

NETWORK NEUTRALITY SURVEY

Anuj Pathania

Master Student, School of Computing, National University of Singapore
Kent Ridge, Singapore
anuj.pathania@nus.edu.sg

Puneet Kalra

Master Student, School of Computing, National University of Singapore
Kent Ridge, Singapore
puneet.kalra@nus.edu.sg

Abstract

Network Neutrality is one of the most acrimoniously debated topics in Academia and Industry. Extensive literature has been written on it on both sides of the subject. In this survey paper we summarize the related prominent literature categorically and then evenhandedly analyze the arguments given in them. In the end we conclude that network neutrality is a manifestation of fear of monopoly on Internet which can be alleviated easily by providing a healthy competition rather than passing a stifling and stringent legislation.

Keywords: Network Neutrality; Internet; Computer Networks.

1. Introduction

Network Neutrality is a widely discussed subject in many different domains of academics. Literature has been written to explore its economic, political, psychological, sociological and technical aspects. In this survey we have tried to cover significant literature on subject taken from varied domains. Often, one paper discusses multiple facets of the subject, but we have tried to categorize the points made into clearly defined sections. Even though network neutrality is an emotionally charged up subject, authors of this paper have tried to be neutral in their reporting and analysis.

We begin by defining Network Neutrality in section 2. Then we report the important events which shaped the debate in section 3. Network Neutrality is all centered on subject of discrimination. Therefore we define what it means in the context, in section 4. We then continue in section 5 by reporting emerging trends, which are influencing the Network Neutrality debate, as the internet continues to evolve. Next in section 6 we discuss the hidden motivations which are said to be fueling the debate. In section 7, we report the possible impacts if discrimination is permitted. In section 8 we report the possible impacts if discrimination is not permitted by passing legislation. In section 9, we discuss the challenges to implement such legislation. In section 10, we discuss issues which were only remotely related to the subject but got negatively impacted by it. In section 11, we summarize some of the proposed solutions and finally in section 12, we give our analysis of the points we summarized in all previous sections and present our own solution to the problem.

2. Meaning of Network Neutrality

In this section we summarize our understanding of Network Neutrality which we developed from multiple sources in our literature survey.

Internet technically is a network which transfers bits in form of packets from one source to another. To reach from source to target, packets have to go through many intermediate nodes known as "Routers". Capacity of the routers is limited and packets are added to the queue while they wait for dispatch. [Zhu, (2007)] describes Network Neutrality debate as an issue whether routers can reduce the queuing delays of some packet by increasing delays of other packets.

We define Network Neutrality as a legislation which prevents network owners from discriminating among packets passing through their network based on their content, source or destination. Network Neutrality

legislation also protects the rights of the end users to freely use any legitimate application or device on the internet network they have paid for. Our definition closely resembles the one given in [Wu, (2003)].

3. Timeline

In this section we cover the important events which shaped the Network Neutrality debate from its origin to present time.

The debate started, in 2002, when FCC under high pressure from broad band services decided to move the broadband from "Common Carriage" classification to a less restricted "Information Service" classification, under the pretense of promoting broadband deployment. This means that earlier regulation, which forced the narrow band services (services that carry data to and from a consumer) had to do so on terms and rates which were non-discriminatory, was no longer applicable to broad band services [Russo, (2002)].

In the classical paper, [Wu, (2003)] coined the term "Network Neutrality", kick starting the debate.

In April 2005, broadband customers of Mexico's largest telephone operator Telmex reported that their VOIP call quality tanked and they were no longer able to access the site of VOIP providers such as Skype. It was alleged that Telmex identifies VoIP users based on the kind of traffic they send, and then chokes their bandwidth to disrupt the calls. Also by blocking the VOIP Provider site, Telmex could prevent potential new users from signing up, and existing users wouldn't be able to renew minutes on their prepaid calling cards or order other premium services. Michael Powell in White House announced that such blocking would be illegal if practiced in U.S. [Charny, (2005)]. Something similar happened in March 2005 (though on a very small scale) when a small ISP Madison River Communications blocked Vonage VOIP, but issue was quickly resolved with the intervention from FCC [McCullagh, (2005)].

