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Intended status: Informational ICIR
Expires: 29 December 2007 29 June 2007

Comments on the Usefulness of Simple Best-Effort Traffic draft-floyd-tsvwg-besteffort-00.ps

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Abstract

This document presents some observations on "simple best-effort" traffic, defined loosely for the purposes of this document as Internet traffic that is not covered by Quality of Service mechanisms, congestion-based pricing, or the like. One observation is that simple best-effort traffic serves a useful role in the Internet, and is worth keeping. While traffic with Quality of Service mechanisms, congestion-based pricing, or the like can also be useful, we believe that they are useful as **adjuncts** to simple best-effort traffic, not as **replacements** of simple best-effort traffic. A second observation is that for simple best-effort traffic, some form of rough flow rate fairness is a useful goal for resource allocation, where "flow rate fairness" is defined by the goal of equal flow rates for different flows.

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1. Introduction

This document gives some observations on the role of simple best-effort traffic in the Internet. We define the term "simple best-effort traffic" to avoid unproductive semantic discussions about whether the phrase "best-effort traffic" does or does not include traffic with cost-based fairness or some other form of congestion-based pricing. For the purposes of this document, we define "simple best-effort traffic" as traffic that does not *rely* on the *differential treatment* of flows either in routers or in policers, enforcers, or other middleboxes along the path. "Simple best-effort traffic" in the current Internet uses end-to-end transport protocols (e.g., TCP, UDP, or others), with minimal requirements within the network in terms of resource allocation. However, that is not the only possible implementation of a simple best-effort service. As an example, "simple best-effort traffic" could also be implemented in an infrastructure with Fair Queueing scheduling in congested routers. "Simple best-effort traffic" is the dominant traffic class in the current Internet.

In contrast to "simple best-effort traffic", intserv or diffserv-enabled traffic relies on differential scheduling mechanisms at congested routers, with packets from different intserv or diffserv classes receiving different treatment. Similarly, in contrast to "simple best-effort traffic", cost-based fairness [B07] would most likely require the deployment of traffic marking (e.g., ECN) at congested routers, along with policing mechanisms near the two ends of the connection providing differential treatment for packets in different flows or in different traffic classes. Intserv/diffserv, cost-based fairness, and congestion-based pricing would also require complex economic relationships among Internet Service Providers (ISPs), and between end-users and ISPs.

This document suggests that it is important to retain the class of "simple best-effort traffic" (though hopefully augmented by a wider deployment of other classes of service). Further, this document suggests that some form of rough flow-rate fairness is a perfectly appropriate goal for simple best-effort traffic. We do not argue in this document that flow-rate fairness is the *only possible* or *only desirable* resource allocation goal for simple best-effort traffic. We would maintain, however, that it is an appropriate resource allocation goal for simple best-effort traffic in the current Internet, evolving from the Internet's past of TCP and UDP.

This document was motivated by [B07], an internet-draft on "Flow Rate Fairness: Dismantling a Religion" that asserts in the abstract that "Comparing flow rates should never again be used for claims of fairness in production networks." This document does not attempt to be a rebuttal to [B07], or to answer any or all of the issues raised in [B07], or to give the "intellectual heritage" for flow-based fairness in philosophy or social science, or to commit the authors of this document to an extended dialogue with the author of [B07]. This document is simply a separate viewpoint on some related topics.

2. On Simple Best-Effort Traffic

This section makes some observations on the usefulness and limitations of the class of simple best-effort traffic, in comparison with QoS-enabled traffic, traffic with cost-based fairness or congestion-based pricing, and the like.

2.1. The Usefulness of Simple Best-Effort Traffic

This section discusses some of the useful aspects of simple best-effort traffic.

Minimal technical demands on the network infrastructure:

Simple best-effort traffic, as implemented in the current Internet, makes minimal technical demands on the infrastructure. There are no technical requirements for scheduling mechanisms and queue management mechanisms in routers, or for enforcement mechanisms along the path. This is a source of many of the weaknesses as well as many of the strengths of simple best-effort traffic.

Minimal demands in terms of economic infrastructure:

Simple best-effort traffic makes minimal demands in terms of economic infrastructure, relying on fairly simple pair-wise economic relationships among ISPs, and between users and their immediate ISPs.

