COMP 5416 Assignment 2

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1. Question 1:

R = 1 $Mbit/sec$ = 1000 $Kbit/sec$ = 125 $Kbyte/sec$
Packet size = 500 $Bytes$
$T_{prop} = 4\,msec$
$T_{tran} = \dfrac{500\,byte}{125\,Kbyte/sec} = 4\,msec$
RTT = 3 * 4 + 6 * 4 = 36 $msec$

1) For file size = 80000 $Bytes$:
   We can get the packet number we need to transmit:
$$\frac{80000\,Bytes}{500\,Bytes} = 160$$
   For Go-Back-6:
   We can get the group number we need to transmit:
$$\frac{160}{6} = 26.6667$$
   Which means: we need to transmit 26 Groups of 6 packets, the 27th group has only 4 packets.
$$\begin{aligned} \text{total tranmist time} &= \text{RTT} * 27 + T_{tran} * (4-1) \\ &= 36\text{ msec} * 27 + 4\text{ msec} * 3 \\ &= 972\text{ msec} + 12\text{ msec} \\ &= 984\text{ msec} \end{aligned}$$

2) For Go-Back-8:
   We can get the group number we need to transmit:
$$\frac{160}{8} = 20$$
   So, we have:
$$\begin{aligned} \text{total transmit time} &= \text{RTT} * 20 + T_{tran} * (8-1) \\ &= 36\,msec * 20 + 4\,msec * 7 \\ &= 720\,msec + 28\,msec \\ &= 748\text{ msec} \end{aligned}$$

3) For Go-Back-10:
   According to $\text{RTT} = 36\text{msec}$ and $T_{tran} = 4ms$, there are only 9 packets can be transmitted in one RTT. So, for Go-Back-9 and higher, the

transmitting times are same.

So, we have:

$$\text{total transmit time} = \frac{80000Bytes}{125KBytes/sec} + 9 * 4\text{msec} = 672 \text{ msec}$$

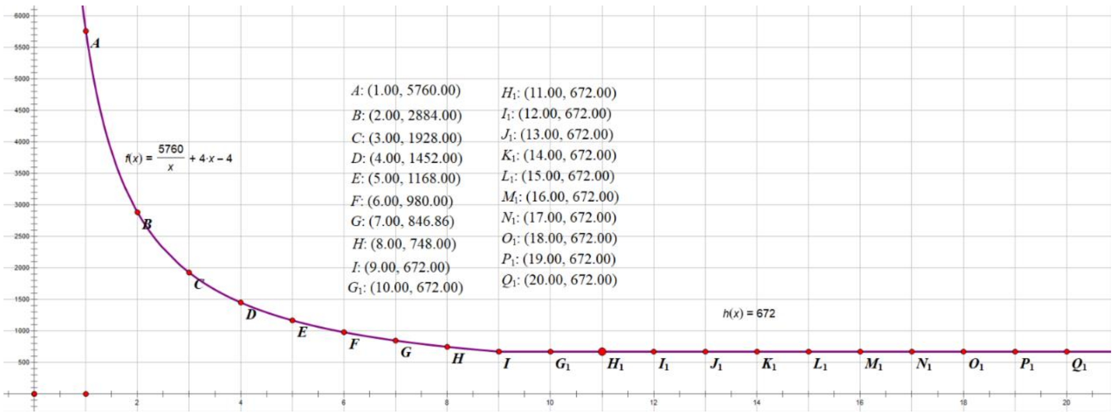
4) For Go-Back-20:
Similarly, the answer is 640 msec.

5) For N range from 1 to 20:

$$\text{total transmit time} = \begin{cases} \text{RTT} * \dfrac{Packet\ Number}{N} + T_{tran} * (N-1), 0 < N < 9 \\ 672\ msec, N \geq 9 \end{cases}$$

So, I can draw the curve of N:

6) The curve of time VS N:

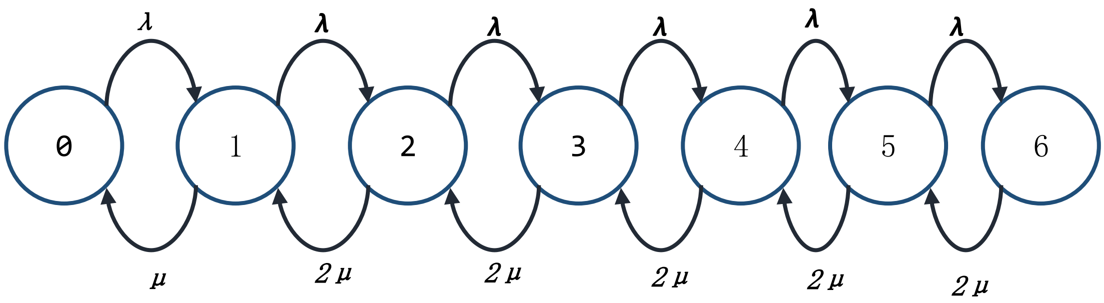


7) The timeout duration is 50 msec and the RTT = 36 msec
So, the timeout should happen after the ACK of 1 has been received.
According to the $T_{tran} = 4\,msec$, the timeout happens at 54 msec. Then, the packets are transmitted as usual from 2 to 160
So:

$$\text{total transmit time} = 54 \text{ msec} + \text{RTT} * \frac{160}{8} + 4 * (7-1)$$
$$= 54 \text{ msec} + 720 \text{ msec} + 24\text{msec} = 798 \text{ msec}$$

2. Question 2

a) When $\lambda = 1, \mu = 2$, *M/M/2/6*:



By analysis:

$$\rho = \frac{\lambda}{2\mu} = \frac{1}{4} < 1$$

and:

$$\pi_n = \begin{cases} \pi_0 * \frac{(2\rho)^n}{n!}, 0 < n < 2 \\ \pi_0 * \frac{2^2 \rho^n}{2!}, 2 \le n \end{cases} \text{ and } \sum_{i=0}^{n} \pi_n = 1$$

So, we can get:

$$\pi_0 = \frac{2048}{3413}, \pi_1 = \frac{1024}{3413}, \pi_2 = \frac{256}{3413}, \pi_3 = \frac{64}{3413}, \pi_4 = \frac{16}{3413}, \pi_5 = \frac{4}{3413},$$
$$\pi_6 = \frac{1}{3413}$$

By simulation:

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[0.600804738868683, 0.29963183272650895, 0.07476407178351184, 0.01873364208074193, 0.004683360025645608, 0.0011388446233336336, 0.0002435098915750658]
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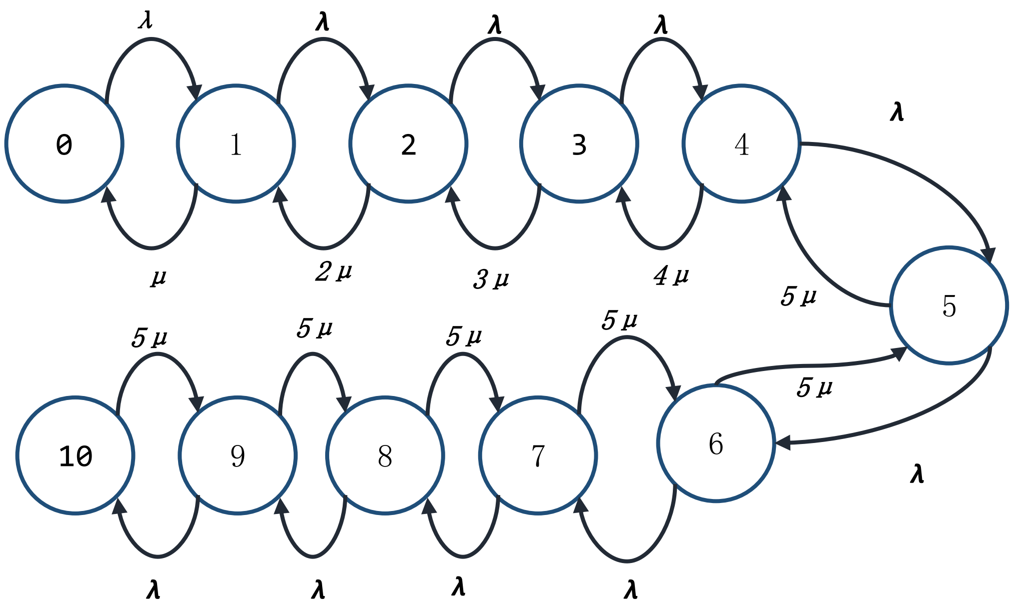
$$\pi_0 = 0.6008, \pi_1 = 0.2996, \pi_2 = 0.0748, \pi_3 = 0.01873, \pi_4 = 0.00468, \pi_5 = 0.001138, \pi_5 = 0.0002435$$

b) When $\lambda = 1, \mu = 1$, *M/M/5/10*:



By analysis:

$$\rho = \frac{\lambda}{5\mu} = \frac{1}{5} < 1$$

and:

$$\pi_n = \begin{cases} \pi_0 * \dfrac{(5\rho)^n}{n!}, 0 < n < 5 \\ \pi_0 * \dfrac{5^5 \rho^n}{5!}, 5 \le n \end{cases} \quad \text{and} \sum_{i=0}^{n} \pi_n = 1$$

So, we can get:

$$\pi_0 = \frac{375000}{1019531}, \pi_1 = \frac{375000}{1019531}, \pi_2 = \frac{187500}{1019531}, \pi_3 = \frac{62500}{1019531}, \pi_4 = \frac{15625}{1019531}, \pi_5 = \frac{3125}{1019531}, \pi_6 = \frac{625}{1019531}, \pi_7 = \frac{125}{1019531}, \pi_8 = \frac{25}{1019531}, \pi_9 = \frac{5}{1019531}, \pi_{10} = \frac{1}{1019531}$$

By simulation:

[0.366815736940724, 0.3682835102044286, 0.1843656775228279, 0.06147953101076606, 0.015285317499314192, 0.003060095049381681, 0.0005967038164352282, 9.464200898209323e-05, 1.875765723830992e-05, 2.82899018981613 4e-08]

c) For M/M/m/m queue:

$$\lambda\pi_0 = \mu\pi_1, \lambda\pi_1 = 2\mu\pi_2, \dots\dots, \lambda\pi_{n-1} = n\mu\pi_n$$

so, we have:

$$\frac{\pi_n}{\pi_{n-1}} = \frac{\rho}{n}, where\ \rho = \frac{\lambda}{\mu}, 0 < n \le m$$

According to: $\sum_{i=0}^{m} \pi_i = 1$,

We have: $\sum_{i=0}^{m} \frac{\rho^i}{i!} \pi_0 = 1$

$$\pi_0 = \frac{1}{\sum_{i=0}^{m} \frac{\rho^i}{i!}}, \text{where } \rho = \frac{\lambda}{\mu}; \text{ and } \pi_k = \pi_0 * \frac{\rho^k}{k!} = \frac{\rho^k}{k! \sum_{i=0}^{m} \frac{\rho^i}{i!}}, 1 < k \le m$$

The dropped probability:

$$P_b = \pi_m = \pi_0 * \frac{\rho^m}{m!} = \frac{\rho^m}{m!\sum_{i=0}^{m}\frac{\rho^i}{i!}}, \text{where } \rho = \frac{\lambda}{\mu}$$

So, we have:

$$P_b = \frac{(\frac{\lambda}{\mu})^m}{m!\sum_{i=0}^{m}\frac{(\frac{\lambda}{\mu})^i}{i!}}$$

d) For $\mu = 1, \text{m} = 10$ and $P_b < 0.001$

We have:

$$P_b = \frac{(\frac{\lambda}{\mu})^m}{m!\sum_{i=0}^{m}\frac{(\frac{\lambda}{\mu})^i}{i!}} < 0.001 \Rightarrow \frac{(\frac{\lambda}{1})^{10}}{10!\sum_{i=0}^{10}\frac{(\frac{\lambda}{1})^i}{i!}} < 0.001$$

After calculated by my computer with exhaustive method, I got the answer which is 3.092

e) For $\lambda = 10, \mu = 1$ and $P_b < 0.001$

We have:

$$P_b = \frac{(\frac{\lambda}{\mu})^m}{m!\sum_{i=0}^{m}\frac{(\frac{\lambda}{\mu})^i}{i!}} < 0.001 \Rightarrow \frac{(10)^m}{m!\sum_{i=0}^{m}\frac{(10)^i}{i!}} < 0.001$$

After calculated by my computer with exhaustive method, I got the answer which is 21

f) (1) What are Erlang-B and Erlang-C Formulas? When are they used? What is the difference between them?

