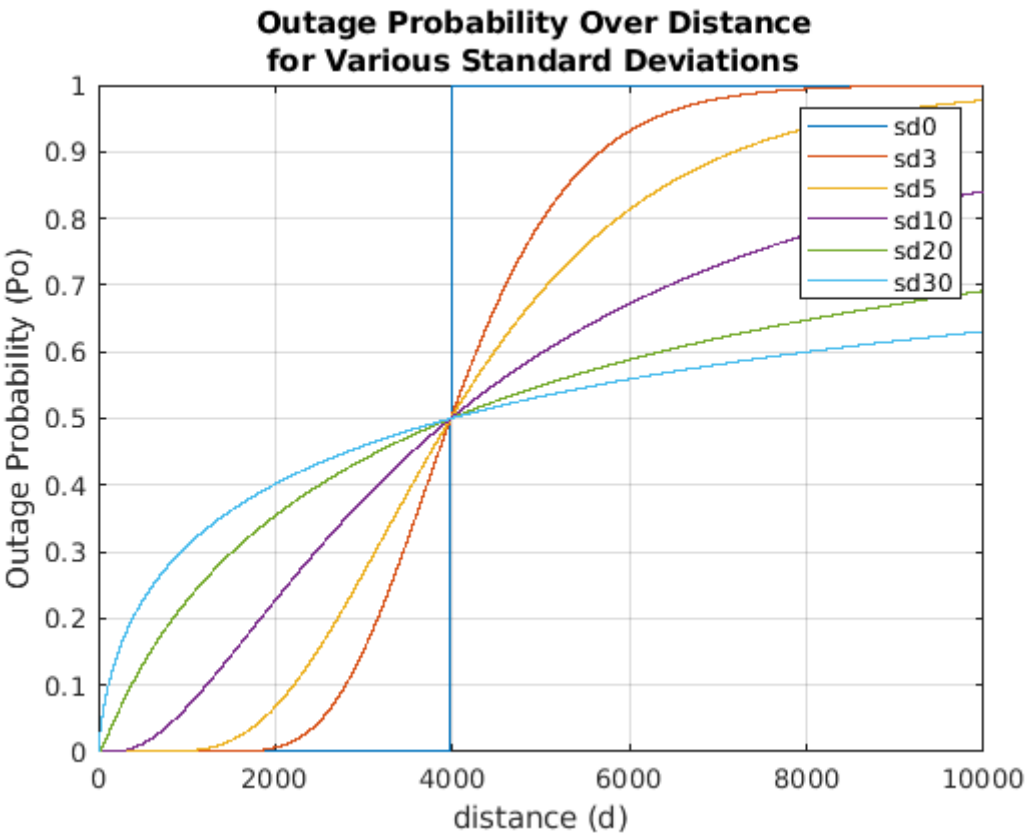
by

Bill Wang student id: and Spencer McDonough student id:

### Outage Probability as a function of distance for Log-Normal Shadowing

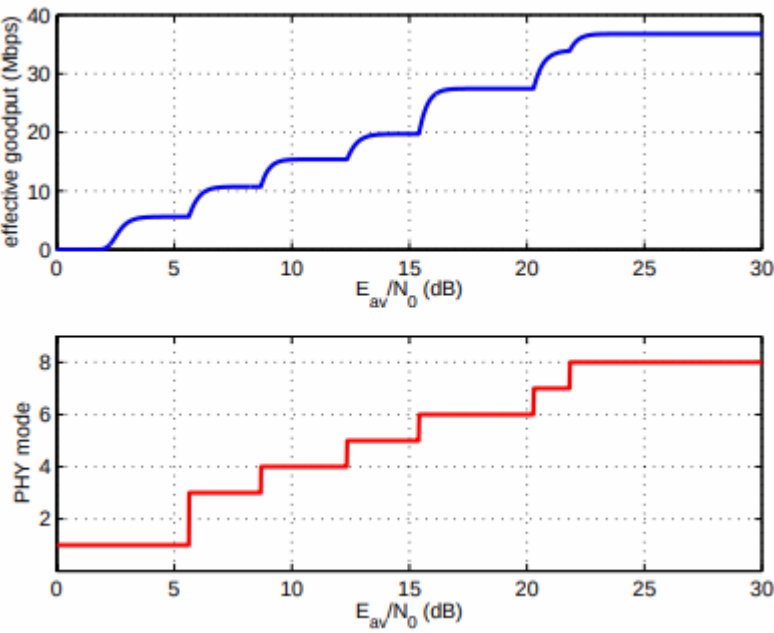


We can see that the probability of outage sigmoid function gets skewed left as we increase the value of the path loss exponent (PLE). This means that the probability of outage increases exponentially by a greater factor when the PLE is increased. This makes sense, as the PLE represents the attenuation due to the nature of the environment ( $\eta > 2$  : loss,  $\eta = 2$  : vacuum, or no loss,  $\eta < 2$  : gain).



We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponent (PLE) increases. This makes sense, as the probability of outage is inversely proportional to the log of the PLE's standard deviation.

Rate Adaptation



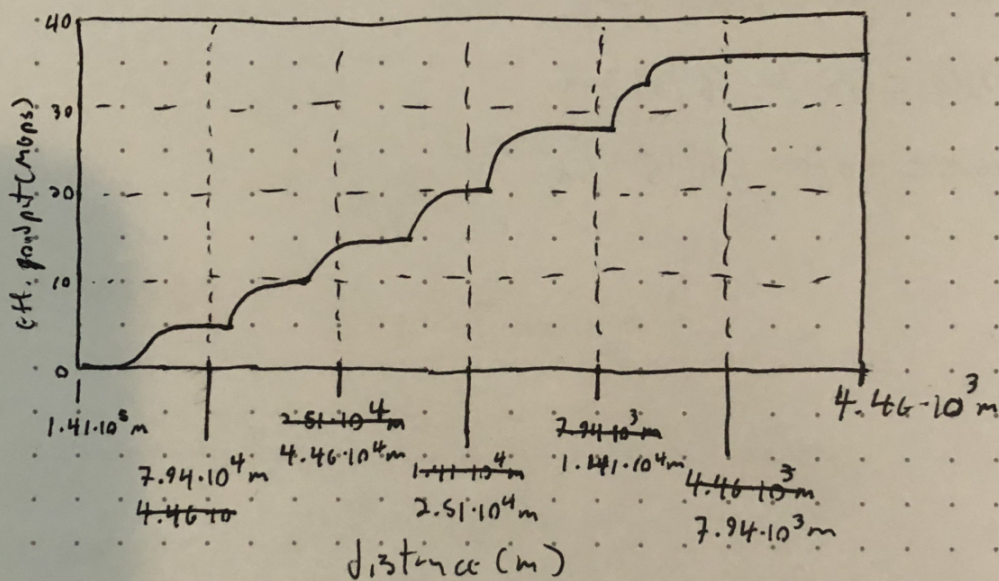
## Effective Goodput as a Function of Distance

$$SNR_{dBm} = P_{TdBm} - N_{dBm}$$

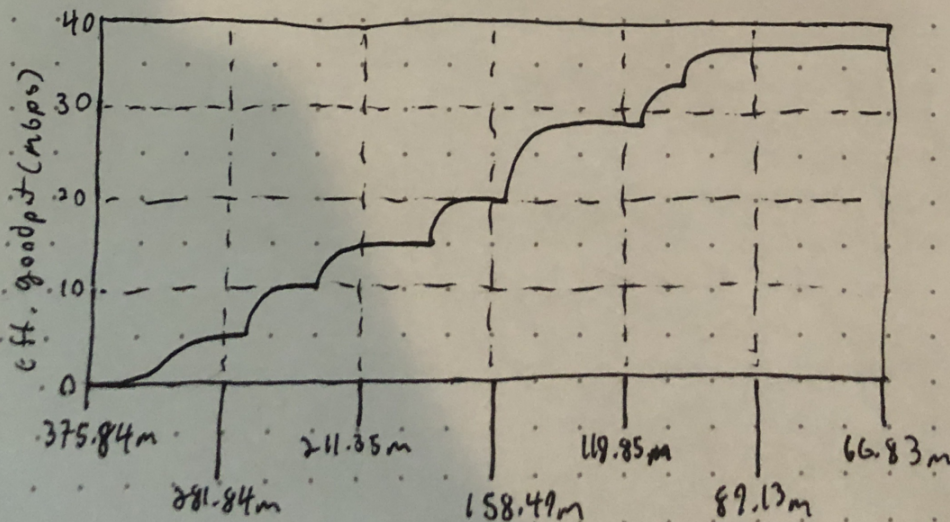
$$P_{dBm} = P_{TdBm} + K_{refdBm} - \eta \cdot 10 \log_{10} \left( \frac{d}{d_0} \right)$$

$$\therefore d = d_0 \cdot 10^{\left[ \frac{P_{TdBm} + K_{refdBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10} \right]}$$

