# EE597

# Simulation Project 2
# MAC

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# Introduction

In this project, we will study the saturation throughput of IEEE802.11b network that uses CSMA/CA with a binary exponential backoff to avoid collisions (also referred to as DCF).

Here, we will be using NS-3 for simulating a wireless transmission scenario and MATLAB for numerical calculations and plotting. The throughput based on the simulation of 802.11b DCF using NS-3 closely follows the paper written by Bianchi ("IEEE 802.11-saturation throughput analysis," in IEEE Communications Letters, vol. 2, no. 12, pp. 318-320, Dec. 1998").

In our experiment, we have assumed some default values to maintain the test conditions constant through the simulation and numerical calculations as per the test conditions detailed by Bianchi. These assumptions are listed below.

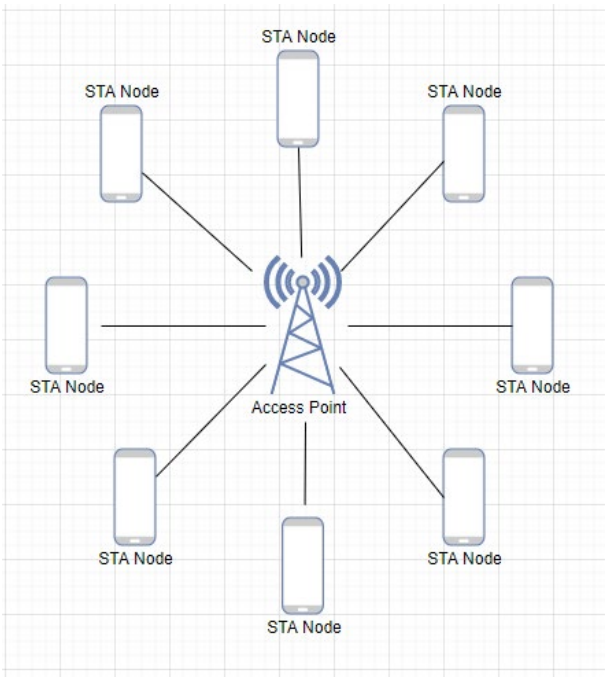
- Packet Size=512 Bytes
- SIFS=28 microseconds
- Slot time=50 microseconds
- Standard= IEEE 802.11b
- Simulation time=20 seconds

# Simulation Results

The simulation has been carried out as per the below cases outlined in the project requirement.

- Case A: minimum backoff window size as 1 and maximum backoff window size as 1023 units of slot times.
- Case B: minimum backoff window size as 63 and maximum backoff window size as 127 units of slot times.
- E1 -- Increase the offered load by increasing the number of nodes N: Set the data rate to a reasonable value and vary the number of nodes N and calculate the throughput at the receiver for each value of N.
- E2 -- Increase the offered load by increasing the data rate: Keep the number of nodes fixed at 20 and vary X in sufficiently fine granularity.

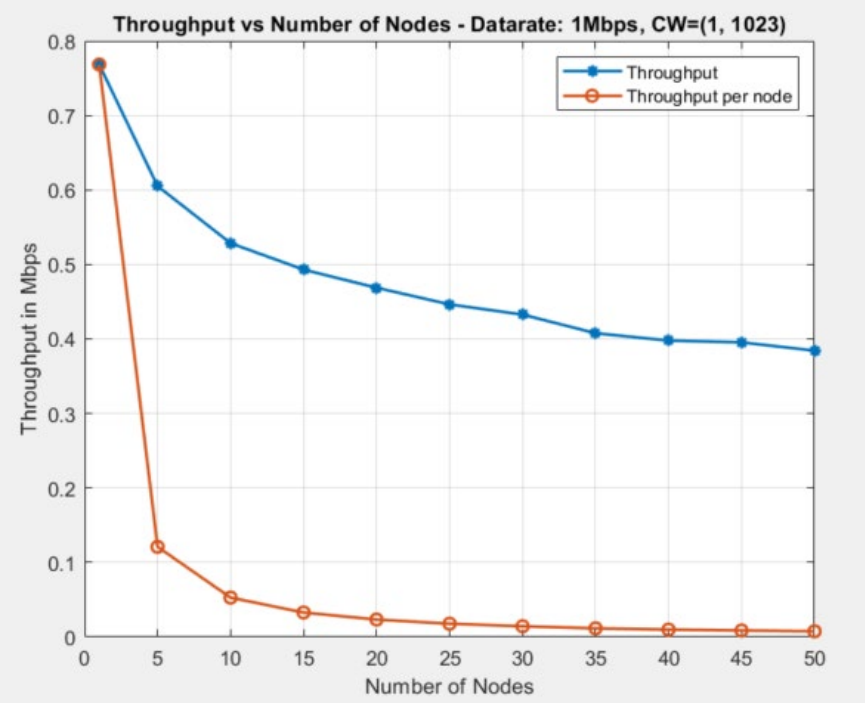
Topology implemented in NS-3: Star topology was the best fit for the simulation.



