A Primer on Network Management
Summary

- Background information on the Internet
- Explain what network management is
- Quality of Service (QoS) and the Internet
- Wireless – The new frontier of the Internet
- Implications of regulatory proposals on the management and operation of networks
Why the engineering matters

- The debate over net neutrality has evolved in at least three main stages.
  - Issues of blocking or degrading (e.g., Madison River)
  - Should the Internet permit multiple tiers of priority and pricing?
  - What kind of network management, if any, should be permitted on the Internet?

- Effective Internet and telecom policy relies on a solid technical understanding of how the Internet works.
What is the Internet?

- The Internet is a network of networks
  - A federation of independent networks
  - Transmits data in little pieces called packets

- The Internet is also a packet delivery service
  - Network operators ship packets; FEDEX, UPS, and DHL ship packages
  - Network operators are similar to shipping companies; but the difference is that network operators hand off packets
Circuit switching vs. packet switching

<table>
<thead>
<tr>
<th>Circuit switching network</th>
<th>Packet switching network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed bandwidth allocation</td>
<td>Variable/Dynamic bandwidth allocation</td>
</tr>
<tr>
<td>Inefficient bandwidth allocation</td>
<td>Efficient bandwidth allocation</td>
</tr>
<tr>
<td>Inherently predictable bandwidth and latency</td>
<td>Inherently unpredictable bandwidth and latency</td>
</tr>
<tr>
<td>Limited functionality</td>
<td>Extremely flexible with wide range of functionality</td>
</tr>
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</table>

PSTN = Public Switched Telephone Network
Internet communication standards

- The communication standard of the Internet is Transmission Control Protocol/Internet Protocol (TCP/IP)

- TCP handles data transmissions
  - Connection establishment and error correction
  - Transmission rates and congestion control

- IP handles the addressing and routing of packets
Three distribution models of the Internet

- Client-Server
- Peer-to-Peer (P2P)
- Content Delivery Network (CDN)
Client-Server

• **Pros**
  
  • Quick and easy to set up
  
  • Good for few users or low bandwidth applications

• **Cons**

  • Limited bandwidth
  
  • Limited content delivery scalability
  
  • Higher latency to distant locations
Peer-to-peer (P2P)

- **Pros**
  - Unlimited file distribution scalability
  - Shifts most costs to end-users
  - P4P (improved P2P) helps decrease strain on core of Internet

- **Cons**
  - End-user pays distribution costs
  - 2x more bandwidth load on broadband
  - Low resolution video-on-demand due to out-of-order deliver
Content Delivery Network (CDN)

**Pros**
- Unlimited file distribution scalability
- Least bandwidth load on the core or edge of Internet
- High quality video-on-demand
- Doesn’t offload costs to end-users

**Cons**
- Content provider must pay to use the service
The history of network management

Birth of the Modern Internet

1983 1986 1987
The goal of network management

1. Fair and equitable bandwidth allocation
   - Customers who pay for the same service should have the same bandwidth for the same duration of time

2. Improve multi-tasking capability of network
   - Better simultaneous application usage
   - Minimize jitter at any bottleneck on the network
Shared bandwidth is good for consumers

- Why are networks even shared to begin with?
- Networks will always be shared somewhere
- Shared networks are faster and cheaper
  - Dedicated 1.5 Mbps T1 circuit is at least $180 per Mbps
  - Shared 6 Mbps broadband is $7 per Mbps
P2P bypasses Jacobson’s algorithm

Exploiting TCP congestion control

Fair

A gets same bandwidth as B

Unfair

A gets 4 times more bandwidth than B

Really unfair

A gets 11 times more bandwidth than B
Protocol agnostic solutions restore fairness

Unmanaged & unfair

Per-flow fairness

A gets 11 times more bandwidth than B

Managed & fair

Per-user fairness

A gets same bandwidth as B

User A 1-flow
User B 1-flow
User A 1-flow
User B 1-flow
The goal of network management

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QoS and the Internet

- Quality of Service (QoS) fixes the inherently unstable bandwidth and packet delay of packet switching

- There are many Internet standards for QoS
  - Type of Service (ToS) standard in 1981
  - Integrated Services (IntServ) in 1994
  - Differentiated Services (DiffServ) in 1998

- QoS is a **very** broad term
  - Used in telephony, other data networks, and Internet Protocol (IP) networks

- Alternate names
  - “Enhanced QoS” or “Prioritization” or “Premium service”
Why do we need QoS?