The first real test of reclassification ruling in US came when in October 2007 it was alleged that Comcast among many other broadband providers is throttling Bit-Torrent Traffic [Soghoian, (2007)]. In November 2007, Pro-Network Neutrality Communities and Scholars urged FCC to start an investigation against Comcast [Reardon, (2007)]. FCC began an investigation against Comcast for the same in January 2008 [Broache, (2007)]. [Dischinger, Mislove et al., (2008)] confirmed that broadband providers such as Comcast/Cox were indeed blocking Bit-Torrent traffic. The Comcast defended its policy as "Reasonable Network Management". In August 2008, FCC ruled against Comcast and asked it to stop the practice and initially Comcast agreed [McCullagh, (2008)]. Later Comcast in September 2008 challenged the authority of FCC to regulate its behavior [Musil, (2008)] and court ruled in their favor in April 2010 [Musil, (2010)]

4. Discrimination

Issue of discrimination is at heart of the Network Neutrality debate and in this context it refers to the possible packet discrimination done by network providers based on packets source and content.

[Felten, (2006)] describes two kinds of discrimination. In Minimal Discrimination, low priority packet is discriminated if and only if resource it requires is being consumed by a high a priority packet. If not, the resource is completely allocated to the low priority packet. This can be technically required in a scenario in which real time traffic is given priority over delay insensitive traffic. On the other end is Non-Minimal Discrimination in which low priority packet is not given the entire available resource even if it is sitting idle.

[Felten, (2006)] also describes two types of discriminations possible functionally. Dropping Discrimination, happens when buffers get full, the low priority packets are dropped in preference to high priority ones. In non-minimal discrimination, a router can be designed in such a way that low priority packets are never allocated more than 20% of buffer, i.e. low priority packets are dropped even when buffer is 20% filled and the rest 80% is unutilized. Delay Discrimination happens when high priority packets in buffer are transmitted first and then low priority packets get transmitted. This is done by reordering the packets in buffer. As a result low priority

packets experience more delay than high priority ones. In non-minimal discrimination there is a delay introduced in transmission of low priority packets even when the link they required is available for transmission.

[Felten, (2006)] strongly states that minimal discrimination is acceptable, but non-minimal discrimination is down-right unethical.

[Wu, (2003)] says discrimination can sometimes be clearly justified even if it breaches network neutrality, like operator blocking network viruses. Even though it is a step away from neutrality of the network, it is clear that operator has taken this step to solve a problem of negative externality. At the other end, blocking a chat program or VOIP application is unjustified.

5. Internet Evolution

Internet has come a long way from being a research project in 1969 to a global commercial entity today. It has undergone extensive evolution and continues to do so. Emergence of new trends is intricately related to Network Neutrality debate and has been discussed in detail in several literatures we surveyed. We will summarize the same in this section.

Rise of Bandwidth Intensive Applications - [Labovitz, (2011)] reports that peer to peer application consumes 30 - 40 % of internet bandwidth, while in rest is mainly dominated by video streaming. In future, these applications share of bandwidth is only expected to increase as these application gain popularity.

Complex Interconnection - [Yoo, (2010)] makes a point that as the internet has evolved to a commercial entity, new kinds of inter connections have appeared which are different from the tripartite interconnection of the early evolution of internet. Private Peering, emerged when access point started to become too congested. Backbone networks decided to exchange packets at private internet connection points. Multihoming emerged when regional ISP started connecting to more than one backbone ISP to safeguard them against an outage and arm twisting by one backbone. Secondary Peering emerged when Regional ISP's started to peer among them. Secondary peering is generally on free settlement basis. The emergence of this kind of connection led to divergence from the principle of network neutrality not because of any malevolent intention but because of the commercial evolution of the heterogeneous nature of the internet network and networks' attempt to minimize cost. Now let say your ISP has a secondary peering with ISP of site A but not B then traffic from site B will have to pay transit as it came via backbone network. As a result packets which are functionally same will end up paying different amount for reaching you. Also due to secondary peering Site A will have better quality of service then B. In addition all contracts are settle on predetermined rate for fixed volume and additional charges for volume above that. Multihomed ISPs have incentives to use up their fix volume before paying per usage additional fees. This may lead ISP to route packets through longer path, deteriorating their quality. Same can be result for ISP effort to maintain its ratio in peering contracts. This means that quality of service a packet receives and cost of transporting it depends heavily on the business relationships and contracts between networks through which it travels. [Dhamdhere and Dovrolis, (2008)] developed an economic model which showed that secondary peering connections among ISP can considerably improve their profitability.

