Table II
QUARTILES OF THE QUEUING TIME T_Q FOR VARYING BUFFER SIZES AND A $MaxLinkTimeout$ OF 1 S.

Buffer size	OLSR: T_Q (s)			BATMAN: T_Q (s)		
	Q1	Q2	Q3	Q1	Q2	Q3
50	0.23	0.48	0.84	0.16	0.91	3.00
100	0.25	0.51	0.97	0.36	1.45	5.21
200	0.26	0.56	1.20	0.68	2.20	7.87
500	0.29	0.61	1.69	0.81	3.06	10.07
1000	0.29	0.63	1.81	0.81	3.17	10.64

queued. This is an indication that most packets are stored because of short-lived link disruptions (i.e., the link validity check method returns false) and not as a result of long term disruptions, caused by the mobility of nodes.

As the basic route calculation algorithms of BATMAN and OLSR are not changed, the hybrid MANET-DTN scheme does neither directly impact the hop count of a packet nor the overall routing control traffic. However, it is important to note that the store-and-forward mechanism has some implications on these two measures. Particularly, it decreases the relative routing overhead (i.e., the ratio between control traffic and data traffic) as more data packets can be delivered. Similarly, the average hop count is slightly increased as the store-and-forward mechanism mainly increases the PDR of the nodes that are farther away from the destination and utilize longer multi-hop paths.

VIII. CONCLUSION AND FUTURE WORK

In this paper, we evaluated how a hybrid MANET-DTN approach, based on the integration of a store-and-forward mechanism into a proactive MANET routing protocol, performs in a disaster scenario. The simulation scenario included a realistic first responder mobility model and a wireless obstacle model that allowed us to model a realistic emergency response. The simulation results show that a store-and-forward mechanism is beneficial for the packet delivery ratio of both MANET routing protocols. Thus, it can be stated that a hybrid MANET-DTN routing scheme increases the robustness of the network as disruptions can be compensated. On the other hand, the increase comes at the expense of a higher packet delay. Although there are applications that cannot cope well with high and varying delays (e.g., multimedia streaming, real-time communication), we believe that networks for emergency responses benefit from this extension. Future work could include to identify the application and its type of traffic (e.g., by means of the port number) to decide which packets to buffer.

The hybrid MANET-DTN mechanism could also be adapted for reactive routing protocols. Actually, reactive protocols contain a similar store-and-forward mechanism as data packets are usually stored until the route finding process has finished. However, data packets are dropped if no route can be found. If a reactive routing protocol is used, it is more difficult to decide when to send buffered packets as there are no periodic routing updates that can be used as decision points. Instead, new routes have to be explicitly requested, which causes a higher routing overhead. Hence, finding a trade-off between discovering communication opportunities on time and saving network resources is another interesting topic for future work.

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