ECE 6110 : Project 3 Report
Measuring Wireless Throughput Capacity

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Topology :
We consider a random deployment of nodes across a large area (1000m x 1000m) as shown in Fig 1. The nodes form a wireless ad-hoc network and every node is paired randomly with a peer in the given area. We make the following assumptions about the network :

- The node deployment in the experiment is restricted to the given area and no nodes exist beyond this region.
- The nodes only use the ad-hoc routing protocols to construct their routing tables and no other information is available to the nodes
- The node-peer pairing is unique for every node in the network.
- The seed for the random number generator(s) used in the code is fixed so as to replicate the same configuration across different machines at different times.

The aim of the experiment is to analyze the performance of the network under varying traffic and channel conditions for a given routing protocol.

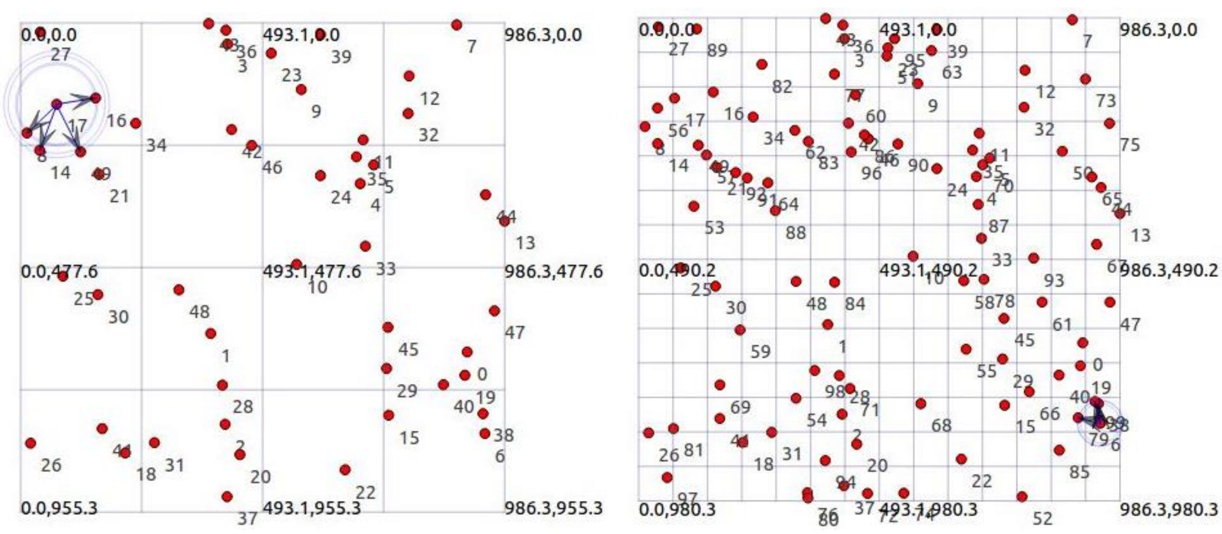


Fig 1: Network Topologies

In particular, we analyze the effect of the following parameters on the network performance:

1. Node density

We formally define the node density as:

$$Node\ density = \frac{Number\ of\ nodes}{Total\ area}$$

Since we assume a fixed size region (1000 m x 1000m), we can achieve varying degrees of node density by changing the number of nodes. We vary the node density from a very low value (sparse network) to a very high value (dense network) and the simulation parameters are captured in Table 1.

2. Transmit Power

The maximum transmit power for all the nodes in the network is assumed to be constant and fixed for the simulations. Furthermore, we use the Tx power to determine the signal to noise ratio (SNR) for the channel and use it to calculate the maximum link capacity using the formula:

$$Capacity = Bandwidth * log2(1 + SNR)$$

It can be observed that the link capacity increases as the effective SNR increases. However, this may not necessarily lead to a higher throughput primarily because of effects such as increased interference due to high transmit power and/or higher node density.

3. Traffic Intensity

We derive the traffic intensity from the link capacity shown in the previous equation.

4. Routing protocols

In this experiment, we shall consider two main ad-hoc routing protocols i.e. Ad-Hoc On-Demand Distance Vector (AODV) and Optimized Link State Routing (OLSR) protocols.

4.1 AODV Ad-Hoc On-Demand Distance Vector Routing Protocol

AODV is a routing protocol designed for ad hoc mobile networks with large numbers of mobile nodes. The routing algorithm creates routes between nodes only on demand i.e. when the routes are requested by the source nodes. This makes it flexible for nodes to enter and leave the network without complications. Routes remain active so long as data packets travel along the paths from the source to the destination. The route times out and closes when the source stops sending packets. AODV supports both unicast and multicast.