- Internet Protocol (IP) networks are inherently bad at application multitasking.
- Multiple computers, Internet enabled TVs or set top boxes with P2P capability will soon become common.
  - “Honey, can you shut the TV download so I can make a phone call” will become more common at home.
- Voice over IP (VoIP) and online gaming are extremely “allergic” to P2P without QoS.
Three basic services of the Internet

Low Packet Delay
- latency & jitter

High Bandwidth
- File transfer rate

High Volume
- Bandwidth * Duration = Volume

Real-time
- VoIP
- Video conferencing
- Online gaming
- IPTV

Internet streaming
- YouTube
- DailyMotion, Vimeo
- iTunes or Xbox Live
- Netflix or Hulu

Interactive
- Web browser
- Email

Background
- Peer-to-peer (P2P)
- File Transfer Protocol (FTP)
The logical order of packet priority

Packet Priority

Highest

Outcome

Lowest average bandwidth

Highest average bandwidth

Application Criteria

Lowest bandwidth

Highest bandwidth

Lowest duration

Highest duration

Highest sensitivity to packet delay

Least sensitivity to packet delay

George Ou
December 11, 2008
Dumb networks multitask poorly

Dumb network

equal priority (P2P multi-flow advantage)

P2P bandwidth

Web bandwidth

Bandwidth

Time

George Ou
December 11, 2008
Smart networks multitask better

Smart network
90% bandwidth prioritization for web

P2P bandwidth
Web bandwidth

Time
Bandwidth

George Ou
December 11, 2008
The goal of network management

1. Fair and equitable bandwidth allocation
   - Customers who pay for the same service should have the same bandwidth for the same duration of time

2. Improve multi-tasking capability of network
   - Better simultaneous application usage
   - Minimize jitter at any bottleneck on the network
High jitter at low traffic levels

High jitter inducing application

Jitter magnitude of 280 ms

10 packets clumped together

Link utilization

100%

10%

average measured link utilization

Time
Spaced out packets don’t produce jitter

Low jitter inducing application

Jitter magnitude of 28 ms

single packet

average measured link utilization
P2P doesn’t mix well with VoIP

High jitter much more destructive to VoIP

283 ms jitter from P2P upstream

13 VoIP packets lost due to excessive jitter. 26% packet loss very severe.

Link utilization

40% 100%

Time

average measured link utilization
P2P usage causes massive jitter

1000+ ms jitter above baseline from P2P usage

Measured by George Ou on DSL broadband in May 2008
Even mild P2P usage causes jitter

60 ms jitter from just 10 KB/sec P2P usage

4 ms jitter from 11 KB/sec VoIP usage

Measured by George Ou on DSL broadband in May 2008
Mitigating jitter with QoS

QoS can completely mitigate jitter damage

Nudge large packets to create gaps between packets

0 VoIP packets lost with minimal delay on a few packets

Link utilization

100%

40%

Time

average measured link utilization
Mitigating jitter with QoS

Dumb network
First In First Out (FIFO)

Network with QoS
Multiple Queues or “onramps”

Small VoIP packet (80 - 220BYTES)
Large P2P packet (1472BYTES)
QoS needed on both ends to fight jitter

Home modem must manage upstream jitter

ISP has to eliminate downstream jitter

Will always remain a relative bottleneck
Wireless – The new frontier of the Internet
Network management is critical for wireless

- Average of $650,000 per 3G cell tower
- One radio shared between 100 to 1000 people