**Case A E1:** Backoff window size= {1, 1023}, Data rate=1Mbps and load is increased by increasing number of nodes(N).

Data obtained from NS-3 Simulation:

| Number of STA nodes(N) | Throughput | Throughput per node |
|---|---|---|
| 1 | 0.76841 Mbit/s | 0.76841 Mbit/s |
| 5 | 0.605184 Mbit/s | 0.121037 Mbit/s |
| 10 | 0.528589 Mbit/s | 0.0528589 Mbit/s |
| 15 | 0.493158 Mbit/s | 0.0328772 Mbit/s |
| 20 | 0.468787 Mbit/s | 0.0234394 Mbit/s |
| 25 | 0.446464 Mbit/s | 0.0178586 Mbit/s |
| 30 | 0.432742 Mbit/s | 0.0144247 Mbit/s |
| 35 | 0.407757 Mbit/s | 0.0116502 Mbit/s |
| 40 | 0.397926 Mbit/s | 0.00994816 Mbit/s |
| 45 | 0.395469 Mbit/s | 0.0087882 Mbit/s |
| 50 | 0.38441 Mbit/s | 0.00768819 Mbit/s |



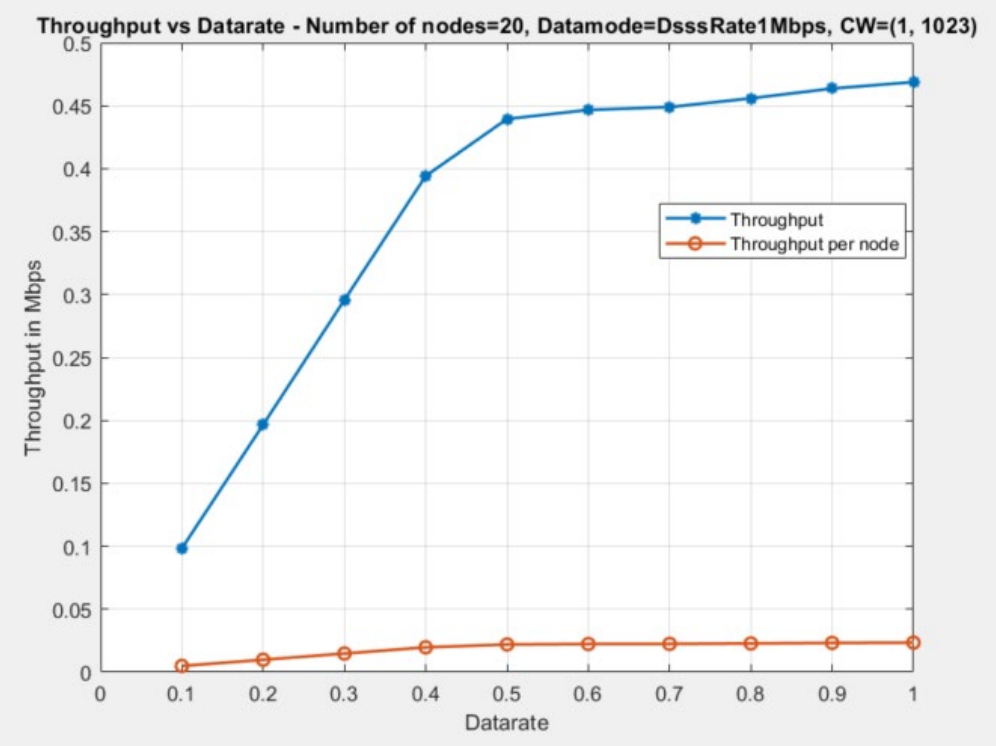

Observations and Discussion:

From the graph, we see that as the number of nodes increases, the throughput and the throughput per node decreases. The reduction in throughput resembles an exponential decay.

**Case A E2:** Backoff window size= {1, 1023}, Data mode= DsssRate1Mbps, N=20 nodes and the load is increased by increasing the data rate.

