Some Thoughts on Wireless Network Modelling

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Traditionally, wireless networks are modelled using a reachability or connectivity graph (say, G). We offer some out-of-the box re-thinking of the traditional graph model. Due to its graphical appearance and because of its historical use in wired networks the graph encourages to think of the edges as "tunnels" between nodes. This does not reflect reality of wireless networks at all. In wireless networks, especially when using omni-antennas, links are less well defined. A link is not some kind of "tunnel" between two nodes but rather a cloud of wave propagation around the node (typically idealized as a sphere or as a circle in 2D visualizations). Basically, every unicast in a wireless network is just like a broadcast which is ignored by every node except the intended receiver. The graph must therefore be interpreted as connecting all nodes which are in transmission range within each other. In other words an edge and therefore a "link" exists between two nodes if and only if these two nodes experience sufficient SINR to decode packets from each other with a packet loss below a certain threshold.

The carrier sense or interference range, on the other hand, is usually not modelled in the graph. Carrier sense range is defined as the range at which a node's clear channel assessment function (CCA) can still detect the channel as busy but the packets can not be successfully decoded anymore. As shown in literature, for CSMA/CA protocols, carrier sensing has a significant influence on the interaction of links (interference between links on layer 2). When nodes sense the medium as busy they can not send themselves (known as exposed node problem) which leads to throughput degradation when two or more links interfere with each other in this way. This has been described eg. by (S.M. Das, et al, 2006) and (J. Padhye, et al, 2005). As the carrier sensing / interference range is not modelled in the graph, links which actually interfere with each other appear to be independent. Also, nodes which are affected by other nodes' transmissions seem unaffected. Therefore, we propose an extended version of the traditional reachability / connectivity graph which combines edges for transmission range and edges signifying the carrier sensing / interference range. We call this extended graph G*.

We also demonstrate what happens in the network over time observing G*(t): when a node transmits a packet, all nodes apart from the intended receiver which are one hop (regardless of whether connected by an edge signifying reachability or carrier sense range) away from the sending node must be considered deaf and dumb for the duration of the packet transfer: they can neither send their own packets (because of the CSMA/CA protocol) nor receive packets from other nodes because these would be interfered with by the ongoing transmission (hidden node problem). Since these nodes are for all practical purposes disabled during the transmission time, their associated links (edges in the graph) must also be considered non-existent during this time.
Assuming a protocol using acknowledgments like, eg., the 802.11x family, the receiving node will send ACK packets. During the sending of these, the same as above applies to all nodes one hop away from the receiving node. Considering the effect of a completed send instead of the transmission of data packets and ACKs separately, the transmission of ACKs has less impact on neighboring nodes, though, because ACKs typically are much smaller than data packets and also one ACK might acknowledge a whole frameburst of data.

Finally, we offer some thoughts on how to use and construct this extended graph. Usage can be by 1) deploying new routing protocols on the static G* which take the carrier sensing edges into account, 2) by recalculating the original link weights of G to account for the influence of sending on a link and then executing legacy routing protocols as usual, and 3) by developing new time-variant graph aware protocols (which we think is infeasible). For construction we propose to use a method similar to the ETX measurement method shown in (D.S.J. DeCouto et al, 2005). All nodes take turns sending hello messages at defined time intervals and using unique time slots. Listening nodes can then determine whether a link or a carrier sense edge exists.

References

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