Software Defined Disruption Tolerant Networks

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by

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Abstract

Wireless networks play a crucial role in our activities of daily living, especially due to the surge of mobile devices since 1990. Apart from the widely-accepted domains of cellular and local area networking, wireless networks find their applications in tactical networks, emergency response systems, underwater networks, satellite networks, and emerging Internet of Things (IoT). However, the limited communication range, bandwidth constraints, as well as the mobility of end-user devices make the seamless end-to-end communication a challenging task in such networks. In addition, the traditional networking frameworks seem inadequate to cater the dynamic application-specific requirements of users and business community. Software Defined Networking (SDN) emerged as a new networking paradigm in this regard to provide flexibility in network control with the separation of control plane from data plane which are otherwise coupled together in traditional networking devices. In SDN, the devices in data plane, known as *switches*, are considered as non-intelligent devices which forward the packets as per the rules dictated by a logically centralized control plane point known as the *controller*. The data and control planes are assumed to have a secure and reliable communication channel to exchange the network control decisions. However, such an assumption becomes invalid in wireless environments that involve node mobility and frequent link disruptions.

In this thesis, we propose an SDN framework for wireless environments that involve link disruptions and mobility of nodes, *including switches and controllers*. As the first step toward adopting SDN to such disruption-prone wireless networks, we design a novel resource discovery and self-configuration scheme to enable the SDN devices to identify and adjust themselves depending on the changing network conditions. In order to capture the network dynamics as well as to identify the SDN resources in a network, we extend the existing Optimized Link State Routing (OLSR) protocol to Software Defined OLSR (SD-OLSR) and provide it as the medium for switch-controller communication. In addition, two controller handoff schemes, Switch-Initiated Handoff (SIH) and Controller-Initiated Handoff (CIH), are designed to achieve the self-configuration of switches and controllers. The results from an experimental wireless mesh network testbed show that CIH is appropriate for environments offering easy on-the-fly configuration of nodes while SIH is best suited for real-world time-sensitive and strategic networks.

In order to cope with the link disruptions between devices in data plane, we proposed a novel Software Defined Disruption Tolerant Networking (SD-DTN) framework with controlled buffering of packets at the switches using a proposed STORE action. In SD-DTN, the controller exploits switches' memory to buffer packets during link disruptions and forward them toward the destination when appropriate links get established. We model the network involving link disruptions using temporal graphs and Markov chain, and propose an SDN controller algorithm Earliest Arrival Path with Minimal Storage Time (EAPMST) to compute the buffering/routing decision for the switches. Our SD-DTN is realized using a new SDN switch architecture integrated with a storage subsystem to handle the controlled buffering operation. The performance of our framework is tested using a disruption-prone wireless mesh network testbed deployed in the campus building and the results show an improvement in throughput beyond 25% with random mobility model.

Finally, we explored two emerging application domains of SD-DTN: (*i*) Software Defined Vehicular Networks (SD-VNs) and (*ii*) Software Defined Satellite Networks (SD-SNs). In order to improve the vehicles' contacts with the wireless points deployed at the roadsides, we define a new metric *Effort* for road networks and devise an *Effort*-based Roadside Unit (RSU) placement scheme for SD-VNs considering the structural properties of road networks. On the other hand, the performance of EAPMST algorithm is studied in the context of SD-SNs using two satellite constellation models, *Constrained*-Iridium-NEXT and DebriNet. Further, we discuss the scope and importance of our self-configuration scheme and SD-DTN framework in software defined tactical and emergency response networks. Our studies reveal that the SD-DTN framework along with the EAPMST algorithm is capable of buffering and carrying packets, and maintaining the communication sessions during disruptions, thereby, making our approach a suitable candidate for efficient network control in next generation disruption tolerant wireless networks.