Multiple Point of Presence - Stated in [Yoo, (2010)], content providers instead of placing a single large server at one location, are placing there servers across the globe in a distributed manner, so that they can move their contents closer to their customers. This gives the content providers ability to bypass public backbone and use 2-tier ISPs peering arrangement instead. Difference in topology allows their contents to be delivered faster and at lower cost with enhanced quality of service over similar contents, even though networks were not giving any preferential treatment to them.

Content Delivery Networks - Also stated in [Yoo, (2010)], Content providers are also now opting to deliver their content through Content Delivery Networks (CDNs) such as Akamai and Limelight. They maintain a local cache of long distance networking capacity. To reduce cost and latency a local cache closest to the request geographic location is chosen. Distributed nature of the caches provides protection against Denial of Service attacks and also provides option of redirection in case of congestion. The issue is that they are non neutral.

They work best for static contents than interactive dynamic contents. Also CDNs are commercial service and is available to those only who are ready to pay. Increasingly, CDNs are being maintained on dedicated private networks by passing public backbone entirely. Hence the content that has CDNs will have better quality than one that does not, even though ISPs are treating the packets neutrally.

Vertical Integration Proximity Performance Gain - [Crowcroft, (2007)] remarks that service providers who vertically integrated applications generally have higher performance than the competitors and it may not be the case that it is because of unfair treatment to competitor's content. It is generally the case that these vertical integrated services are provided from the server racks which are very close to access point of a customer as the two often belong to same network. Proximity provides the performance gain to vertically integrated services without any willful breach of neutrality.

6. Motivation

In this literature survey, several issues are analyzed which explain the driving motivation of the various stake holders in the Network Neutrality debate. These are summarized below :

Eyeball ISP Envy - [Clark, (2007)] attributes the emerging trend of the movement of revenue into the domain of Internet from the existing domains (like telephony and music in the past and now video), as the motivation of access providers to violate Network Neutrality. They want to be compensated for carrying the contents which are raking in money, while access providers have to foot higher bill because of these applications being bandwidth intensive. Moreover the internet is dominated by flat monthly rate plans, rather than pay per use, which prevents the eyeball ISP's to get compensated from consumers. To overcome this, eyeball ISPs may try to break a deal with a content provider to give his content preferential treatment over the others. Consequentially it enhances the user experience for that content provider over others. This represents the interconnection discrimination facet of the network neutrality debate. This places internet provider in a powerful vantage point to haggle among the content ISPs and also allow them to indirectly affect the user content preferences. On account of this eyeball ISP want the so called virtue of Internet "Bits is Bits" and "All Bits are Equal" to be thrown to the wolves. They defend it by saying that it is necessary for justification of further investment in Internet .

Controlling Network Intelligence - [Felten,(2006)] states that Network Neutrality is a manifestation of fight between internet operators at the edges and the middle one to obtain a control over network. Classic "End to End Principle" of Internet [Saltzer, Reed et al., (1984)] puts most of the intelligence at the edges of Internet (End Node) and hardly any at the middle (Routers). The supporters of network neutrality are the companies that provide services at the edge of the network and are opposed by the companies that manage the middle of the network. Each wants intelligence to be in their part of the network because it brings the opportunity to innovate and therefore profits. [Hahn and Litan, (2006)] claim that "End to End" argument has outlived its usefulness and should be abolished because it hinders instead of fostering innovation in today's Internet.