Erlang-B Formula: The Erlang B formula (or Erlang-B with a hyphen), also known as the Erlang loss formula, is a formula for the blocking probability that describes the probability of call losses for a group of identical parallel resources (telephone lines, circuits, traffic channels, or equivalent), sometimes referred to as an *M/M/c/c* queue.

Erlang-C Formula: The Erlang C formula expresses the probability that an arriving customer will need to queue (as opposed to immediately being served).

They are used to measure the blocking rate of a queue. Also, they can tell the quality of the services.

Difference: in Erlang-B, if the service tables are full, customers will leave. While in the Erlang-C, customers can wait for the services. With limited queue length, if the capability and service table number are same, the blocking rate of Erlang-C is much smaller than the blocking rate of Erlang-B. So, Erlang-C has higher utilization than Erlang-B. The longer queue has smaller blocking rate.

(2) For $\mu = 1, m = 10$, I'd like to choose Erlang-C. The departure rate and service table number are fixed, and we are going to find the maximum arrival rate. This scenario is going to find out the largest capability under the condition. The Erlang-C has higher channel utilization.

For $\lambda = 10, \mu = 1$, I'd like to choose Erlang-B. The arrival and departure rate are fixed, and we are going to find the minimum value of service tables. This scenario is going to find the lowest cost. With using Erlang-B, the cost can be lower.

