



NETWORK TRAFFIC EMULATION PROJECT

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SCENARIOS EVALUATED

Description

- **Single Matrix Scenario**

For a given value of M, fix the number of Monte Carlo runs for which the distributions of the metrics are stable (executing other Monte Carlo runs, the distribution does not change).

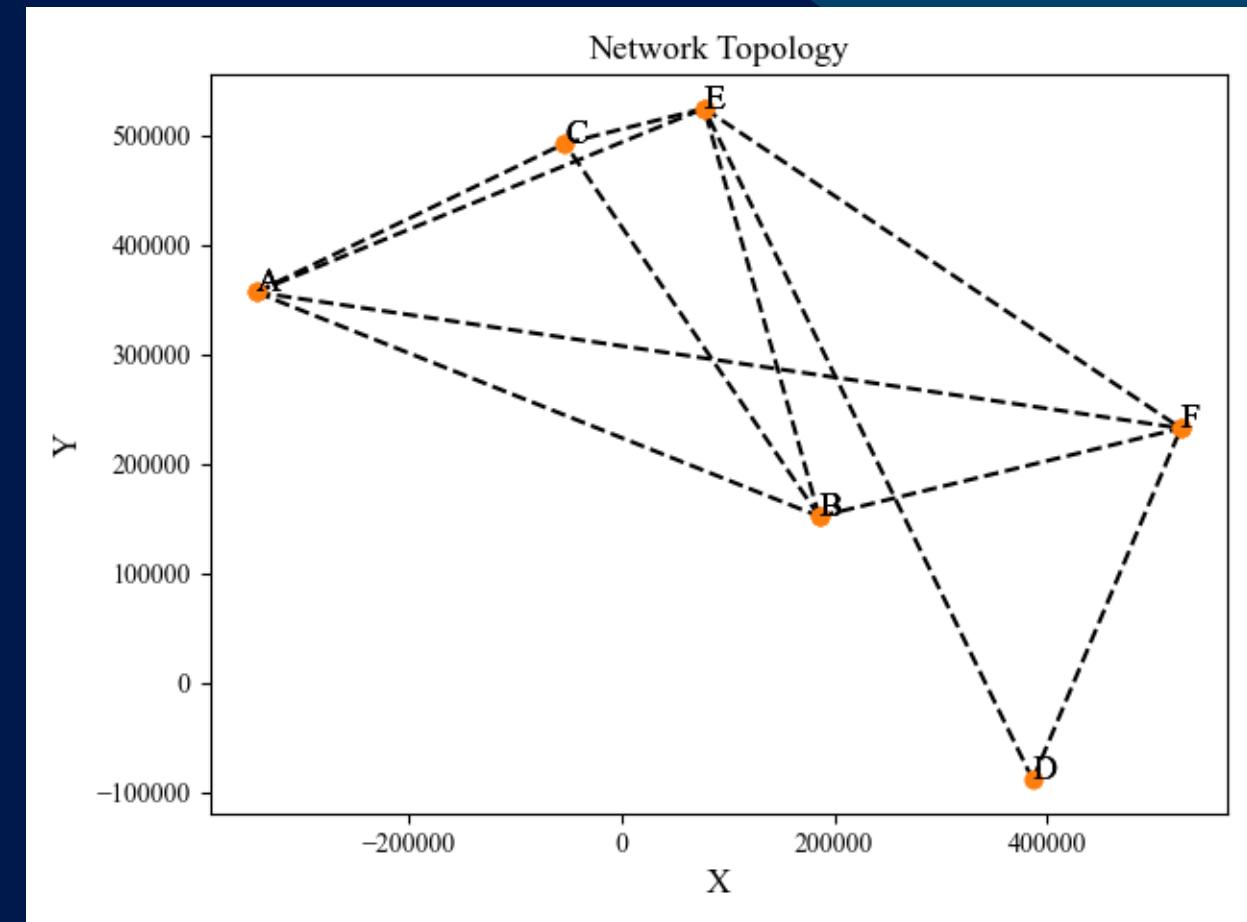
- **Congestion Scenario**

In this scenario, the traffic generated by the matrix will increase by an integer M. Therefore, the bit rate requested by each pair of nodes is given by $M*100$ Gbps.

NETWORK CHARACTERISTICS

These scenarios has been applied to 3 different network definitions, which are presented in the following *json* files.

- **Networks.json**
 - Connected Nodes
 - Position of the nodes
- **Full_Network.json**
 - Connected Nodes
 - Position of the nodes
 - Switching Matrix with the full channels available
- **Non_full_network.json**
 - Connected Nodes
 - Position of the nodes
 - Switching Matrix with not full channel available



Network Topology

SINGLE TRAFFIC MATRIX SCENARIO

CONSIDERATIONS

- A factor of M=4 was set to initialize the traffic matrix of each pair of nodes.
- A total of 50 Monte Carlo runs were conducted to estimate each parameter evaluated in the network.
- As the file *Networks.json* lacked the switching matrix, the emulator (code) proceeded to create one for each mode. For the cases of *full_network.json* and *not_full_network.json* files, the switching matrix was already pre-defined, therefore, the emulator operated on it.
- The number of **completed connections** was set to 30. This means that the connection between each pair of nodes in the Traffic Matrix has to be saturated.

FILES	NUMBER OF CHANNELS	TRANSCEIVERS STRATEGIES
Network.py	10	Fixed Rate Flexible Rate Shannon Rate
Full_network.py	6	Fixed Rate Flexible Rate Shannon Rate
Not_full_network.py	6	Fixed Rate Flexible Rate Shannon Rate

NOTE: Completed connections ≠ Accepted connections

TRANSMISSION RATE (R_b) given a $BER_t = 10^{-3}$

1. Fixed-Rate Transceiver Strategy (PM-QPSK Modulation)

$$R_b = \begin{cases} 100 \text{ Gbps} & \text{if } GSNR \geq 2 \operatorname{erfcinv}^2(2 BER) \frac{R_s}{B_n} \text{ Gbps} \\ 0 \text{ Gbps} & \text{otherwise} \end{cases}$$

2. Flex-Rate Transceiver Strategy (PM-QPSK, PM-8-QAM, PM-16QAM Modulations)

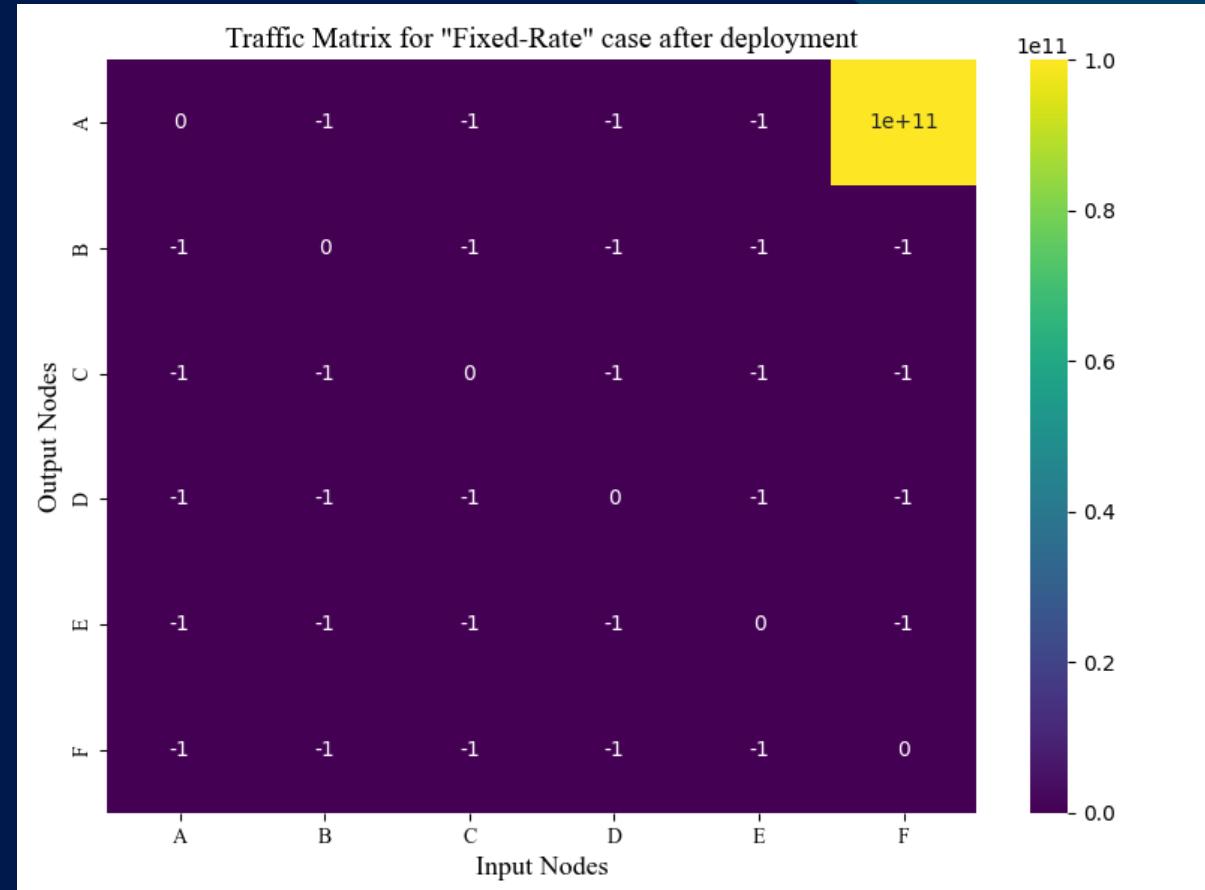
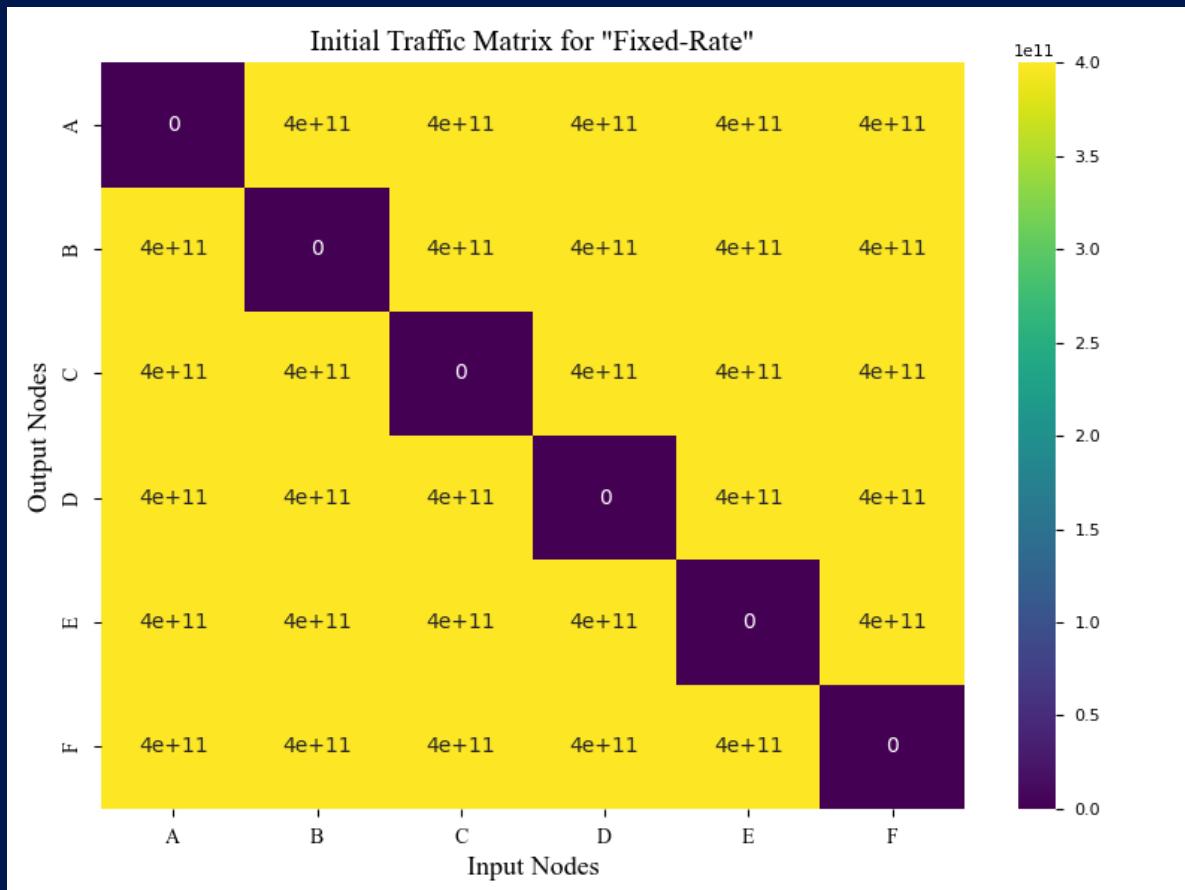
$$R_b = \begin{cases} 0 \text{ Gbps if } GSNR \leq 2 \operatorname{erfcinv}^2(2 BER) \frac{R_s}{B_n} \\ 100 \text{ Gbps if } 2 \operatorname{erfcinv}^2(2 BER_t) \frac{R_s}{B_n} \leq GSNR < \frac{14}{3} \operatorname{erfcinv}^2\left(\frac{3}{2} BER_t\right) \frac{R_s}{B_n} & \text{PM-QPSK} \\ 200 \text{ Gbps if } \frac{14}{3} \operatorname{erfcinv}^2\left(\frac{3}{2} BER_t\right) \frac{R_s}{B_n} \leq GSNR < 10 \operatorname{erfcinv}^2\left(\frac{8}{3} BER_t\right) \frac{R_s}{B_n} & \text{PM-8-QAM} \\ 400 \text{ Gbps if } GSNR > 10 \operatorname{erfcinv}^2\left(\frac{8}{3} BER_t\right) \frac{R_s}{B_n} & \text{PM-16-QAM} \end{cases}$$

3. Maximum Theoretical Shannon Rate (Ideal Gaussian Modulation)

$$R_b = 2R_s \log_2 \left(1 + \frac{GSNR \cdot R_s}{B_n} \right) \text{ Gbps}$$

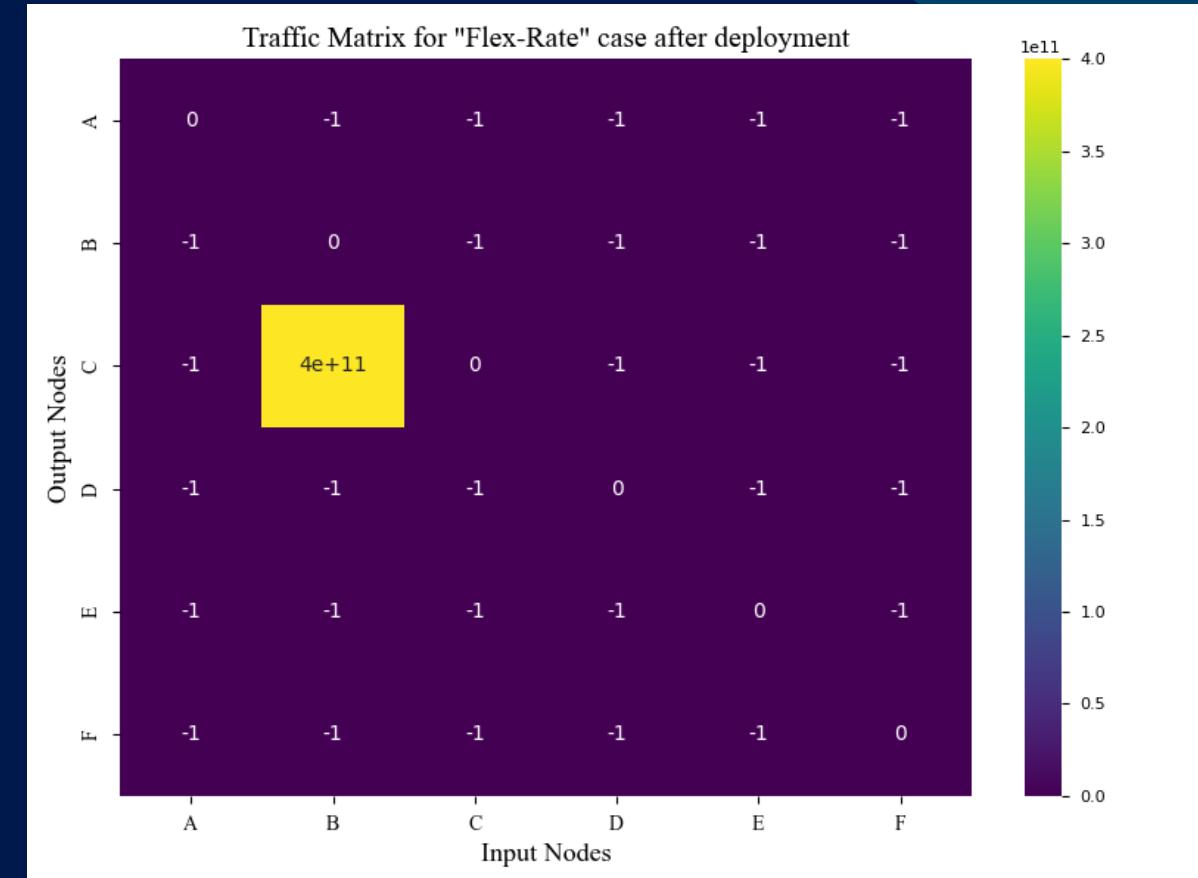
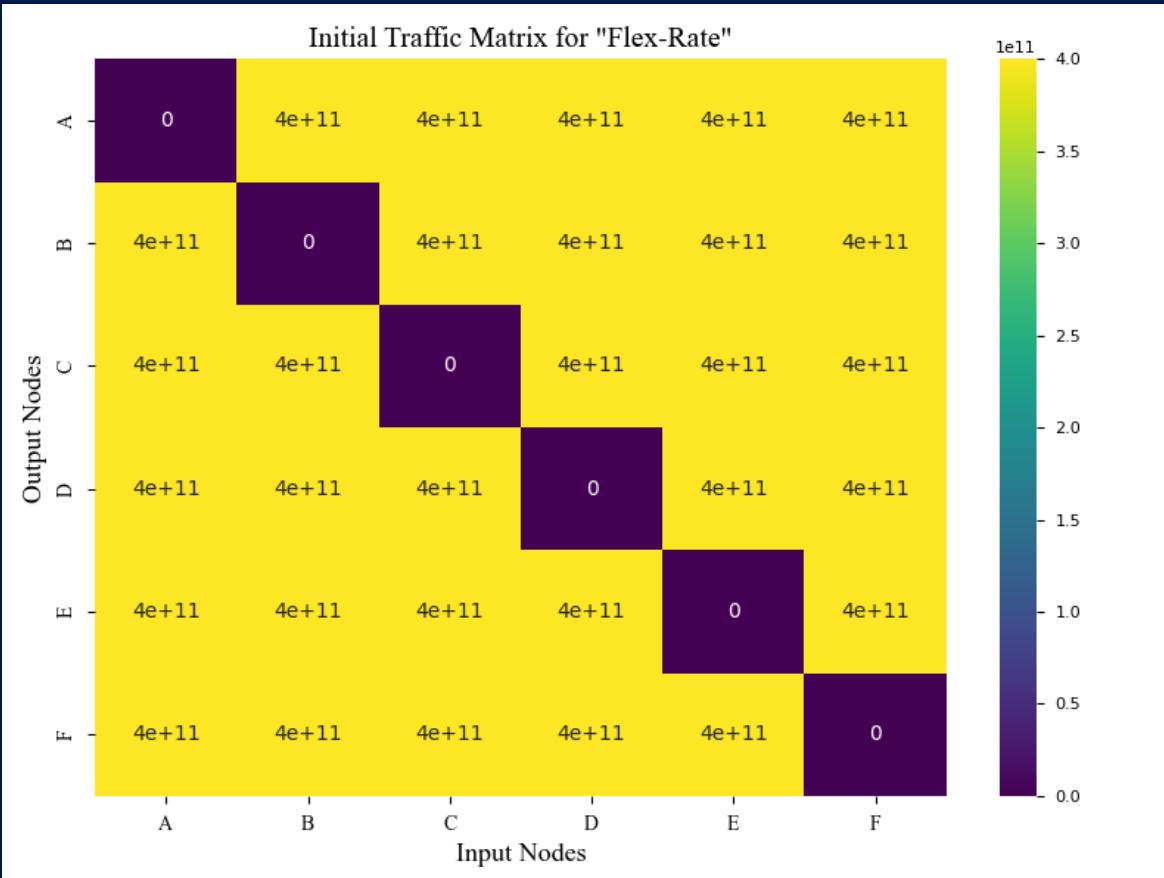
SINGLE TRAFFIC MATRIX SCENARIO RESULTS

USING NETWORK FILE



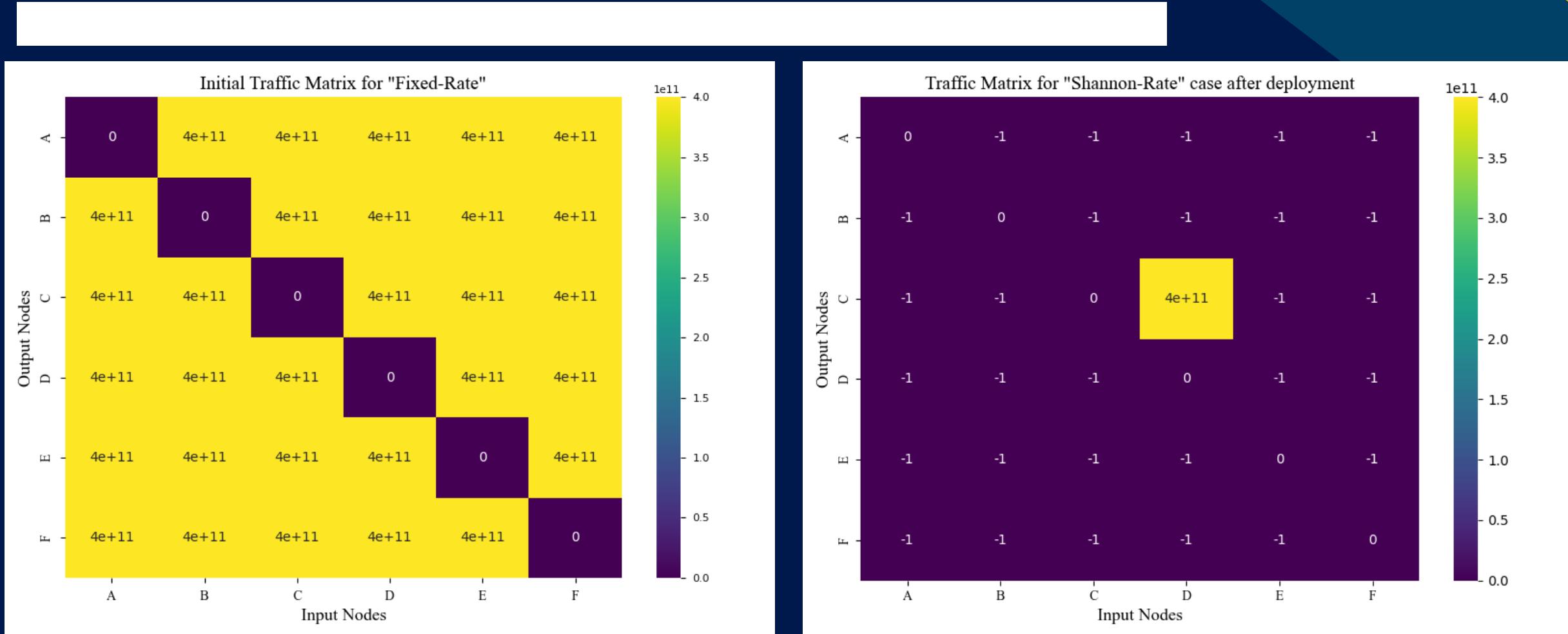
SINGLE TRAFFIC MATRIX SCENARIO RESULTS

USING NETWORK FILE



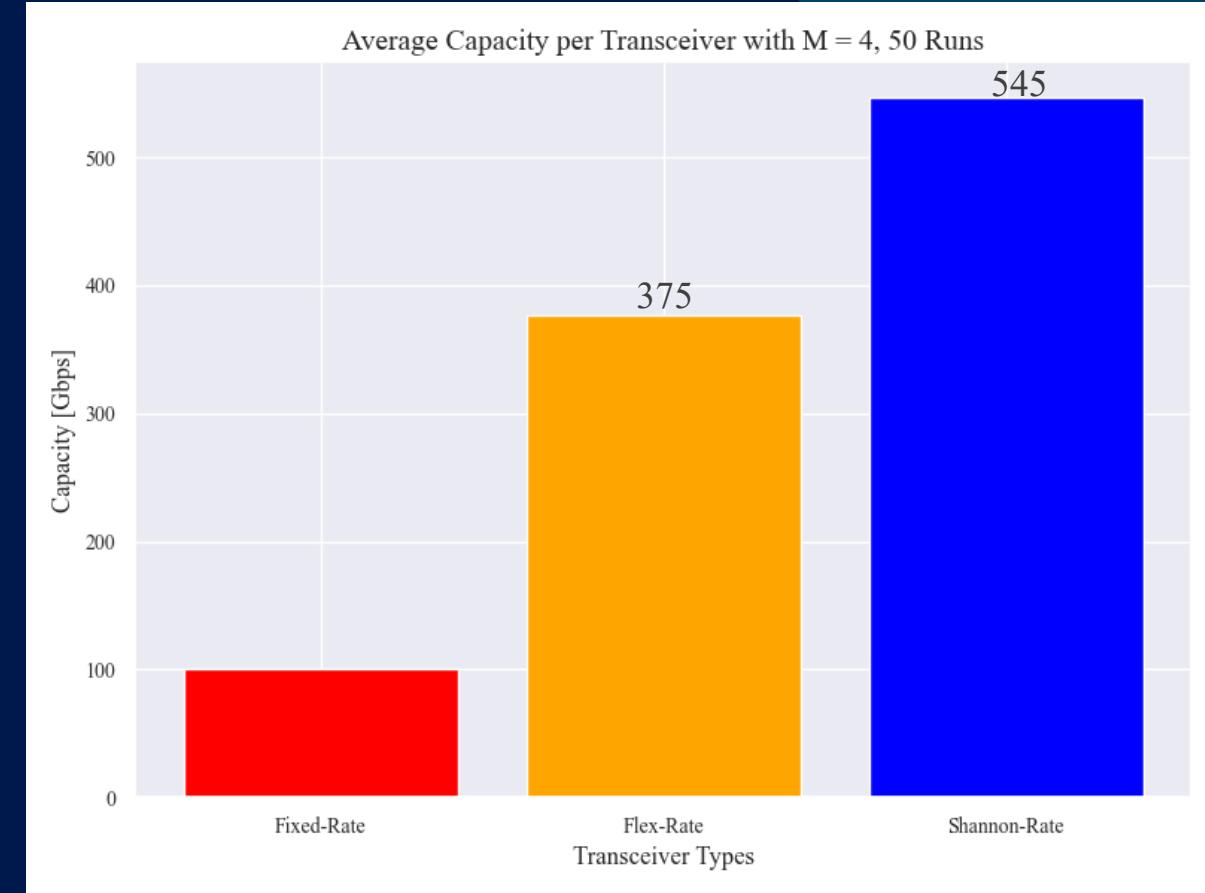
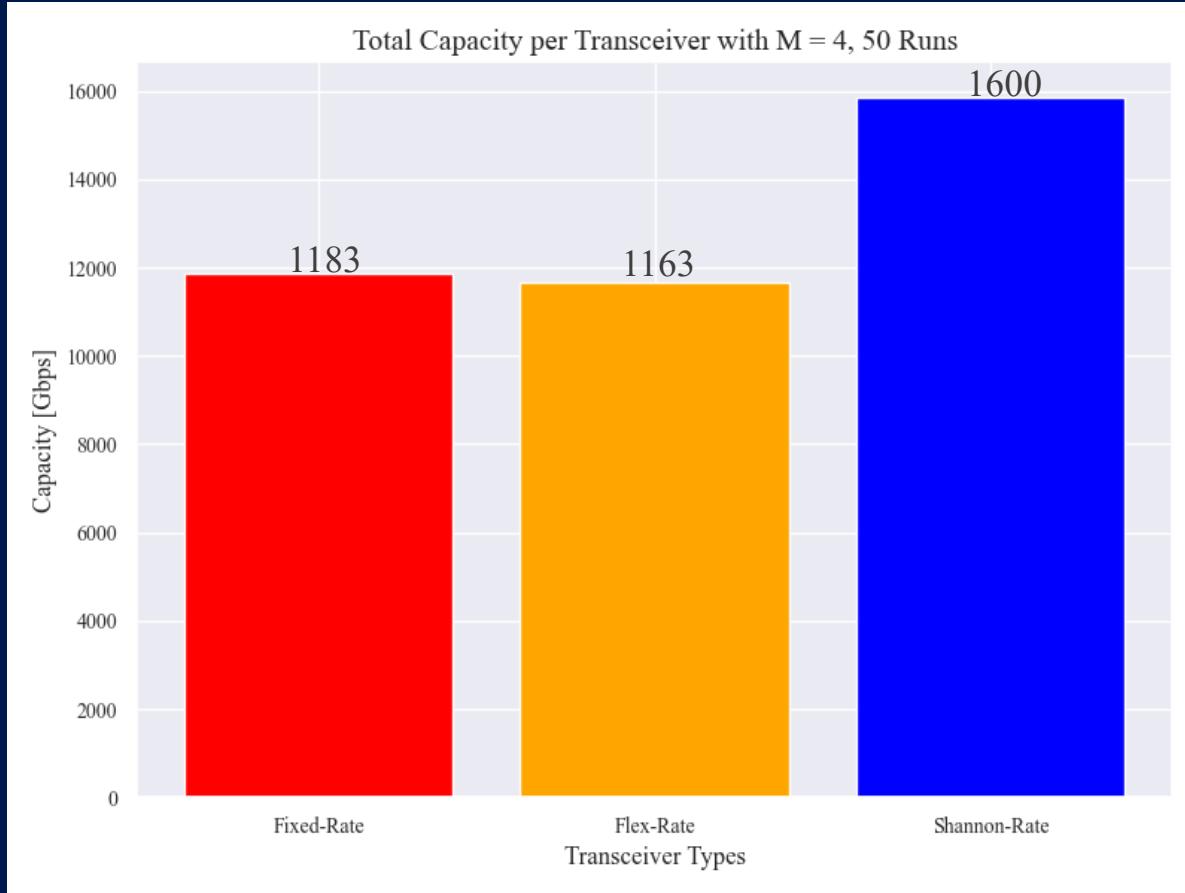
SINGLE TRAFFIC MATRIX SCENARIO RESULTS

USING NETWORK FILE

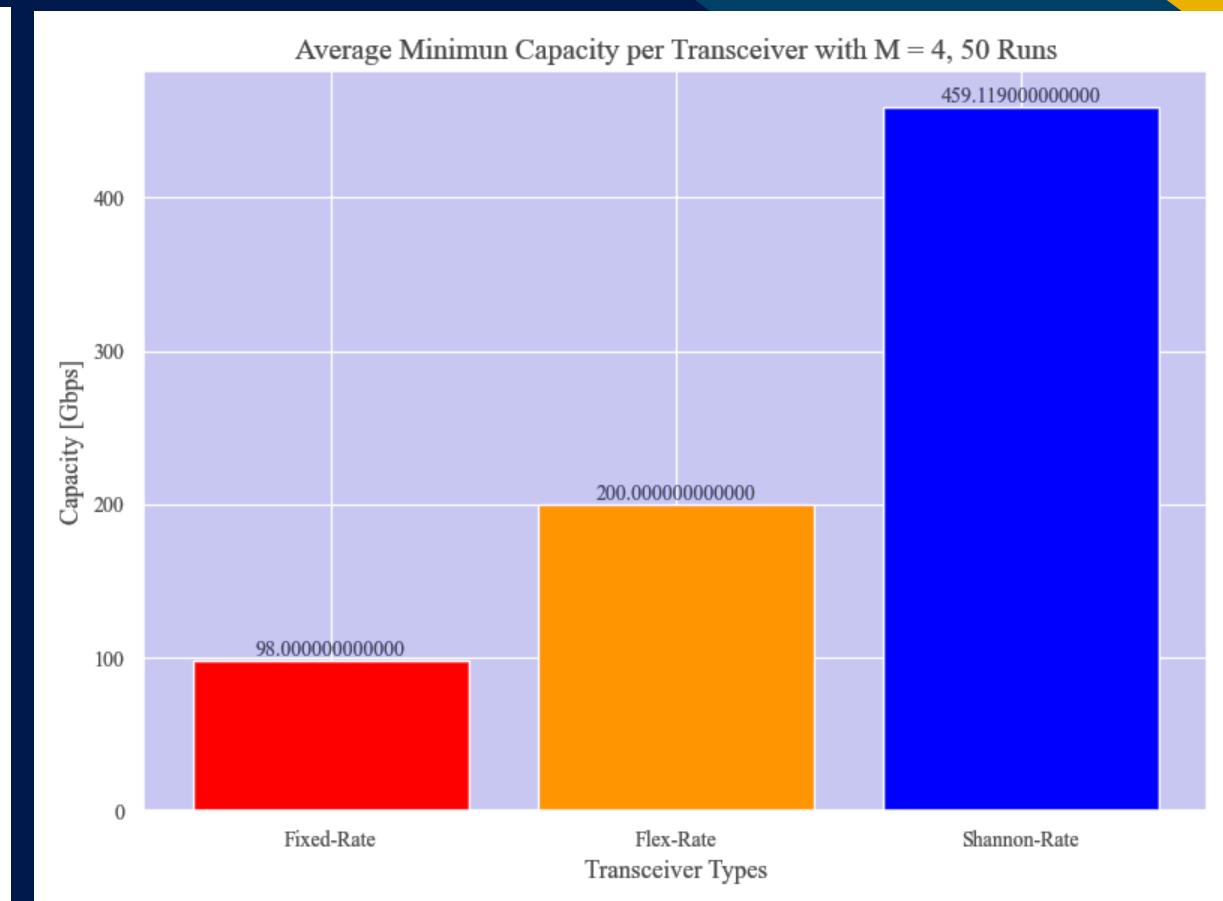
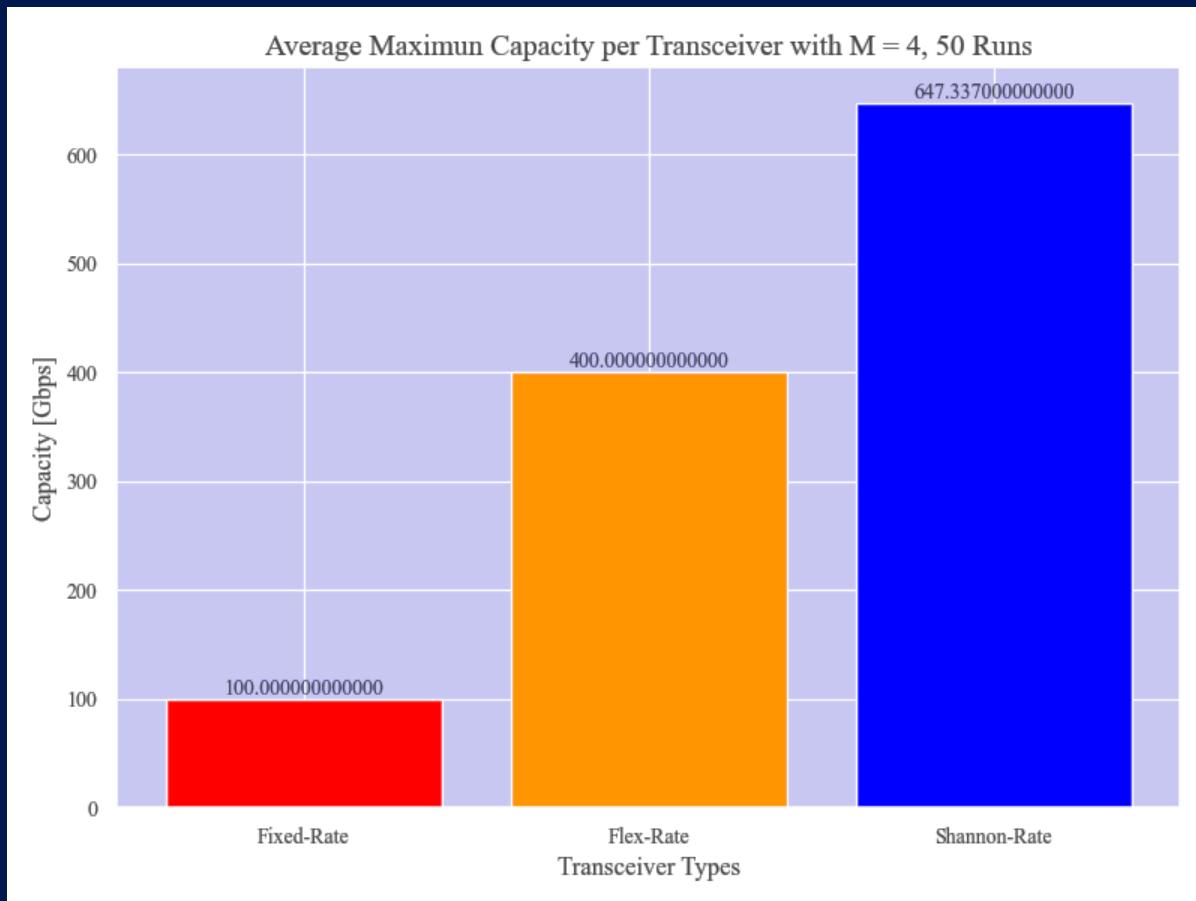


