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A Non-Net Neutral Approach to Net Neutrality: Who Said Vine is More Important than Email? Us!

The Internet: Then and Now

The internet has transformed tremendously from its initial conception to the internet as we know it today. In 1991, Swiss computer programmer Tim Berners-Lee created the World Wide Web[1], consisting of a network of interconnected networks in which anyone with access could send and receive information at any time. Since then, the internet has been used for far more than accessing static web pages and sending files from one computer to the next. The internet as we know it today has a variety of uses. From connecting through social media, such as Facebook, Twitter, and Instagram, to teaching and researching, and even to online banking, the web seems to most a necessity for living in today's digital age[2]. In fact, it is estimated that almost one-third of the world uses the internet regularly[3], and it is only expected to grow exponentially.

With the ever-growing popularity of the internet, a problem that often arises is network congestion — the internet becoming "too crowded". Internet traffic, the flow of data, is a term commonly used to outline this issue. The global volume of internet traffic has increased by almost 60,000% since 2000[4], and it i is not just due to more users. People are also interacting more frequently with their technology. Virtual and augmented reality, smart TVs, and music streaming are merely a few examples of the many ways in which people currently rely on the internet to provide speedy service. The exponential growth of web traffic is also, in part, due to the fact that the services the internet provides are more complex. Today's net services are far more dynamic and sophisticated than those of the past and often contain videos or some form of user interaction. Increased use of smartphones and smart TVs, online gaming, virtual and augmented reality, and immersive video are a few examples of today's advanced technology that generate a spike in network traffic. To compare, the total *global* internet traffic in 1984 was 15 GB/month. Only twenty years later, the average internet traffic per *user* was 15 GB/month[4]. Too much web traffic leads to server crashes, slower connections, and possible packet loss.

The Services Provided by the Internet as They Relate to Classification

The internet as it was first designed and as it exists today is defined by five layers. Each layer is responsible for providing some discrete set of services, all of which are related to transmitting, not altering or creating, data. The physical layer, responsible simply for transporting bits between nodes via either a physical medium or radio waves, is the most direct example of this.

Next up from the physical layer is the link layer, responsible for error detection and correction, as well as reliability and coordinating access. Collision detection and avoidance is clearly concerned only with the transportation of data. From the link layer we move to the network layer, responsible for routing and forwarding packets, as well as managing network congestion. Forwarding and routing are done by determining what path packets should take based on their destination IP address, and have nothing to do with changing or creating payload data. Congestion control for TCP is performed by the host based on the reception of ACKs and again has nothing to do with payload data. The transport layer is responsible for multiplexing and demultiplexing packets, managing connections, providing limited error checking, and in the case of TCP, providing reliable transport. Multiplexing and demultiplexing is concerned only with the IP addresses and socket numbers of the destination and, in the case of TCP, source.

The final layer of the internet is the application layer, which runs only on hosts at the edge of the internet. While ISPs may provide their own application services such as email or web browsing, the application layer is not inherently the domain of the ISP. Additionally, with the rise of web browsers such as Firefox and Chrome, as well as an ever increasing number of email servers, ISP's information services are becoming less and less relevant[5]. Even DNS and caching, at one time a main service of ISPs, are being outsourced to third parties.

The fundamental basis of our proposal is that based on the services outlined above, the internet should be classified as a telecommunications service. The telecommunication classification allows the government to regulate, which minimizes the role of ISPs. Although the data transported by the internet is more complex than that transported by phone lines, their basic function is the same, and thus they should be classified and regulated in the same way. Any government regulatory approach to net neutrality hinges on the internet being a public utility rather than a private, corporation-controlled entity[6].

We are proposing a plan for intelligent queueing of packets that provides the necessary quality of service to different types of data, while still preserving the basic ideas of fairness engendered by net neutrality. Under our proposed protocol, ISPs could provide differentiated service to packets based on the quality of services needed to provide the full experience to users, which would be outlined by the FCC. For example, packet delay in real-time gaming has a major and disruptive effect, so real-time gaming packets would be prioritized over packets like email, which can suffer from several second-long delays with no detriment to the user.