Data obtained from NS-3 Simulation:

| Data rate | Throughput | Throughput per node |
|---|---|---|
| 0.1 Mbps | 0.098304 Mbit/s | 0.0049152 Mbit/s |
| 0.2 Mbps | 0.196608 Mbit/s | 0.0098304 Mbit/s |
| 0.3 Mbps | 0.295731 Mbit/s | 0.0147866 Mbit/s |
| 0.4 Mbps | 0.39424 Mbit/s | 0.019712 Mbit/s |
| 0.5 Mbps | 0.439501 Mbit/s | 0.021975 Mbit/s |
| 0.6 Mbps | 0.446669 Mbit/s | 0.0223334 Mbit/s |
| 0.7 Mbps | 0.448922 Mbit/s | 0.0224461 Mbit/s |
| 0.8 Mbps | 0.455885 Mbit/s | 0.0227942 Mbit/s |
| 0.9 Mbps | 0.463667 Mbit/s | 0.0231834 Mbit/s |
| 1 Mbps | 0.468787 Mbit/s | 0.0234394 Mbit/s |



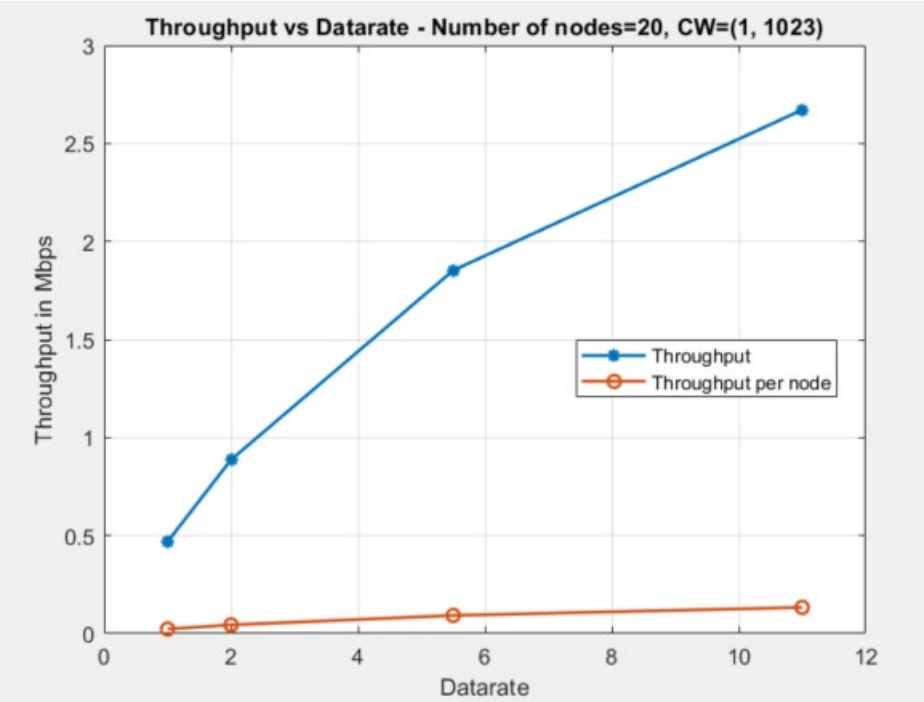

Observations and Discussion:

From the graph, we see that the throughput increases as the data rate of the STA nodes increase. However, after a particular threshold say 0.6 Mbps, the throughput saturates to about 0.45 Mbps.

In addition, we can set different data modes namely DsssRate1Mbps, DsssRate2Mbps, DsssRate5_5Mbps, DsssRate11Mbps and obtain the throughput plot as the data rate increases.

Data obtained from NS-3 Simulation:

| Data Rate | Throughput | Throughput per node |
|---|---|---|
| 1 Mbps | 0.468787 Mbit/s | 0.0234394 Mbit/s |
| 2 Mbps | 0.886784 Mbit/s | 0.0443392 Mbit/s |
| 5.5 Mbps | 1.85221 Mbit/s | 0.0926106 Mbit/s |
| 11 Mbps | 2.67121 Mbit/s | 0.13356 Mbit/s |