SINGLE TRAFFIC MATRIX SCENARIO RESULTS

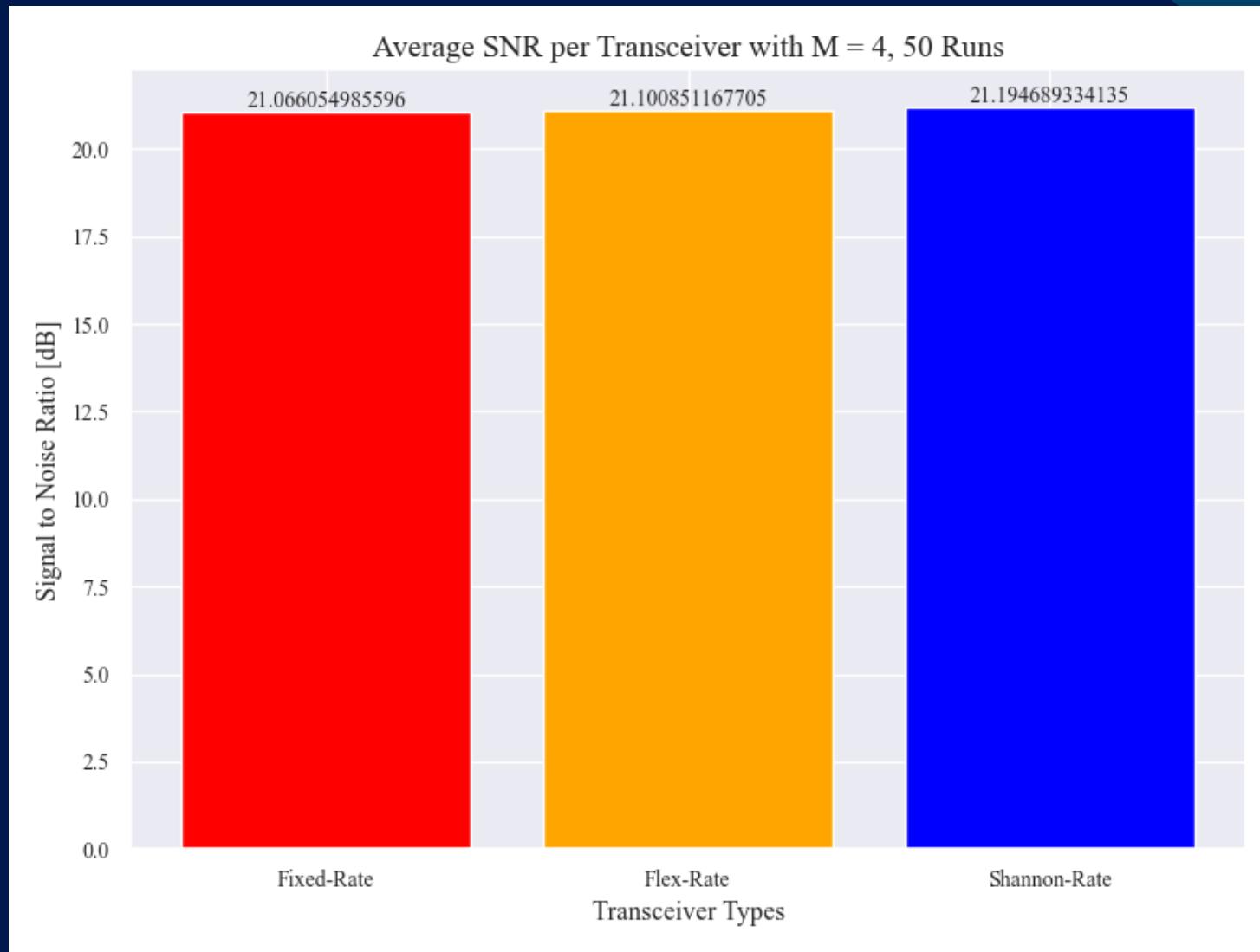
NETWORK.py definition



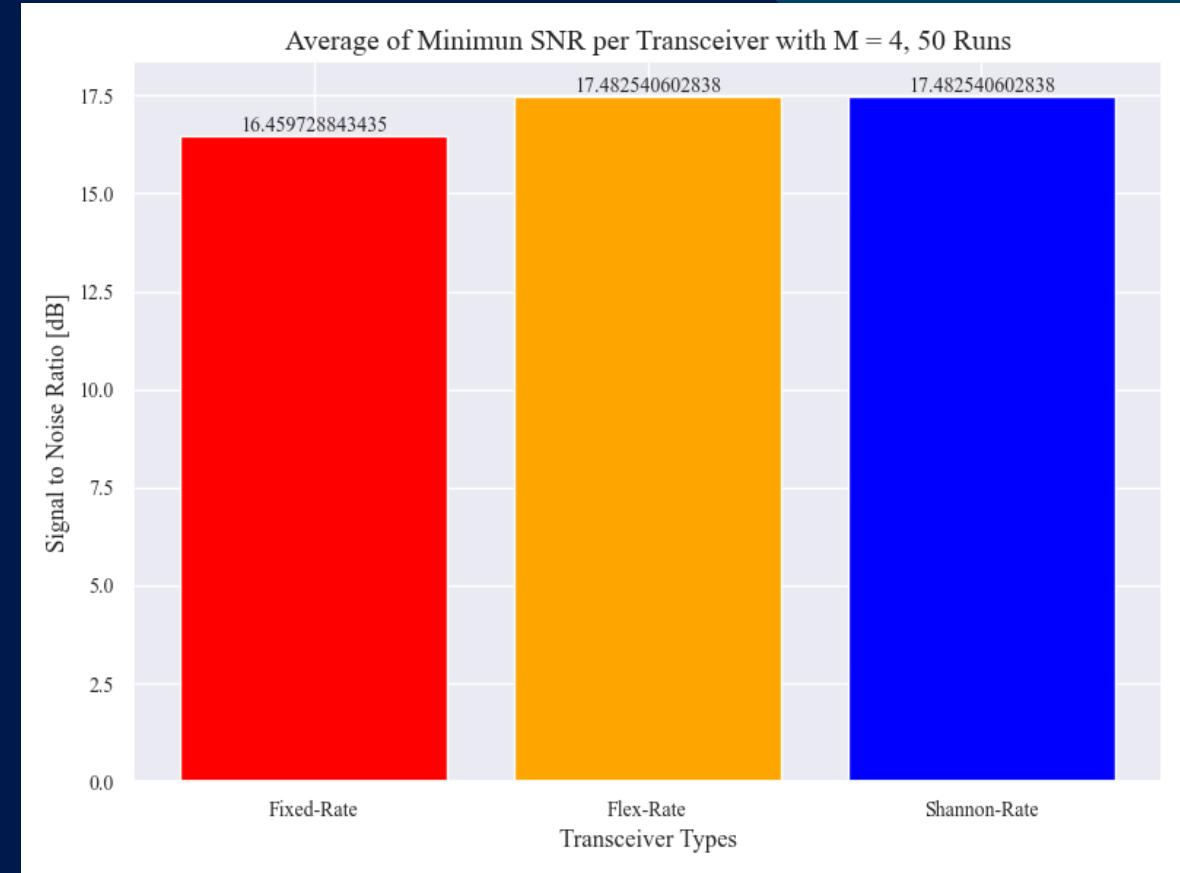
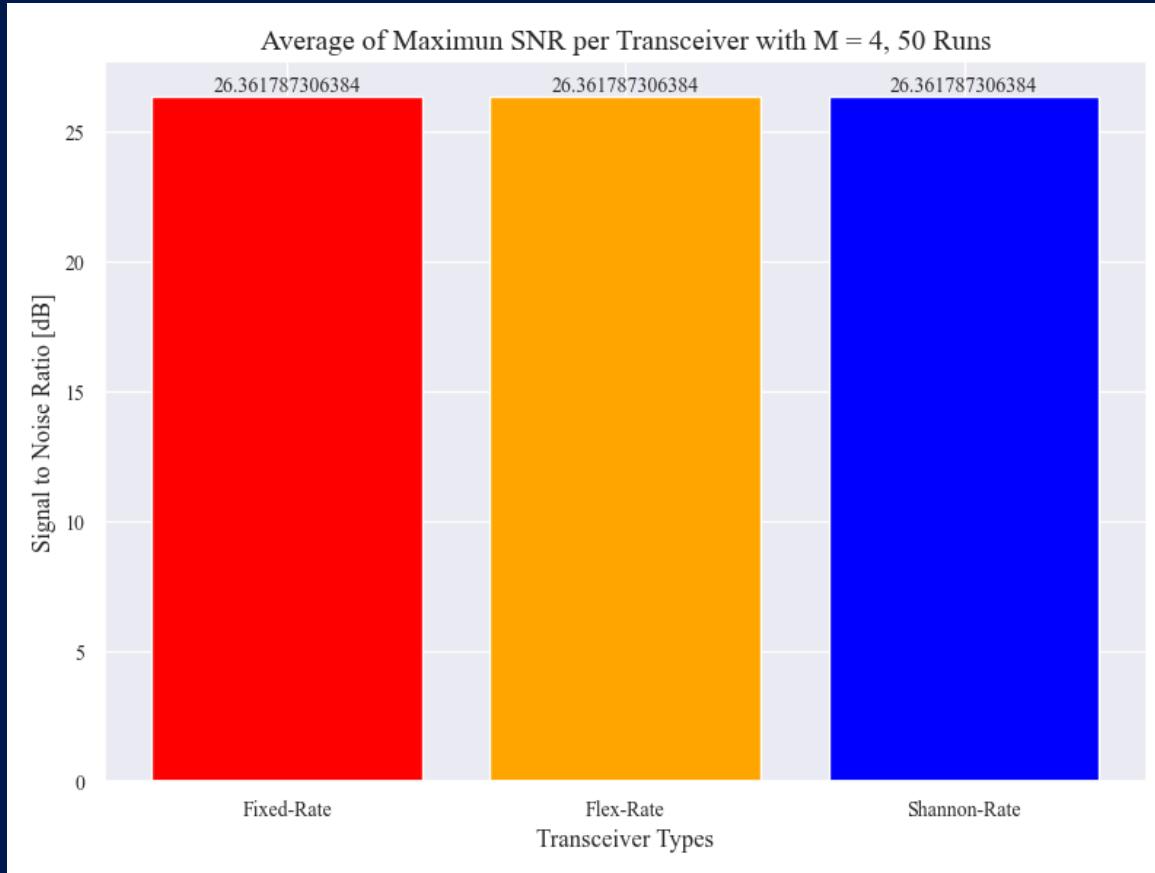
MIN AND MAXIMUN CAPACITY



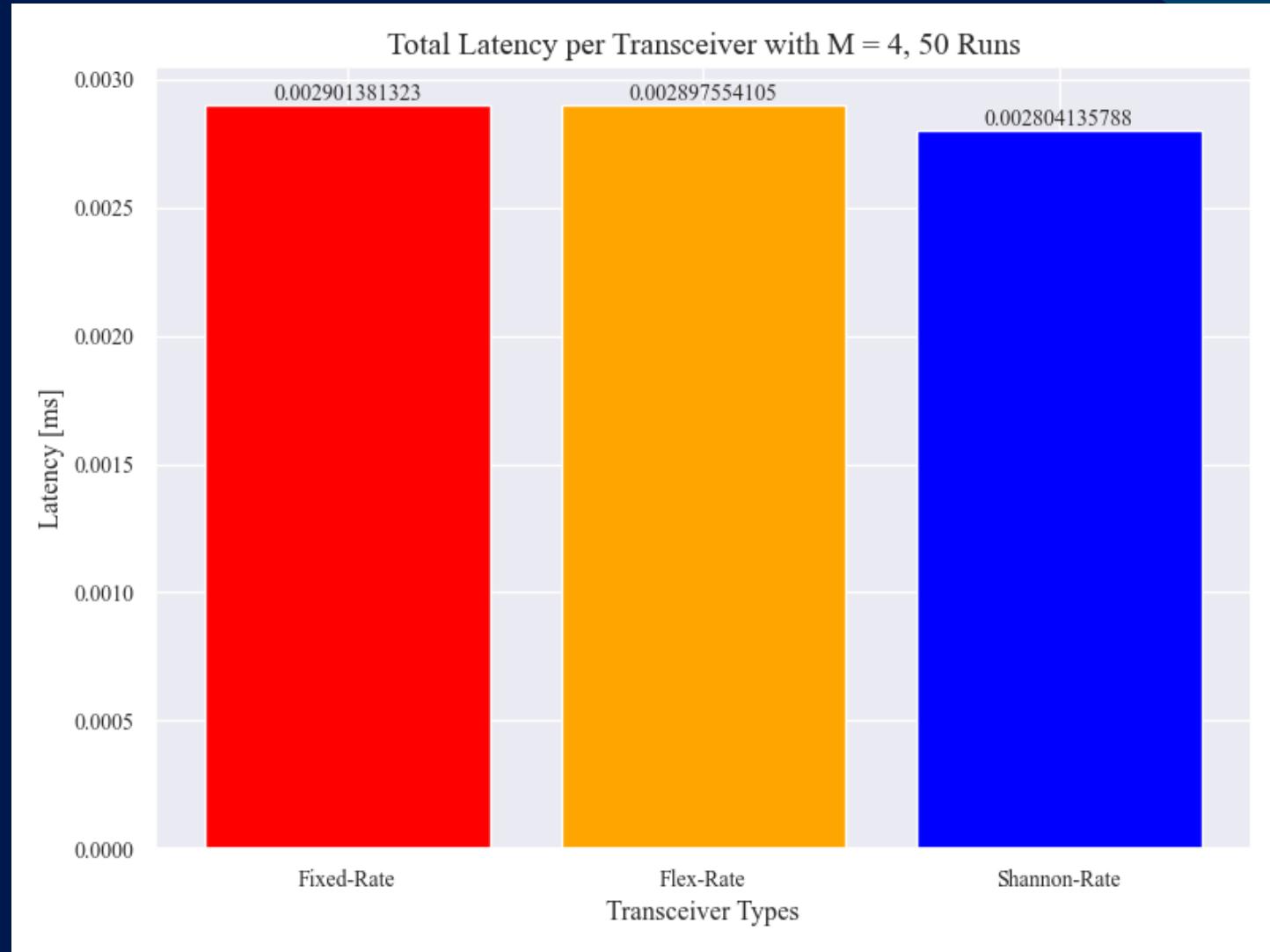
SIGNAL TO NOISE RATIO (SNR)



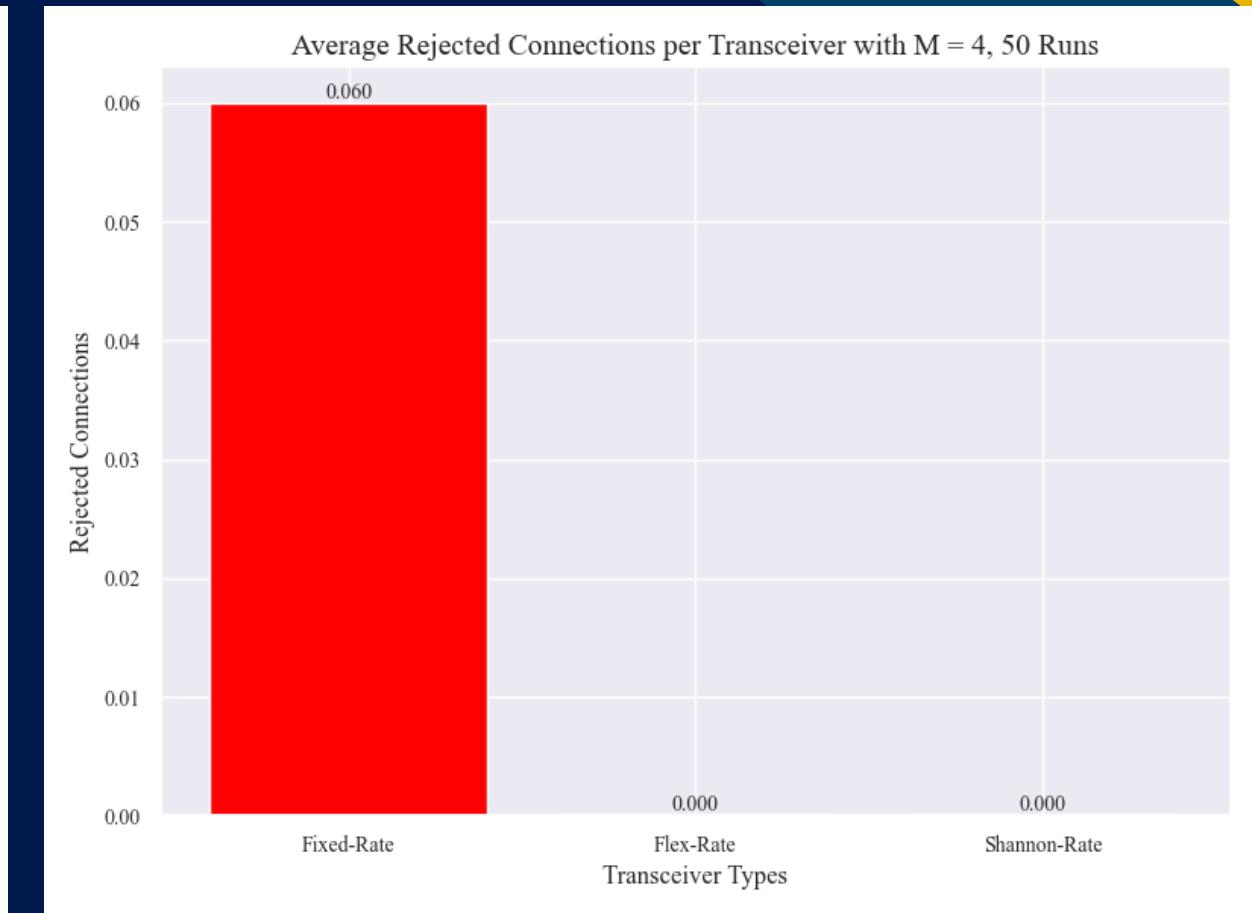
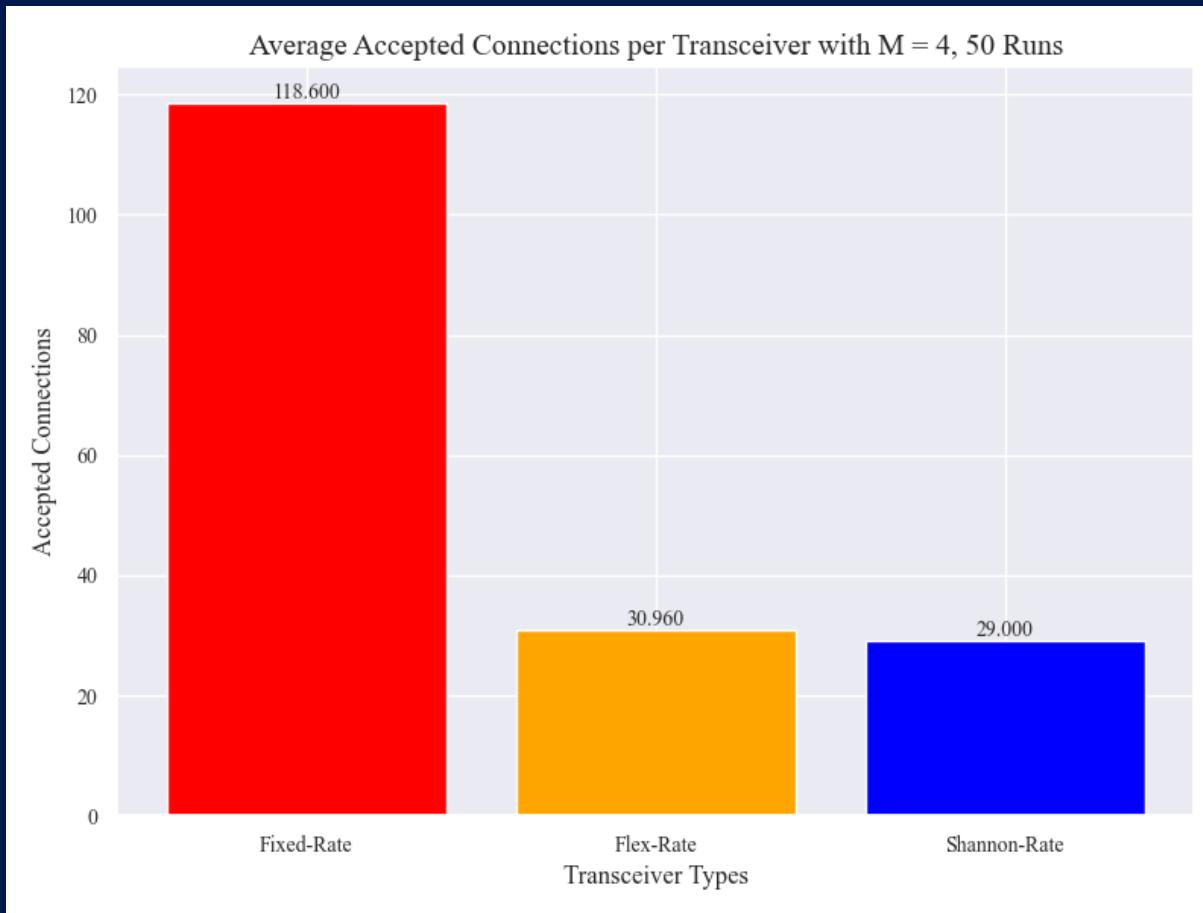
MAXIMUM AND MINIMUM SNR



LATENCY



ACCEPTED AND REJECTED CONNECTIONS

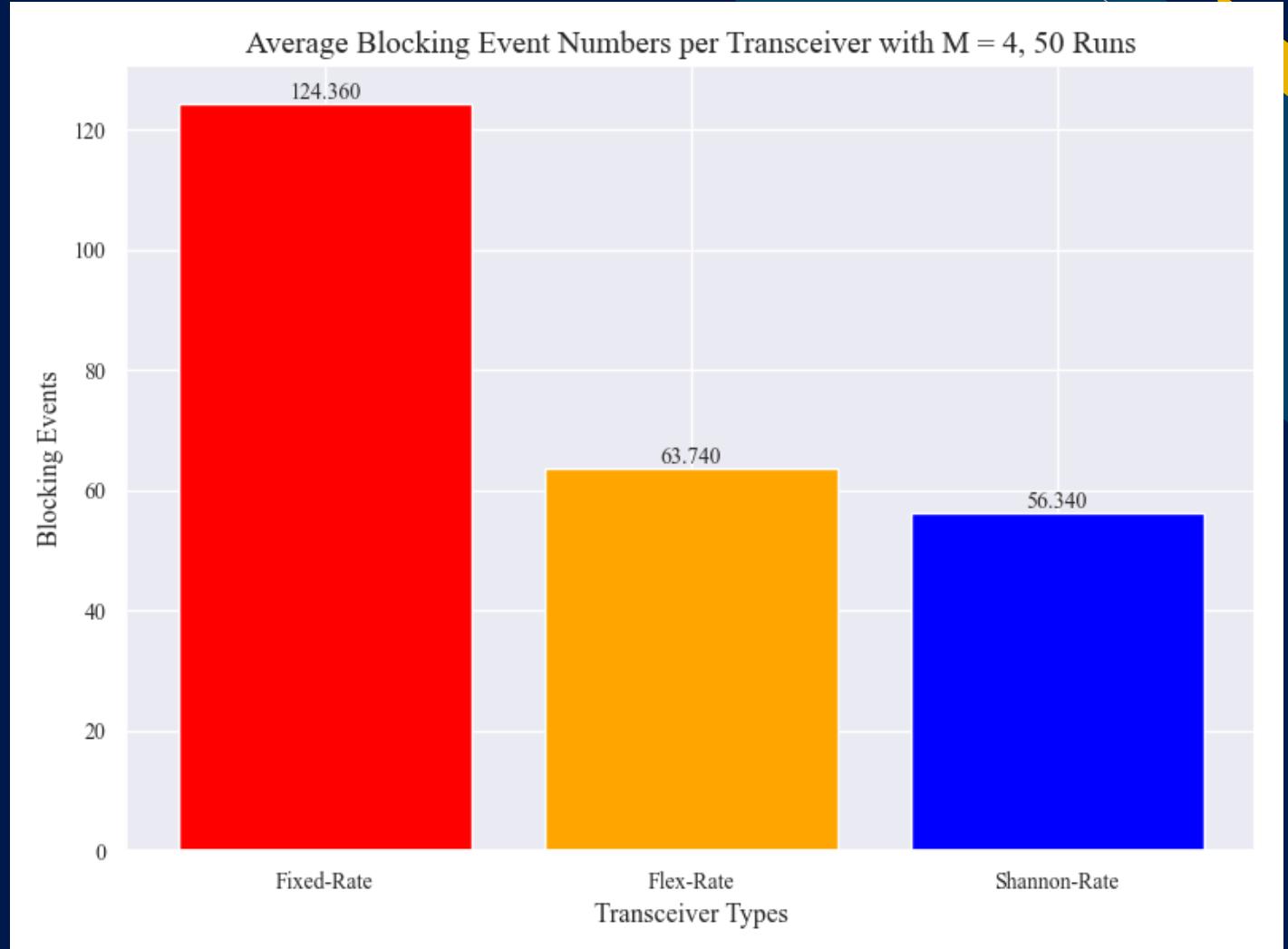


Connections were rejected because no path was available or the bit rate was 0.

BLOCKING EVENTS

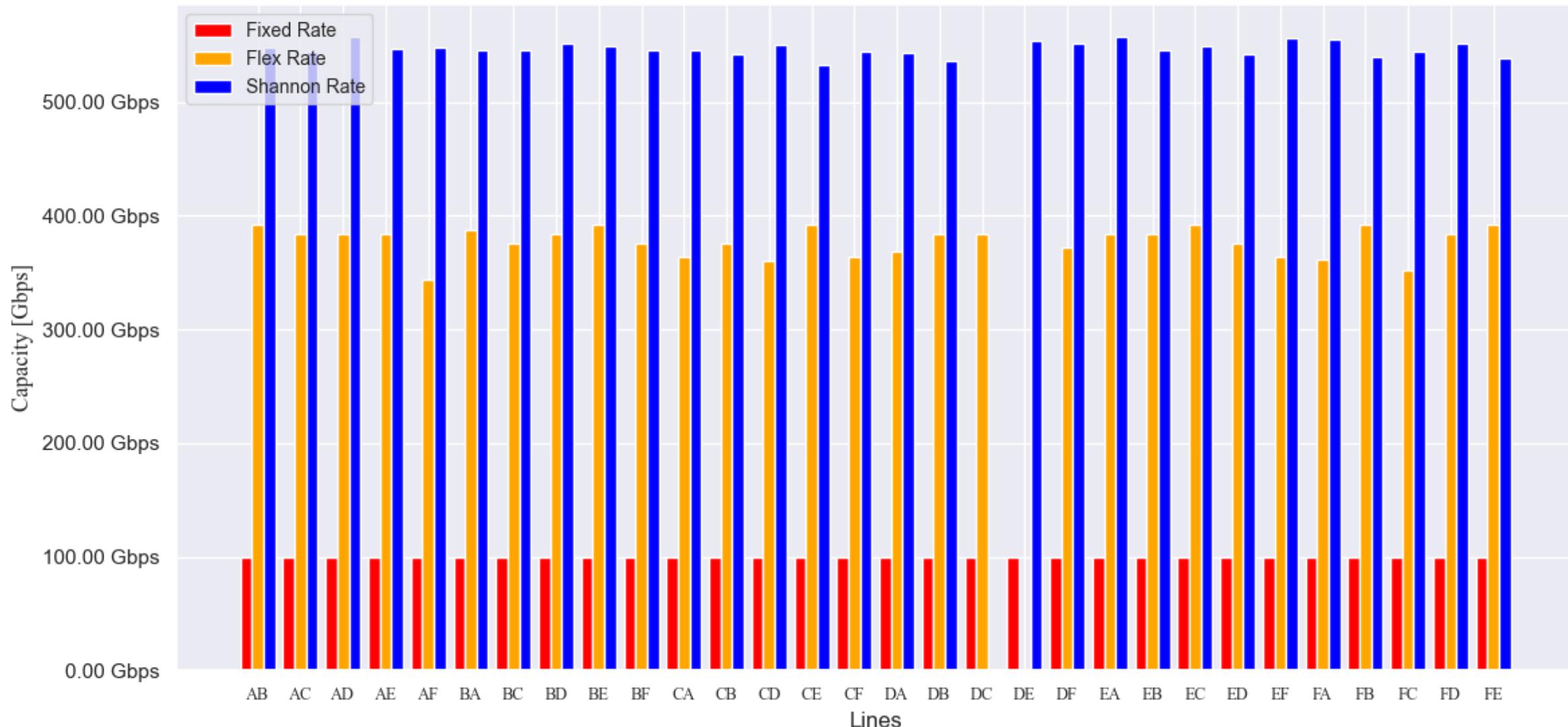
Not Traffic Matrix Assignment due to:

- Matrix saturation
- It was not possible to assign a suitable path for the connection



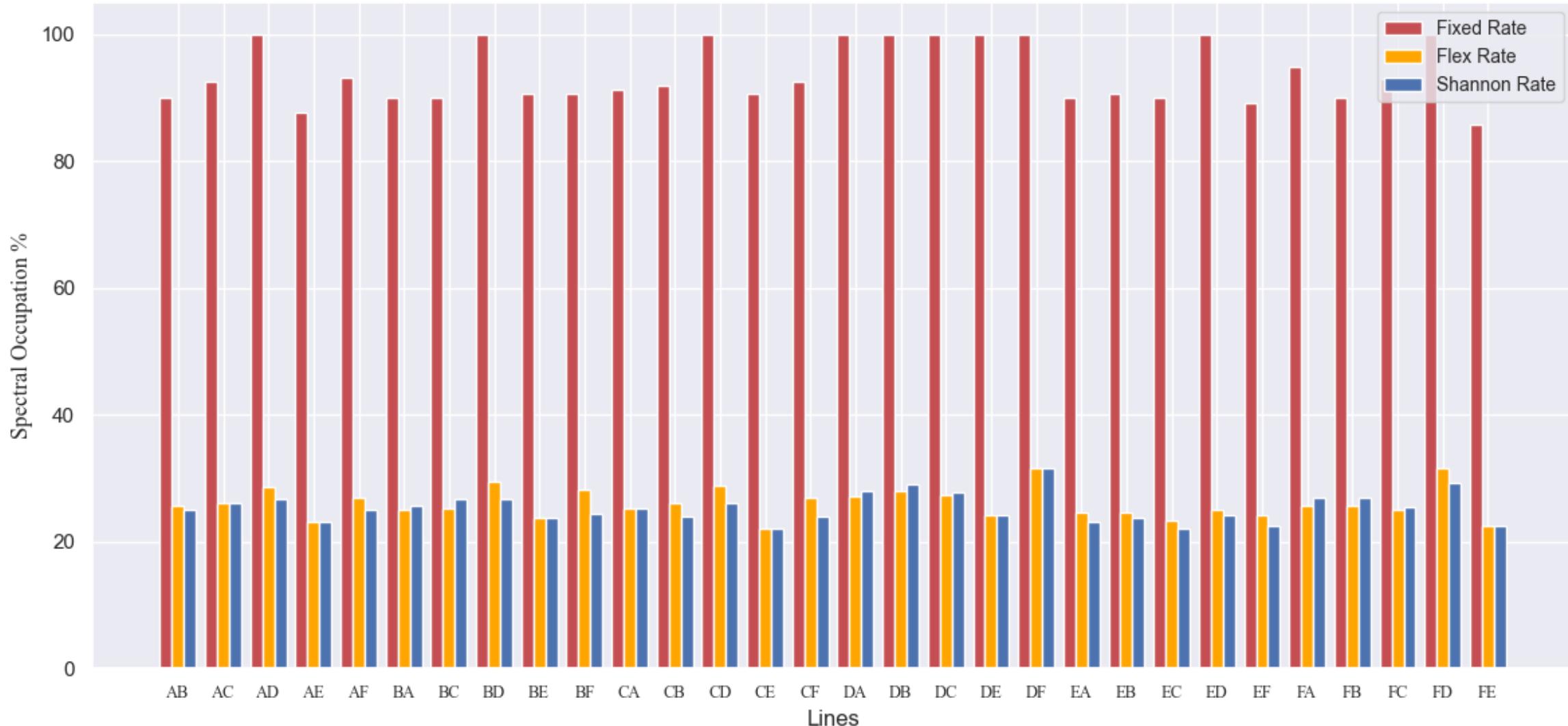
PER- LINK CAPACITY

Per-link Average Capacity for M=4, with MC=50



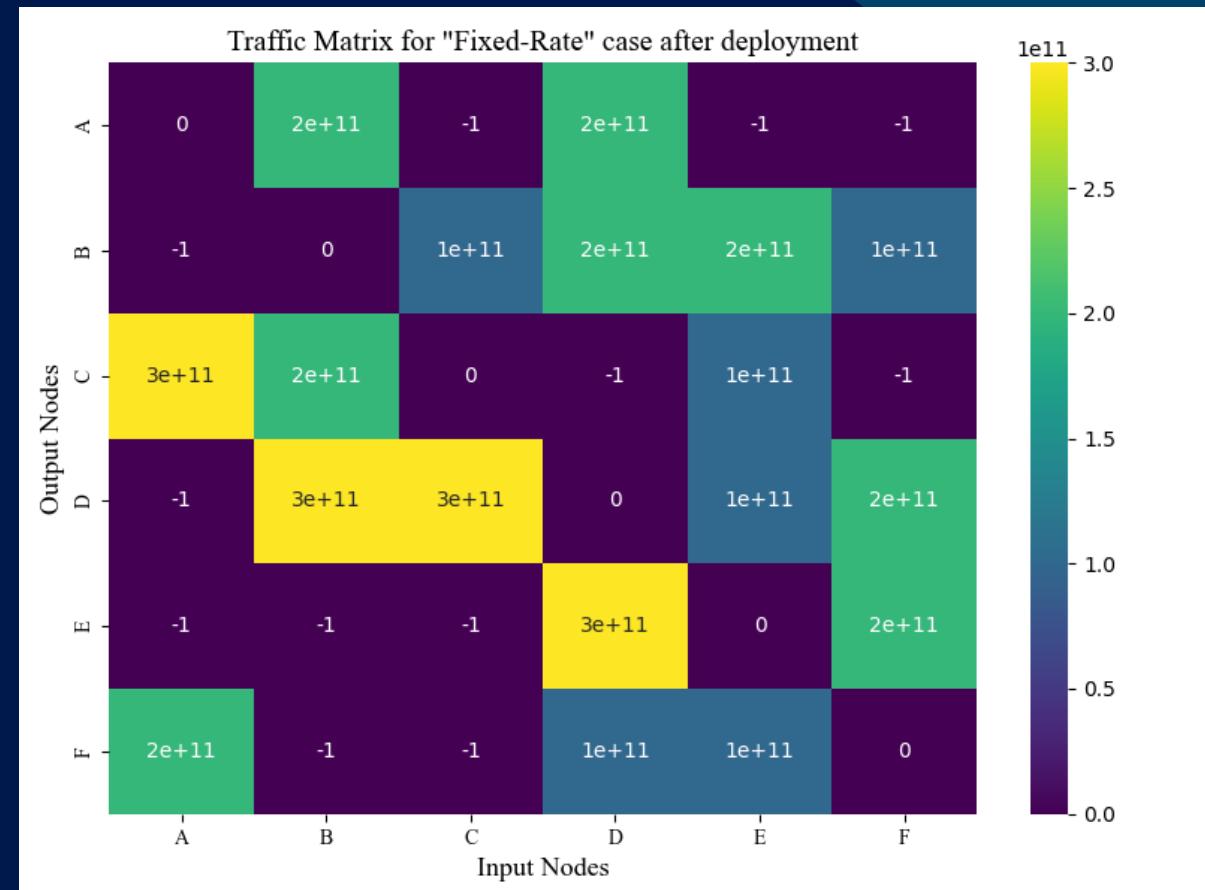
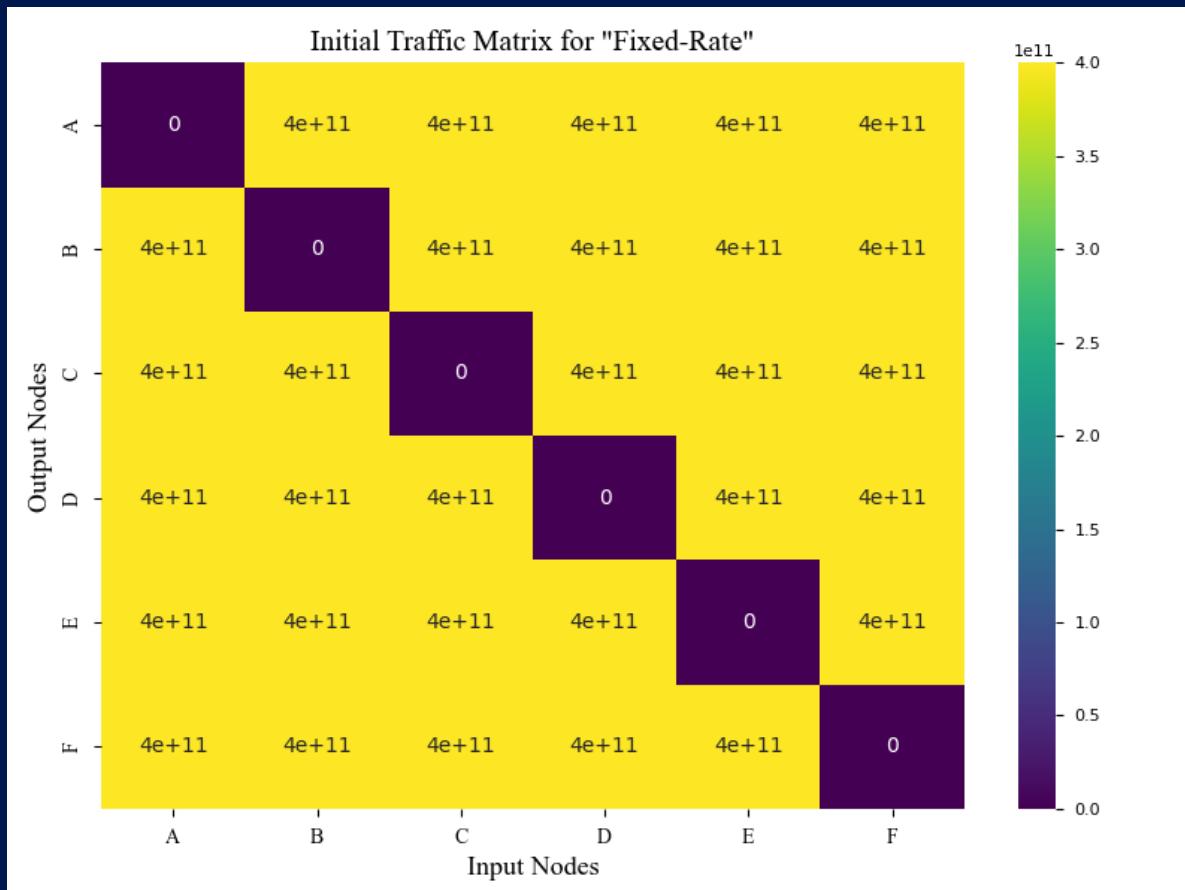
SPECTRAL OCCUPATION PER LINE

Single Matrix Scenario - Spectral occupation per Line for M=4



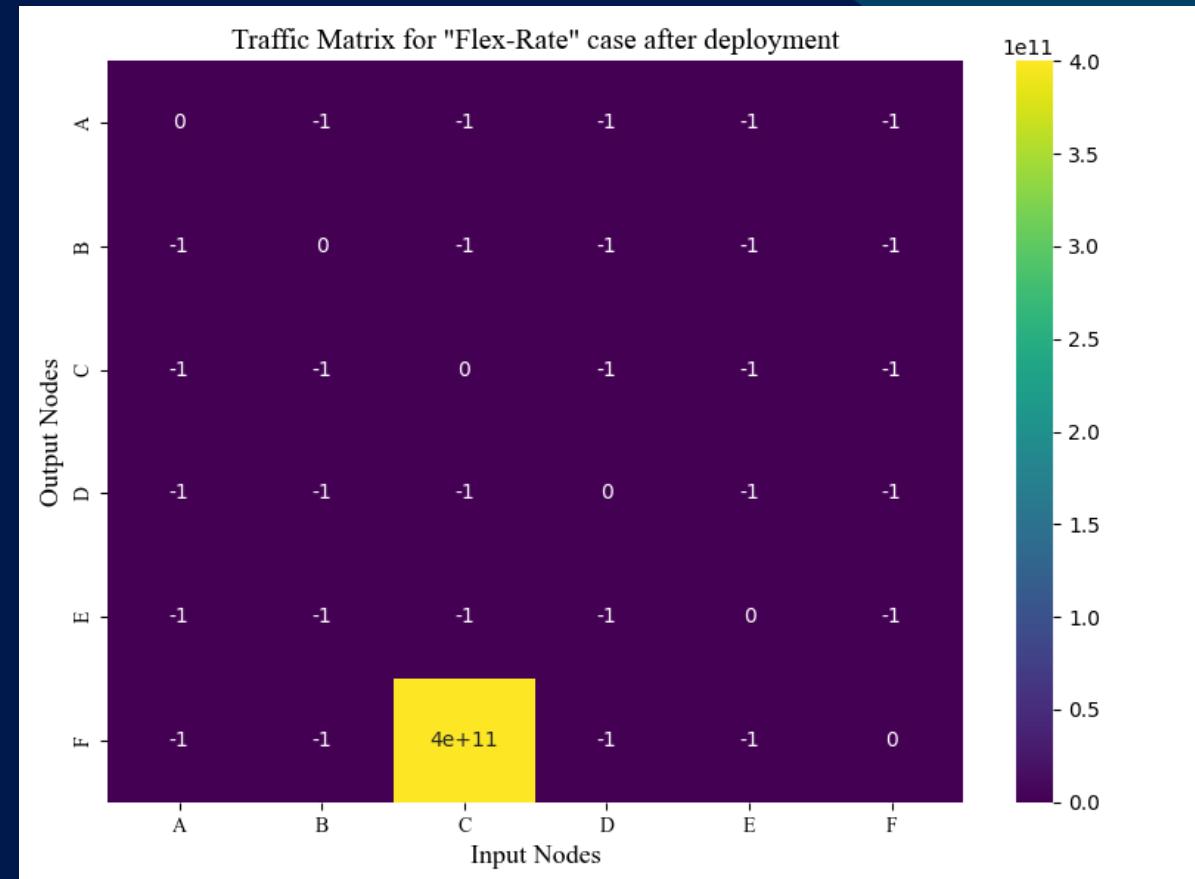
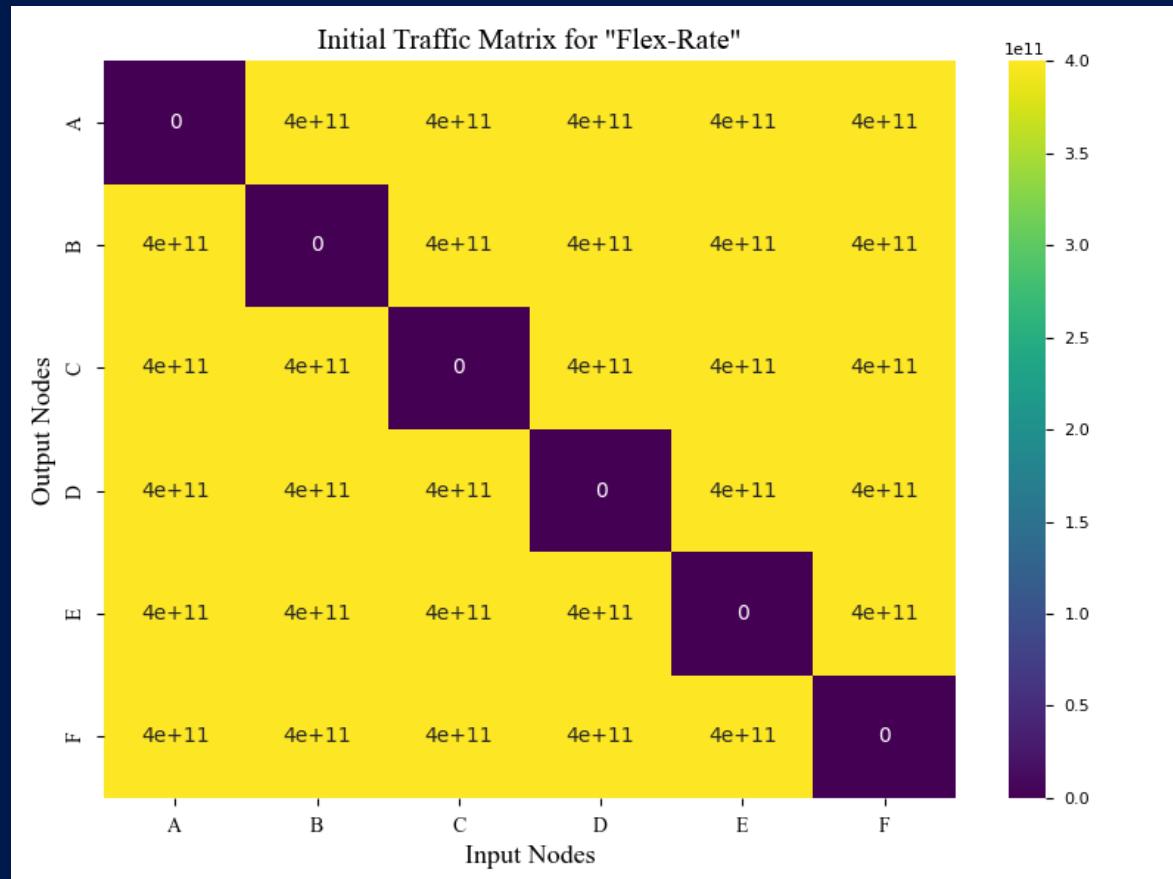
SINGLE TRAFFIC MATRIX SCENARIO RESULTS