Queuing

When packets of information are transported across the internet, they pass through routers. Ensuring that routers efficiently manage their web traffic helps users send and receive information faster. Queuing is used when there are too many packets at a single output port for all the packets to all be transmitted instantaneously. In other words, queuing is necessary when there is not enough bandwidth to accommodate the traffic[7]. The router needs to build a queue to maintain order. Queues only have a finite amount of memory. This means that when packets arrive at a full queue, they are dropped. In a totally net neutral approach, packets would be queued in the order that they arrive, not giving priority to any particular content[6].

Our Proposal

In our proposal, packets are intelligently queued at the output ports of routers based on the quality of service they require. This is achieved through an additional network-layer header-field for Quality of Service. Packets are broken down into four distinct tiers.

The top tier is solely reserved for urgent services, such as virtual medicine. This requires immediate response, as any delay would greatly affect its quality of service. Therefore, it is deemed as top priority. The second tier is for content that requires near-instantaneous response and is comprised of delay-sensitive network traffic. These services include real-time gaming, where online play requires a sense of urgency, live streaming of video, such as live sports, and video communication, like FaceTime. Delays for these services are non-negligible, as they significantly affect the quality of their service, yet they are not as high priority as virtual medicine. Tier three contains the majority of web activity with instant messaging services, online monetary transactions, streaming stored video, such as Netflix, and all general web browsing. These services sit below live streaming and communication because their quality is not contingent on instantaneous service. If a user is on a social media website, they do not need the page to update in real time. A short delay is tolerable and barely impacts user experience. For streaming stored video, the application on the user's end has a buffer. That way, if incoming packets get delayed, there is already some stored video that can play while new packets are still in the network. Finally, tier four encompasses all services that can withstand delays, without affecting their overall quality and function. It is comprised of electronic mail and file transfer. Additionally, any packet without a QoS header-field, or with a QoS header-field that the router cannot read, are allocated to the lowest priority. By applying different degrees of priority, we can better manage network traffic.

Tier 1 Virtual Medicine
Tier 2 Real-Time Gaming, Live Streaming of Video, Video Communication
Tier 3 Web Browsing, Online Monetary Transactions, Texting/Instant Messaging, Streaming Stored Video
Tier 4 Email, File Transfer, Traffic with no QoS Header-Field, Traffic with Encrypted QoS Header-Field

How It Works

As it stands now, routers have some number of output ports, each with their own queue. Under our protocol, each output port would either have four sub-queues or one sorted queue (see below). As packets arrive at the output port for their destination, they are stored in the sub-queue or section of the queue corresponding to their priority level. Within a priority-level queue, packets are ordered in a first-in first-out manner, such that the head of each queue is the packet that has been in the queue the longest.

In order to prevent packets from sitting in the queue forever while higher priority packets are transported, packets in each tier would have some defined maximum wait time (such that tier one packets have shorter max wait times than tier four packets). Before transporting the next packet, the router would check the head of each queue, and check if any of the head-packets have been in the queue for their maximum wait time. If any of them have been, the packet that has waited its maximum wait time is transported. Otherwise, the head-packet of the highest priority queue is transported.

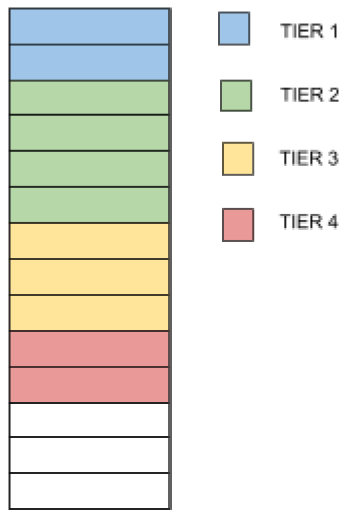
In the case that multiple head-packets have reached their maximum wait time, the router should enter a separate protocol, in which it sends only packets that have reached their maximum wait time. This is done in the following manner: if tier one has reached max wait time, send up to four packets. If tier two has reached maximum wait time, send up to three packets. If tier three has reached maximum wait time, send up to two packets. If tier four has reached maximum wait time, send one packet. This cycle then repeats until only one or no tiers have packets that have reached their maximum wait time. Then the normal protocol resumes. In cases of heavy congestion, our proposal is similar to first-in-first-out queueing, but still maintains some sense of priority.