Usefulness in the real world:

The Internet is chugging along, however imperfectly. As discussed below, simple best-effort traffic is not optimal. However, experience in the Internet has shown that there is value in having a mechanism that generally allows all users to get a portion of the resources, while still preventing congestion collapse.

2.2. The Limitations of Simple Best-Effort Traffic

This section discusses some of the limitations of simple best-effort traffic.

2.2.1. QoS

Some users would be happy to pay for more bandwidth, less delay, less jitter, or fewer packet drops. It is desirable to accommodate such goals in the Internet architecture while preserving a sufficient amount of bandwidth for best-effort traffic.

One of the obvious dangers of simple implementations of QoS mechanisms or of cost-based

fairness, in the absence of the protection of simple best-effort traffic, would be that the users with more money *could* end up completely shutting out users with less money in times of congestion. There seems to be fairly widespread agreement that this would not be a desirable goal.

As a sample of the range of positions, the Internet Society's Internet 2020 Initiative, entitled "The Internet is (still) for Everyone", states that "we remain committed to the openness that ensures equal access and full participation for every user" [Internet2020].

The wide-ranging discussion of "network neutrality" in the United States includes advocates of several different positions, including that of "absolute non-discrimination" (with no QoS considerations), "limited discrimination without QoS tiering" (no fees charged for higher-quality service), and "limited discrimination and tiering" (including higher fees allowed for QoS) [NetNeutral]. The proponents of "network neutrality" are all opposed to charging based on content (e.g., based on applications, or the content provider).

As the "network neutrality" discussion should make clear, there are many voices in the discussion that would disagree with a resource allocation goal of maximizing the combined aggregate utility, particularly where a user's utility is measured by the user's willingness to pay. "You get what you pay for" does not seem to be the consensus goal for resource allocation in the Internet, either in the IETF or in the commercial or political realms of the Internet.

[Add citations of papers about the importance of the role of the high-priced services in financing the infrastructure.]

Briscoe argues for cost-fairness [B07], so that senders are made accountable for the congestion they cause. There are, of course, differences of opinion about how well cost-based fairness could be enforced, and how well it fits the commercial reality of the Internet, with [B07] presenting an optimistic view.

With *only* best-effort traffic, there would be fundamental limitations to the performance that real-time applications could deliver to their users. In addition to the obvious needs for high bandwidth, low delay or jitter, or low packet drop rates, some applications would like a fast start-up, or to be able to resume their old high sending rate after a relatively-long idle period, or to be able to rely on a call-setup procedure so that the application is not even started if network resources are not sufficient. There are severe limitations to how effectively these requirements can be accommodated by simple best-effort service in a congested environment.

2.2.2. The Enforcement of Fairness

As discussed in Section 3.2 below, there are well-known problems with the enforcement of fairness with simple best-effort traffic (whatever "fairness" goal is used for bandwidth allocation for the simple best-effort traffic), and with enforcement of mechanisms for the avoidance of congestion collapse [RFC2914].

3. On Flow-Rate Fairness for Simple Best-Effort Traffic

This section argues that rough flow-rate fairness is a perfectly acceptable goal for simple best-effort traffic. This section does not, however, claim that flow-rate fairness is necessarily an *optimal* fairness goal or resource allocation mechanism for simple best-effort traffic. Simple best-effort traffic and flow-rate fairness are in general not about optimality.

This document does *not* address any issues about the implementation of flow-rate fairness. In the current Internet, rough flow-rate fairness is achieved by the fact that *most* of the traffic in the Internet uses TCP, and *most* of the TCP connections in fact use conformant TCP congestion control [MAF05]. However, rough flow-rate fairness could also be achieved by the use of per-flow scheduling at congested routers [DKS89] [LLSZ96], by related router mechanisms [SSZ03], or by congestion-controlled transport protocols other than TCP. None of those issues are addressed in this document. In particular, this document does not address the pros and cons of TCP-friendly congestion control, equation-based congestion control [FHPW00], or any of the myriad of other issues concerning mechanisms for approximating flow-rate fairness. Le Boudec's tutorial on rate adaption, congestion control, and fairness gives an introduction to some of these issues [B00].

In a traffic class of simple best-effort traffic, it would be possible to have explicit fairness mechanisms that are implemented by the end-hosts in the network (as in proportional fairness or TCP-fairness), explicit fairness mechanisms enforced by the routers (as in max-min fairness with Fair Queueing), or a traffic class with no explicit fairness mechanisms at all (as in the Internet before TCP congestion control).