4.2 OLSR Optimised Link State Routing Protocol

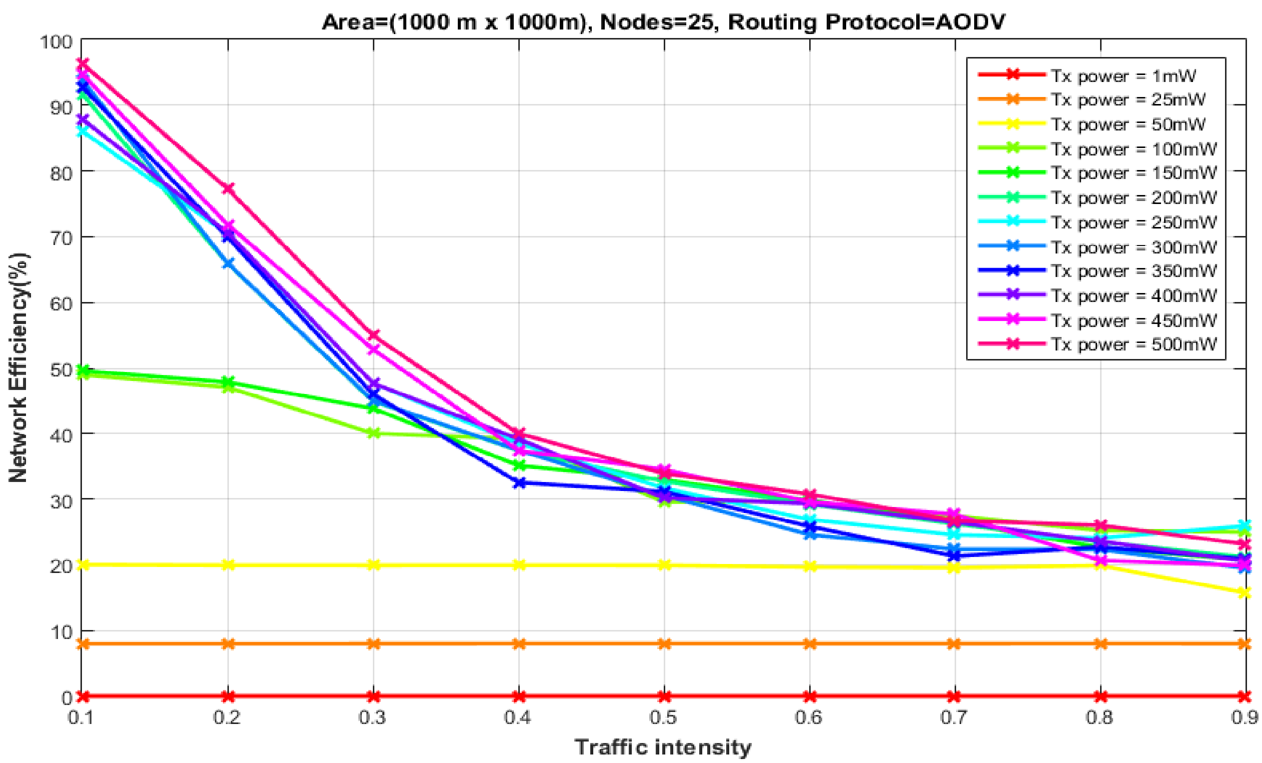
OLSR is a routing protocol designed for ad hoc mobile networks but can also be used on other wireless ad hoc networks. It can be classified as a proactive routing table driven routing that exchanges topology information with other nodes of the network regularly.

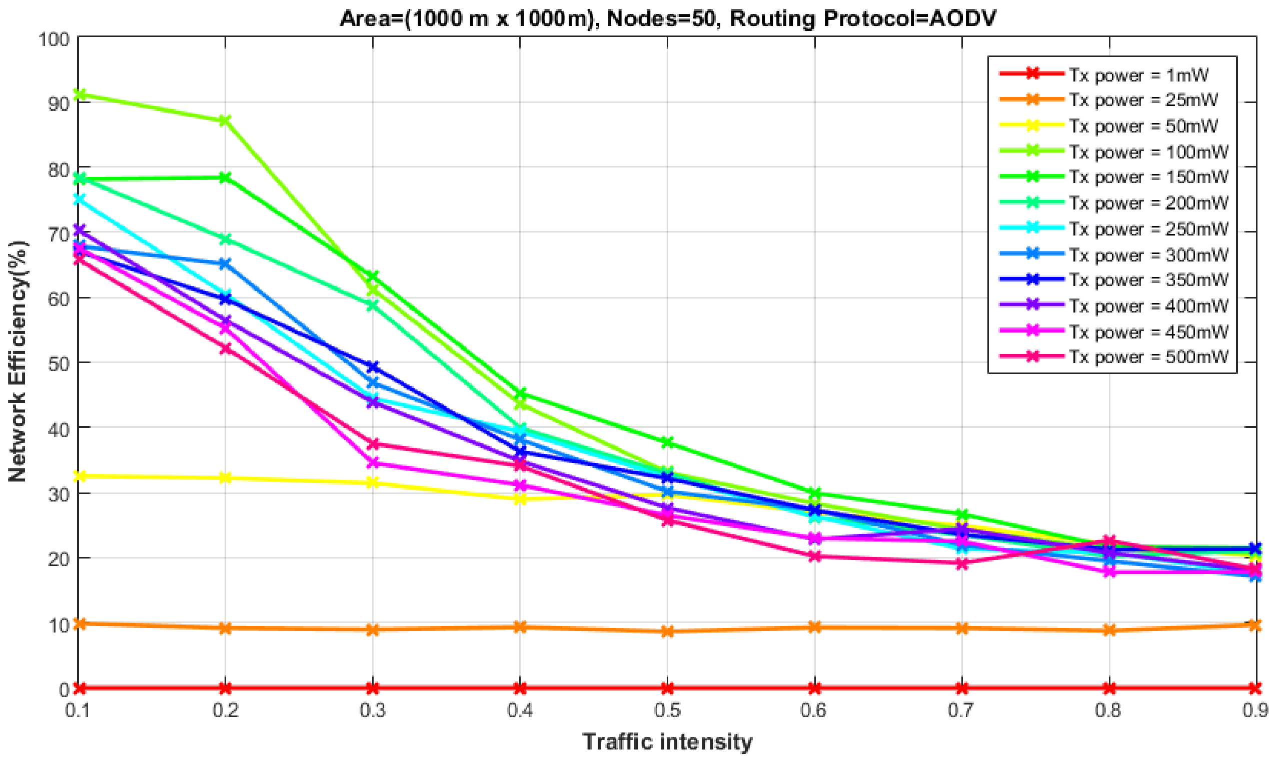
Table 1 : Simulation Parameters:

