Performance and Scheduling Techniques for Wired/Wireless Data Networks

by

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy (Electrical and Computer Engineering) in the Michigan State University 2022

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ABSTRACT

This thesis is an establishment for routing enhancement in wired and wireless data communications. The work is classified into three distinct parts. Part I is focused on the IP packet networks. Part II concerns routing and interference handling in cellular communications. Part III illustrates our scheme of collision handling in TDMA-based and ad-hoc networks. **Wired communications:** Relay routing for IP networks has been well-documented in past years. However, the implementation cost of relay solutions has not yet been conclusively identified. Dynamic relay relies on periodic probing of routing changes for enhanced performance. Static relay routing, however, uses non-periodic probes to measure latency and packet loss at a lower rate. The ultimate goal of a dynamic relay is to maximize QoS, while a static relay seeks reliability in routing over time. There exists considerable research focused on understanding IP link changes due to fluctuations in routing dynamics. This thesis, in particular, examines characteristics such as the number of hops in a relay path or Hop-To-Live (HTL) of minimum delay relay paths. The thesis introduces HTL to assist in predicting minimum and stable relay paths while minimizing probing overhead. By considering delay, we find those relay paths are more stable and short. Further, the HTL can be used to derive inexpensive relay paths for any routing changes. Our study proposes a performance analysis for using UDP as an alternative to TCP-based services such as YouTube and VoIP applications. We provide an analysis for a streaming performance on a network of 140 nodes using estimation-based schemes that provide better relay paths for UDP streams. Further, we have included an analysis of 18,906 delay traces from a network of 138 hosts to demonstrate the rich existence of IP relay paths that can be leveraged to significantly enhance Internet routing performance. We try to make the case for using layer-3 forwarding minimum delay overlay paths by demonstrating superior performance in this approach compared to existing overlay designs which work mostly at the TCP and application layers. The work was conducted to benefit applications that are sensitive to end-to-end delay and throughput. Here, we present a specific analysis of end-to-end delay to enhance TCP performance by increasing throughput and reducing file transfer time via relay paths using the default TCP settings. Results show that using shortest delay paths between physically disjoint node pairs can benefit TCP throughput and minimize transfer time by orders of magnitude. Ultimately, our study opens a window for large-scale estimation-based relay routing and a new future of layer-3 hybrid forwarding. **Cellular communications:** There is a new trend in cellular networks that allows mobile carriers for dynamic spectrum access. The FCC
adopted rules for shared commercial use of the 3550-3700 MHz band, Citizen Broadband Radio Service (CBRS) in 2015. This band is occasionally in radar data communications and is now open for future LTE-based dynamic-spectrum access. Further, currently, there is no infrastructure corporation between cellar carriers like Verizon Wireless, AT&T, T-Mobile, or Sprint for instance, in normal or emergencies. Dynamic spectrum access is proposed to better utilize the scarce spectrum resources. Recently, the FCC opened up the Citizen Broadband Radio Service (CBRS) for wireless service providers to enable dynamic spectrum access for 5G networks. However, the lack of collaboration among cellular providers has been hampering reliable access due to the increasing interference from multiple carriers. This work considers a new network architecture to foster collaboration among providers through Collaborative Multihop and Multi-Channel Cellular Networks (CMCNs). This work proposes a near-optimal solution to manage interference and congestion by utilizing minimum backoff schemes. Moreover, we develop a near-optimal scheduling algorithm to provide Minimum Broadcast Delay Forwarding (MBDF), which approximates a polynomial scheduling paradigm. Then, we present 6-policy based scenarios that summarize the scheduling paradigm. The designed mapping paradigm is to compute a near-optimal solution. This mapping via conflict graphs allows our analysis to establish a new transformation for MBDF, on which dependency between interference components can be easily visualized and solved. The simulation results show that our approach outperforms the existing models in terms of scheduling delay and message redundancy. The confidence in our proposed scheduling has been examined over distinct sets of CBRS channels by comparing MBDF with a minimum scheduling demand.

Ad-Hoc communications: In ad-hoc collision is a major cause of performance degradation. TDMA scheduling is a well-studied subject for ad-hoc networks to manage collisions. Reinforcement Learning (RL), in particular, Q-Learning (QL) is a tool to achieve a collision-free TDMA schedule. However, the slow convergence and the complex reward designing might be a challenge for a distributed QL-based TDMA over a minimum frame length. This work proposes a QL-based TDMA for distributed systems via control from a slot-based weighted exploration algorithm. This new algorithm is a distributed count-based search and cycle detection for sensor networks with a reduced search overhead comparing existing schemes like Rocha–Thatte algorithm. The proposed QL-based TDMA applies a slot of length 2.5 milliseconds in a minimum frame length for any given topology. The reasons behind such a modification when using a minimum required frame are: (1) To achieve smaller communication delay. (2) Then such a minimum frame reduces the scheduling handshaking signals or acknowledgments and so a minimum flow burden using such a frame while scheduling. The literature is rich in conventional TDMA protocols that operate above minimum frame length and are designed as ACK/NACK-based scheduling schemes. The main aim is to allow each wireless node learns a successful policy that leads to a zero collision frame allocation. This occurs while maintaining no ACK and minimum NACK flow during such
a learning process. Each node collects collision statistics from previous frames. This information is utilized to guide such an ultimate aim. Each newly chosen slot for the next learning frame in our current work context is permitted to be examined only over the next frame and not a currently examined one. This enforced usage could raise our QL convergence time. However, a node with a synchronized and just elapsed current sending slot of a current frame of a learning episode and a new chosen slot, such a node can examine all possible slot between those ones within the current frame to reduce the convergence time. This work has shown how wireless nodes could benefit from collided signals to avoid the next collisions, and while being in a listening mode can infer 1-hop and 2-hops surrounding collisions. The simulation has shown that wireless sensor nodes can learn a minimum frame collision-free frames within a practical convergence episode count.

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