

Elly Amani Gamukama

Department of Computer and System Sciences
Stockholm University/KTH, Forum 100, Isafjordsgatan 39, SE-16440, Kista, Sweden
Tel: +46-70-7568891, Fax: +46-8- 703 90 25
E-mail: gamukama@dsv.su.se

Topic: Formal models for Fairness and Congestion Control on the Internet

Research questions

The study strives to get solutions of the following questions:

- To establish if there exists a trade-off between efficiency and fairness in IP based networks
- Can such a trade-off be exploited to establish the appropriate network operational¹ levels that can foster /accelerate development of poor nations.
- Can such a trade-off be used to model Internet costing that address users levels of income in poor nations?

Rational for the work

The IP based network technology has proved its cost-effectiveness in delivering services to the end user that used to be delivered by discrete networks. The Internet which is purely the IP based technology is now world widely deployed and adopted as a solution to the services delivery mechanism for the society. In respect to developing regions and emerging economies, the Internet is seen as a catalyst for development [1-3]. Despite the wide adoption of the Internet technology, there are still notches to be fixed to ensure that the aggregate flows of traffic meets the quality and functionality requirements as used to be fulfilled by the discrete networks.

In this study we address the issues of fair network resource allocation in context of development. Though the topic of fair resource allocation has been widely studied, mainly the focus has been on the inter-protocol and intra-protocol fairness [4-6] under the framework of systems optimization [7, 8]. This approach has provided solutions that have extremely performed well in delivering services that basically use the responsive protocols, e.g. TCP.

However, the current Internet is driven by a congregate of ideas from the society. Thus, the society's dynamics have led to a congregation of heterogeneous applications on the Internet, of which some of their flows cannot adapt to the TCP-fair network resource allocation style. Even if the adaption was possible, for unresponsive flows that offered fair rate might not meet the minimum required quality of service (QoS) rate for such an application. Consequently, this has raised divergent views that contravene the TCP-fair network resource allocation compromise.

Furthermore, even to other applications that use responsive protocols (TCP) e.g. the P2P applications – Gnutella, BitTorrent, etc., their use at run-time have distorted the essence of fairness [9, 10]. According to the end-to-end philosophy, TCP fair sharing of network resources is between the flows not the users. With P2P, an application can open a hundred of multiple connections concurrently at their run time that can congest links with less capacity. We demonstrate this perception of TCP distortion at run-time with the following example. Assume a network with a bottleneck of capacity C is being used by N users. Each user has a one unit flow, then TCP would allocate the available capacity fairly and each flow would get a capacity of C/N . Assume that later, one of the users starts to run a P2P application that generates N flows in the network. Then the total flows in the network would be $2N$. TCP would evenly allocate the bottleneck capacity to each flow with $C/2N$ capacity. This implies that the one user with a P2P application that generated N flows gets a total of $N * C/2N = C/2$ capacity of the network which is as much as the capacity for the rest of the $N-1$ users. Therefore from a user perspective, this way of resource allocation is unfair.

Consequently, TCP fairness is distorted² at run-time though at protocol design-level it perfectly fulfills the ethical fairness notion. Therefore this calls for creation of a run-time policy framework within which users and operators can control relative resource shares.

In this study we take a societal perspective too, in addressing the issues of fair network resource allocation in context of development. We argue that the present level of Internet technology is sufficient enough to foster

¹ Operational level - in the sense that a user is guaranteed a rate within given bounds at which a service is delivered, that meets the requirements (capacity, delay, jitter, etc.) of the application in use.

² Note only that P2P applications distort the state of fairness through misuse of protocols like TCP, but they are also security threats in poor and slow Internet infrastructures. The million multiple concurrent connections can exhaust the routers' resources. In such a state a router can't accept any more connections, thus creating a new problem of DOS form of congestion.

development in poor nations. But to achieve this, we need to address the current distorted notion of fairness on the Internet today. Though there is a fundamental conflict between achieving flow fairness and maximizing overall network efficiency, the present state of poor infrastructure in developing regions calls for establishing levels at which these two conflicting criteria could be controlled. We propose that the best approach is to undertake a study on the trade-off between efficiency and fairness. Through this approach we foresee establishing recommendable levels that may lead to efficient and fair use of the limited network resources for connecting to the global Internet.

Research Methodology:

There are two methodological approaches that can be used in addressing the problem under the study. These are either the optimal flow control (OFC) or the game-theoretical approach.

Precisely this work is based on the theory of optimal flow control (OFC). The optimal flow control theory lies on the premise that for every network user/source there exists an associated utility function which may be used to measure the application's QoS performance over the available bandwidth. The OFC objective is basically to maximize the aggregate utility (QoS performance) for all users under the link capacity constraints across the network. Consequently OFC algorithm usually consist of two components of which one takes the control of measuring the congestion link price in the network while the other takes care of the source transmission rate to adapt to the response of congestion feedback signals.

Under OFC framework, this study uses two methodological tools; a) analytical tools – this involves mathematical modeling of the problem and b) simulation of the situation. In this case, simulation is done by using the network simulator NS-2.

Summary of the initial findings

- A proposed framework under which the study is conducted[11]; i.e.
 - o Classification of the key services that can foster development in the study areas
 - o Identification of appropriate network protocols in use to deliver such services
- Analytical model formulated for solving fairness-efficiency network optimization problem

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