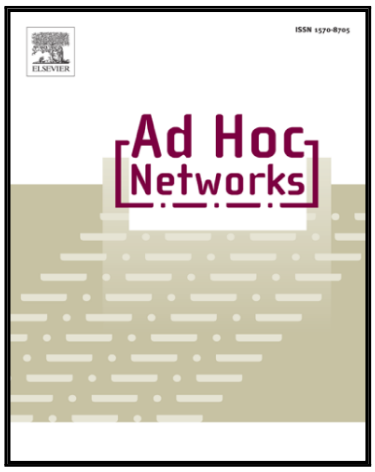

Internet Congestion Control Using the Power Metric:Keep the Pipe Just Full, But No Fuller

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PII: S1570-8705(18)30247-6
DOI: 10.1016/j.adhoc.2018.05.015
Reference: ADHOC 1683

To appear in: *Ad Hoc Networks*

Received date: 8 March 2018
Accepted date: 21 May 2018

Please cite this article as: Leonard Kleinrock, Internet Congestion Control Using the Power Metric:Keep the Pipe Just Full, But No Fuller, *Ad Hoc Networks* (2018), doi: 10.1016/j.adhoc.2018.05.015

Internet Congestion Control Using the Power Metric: *Keep the Pipe Just Full, But No Fuller*

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Abstract

Recently there has been considerable interest in a key paper [1] describing a new approach to congestion control in Internet traffic which has resulted in significant network performance improvement. The approach is based on a 1978 paper [2] and a companion 1979 paper [3] which identified a system operating point that was optimal in that it maximized delivered throughput while minimizing delay and loss. This operating point is simply characterized by the insight that one should *"Keep the pipe just full, but no fuller"* and we show this is equivalent to loading the system so that in many cases (including those relevant to TCP connections) the optimized average number in the pipe is exactly equal to the *Bandwidth-Delay Product*. It is important to understand the reasoning and intuition behind this early insight and why it provides such improved behavior of systems and networks. In this paper, we first develop this insight using purely deterministic reasoning. We then extend this reasoning by examining far more complex stochastic queueing systems and networks using a function called *Power* to mathematically and graphically extract exact and surprising results that support the insight and allow us to identify the optimum operating point for a broad class of systems. These observations allow us to study the impact of Power on networks leading eventually to supporting the statements about steady state congestion and flow control as presented in [1] for today's Internet. We point out that the discussions about the latest congestion control algorithms [1, 4, 5, 6, 7, 8, 9, 10, 11] address the dynamics of tracking flow, dealing with multiple intersecting flows, fairness, and more, and which focus on the dynamic behavior of data networks whereas our work here focuses only on the steady state behavior.

Keywords: TCP Congestion Control; Bandwidth-Delay Product; Internet; Optimal Power Operating Point; Universal Power Profile; Queueing.