Step 5. Check the output result. What do the following terms mean?

[Exercise 1]

Report your output result by screenshots and explain the following terms (including how they are calculated) in the output result.

- Total Received Flit
- Total Received Packet
- Global Average Delay
- Network throughput
- Average IP throughput

```
Loading configuration from file "../config_examples/default_config.yaml"... Done
Loading power configurations from file "power.yaml"... Done
Reset for 1000 cycles...  done!
 Now running for 10000 cycles...
Noxim simulation completed. (11000 cycles executed)

% Total received packets: 1422
% Total received flits: 11374
% Received/Ideal flits Ratio: 0.987326
% Average wireless utilization: 0
% Global average delay (cycles): 11.4578
% Max delay (cycles): 61
% Network throughput (flits/cycle): 1.26378
% Average IP throughput (flits/cycle/IP): 0.0789861
% Total energy (J): 2.11555e-06
%       Dynamic energy (J): 1.40302e-07
%       Static energy (J): 1.97525e-06
```

Q1. Total Received Flit :

1. Flit 是 Flow control unit。
2. 而 Total Received Flit 是 simulation 的期間，成功收到的所有 flit 的數量。
3. 而計算方法為所有 flit 數量的加總。

Q2. Total Received Packet :

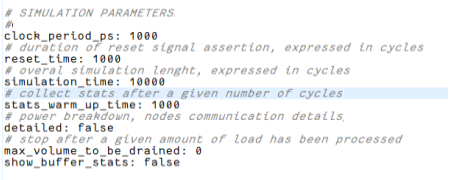
1. Data 通常被打包成 packet 進行傳輸，每個 packet 通常由多個 flit 組成。
2. 而 Total Received Packet 是 simulation 期間，成功收到的所有 packet 數量
3. 而計算方法為所有 packet 數量的加總。

Q3. Global Average Delay :

1. Global Delay 是指一個 packet 從 src 到 des 的時間
2. Global Average Delay 是指所有 Global Delay 的平均時間
3. 通常以 clock cycle 作為單位
4. 公式為 Global Average Delay = (所有 packet delay) / (所有 packet 數)

Q4. Network Throughput :

1. Throughput 是指單位時間內，能夠處理的平均資料數。
2. 用來衡量網路資料傳輸能力的重要指標
3. 通常以 bits/second 或是 bps 作為單位，而此處以 flits/second 當單位
4. 公式為 Network Throughput = (接收資料總單元數) / (模擬的總週期數)



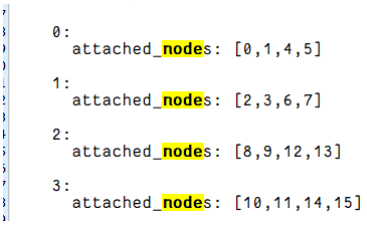
開始的 warm_up_time 1000cycles

所以總共剩餘 10000 – 1000 = 9000

➔ Network Throughput = total flits / total cycles = 11374 / 9000 = 1.26378

Q5. Average IP Throughput :

1. Average IP through 是指每個 IP 在單位時間內所處理的平均資料數。
2. 用來衡量每個 IP 是否公平運用的重要指標
3. 公式為 Average IP through = (Network Through / IP 總數量)



根據 config_examples.yaml 的內涵，

我們知道這裡有 4 x 4 共 16 個 IP node

拿剛剛的 throughput，再根據公式

➔ Average IP through = (Network Through / IP 總數量) = 1.26378 / 16 = 0.078986

[Exercise 2]

Create a `my_config.yaml` (from `default_config.yaml`), change modify some parameters and re-run the simulation by using:

```
$ ./noxim -config ../config_examples/my_config.yaml
```

Now, monitor the effect, and see how the following parameters will affect the output result mentioned in Exercise 1. Please also explain the reason.

- packet_size (min & max)
- packet_injection_rate
- simulation_time

```
min_packet_size: 8 packet_injection_rate: 0.01          # overal simulation lenght, expressed in cycles
max_packet_size: 8 probability_of_retransmission: 0.01 simulation_time: 10000
```

Default_config.yaml 的原始數據 ：

Max_packet_size = min_packet_size = 8

packet_injection_rate = 0.01

simulation_time = 10000

```
min_packet_size: 16
max_packet_size: 16
```

```
Loading configuration from file "../config_examples/my_config.yaml"... Done
Loading power configurations from file "power.yaml"... Done
Reset for 1000 cycles...  done!
 Now running for 10000 cycles...
Noxim simulation completed. (11000 cycles executed)

% Total received packets: 1418
% Total received flits: 22682
% Received/Ideal flits Ratio: 0.984462
% Average wireless utilization: 0
% Global average delay (cycles): 41.0275
% Max delay (cycles): 249
% Network throughput (flits/cycle): 2.52022
% Average IP throughput (flits/cycle/IP): 0.157514
% Total energy (J): 2.26431e-06
%       Dynamic energy (J): 2.89057e-07
%       Static energy (J): 1.97525e-06
```