7. Consequences of Discrimination

In this section we summarize the possible consequence of what can happen if the service providers are allowed to discriminate on their networks, in the surveyed literature,

Hamper Grass Root Innovations - [Lee and Wu (2009)] opine that the neutral and open structure of Internet promotes innovation from the bottom. It provides an unbiased environment in which grassroots entrepreneurs with their "Garage-Based Companies" can emerge and challenge existing established companies without any handicap. Discrimination can make some of these new applications unusable. Since many eyeball ISP are threatened by these startups, they can use discrimination as a tool to hold on to their customers.

Incentive for Scarcity - [Wu and Yoo, (2007)] have remarked that if you allow service providers to charge content providers for reaching customers, instead of charging only for the bandwidth they provide to the end user, you give service providers an incentive to maintain a level of scarcity as to maximize their revenue as the

gate keepers. Network provider innovations shall be to create and continue scarcity, instead of doing the right thing of other way around.

Network Fragmentation - [Lee and Wu, (2009)] claim that if the content that can be accessible on a network is determined by service providers then it is inevitable that certain content will be available on some service providers but not on others creating "Multiple Internets", which are just subset of whole internet. Even worse they would make user on different service providers incompatible to each other if their service providers are uncooperative. This would lead to severe Network fragmentation.

Uncooperative User Behavior - [Felten (2006)], warns that today's internet is dependent upon a tacit social agreement between users to cooperate with networks. For example in congestion control, when a host's packet is dropped, he responds by slowing down to reduce congestion. When many hosts do that simultaneously congestion is indeed brought under control. Now if network start discrimination against certain users and applications and start sending them wrong signals by unfairly dropping their packets, then host can become uncooperative and can refuse to slow down. If there are a considerable number of such renegades, there is a risk of entire internet network breaking down.

Encryption | VPN Countermeasure - [Felten, (2006)] also points out that if pushed by networks, user can use encryption to prevent ISP from doing so. They can even use VPN to hide the destination of the packets. ISP can perform network discrimination on packets only if they can read them. ISPs in return can respond by discriminating against all encrypted packets which may cause users to abandon encryption even when it is necessary, exposing confidential information to intruders. Even if these counter measures cannot completely shield the user from discrimination, they can force ISP to disclose their discriminating policies.

"Win-Win" Economics - [Yoo (2010)] talks out about impacts of "Two Sided Markets" involved in Network Neutrality Debate. Two Sided Market is a market in which there are two different classes of stakeholders. Value for user of one class is directly proportional to the number of users of different class in the market and inversely proportional to the number of users of the same class. There are two, "Two Sided Markets" involved in network neutrality debate. First is between the two different classes of last mile providers. One those who serve the end users, such as "Comcast" and "Verizon" and those such as "Cogent" and "Abovenet" who serve the content providers. The cost of later for building and maintaining network is much lower because it involves just few high speed lines to small number of locations. For the former, there is large number of distributed users connected using a highly segmented network. Second one is between the end users and content providers (along with their sponsors). Larger the number of end user more will be the value of advertisement supporting the contents for the sponsor. Economic theory suggest that social welfare will maximized if there is a price discrimination on both sides of the two-sided market. It means that it makes economical sense for one side to subsidize the other. In our domain it means that content ISPs should subsidize (pay) the user ISPs which help them improving their network, which will lead to a larger users base because of increased network penetration. This will indirectly enhance value for the customers (content providers) of content ISPs, in turn increasing their own services demand. It also means that advertisers should subsidize the end users, because lower cost of accessing content will make their sponsored content more popular among the end user and will in turn enhance their reach, allowing them to extract more value from their sponsorship. The cost of subsidizing more users would be more than offset by the additional revenue generated for the sponsors. The two subsidization are related, in fact they are part of a economically positive value enhancing cycle. Eyeballs ISP subsidize their user fees and pass it on to the Content ISP, Content ISP beside subsidizing the users through Eyeball ISP also subsidize their network maintenance and deployment cost, and pass it on to the Content Providers. Content Providers pass it on their sponsors. Sponsors finally pass it back to their user but of the grid. In this scenario everyone is better off. therefore imposing network neutrality regulation could ultimately harm the very consumer such regulation is apparently designed to protect.