USING *FULL_NETWORK* FILE



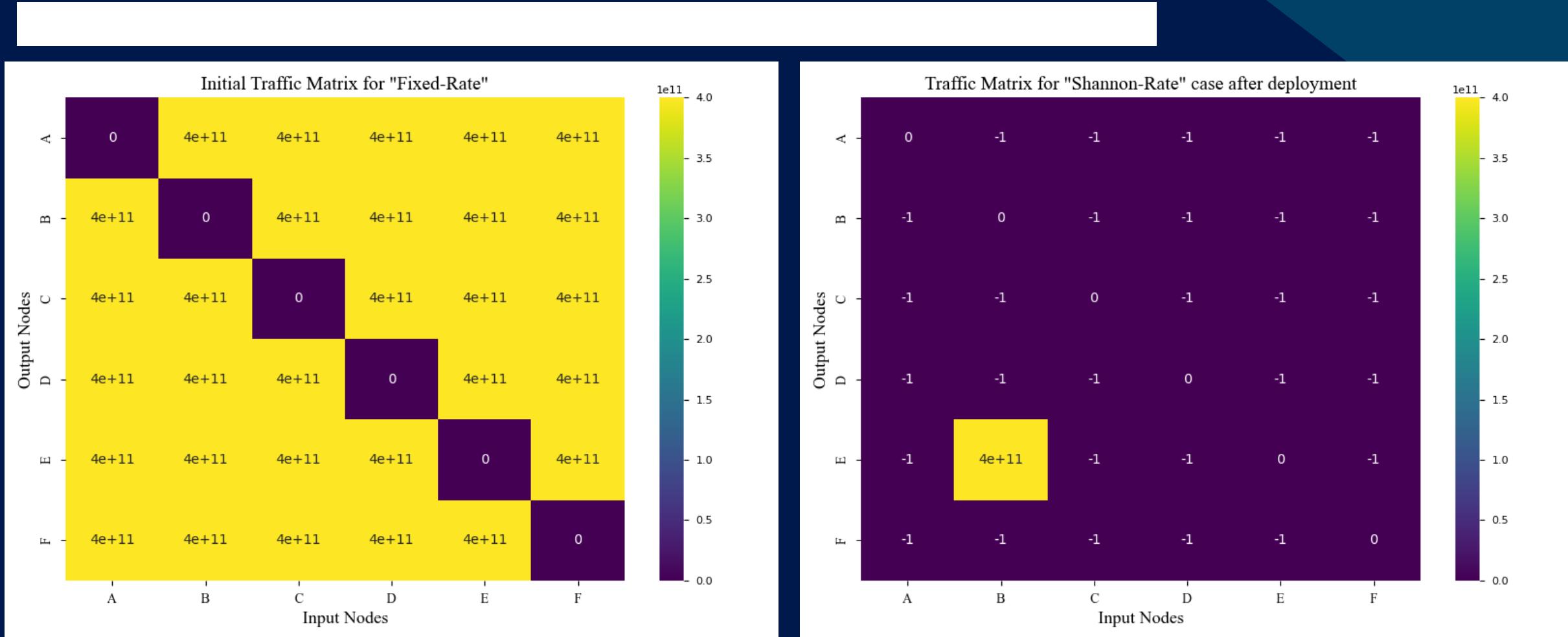
SINGLE TRAFFIC MATRIX SCENARIO RESULTS

USING *FULL_NETWORK* FILE

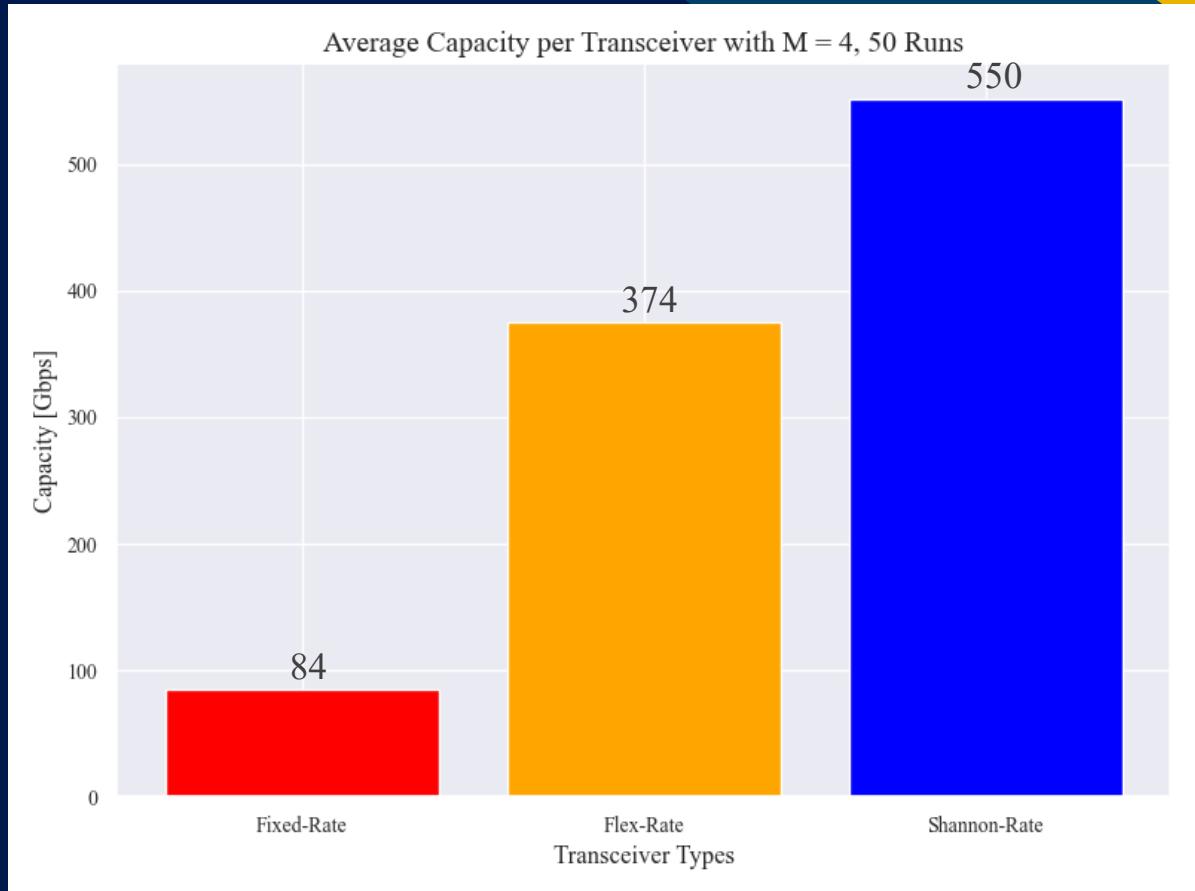
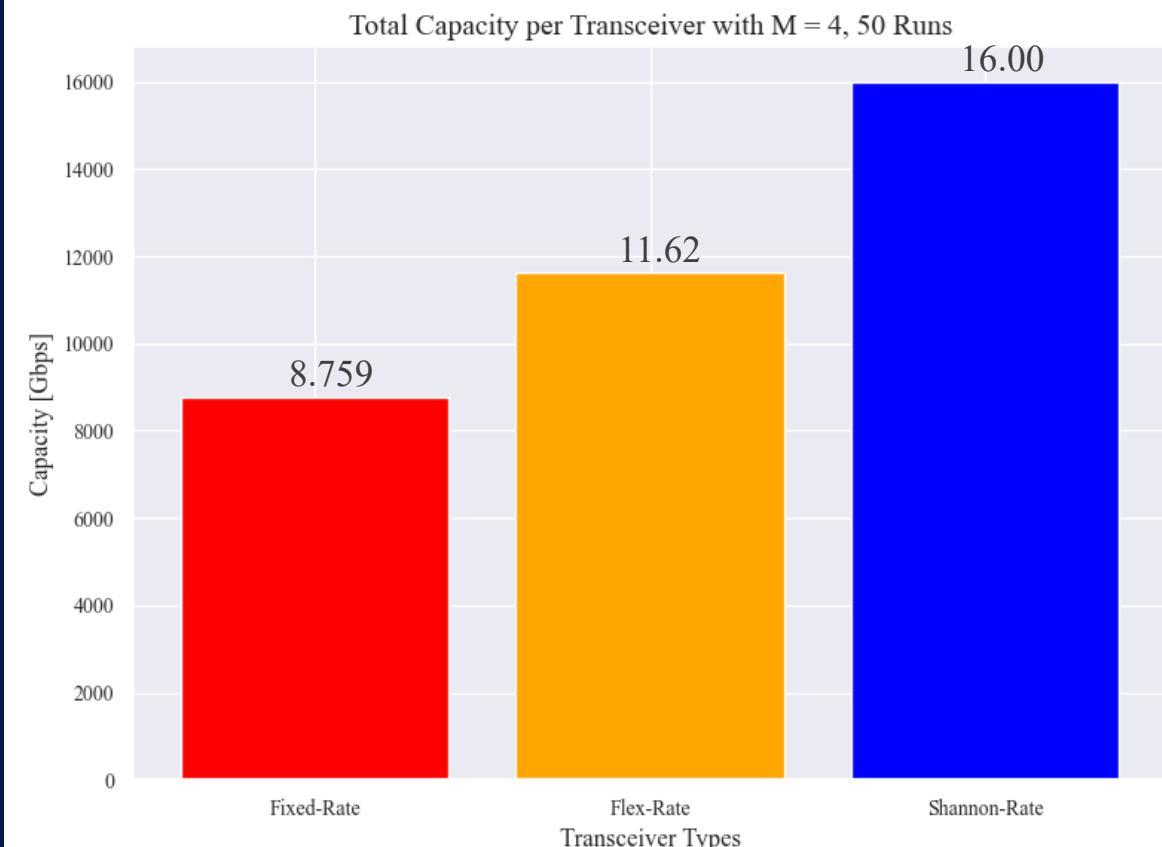


SINGLE TRAFFIC MATRIX SCENARIO RESULTS

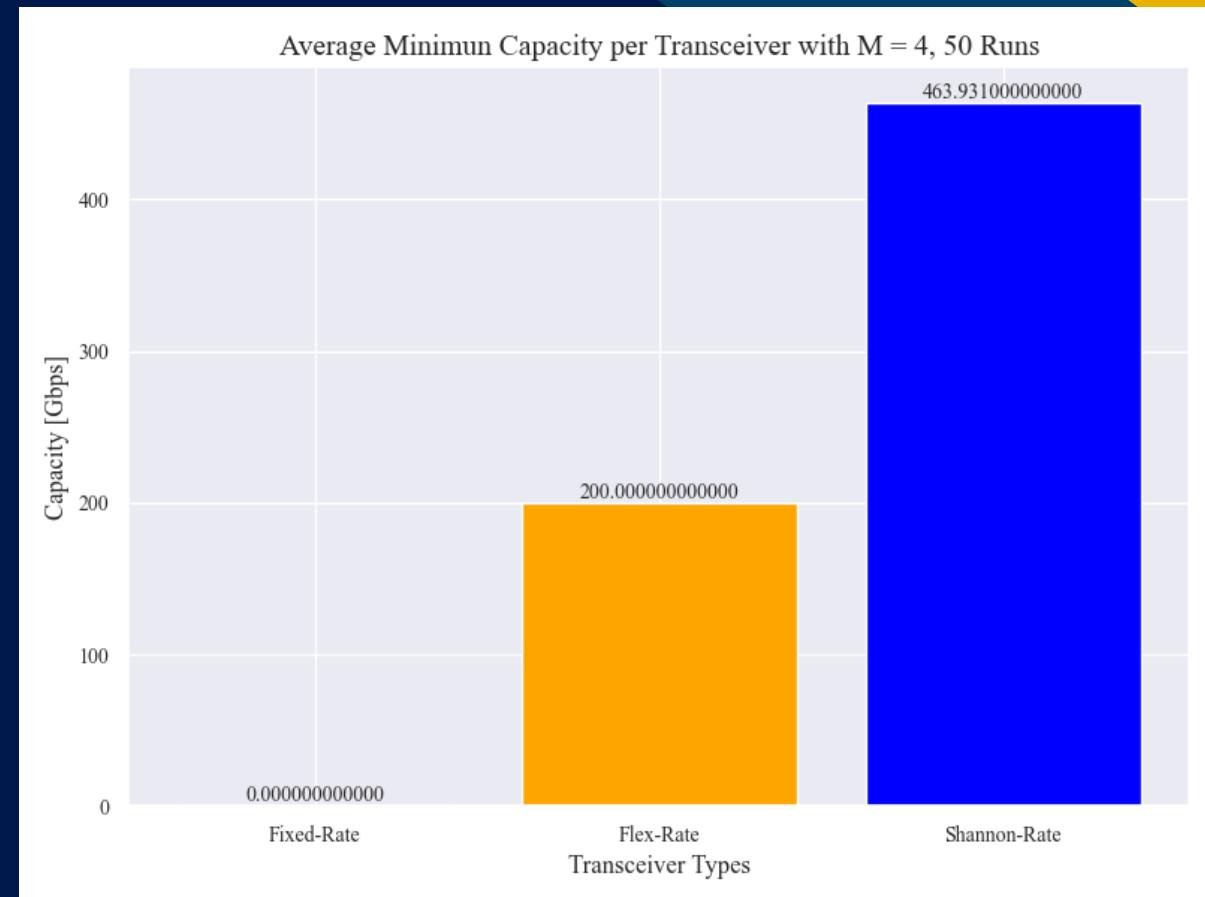
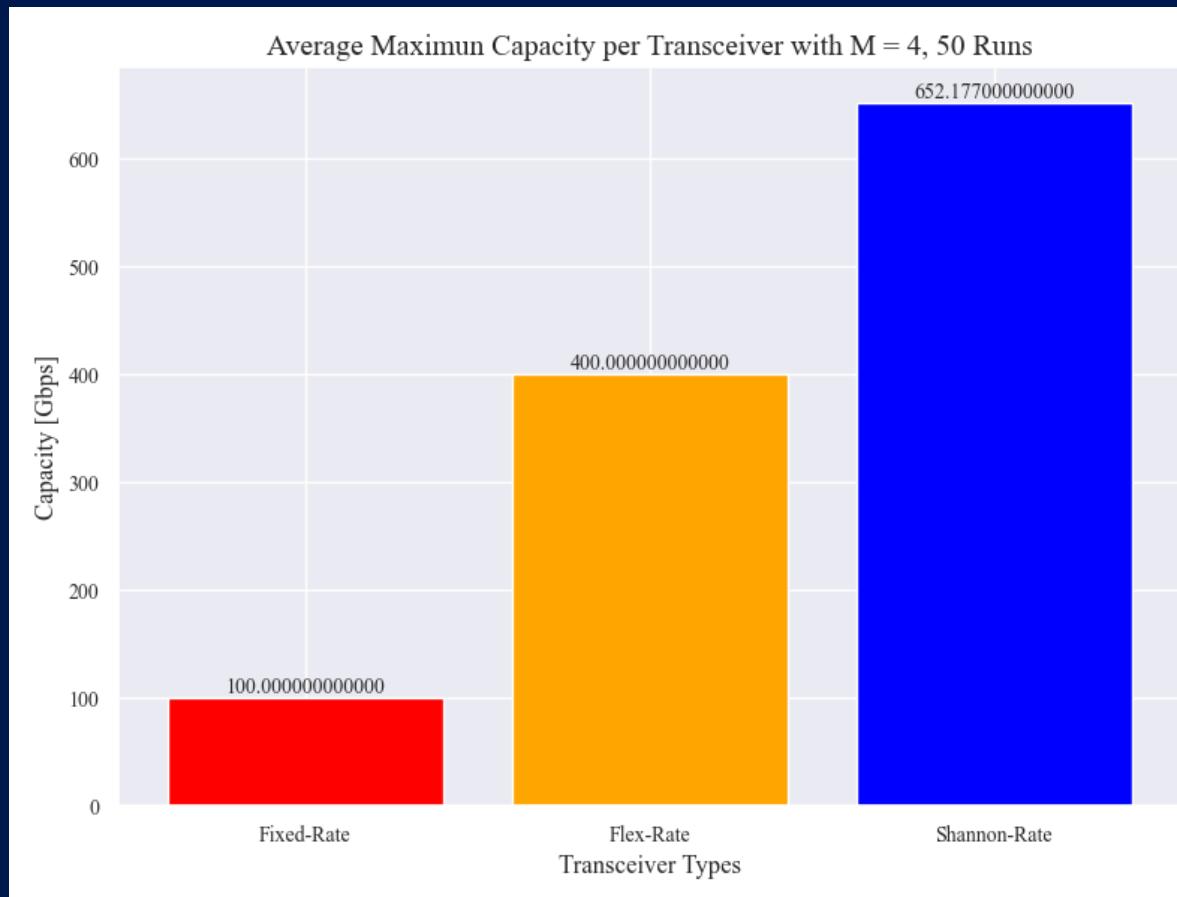
USING *FULL_NETWORK* FILE



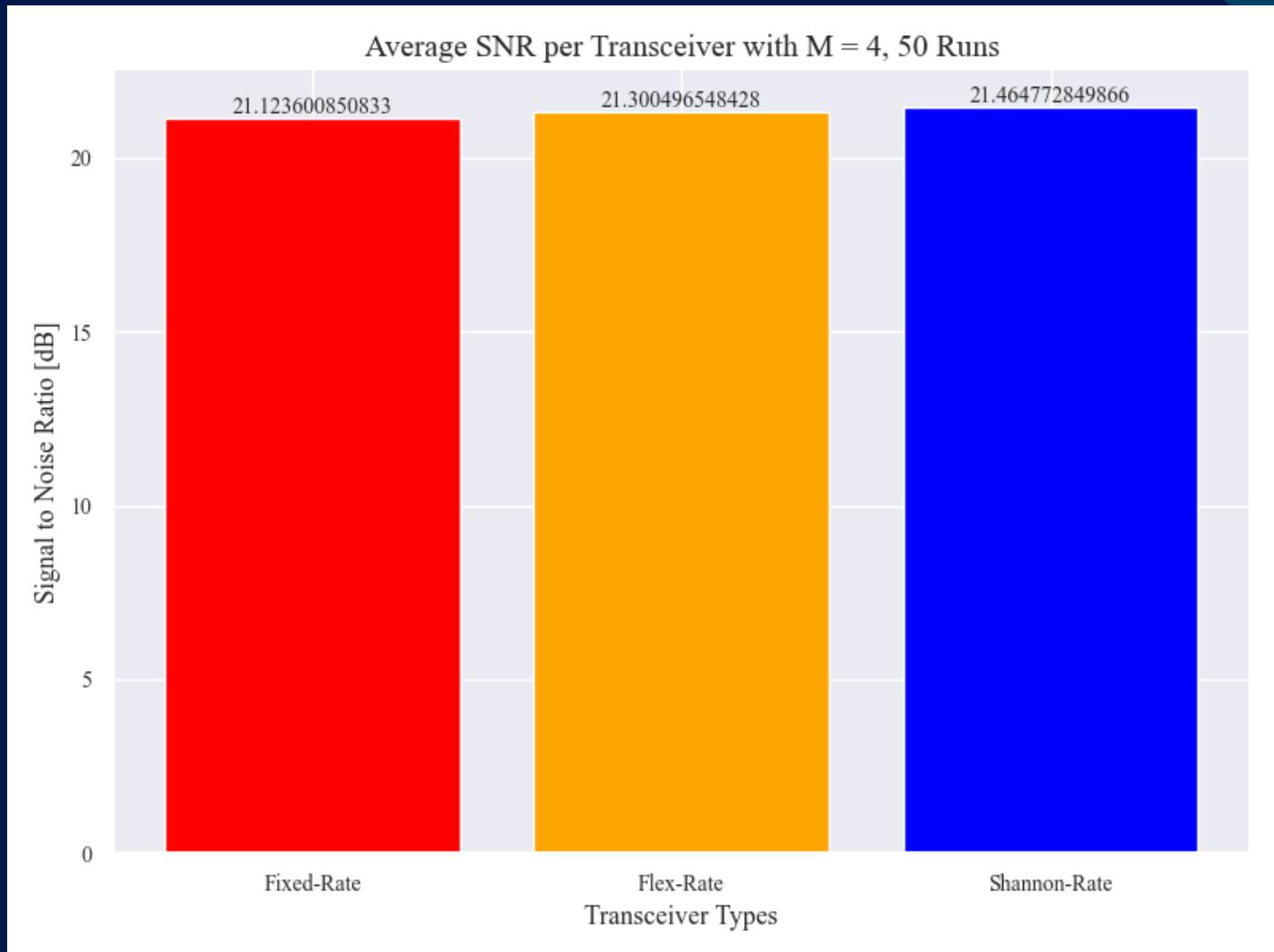
TOTAL AND AVERAGE CAPACITY



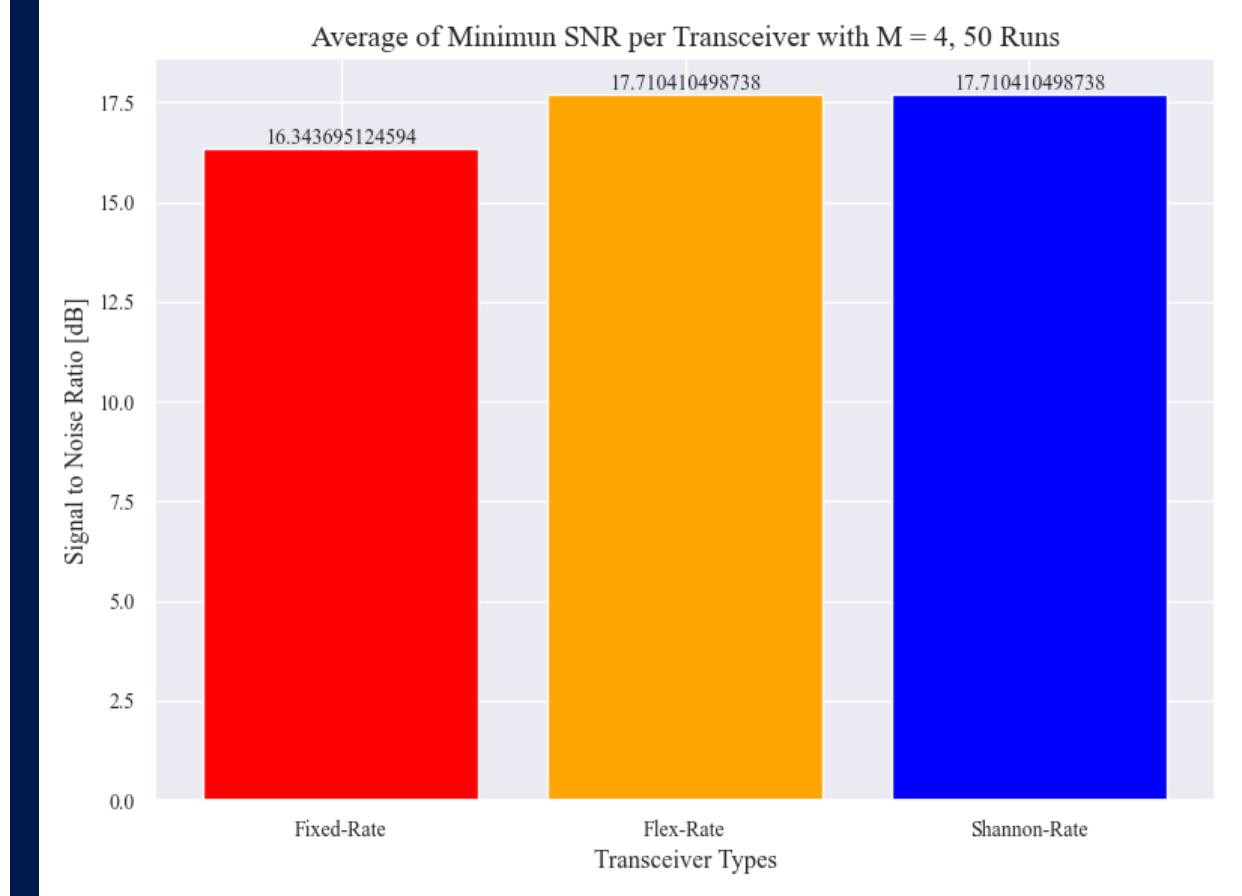
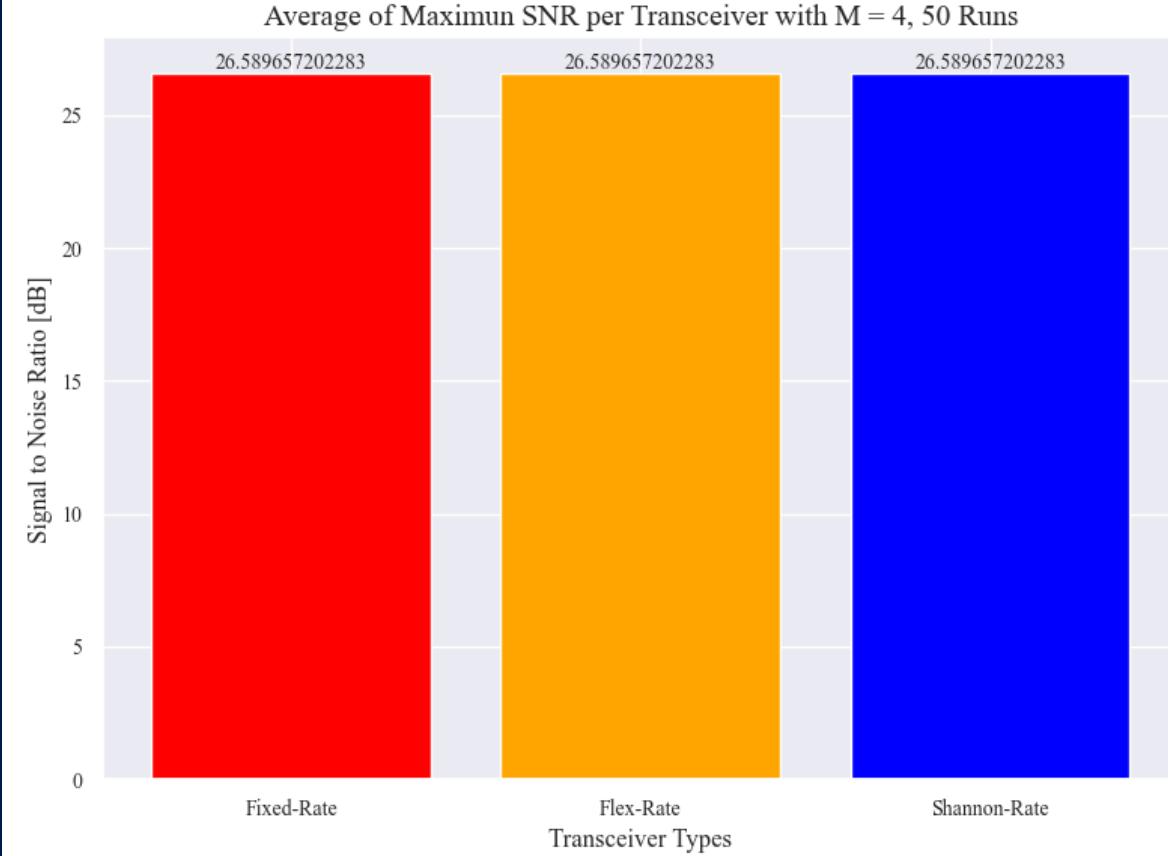
MIN AND MAXIMUN CAPACITY



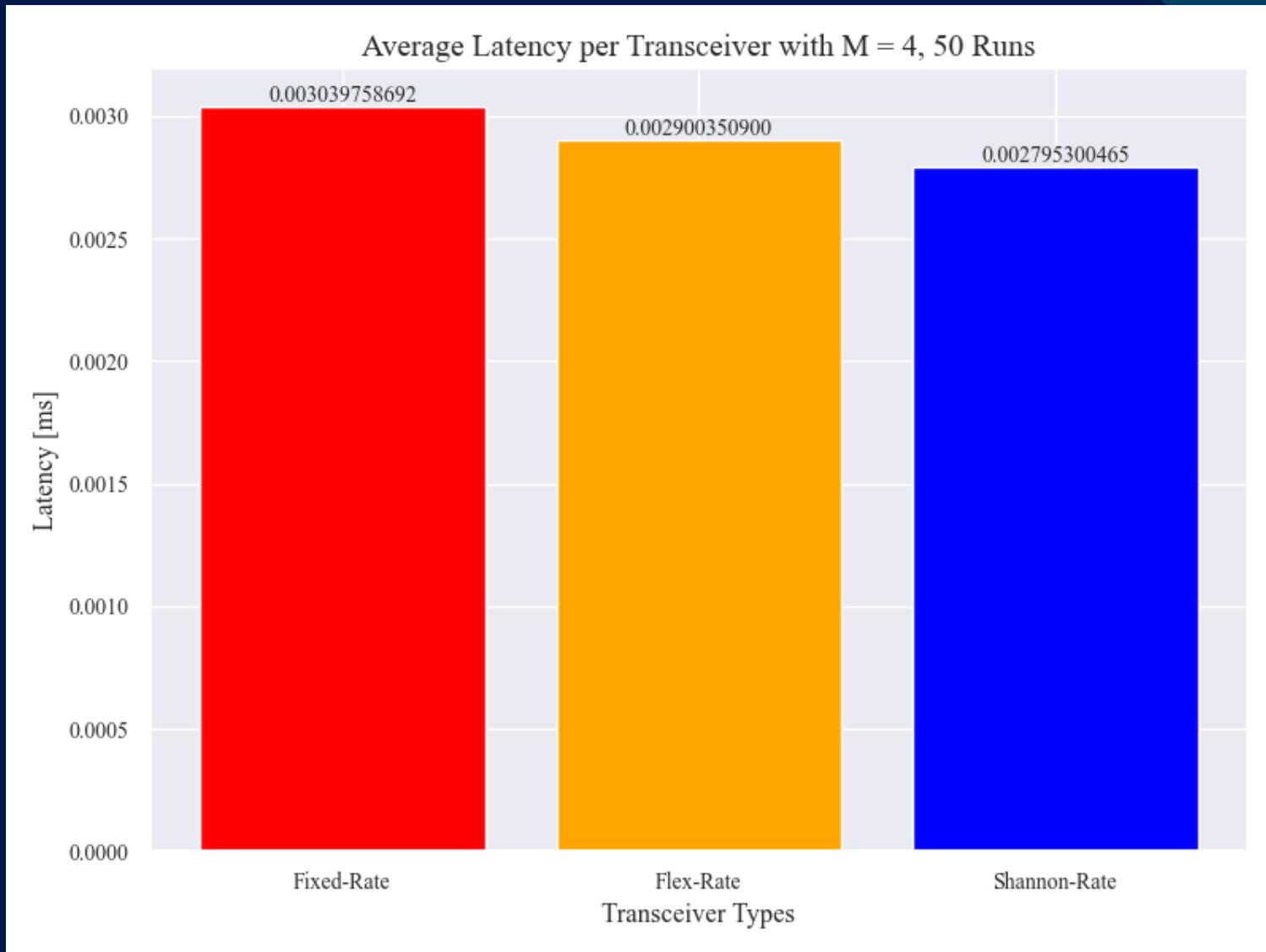
SIGNAL TO NOISE RATIO (SNR)



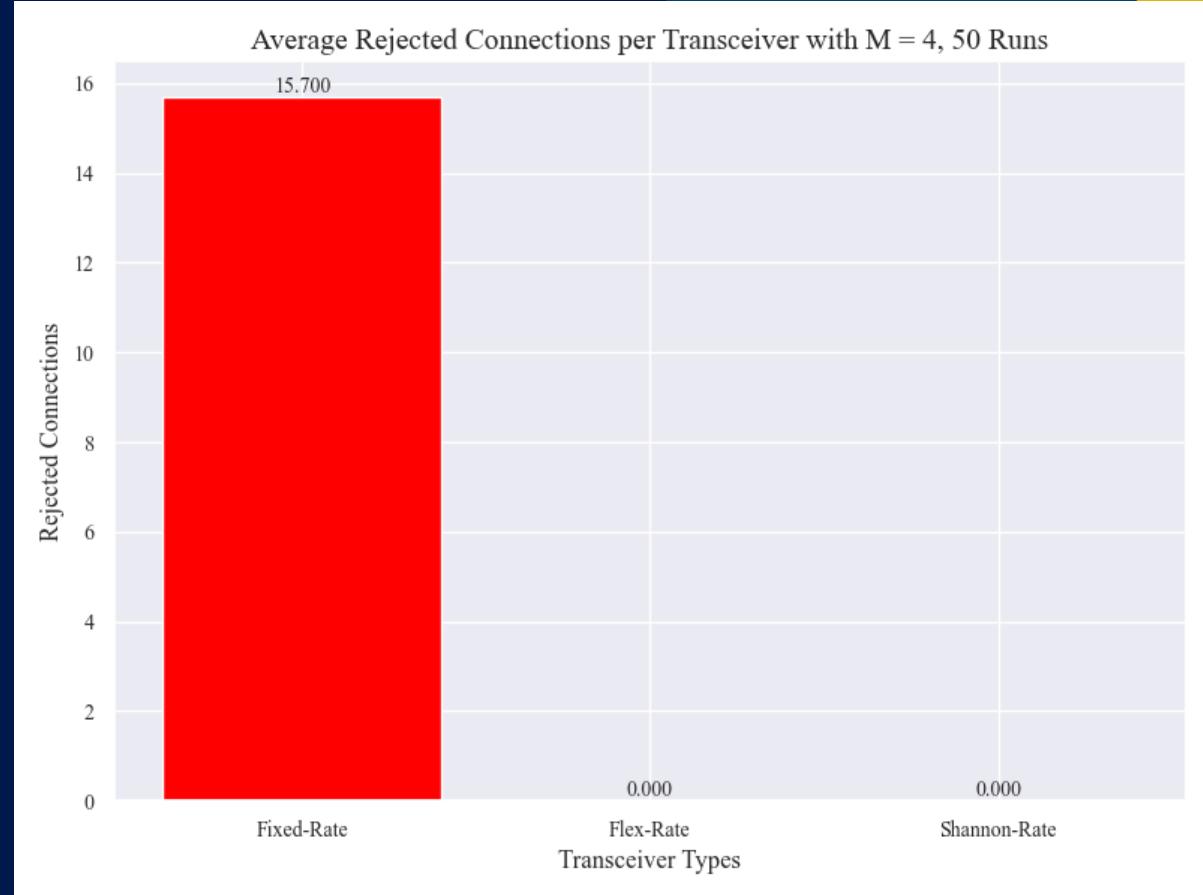
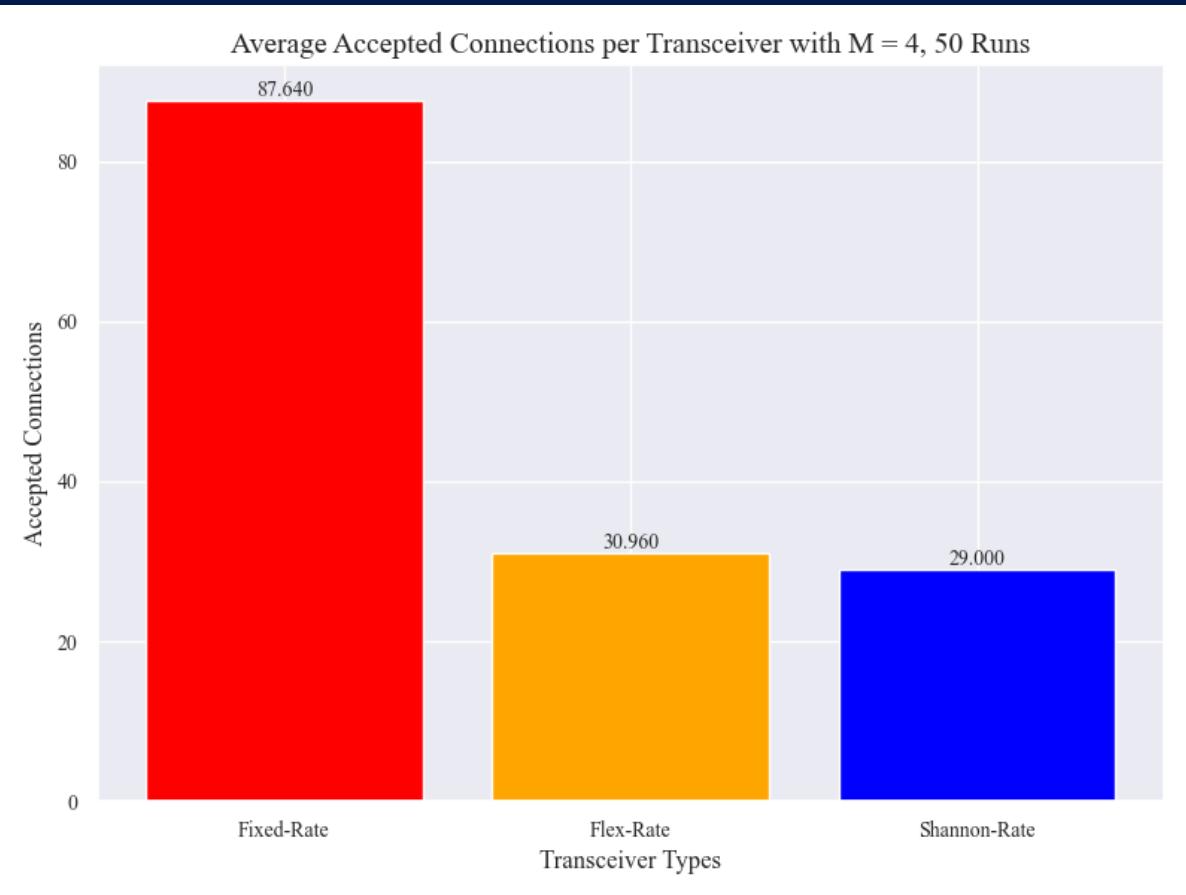
MAXIMUN AND MINIMUM SNR



LATENCY



ACCEPTED AND REJECTED CONNECTIONS

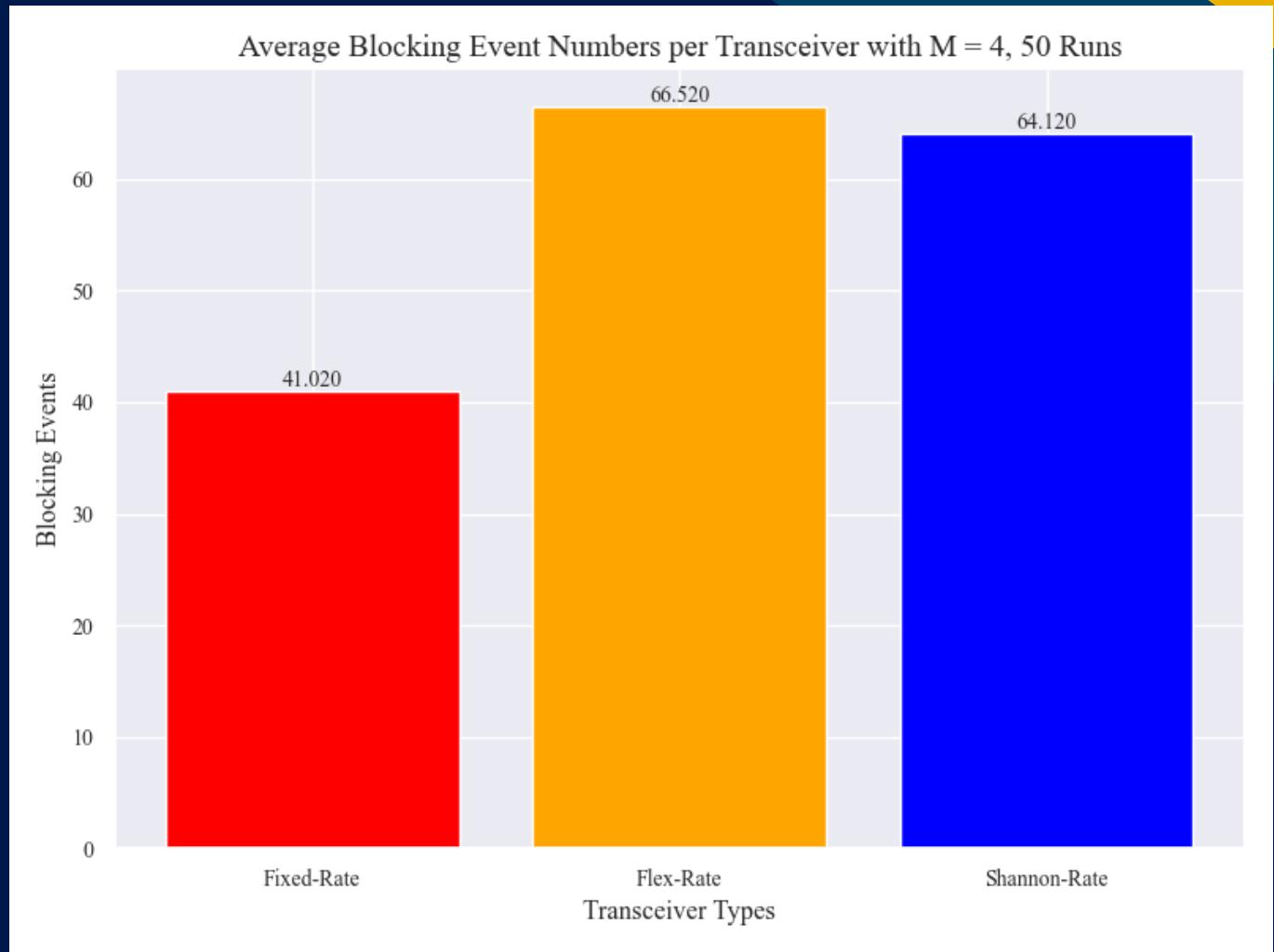


Connections were rejected because no path was available or the bit rate was 0.