Implementation: Queue Structure

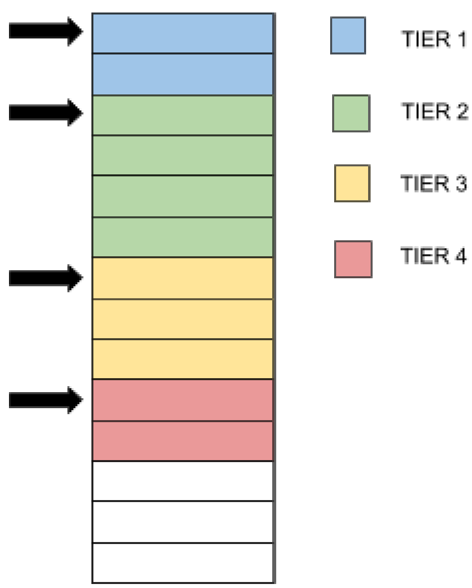
There are two efficient methods that would execute our proposal:

One Sorted Queue:

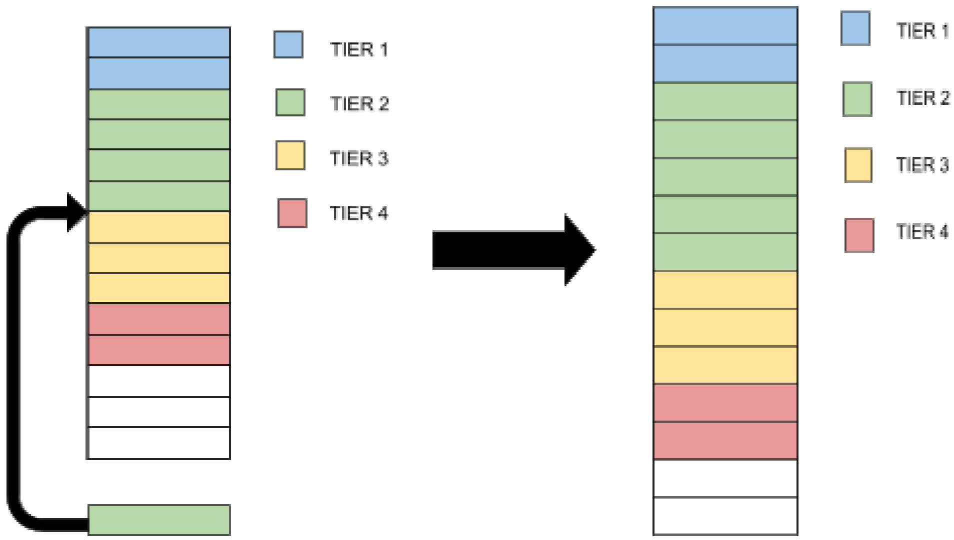
The first option is a single, sorted queue. (In actuality this would be an array, where each sorted section acts as a queue). White space indicates available memory for packets of any tier.



At the beginning of each transmission cycle, the router checks the first packet in each sorted section. This is a O(n) operation.



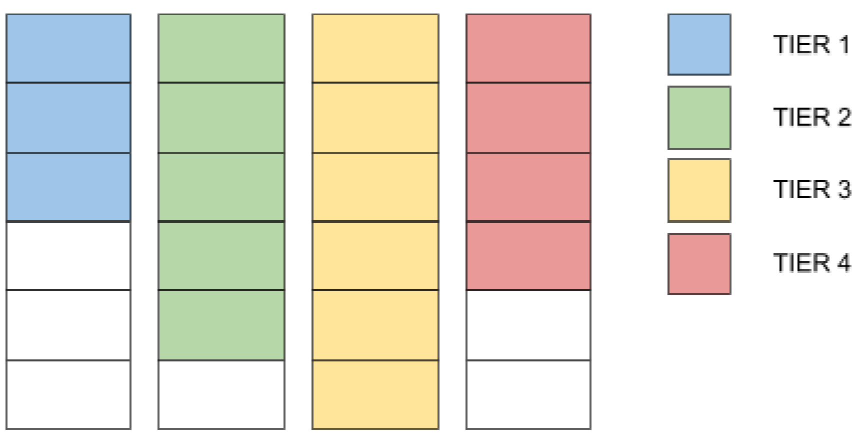
After checking each head-packet, the router would transmit based on the rules defined above. When a packet arrives at the output port, the queue is first checked to make sure it is not full. If there is empty memory in the buffer, the packet is inserted at the end of its priority section. This is a O(n) operation at the worst case.