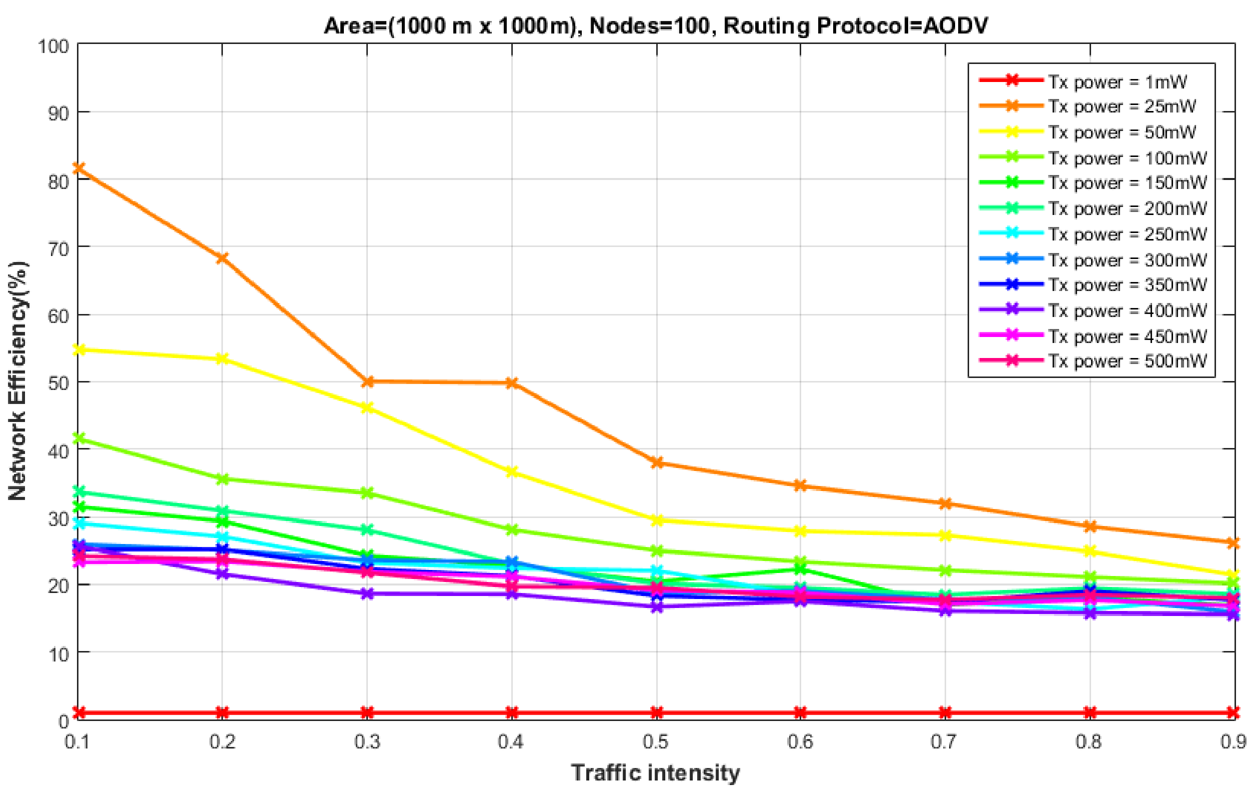
Parameter	Value
Traffic intensity	[0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9]
Number of nodes	[25, 50, 100, 250, 500, 750, 1000]
Transmit power (mW)	[1,25, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500]
Routing protocols	[AODV, OLSR]

Observations:

AODV




Area=(1000 m x 1000m), Nodes=50, Routing Protocol=AODV
Network Efficiency(%)
Traffic intensity
Tx power = 1mW
Tx power = 25mW
Tx power = 50mW
Tx power = 100mW
Tx power = 150mW
Tx power = 200mW
Tx power = 250mW
Tx power = 300mW
Tx power = 350mW
Tx power = 400mW
Tx power = 450mW
Tx power = 500mW

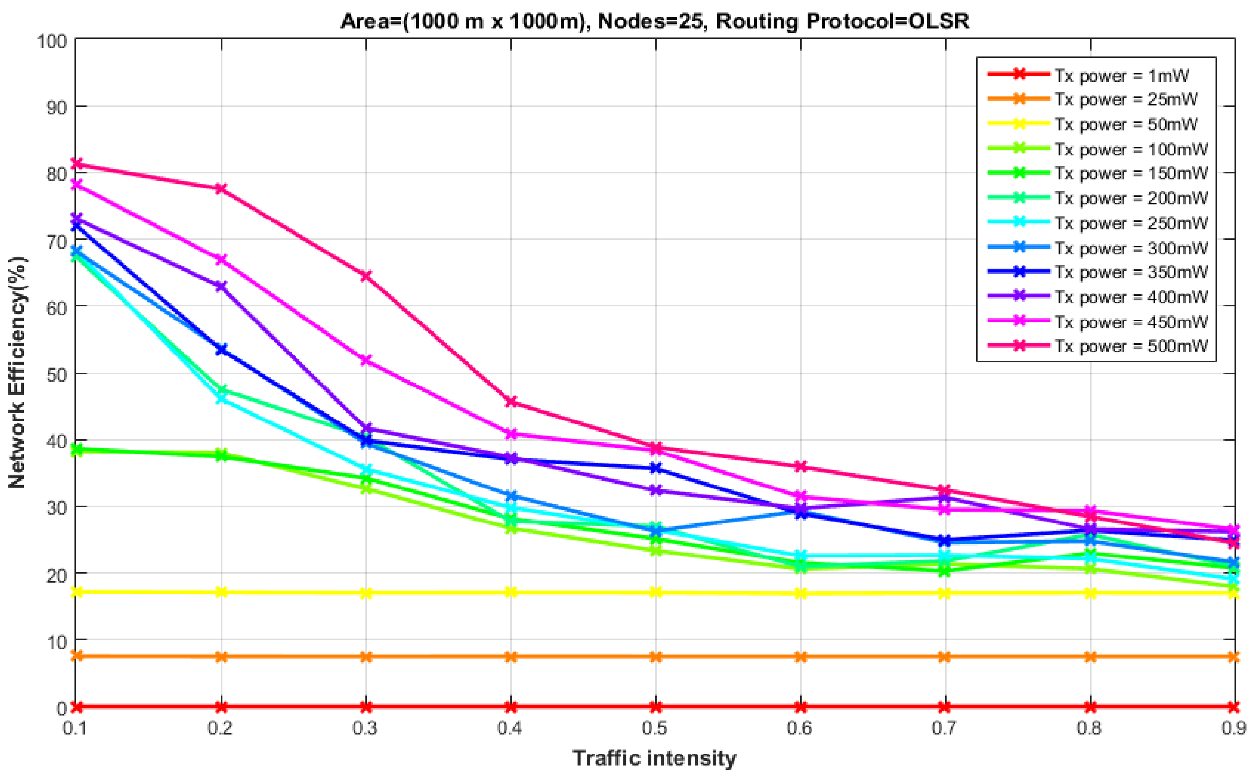

Area=(1000 m x 1000m), Nodes=100, Routing Protocol=AODV
Network Efficiency(%)
Traffic intensity
Tx power = 1mW
Tx power = 25mW
Tx power = 50mW
Tx power = 100mW
Tx power = 150mW
Tx power = 200mW
Tx power = 250mW
Tx power = 300mW
Tx power = 350mW
Tx power = 400mW
Tx power = 450mW
Tx power = 500mW