8. Consequences of Non-Discrimination

In this section we summarize the possible consequence of what can happen if the service providers are not allowed to discriminate on their network by passing a legislation forcing Network Neutrality, in the surveyed literature.

Coming 'Exaflood' - [Singer (2007)] warns that Network Neutrality legislation if passed will make us incapable of preparing for the “ Coming ‘Exaflood’ ”. Coined by Bret Swanson in the Wall Street Journal, "Coming Exaflood" means the massive common use of bandwidth intensive application such as HD Video Sharing, Medical Imaging and Digital Surveillance. These applications can benefit greatly from preferential treatment. A heavy investment from the ISPs in the internet is needed to match requirement to prevent Internet traffic jams. A surcharge from content providers for these applications can help ISPs foot the bill. Network Neutrality legislation can kill the incentive to do so.

Inhibit Emergence of Real Time Application - [Hahn and Litan, (2006)] claims that real time application like computer gaming and VOIP are now very popular on internet. These applications are highly delay sensitive and cannot operate if their packets are not given preferential treatment over regular internet traffic. Content Providers in this case are willing to pay extra money for preferential treatment of their content, which they pass on to their user. Network Neutrality legislation prevents them from getting this priority service without which they cannot operate. Hence, Network Neutrality obstructs the emergence of new innovative real time application and their further development.

Prevent Content Specialized Networks - Yoo in [Wu and Yoo(2007)] argues that Network Neutrality thwarts any attempt by last mile network providers to specialize in certain kind of traffic or internet application. It forces the networks to compete solely on basis of price and size, which favors the largest player. By deviating from Network Neutrality, Network may develop specialized protocols which give them edge in one niche over other, which in turn may allow multiple last mile networks to co-exist like one optimize for web, other for real time services and yet another for encrypted traffic.

Peer-to-Peer Congestion -[Yoo (2010)] states that peer to peer traffic threatens to cause severe congestion on internet in near future. Internet was originally designed for client server architecture with proportionally high download speed in comparison to upload speed. Peer to peer application make use of both directional speeds in equal proportional which current networks cannot handle. As these peer to peer applications grow in popularity the service providers will have to treat their traffic differently to prevent severe network congestion. Network neutrality binds their hand in performing vital bandwidth management.

9. Implementing Network Neutrality

[Felten (2006)] points out that exposing discrimination is a far more difficult job than it is apparent. Some discrimination strategies are obvious and can be easily detected & punished. Sometimes though it is possible that provider did not take any overt measure that lead to discrimination but is happy that it exists and does nothing to alleviate the issue if there is a possible solution. Moreover it can be subtly managing its network in a way that indirectly fosters certain discrimination. It can be possible that discrimination is honestly due to issue beyond the control of provider or is only temporary or because of some genuine technical limitation. It is difficult to draw a line among the above scenarios by regulators and take appropriate actions. Thus Anti-Discrimination laws can be very tough to legislate and even tougher to enforce.

10. Collateral Damage

Tussle in Network Neutrality has negative impact on many things which are only remotely related to it the prominent example is “Quality of Service”. Despite intense research on QOS, it failed to emerge as explicit open end to end service. Conflict arose while deciding whether QOS should be implemented in a closed or open way. “Closed QOS” is a concept which is alleged to violate network neutrality. It provides an opportunity for enhanced revenue and vertical integration for ISP. They can simply turn on QOS for their services giving them

unfair advantages over competing services. On the other hand open QOS which does not affect the open nature of internet, demands a substantial investment from the ISP but does not provide any guarantee for return on investment. It is one of the possible explanations of failure of QOS deployment given in [Clark, Wroclawski et al. (2005)]. [Bachula (2006)], Vice President of an influential network consortium, Internet 2, gave a testimony in front of US State Congress stating that option of adding more bandwidth was more effective in serving future internet requirements than any form of QOS, which further reduces the chances of any widespread QOS implementation and adoption. [Schwartz, Shetty et al., (2008)] proposed a compromise between in form of “x-network” in which closed QOS is deployed on only x % of network capacity as a premium service for certain privileged users. Value of x is determined by external regulators independent of ISPs.