BLOCKING EVENTS

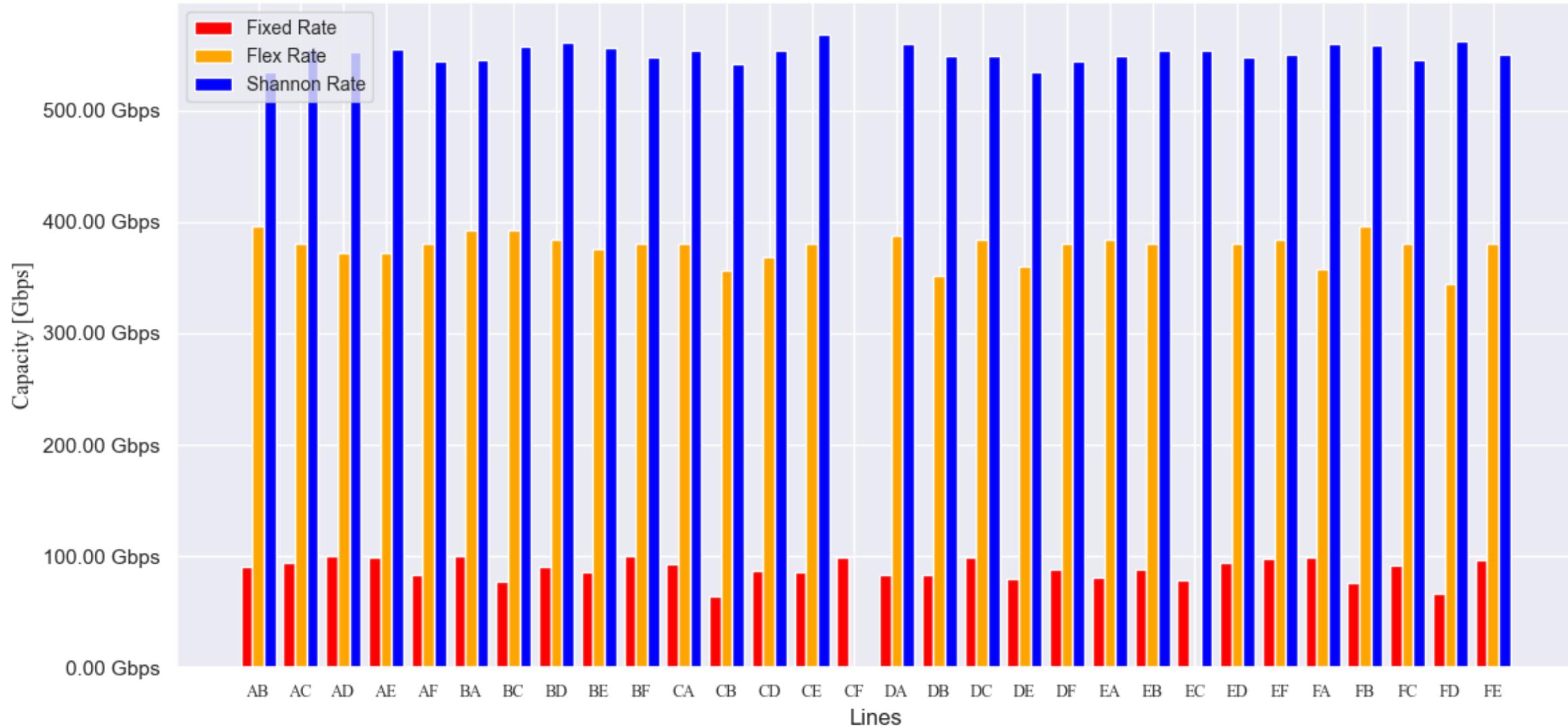
Not Traffic Matrix Assignment due to:

- Matrix saturation
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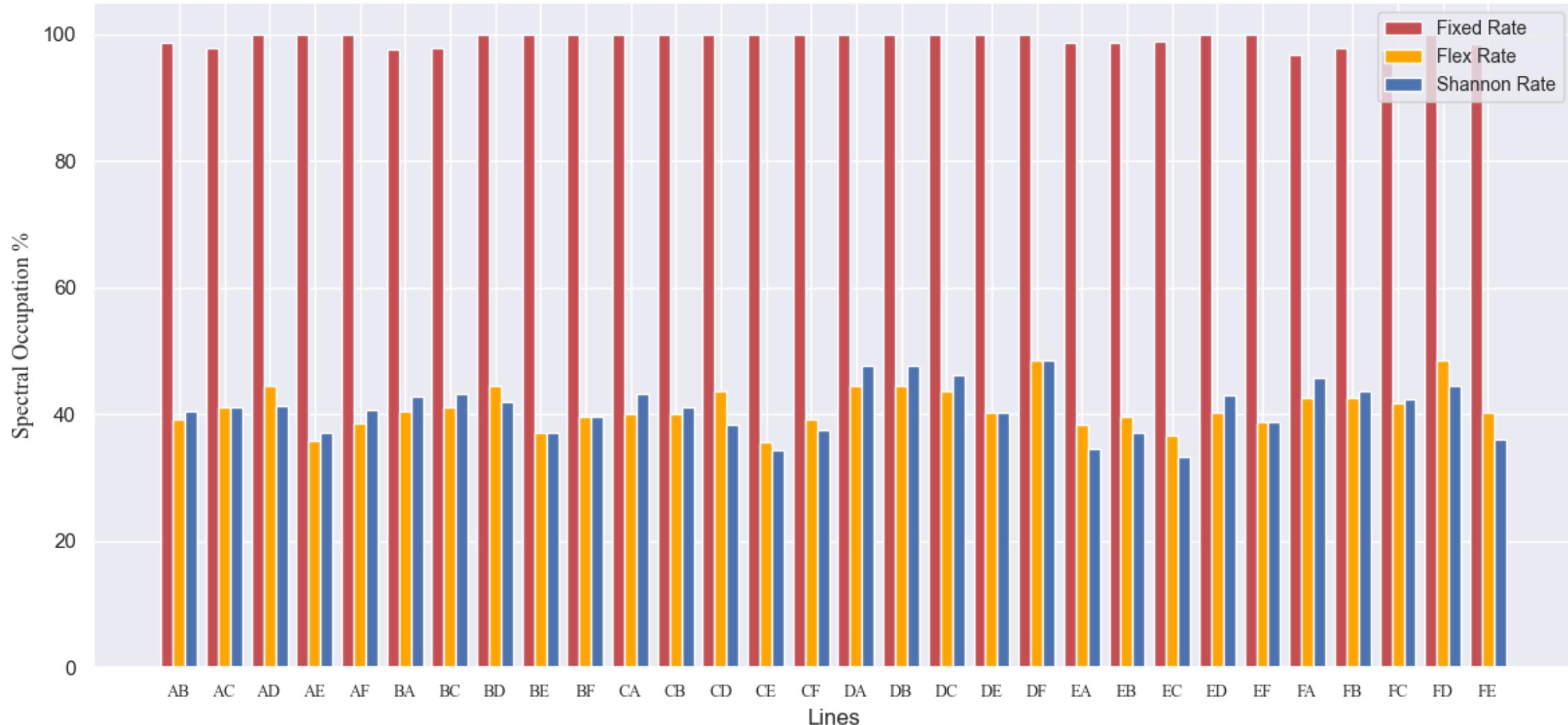
PER- LINK CAPACITY

Per-link Average Capacity for M=4, with MC=50



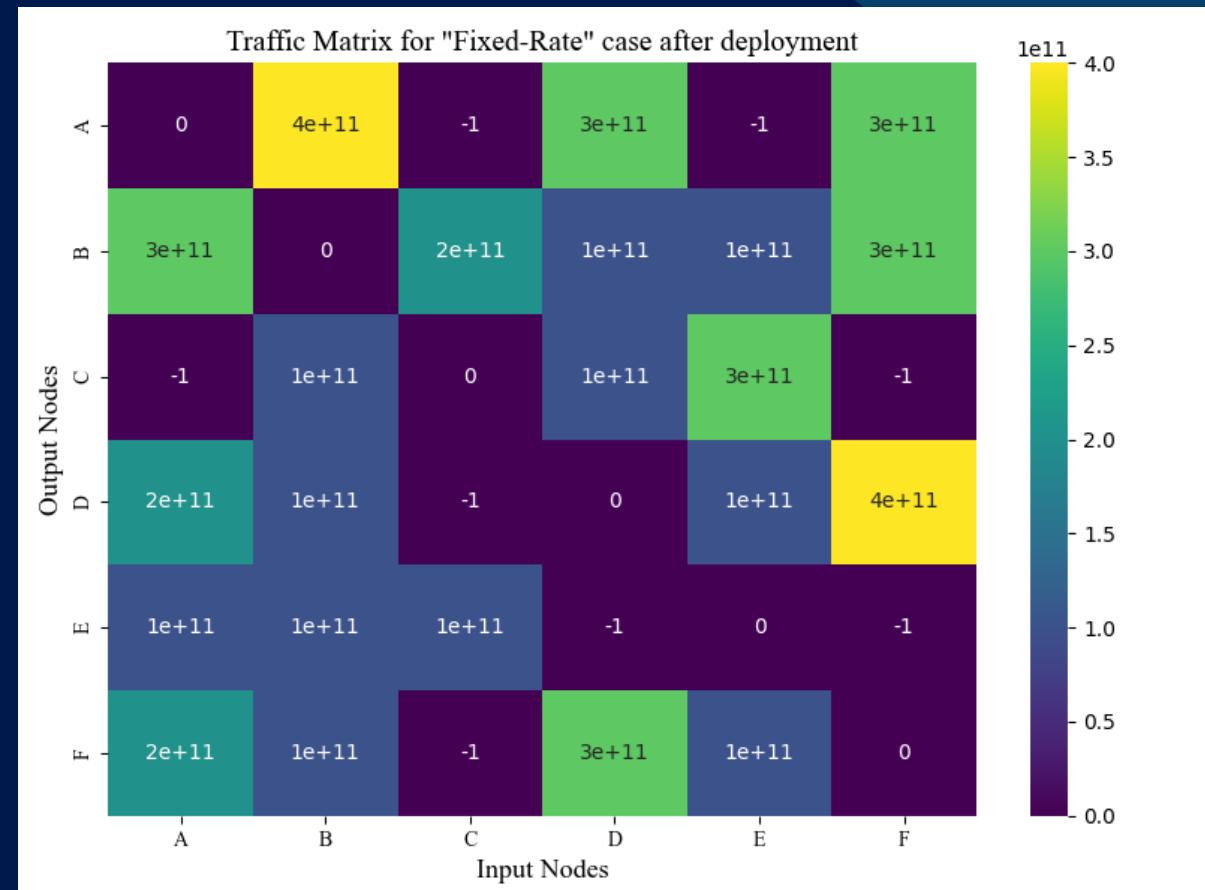
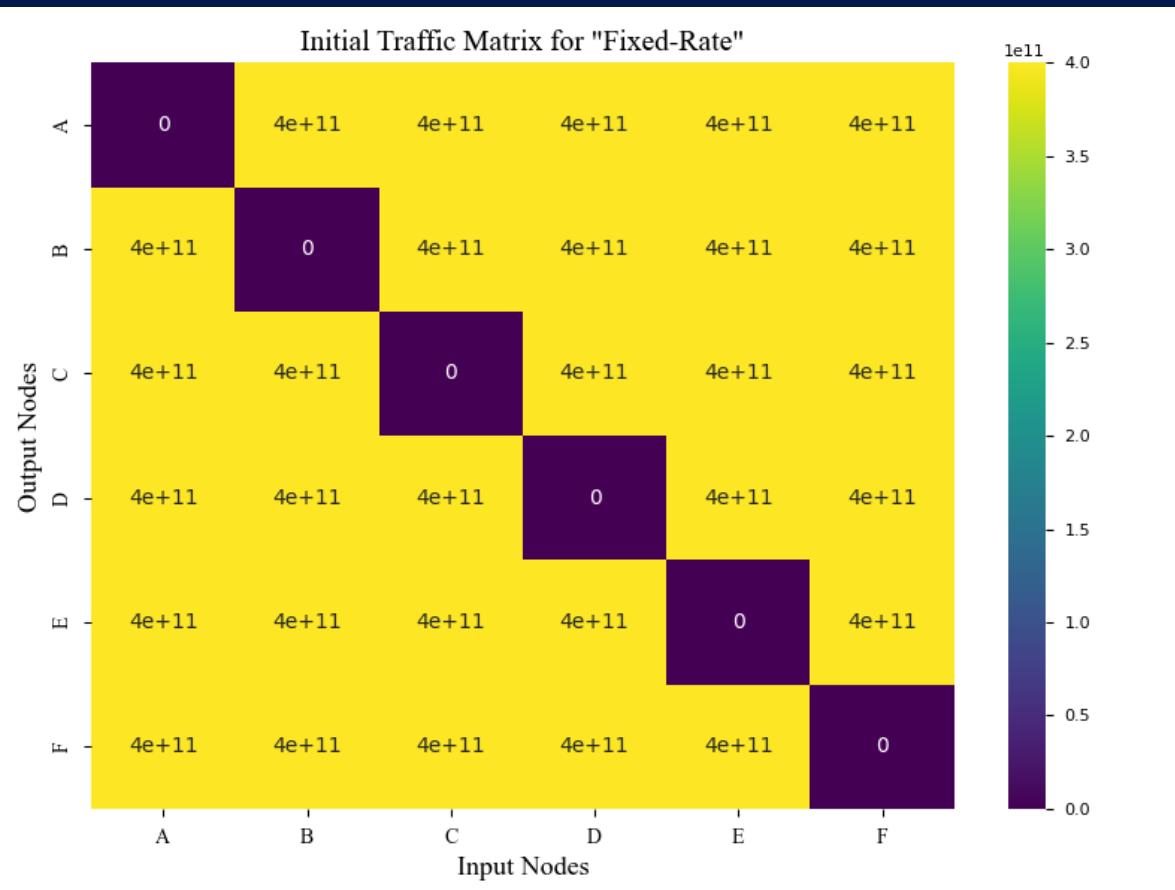
SPECTRAL OCCUPATION PER LINE

Single Matrix Scenario - Spectral occupation per Line for M=4



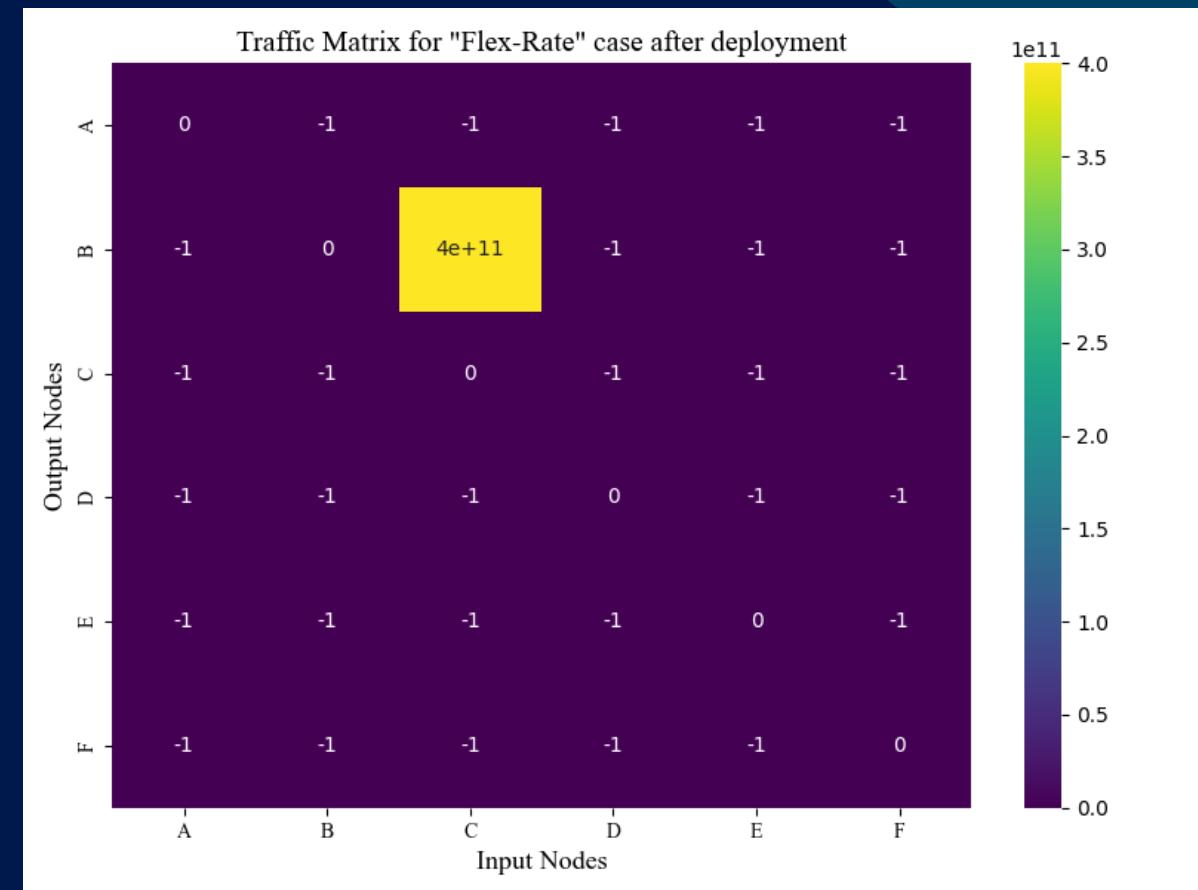
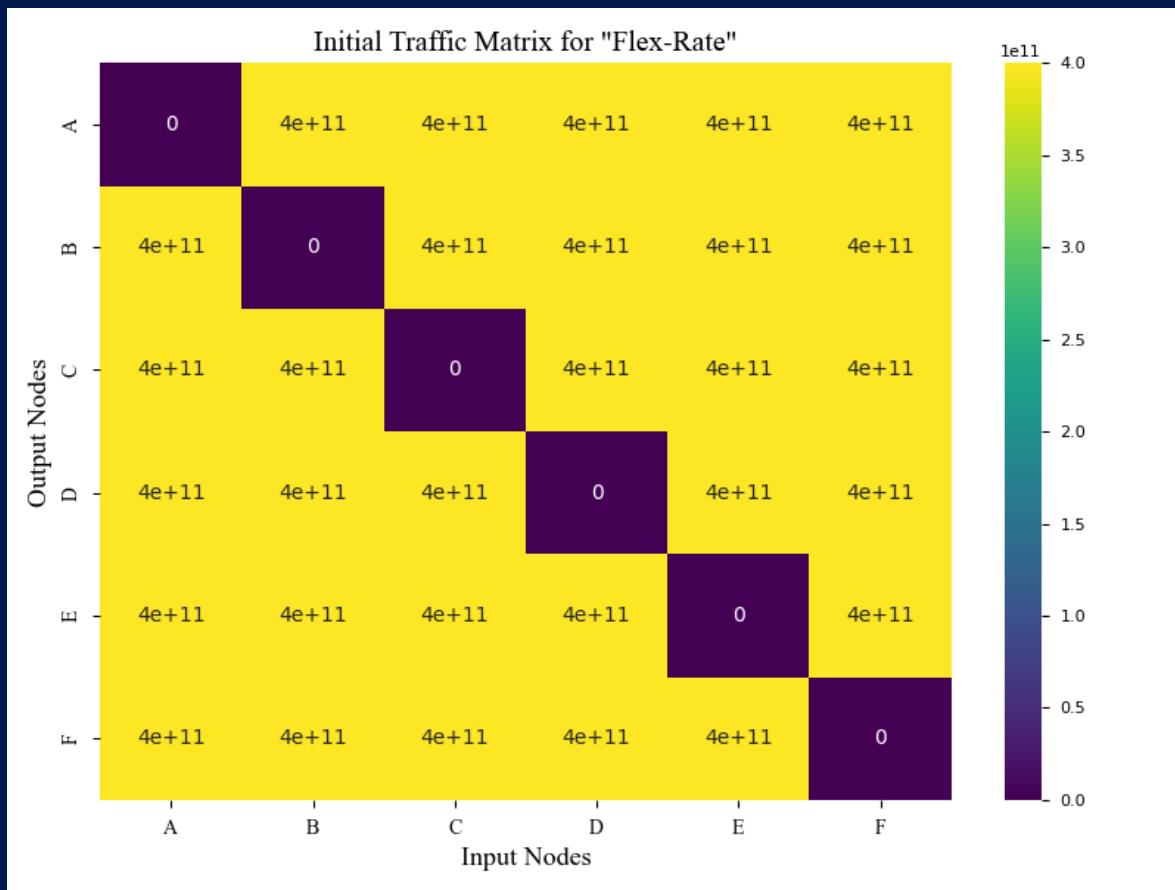
SINGLE TRAFFIC MATRIX SCENARIO RESULTS

USING *NOT_FULL_NETWORK* FILE



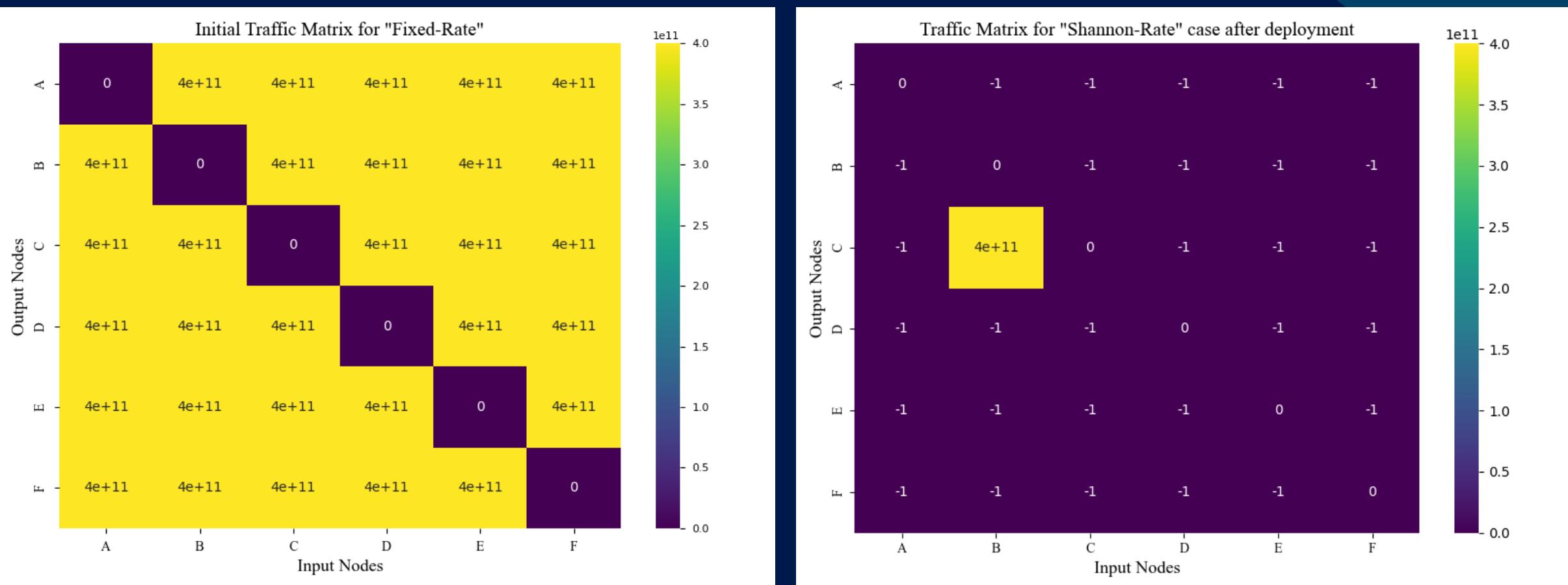
SINGLE TRAFFIC MATRIX SCENARIO RESULTS

USING *NOT_FULL_NETWORK* FILE

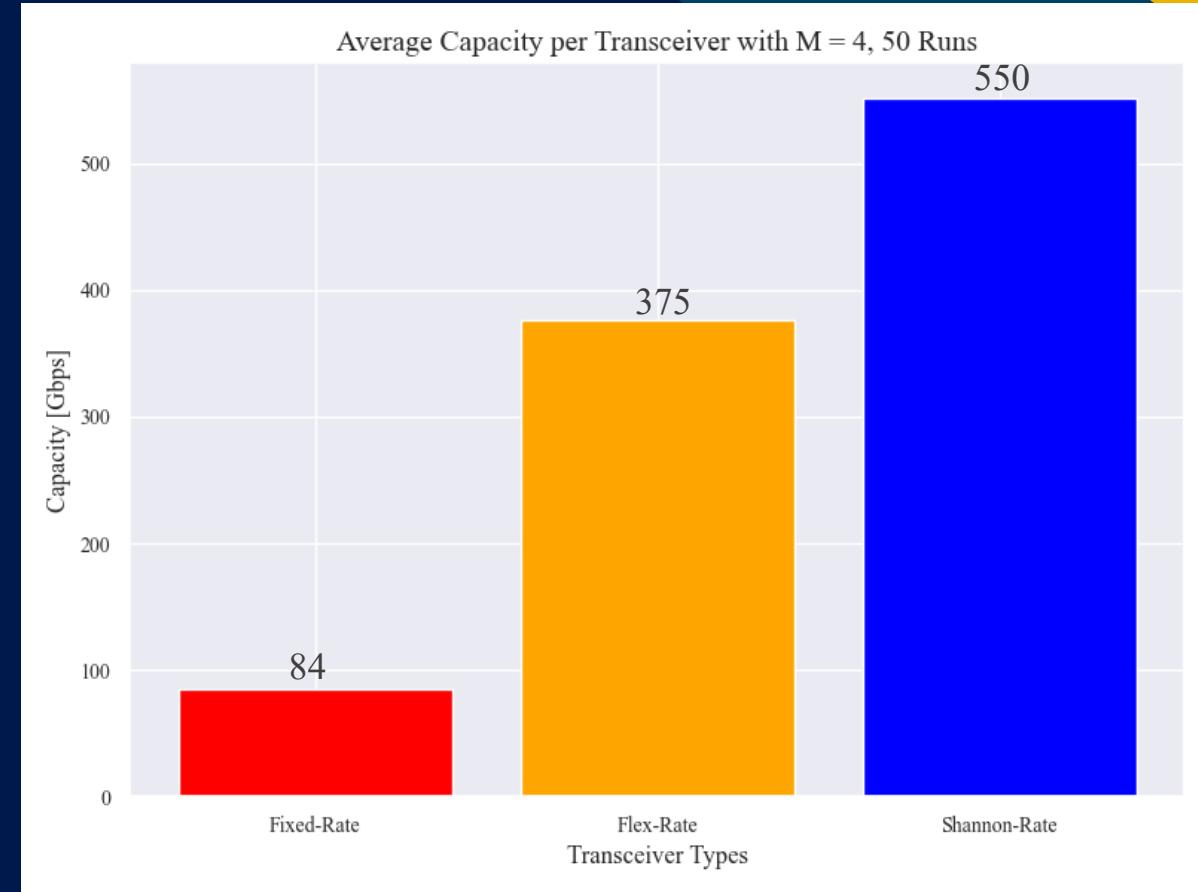
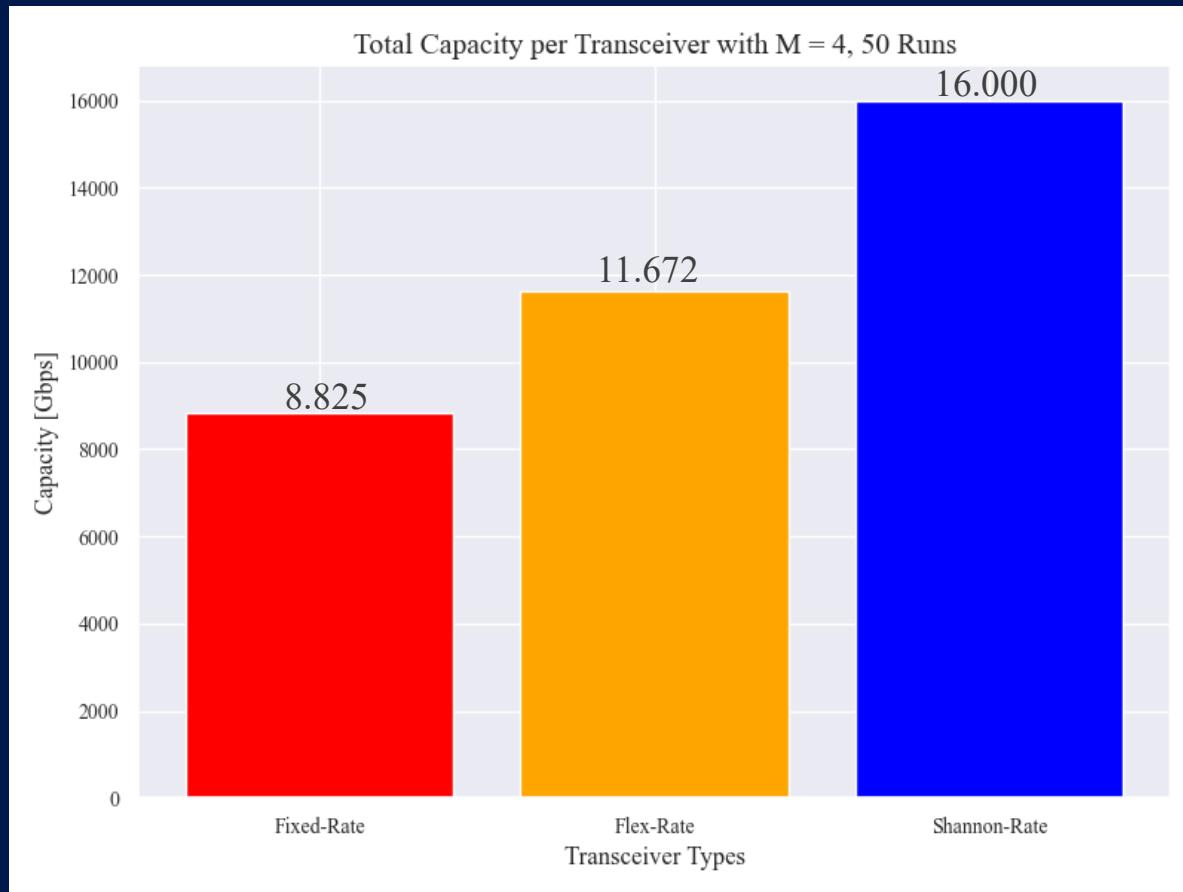


SINGLE TRAFFIC MATRIX SCENARIO RESULTS

USING *NOT_FULL_NETWORK* FILE

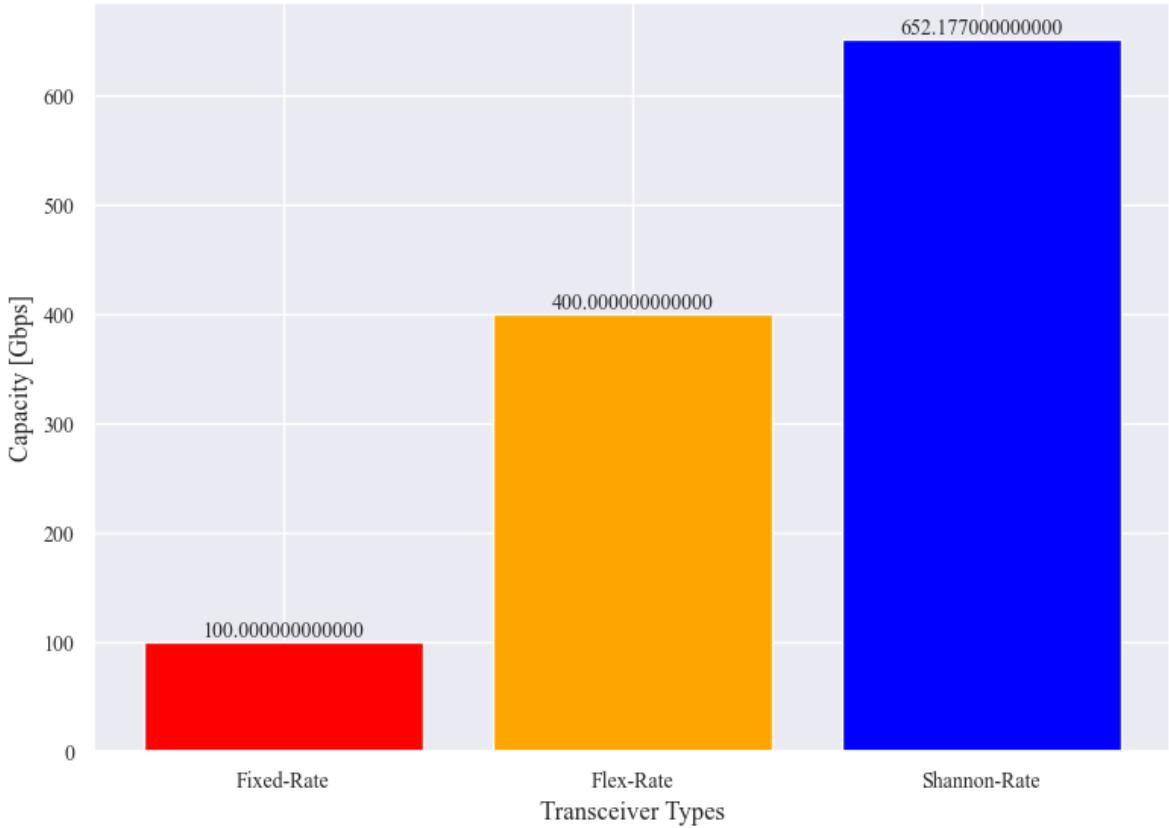


TOTAL AND AVERAGE CAPACITY

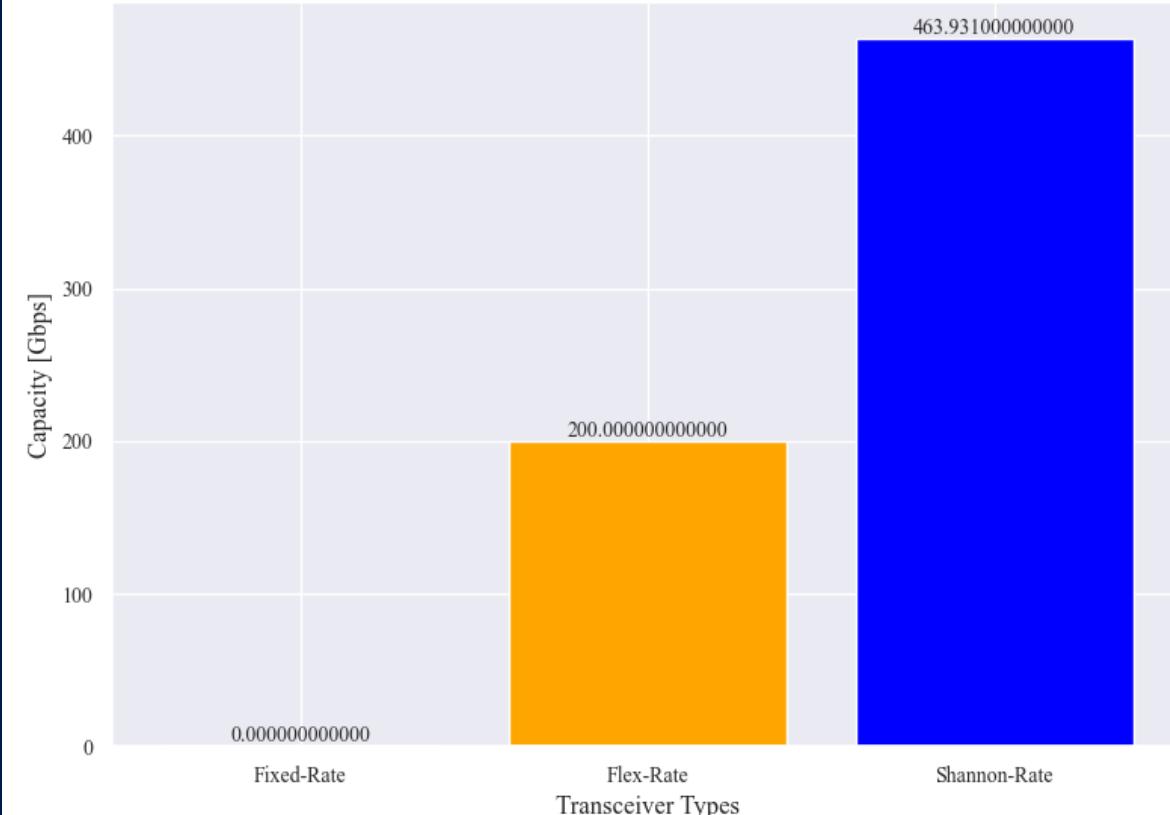


MIN AND MAXIMUN CAPACITY

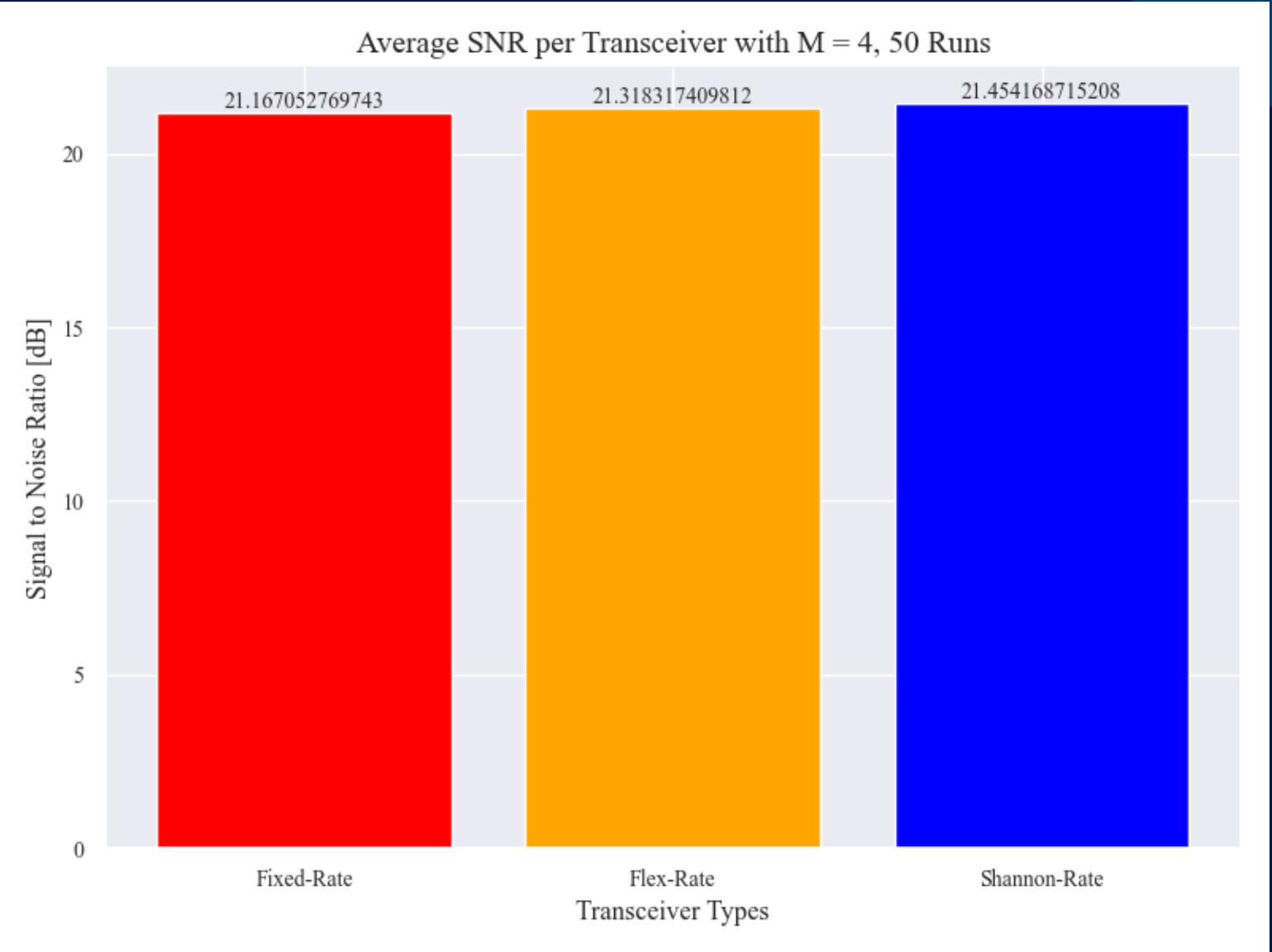
Average Maximum Capacity per Transceiver with M = 4, 50 Runs



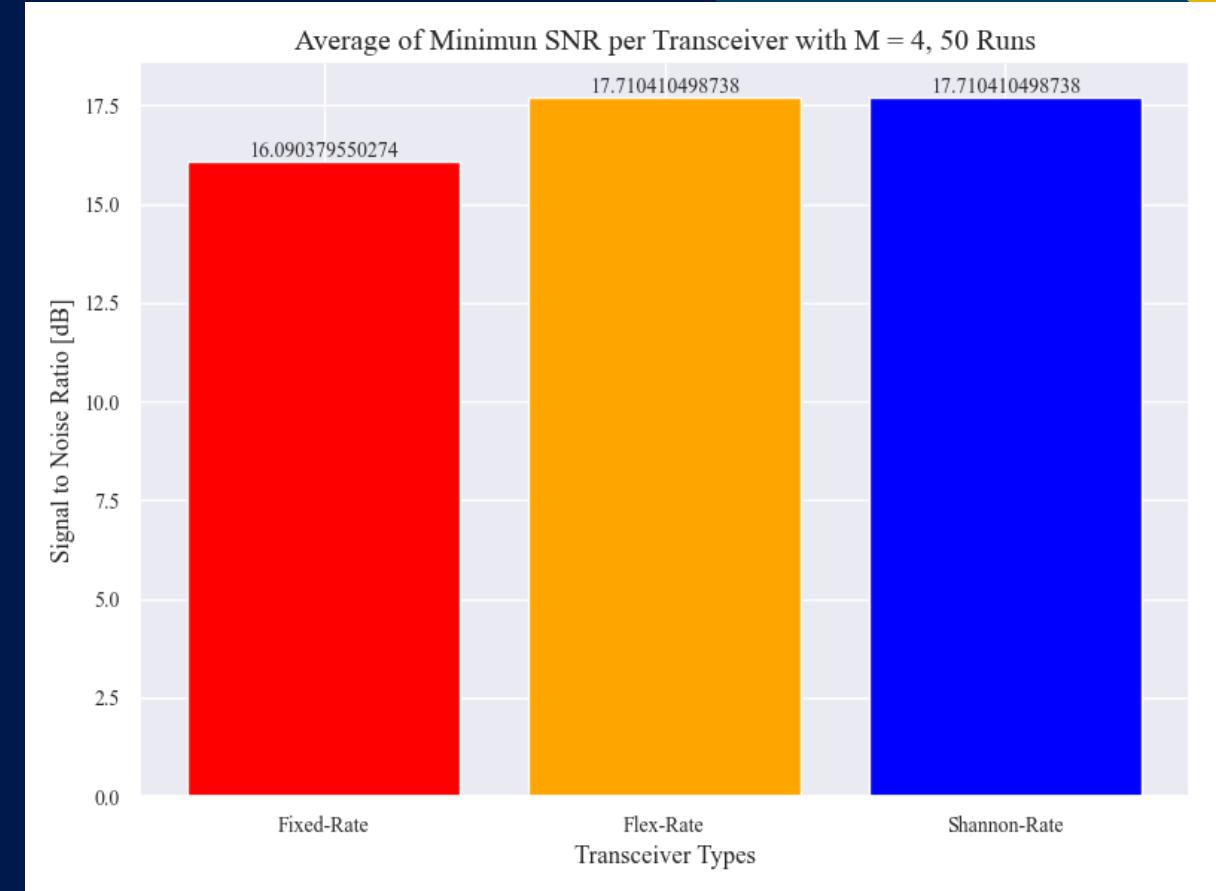
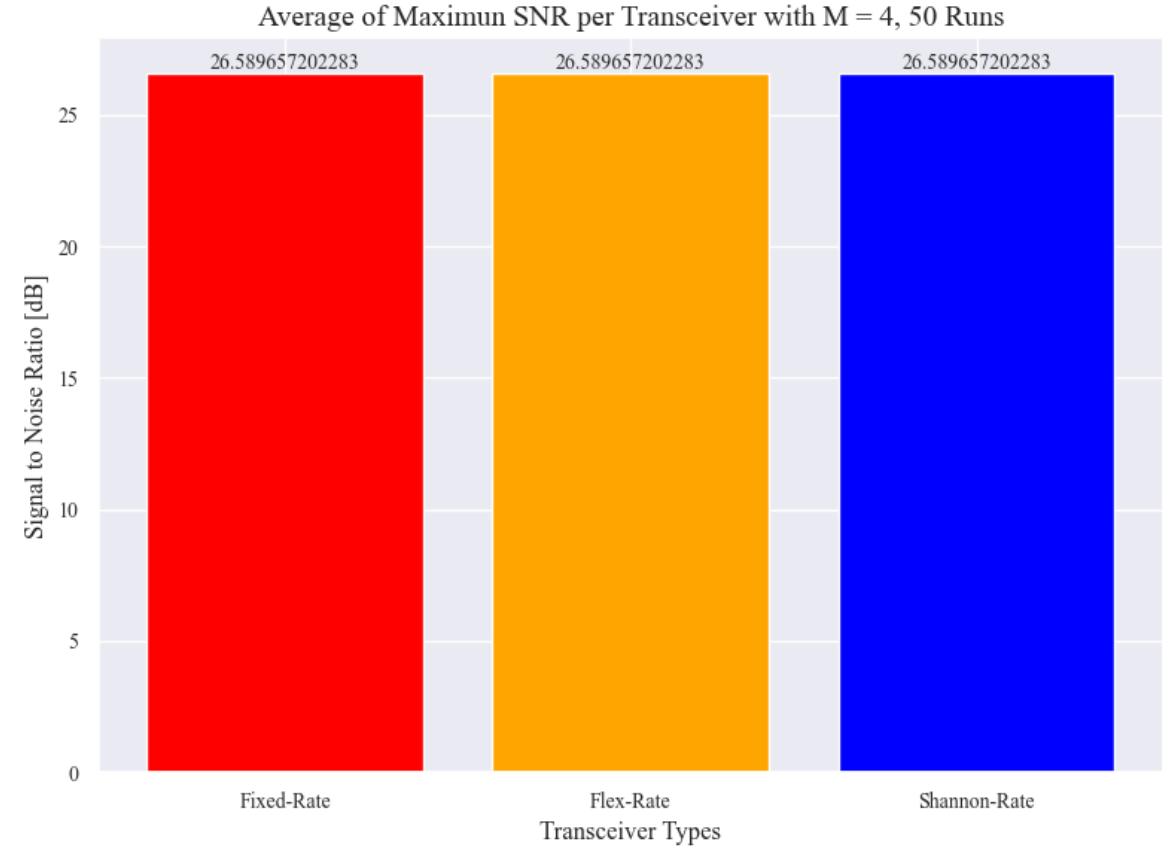
Average Minimum Capacity per Transceiver with M = 4, 50 Runs