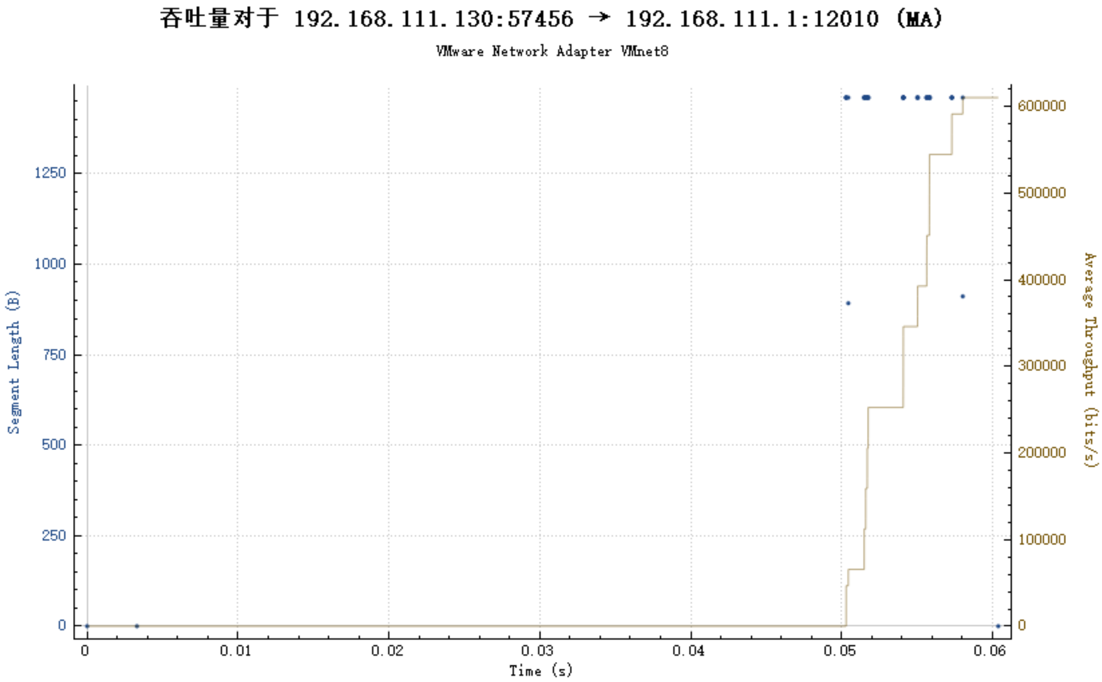
3. Question 3

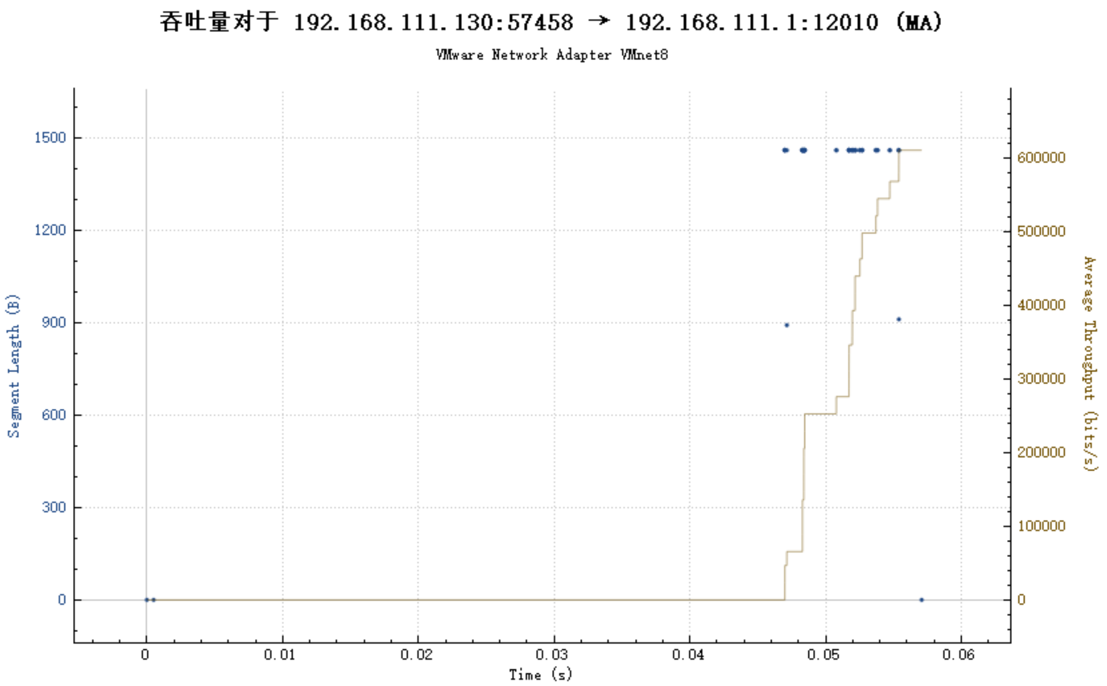
(3) IP address of three clients: 192.168.111.130

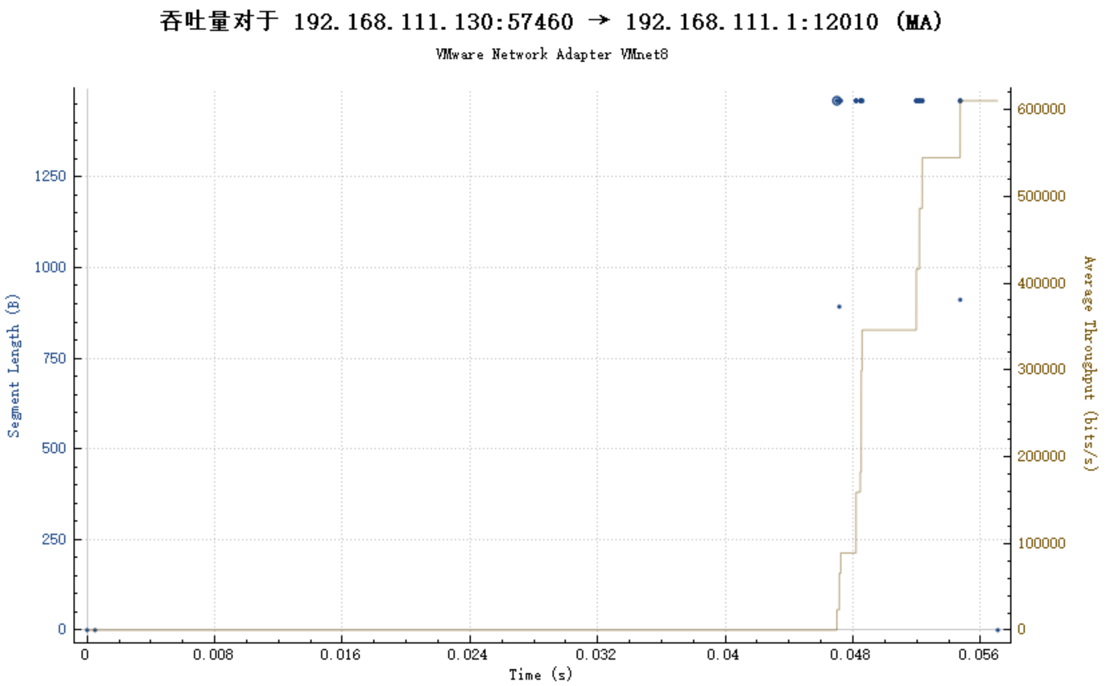
Port numbers of three clients:57456, 57458, 57460