11. Solutions

In this section we present the various proposed solutions to the network neutrality debate, which we came across in our literature survey.

Perfect Stalemate - [Felten, (2006)] recommends that, by not taking a decision at present it may turn out to be a great decision in itself. ISPs are worried that any discrimination from their end would make regulation seem more necessary and hence are on their best behavior, avoiding any confrontation. Stringent regulation can have side-effects like reduction in investment into the network and its expansion. Blunt regulation on other hand would remove threat of a menacing retribution to the ISPs, making them risk misadventures. Instead, we should wait and see how this tussle plays itself out. Any regulation, if any required, should be thoroughly thought and must be flexible on both ends to adapt as the tug of war continues.

Case by Case Basis - Yoo in [Wu and Yoo, (2007)] suggested that instead of a broad restrictions on discrimination of the kind being proposed by network neutrality legislation, we should treat discriminations on case to case basis. Only the cases in which vertically integrated network owners block content and application directly competing with them shall require a regulatory intervention. Network should be allowed to experiment and innovate and discriminatory practices other than which are anti-competitive in nature should be permitted. New practices should be permitted to continue till those challenging them can show concrete harm to competition.

Pro-Competition Policies - [Atkinson and Weiser, (2006)] have pointed out that Network Neutrality is a hotly debated topic in USA because lack of competition and low levels of available bandwidth. In countries like Japan and France with ‘line sharing model’, issue of Network Neutrality is hardly discussed. They argue that Network Neutrality legislation is just a short term solution, and a more long term sustainable solution can be obtained by adopting a healthy competition promoting policies, alongside a heavy Government subsidized investment in Internet infrastructure.

12. Analysis

In this section we give our analysis and opinion on Network Neutrality and on the point made in literature we surveyed. We realize that debate on emotionally charged topic like Network Neutrality often ignores the ground realities. We believe that proposed Network Neutrality legislation is an over kill, but also acknowledge that in current structure of internet network, some ISP are in position to misuse their powers We believe that if there is enough free market, it will force healthy competition and then the negative externalities of breach of neutrality can be avoided, while benefits gained from it can be reaped concurrently.

Discrimination is often a term with negative connotation, but in order to address today’s internet challenges is absolutely essential. We agree with [Labovitz, (2011)] that use of bandwidth intensive application is on the rise and trend will only accelerate in future. We also agree with [Singer, (2007)] and believe that Internet is in a substantial risk of getting severely congested as per capita bandwidth consumption increases and more people come online due to internet penetration deeper in society. Beside considerable investment in network infrastructure, network providers will have to come up with innovations to effectively manage their network. A stringent network neutrality bill may restrict their ability to rise to the challenges.

Often the strongest point made in favor of preserving neutrality is that it will promote grass roots innovations [Lee and Wu, (2009)]. We argue that even if the network neutrality legislation is passed technical developments such as Content Delivery Networks and Multiple Point of Presence [Yoo (2010)] will still give an upper hand to the big players, only who can afford it. Even if the ISPs are forced to treat all packets equally, no level playing competitive playground is guaranteed to all players. It can be assumed that established content providers such as Google, Microsoft, Amazon know it and they are supporting network neutrality bill to avoid bearing any additional cost in form of payment to eyeballs ISPs. Luckily price barrier is not big enough to prevent the new entrants to enter and challenge the incumbents. The accelerating increase of innovations emerging on internet is a proof of it. Still, we realize that the ISPs are inherently in a powerful position and cannot be blindly trusted with it. A strong regulatory action should be taken against any such unethical misuse of this power.

Tim Wu, in [Wu and Yoo, (2007)] says that absence of Network Neutrality will promote network scarcity. We disagree, according to us freedom to innovate inside their network will promote investment from ISP into their networks, and condition being there is enough competitive pressure on them to force it.