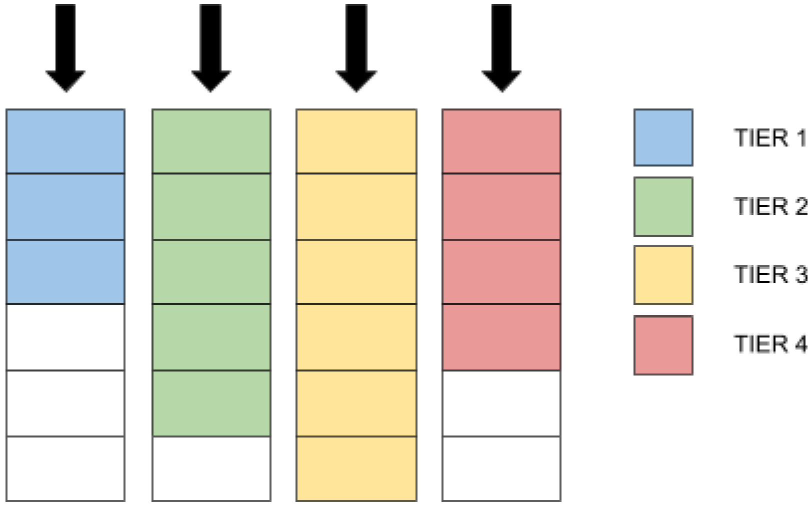
The advantage of this method is that all memory can be utilized, since unused memory is available to be allocated to any packet. The downside is that it is more computationally complex. If the time to perform the required searches and insertions is less than the average transmission time of the output port, the computation to find the next packet to transmit can be done while the previous packet is being transmitted. No additional delay is introduced by our protocol. However, if the searches and insertions take more time than transmission, the network will experience additional delay.

<u>Four Sub-Queues:</u>

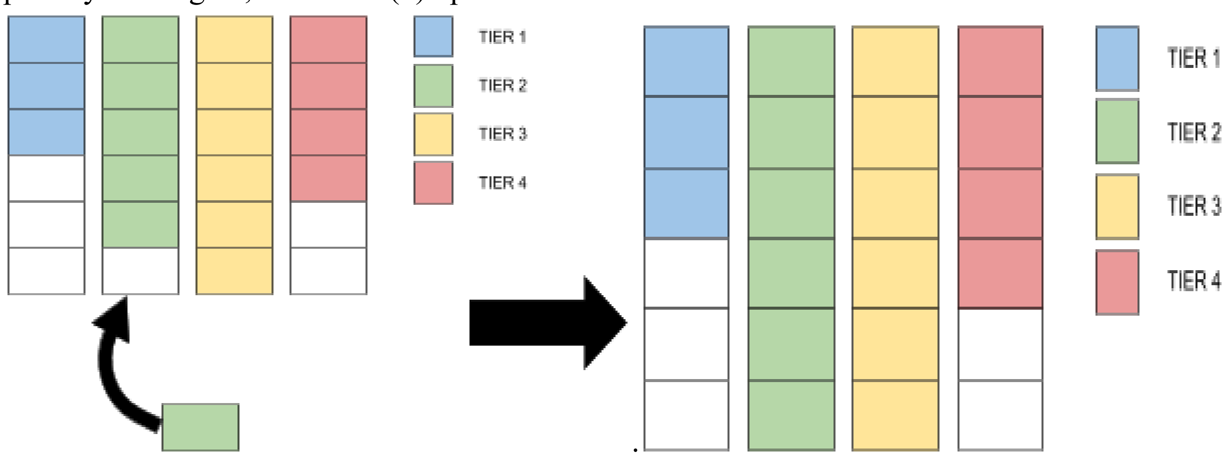
In this approach, each output port would have separate space in memory allocated for each of the four tiers of packets. When a new packet is forwarded to that output port, it is added to the appropriate sub-queue. The white spaces in sub-queues indicate unused memory available for packets of that particular sub-queue. A router that allocates totally equal amounts of memory for each queue would look as follows:



The major advantage to this approach is that you only need to check the four head-packets before deciding which packet to transmit, which is a O(1) operation. The process of selecting the next packet is computationally simpler than the other approach.