3.1. The Usefulness of Flow-Rate Fairness

Many of the useful aspects of best-effort traffic discussed above also quality as useful aspects of flow-rate fairness.

Minimal technical demands on the network infrastructure:

> First, the rough flow-rate fairness for best-effort traffic provided by TCP or other transport protocols makes minimal technical demands on the infrastructure (in the absence of policing, that is, as discussed further in the section below). The rough flow-rate fairness of TCP is provided by the transport protocol at the end-nodes, and doesn't require any mechanisms in routers or middleboxes. However, mechanisms for enforcement of the flow-rate fairness *would* require some support from the infrastructure.

Minimal demands in terms of economic infrastructure:

> Second, a system based on rough flow-rate fairness for best-effort traffic makes minimal demands in terms of economic relationships among ISPs or between users and ISPs.

Usefulness in the real world:

> Third, the current system based on rough flow-rate fairness and best-effort traffic has shown its usefulness in the real world. In particular, the current Internet is largely based of the rough flow-rate fairness provided by TCP with best-effort traffic, and the Internet is still chugging along, however imperfectly.

Getting a share of the available bandwidth:

In addition, a system based on rough flow-rate fairness with best-effort traffic gives all users a reasonable chance of getting a share of the available bandwidth. This seems to be a quality that is much appreciated by today's Internet users.

3.2. The Limitations of Flow-Rate Fairness

This section discusses some of the limitations of flow-rate fairness for simple best-effort traffic. We would note that the limitations of flow-rate fairness are many, with a long history in the literature, while there is not much to be said about the benefits of flow-rate fairness. This does *not* mean that flow-rate fairness is without benefit. For simple best-effort traffic with rough flow-rate fairness, the quote from Winston Churchill about democracy comes to mind: "It has been said that democracy is the worst form of government except all the others that have been tried."

One of the obvious limitations of flow-rate fairness is the difficulty of enforcement. If an infrastructure is designed from the start with a requirement for ubiquitous per-flow scheduling, flow-rate fairness enforced by a scheduling mechanism in routers might be viable. However, when starting with an infrastructure such as the current Internet with best-effort traffic largely served by FIFO (First-In First-Out) scheduling in routers and a design preference for intelligence at the ends, enforcement of flow-rate fairness is difficult at best. Further, a transition to an infrastructure that provides actual flow-rate fairness for best-effort traffic enforced in routers would be difficult.

A second possibility, which is largely how the current Internet is operated, would be best-effort traffic where most of the connections, packets, and bytes belong to connections using similar congestion-control mechanisms (in this case, those of TCP congestion control), with few if any enforcement mechanisms. Of course, when this happens, the result is a rough approximation of flow-rate fairness, with no guarantees that the best-effort traffic will continue to be dominated by connections using similar congestion-control mechanisms or that users or applications cannot game the system for their benefit. That is our current state of affairs. The good news is that the current Internet continues to successfully carry traffic for many users. In particular, we are not aware of reports of frequent congestion collapse, or of the Internet being dominated by severe congestion or intolerable unfairness.

A third possibility would be best-effort traffic with flow-rate fairness provided by the congestion control mechanisms in the transport protocols, with some level of enforcement, either in congested routers, in middleboxes, or by other mechanisms. [Add citations to some of the literature on this.] There seems to us to be considerable promise that incentives among the various players (ISPs, vendors, customers, standards bodies, political entities, etc.) will align somewhat, and that further progress will be made on the deployment of various enforcement mechanisms for flow-rate fairness in best-effort traffic. Of course, this is not likely to turn in to a fully-reliable and ubiquitous enforcement of flow-rate fairness, or of any related fairness goals, for best-effort traffic, so this is not likely to be satisfactory to purists in this area.

The precise definition of flow-based fairness: A second limitation of flow-based fairness is

that there is seemingly no consensus within the research, standards, or technical communities about the precise form of flow-based fairness that should be desired for best-effort traffic. This area is very much still in flux, as applications, transport protocols, and the Internet infrastructure evolve.

Some of the areas where there are range of opinions about the desired goals for rough flow-based fairness in best-effort traffic include the following:

* Granularity: What is the appropriate granularity, for rough flow-based fairness [RFC2914]? What controls should be embedded in end-to-end protocols about the number of connections opened by a single session?