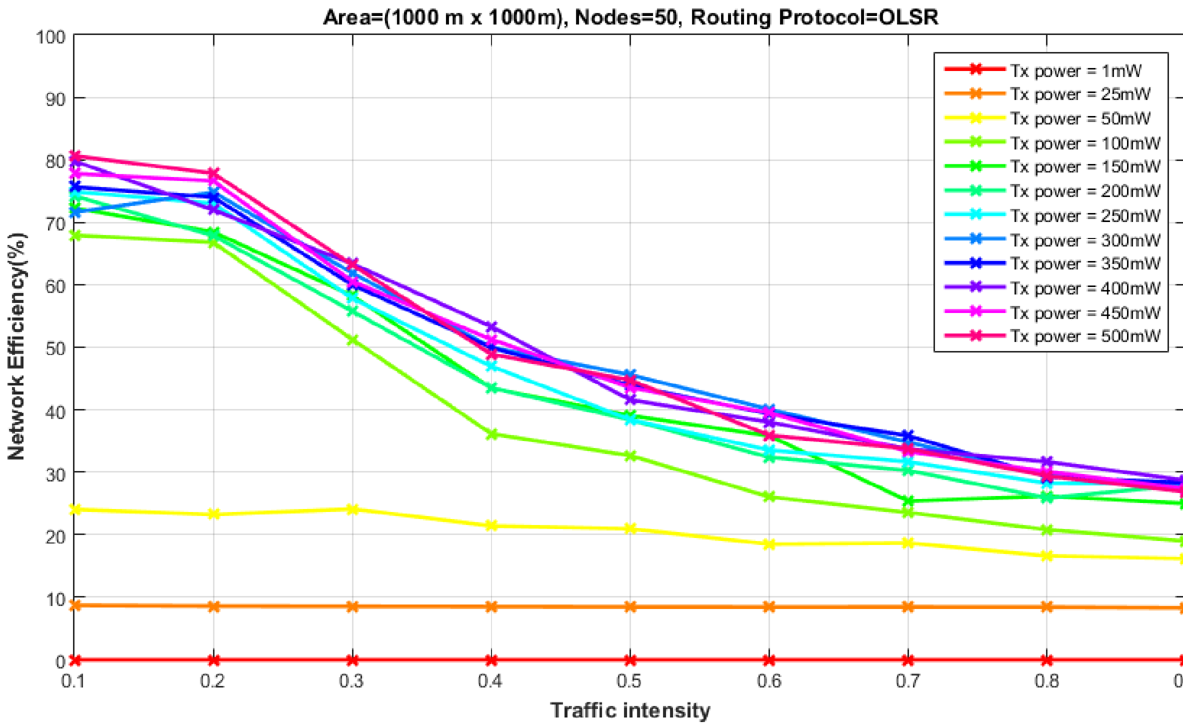
Observations:

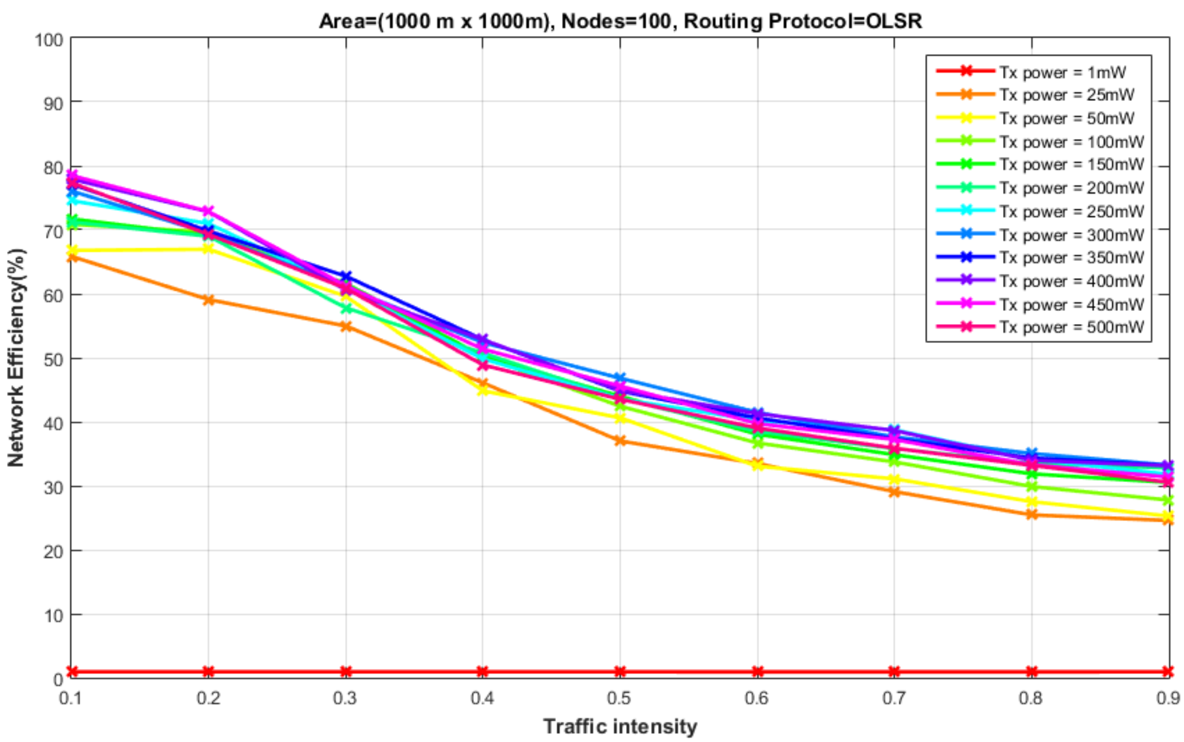
We can see that as a general trend the network efficiency comes down with increasing traffic intensity.

- Also, as the number of nodes are increase, the network efficiency comes down quicker than it did in the case of fewer nodes. This happens because of increased probability of collisions and the channel being busy.
- For lower transmission powers the network efficiency is low because of the inability of nodes to form links and transport packets. Varying transmission power gives us interesting results. Increasing transmission power when the nodes are fewer in number results in higher efficiency.
- However in dense networks increase in transmission power gives rise to increased chances of collisions as density of nodes under each node's transmission range is higher in the case of dense networks. Hence an optimum value of transmission power needs to be chosen depending on the network density.

OLSR







The overall trends remain identical to what we observed in the case of AODV. However one major difference between AODV and OLSR is that as the network density increases, OLSR gives us more network efficiency than when compared to AODV. On the other hand AODV gives us more efficiency in the case of lower network density.

Simulating large number of nodes

It has been observed that increasing the number of nodes required for simulating a given node density (for a large deployment area such as 1000m x 1000m) increases exponentially and a particular iteration can take significantly long time to complete. To circumvent this problem and and still obtain the results, we propose to use the following approach :

- We propose to reduce the size of area to the following : 400m x 400m.
- We simulate the network performance using this assumption, while maintaining the same node density (Nodes/Total area). This requires mapping the original number of nodes to the new configuration and is shown in Table 2:

Node Density (Nodes/Area)	**Number of nodes**	
	Size : 1000m x 1000m	**Size : 400m x 4000m**
0.000025	25	4
0.00005	50	8
0.0001	100	16
0.00025	250	40
0.0005	500	80
0.00075	750	120
0.001	1000	160

Justification:

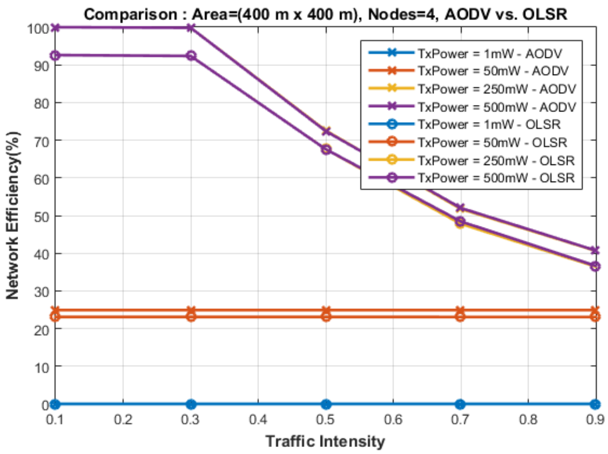
- We demonstrate that by scaling down the network (while maintaining the node density) will exhibit similar trends in terms of network efficiency.
- The network efficiency is expected to be a function of SNR at the receiving node(s). Since the node density is the same, we expect the ‘average’ SNR of all the nodes in the network to be same. It is important to note that we use the term ‘average’ to denote the mean SNR at a given node (since all the nodes have the same Tx power and the random pairing of nodes will determine the instantaneous SNR at a given node). We assume that the channel does not exhibit multipath behaviour.

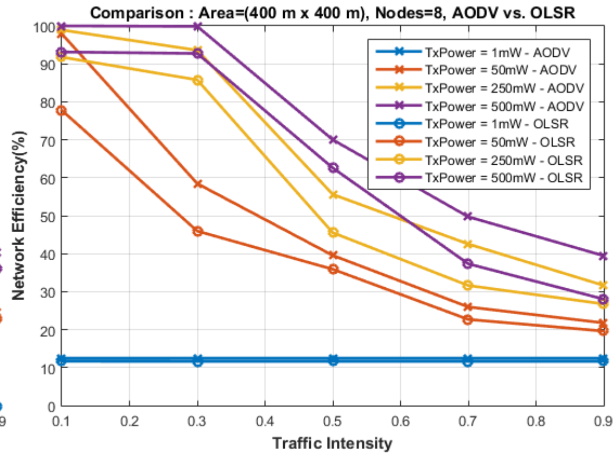
Simulation:

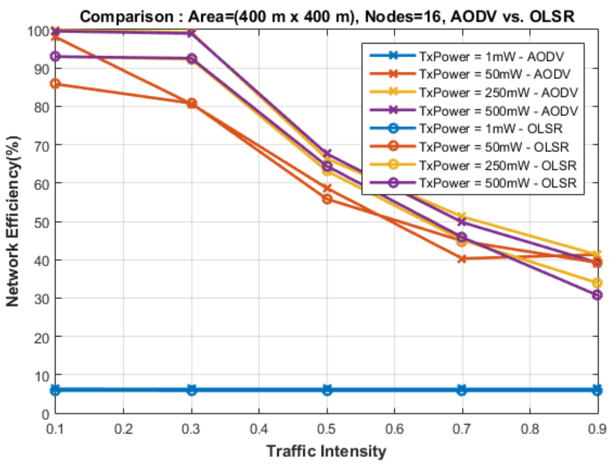
- We demonstrate this effect using the results obtained for low network density plots for both cases (large and small areas) and illustrate the equivalence
- We use the equivalence argument above to networks with high node densities. As a result, we shall plot the results for only the ’scaled down’ network and observe the trend(s).
- This approach will help us understand the network behavior while simulating the ad-hoc network in reasonable wall-clock time.

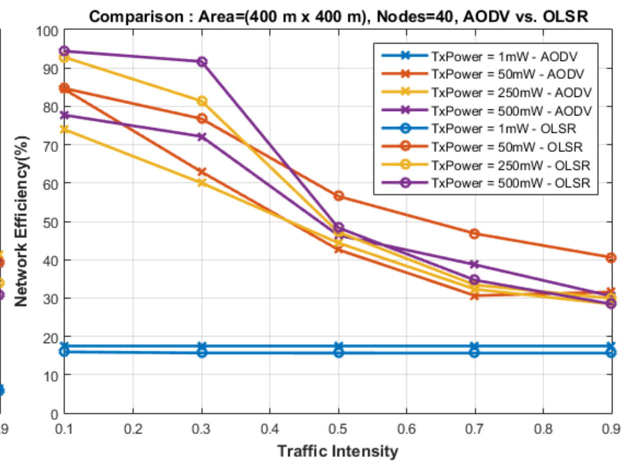
Observations:

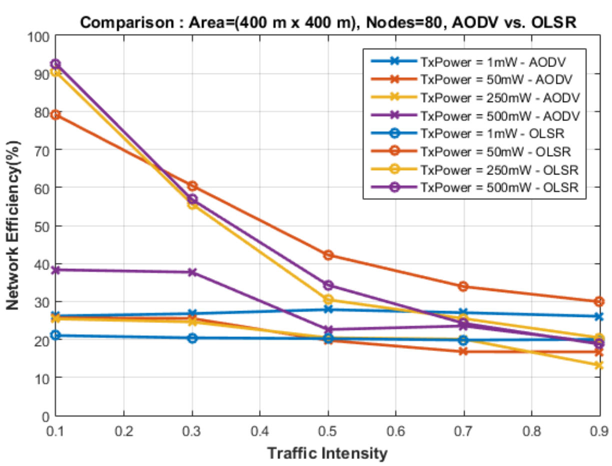
Effect of Transmit Power on Network Efficiency : AODV vs. OLSR

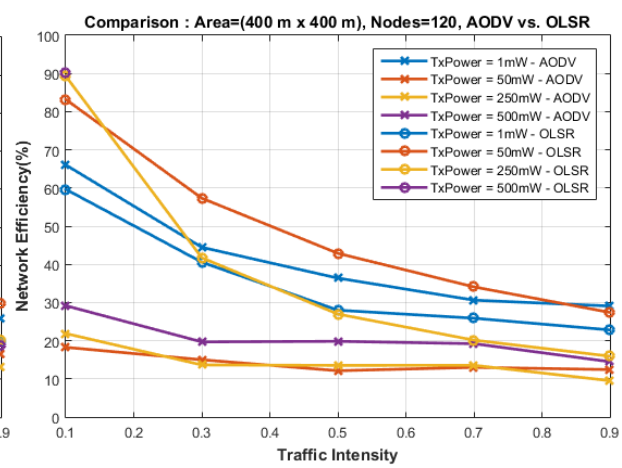












Node Density - Low (0.000025 - 0.00005)

- For a low transmit power, the network efficiency is close to zero. This is primarily because the nodes are spaced far apart in the network. As a result, the pairs cannot establish a wireless link to each other and no data transfer takes place for any traffic intensity.
- As the transmit power increases, the network efficiency increases since the nodes can effectively reach other nodes in the network. As a result, a link can be established and the packets routed by the ad-hoc routing protocols such as AODV or OLSR.
- The network efficiency for medium to high transmit powers lie in the same range suggesting that the increase in transmit power will have minimal effect on the data transfer.
- The network efficiency reduces with increasing traffic intensity. This is because increased traffic lead to high number of collisions in the network, which cause packet loss and thus reduce the overall throughput. The effect is worsened at higher traffic intensities.

Node Density - Medium (0.0001 - 0.0005)

- For a low transmit power, the network efficiency is non-zero. Infact, the network efficiency is sufficiently high indicated a good throughput. This is because the nodes are placed closer to each other now and a low transmit power is sufficient power is enough to establish a connection/link with a peer.
- As the transmit power is increased, the network efficiency increases for low traffic intensity. This may indicate that the nodes that were previously out of coverage are now connected to the network and able to transmit/receive packets. A further increase in transmit power has minimal effect on the network efficiency, indicating that the coverage is just enough to route packets but not enough to cause interference
- Given a particular transmit power, as the traffic intensity increases, the network efficiency is observed to degrade progressively. This is because the nodes are now pumping more data into the network, leading to increased collisions and packet losses.
- The network efficiency for AODV degrades as the node density increases. This is due to the increased overhead for route discovery.

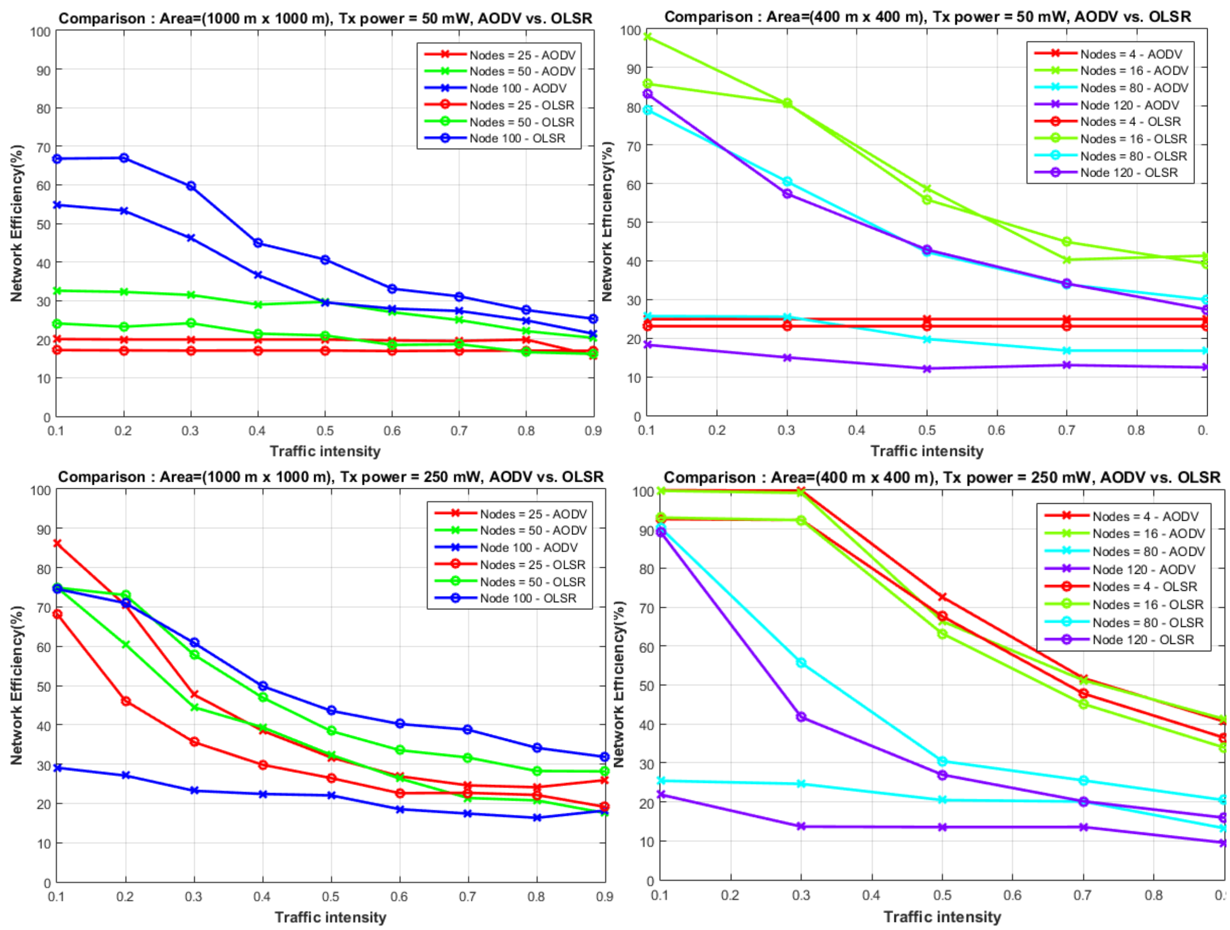
Node Density - High (0.00075 - 0.001)

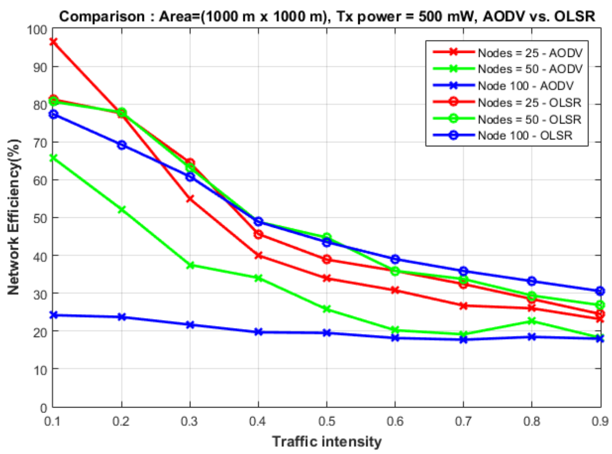
- For low transmit power, the network efficiency is high. This is because the nodes are placed very close to each other and thus, do not require a very transmit power to establish a connection with a peer.
- As the transmit power increases, the network efficiency increases due to increased coverage of nodes and higher interference at every node (as a result of reduced SINR). This directly increases the number of collisions experienced in the network, resulting in high packet loss rates.

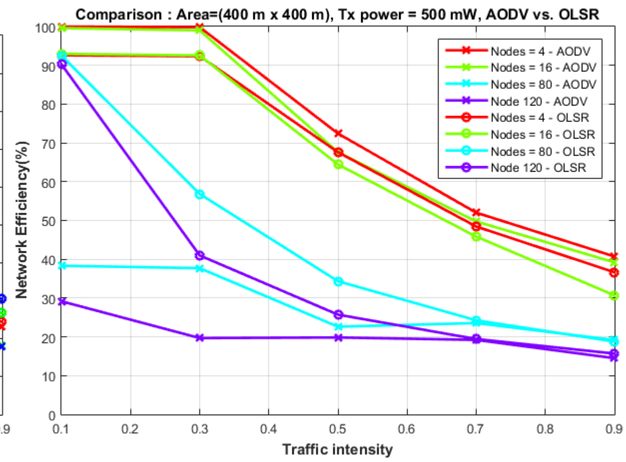
Conclusions:

- For low node density, AODV performs better than OLSR for the same network configuration (transmit power and the traffic intensity)
- As we move towards higher node densities, the OLSR protocol gives a superior network efficiency compared to the AODV protocol, for the same network configuration (transmit power and traffic intensity).
- The simulation time (in wall-clock seconds) is similar for AODV and OLSR for low node densities and diverge for high node densities. The execution time for AODV becomes prohibitively large for AODV for very high node densities.

❖ Effect of Node Density on Network Efficiency : AODV vs. OLSR







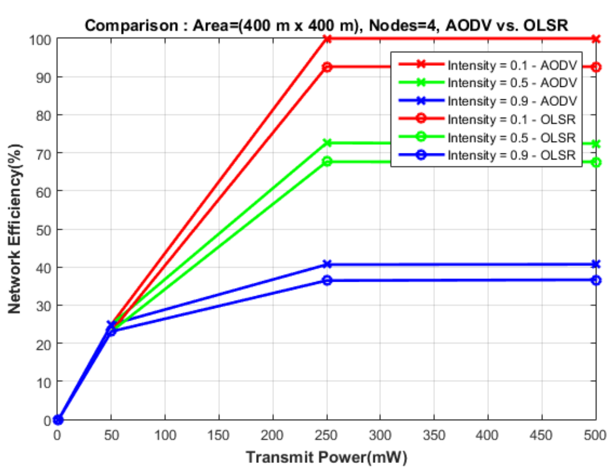
As it is evident from the graphs, AODV performs better than OLSR when the network node density is low. On the other hand OLSR performs better when the network density is higher.

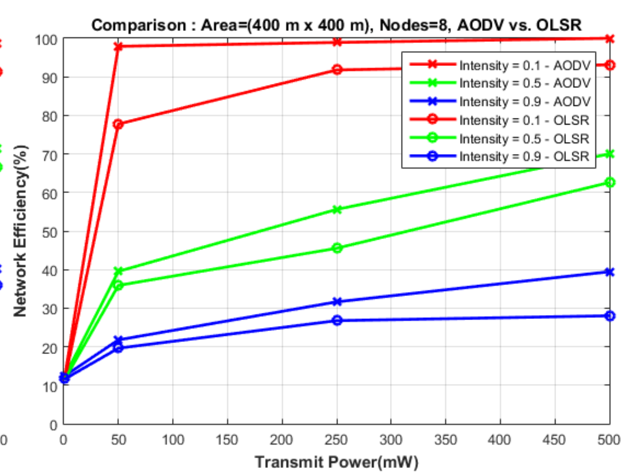
In dense networks, in the case of AODV, there are repeated route discovery and error messages which cause significant overhead in the network resulting in decrease in throughput. On the other hand OLSR does not have as much overhead as AODV in the case of denser networks. This is because once routing tables are formed, the overhead because of repeated requests does not arise.

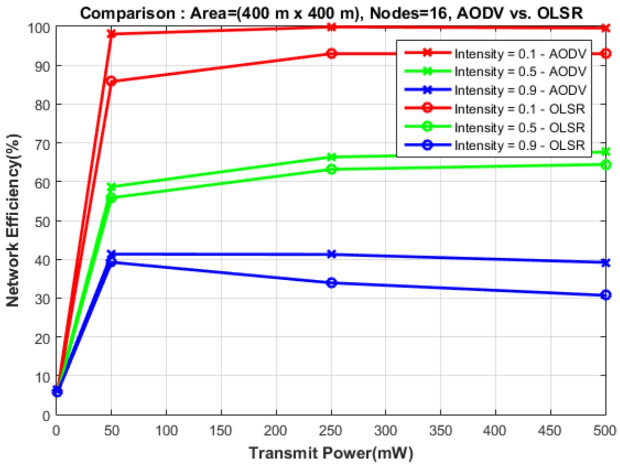
In scattered networks, the overhead caused by exchanging topology information in the case of OLSR reduces the network efficiency. On the other hand AODV does not have so much overhead as OLSR does as there not many repeated route requests and routes are formed only on a need basis.

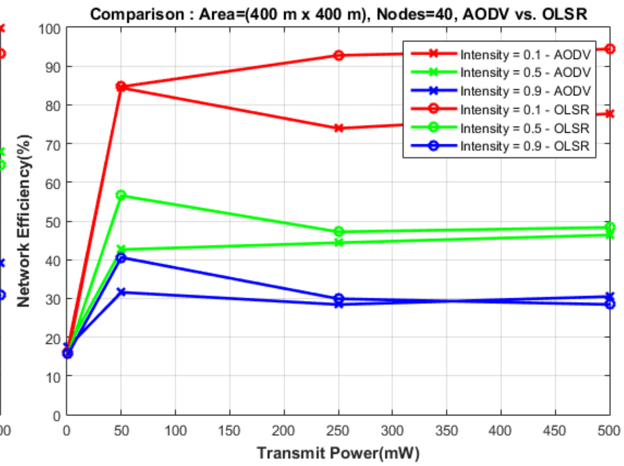
Furthermore, the performance of AODV and OLSR converge at high node densities for all values of transmit power.

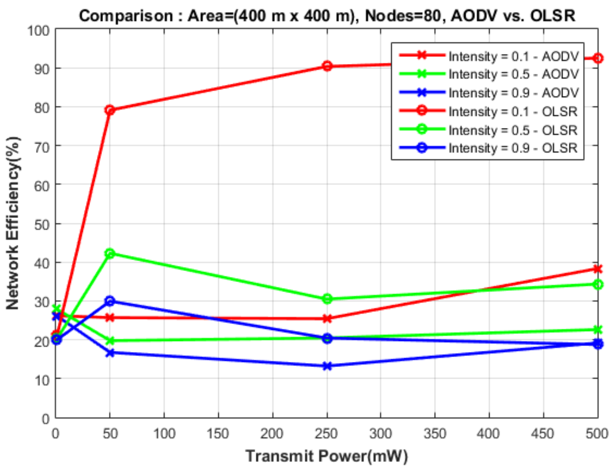
❖ Effect of Traffic Intensity : AODV vs. OLSR

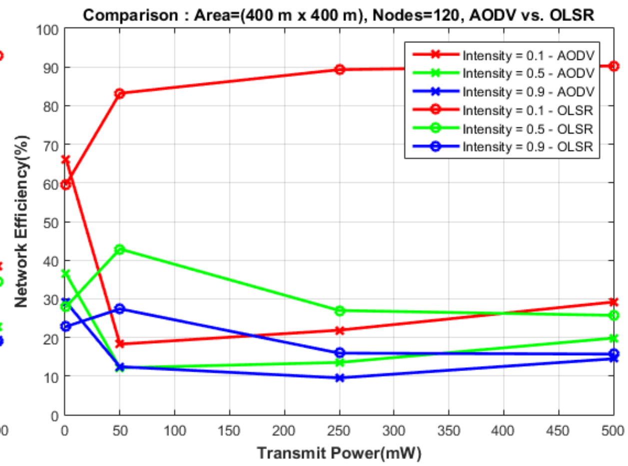












Observations :

- For low node densities, AODV performs consistently better than OLSR for all traffic intensities.
- As the node density increases, OLSR gradually performs better to surpass AODV, in terms of network efficiency for a given traffic intensity.
- The network efficiency varies greatly for AODV and OLSR at low traffic intensities, with OLSR performing much better than AODV because of the high overhead costs required for setting up the links for the latter and the lower end-to-end latency for OLSR. The difference progressively diminishes as the traffic intensity increases. This effect is more prominent at high node densities.