Performance Modeling of Delay-Tolerant Network Routing via Queueing Petri Nets

Abstract:

With the advent of wireless technologies such as Wi-Fi Direct and Near Field Communication (NFC), infrastructure-less Peer-to-Peer (P2P) content sharing among mobile devices is set to become more ubiquitous. Delay-Tolerant Networks (DTNs), with their opportunistic message forwarding strategy, can be leveraged to provide seamless connectivity in such scenarios. To the best of our knowledge, little has been done to understand the performance of DTNs under realistic settings involving the interplay of diverse factors such as bundle fragmentation, scheduling, and buffer spacing. In this paper, we look at Queueing Petri Nets (QPNs) as a modeling framework to study the performance of DTN routing. We develop QPN models for DTNs of increasing complexity in an incremental fashion, starting from a network that employs the rudimentary direct transmission routing protocol to a network that employs a family of multi-hop and replication-based routing protocols. The complete QPN model considers a number of realistic factors that impact performance such as finite buffer space, finite link bandwidth, bundles with different priorities and intra-scheduling delays arising due to different levels of the memory hierarchy at the nodes. We come up with a three-fold validation scheme to assert the veracity of our proposed models, via comparison of results obtained from simulations of the QPN vis-a-vis those obtained from direct simulation of the underlying DTN and experimental results obtained from a testbed of Android based devices that employ a mobility emulation scheme. We also show a case to exemplify the analytical capability of the QPN, by deriving the underlying reachability graph and constructing an equivalent stochastic jump process. We identify the

stochastic process to be a Semi-Markov Process (SMP) and hence arrive at a closed form expression for the end-to-end delivery la- ency by computing the hitting time of the SMP. We find that the model accurately captures the behavior of a DTN in numerous realistic scenarios, showing the efficacy of QPNs as a suitable modeling framework for evaluating the DTN routing protocols.