當 max & min_packet_size 從 8 -> 16(上升)的時候，可以發現 ：

Total received packets 從 1422 -> 1418，**幾乎不變**

Total received flits 從 11374 -> 22682，可能因為 packet 的數量雖然沒變，但增加數量不多，而 min&max _packet_size 卻增加，**導致 Total flits 大幅上升。**

Global average delay 從 11.4578 -> 41.0275，可能因為 packet size 變大，致使每個 packet 在 router 處理時間更長，**因此增加了 delay**。

Network Throughput 從 1.26378 -> 2.52022，因為 total flits 增加，而 cycle 數依舊，**所以 Network Throughput 會增加**。

Average IP Throughput 從 0.0789861 -> 0.157514，因為 Throughput 增加，而 IP_node 數沒有改，**所以 Average IP Throughput 也跟著增加**。

```
min_packet_size: 2
max_packet_size: 2
```

```
Loading configuration from file "../config_examples/my_config.yaml"... Done
Loading power configurations from file "power.yaml"... Done
Reset for 1000 cycles...  done!
 Now running for 10000 cycles...
Noxim simulation completed. (11000 cycles executed)

% Total received packets: 1453
% Total received flits: 2906
% Received/Ideal flits Ratio: 1.00903
% Average wireless utilization: 0
% Global average delay (cycles): 7.47488
% Max delay (cycles): 18
% Network throughput (flits/cycle): 0.322889
% Average IP throughput (flits/cycle/IP): 0.0201806
% Total energy (J): 2.0125e-06
%       Dynamic energy (J): 3.72467e-08
%       Static energy (J): 1.97525e-06
```

當 max&min_packet_size 從 8 -> 2(**下降**)的時候，可以發現：

Total received packets 從 1422 -> 1453，**幾乎沒變**。

Total received flits 從 11374 -> 2906，可能因為 packet 的數量雖然沒變，但最大 packet_size 卻大幅下降，**至使 Total flits 大幅下降**。

Global average delay 從 11.4578 -> 7.47488，可能因為 packet size 變小，致使每個 packet 在 router 處理時間需要更快，**因此降低了 delay**。

Network Throughput 從 1.26378 -> 0.322889，因為 total flits 降低，而 cycle 數依舊，**所以 Network Throughput 會降低**。

Average IP Throughput 從 0.0789861 -> 0.0201806，因為 Throughput 降低，而 IP_node 數沒有改，**所以 Average IP Throughput 也跟著降低**。

```
packet_injection_rate: 0.005
```

```
Loading configuration from file "../config_examples/my_config.yaml"... Done
Loading power configurations from file "power.yaml"... Done
Reset for 1000 cycles...  done!
 Now running for 10000 cycles...
Noxim simulation completed. (11000 cycles executed)

% Total received packets: 741
% Total received flits: 5926
% Received/Ideal flits Ratio: 1.02882
% Average wireless utilization: 0
% Global average delay (cycles): 9.36707
% Max delay (cycles): 41
% Network throughput (flits/cycle): 0.658444
% Average IP throughput (flits/cycle/IP): 0.0411528
% Total energy (J): 2.0488e-06
%       Dynamic energy (J): 7.35523e-08
%       Static energy (J): 1.97525e-06
```

當 packet_injection_rate 從 0.01 -> 0.005(**下降**)的時候，可以發現：

Total received packets 從 1422 -> 719，可能因為 injection rate 下降，造成生成 packet 的頻率下降，**因此 packets 大幅下降(將近一半)**

Total received flits 從 11374 -> 5926，可能因為 injection rate 下降，造成生成 packet 的頻率下降，**致使 flits 大幅下降(將近一半)**

Global average delay 從 11.4578 -> 9.36707，可能因為 injection rate 下降，讓 packet 在 router 的 buffer 排隊時間減少，因此使得 **Global 的 delay 下降。**

Network Throughput 從 1.26378 -> 0.658444，因為 total flits 下降，而 cycle 數依舊，**所以 Network Throughput 會下降**。

Average IP Throughput 從 0.0789861 -> 0.411528，因為 Throughput 下降，而 IP_node 數沒有改，**所以 Average IP Throughput 也跟著下降。**

```
packet_injection_rate: 0.02
```

```
Loading configuration from file "../config_examples/my_config.yaml"... Done
Loading power configurations from file "power.yaml"... Done
Reset for 1000 cycles...  done!
 Now running for 10000 cycles...
Noxim simulation completed. (11000 cycles executed)

% Total received packets: 2894
% Total received flits: 23150
% Received/Ideal flits Ratio: 1.00477
% Average wireless utilization: 0
% Global average delay (cycles): 21.8386
% Max delay (cycles): 178
% Network throughput (flits/cycle): 2.57222
% Average IP throughput (flits/cycle/IP): 0.160764
% Total energy (J): 2.27081e-06
%       Dynamic energy (J): 2.95558e-07
%       Static energy (J): 1.97525e-06
```

