

**Optimal Control for Generalized Network-Flow Problems**

**Abstract:**

We consider the problem of throughput-optimal packet dissemination, in the presence of an arbitrary mix of unicast, broadcast, multicast and anycast traffic, in a general wireless network. We propose an online dynamic policy, called Universal Max-Weight (UMW), which solves the above problem efficiently. To the best of our knowledge, UMW is the first throughput-optimal algorithm of such versatility in the context of generalized network flow problems. Conceptually, the UMW policy is derived by relaxing the precedence constraints associated with multi-hop routing, and then solving a min-cost routing and max-weight scheduling problem on a virtual network of queues. When specialized to the unicast setting, the UMW policy yields a throughput-optimal cycle-free routing and link scheduling policy. This is in contrast to the well-known throughput-optimal Back- Pressure (BP) policy which allows for packet cycling, resulting in excessive delay. Extensive simulation results show that the proposed policy incurs a substantially lower delay as compared to the BP policy. The proof of throughput-optimality of the UMW policy combines techniques from stochastic Lyapunov theory with a sample path argument from adversarial queueing theory and may be of independent theoretical interest.

**Existing System:**

We provide the first such universal solution: A throughput optimal dynamic control policy for the generalized network flow problem. We start with a brief discussion of the above networking problems and then survey the relevant literature. The resulting algorithm is combinatorial in nature and does not have a wireless counterpart, with associated interferencefree edge activations. Following Edmonds’ work, a variety of different broadcast algorithms have been proposed in the literature, each one targeted to optimize different metrics, such as, delay, energy consumption and fault-tolerance. In the context of optimizing throughput, the paper proposes a randomized broadcast policy, which is optimal for wired networks. However, extending this algorithm to the wireless setting proves to be difficult. In the paper, we propose an optimal

broadcast algorithm for a general wireless network, albeit with exponential complexity. In addition to this, in a recent series of papers, we propose a simple Throughput -optimal broadcast algorithm for wireless networks with an underlying DAG topology. However, this algorithm does not extend to non-DAG networks.

**Proposed System:**

Our proposed solution uses a virtual network of queues - one virtual queue per link in the network. We solve the routing problem dynamically by using a “weighted-shortestroute” computation on the virtual network and then using the corresponding route on the physical network. Optimal link scheduling is performed by a max-weight activation, also in the virtual network, and then using the resulting activation in the physical network. The overall algorithm is dynamic, cycle-free, and solves the generalized routing and scheduling problem optimally (i.e., maximally stable or throughputoptimal).

Unlike the BP policy, which solves only the unicast problem, the proposed UMW policy efficiently addresses all of the aforementioned network flow problems in both wired and wireless networks in a very general setting.

Although the celebrated BP policy is throughput-optimal, its average delay performance is known to be poor due to the occurrence of packetcycling in the network. In our proposed UMW policy, each packet traverses a dynamically selected acyclic route, which drastically reduces the average latency.