IP address of the server: 192.168.111.1

Port number of the server: 12010




吞吐量对于 192.168.111.130:57458 → 192.168.111.1:12010 (MA)
VMware Network Adapter VMnet8
Segment Length (B)
1500
1200
900
600
300
0
Average Throughput (bits/s)
600000
500000
400000
300000
200000
100000
0
0
0.01
0.02
0.03
0.04
0.05
0.06
Time (s)


吞吐量对于 192.168.111.130:57460 → 192.168.111.1:12010 (MA)
VMware Network Adapter VMnet8
Segment Length (B)
1250
1000
750
500
250
0
Average Throughput (bits/s)
600000
500000
400000
300000
200000
100000
0
0
0.008
0.016
0.024
0.032
0.04
0.048
0.056
Time (s)

4. Question 4

a) When i = 0, $\delta^2 = 1$

$$\mathrm{R} = 1 \cdot (-1 + n_1, -1 + n_2, -1 + n_3, +1 + n_4, -1 + n_5, +1 + n_6, +1 + n_7, +1 + n_8)$$
$$= 1 + \frac{\sum_{k=1}^{8} n_k}{8}$$

According to: $n_i \sim N(0,1)$,

So, $\frac{n_k}{8} \sim N\left(0, \frac{1}{64}\right)$ and $\frac{\sum_{k=1}^{8} n_k}{8} \sim N\left(0, \frac{1}{8}\right)$

So, we have: $1 + \frac{\sum_{k=1}^{8} n_k}{8} \sim N\left(1, \frac{1}{8}\right)$, which means $\mu = 1, \sigma = \sqrt{\frac{1}{8}}$.

According to: $\mathrm{P(R < a)} = Q(\frac{|a-\mu|}{\sigma})$,

So, we have: $\mathrm{P(R < a)} = Q\left(\frac{|0-1|}{\sqrt{\frac{1}{8}}}\right) = Q(2.828427) = 2.3388684 \times 10^{-3}$

b) When i = -1, $\delta^2 = 0.1$

$$\mathrm{R} = 1 \cdot (-1 + n_1, -1 + n_2, -1 + n_3, +1 + n_4, -1 + n_5, +1 + n_6, +1 + n_7, +1 + n_8)$$
$$= 1 + \frac{\sum_{k=1}^{8} n_k}{8}$$

According to: $n_i \sim N(0,0.1)$,

So, $\frac{n_k}{8} \sim N\left(0, \frac{0.1}{64}\right)$ and $\frac{\sum_{k=1}^{8} n_k}{8} \sim N\left(0, \frac{0.1}{8}\right)$

So, we have: $1 + \frac{\sum_{k=1}^{8} n_k}{8} \sim N\left(1, \frac{0.1}{8}\right)$, which means $\mu = 1, \sigma = \sqrt{\frac{0.1}{8}}$.

According to: $\mathrm{P(R < a)} = Q(\frac{|a-\mu|}{\sigma})$,

So, we have: $\mathrm{P(R < a)} = Q\left(\frac{|0-1|}{\sqrt{\frac{0.1}{8}}}\right) = Q(8.944272) = 1.8720472 \times 10^{-19}$

c) When i = -2, $\delta^2 = 0.01$

$$\mathrm{R} = 1 \cdot (-1 + n_1, -1 + n_2, -1 + n_3, +1 + n_4, -1 + n_5, +1 + n_6, +1 + n_7, +1 + n_8)$$
$$= 1 + \frac{\sum_{k=1}^{8} n_k}{8}$$

According to: $n_i \sim N(0,0.01)$,

So, $\frac{n_k}{8} \sim N\left(0, \frac{0.01}{64}\right)$ and $\frac{\sum_{k=1}^{8} n_k}{8} \sim N\left(0, \frac{0.01}{8}\right)$

So, we have: $1 + \frac{\sum_{k=1}^{8} n_k}{8} \sim N\left(1, \frac{0.01}{8}\right)$, which means $\mu = 1, \sigma = \sqrt{\frac{0.01}{8}}$.