$\therefore$  Effective Goodput (d) for  $\eta = 2$ ,  $P_{TdBm} = 23dBm$ ,  
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$\therefore$  Effective Goodput for  $\eta = 4$ :



In this exercise, we converted SNR to distance with a known path loss model.  $P_{TdBm} = 23dBm$ ,  $P_{ref} = -10dBm$ ,  $N_{dBm} = -90dBm$ . We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with  $\eta$  values 2 and 4. Here is a breakdown of the SNR  $\rightarrow$  d(m) conversions for clarity:  $d = d_0 \cdot 10^{(P_{TdBm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta \cdot 10)}$

heta = 2:

$d(\text{SNR} = 0) = 1.41\text{E}5\text{m}$

$d(\text{SNR} = 5) = 7.94\text{E}4\text{m}$

$d(\text{SNR} = 10) = 4.46\text{E}4\text{m}$

$d(\text{SNR} = 15) = 2.51\text{E}4\text{m}$

$d(\text{SNR} = 20) = 1.41\text{E}4\text{m}$

$d(\text{SNR} = 25) = 7.94\text{E}3\text{m}$

$d(\text{SNR} = 30) = 4.46\text{E}3\text{m}$

heta = 4:

$d(\text{SNR} = 0) = 375.84\text{m}$

$d(\text{SNR} = 5) = 281.84\text{m}$

$d(\text{SNR} = 10) = 211.35\text{m}$

$d(\text{SNR} = 15) = 158.49\text{m}$

$d(\text{SNR} = 20) = 118.85\text{m}$

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In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

*p00 - the probability that we remain in the "outage" state*

*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

$p00 = 0.0780$

$p01 = 0.1400$

$p10 = 0.1395$

$p11 = 0.6420$

mobile speed = 5:

$p00 = 0.0775$

$p01 = 0.1490$

$p10 = 0.1490$

$p11 = 0.6240$

mobile speed = 10:

$p00 = 0.0715$

$p01 = 0.1430$

$p10 = 0.1425$

$p11 = 0.6425$

mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

p11 = 0.6215

heta = 2:

## ee597-assignment2

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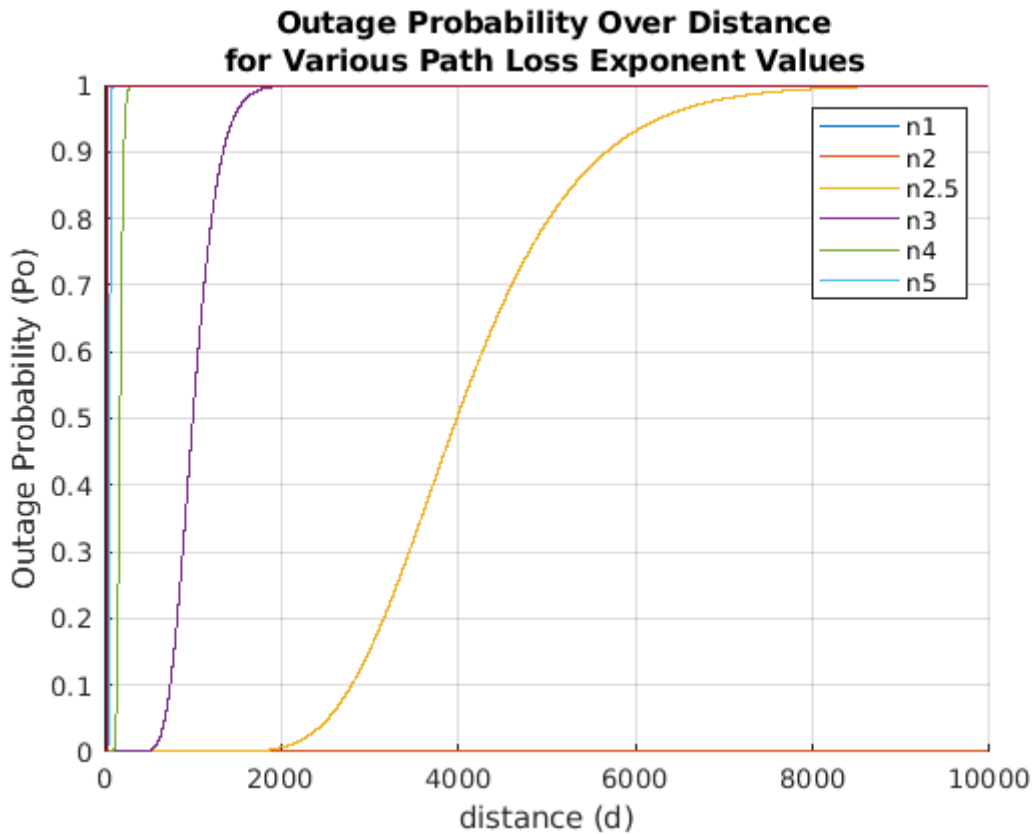
Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

by

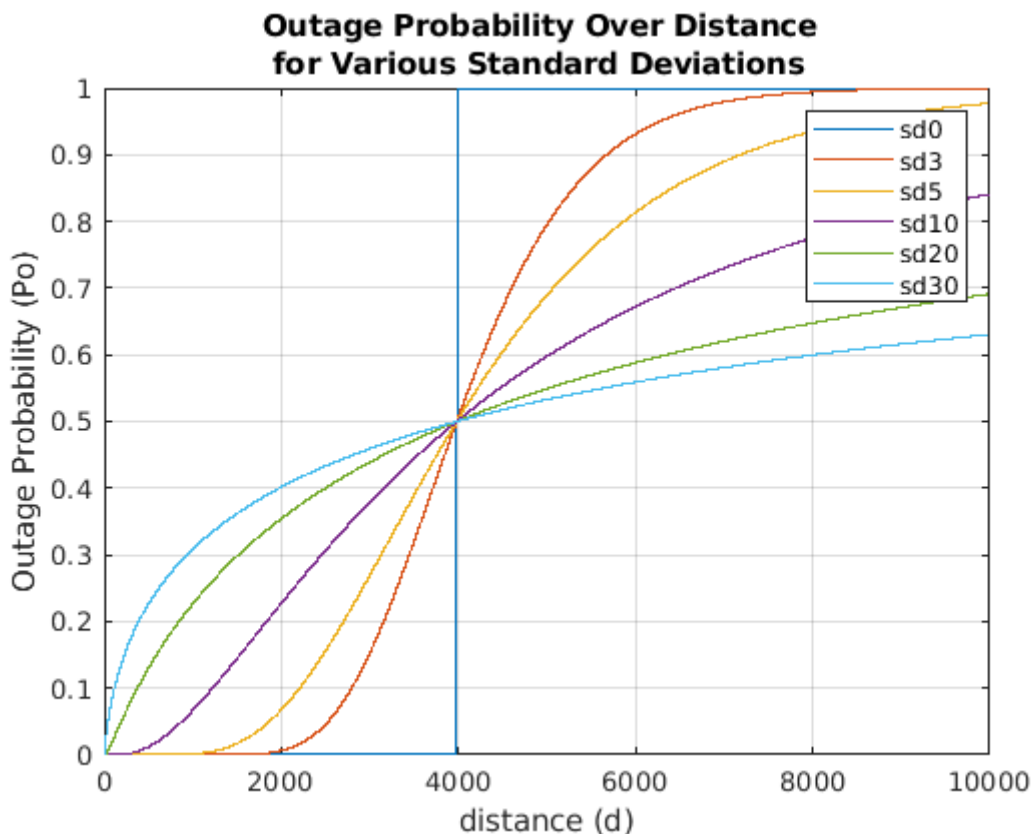
Bill Wang student id: and Spencer McDonough student id:

### Outage Probability as a function of distance for Log-Normal Shadowing





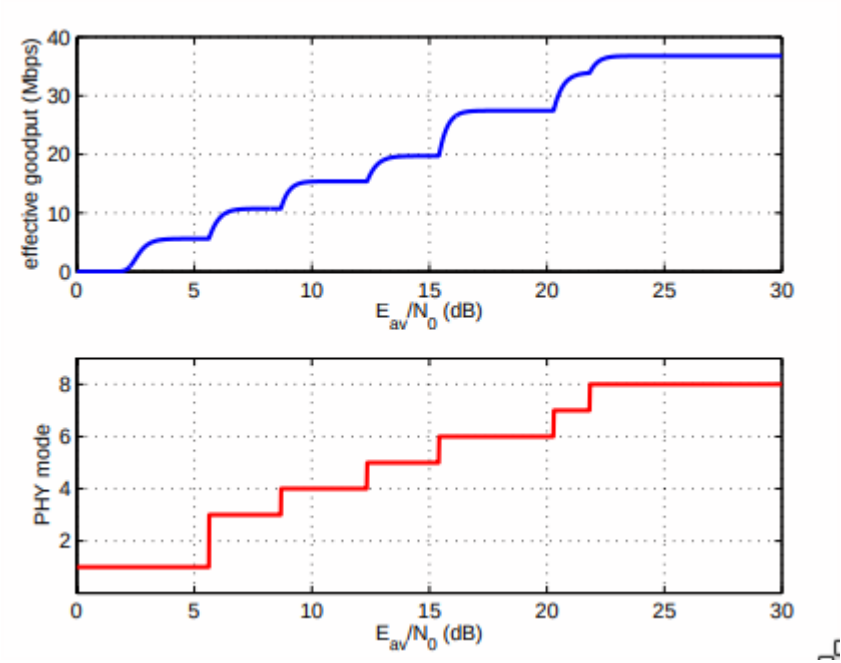
We can see that the probability of outage sigmoid function gets skewed left as we increase the value of the path loss exponent (PLE). This means that the probability of outage increases exponentially by a greater factor when the PLE is increased. This makes sense, as the PLE represents the attenuation due to the nature of the environment ( $\eta > 2$  : loss,  $\eta = 2$  : vacuum, or no loss,  $\eta < 2$  : gain).



We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponent (PLE) increases. This makes sense, as the probability of outage is inversely

proportional to the log of the PLE's standard deviation.

# Rate Adaptation



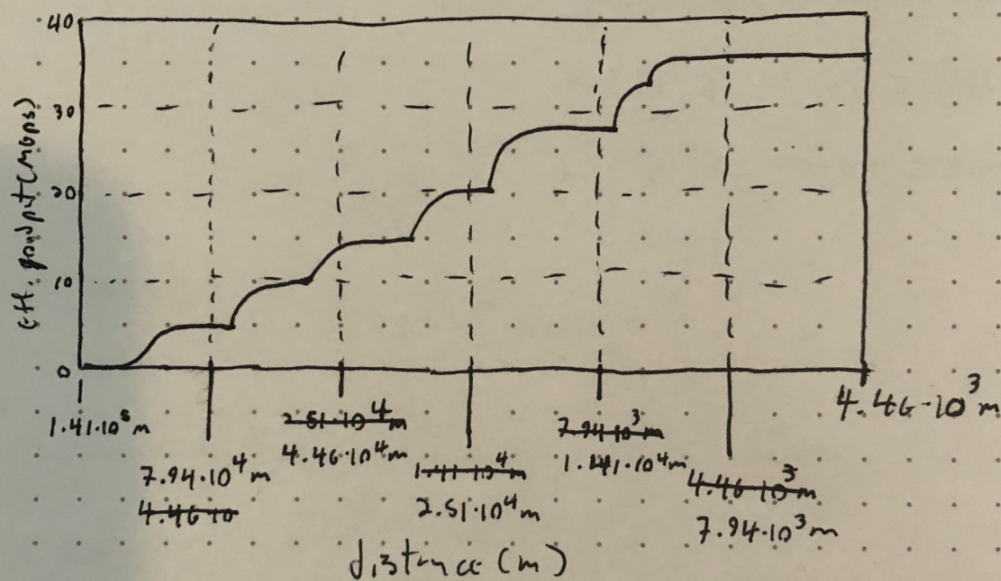
## Effective Goodput as a Function of Distance

$$SNR_{dBm} = P_{TdBm} - N_{dBm}$$

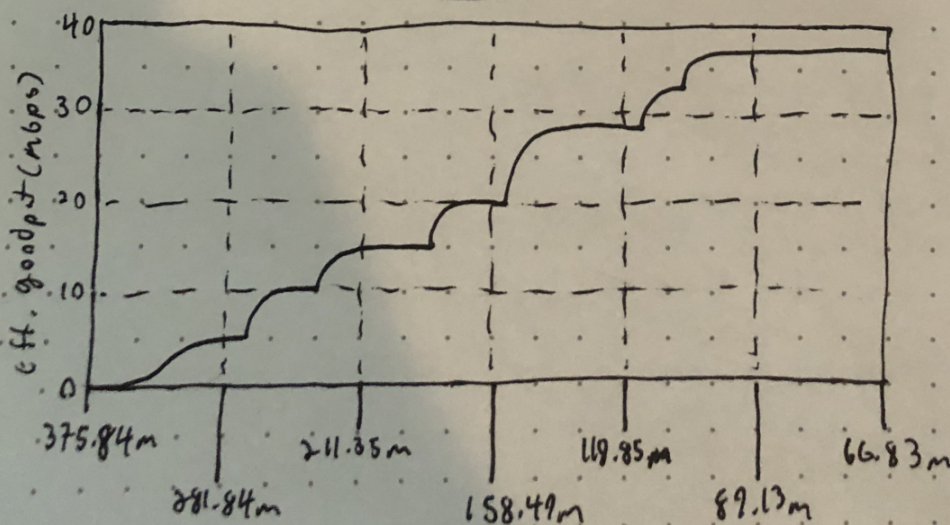
$$P_{dBm} = P_{TdBm} + K_{refdBm} - \eta \cdot 10 \log_{10} \left( \frac{d}{d_0} \right)$$

$$\therefore d = d_0 \cdot 10^{\left[ \frac{P_{TdBm} + K_{refdBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10} \right]}$$

$\therefore$  Effective Goodput (d) for  $\eta = 2$ ,  $P_{TdBm} = 23dBm$ ,  
 $K_{refdBm} = -10dBm$ ,  $N_{dBm} = -90dBm$ .



$\therefore$  Effective Goodput for  $\eta = 4$ :



In this exercise, we converted SNR to distance with a known path loss model.  $P_{TdBm} = 23dBm$ ,  $P_{ref} = -10dBm$ ,  $N_{dBm} = -90dBm$ . We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with  $\eta$  values 2 and 4. Here is a breakdown of the SNR  $\rightarrow$  d(m) conversions for clarity:  $d = d_0 \cdot 10^{(P_{TdBm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta \cdot 10)}$

heta = 2:

$d(\text{SNR} = 0) = 1.41\text{E}5\text{m}$

$d(\text{SNR} = 5) = 7.94\text{E}4\text{m}$

$d(\text{SNR} = 10) = 4.46\text{E}4\text{m}$

$d(\text{SNR} = 15) = 2.51\text{E}4\text{m}$

$d(\text{SNR} = 20) = 1.41\text{E}4\text{m}$

$d(\text{SNR} = 25) = 7.94\text{E}3\text{m}$

$d(\text{SNR} = 30) = 4.46\text{E}3\text{m}$

heta = 4:

$d(\text{SNR} = 0) = 375.84\text{m}$

$d(\text{SNR} = 5) = 281.84\text{m}$

$d(\text{SNR} = 10) = 211.35\text{m}$

$d(\text{SNR} = 15) = 158.49\text{m}$

$d(\text{SNR} = 20) = 118.85\text{m}$

$d(\text{SNR} = 25) = 89.13\text{m}$

$d(\text{SNR} = 30) = 66.83\text{m}$

## Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

*p00 - the probability that we remain in the "outage" state*

*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

$p00 = 0.0780$

$p01 = 0.1400$

$p10 = 0.1395$

$p11 = 0.6420$

mobile speed = 5:

$p00 = 0.0775$

$p01 = 0.1490$

$p10 = 0.1490$

$p11 = 0.6240$

mobile speed = 10:

$p00 = 0.0715$

$p01 = 0.1430$

$p10 = 0.1425$

$p11 = 0.6425$

mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

p11 = 0.6215

d(SNR = 0) = 1.41E5m

## ee597-assignment2

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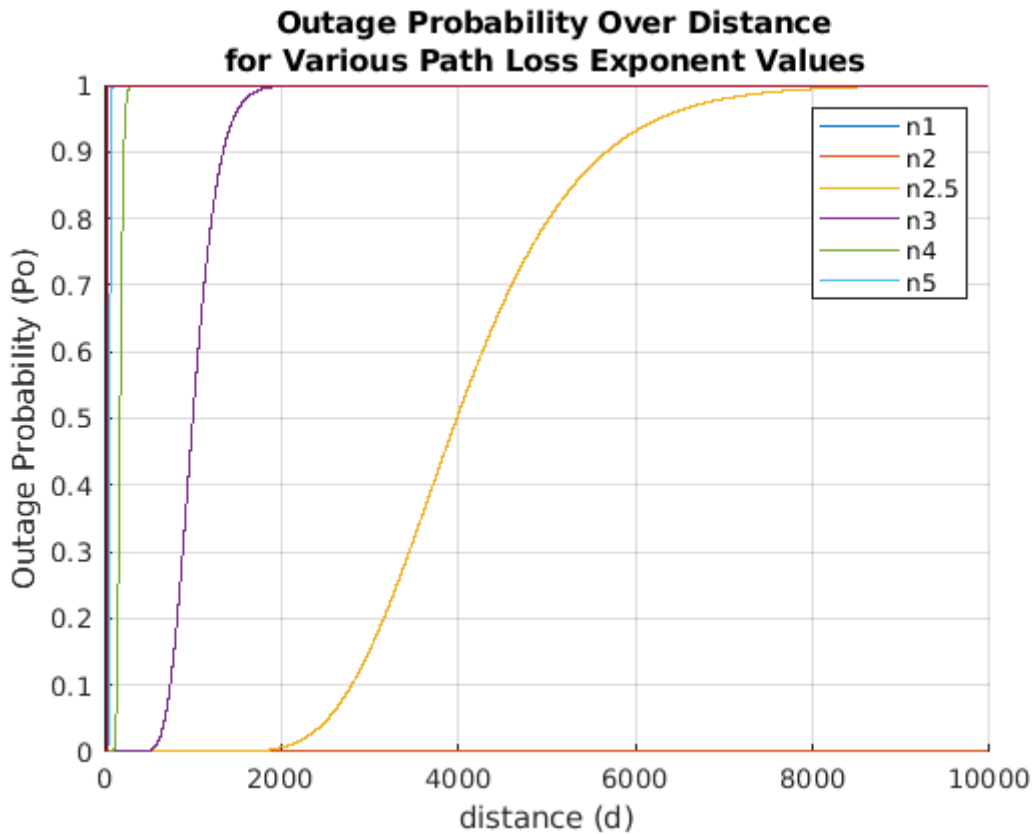
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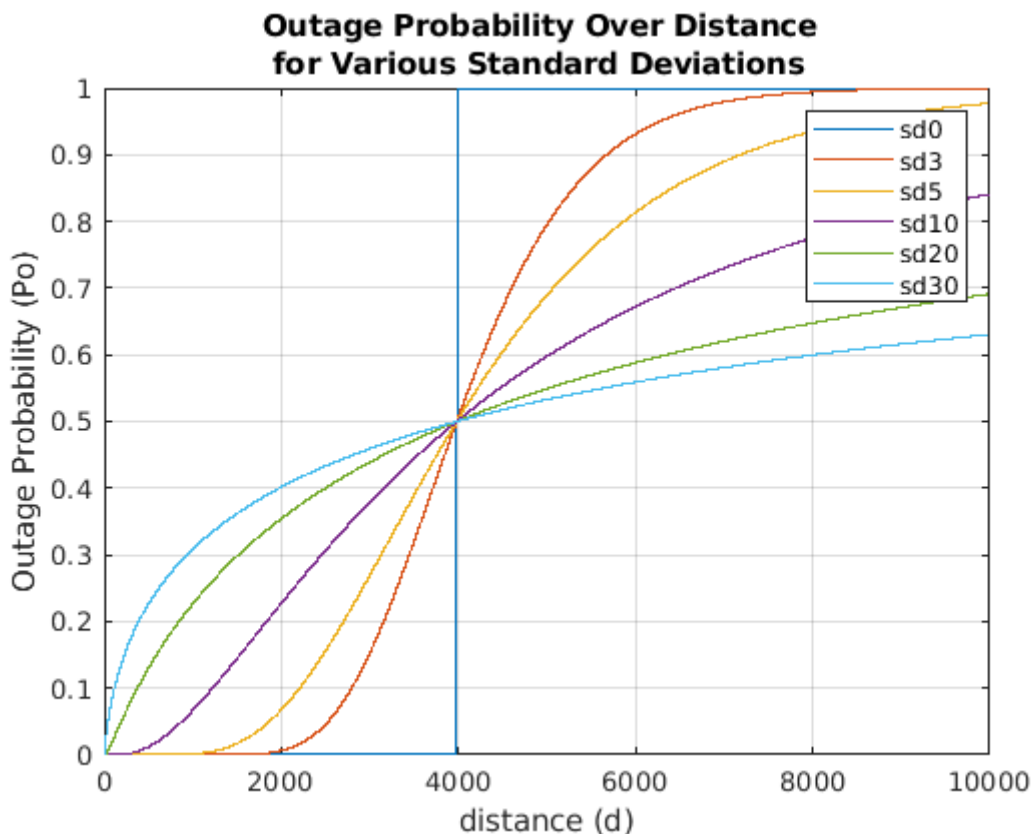
Bill Wang student id: and Spencer McDonough student id:

### Outage Probability as a function of distance for Log-Normal Shadowing





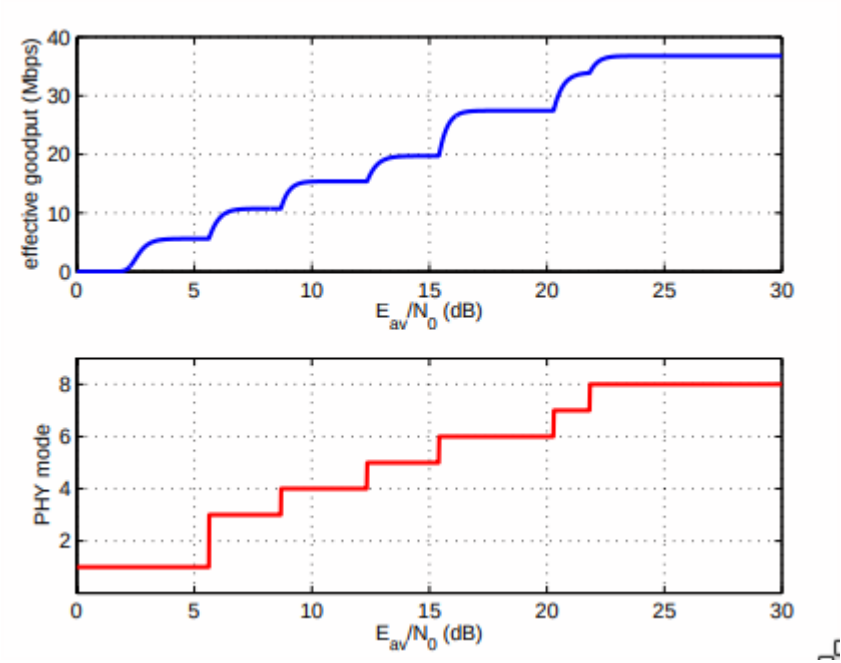
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We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponent (PLE) increases. This makes sense, as the probability of outage is inversely

proportional to the log of the PLE's standard deviation.

# Rate Adaptation



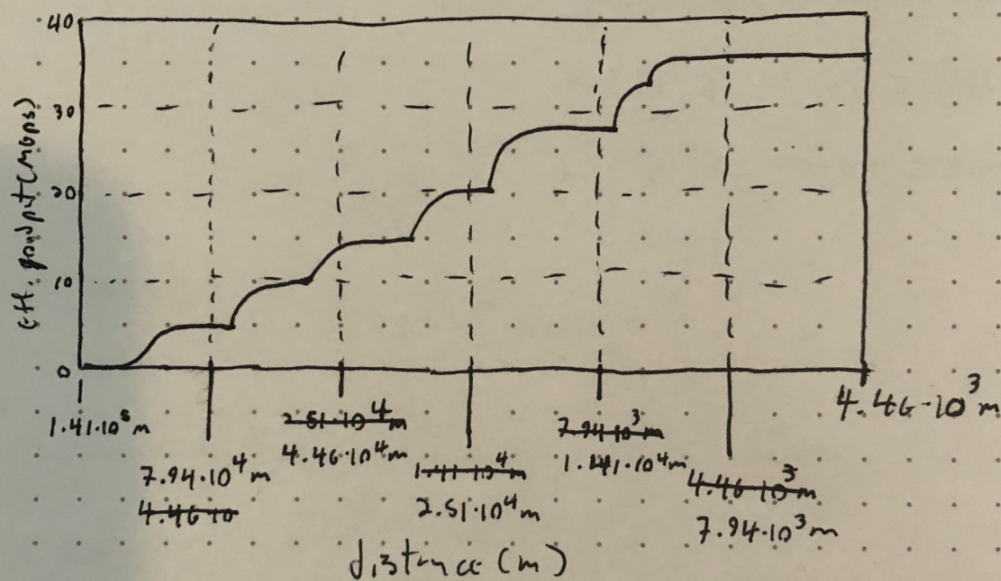
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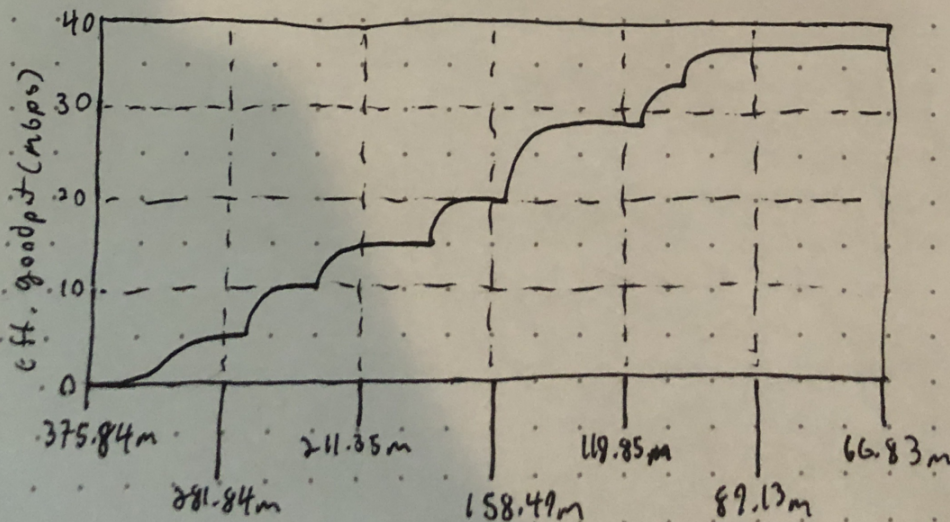
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$\therefore$  Effective Goodput (d) for  $\eta = 2$ ,  $P_{TdBm} = 23dBm$ ,  
 $K_{refdBm} = -10dBm$ ,  $N_{dBm} = -90dBm$ .



$\therefore$  Effective Goodput for  $\eta = 4$ :



In this exercise, we converted SNR to distance with a known path loss model.  $P_{TdBm} = 23dBm$ ,  $P_{ref} = -10dBm$ ,  $N_{dBm} = -90dBm$ . We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with  $\eta$  values 2 and 4. Here is a breakdown of the SNR  $\rightarrow$  d(m) conversions for clarity:  $d = d_0 \cdot 10^{(P_{TdBm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta \cdot 10)}$

heta = 2:

$d(\text{SNR} = 0) = 1.41\text{E}5\text{m}$

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$d(\text{SNR} = 15) = 2.51\text{E}4\text{m}$

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$d(\text{SNR} = 25) = 7.94\text{E}3\text{m}$

$d(\text{SNR} = 30) = 4.46\text{E}3\text{m}$

heta = 4:

$d(\text{SNR} = 0) = 375.84\text{m}$

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$d(\text{SNR} = 30) = 66.83\text{m}$

## Rayleigh Fading

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*p00 - the probability that we remain in the "outage" state*

*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

$p00 = 0.0780$

$p01 = 0.1400$

$p10 = 0.1395$

$p11 = 0.6420$

mobile speed = 5:

$p00 = 0.0775$

$p01 = 0.1490$

$p10 = 0.1490$

$p11 = 0.6240$

mobile speed = 10:

$p00 = 0.0715$

$p01 = 0.1430$

$p10 = 0.1425$

$p11 = 0.6425$

mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

p11 = 0.6215

d(SNR = 5) = 7.94E4m

## ee597-assignment2

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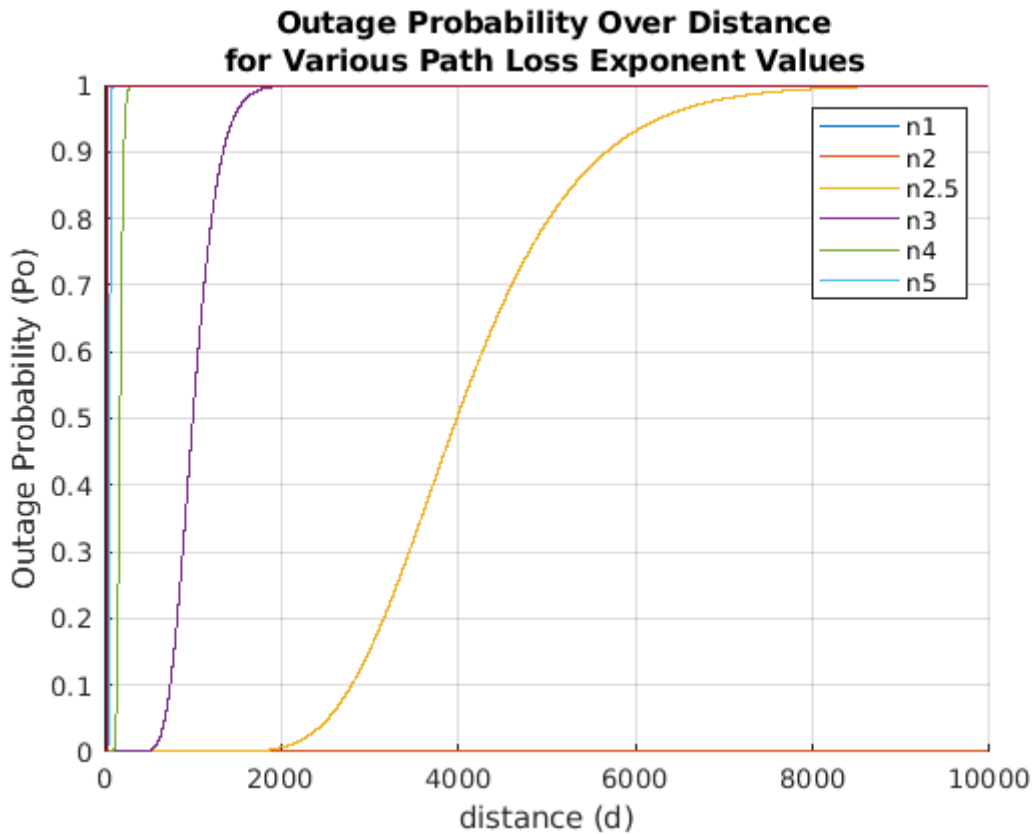
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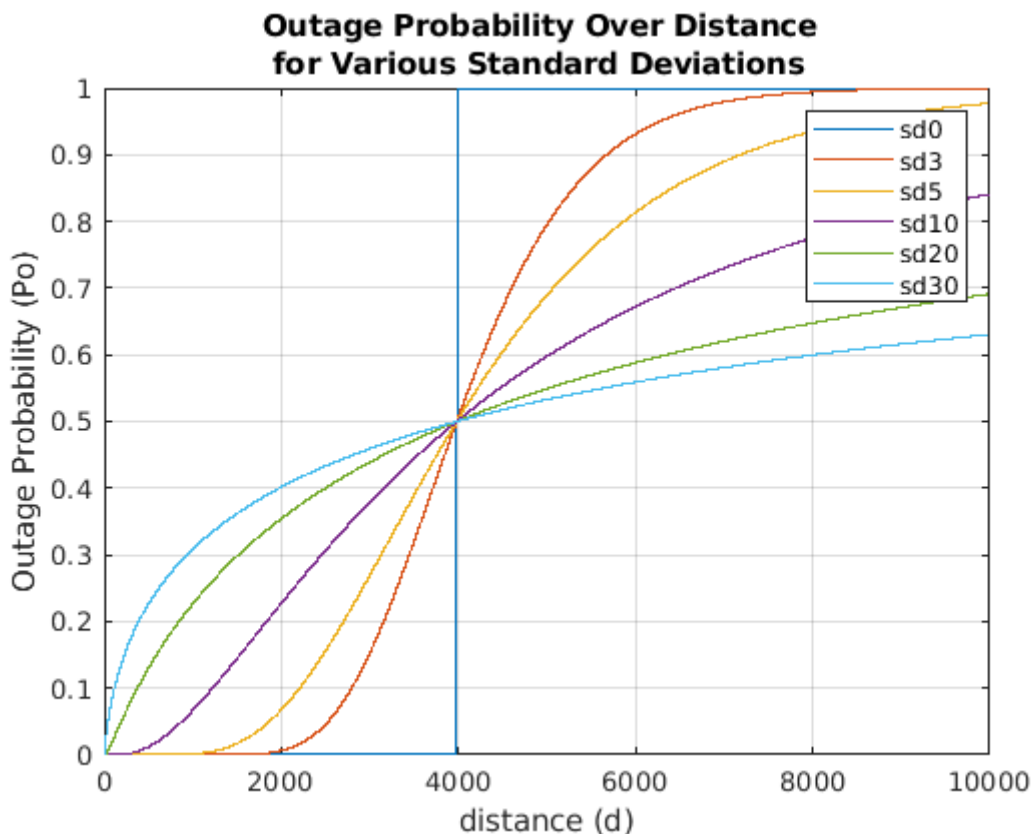
Bill Wang student id: and Spencer McDonough student id:

### Outage Probability as a function of distance for Log-Normal Shadowing





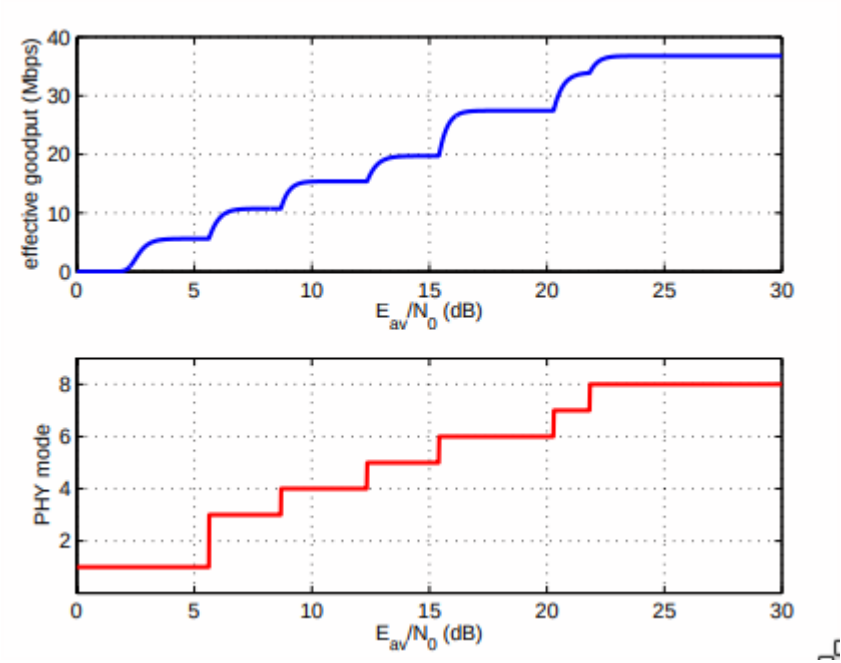
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We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponent (PLE) increases. This makes sense, as the probability of outage is inversely

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# Rate Adaptation



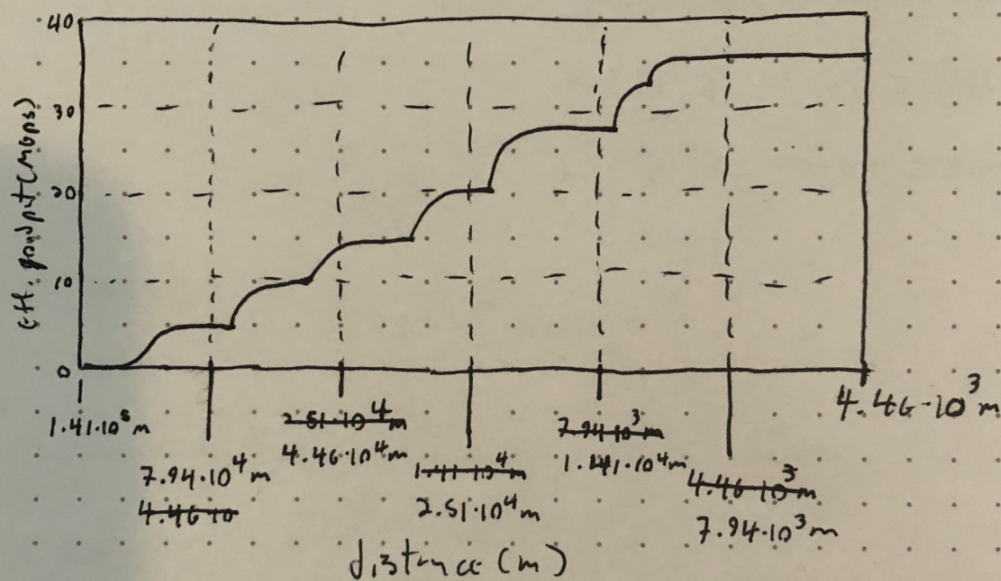
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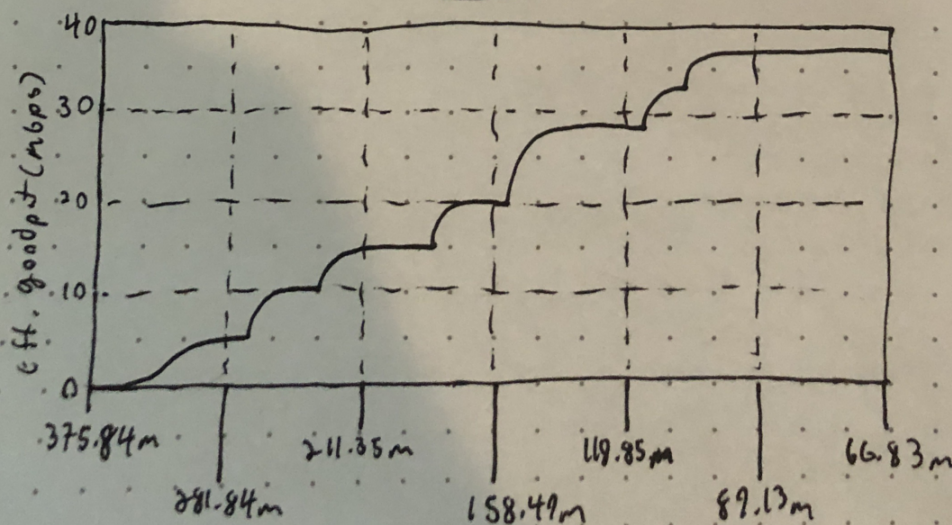
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$$\therefore d = d_0 \cdot 10^{\left[ \frac{P_{TdBm} + K_{refdBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10} \right]}$$

$\therefore$  Effective Goodput (d) for  $\eta = 2$ ,  $P_{TdBm} = 23dBm$ ,  
 $K_{refdBm} = -10dBm$ ,  $N_{dBm} = -90dBm$ .



$\therefore$  Effective Goodput for  $\eta = 4$ :



In this exercise, we converted SNR to distance with a known path loss model.  $P_{TdBm} = 23dBm$ ,  $P_{ref} = -10dBm$ ,  $N_{dBm} = -90dBm$ . We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with  $\eta$  values 2 and 4. Here is a breakdown of the SNR  $\rightarrow$  d(m) conversions for clarity:  $d = d_0 \cdot 10^{(P_{TdBm} + P_{ref} - N_{dBm} - SNR_{dBm})/(\eta \cdot 10)}$

heta = 2:

$d(\text{SNR} = 0) = 1.41\text{E}5\text{m}$

$d(\text{SNR} = 5) = 7.94\text{E}4\text{m}$

$d(\text{SNR} = 10) = 4.46\text{E}4\text{m}$

$d(\text{SNR} = 15) = 2.51\text{E}4\text{m}$

$d(\text{SNR} = 20) = 1.41\text{E}4\text{m}$

$d(\text{SNR} = 25) = 7.94\text{E}3\text{m}$

$d(\text{SNR} = 30) = 4.46\text{E}3\text{m}$

heta = 4:

$d(\text{SNR} = 0) = 375.84\text{m}$

$d(\text{SNR} = 5) = 281.84\text{m}$

$d(\text{SNR} = 10) = 211.35\text{m}$

$d(\text{SNR} = 15) = 158.49\text{m}$

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## Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

*p00 - the probability that we remain in the "outage" state*

*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

$p00 = 0.0780$

$p01 = 0.1400$

$p10 = 0.1395$

$p11 = 0.6420$

mobile speed = 5:

$p00 = 0.0775$

$p01 = 0.1490$

$p10 = 0.1490$

$p11 = 0.6240$

mobile speed = 10:

$p00 = 0.0715$

$p01 = 0.1430$

$p10 = 0.1425$

$p11 = 0.6425$

mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

p11 = 0.6215

d(SNR = 10) = 4.46E4m

## ee597-assignment2

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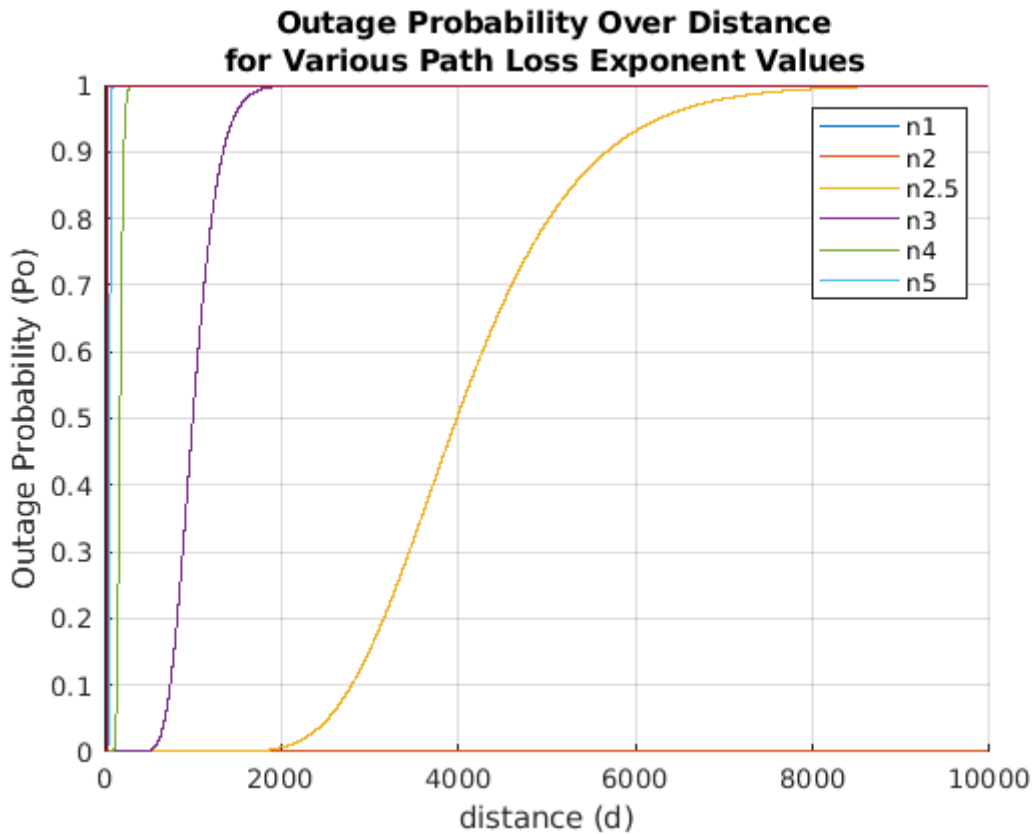
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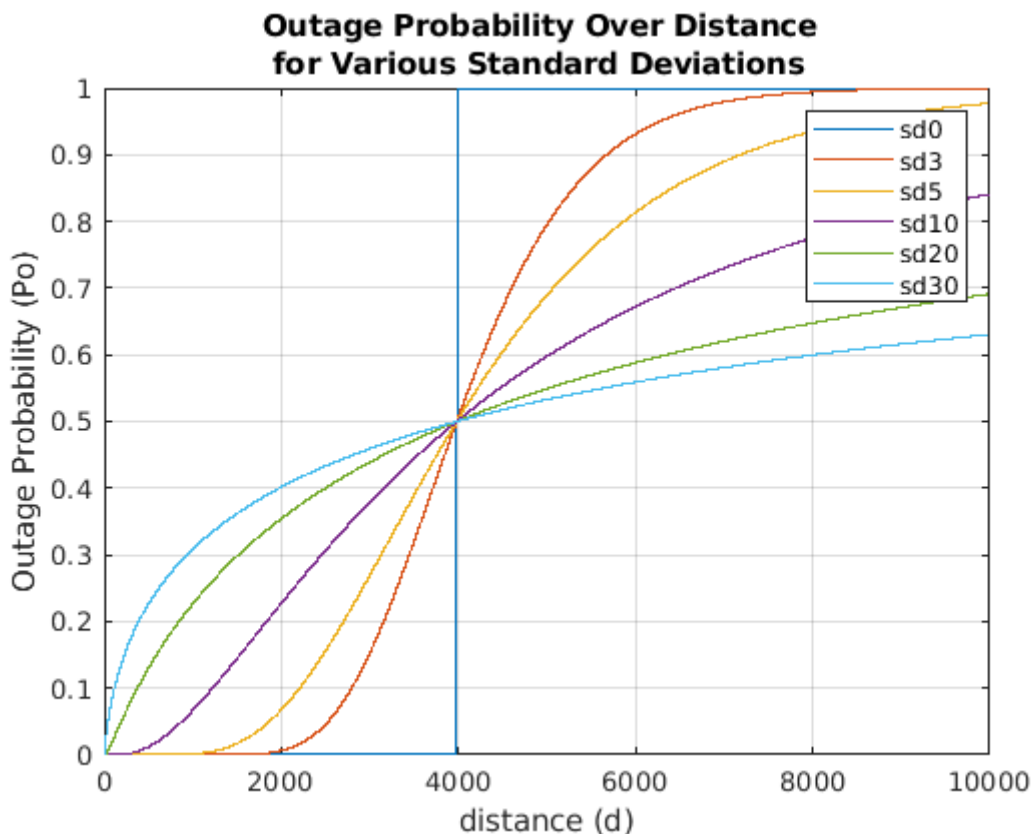
Bill Wang student id: and Spencer McDonough student id:

### Outage Probability as a function of distance for Log-Normal Shadowing





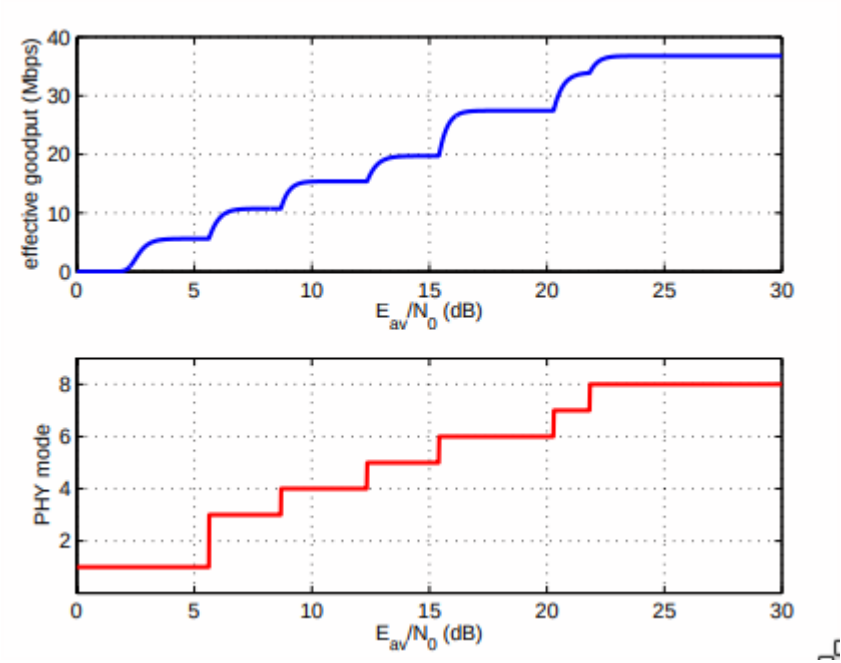
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# Rate Adaptation



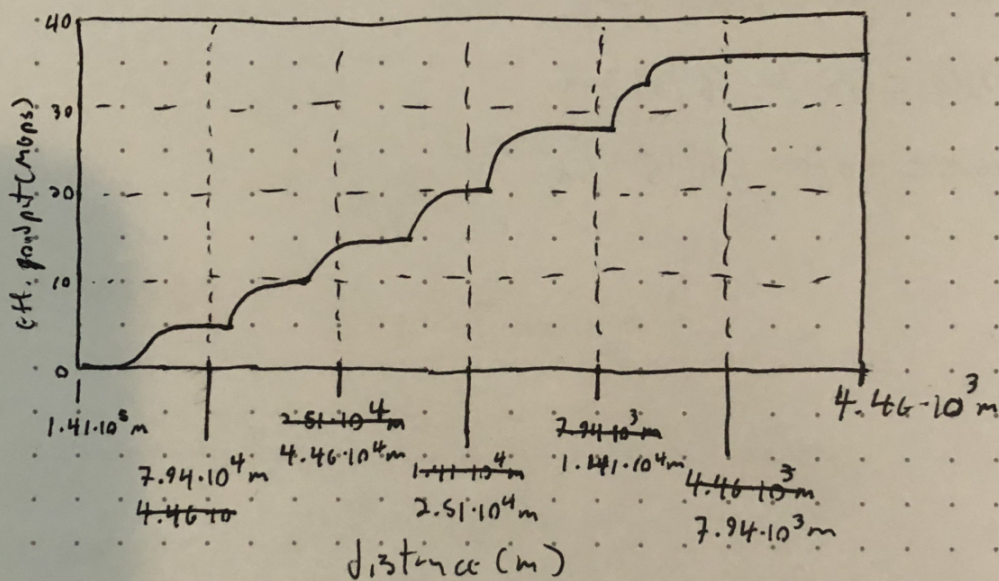
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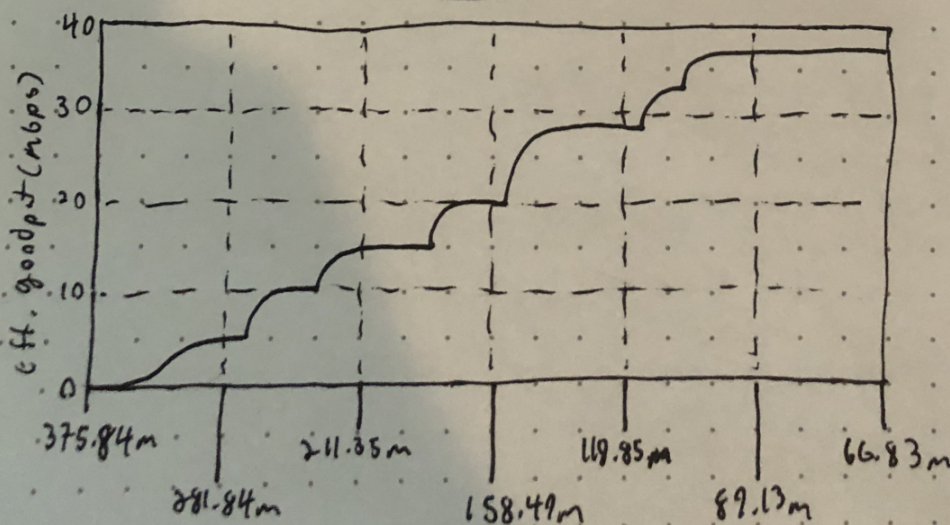
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$\therefore$  Effective Goodput for  $\eta = 4$ :



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heta = 2:

d(SNR = 0) = 1.41E5m

d(SNR = 5) = 7.94E4m

d(SNR = 10) = 4.46E4m

d(SNR = 15) = 2.51E4m

d(SNR = 20) = 1.41E4m

d(SNR = 25) = 7.94E3m

d(SNR = 30) = 4.46E3m

heta = 4:

d(SNR = 0) = 375.84m

d(SNR = 5) = 281.84m

d(SNR = 10) = 211.35m

d(SNR = 15) = 158.49m

d(SNR = 20) = 118.85m

d(SNR = 25) = 89.13m

d(SNR = 30) = 66.83m

## Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

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*p01 - the probability that we move from the "outage" state to the "receive" state*

*p10 - the probability that we move from the "receive" state to the "outage" state*

*p11 - the probability that we remain in the "receive" state*

mobile speed = 0:

p00 = 0.0780

p01 = 0.1400

p10 = 0.1395

p11 = 0.6420

mobile speed = 5:

p00 = 0.0775

p01 = 0.1490

p10 = 0.1490

p11 = 0.6240

mobile speed = 10:

p00 = 0.0715

p01 = 0.1430

p10 = 0.1425

p11 = 0.6425

mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

p11 = 0.6215

d(SNR = 15) = 2.51E4m

d(SNR = 20) = 1.41E4m

d(SNR = 25) = 7.94E3m

d(SNR = 30) = 4.46E3m

heta = 4:

d(SNR = 0) = 375.84m

d(SNR = 5) = 281.84m

d(SNR = 10) = 211.35m

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p01 - the probability that we move from the "outage" state to the "receive" state

p10 - the probability that we move from the "receive" state to the "outage" state

p11 - the probability that we remain in the "receive" state

mobile speed = 0:

p00 = 0.0780

p01 = 0.1400

p10 = 0.1395

p11 = 0.6420



mobile speed = 5:

p00 = 0.0775

p01 = 0.1490

p10 = 0.1490

p11 = 0.6240

mobile speed = 10:

p00 = 0.0715

p01 = 0.1430

p10 = 0.1425

p11 = 0.6425

mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

p11 = 0.6405

mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

p10 = 0.1485

p11 = 0.6215