* RTT-fairness: What is the desired relationship between flow bandwidth and round-trip times, for best-effort traffic? As shown in Section 3.3 of [FJ92], it would be straightforward to modify TCP's congestion control so that flows with similar packet drop rates but different round-trip times would receive roughly the same throughput. It remains an open question however (to this author, at any rate), what would be the desired relationship between throughput and round-trip times for best-effort traffic [HSMK98].

* Multiple congested routers: What is the desired relationship between flow bandwidth and the number of congested routers along the path, for best-effort traffic? It is well established that for TCP traffic in particular, flows that traverse multiple congested routers receive a higher packet drop rate, and therefore lower throughput, than flows with the same round-trip time that traverse only one congested router [F91]. There is also a long-standing debate between max-min fairness and proportional fairness, and no consensus within the research community on the desired fairness goals in this area.

* Bursty vs. smooth traffic: What is the desired relationship between flow bandwidth and the burstiness in the sending rate of the flow? Is it a goal for a bursty flow to receive the same average bandwidth as a flow with a smooth sending rate? The same maximum bandwidth? How does the goal depend on the time scale of the burstiness of the bursty flow [K96]? (E.g., a flow that is bursty on time scales of less than a round-trip time has different dynamics than a flow that is bursty on a time scale of seconds or minutes.) (Section 3.2 of [FJ92] shows that the use of Active Queue Management in routers can improve the bias against bursty traffic found in networks with Drop-Tail queues.)

* Packets or bytes: Should the rough fairness goals be in terms of packets per second, or in bytes per second?

* Unicast vs. multicast: What should the fairness goals be between unicast and multicast traffic?

There is a range of literature for each of these topics, and we have not attempted to cite it all above. Rough flow-based fairness for simple best-effort traffic could evolve with a range of possibilities for fairness in terms of round-trip times, the number of congested routers, packet size, or the number of receivers per flow. (Further discussion can be found in [METRICS].)

Fairness over time:

One issue raised in [B07] concerns how fairness should be integrated over time. For example, for simple best-effort traffic, should long flows receive less bandwidth in bits per second than short flows? For cost-based fairness or for QoS-based traffic, it seems perfectly viable for there to be some scenarios where the cost is a function of flow or session lifetime. It also seems viable for there to be some scenarios where the cost of QoS-enabled traffic is independent of flow or session lifetime (e.g., for a private Intranet that is measured only by the bandwidth of the access link, but where any traffic sent of that Intranet is guaranteed to receive a certain QoS).

However, for simple best-effort traffic, the current form of rough fairness that is not integrated over time seems perfectly acceptable. That is, in the current Internet, a user who opens a single TCP connection for ten hours *might* receive the same average throughput in bits per second, during that TCP connection, as a user who opens a single TCP connection for ten minutes and then goes off-line. Similarly, a user who is on-line for ten hours each day *might* receive the same throughput in bits per second, and pay roughly the same cost, as a user who is on-line for ten minutes each day. That seems perfectly acceptable to us. Other pricing mechanisms between users and ISPs seem acceptable also.

4. On the Difficulties of Incremental Deployment

One of the advantages of simple best-effort service is that it is here, today, in the current Internet, along with the rough flow-rate fairness that results from dominance of TCP's congestion control.

While additional classes of service would clearly be of use in the Internet, the deployment difficulties have been non-trivial [B03]. These difficulties in deploying interlocking changes to the infrastructure (as opposed to changes in applications) do not necessarily have an easy fix; they stem in part from the underlying architecture of the Internet, which has its advantages as well as its disadvantages. As explained in RFC 1958 on "Architectural Principles of the Internet": "Fortunately, nobody owns the Internet, there is no centralized control, and nobody can turn it off [RFC1958]."

The difficulties of deployment for end-to-end intserv or diffserv mechanisms are well-known, having in part to do with the difficulties of deployment for the economic infrastructure that would be needed [B03]. It seems likely that cost-based pricing based on re-ECN could also have a difficult deployment path, involving the deployment of ECN-marking at routers, policers at both ends of a connection, and a complex set of economic relationships [B07].

Papers on some of the difficulties of making changes in the Internet infrastructure, including the difficulties imposed by the political and economic context, include [CMB07]. The difficulty of making changes to the Internet infrastructure is in contrast to the comparative ease in making changes in Internet applications.