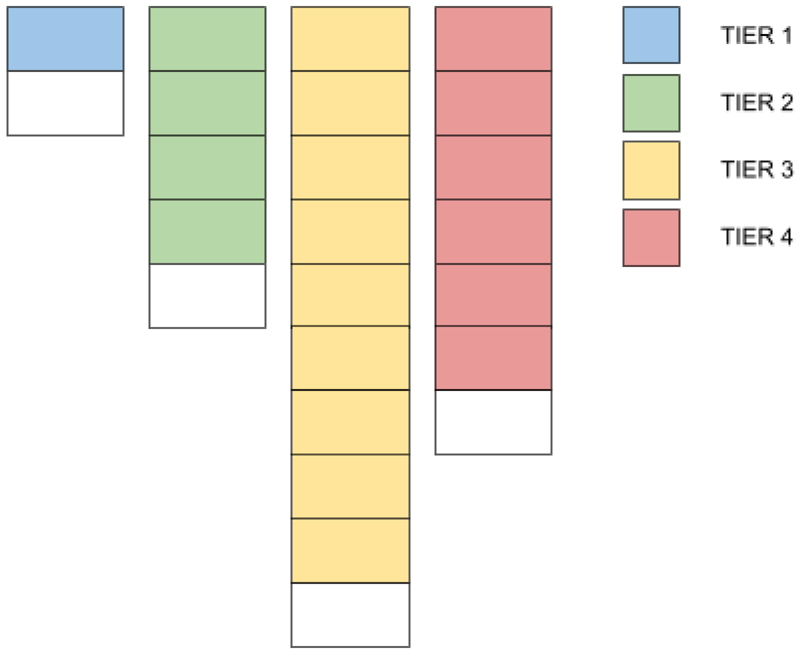


When a packet arrives at the output port, it is inserted at the end of the queue corresponding to its priority tier. Again, this is a O(1) operation.



One of the major drawbacks to this approach is that not all space in memory is being utilized. In the above example, if a tier three packet is forwarded to this output port, it would be dropped, even though there is unused space in memory. A technique to minimize this problem would be intelligently allocating space based on router-use. Network administrators would be responsible for allocating the amount of memory in each sub-queue.

For example, a router at Smith might look as follows:



By giving the tiers different amounts of memory, the router can accommodate more packets. Network administrators would be tasked with observing their own network traffic and making decisions about how to efficiently allocate based on the types of traffic that they expect. The goal is always to be using as much memory as possible and ensure that as few packets as possible get dropped.

Difference from Differentiated Pricing

At its surface level, our plan for differentiated quality of service to different types of packets may seem no different from the practice of zero-rating and differential pricing. In zero-rating, ISPs enter into agreements with information providers, such as Spotify or Netflix[8]. Under these agreements, which usually require the information providers to pay the ISPs extra money, internet users can access the applications in an unlimited manner. For example, if Verizon zero-rates Spotify, Verizon members can stream music from Spotify without paying for the bandwidth, but if they want to stream from Apple Music, they must pay for it[8]. This violates net neutrality by treating packets differently in a manner that harms the customer and potentially restricts their access to legal services. Additionally, this practice restricts innovation by making it more difficult for new services to enter the market. It also decentivises existing services to innovate; they can count on people using their applications, instead of competitors, as customers do not have to pay for the bandwidth.

The key difference between traditional forms of differentiated service and our proposal here, is that our proposal is not based on a capitalist market. Under our plan, no individual information providers would be forced to pay extra money in order to prioritize their packets. Rather, the FCC, likely with help from a group of network engineers, would delineate a hierarchy of priority, based on the general type of data. This would leave doors open to innovation, as new application providers would be on the same footing in terms of quality of service as their direct competitors.

Endnotes

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