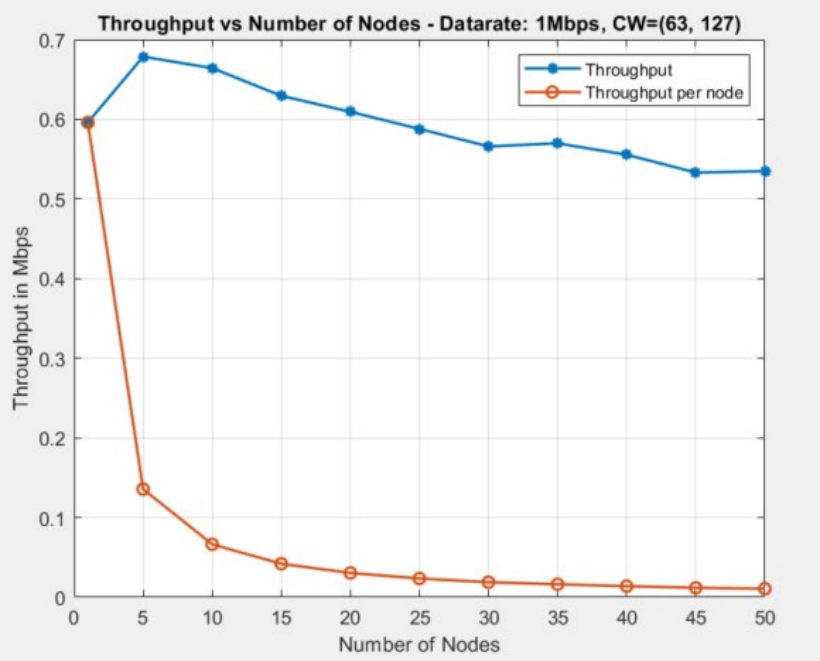

Observations and Discussion:

From the graph, we see that the throughput and its corresponding throughput per node increases with increase in data rate. Hence, the throughput is directly proportional to data rate.

**Case B E1:** Backoff window size= {63, 127}, Data rate=1Mbps and load is increased by increasing number of nodes(N).

Data obtained from NS-3 Simulation:

| Number of STA nodes(N) | Throughput | Throughput per node |
|---|---|---|
| 1 | 0.595968 Mbit/s | 0.595968 Mbit/s |
| 5 | 0.678502 Mbit/s | 0.1357 Mbit/s |
| 10 | 0.664166 Mbit/s | 0.0664166 Mbit/s |
| 15 | 0.62935 Mbit/s | 0.0419567 Mbit/s |
| 20 | 0.60928 Mbit/s | 0.030464 Mbit/s |
| 25 | 0.587776 Mbit/s | 0.023511 Mbit/s |
| 30 | 0.565862 Mbit/s | 0.0188621 Mbit/s |
| 35 | 0.569754 Mbit/s | 0.0162787 Mbit/s |
| 40 | 0.555418 Mbit/s | 0.0138854 Mbit/s |
| 45 | 0.533094 Mbit/s | 0.0118465 Mbit/s |
| 50 | 0.534733 Mbit/s | 0.0106947 Mbit/s |



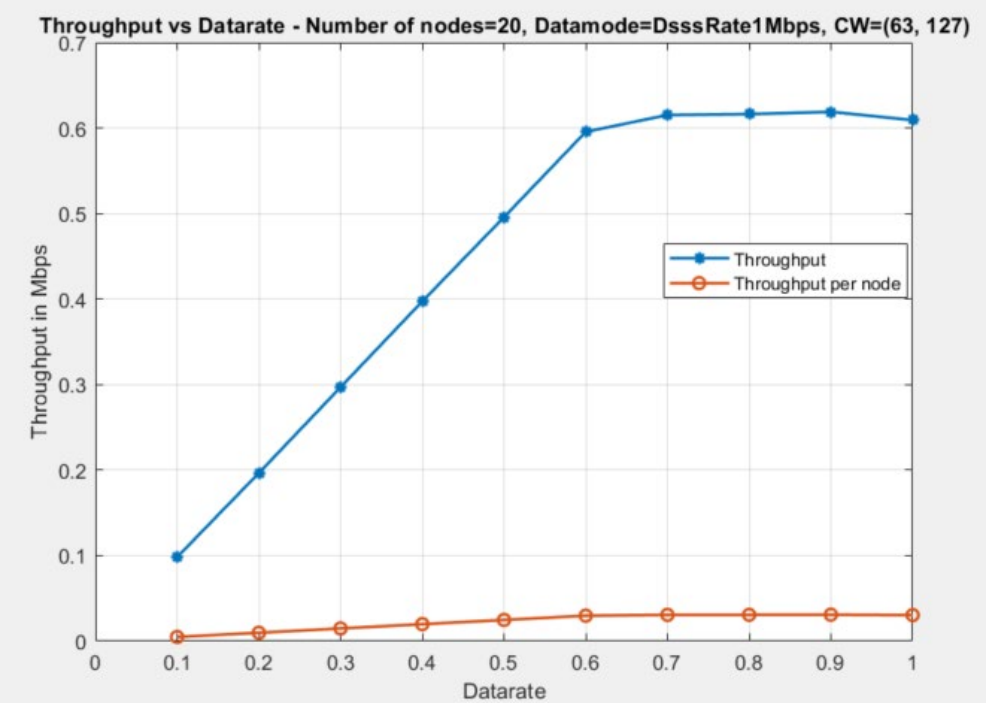

Observations and Discussion:

From the graph, we see that the throughput increases initially as we increase the number of nodes from 1 to 5. After this, the throughput starts gradually decreasing. However, the throughput per node decreases exponentially as the number of nodes increase.

**Case B E2:** Backoff window size= {63, 127}, Data mode= DsssRate1Mbps, N=20 nodes and the load is increased by increasing the data rate.

Data obtained from NS-3 Simulation:

| Data rate | Throughput | Throughput per node |
|---|---|---|
| 0.1 Mbps | 0.098304 Mbit/s | 0.0049152 Mbit/s |
| 0.2 Mbps | 0.196608 Mbit/s | 0.0098304 Mbit/s |
| 0.3 Mbps | 0.29696 Mbit/s | 0.014848 Mbit/s |
| 0.4 Mbps | 0.397312 Mbit/s | 0.0198656 Mbit/s |
| 0.5 Mbps | 0.495821 Mbit/s | 0.024791 Mbit/s |
| 0.6 Mbps | 0.595558 Mbit/s | 0.0297779 Mbit/s |
| 0.7 Mbps | 0.615219 Mbit/s | 0.030761 Mbit/s |
| 0.8 Mbps | 0.616243 Mbit/s | 0.0308122 Mbit/s |
| 0.9 Mbps | 0.618906 Mbit/s | 0.0309453 Mbit/s |
| 1 Mbps | 0.60928 Mbit/s | 0.030464 Mbit/s |



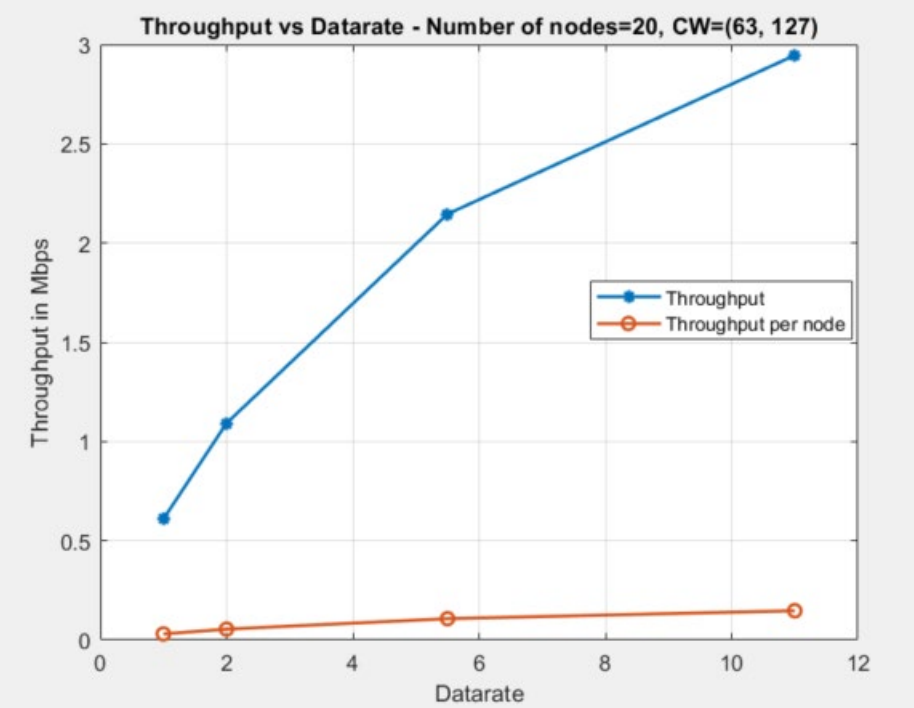

Observations and Discussion:

From the graph, we see that the throughput increases as the data rate of the STA nodes increase. However, after a particular threshold say 0.6 Mbps, the throughput saturates to about 0.61 Mbps.

In addition, we can set different data modes namely DsssRate1Mbps, DsssRate2Mbps, DsssRate5_5Mbps, DsssRate11Mbps and obtain the throughput plot as the data rate increases.

Data obtained from NS-3 Simulation:

| Data Rate | Throughput | Throughput per node |
|---|---|---|
| 1 Mbps | 0.60928 Mbit/s | 0.030464 Mbit/s |
| 2 Mbps | 1.0924 Mbit/s | 0.0546202 Mbit/s |
| 5.5 Mbps | 2.1461 Mbit/s | 0.107305 Mbit/s |
| 11 Mbps | 2.94584 Mbit/s | 0.147292 Mbit/s |



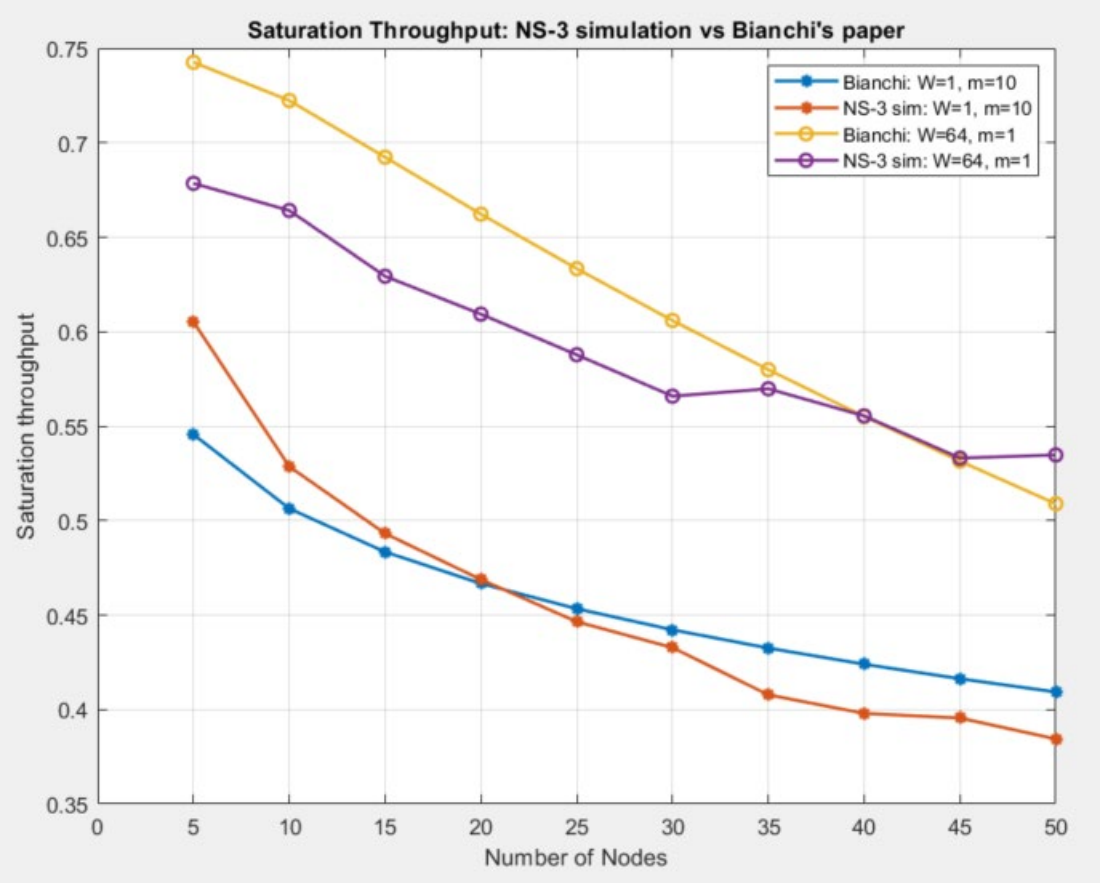

Observations and Discussion:

From the graph, we see that the throughput and its corresponding throughput per node increases with increase in data rate. Hence, the throughput is directly proportional to data rate.

**Theoretical analysis:**

We implemented the MATLAB and NS-3 code as per the analysis from Bianchi's paper for the below parameters.

- W=1, m=1 which corresponds to minCW=1 and maxCW=1023
- W=63, m=1 which corresponds to minCW=63 and maxCW=127
- Packet Size=512 Bytes
- SIFS=28 microseconds
- Slot time=50 microseconds
- Simulation time=20 seconds




Observation and Discussion:

The trend of the plot from NS-3 simulation follows the plot from Bianchi's paper, i.e., the throughput decreases with increase in the number of nodes in the network.