We also don't agree with [Lee and Wu, (2009)] that without network neutrality there will be severe network fragmentation. In a competitive free market, any network which provides unrestricted access to all types of contents will be able to turn to convert customers from the networks which only gives fragmented access. The fear of losing customers alone will keep the fragmentation of internet in check. Also as said above, any illegal

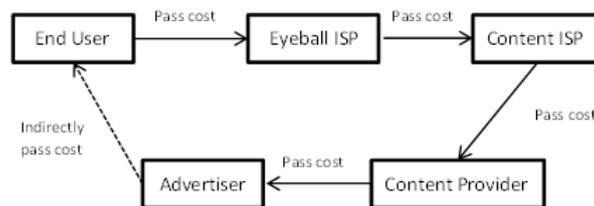


Fig. 1. Economic Cycle of Passing Network Expenditure

blocking should be awarded with harsh punishment by regulators.

We agree with [Felten (2006)] that it is possible that uncooperative user behavior and deployment of encryption & VPN countermeasure is a real possibility if user feel pushed to a limit. But, we don't believe it to be as severe threat as portrayed because of technical difficulty in doing so by majority of users. Fortunately, the users if harassed can get far more potent retribution easily, by simply changing their provider provided they have enough options. Again fear of losing customers can be a strong deterrent for ISPs to violate their trusts.

As stated before heavy investments are required in networks and we agree with [Yoo (2010)] that an economically beneficial self-reinforcing cycle can be generated by allowing sponsor of internet content providers to subsidize the internet end user. Economics does not have to be a zero sum game & with sustained cyclic Pareto improvements, Pareto optimal solution can be achieved in which participants are in better position

than from which they began as shown in figure 1.

We agree with [Hahn and Litan, (2006)] that a strict Network Neutrality bill will inhibit the emergence of new real time applications. Additionally effective QOS technology is a vital requirement for next wave of innovation on internet. But, we also agree that QOS being implemented in an open way so that its benefits are not limited only to the applications from big players which can afford it ; otherwise it will certainly retard any grass root innovations based on it. We also believe the QOS should be integrated into the very architecture of internet even it means violating scared "End to End" principle given in [Saltzer, Reed et al., (1984)]. Internet should be flexible enough to adapt to today's need . What worked in past may not work today and we should not be hesitant to challenge it. Also, government should step in and bear the cost of implementing QOS removing any dependency on the willingness of ISPs. Other alternative to get investment is to try "x-network" from [Schwartz, Shetty et al. (2008)] but we are skeptical that it may not work in practice. Biggest obstacle will be coming to the consensus on the value of x.

We also agree with [Felten, (2006)] that enforcing a Network Neutrality Bill by detecting its violation is a challenge in itself. Detecting unethical misuse of power from ISP can also be equally non trivial. For this we are

at present unable to give any technical solution For time being we should put trust in the law to deal with it on a case- to-case basis.

Finally we will like to propose a solution which merge harmoniously the solution from [Felten, (2006)], [Wu and Yoo, (2007)] and [Atkinson and Weiser, (2006)]. We begin by repeating that no stifling Network Neutrality bill should be passed and any misdeed of network providers if proven should be made an example of, to prevent any future repetition. Government agencies should continue to regulate and monitor the networks for breach in trust, but should also be flexible enough to address genuine concerns as they emerge. Investment from the government in expansion of network is a must. Also governments should put forward policies which promote competition in the network providers. Policy should be favorable to new entrants and government should subsidize the cost of capital. Ideally it should be as easy to innovate and compete in domain of internet network provider as it is in the domain of internet content provider. Revolutionary innovations should not be limited to only one end of the network.

For our solution to work there should be a healthy competition among network providers. There should be substantial number of players in the market, not just a few big names, like it is today. There is no bigger fear to corporates than to fear of alienating its customers and losing their business to a competitors.

In our opinion Network Neutrality legislation in its present form is equally harmful to innovation on internet both at end of network and content, as absolutely biased networks.

13. Future Work

Network Neutrality is far from a solved issue. In future we would like to cover more literature related to the subject to address more related questions. Given the broad scope of the problem solution is unlikely to come from a single domain of academia. But we would like to explore the problem deeply from engineering perspective.

In future we shall attempt to provide technical alternatives which will help regulators to distinguish between just and unjust discrimination.

We will also work upon giving technical solutions to the new emerging challenges of Internet using discrimination as an ally.

14. Acknowledgement

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