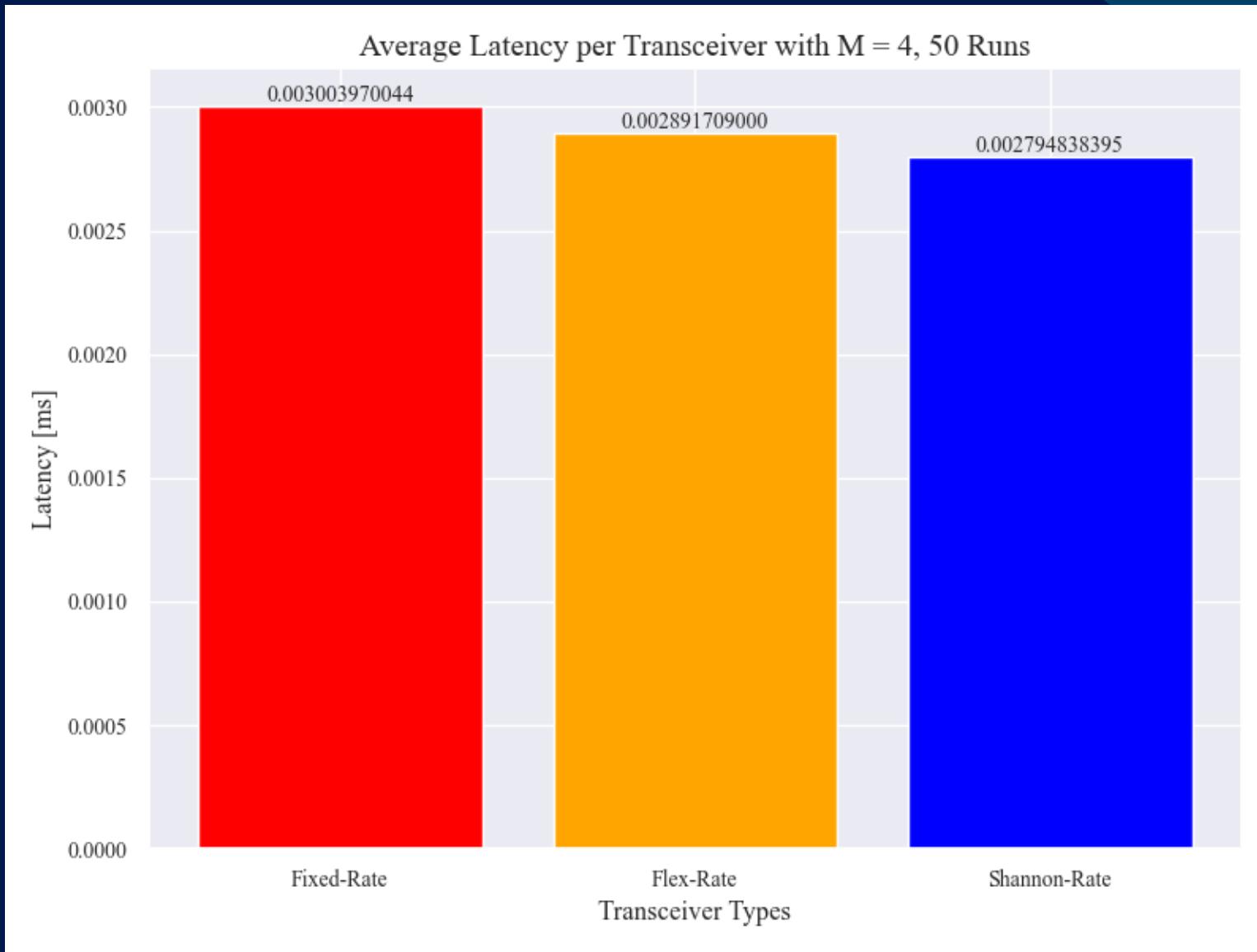
SIGNAL TO NOISE RATIO (SNR)



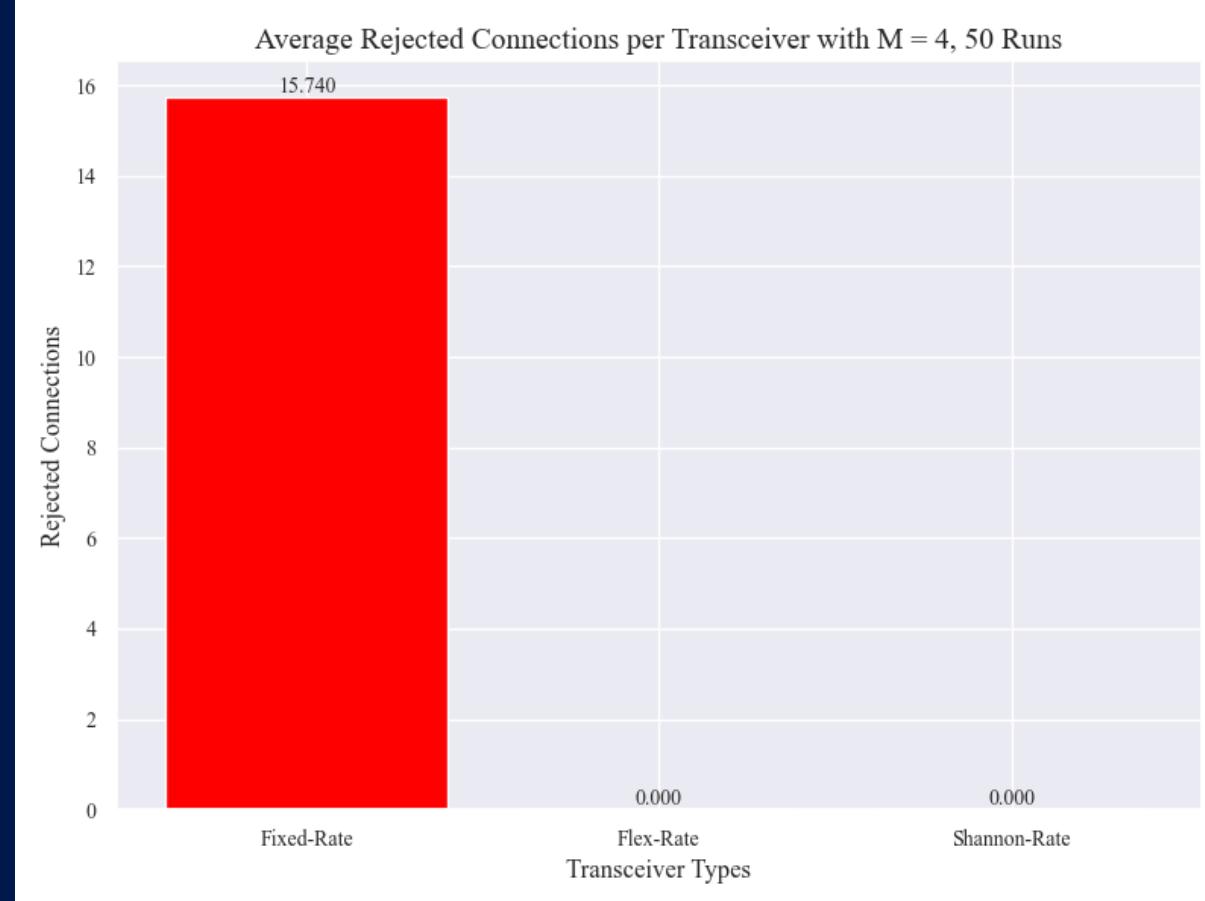
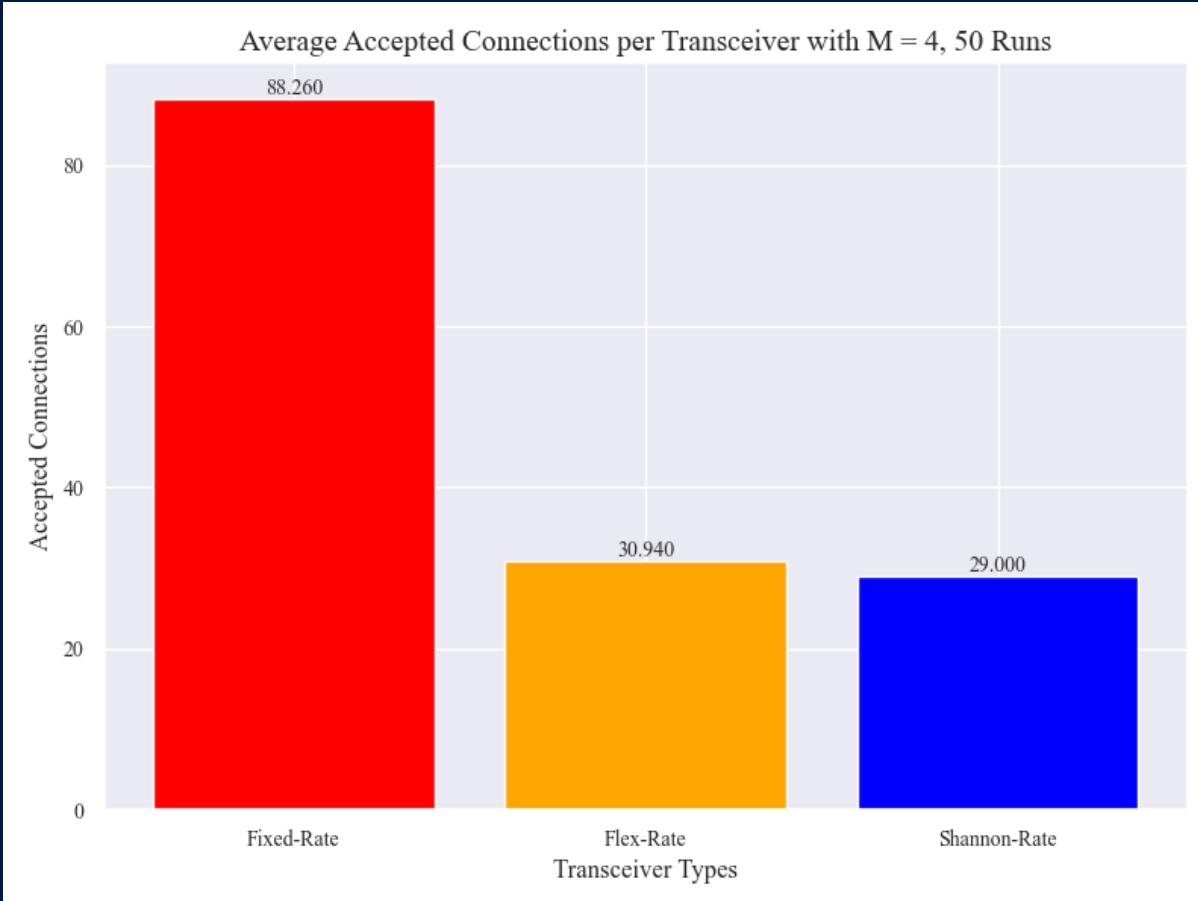
MAXIMUM AND MINIMUM SNR



LATENCY



ACCEPTED AND REJECTED CONNECTIONS

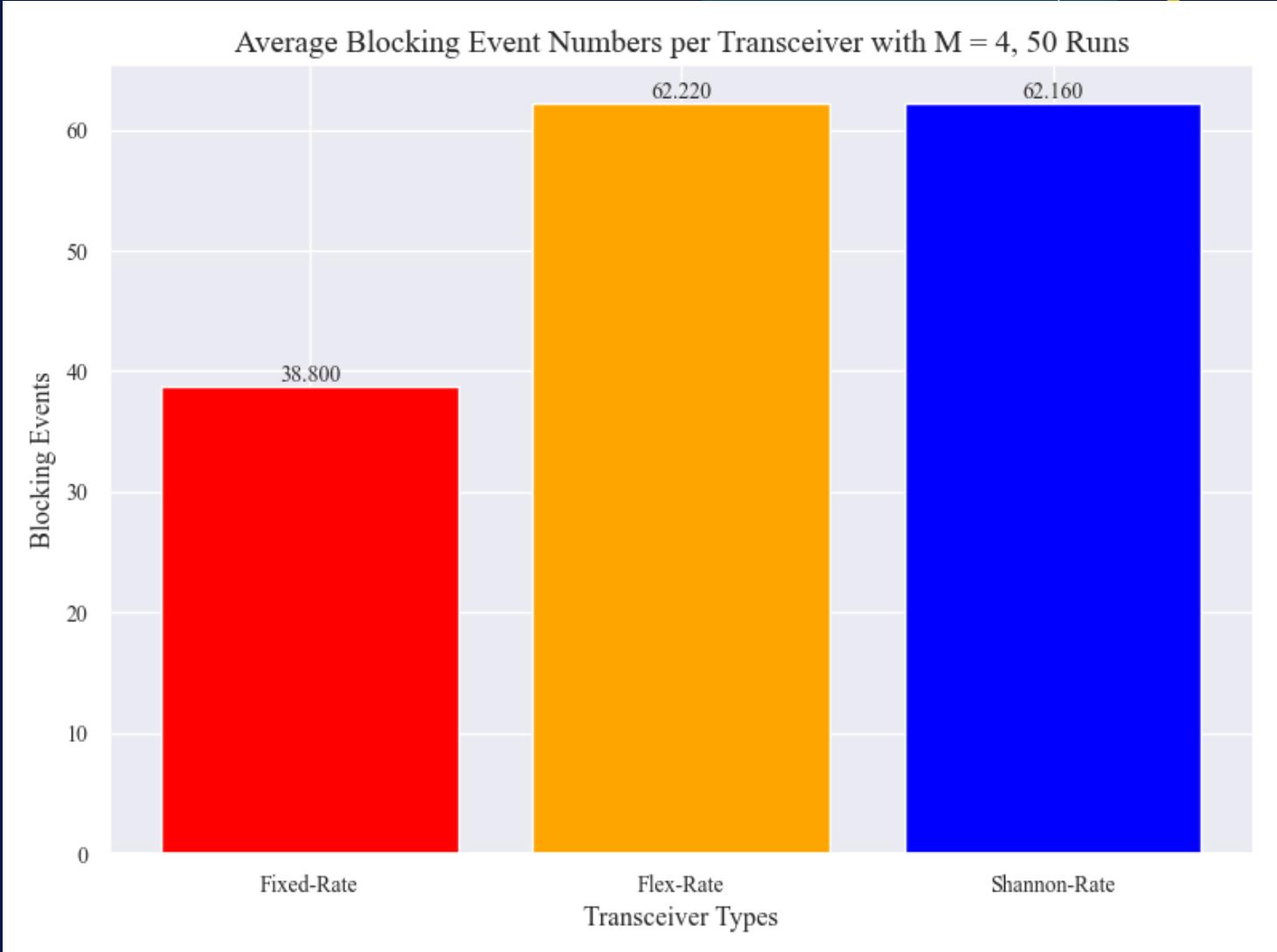


Connections were rejected because no path was available or the bit rate was 0.

BLOCKING EVENTS

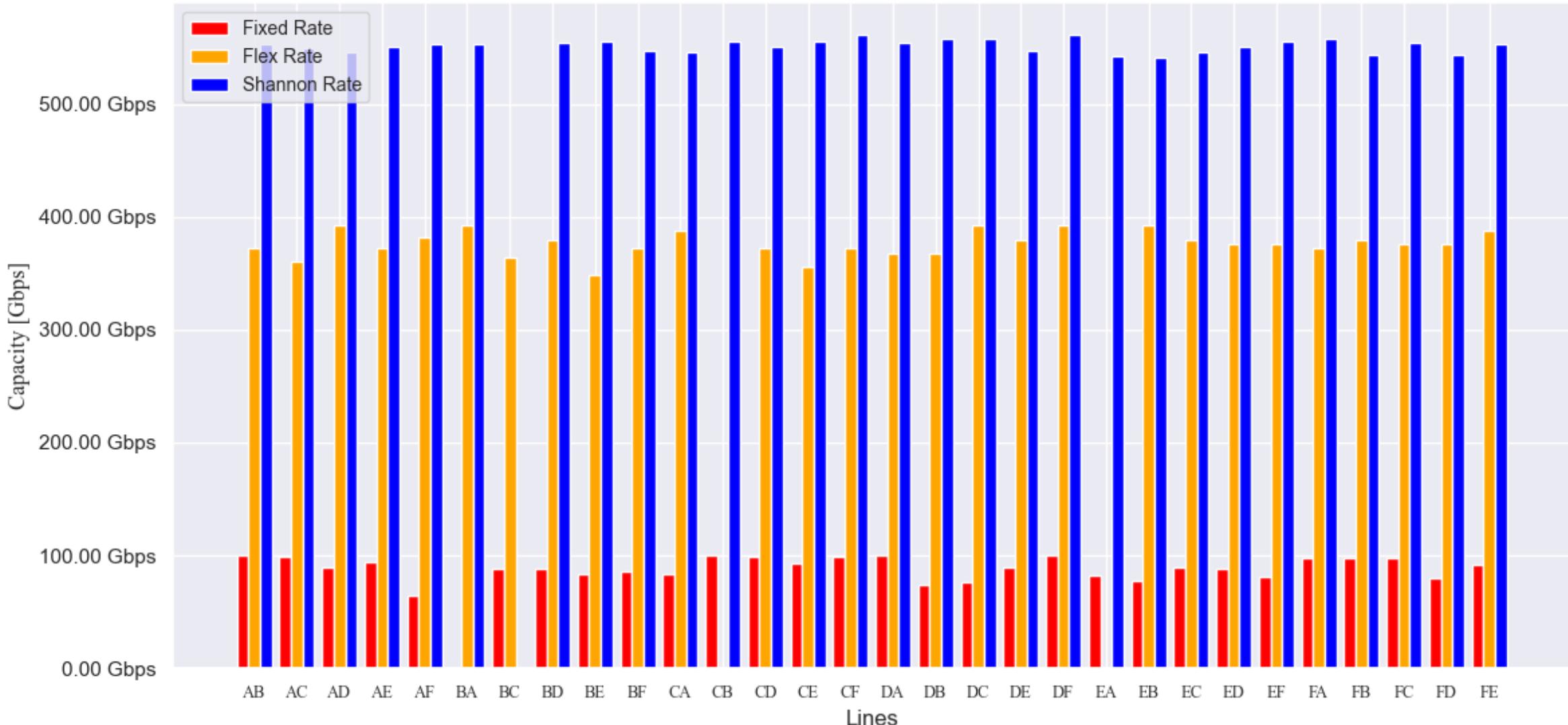
Not Traffic Matrix Assignment due to:

- Matrix saturation
- It was not possible to assign a suitable path for the connection



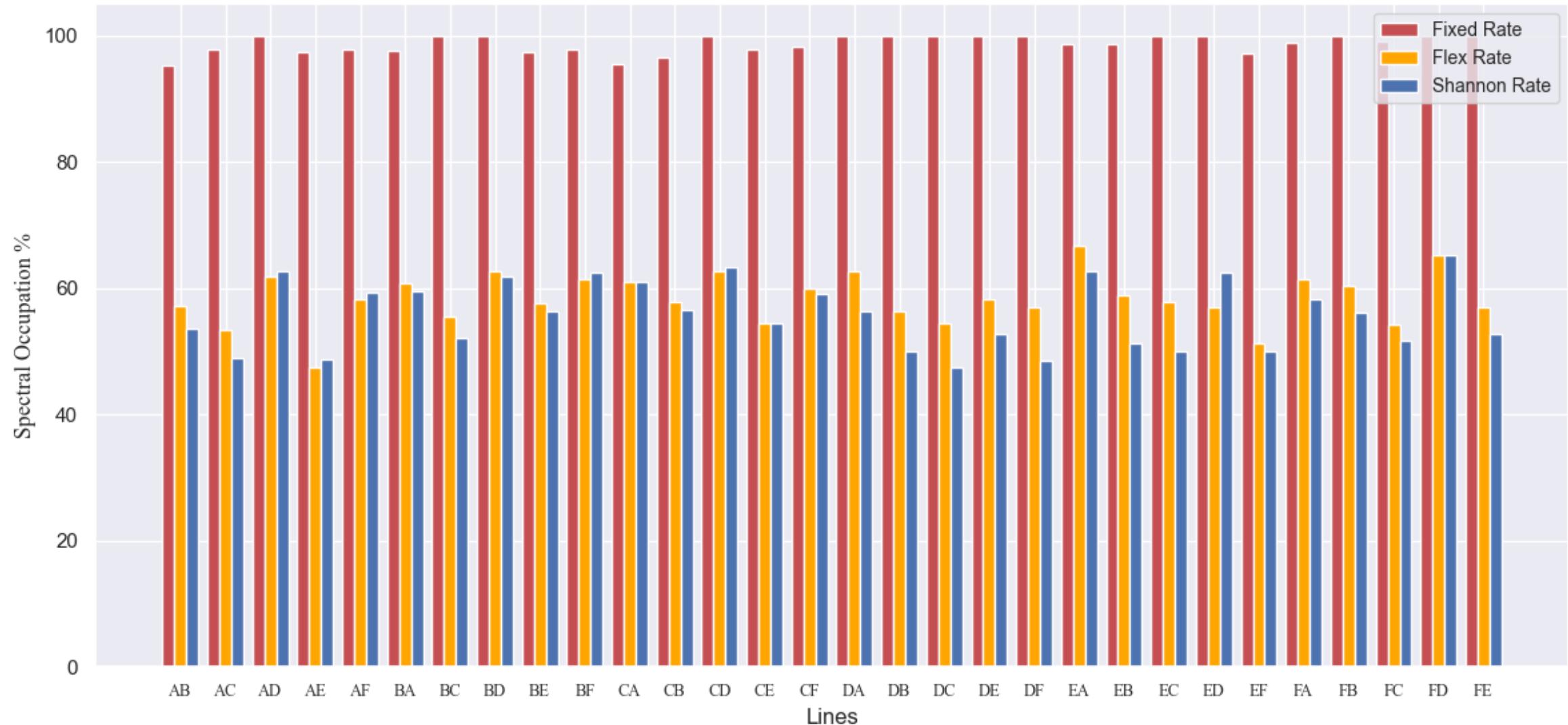
PER- LINK CAPACITY

Per-link Average Capacity for M=4, with MC=50



SPECTRAL OCCUPATION PER LINE

Single Matrix Scenario - Spectral occupation per Line for M=4

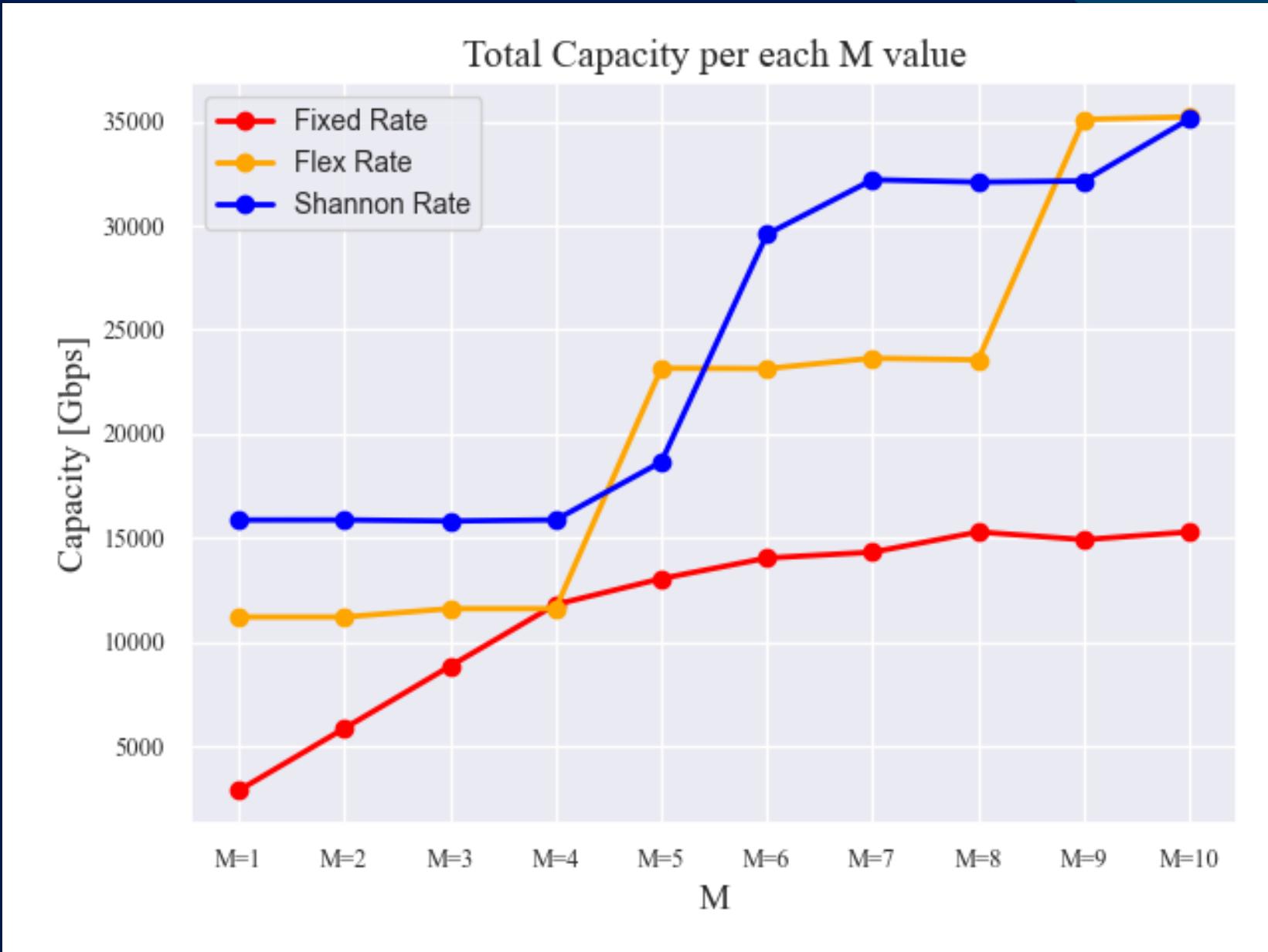


CONGESTION SCENARIO

CONSIDERATIONS

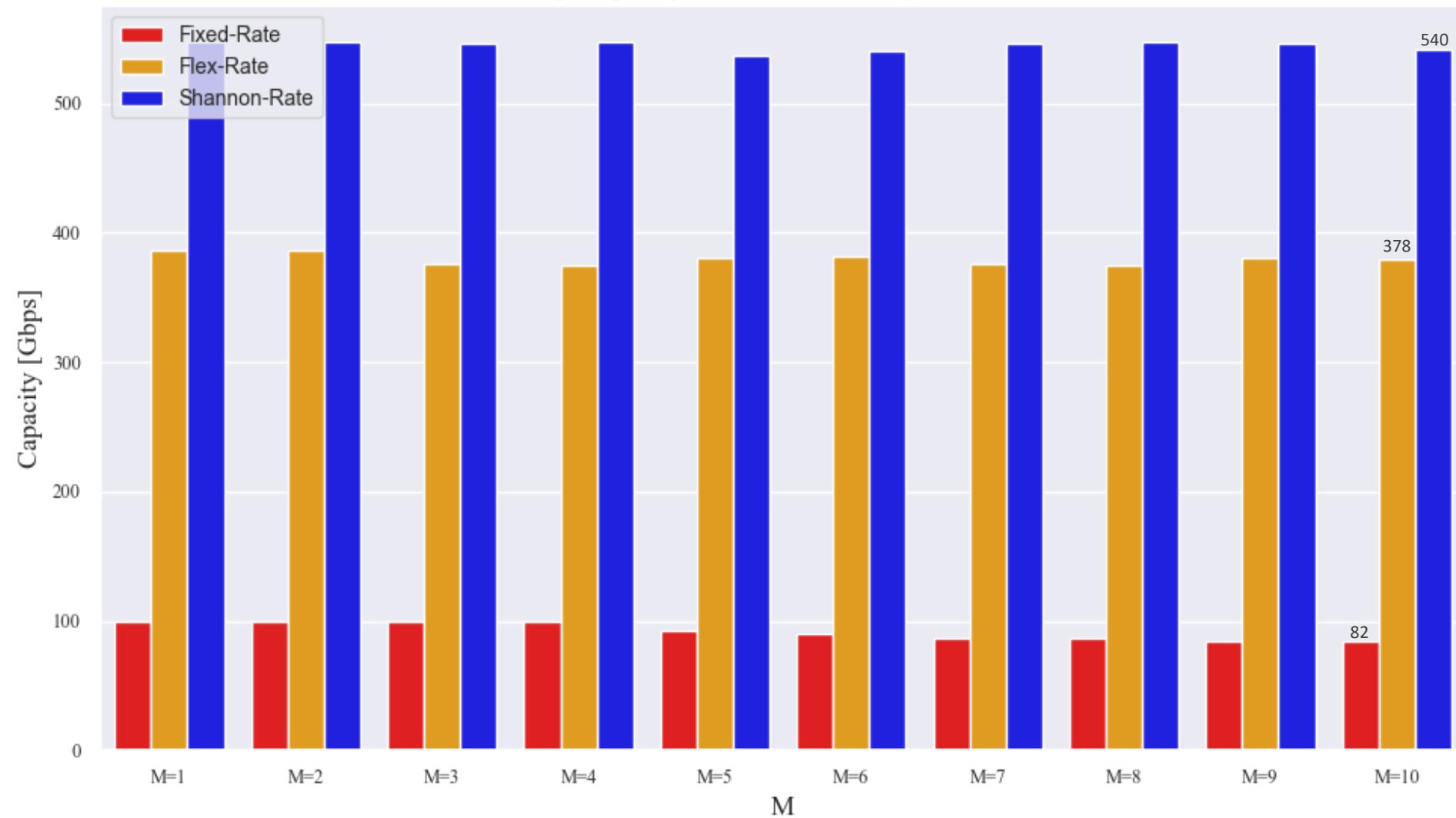
- In order to evaluate the impact of congestion on the network, the value of the M factor was assessed at 10 discrete values, ranging from 1 to 10. Each test was conducted 10 times, with the aim of estimating the metric at the conclusion of the test.
- The json files evaluated were once again *Network*, *full_network*, and *not_full_network*.
- The number of completed connections was set to 30. This means that the connection between each pair of nodes in the Traffic Matrix is saturated.

