Lastly, the third column in figure 13 shows the load distribution of the real data transmission. As all nodes uniformly contribute to the generation of messages and forward these messages in a directed way towards the sink node, a permanent increase of the load towards the sink can be seen. Again, steps can be seen in the *high density* scenario as nodes try to forward the message in each hop as far as possible (DYMO uses only the hop count as a metric to determine the shortest path).

4.10 Spatial load distribution (11 nodes in a line)

In order to verify the results, we created a very special scenario, which is commonly used to evaluate the performance of protocols in wireless ad hoc networks. In this scenario, 11 nodes are placed in a straight line. Ten of these nodes generate data using the same traffic characteristics as used in the grid scenario. The 11th node is used as a sink to transmit all data messages to.

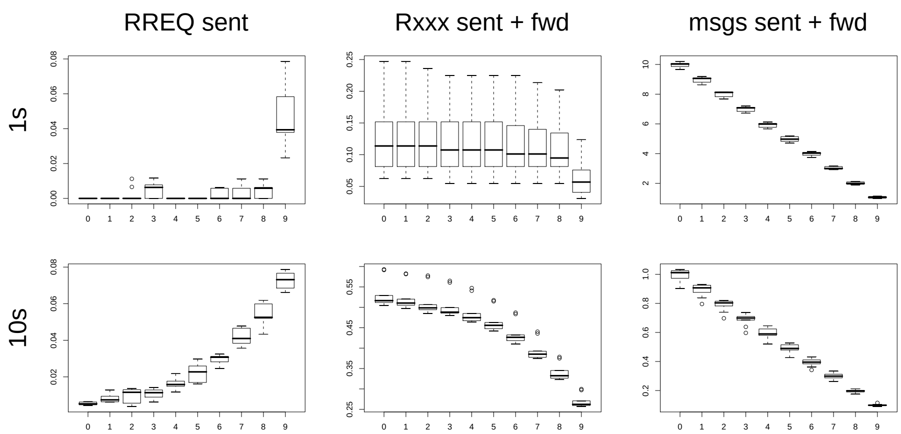

Fig. 15. Spatial load distribution in the line scenario

The measurement results are summarized in figure 15. The left column depicts the number of necessary RREQs to set up routes towards the sink. It can be seen that the number of RREQs increases with the distance to the sink. This validates the results from the grid scenario. Depending on the data rate, routes may time out and additional RREQs are necessary if the inter-packet time is greater than the route timeout used by DYMO.

The second column shows the number of all DYMO messages sent, i.e. either generated or forwarded on behalf of other nodes. As in this small network each generated RREQ is forwarded by every node exactly once, any participating node sends a minimum of the sum of all generated RREQs per second, a measure which is uniformly distributed across the network. Additionally, each node has to relay RREPs generated by the sink. As RREPs are distributed via unicast, a particular node in this network will only have to forward RREPs addressed to any node further away from the sink than itself, which is why this measure decreases with rising distance from the sink. This effect is even more pronounced, because (as explained earlier) nodes further away from the sink generate more RREQs and thus will have more RREPs sent to them by the sink. This can be clearly seen in the top row where the number of DYMO packets sent through the network is almost only due to the RREQs sent by the node farthest from the sink. Each of its RREQs triggers a RREP, both of which need to be relayed by all intermediate nodes, but not by the node itself, which thus ends up having sent the smallest amount of DYMO messages – in spite of being the almost only node generating RREQs.

The third column shows the number of data messages generated and forwarded by all DYMO nodes in the network. As expected, this number linearly increases towards the sink node. Again, the results from the grid scenario are supported by this measure.

5 Conclusion and Future Work

In this work, we motivated, presented, and discussed our implementation of the DYMO routing protocol for OMNeT++ and the *INET Framework*, and we commented on design choices we made in the process. The implementation is available under GPL.

We moved on to demonstrate how our model can be used to evaluate DYMO's performance in a number of different simulation setups and presented the results we obtained in these simulations.

We are currently using this implementation of DYMO, as well as a version which uses the full stack of the Internet protocol family, to evaluate the applicability and performance of DYMO in MANET and especially Vehicular Ad Hoc Network (VANET) scenarios, and are working on comparing the performance of DYMO and AODV.

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