當 packet_injection_rate 從 0.01 -> 0.02(**上升**)的時候，可以發現：

Total received packets 從 1422 -> 2894，可能因為 injection rate 上升，造成生成 packet 的頻率上升，**因此 packets 大幅上升(將近 2 倍)**

Total received flits 從 11374 -> 23150，可能因為 injection rate 上升，造成生成 packet 的頻率上升，**致使 flits 大幅上升(將近 2 倍)**

Global average delay 從 11.4578 -> 21.8386，可能因為 injection rate 上升，讓 packet 在 router 的 buffer 排隊時間增加，因此使得 **Global 的 delay 上升**。

Network Throughput 從 1.26378 ->2.57222，因為 total flits 上升，而 cycle 數依舊，**所以 Network Throughput 會上升**。

Average IP Throughput 從 0.0789861 -> 0.160764，因為 Throughput 上升，而 IP_node 數沒有改，**所以 Average IP Throughput 也跟著上升**。

```
simulation_time: 20000
```

```
% Total received packets: 2966
% Total received flits: 23729
% Received/Ideal flits Ratio: 0.975699
% Average wireless utilization: 0
% Global average delay (cycles): 11.8479
% Max delay (cycles): 83
% Network throughput (flits/cycle): 1.24889
% Average IP throughput (flits/cycle/IP): 0.0780559
% Total energy (J): 4.23584e-06
%       Dynamic energy (J): 2.85333e-07
%       Static energy (J): 3.9505e-06
```

當 simulation_time 從 10000 -> 20000(上升)的時候，可以發現：

Total received packets 從 1422 -> 2966，可能因為 simulation time 變成雙倍，使得 cycle 數變為原來的 2 倍，使得運送的 **packet 大概為原來 2 倍**

Total received flits 從 11374 -> 23150，可能因為 simulation time 變成雙倍，cycle 便 2 倍，使得 packet 變為 2 倍，**致使 flits 大幅上升(將近 2 倍)**

Global average delay 從 11.4578 -> 11.8479，可能因為只有 simulation time 上升， cycle 上升，不會影響任何原來的排隊時間，因此將近**沒變**。

Network Throughput 從 1.26378 ->1.24889，因為 total flits 上升，而 cycle 數也改變，**所以 Network Throughput 幾乎沒變**。

Average IP Throughput 從 0.0789861 -> 0.0780559，因為 Throughput 沒變，而 IP_node 數也沒有改，所以 **Average IP Throughput 也幾乎沒變。**

```
simulation_time: 5000
```

```
% Total received packets: 628
% Total received flits: 5005
% Received/Ideal flits Ratio: 0.977539
% Average wireless utilization: 0
% Global average delay (cycles): 11.7484
% Max delay (cycles): 66
% Network throughput (flits/cycle): 1.25125
% Average IP throughput (flits/cycle/IP): 0.0782031
% Total energy (J): 1.05847e-06
%       Dynamic energy (J): 7.08451e-08
%       Static energy (J): 9.87626e-07
```

當 simulation_time 從 10000 -> 5000(**下降**)的時候，可以發現：

Total received packets 從 1422 -> 628，可能因為 simulation time 變少 1/2 倍，使得 cycle 數變為原來的 1/2 倍，使得運送的 **packet 大概為原來 1/2 倍**

Total received flits 從 11374 -> 5005，可能因為 simulation time 變少 1/2 倍，cycle 變 1/2 倍，使得 packet 變為 1/2 倍，致使 **flits 大幅下降(將近 1/2 倍)**

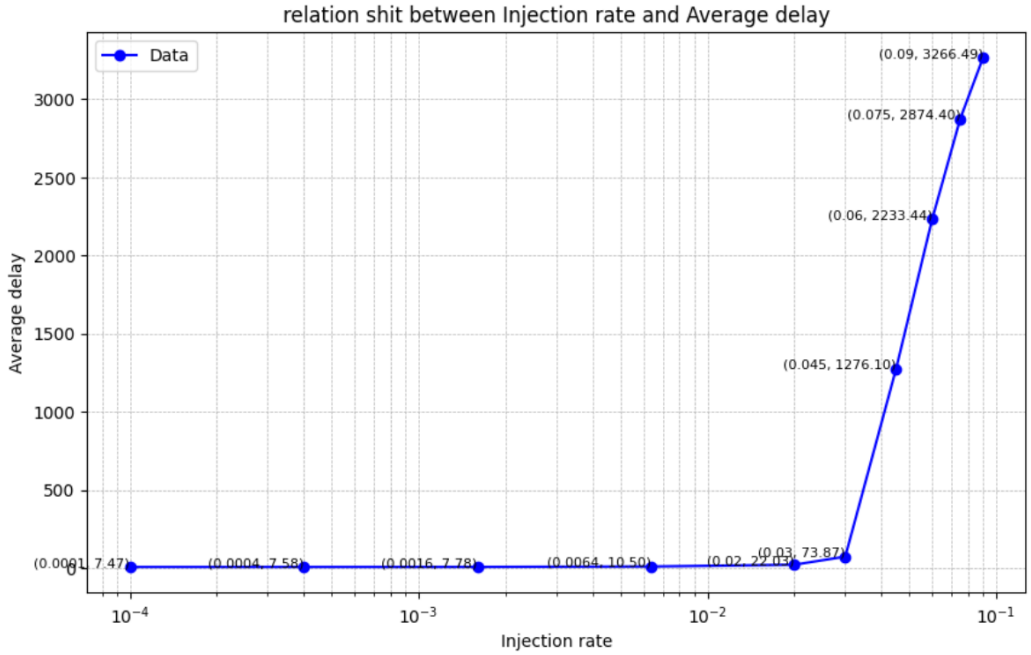
Global average delay 從 11.4578 -> 11.7484，可能因為只有 simulation time 下降， cycle 下降，不會影響任何原來的排隊時間，因此**將近沒變。**

Network Throughput 從 1.26378 -> 1.25125，因為 total flits 下降 2 倍，而 cycle 數也下降 2 倍，所以 **Network Throughput 會跟原來很像。**

Average IP Throughput 從 0.0789861 -> 0.0782031，因為 Throughput 沒變，而 IP_node 數也沒有改，所以 **Average IP Throughput 幾乎沒變。**

[Exercise 3]

The quality of a NoC can be measured by its saturation point. Plot the curve showing the relationship between PIR and average delay and indicate the saturation point.

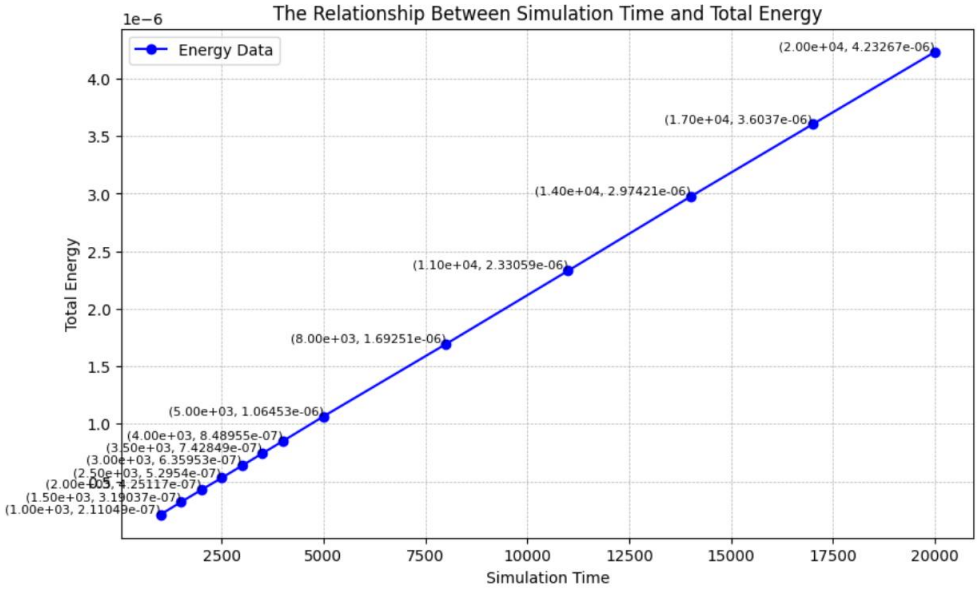


Saturation point = 0.03 左右，從那邊開始大幅上升，

且 flits 不太動，大概維持在 4500 左右。

[Exercise 4]

Try to find the optimal power configuration. You can plot figures showing the relationship between your selected parameters and energy to demonstrate the effect. And please also explain the reason of the phenomenon.



從圖表中可以觀察到，隨著 simulation time 的增加，總能量 Total Energy 也呈現線性增加的趨勢。

Simulation time 短，代表系統需要運行的 cycle 更少，因此整體的 energy 消耗較低。而 simulation time 長時，系統需要完成更多的計算，消耗的能量自然增加。