Network

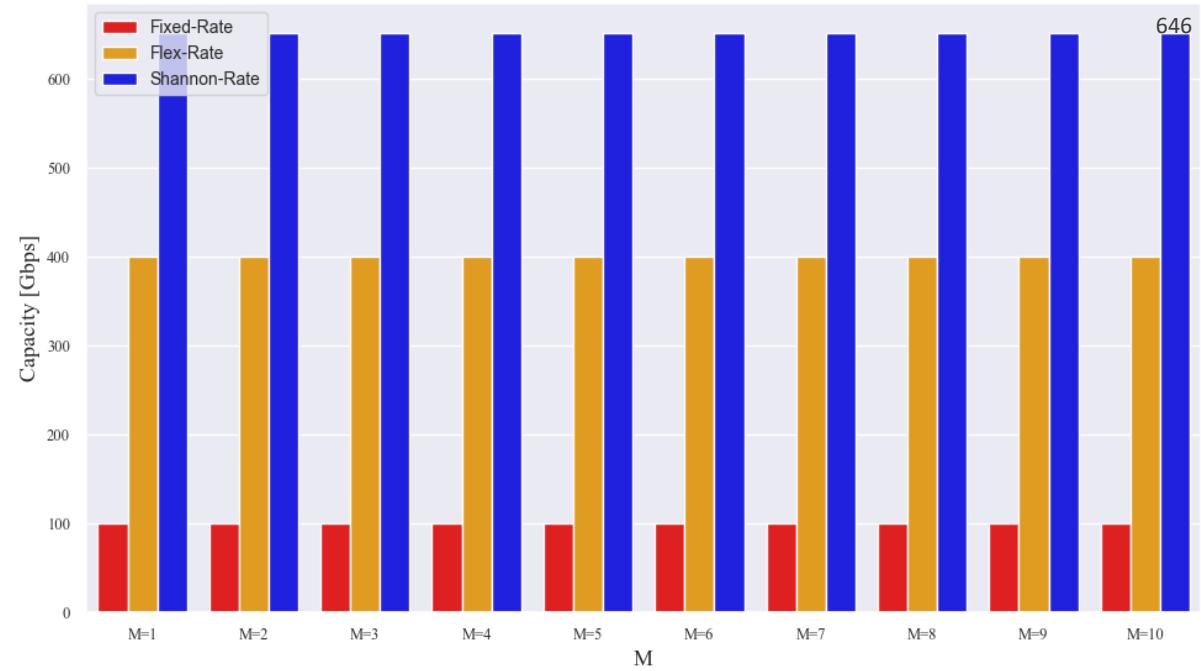


Network

Average capacity obtained according each M value

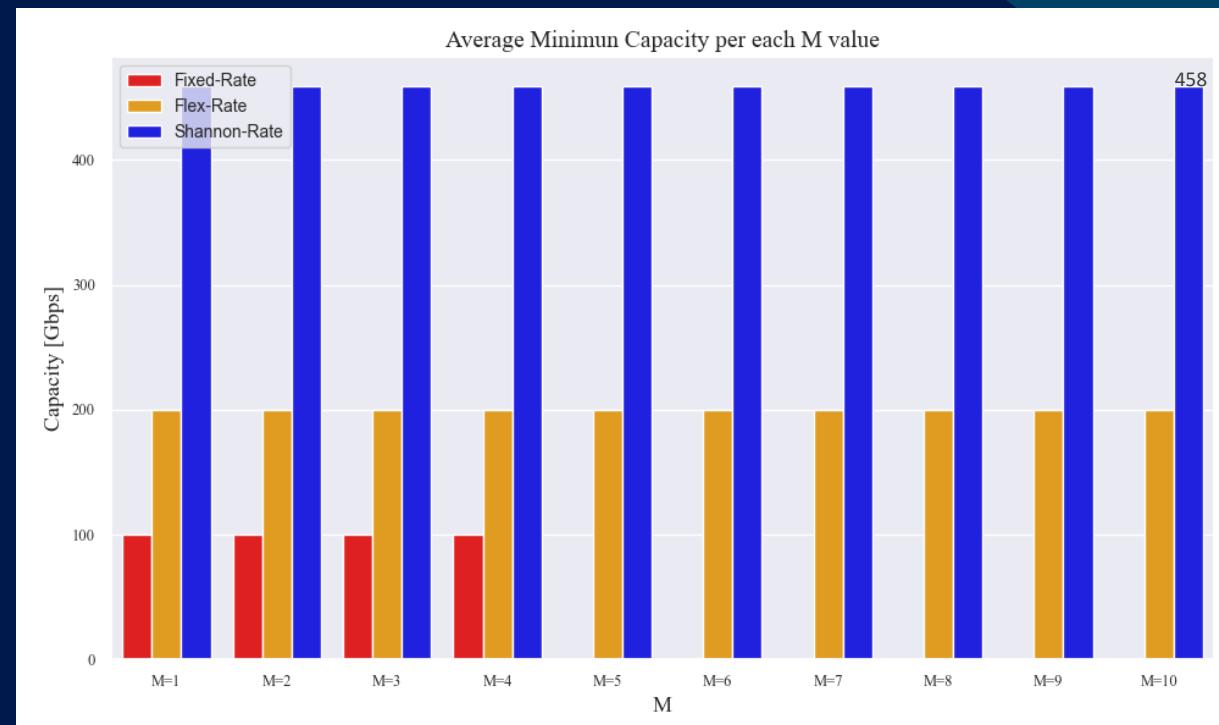


Average Maximum Capacity per each M value

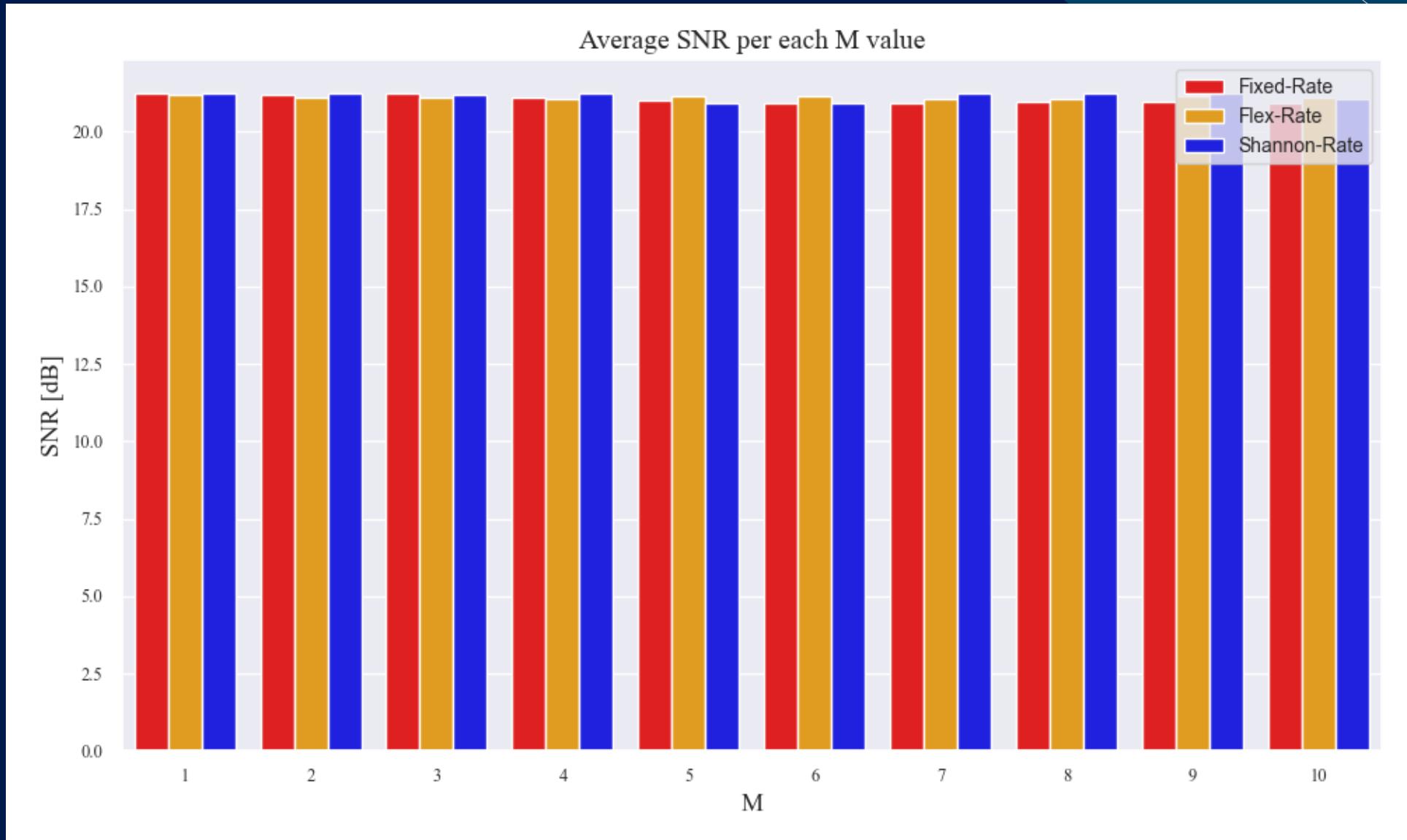


Average Maximum Capacity

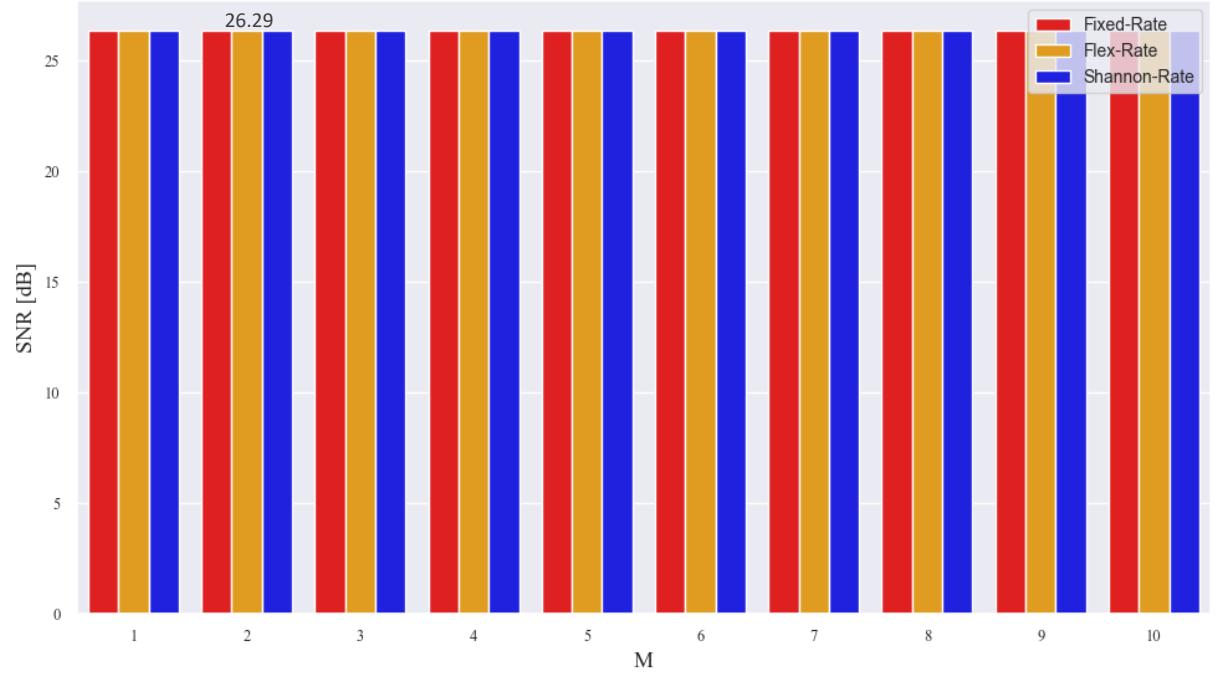
Average Minimum Capacity



Network

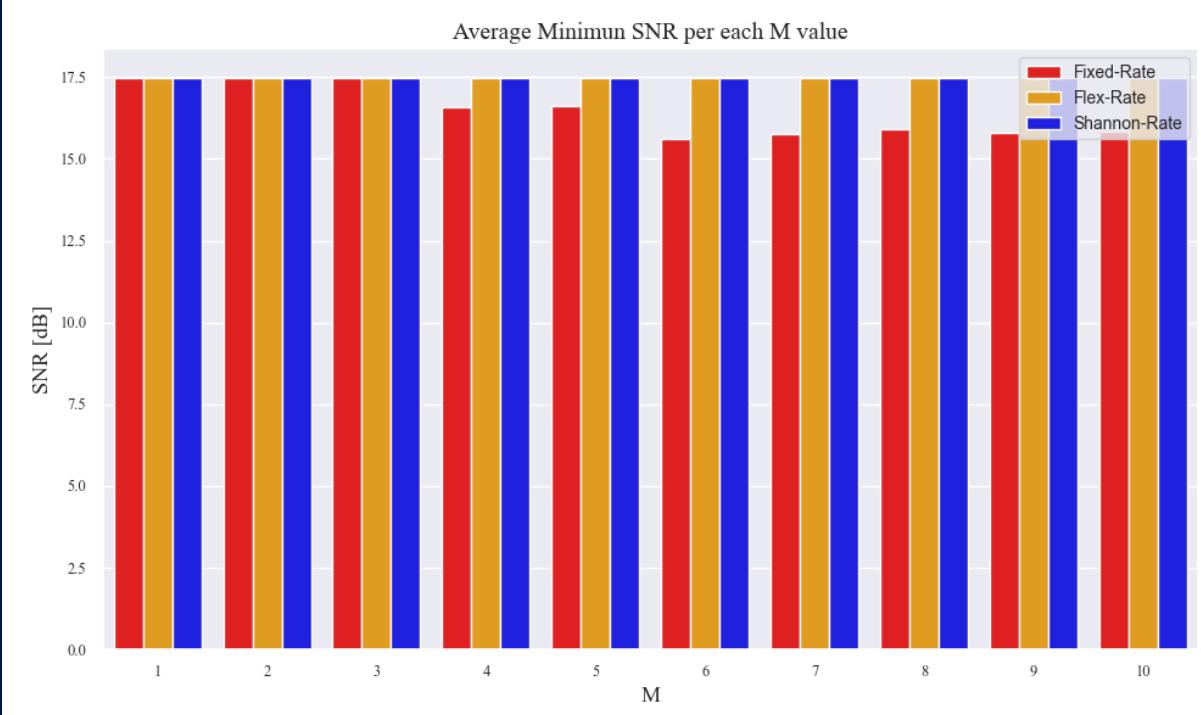


Average Maximum SNR per each M value

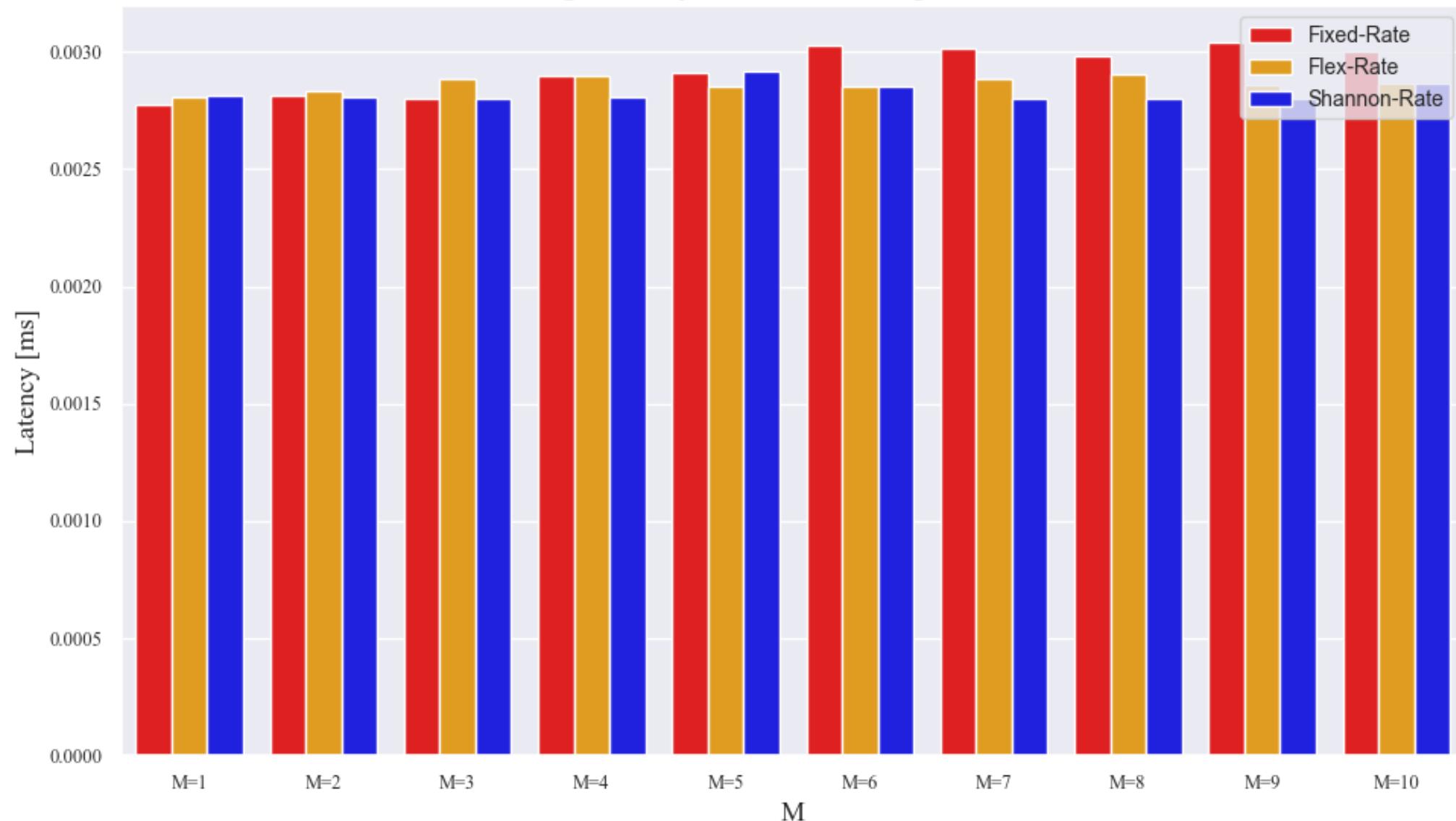


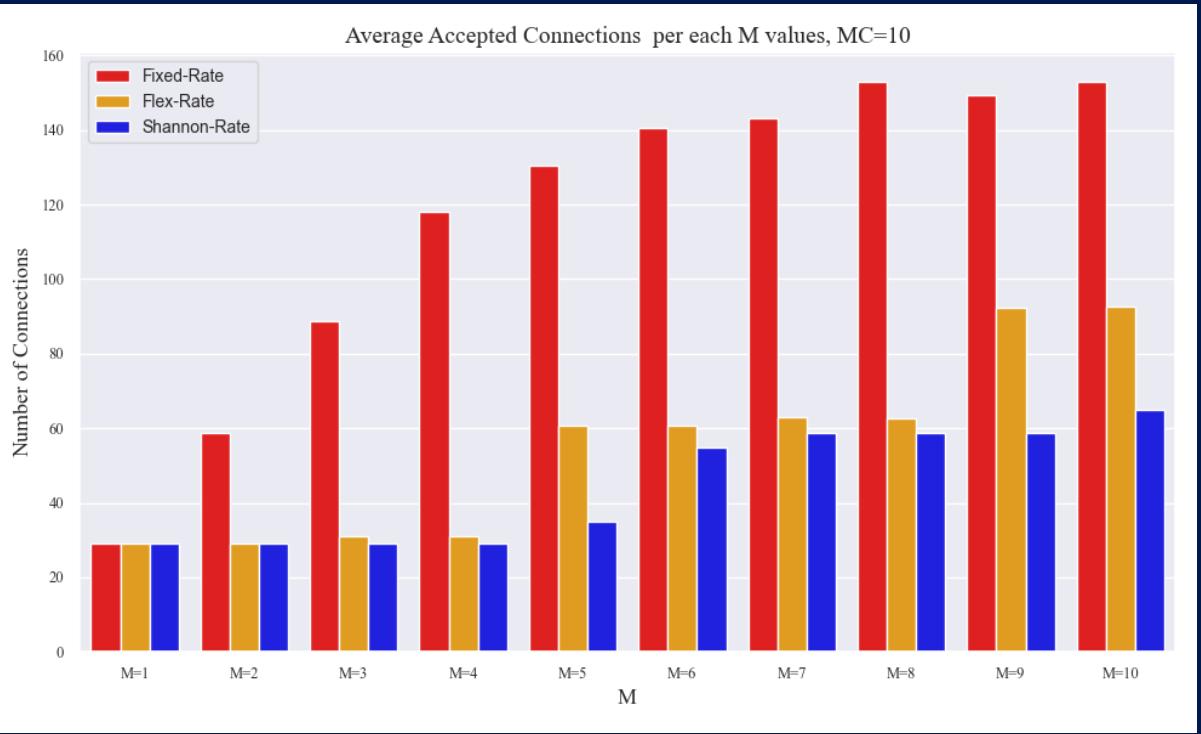
Average Maximum SNR

Average Minimum SNR

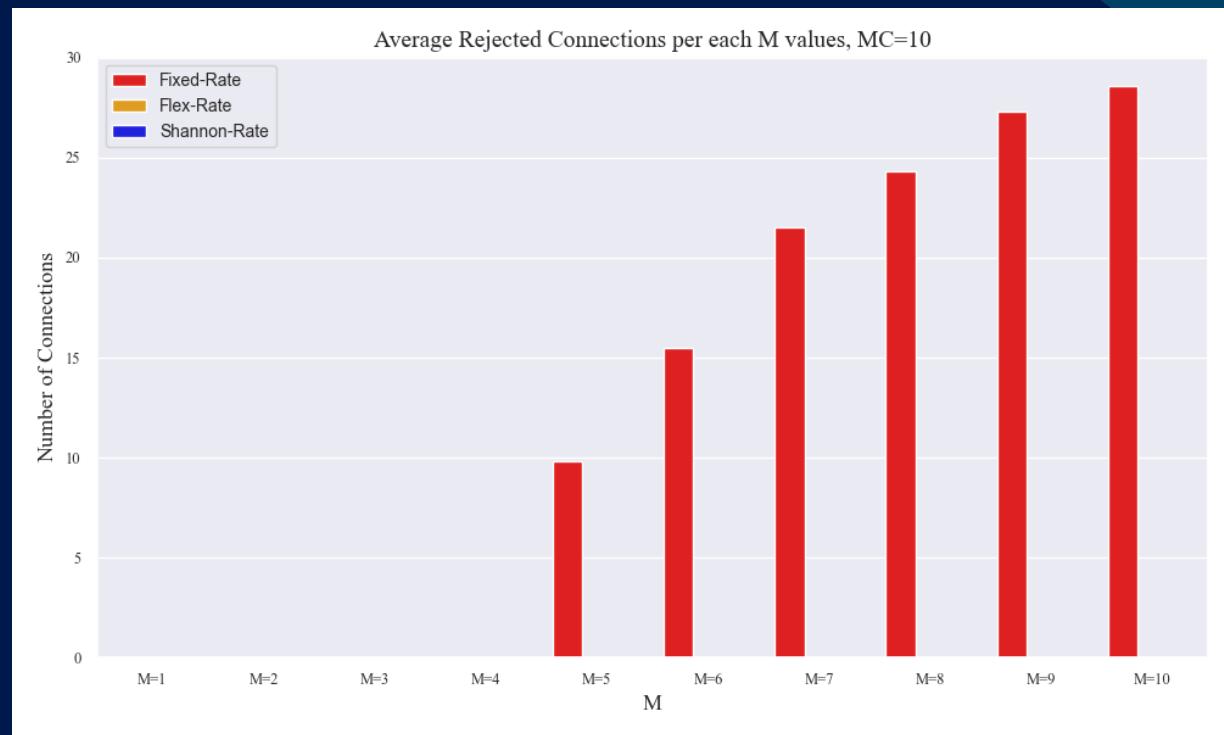


Average Latency obtained according each M value

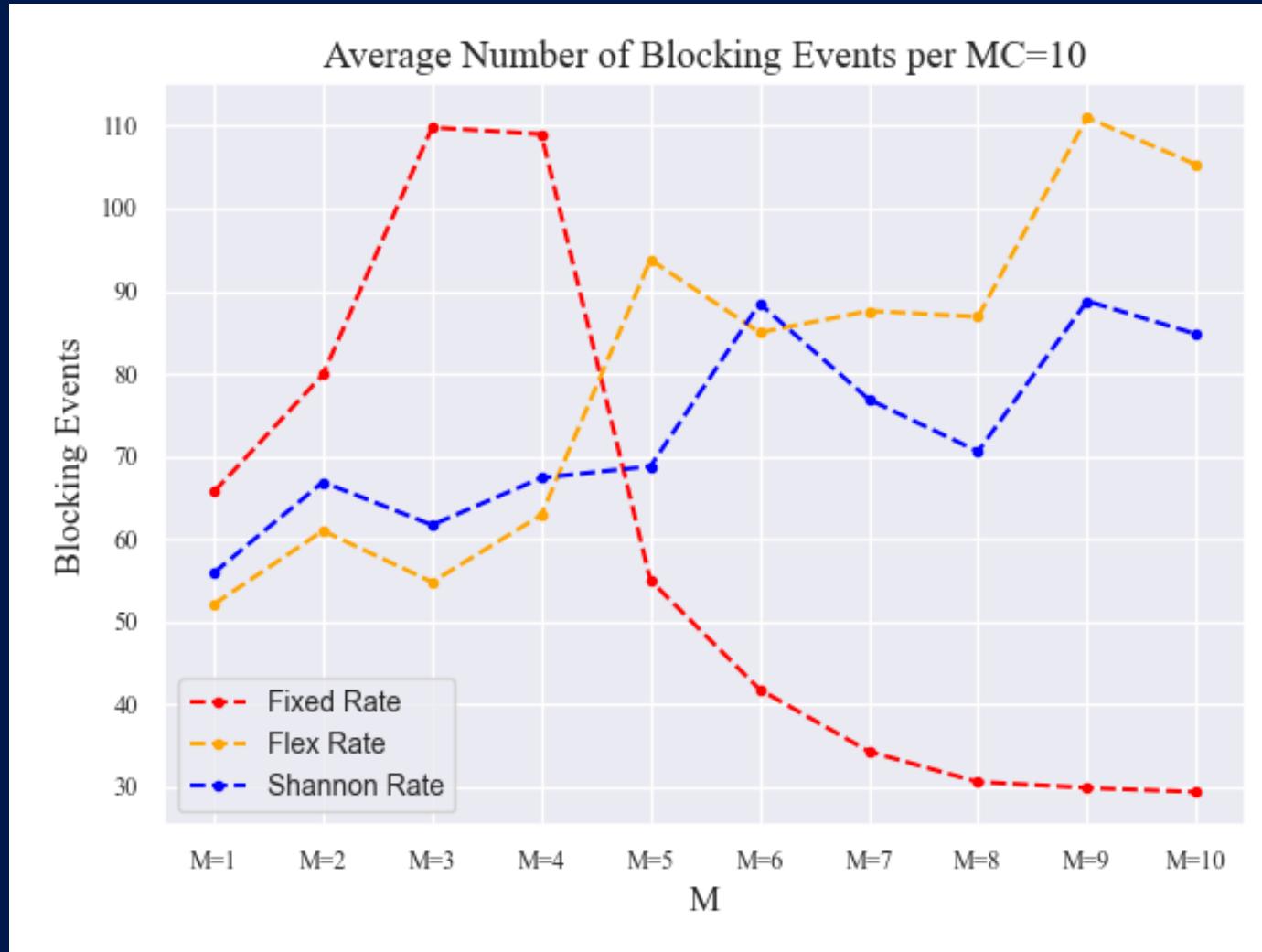




Average Accepted Connection



Network

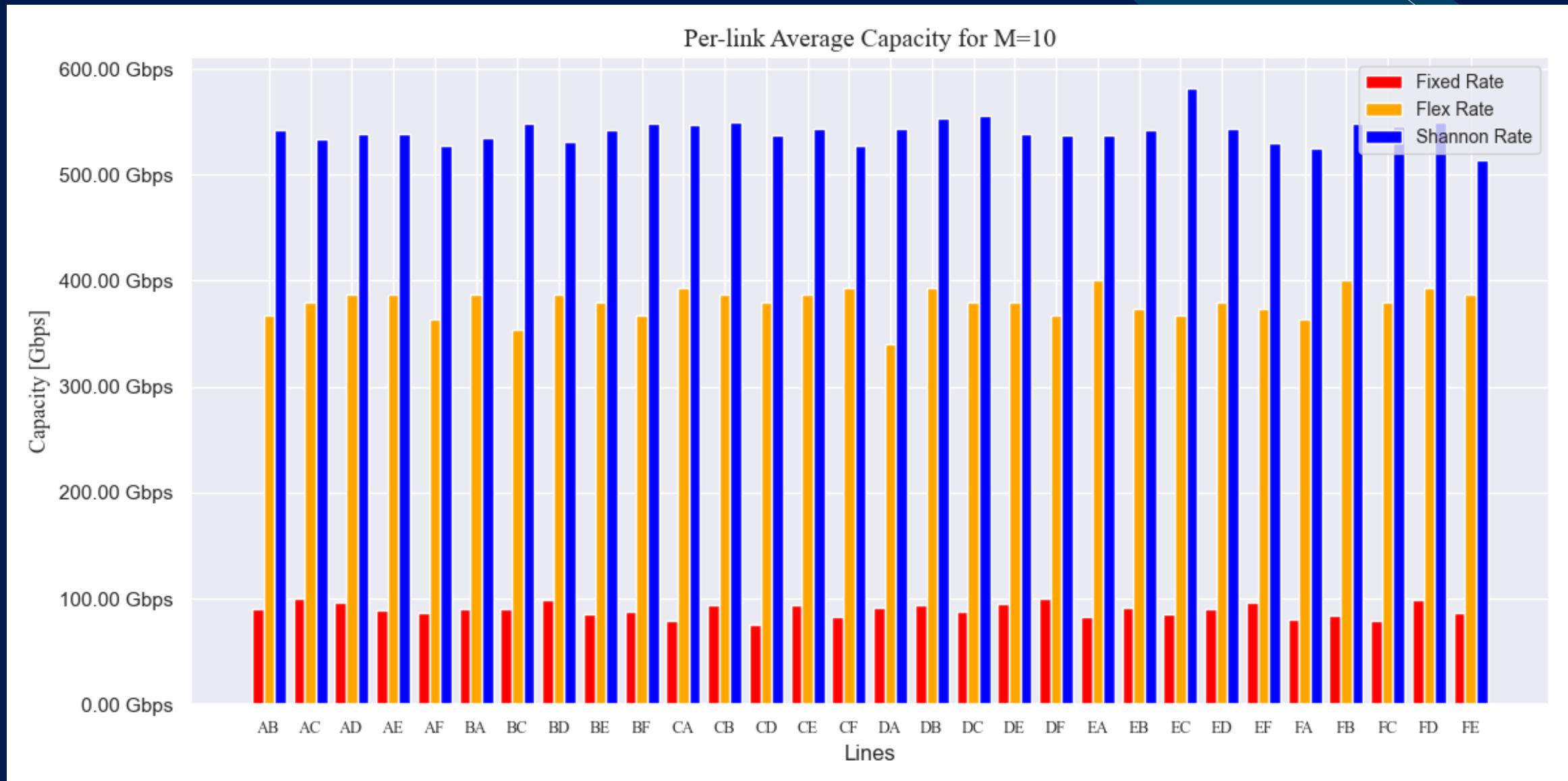


BLOCKING EVENTS

Not Traffic Matrix Assignment due to:

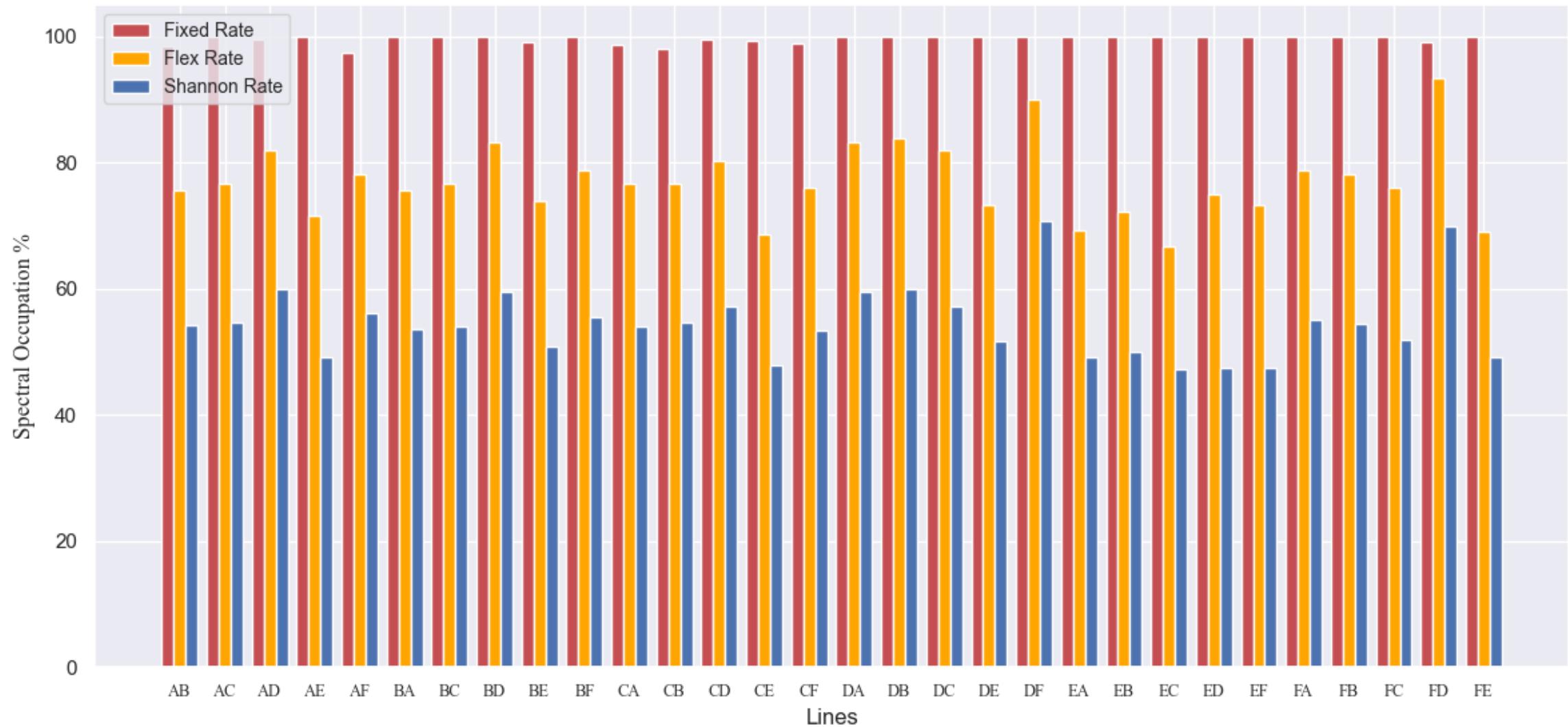
- Matrix saturation.
- It was not possible to assign a suitable path for the connection.

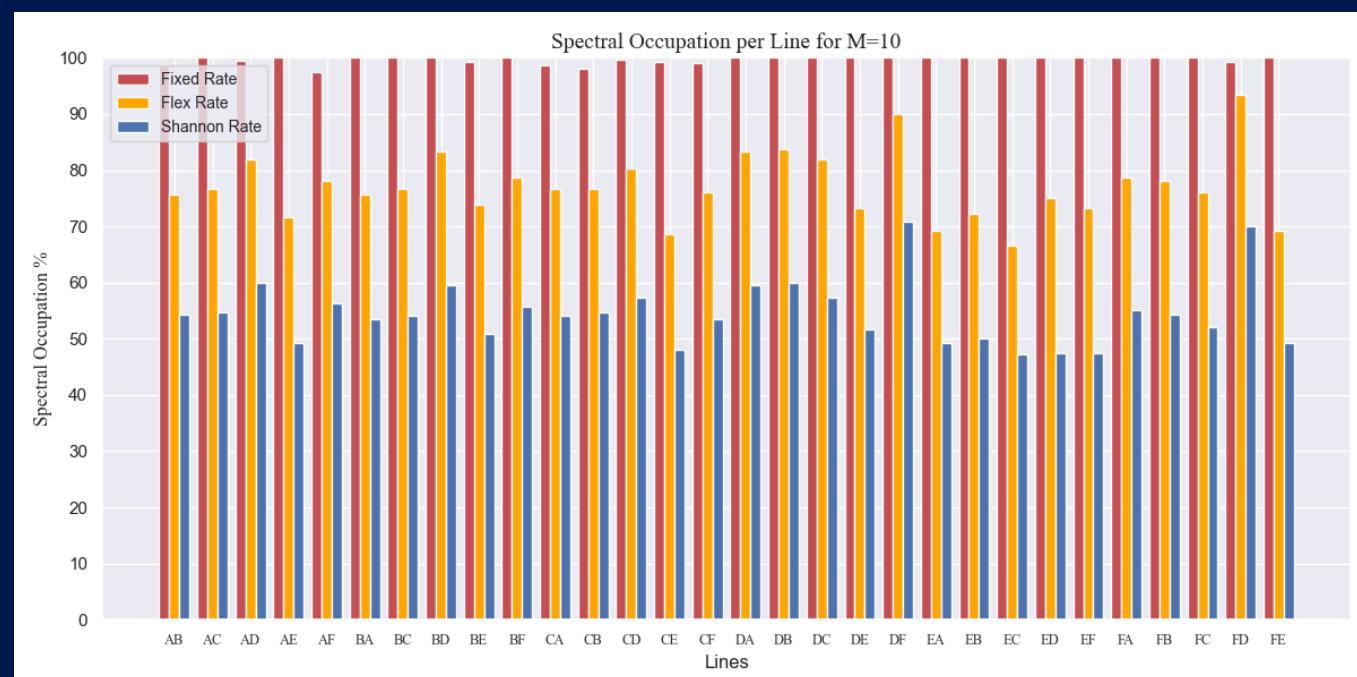
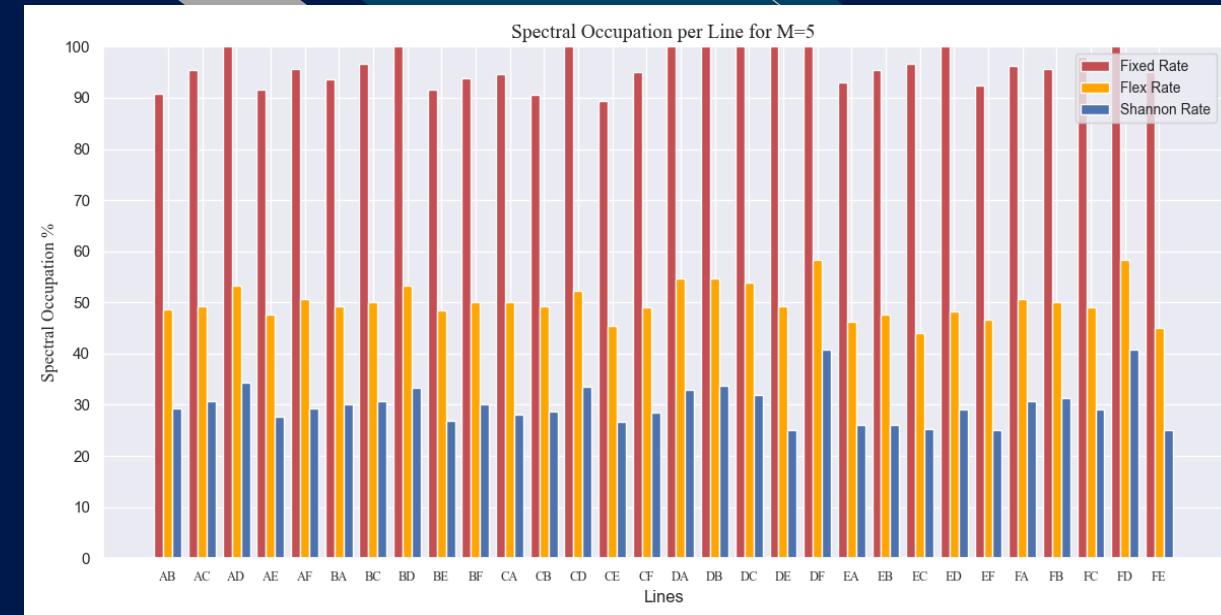
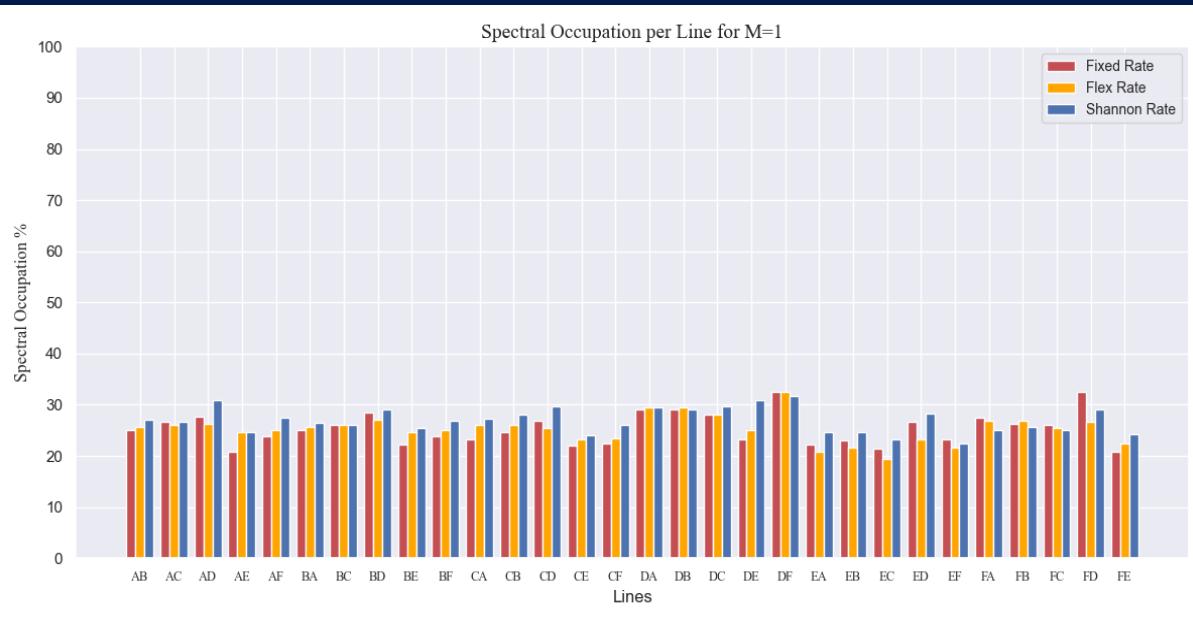
Network



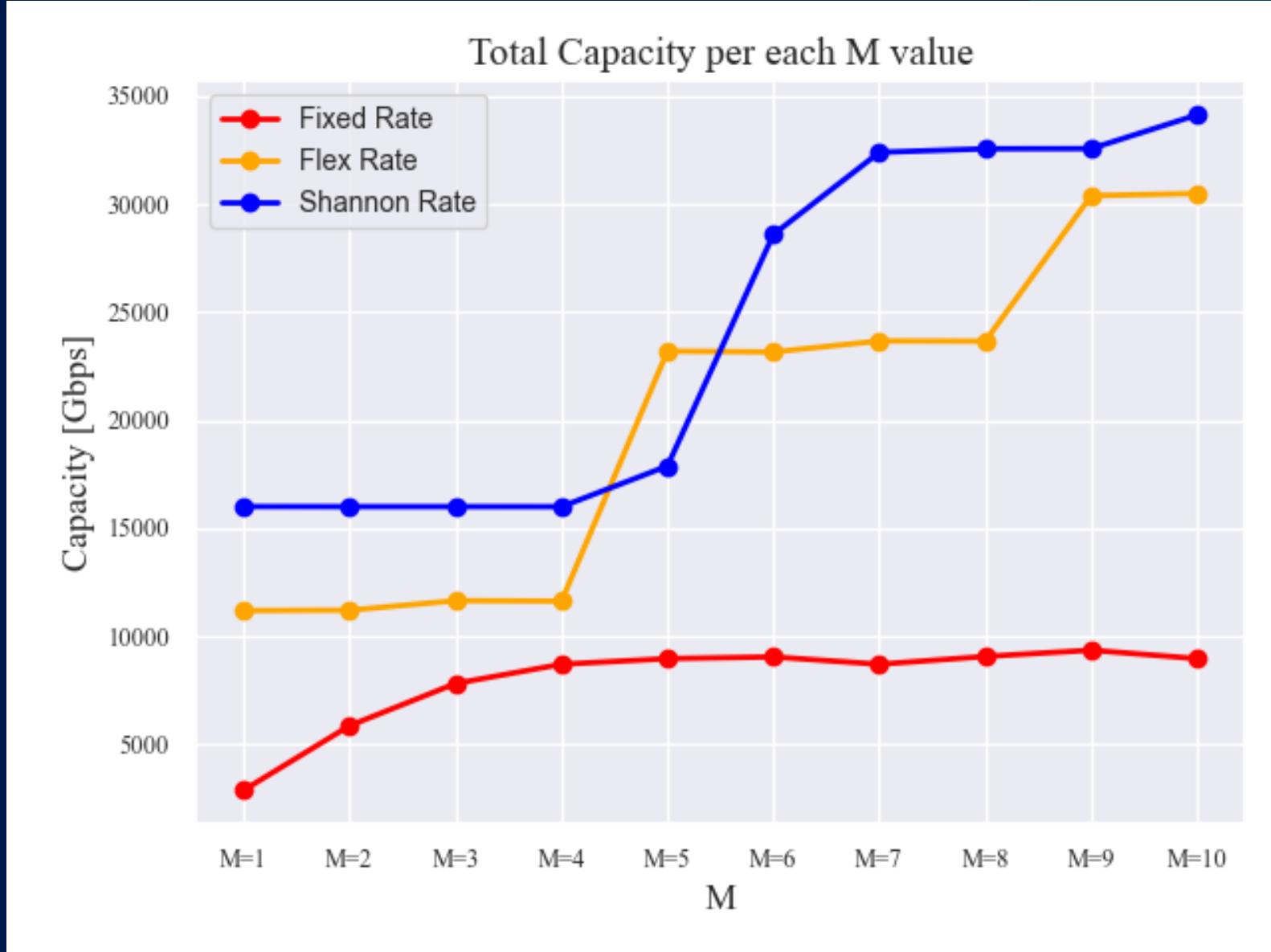
Network

Spectral Occupation per Line for M=10

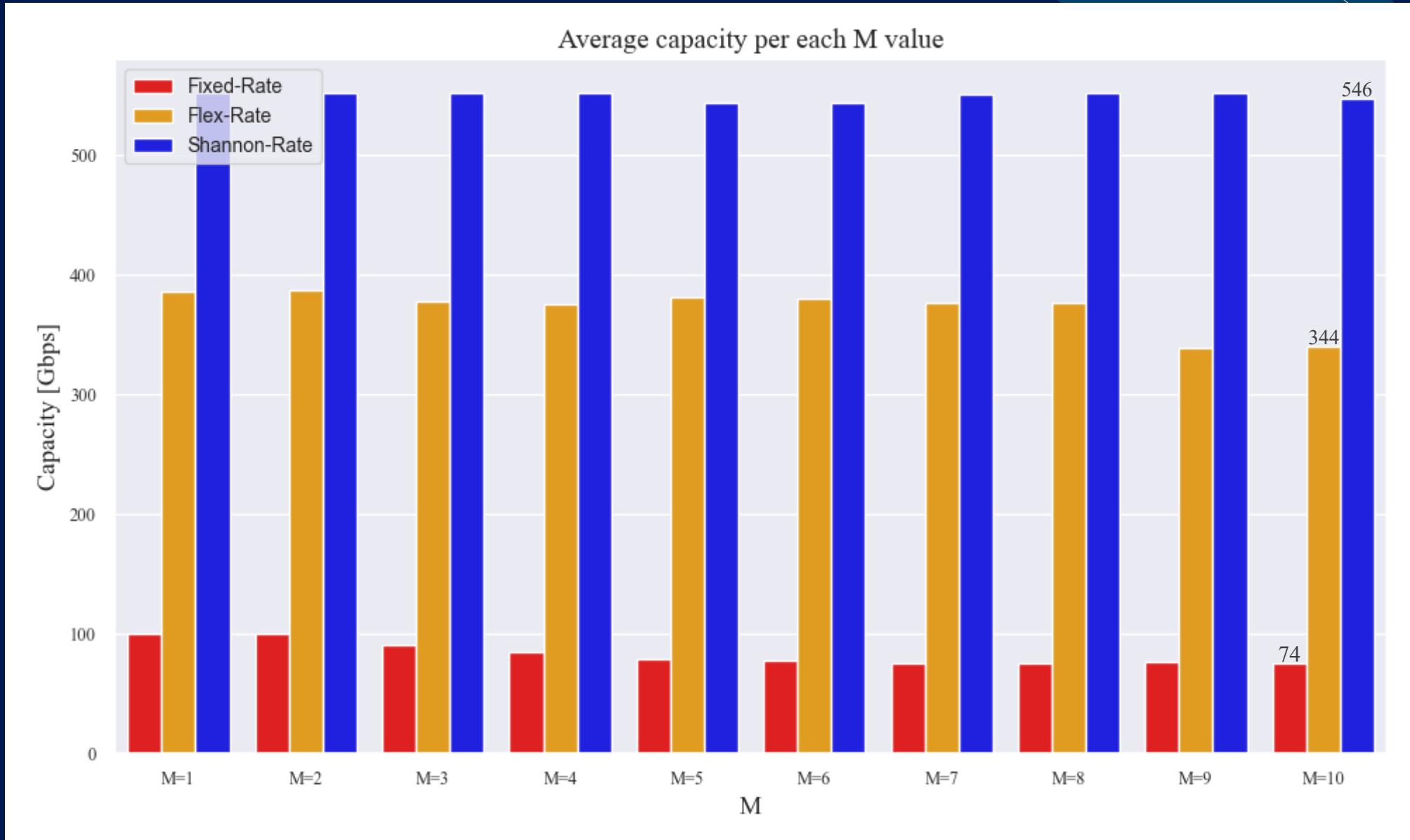




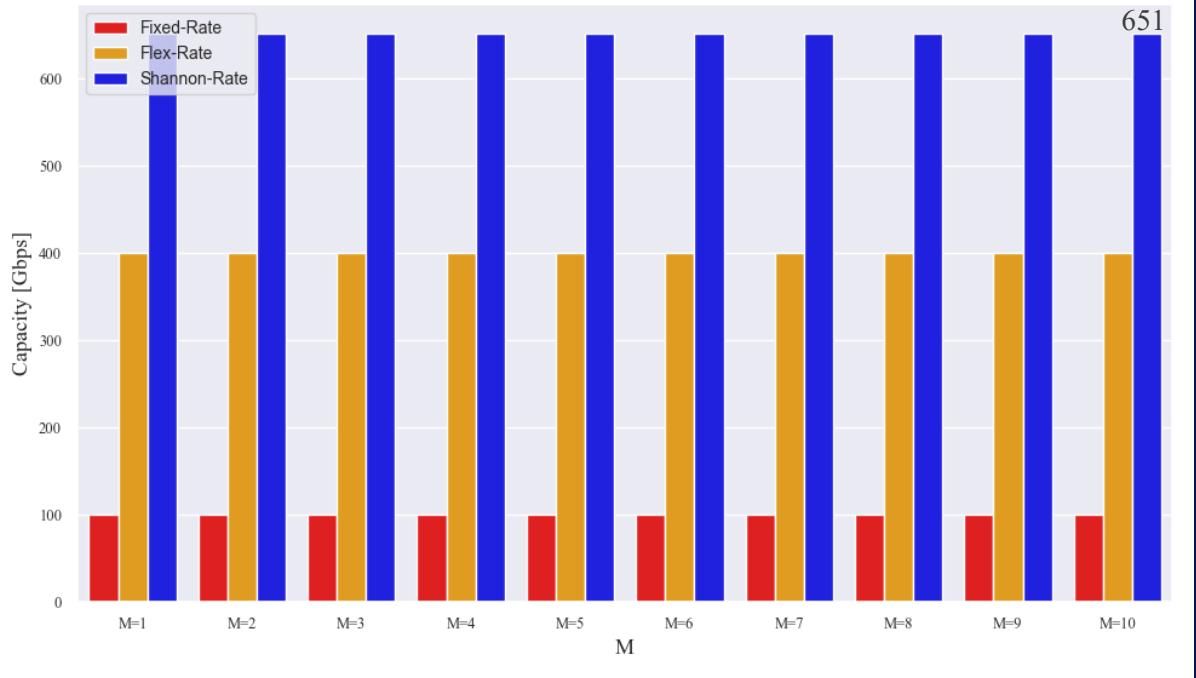
Full Network



Full Network



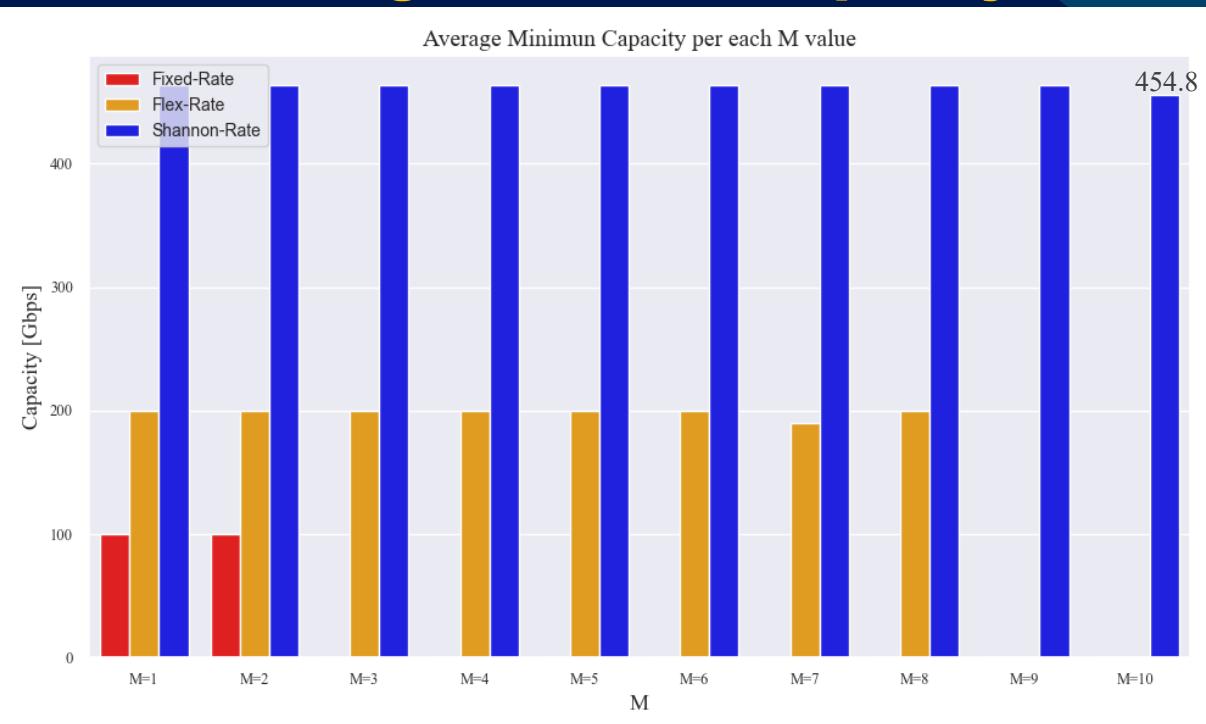
Average Maximum Capacity per each M value



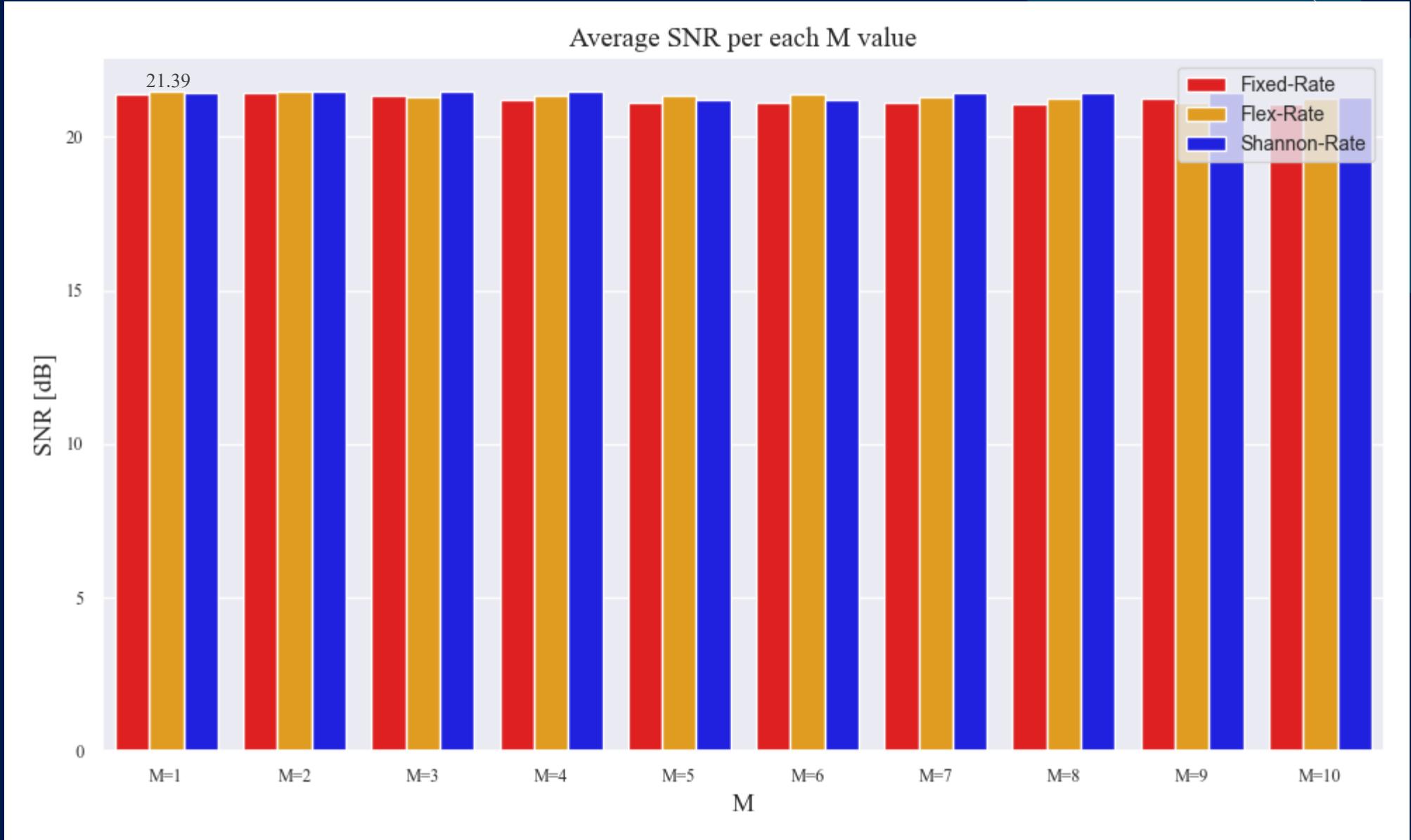
Average Maximum Capacity

Average Minimum Capacity

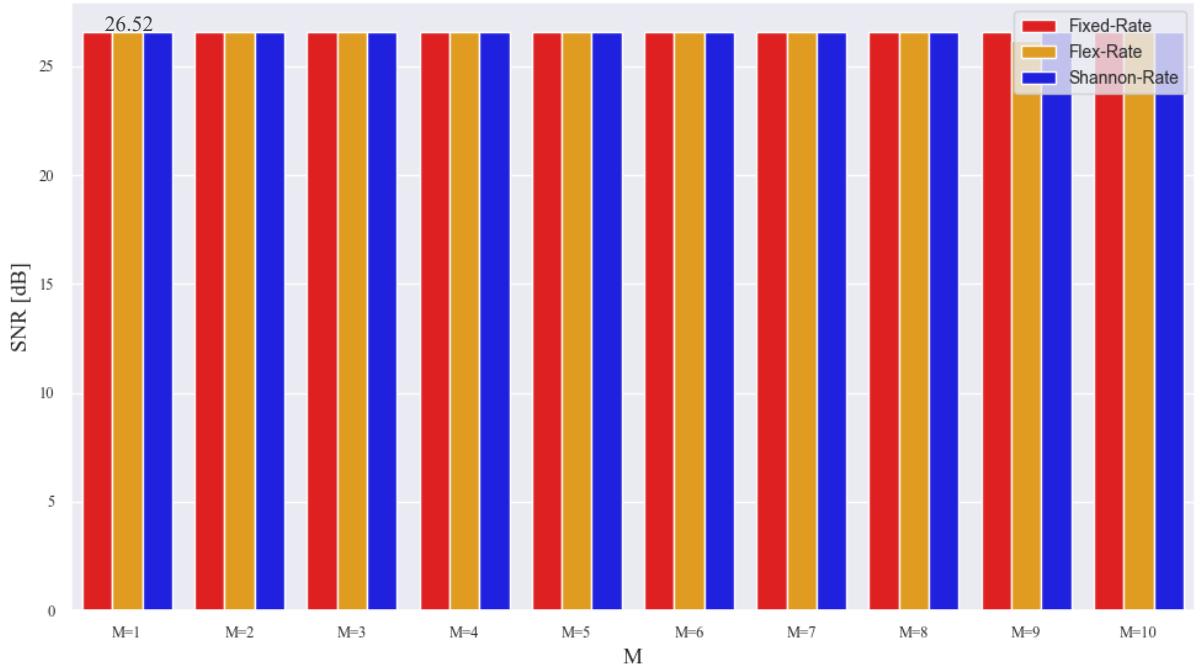
Average Minimum Capacity per each M value



Full Network

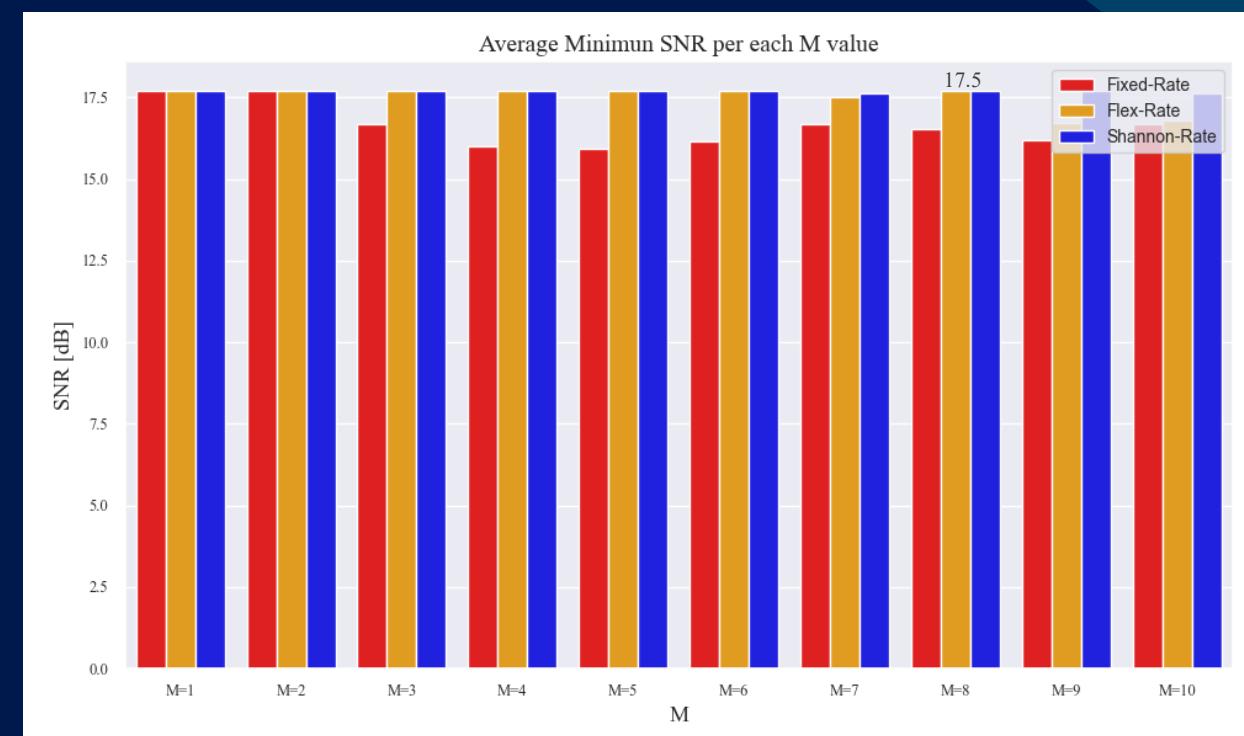


Average Maximum SNR per each M value

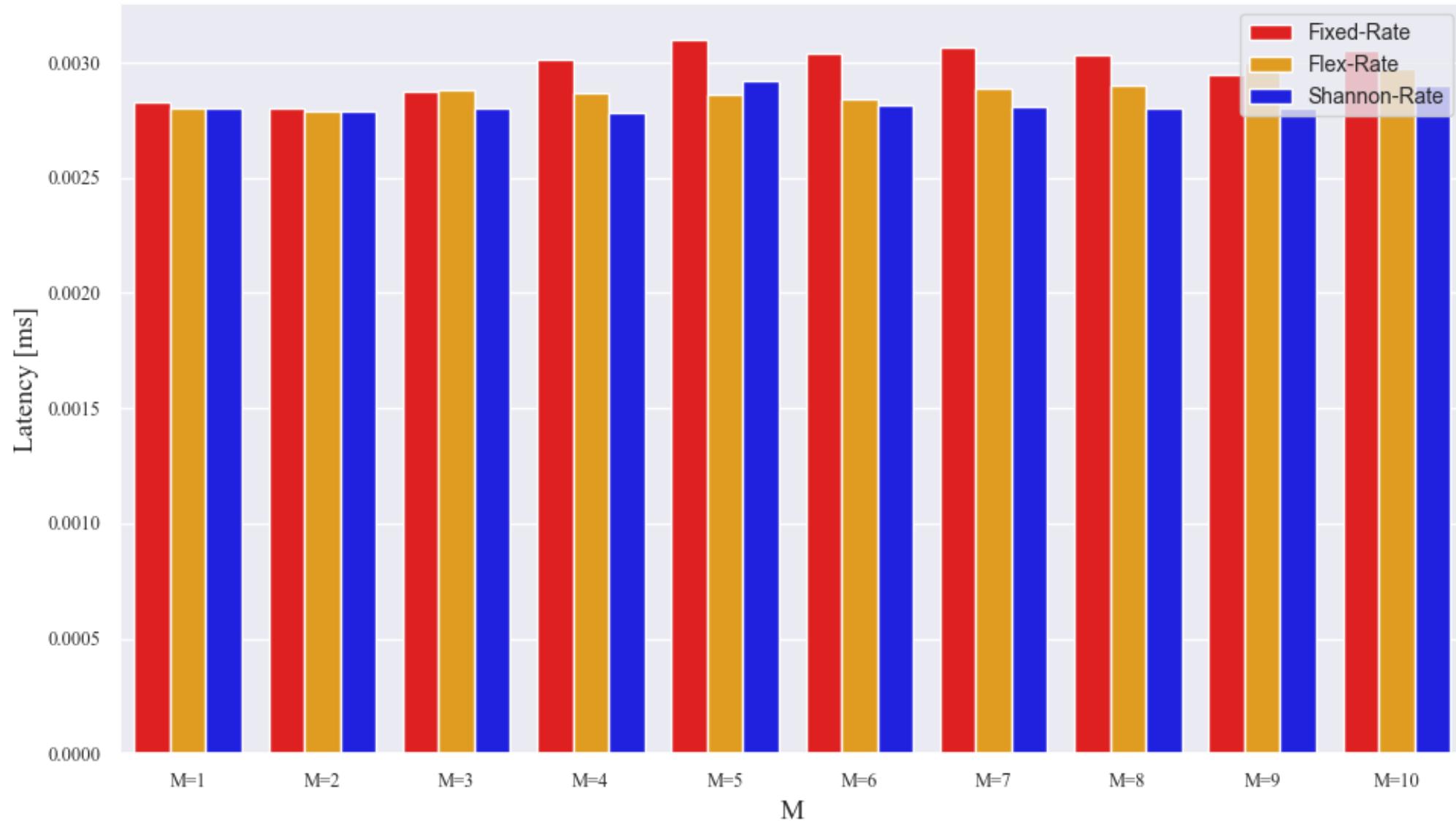


Average Maximum SNR

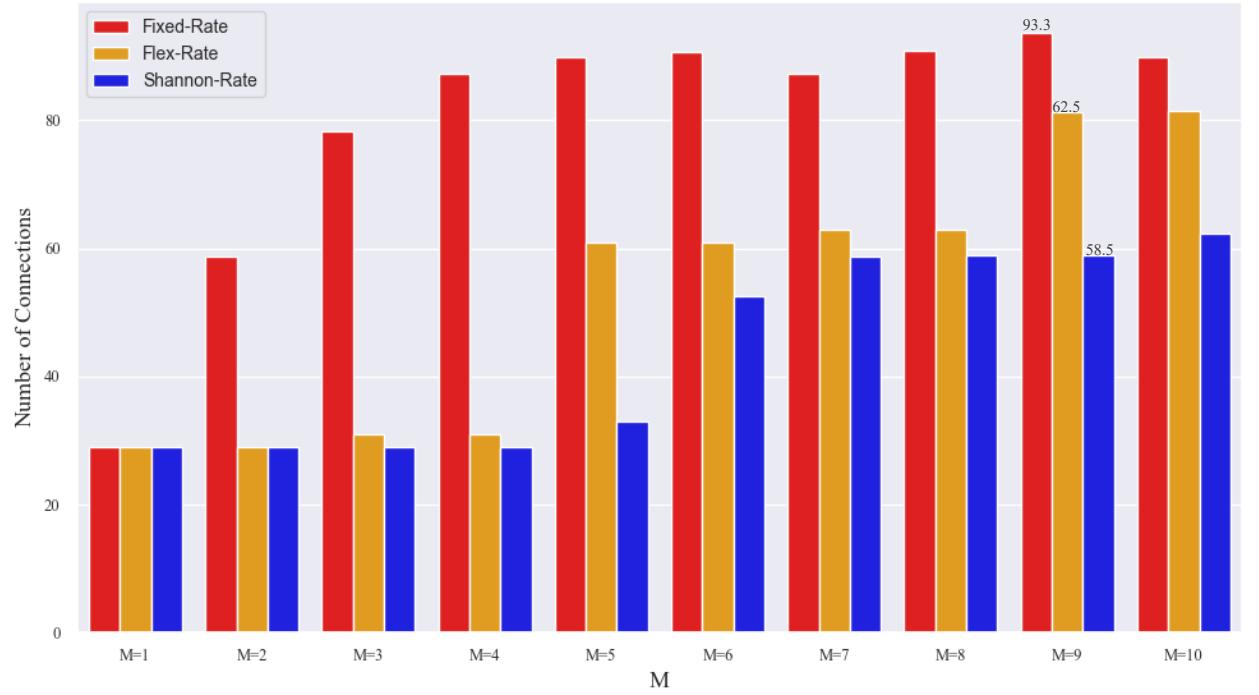
Average Minimum SNR



Average Latency obtained according each M value

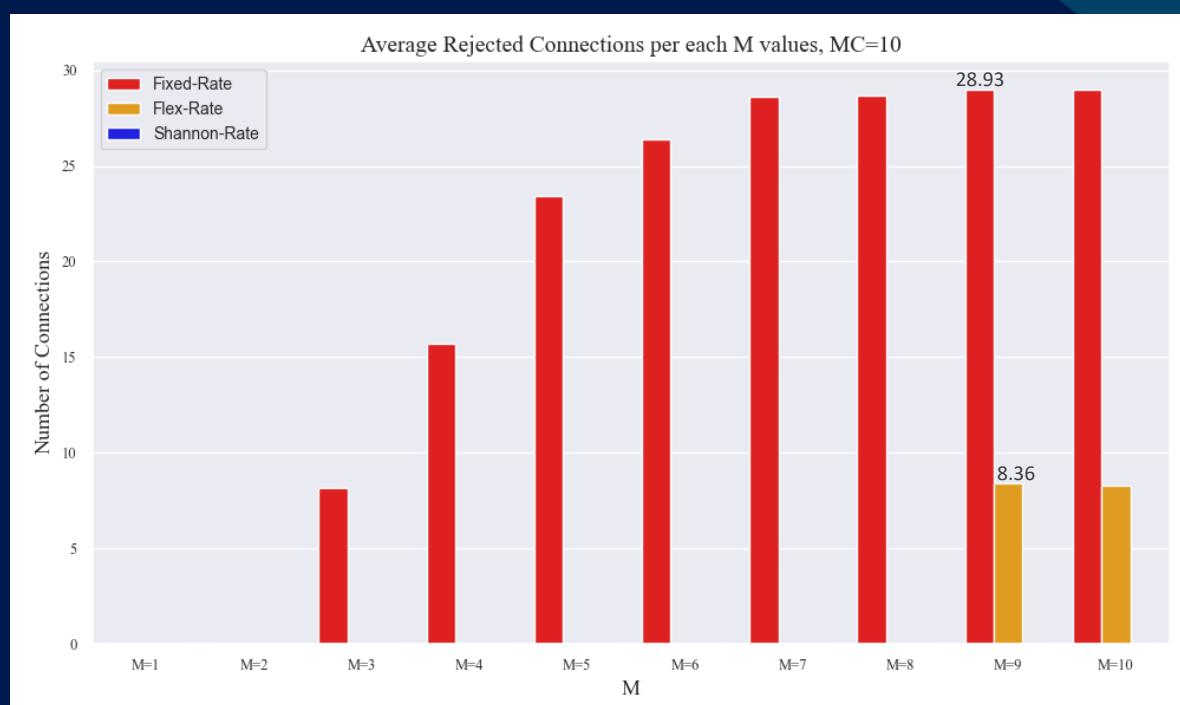


Average Accepted Connections per each M values, MC=10

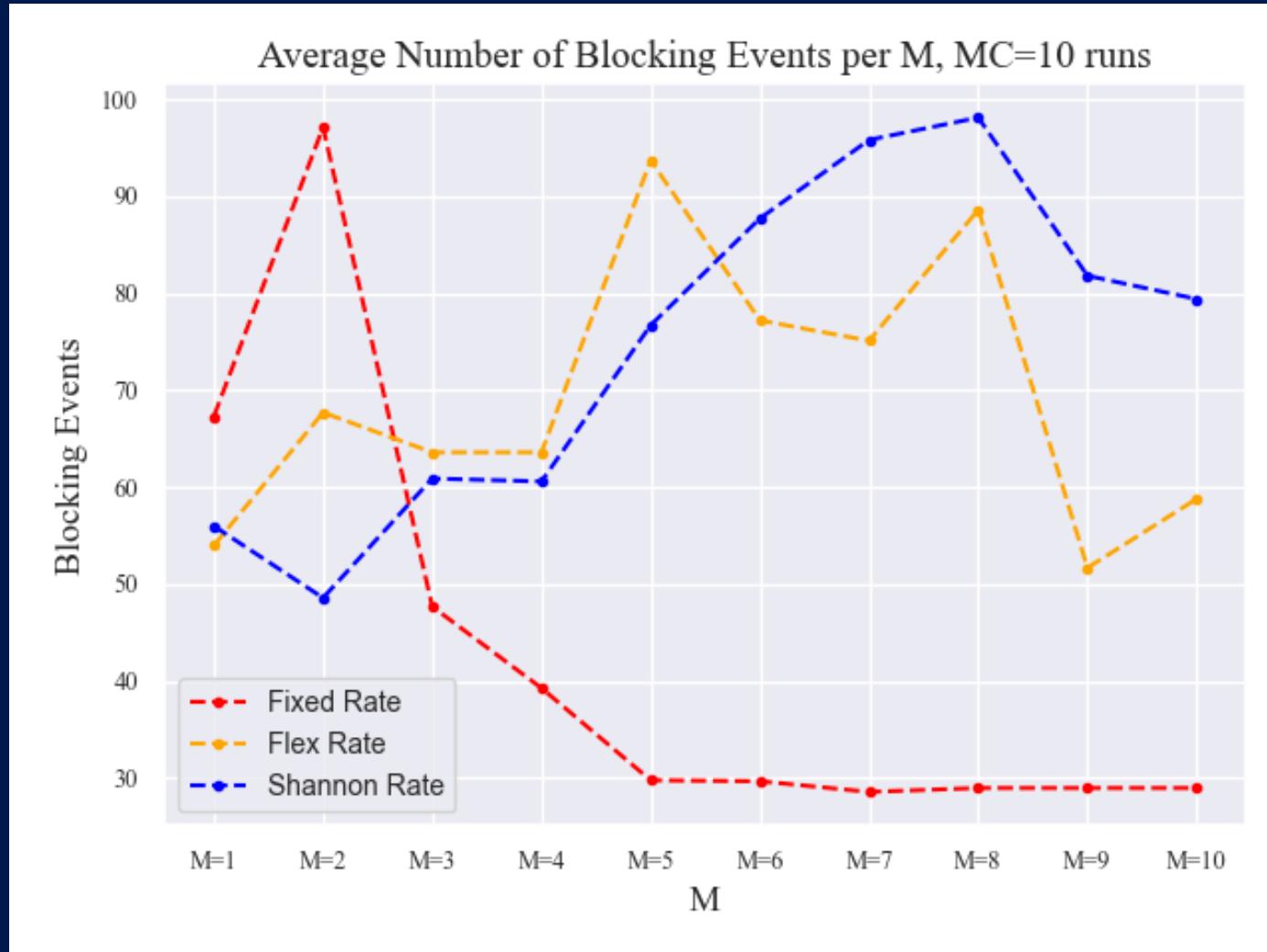


Average Accepted Connection

Average Rejected Connection



Full Network

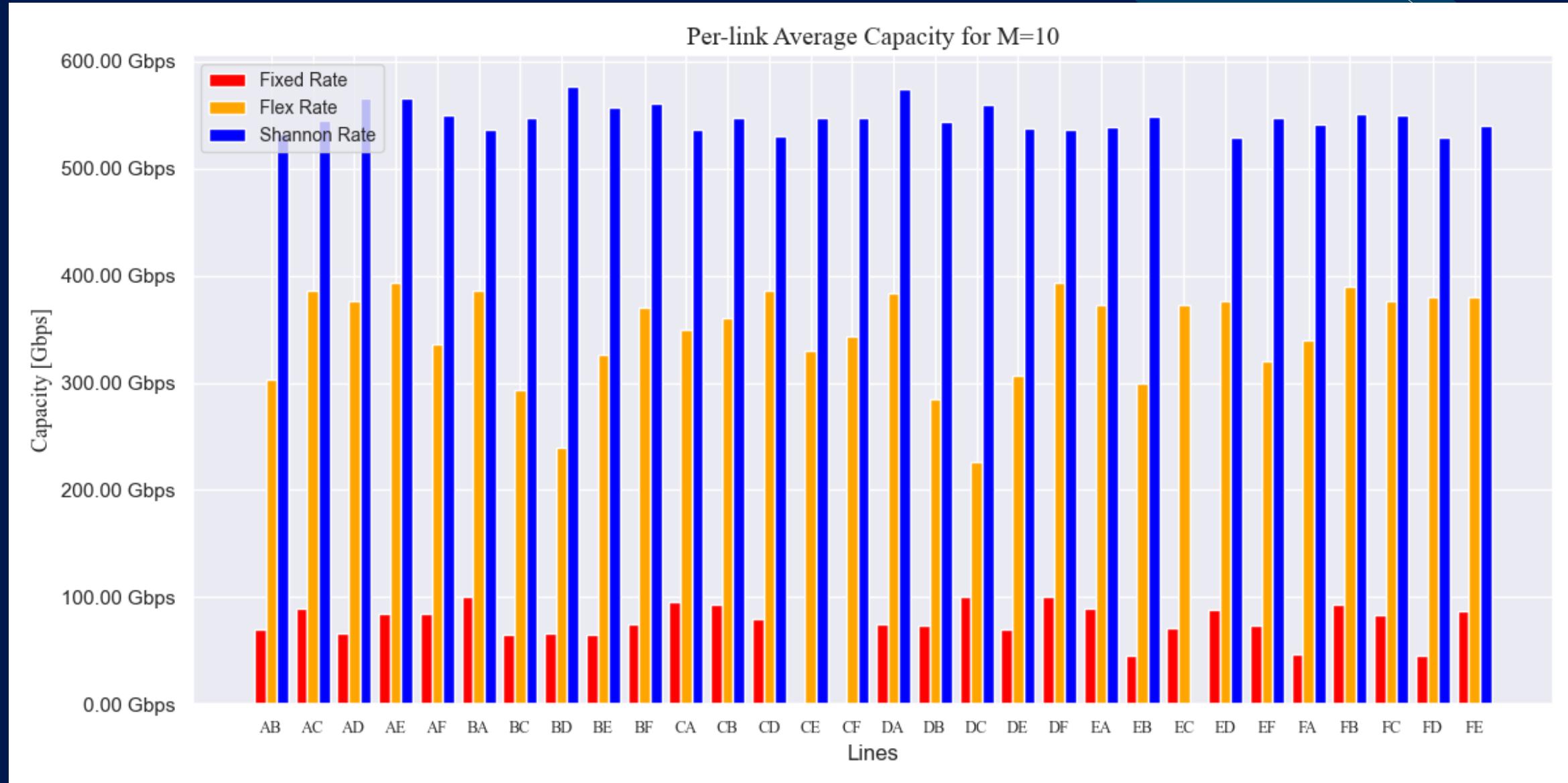


BLOCKING EVENTS

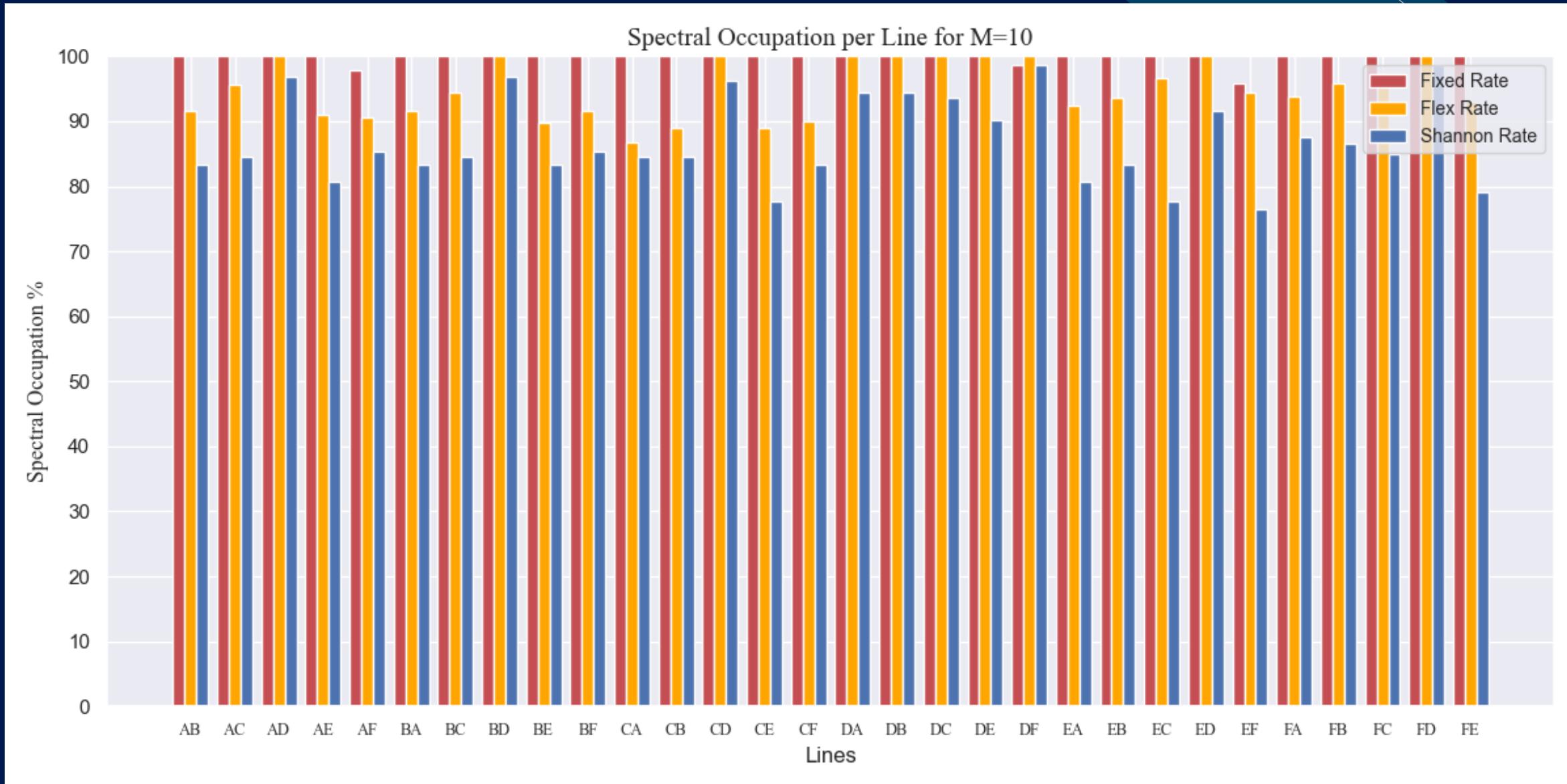
Not Traffic Matrix Assignment due to:

- Matrix saturation.
- It was not possible to assign a suitable path for the connection.

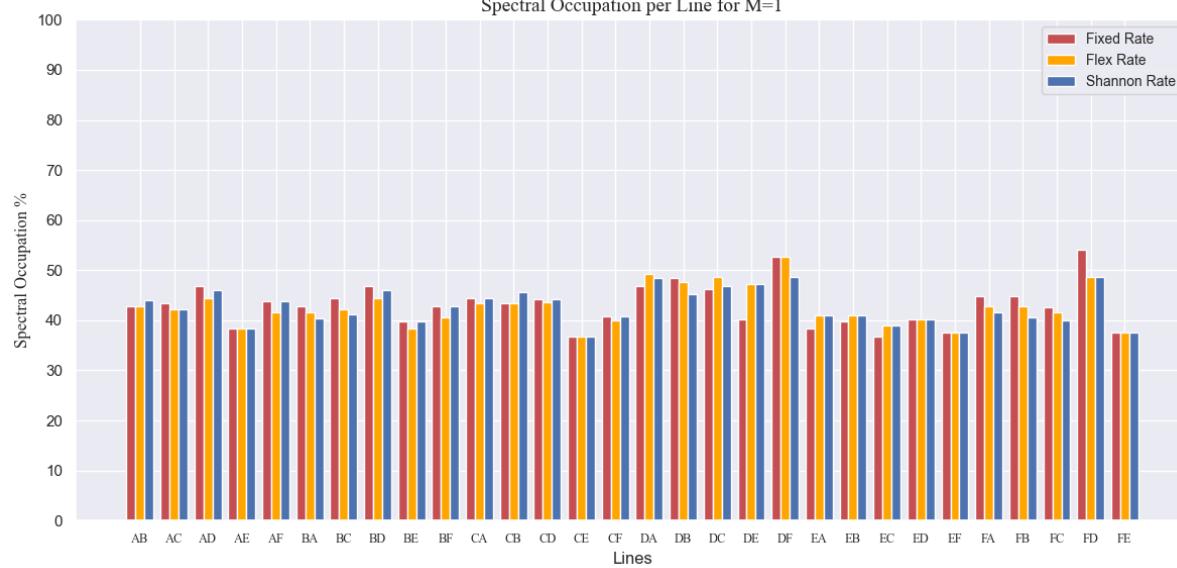
Full Network



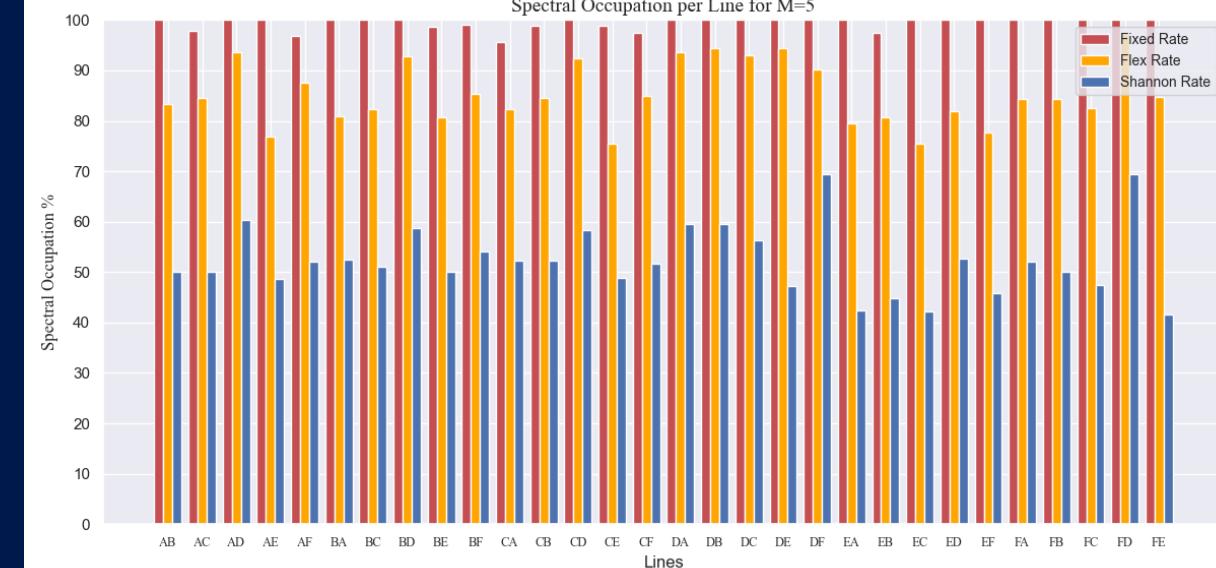
Full Network



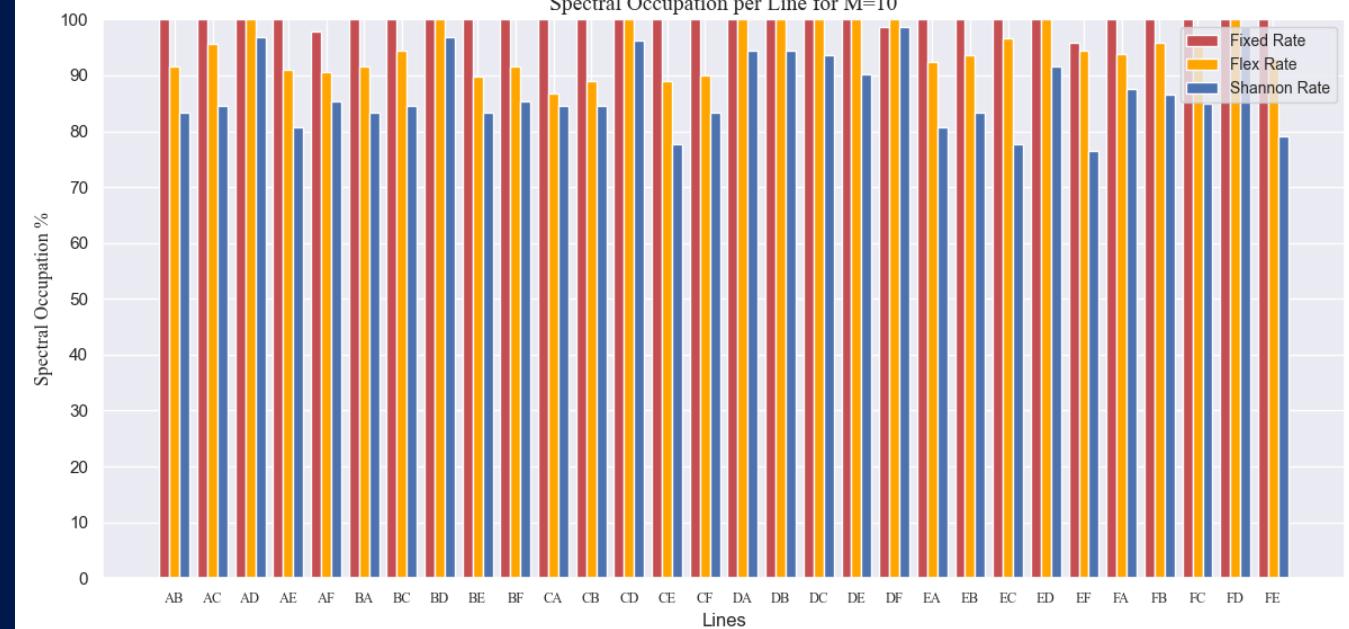
Spectral Occupation per Line for M=1



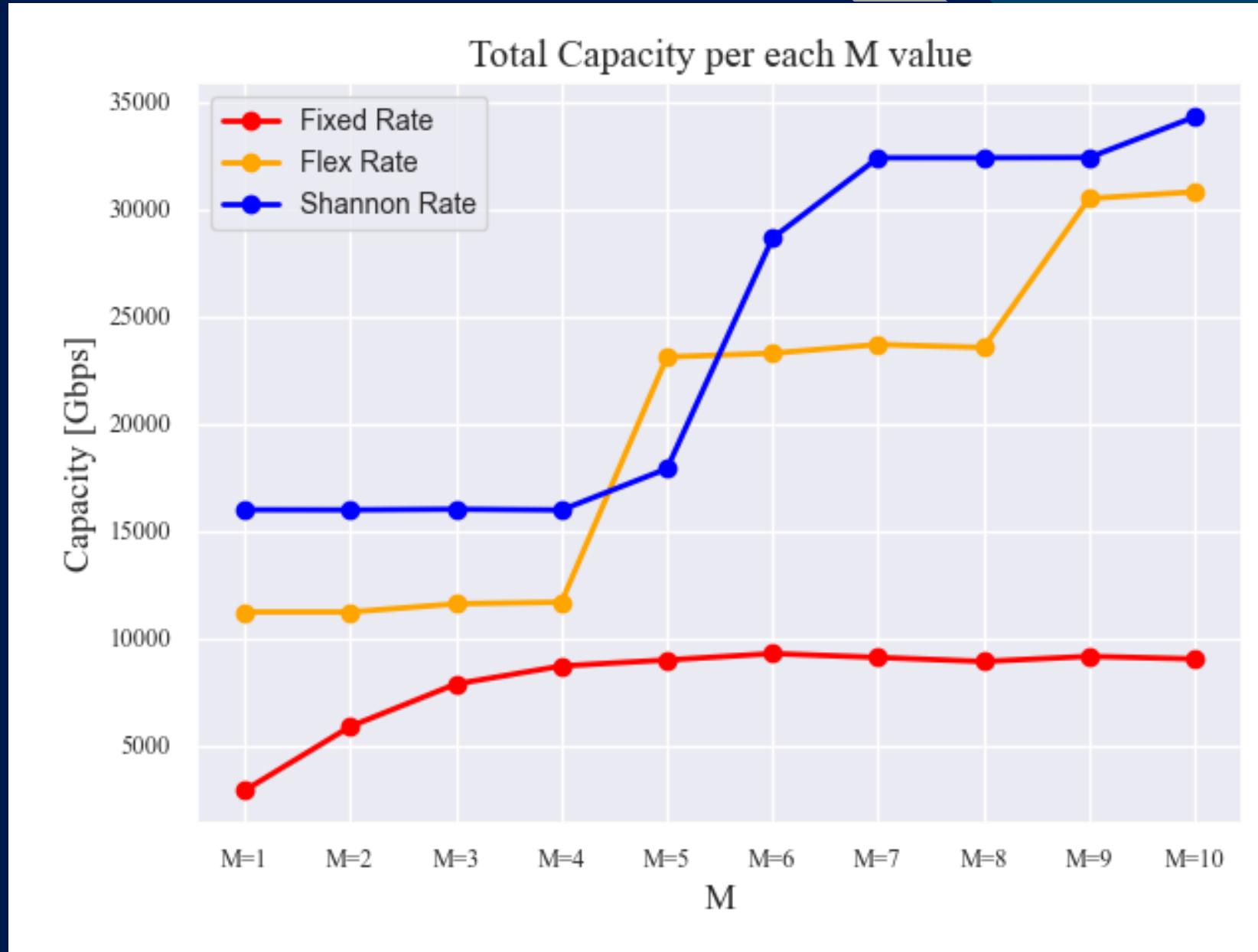
Spectral Occupation per Line for M=5



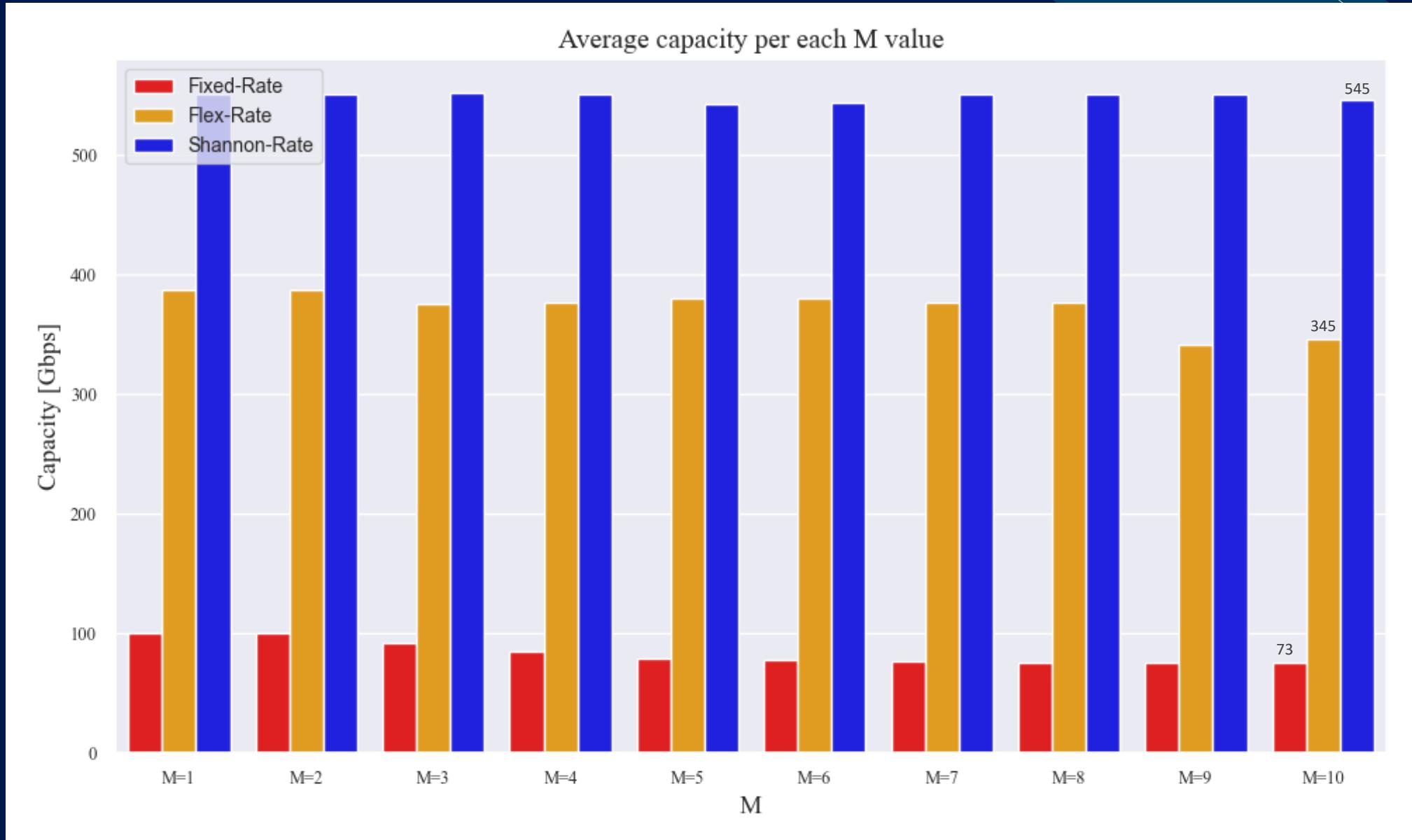
Spectral Occupation per Line for M=10



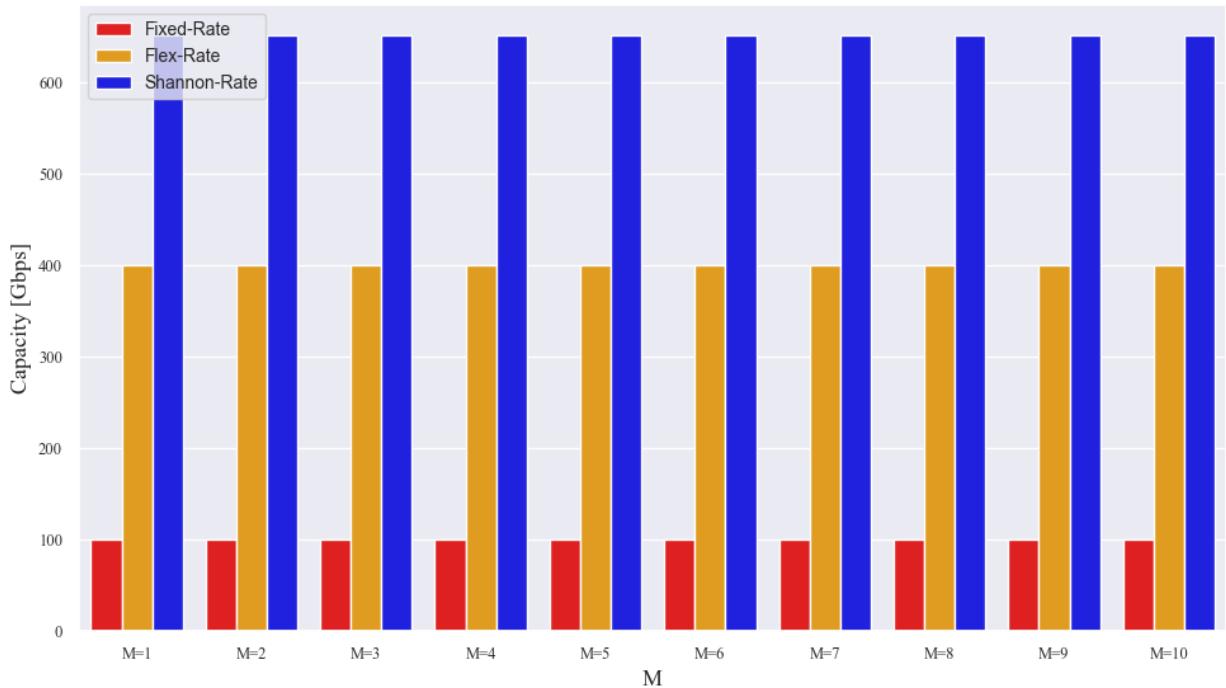
Not Full Network



Not Full Network

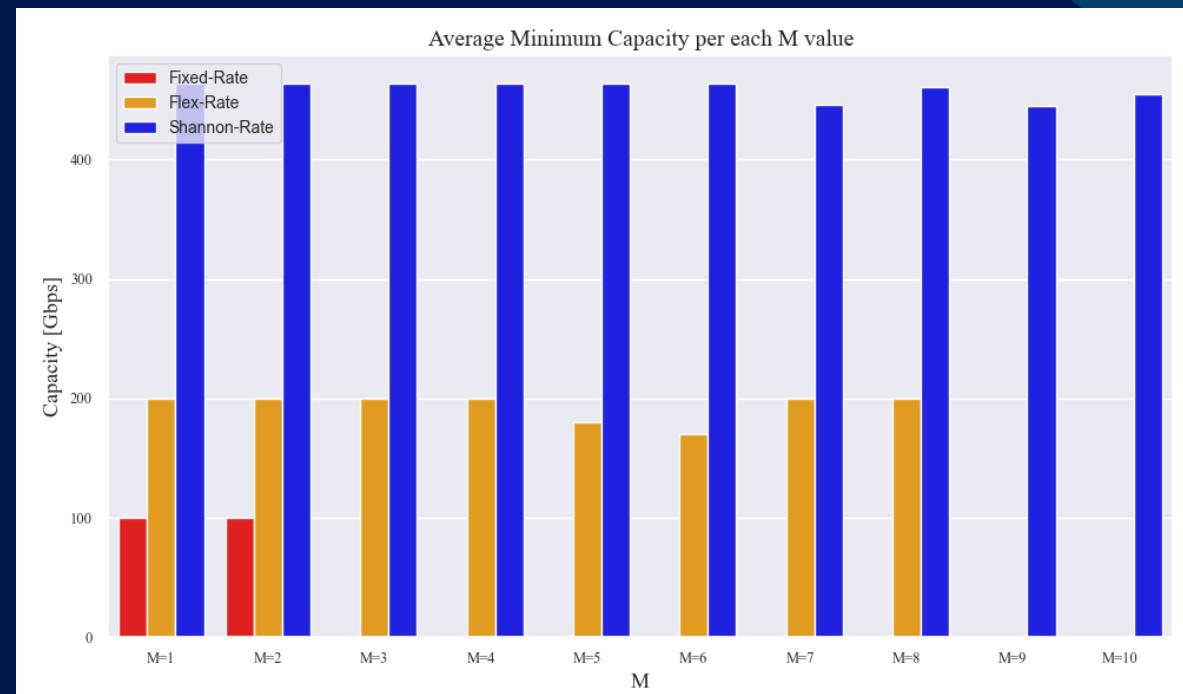


Average Maximum Capacity per each M value

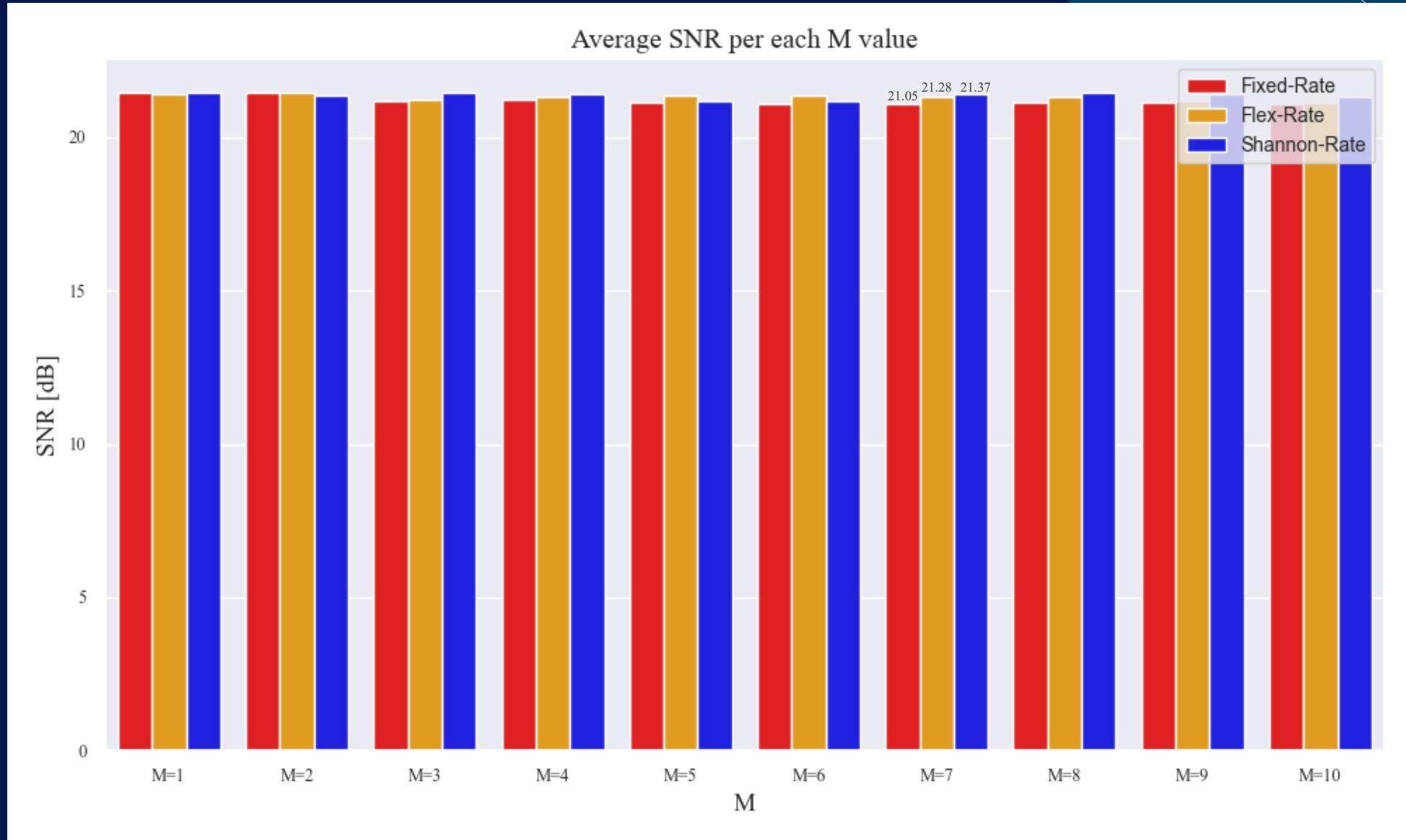


Average Maximum Capacity

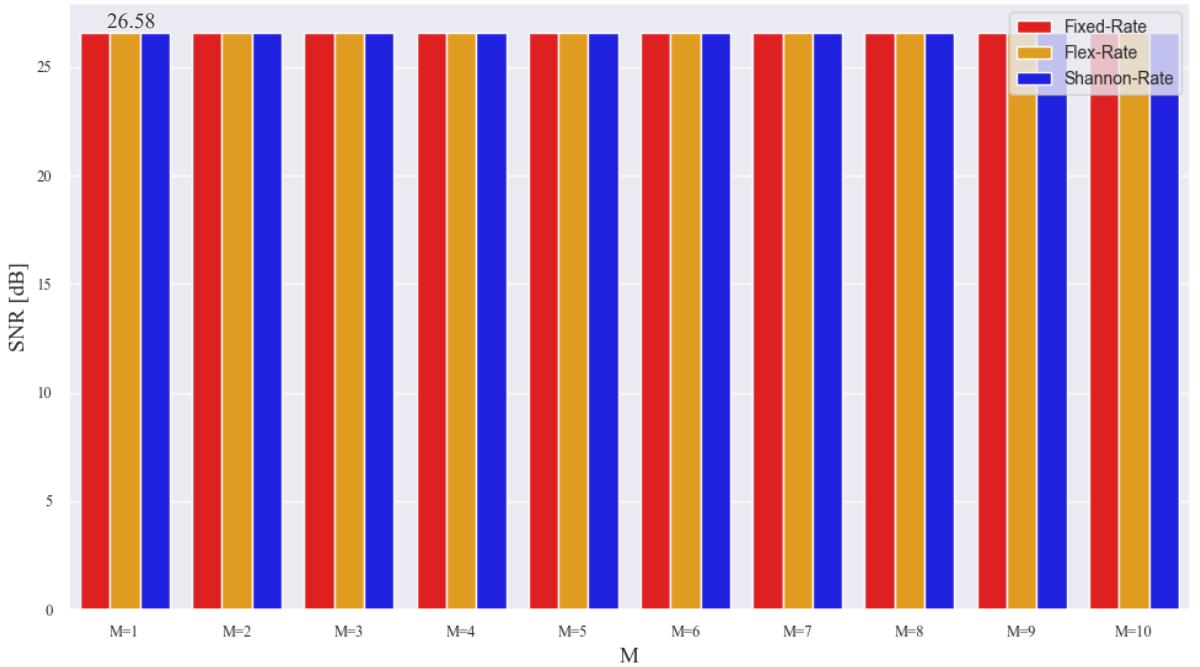
Average Minimum Capacity



Not Full Network



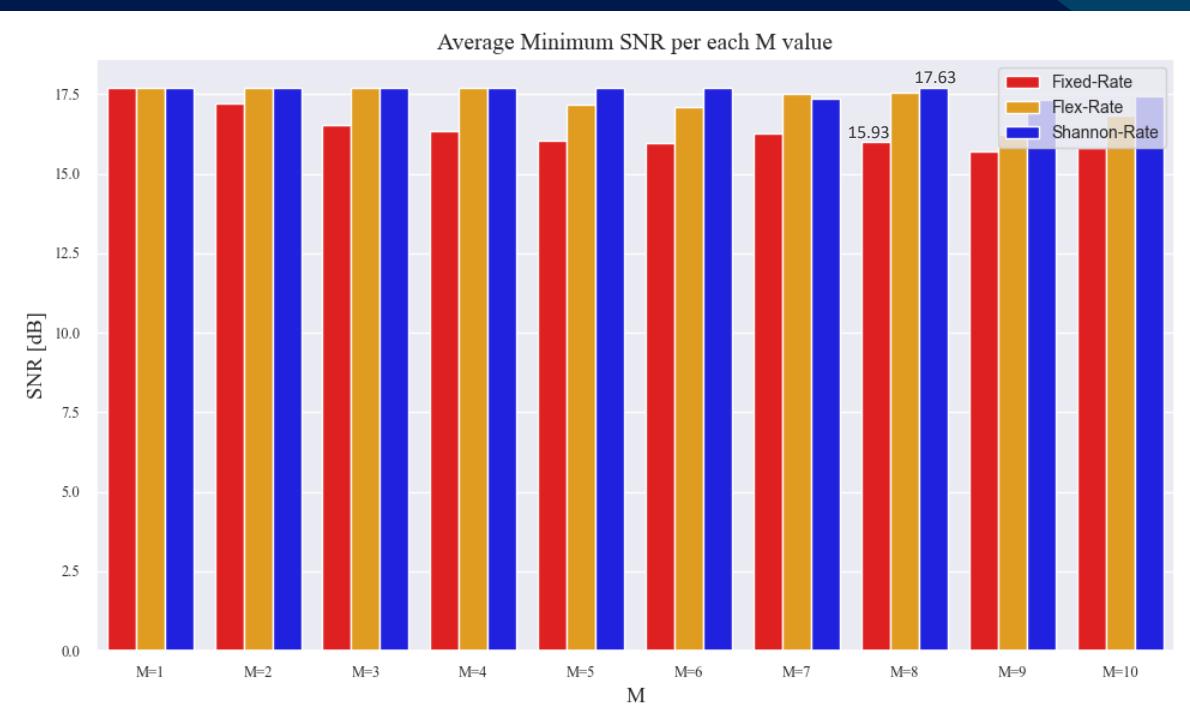
Average Maximum SNR per each M value



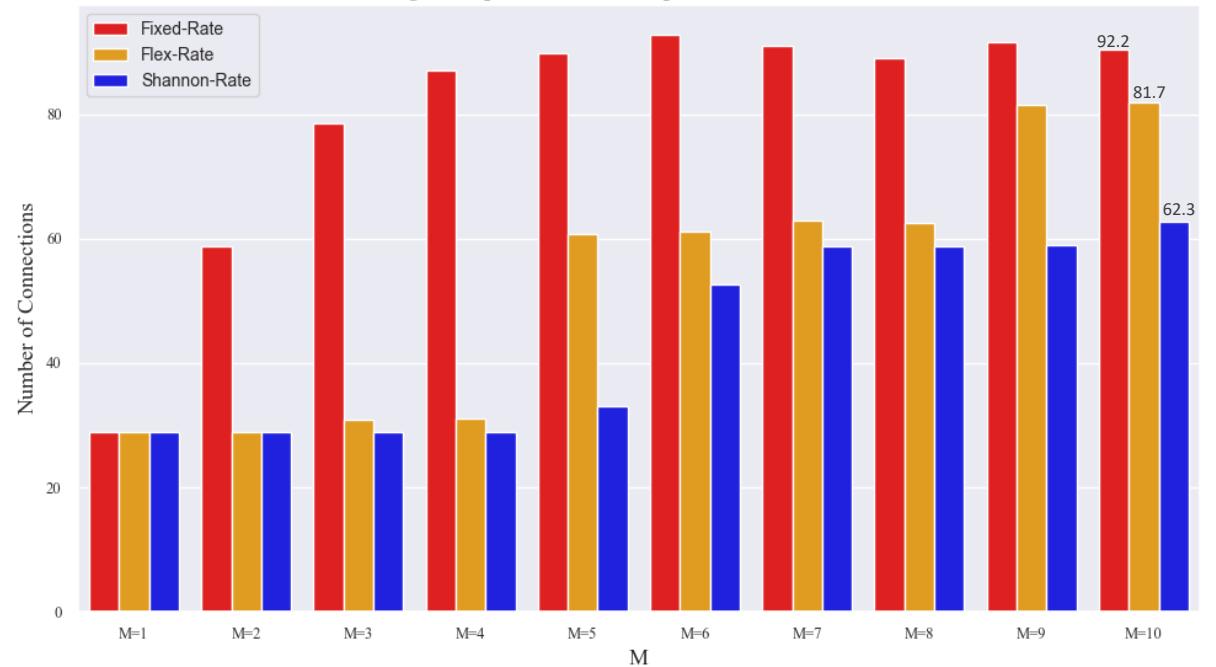
Average Maximum SNR

Average Minimum SNR

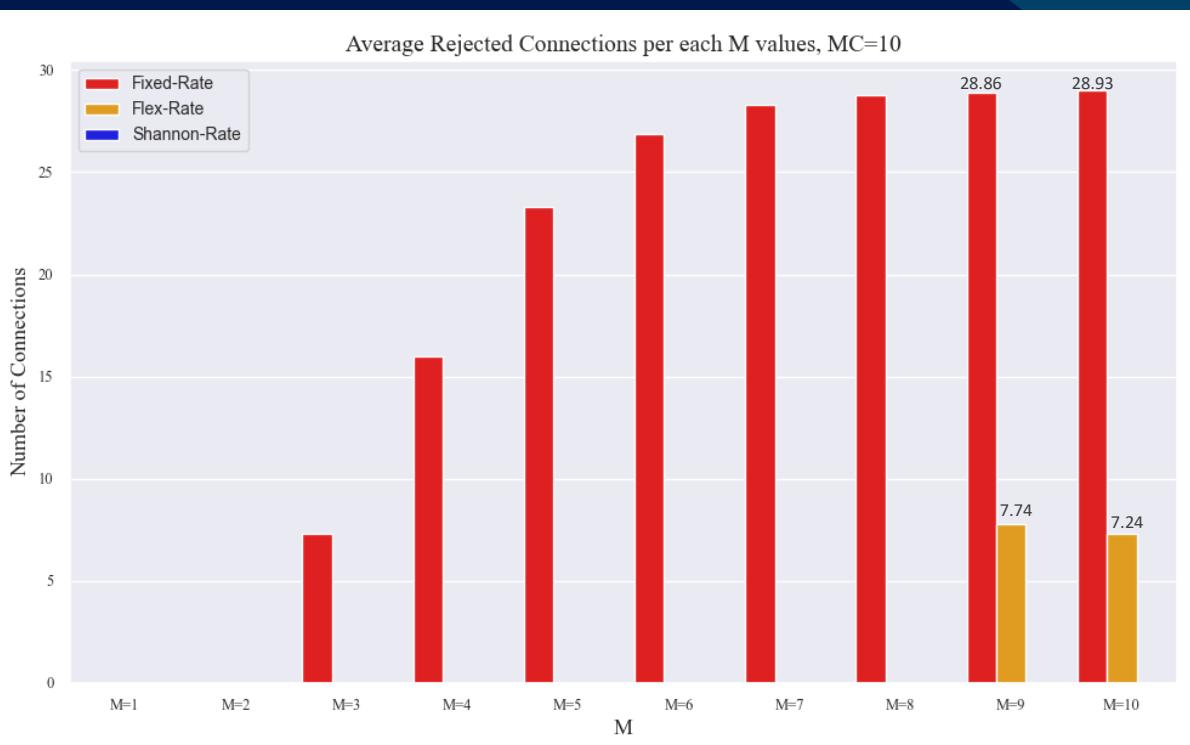
Average Minimum SNR per each M value



Average Accepted Connections per each M values, MC=10



Average Rejected Connections per each M values, MC=10

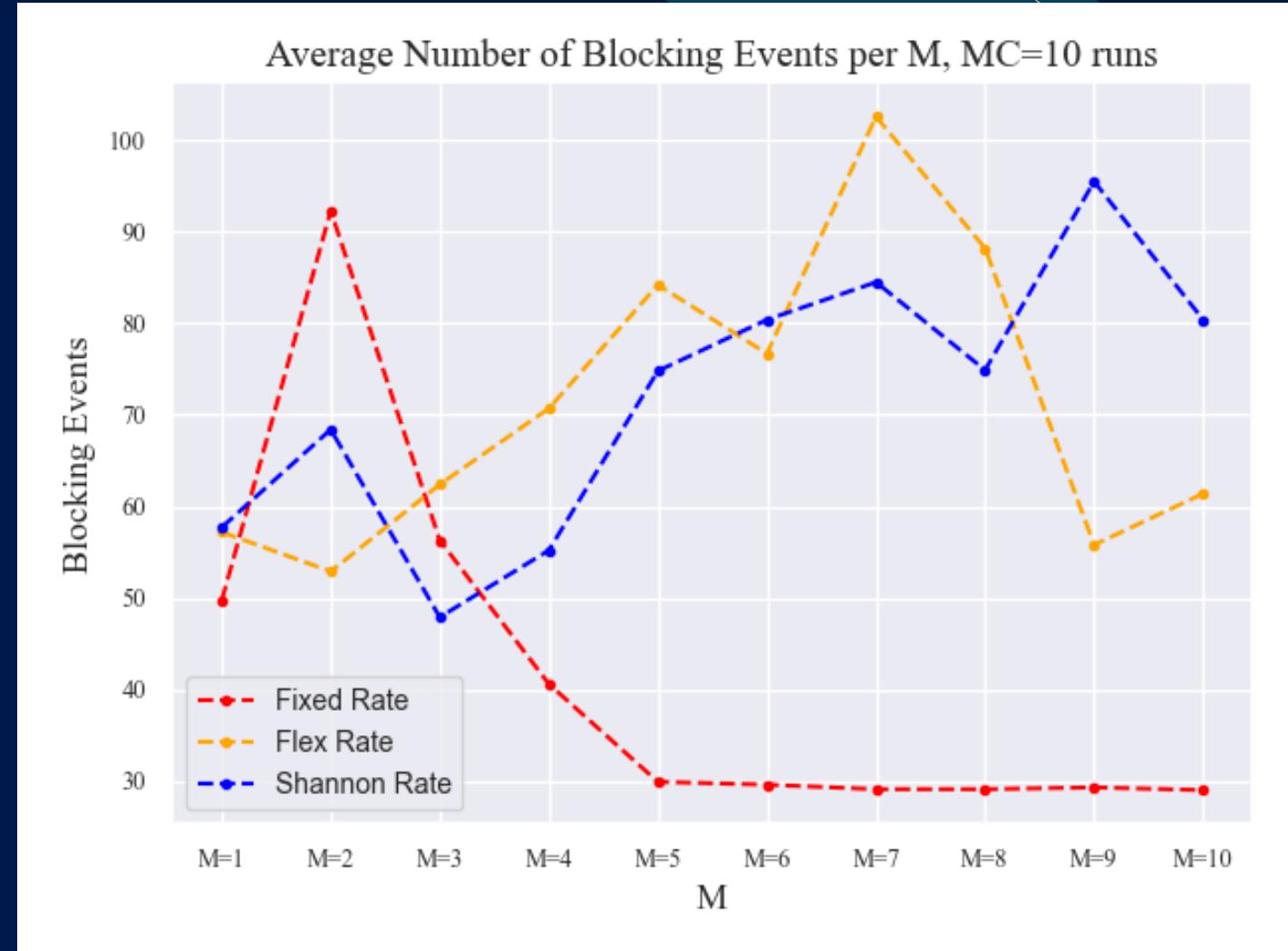


Not Full Network

BLOCKING EVENTS

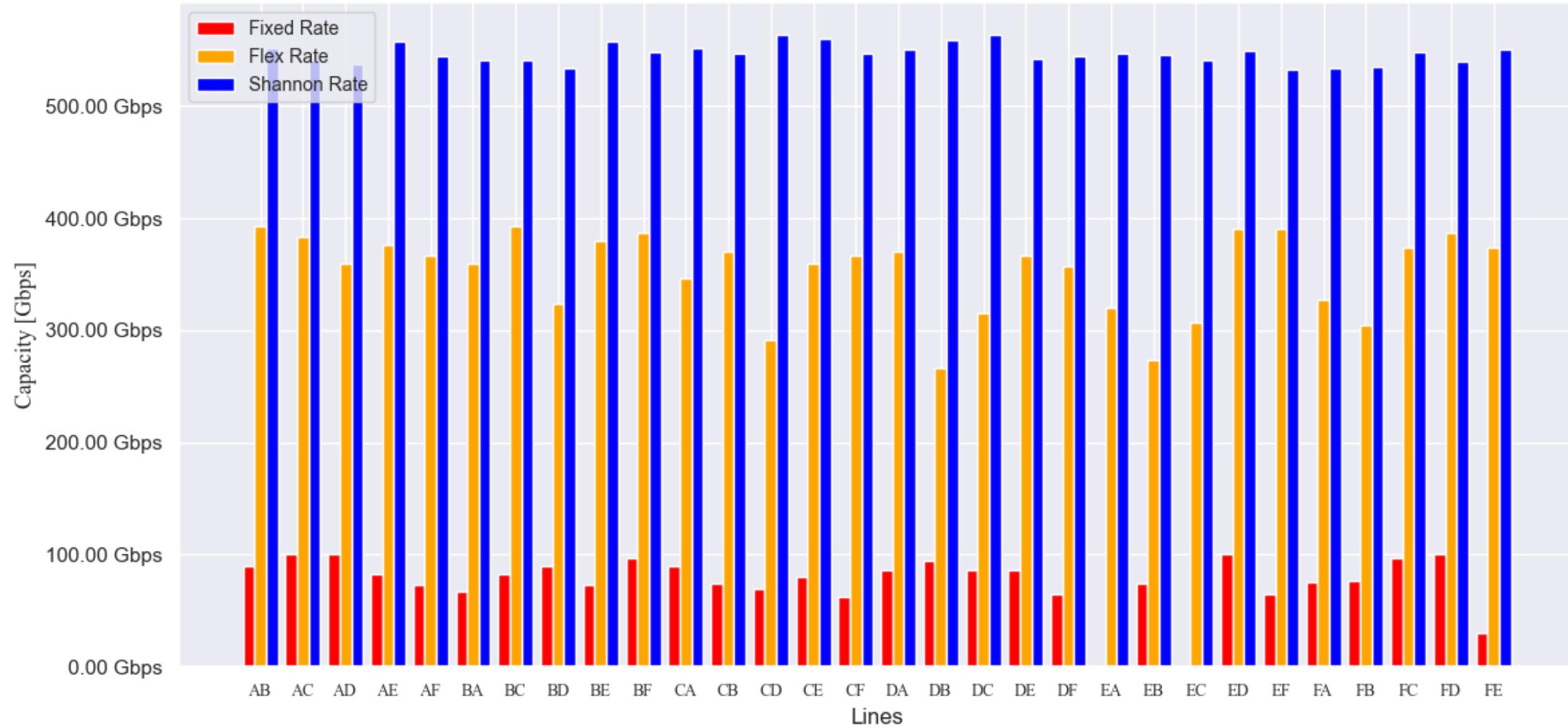
Not Traffic Matrix Assignment due to:

- Matrix saturation
- It was not possible to assign a suitable path for the connection

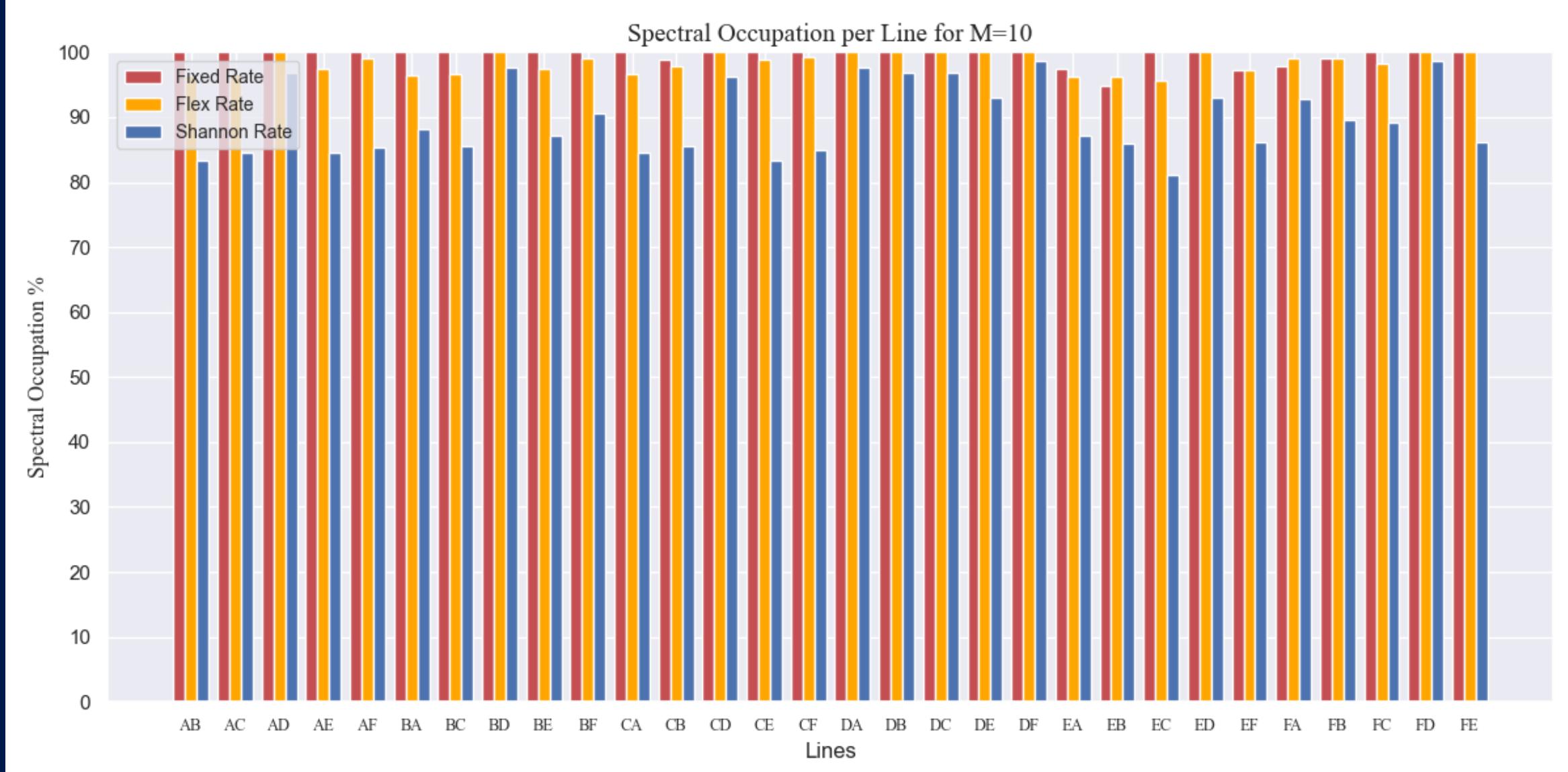


Not Full Network

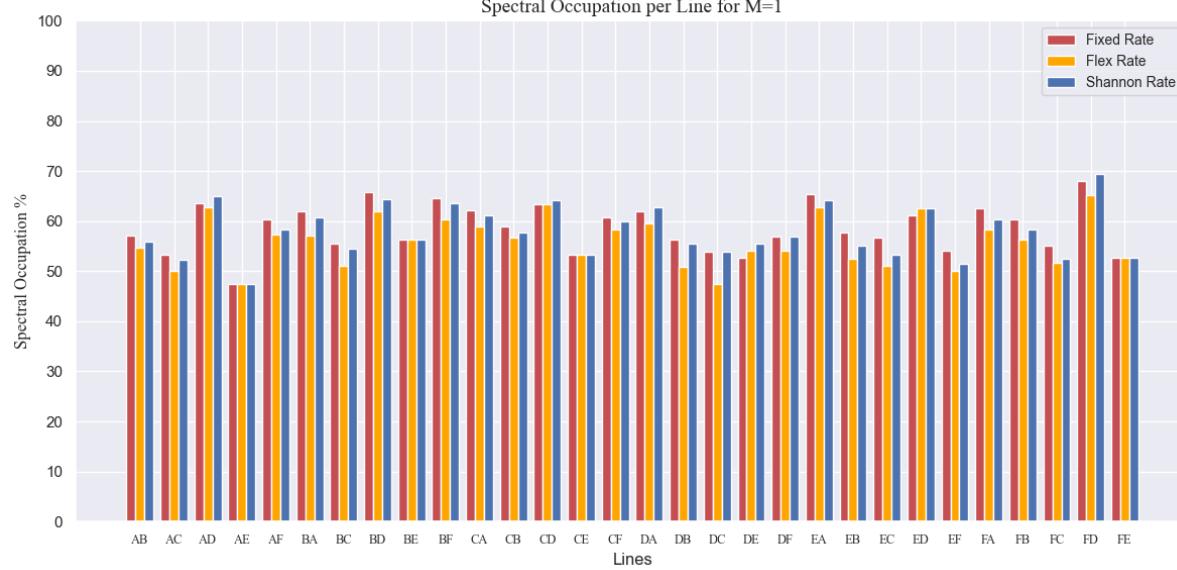
Per-link Average Capacity for M=10



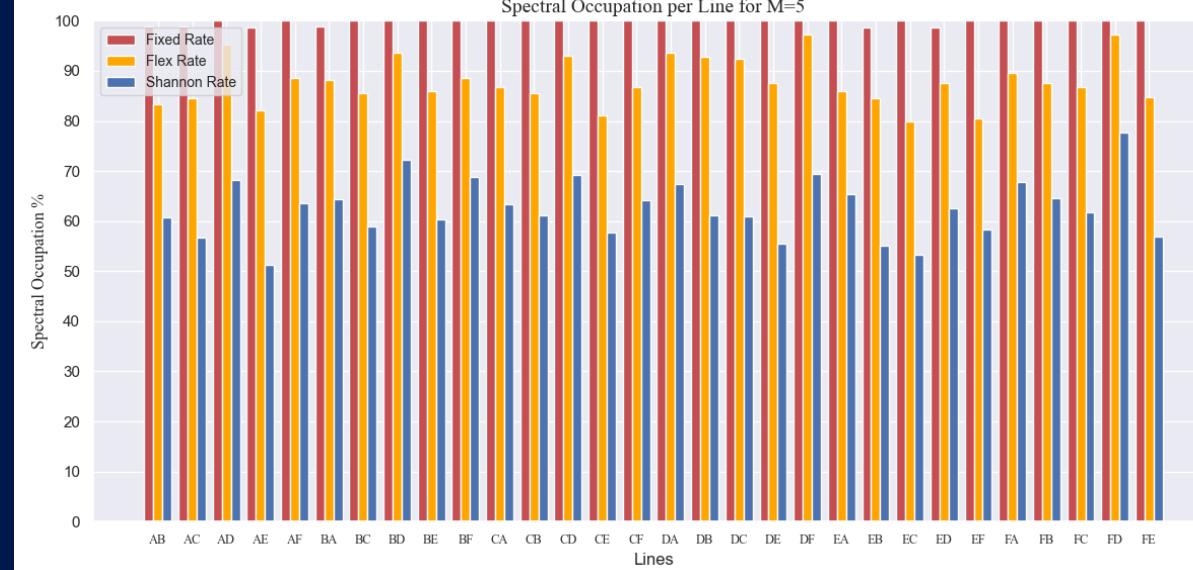
Not Full Network



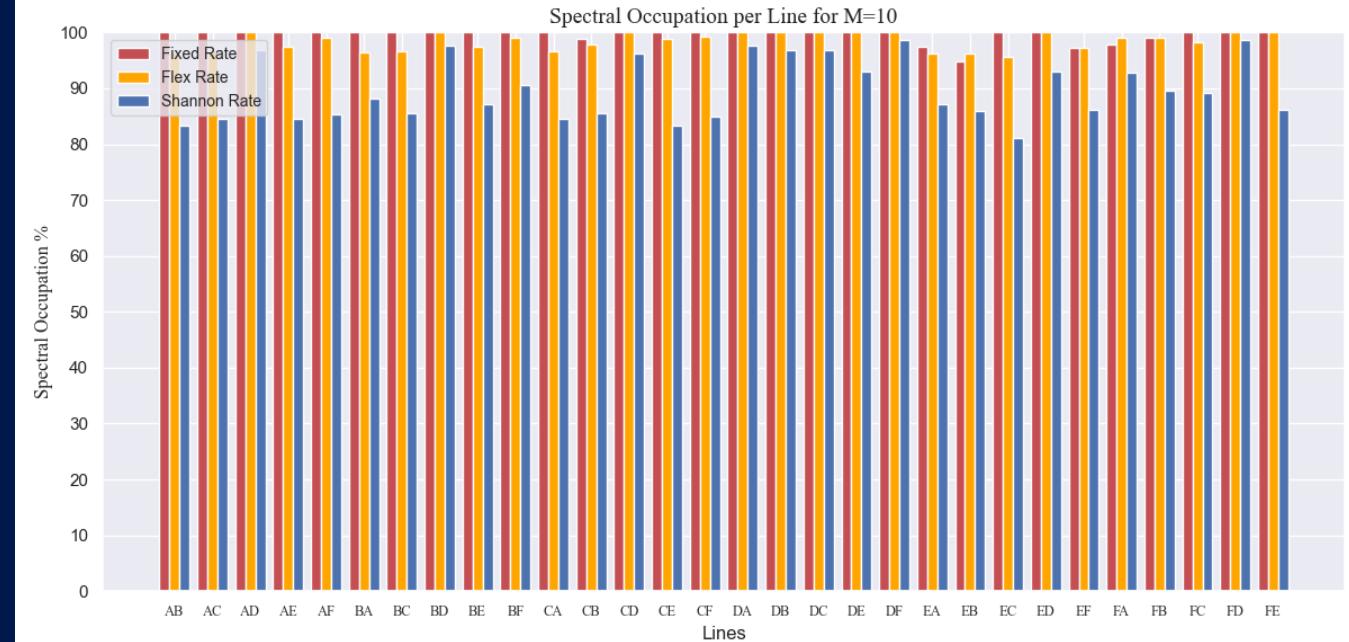
Spectral Occupation per Line for M=1



Spectral Occupation per Line for M=5



Spectral Occupation per Line for M=10



Recommendations for Future Tests

- In the context of the **Congestion Scenario**.

To observe more pronounced alterations in the graphs between the different transceiver strategies, it is recommended to increase M by 5. This will result in a more noticeable change in the graphs between the different transceiver strategies.

- In the case of the **Single Matrix Scenario**.

An increase in M signifies an increase in the number of Monte Carlo runs to be conducted. In order to achieve the same distribution in the traffic matrix with an M=16, for instance, it may be necessary to perform 100 or more runs.



**Thank you for your
attention**