According to: $\mathrm{P(R < a)} = Q(\frac{|a-\mu|}{\sigma})$,

So, we have: $\mathrm{P(R < a)} = Q\left(\frac{|0-1|}{\sqrt{\frac{0.01}{8}}}\right) = Q(28.124271) = 2.4735757 \times 10^{-174}$

d) When i = -3, $\delta^2 = 0.001$

$$\mathrm{R} = 1 \cdot (-1 + n_1, -1 + n_2, -1 + n_3, +1 + n_4, -1 + n_5, +1 + n_6, +1 + n_7, +1 + n_8)$$

$$= 1 + \frac{\sum_{k=1}^{8} n_k}{8}$$

According to: $n_i \sim N(0, 0.001)$,

So, $\frac{n_k}{8} \sim N\left(0, \frac{0.001}{64}\right)$ and $\frac{\sum_{k=1}^{8} n_k}{8} \sim N\left(0, \frac{0.001}{8}\right)$

So, we have: $1 + \frac{\sum_{k=1}^{8} n_k}{8} \sim N\left(1, \frac{0.001}{8}\right)$, which means $\mu = 1, \sigma = \sqrt{\frac{0.001}{8}}$.

According to: $\mathrm{P}(\mathrm{R} < \mathrm{a}) = Q(\frac{|a-\mu|}{\sigma})$,

So, we have: $\mathrm{P}(\mathrm{R} < \mathrm{a}) = Q\left(\frac{|0-1|}{\sqrt{\frac{0.001}{8}}}\right) = Q(89.442719) = 0$

e) When i = -4, $\delta^2 = 0.0001$

$$\mathrm{R} = 1 \cdot (-1 + n_1, -1 + n_2, -1 + n_3, +1 + n_4, -1 + n_5, +1 + n_6, +1 + n_7, +1 + n_8)$$

$$= 1 + \frac{\sum_{k=1}^{8} n_k}{8}$$

According to: $n_i \sim N(0, 0.0001)$,

So, $\frac{n_k}{8} \sim N\left(0, \frac{0.0001}{64}\right)$ and $\frac{\sum_{k=1}^{8} n_k}{8} \sim N\left(0, \frac{0.0001}{8}\right)$

So, we have: $1 + \frac{\sum_{k=1}^{8} n_k}{8} \sim N\left(1, \frac{0.0001}{8}\right)$, which means $\mu = 1, \sigma = \sqrt{\frac{0.0001}{8}}$.

According to: $\mathrm{P}(\mathrm{R} < \mathrm{a}) = Q(\frac{|a-\mu|}{\sigma})$,

So, we have: $\mathrm{P}(\mathrm{R} < \mathrm{a}) = Q\left(\frac{|0-1|}{\sqrt{\frac{0.0001}{8}}}\right) = Q(282.842712) = 0$

f) When i = -5, $\delta^2 = 0.00001$

$$\mathrm{R} = 1 \cdot (-1 + n_1, -1 + n_2, -1 + n_3, +1 + n_4, -1 + n_5, +1 + n_6, +1 + n_7, +1 + n_8)$$

$$= 1 + \frac{\sum_{k=1}^{8} n_k}{8}$$

According to: $n_i \sim N(0, 0.00001)$,

So, $\frac{n_k}{8} \sim N\left(0, \frac{0.00001}{64}\right)$ and $\frac{\sum_{k=1}^{8} n_k}{8} \sim N\left(0, \frac{0.00001}{8}\right)$

So, we have: $1 + \frac{\sum_{k=1}^{8} n_k}{8} \sim N\left(1, \frac{0.00001}{8}\right)$, which means $\mu = 1, \sigma = \sqrt{\frac{0.00001}{8}}$.

According to: $\mathrm{P}(\mathrm{R} < \mathrm{a}) = Q(\frac{|a-\mu|}{\sigma})$, So, we have: $\mathrm{P(R < a)} = Q\left(\frac{|0-1|}{\sqrt{\frac{0.00001}{8}}}\right) = Q(894.427191) = 0$

g) BER-SNR curve: