ECE 6110 – Computer Aided Design of Communication Networks

Project 3

Measuring Wireless Throughput Capacity

Submitted by:

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Procedure:

We place varying number of nodes randomly in a square region of 1000×1000 m^2. Each node chooses a random node among all the other nodes as its peer and sends it data throughout the lifetime of the network. We install OnOffApplication using UDP protocol on the source node and UDPSink on the destination node.

In one set of simulations, AODV routing protocol is implemented on all the nodes and in another set, OLSR routing protocol is used. AODV is a reactive (demand driven) distance vector protocol. Routes are calculated as need arises instead of calculating them beforehand like in traditional routing protocols. Moreover, it is a distance vector protocol, which means nodes share information about the entire topology of the network which their neighboring nodes. OLSR is a proactive (table driven) link state protocol. Routes are calculated before actual data transfer takes place. Moreover, it is a link state protocol, which means that nodes know only about their neighboring links and broadcast this information in the entire network. The above mentioned protocols are meant for mobile ad hoc networks where nodes are moving and new routes need to be calculated often; or some of the nodes fail due to lack of energy like in sensor networks. In our network all the nodes are static. It will be interesting to look at how these protocols work in static scenarios with random placement of nodes.

Each sending node is assigned a fixed traffic intensity value between 0 and 1, with 0 representing a zero transmittance state and 1 representing transmission at maximum capacity. For the purposes of our simulations, a maximum network flow rate was set at 1 mbps. This value was scaled based on desired traffic intensity and then normalized by node count; each node in the simulation used the resulting value as their assigned data rate.

The node stays in On period out of 1 second for the value equal to traffic intensity. It sends at the assigned data rate during the On or busy period. Then it goes off for the remaining time. Duty cycle is effectively 1 second in which On period is equal to traffic intensity value and the remaining time is off period. Increasing intensity therefore increases load on the network.

$$Traffic\ Intensity = \frac{On\ period}{On\ period + Off\ period}$$

Other input parameters we vary are number of nodes in the network, transmit power at the sending nodes (in milliWatts) and choice of routing protocol (AODV or OLSR). Traffic intensity and transmit power is kept same for all the nodes in a particular simulation run.

The only output parameter we calculate is efficiency which is defined as:

$$Efficiency = \frac{Total\ bytes\ received\ at\ all\ the\ sink\ nodes}{Total\ bytes\ transmitted\ by\ all\ the\ source\ nodes}$$

Bytes relayed to other nodes are not counted in total bytes received. Efficiency also varies between 0 and 1, with 0 being all the bytes transmitted are lost and 1 being all the bytes transmitted are received.

We use 802.11b Direct Sequence Spread Spectrum as physical layer standard sending at 1 Mbps. All the nodes send to their corresponding peer nodes at 1 Mbps during the Busy period. Changing the value of traffic intensity changes load on the network. There will be collisions when more than one node try to transmit to the same receiver at the same time. 802.11b uses carrier sense multiple access with collision avoidance to decide when to transmit the packet. Since the neighbors are chosen randomly, we do not know how many intermediate nodes are in between sender and receiver. Depending on the transmission power of nodes and node position, there can be disconnections in the network. Some areas can be hotspots, where there are many transmitters or receivers. That is why ratio of all the transmitted bytes and all the received bytes gives us a good estimate of how well the network is capable of transferring data.

We use the Friis path loss model in our simulations, where the transmitted power decreases as inverse squared distance from transmitter. Nodes that are near the transmitter have higher chances of receiving data as compared to far away nodes.

$$\frac{Received\ power}{Transmitted\ power} = G_t G_r \left(\frac{Wavelength}{4\pi \times distance^2}\right)$$

$$G_t\ and\ G_r\ are\ antenna\ gains\ of\ transmitter\ and\ receiver\ respectively$$

Packets do not reach the intended receivers due to collisions at intermediate nodes or the receiver or because the path does not exist between the sender and receiver due to placement of nodes. Transmission power also affects this as sending at very low power will not allow packets reach from one node to another successfully and sending at high power would result in increased chances of collisions and hence dropped packets. The goal of these experiments is to find the optimal set of parameters for maximum network efficiency when nodes are randomly deployed in an area.

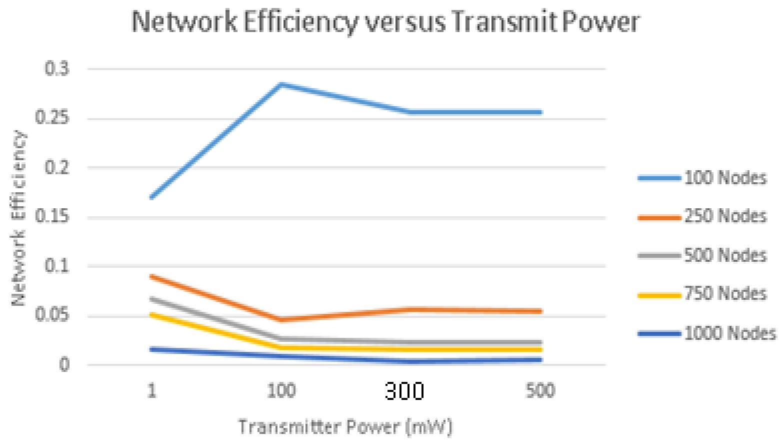
Experiment:

The ns3 adhoc network was simulated for a total runtime time of 5 seconds, in order to make the computing time required tractable. In order to collect sufficient data as to allow analysis of network trends, the simulation was parametrized with the following independent variables:

1. Routing Protocol: Both AODV and OLSR were tested.
2. Node Count: The 1000 sq. meter network area was populated with [100, 250, 500, 750, 1000] OnOffApplication nodes each transmitting a uniform datarate as determined by traffic intensity. Each node in the simulation was randomly placed within the simulated area, distributed uniformly.
3. Transmission Power: Each node was installed with a radio transmitting at [1, 100, 300, 500] milliWatt strength.
4. Traffic Intensity: The network as a whole was subjected to varying loads rated by intensity at [0.1, 0.25, 0.5, 0.75, 0.9].

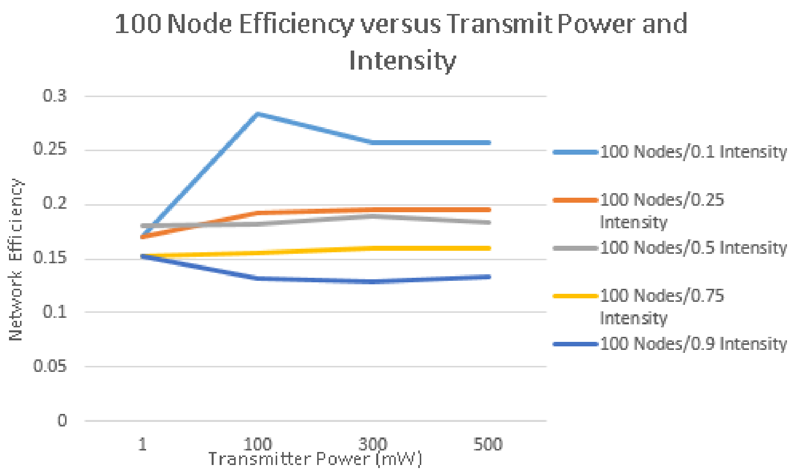
Results:

While each parameter affects the efficiency of the network in a unique way, the ability of network nodes to engage in meaningful network transactions is directly determined at a physical level by the transmit power of the radio hardware. Without enough transmit strength behind a packet transmission, neither the traffic intensity nor the routing protocol will significantly affect the ability of the network to push packets from source to destination. This physical limitation can only be manipulated through a single other parameter, that being the node count of the network being simulated. With fewer nodes occupying the simulated MANET area, it becomes less likely that a weaker transmitter will be able to reach a peer in order to deliver packets. Conversely, a higher node density improves the probability that a transmitter will have their packets reach a peer node capable of forwarding traffic. For our experiments, we equipped each node with a transmitter capable of a minimum of 1mW power, ranging to a maximum of 500mW.

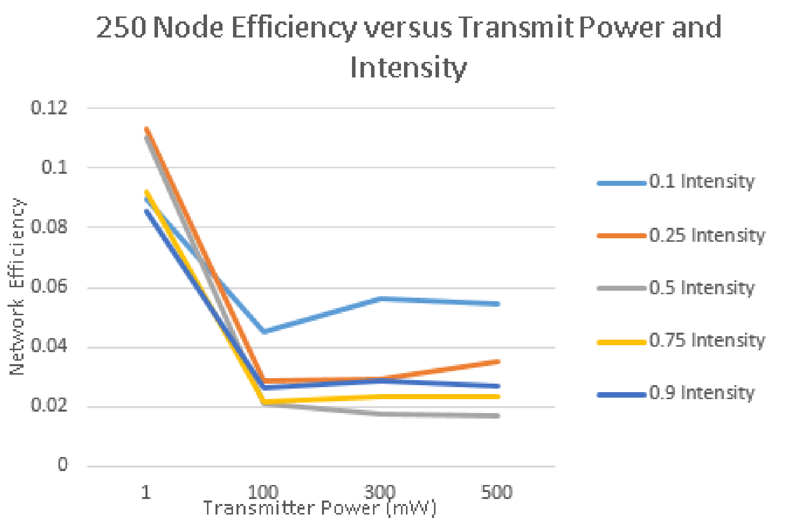


The graph shown was collected at minimal intensity (0.1). As can be seen with the 100 node simulation, the ability of the network to handle network load increases with 1 mW power. The efficiency increases with bumps to transmitter power, as each node is node capable of reaching additional neighbors.

However, the higher node densities reveal that additional transmit power will not necessarily improve network performance. Given the network's tighter spacing under higher node densities and the reduced distance between neighbor nodes, it is observed that a higher transmit power can sometimes overwhelm the network's channel medium. This results in suboptimal efficiency as comparatively distant nodes are now capable of interfering with localized traffic.



With that being said, traffic intensity is relatively decoupled from transmitter power's effects on network efficiency. As can be seen in the 100 node network, with the exception of 0.1 intensity there is a minimal impact on the efficiency of the network when the transmitter power is varied under different network intensities.

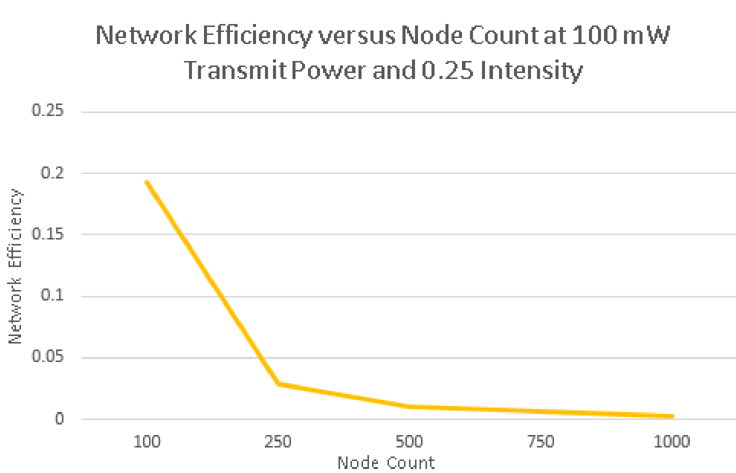


By increasing the number of nodes in the network we can show a slightly more interesting result. Here in a 250 node network we see the impact of transmitter power on network efficiency independent of traffic intensity. By increasing the transmitter power to 100 mW in a more dense network, we decrease throughput due to an increase in channel interference. Similar to before, traffic intensity has very little impact.

It should be noted that in general an increase in traffic intensity will almost always result in a reduction in network efficiency and throughput. Simply put, adding load on the network will eventually produce more traffic than the constituent nodes can handle causing varying levels of congestion. Some of this comes down to the routing protocol used, and this aspect will be analyzed later on.

While not tested within the scope of this experiment, mobility is a significant factor in the ability to physically realize wireless networks. For the purposes of these experiments each node was randomly placed at a location within the 1000 sq. meter area and remained there for the duration of the simulation. However, in real-world systems the movement of nodes during network operation must be considered.

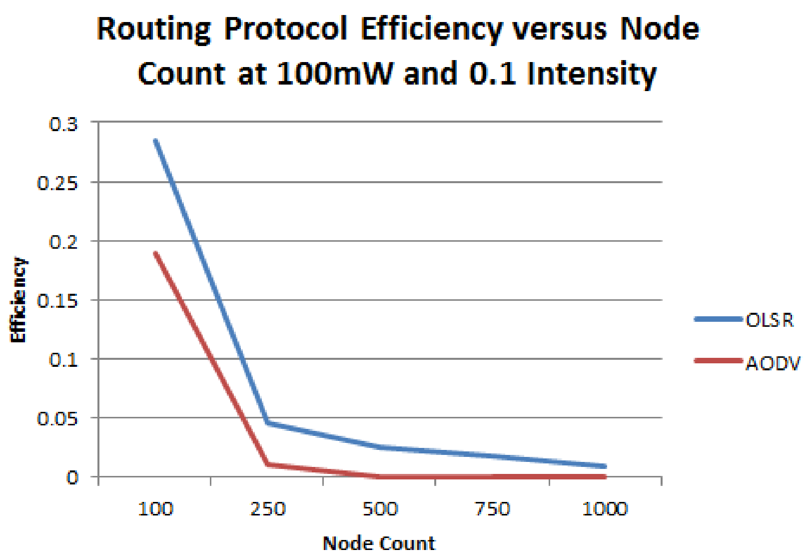
The other physical consideration apart from transmitter power involves the node count of the network. Given that the area over which the nodes are distributed is fixed, adjusting the node count directly affects the density of the network due to the uniformly random distribution of radios.