[Add citations about the deployment difficulties of QoS, IPv6, multicast, ECN, and other mechanisms that have chicken-and-egg deployment problems.]

5. Related Work

5.1. From the IETF

This section discusses IETF documents relating to best-effort service and flow-rate fairness.

RFC 896 on congestion control: Nagle's RFC 896 on "Congestion Control in IP/TCP", from 1984, raises the issue of congestion collapse, and says that "improved handling of congestion is now mandatory" [RFC896]. RFC 896 was written in the context of a heavily-loaded network, the only private TCP/IP long-haul network in existence at the time (that of Ford Motor Company, in 1984). In addition to introducing the Nagle algorithm for minimizing the transmission of small packets in TCP, RFC 896 considers the effectiveness of ICMP Source Quench for congestion control, and comments that future gateways should be capable of defending themselves against obnoxious or malicious hosts. However, RFC 896 does not raise the question of fairness between competing users or flows.

RFC 2914 on congestion control principles: RFC 2914, a Best Current Practice document from 2000 on "Congestion Control Principles", discusses the issues of preventing congestion collapse, maintaining some form of fairness for best-effort traffic, and optimizing a flow's performance in terms of throughput, delay, and loss for the flow in question. In the discussion of fairness, RFC 2914 outlines policy issues concerning the appropriate granularity of a "flow", and acknowledges that end nodes can easily open multiple concurrent flows to the same destination. RFC 2914 also discusses open issues concerning fairness between reliable unicast, unreliable unicast, reliable multicast and unreliable multicast transport protocols.

RFC 3714 on the amorphous problem of fairness: Section 3.3 of RFC 3714, an Informational document from the IAB (Internet Architecture Board) discussing congestion control for best-effort voice traffic, has a discussion of "the amorphous problem of fairness", discussing complicating issues of packet sizes, round-trip times, application-level functionality, and the like [RFC3714].

RFC 2616 on opening multiple connections: RFC 2616, the standards track document for HTTP/1.1, specifies that "clients that use persistent connections SHOULD limit the number of simultaneous connections that they maintain to a given server" [RFC2616] (Section 8.1.4.).

RFC 2309 on unresponsive flows: RFC 2309, an Informational document from the End-to-End Research Group on "Recommendations on Queue Management and Congestion Avoidance in the Internet" in 2000, contains the following recommendation: "It is urgent to begin or continue research, engineering, and measurement efforts contributing to the design of mechanisms to deal with flows that are unresponsive to congestion notification or are responsive but more aggressive than TCP." [RFC2309]

RFCs on QoS: There is a long history in the IETF of the development of QoS mechanisms for integrated and differentiated services [RFC2212, RFC2475].

5.2. From Elsewhere

This section briefly mentions some of the many papers in the literature on best-effort traffic or on fairness for competing flows or users. [B07] also has a section on some of the literature regarding fairness in the Internet.

Fairness with AIMD: Fairness with AIMD (Additive Increase Multiplicative Decrease) congestion control was studied by Chiu and Jain in 1987, where fairness is maximized when each user or flow gets equal allocations of the bottleneck bandwidth [CJ89]. Van Jacobson's 1988 paper on "Congestion Avoidance and Control" defined TCP's AIMD-based congestion control mechanisms.

Fair Queueing: The 1989 paper of Fair Queueing by Demers et al. promoted Fair Queueing scheduling at routers as providing fair allocation of bandwidth, lower delay for low-bandwidth traffic, and protection from ill-behaved sources [DKS89].

Congestion-based pricing: One of the early papers on congestion-based pricing in networks is the 1993 paper on "Pricing the Internet" by MacKie-Mason and Varian [MV93]. This paper proposed a "Smart Market" to price congestion in real time, with a per-packet-charge reflecting marginal congestion costs. Frank Kelly's web page at [Proportional] has citations to papers on proportional fairness, including [K97] on "Charging and Rate Control for Elastic Traffic".

Other papers on pricing in computer networks include [SCEH96], which is in part a critique of some of the pricing proposals in the literature at the time. [SCEH96] argues that usage charges must remain at significant levels even if congestion is extremely low.

6. Security Considerations

This document does not propose any new mechanisms for the Internet, and so does not require any security considerations.

7. IANA Considerations

There are no IANA considerations in this document.

8. Conclusions

9. Acknowledgements

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