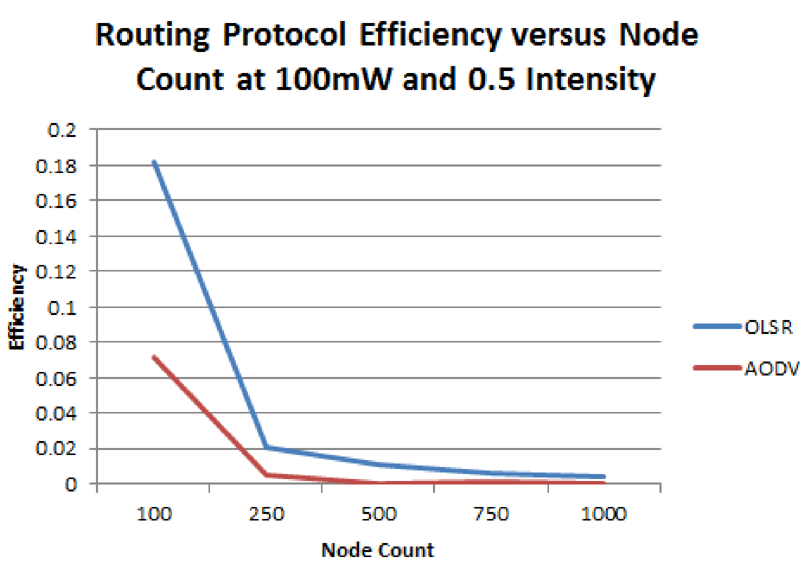
Without overall loss of generality, the data depicted indicates the trend in network efficiency assuming a moderate transmitter power of 100 mW and traffic intensity of 0.25. Clearly, increasing the number of nodes on the network decreases the overall efficiency. This can be attributed to greater network congestion as crowding manifests.

The final aspect in assessing the behavior of our simulated networks involves the choice of routing protocol. By directly comparing each protocol's ability handle variations in node count and traffic intensity, we are able to draw conclusions regarding the operation of a MANET given reactive versus proactive routing methods.

By nature of the simulation, the impact of transmitter power is negligible when comparing the AODV vs OLSR protocols. The uniform distribution of the node placement within the simulation area ensures that each node is capable of reaching neighbors, and the effects on the overall efficiency of the network from the standpoint of transmitter power arises moreso from the effect of congestion of the physical channel itself rather than from any behavior that would result from interaction with the routing protocol.



One of the more immediate factors in assessing protocol performance involves the respective ability of each protocol to scale up in total network size. At a moderate traffic intensity of 0.1 and transmitter power of 100 mW, the data clearly shows that OLSR is optimal for both smaller networks and larger ones at a low traffic intensity.



Increasing the traffic intensity up to 0.5 does not change the results significantly, however it does emphasize that OLSR is much more consistent in its handling of higher volume traffic as compared to AODV. It is clear that while the effect of additional traffic is detrimental to both protocol's performances, AODV experiences a sharp dropoff in a 100 node network as compared to the previously light traffic intensity.

Overall, OLSR has shown to be the more optimal choice of protocol over the tested parametrizations for this experiment. Due to its ability to handle both high and low volumes of network traffic at a comparatively high efficiency relative to AODV, our experimental data concludes OLSR to be the better choice in general. Among other factors, the likely prominent cause of this outcome relates to AODV's higher overhead requirement as a consequence of its reactive routing design.

With that being said, one major factor not tested within this experiment that may yield comparative performance gains for AODV pertains to the resource requirement incurred with OLSR. While AODV falters in this experiment as a consequence of transmuting the majority of its routing discovery into additional overhead network traffic, OLSR may not perform as well when individual nodes are subject to performance and computing resource constraints. OLSR retains an edge in this experiment due to the fact that it utilizes mechanisms such as MPR (multi point routing) and proactive routing design, which allow it to minimize the traffic needed to provide routing services. However, if the computing resources required in order to maintain link state in the manner OLSR does were not readily available, then performance impacts are within the definite realm of possibility.

Future Work:

One area we have considered for further analysis involves assessing the impact of the physical area the MANET is distributed across. Given the timeframe of this project, providing a comprehensive analysis of this variable was intractable due to the excessively long runtime of our network simulations. However, running simulations for more tightly constrained in addition to larger physical spaces may grant insight into the optimal behavior of the MANET when considering variables including routing protocol and transmitter intensity.

The same can be said for testing mobility. Due to simulation run time this factor was not considered tractable for the purposes of this experiment. However, given that most wireless networks in the real-world involve some element of mobility it is important to understand how this aspect influences simulation results. Modeling node mobility could potentially lend further insight into this facet of network simulation.