<table>
<thead>
<tr>
<th>Year</th>
<th>Technology</th>
<th>Bandwidth (mbps)</th>
<th>Latency (ms round trip)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Up</td>
<td>Down</td>
</tr>
<tr>
<td>2007</td>
<td>3GPP R5 – HSDPA</td>
<td>0.375</td>
<td>14.4</td>
</tr>
<tr>
<td>2007</td>
<td>EVDO Rev A (5 MHz)</td>
<td>7.2</td>
<td>12.4</td>
</tr>
<tr>
<td>2008</td>
<td>WiMAX (10 MHz)</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>2009</td>
<td>3GPP R7 – HSPA+</td>
<td>22</td>
<td>42</td>
</tr>
<tr>
<td>2010</td>
<td>LTE (20 MHz 2xMIMO)</td>
<td>50</td>
<td>150+</td>
</tr>
</tbody>
</table>
Managed versus unmanaged wireless

- **Wi-Fi 802.11b unscheduled access**
  - 20 MHz of spectrum per radio
  - 70 simultaneous VoIP calls in theory; 4 simultaneous VoIP in practice
  - 5th phone on network causes all 5 VoIP phones to suffer breakup
  - Unscheduled packets colliding randomly are the culprit

- **LTE scheduled access**
  - 200 active users per radio using 5 MHz of spectrum
  - 200 times more users per MHz
  - 200 times better spectral efficiency than dumb Wi-Fi
Common misconceptions about QoS

- “QoS violates the end-to-end architecture of the Internet”
  - QoS is an Internet standard
  - End-to-end never mandated a dumb Internet

- “Capacity is a cheaper substitute for QoS”
  - Capacity is never cheap enough
  - Jitter can occur on “fat pipes” with very little traffic
Common misconceptions about QoS

- "QoS doesn’t work on the Internet"
  - Based on misconception that QoS must work on every leg of Internet (across multiple network providers) to be useful
  - Reality is that QoS is useful especially for broadband

- "Internet2 concluded that QoS isn’t necessary"
  - Based on a paper by Shalunov and Teitelbaum
    - Admitted QoS was even necessary on high capacity Internet2
    - Wrongly concluded that capacity is cheaper than QoS
    - Admitted QoS works well when targeted at congested links
Common misconceptions about QoS

“Capacity is cheaper than QoS”

• Japan’s 100 Mbps fiber broadband network is often congested
• 10% users using P2P accounted for 65% to 90% of all traffic
• ISPs implemented 30 GB daily upstream caps
• Implemented 3 warnings for piracy before account termination
Regulatory Implications of Net Neutrality

- Bill that attempted to ban prioritization
  - S.2360 - Internet Non-Discrimination Act of 2006 – Wyden (D-Oregon)

- What this bill mandates
  - Prohibit broadband providers from prioritizing bandwidth and allocating bandwidth

- Implications
  - Reduces the quality and utility of broadband
  - May force more use of private circuits for IPTV resulting in less bandwidth for the Internet
Regulatory Implications of Net Neutrality

- **Bills that ban multi-tiered Quality of Service (QoS)**
  - S. 215 - Internet Freedom and preservation act of 2007
    Snowe (R-ME) and Dorgan (D-ND)
  - H.R. 5417 - Internet Freedom and Nondiscrimination Act of 2006
    Sensenbrenner (R-WI) and Conyers (D-MI). (Reintroduced in 2008)

- **What these bills mandate**
  - Would prohibit broadband providers from charging for “enhanced QoS”
  - Permits traffic type prioritization but not based on traffic source

- **Implications**
  - Effectively mandates equal service for unequal payment
  - May force more use of private circuits resulting in less bandwidth for Internet
Why exclusive QoS is necessary

Exclusive QoS

- 0-64%
- 36-100%

Ban exclusive QoS

- 64%
- 36%

DSL/IPTV head-end unit
Fiber to the Node (FTTN)
DSLAM

VDSL2 modem & router

Internet data
0-25 Mbps

Priority IPTV data
(0-16 Mbps)
Policy implications

- ISPs and application providers need to be more transparent
  - Some ISPs are advertising “unlimited” service it isn’t unlimited
  - Some ISPs aren’t disclosing usage caps
  - Some ISPs aren’t explaining minimal bandwidth clear enough
  - Consumers don’t always understand that costs from some applications are offloaded to them

- Government oversight
  - FCC should ensure broadband providers don’t abuse power
  - Industry-wide standard on transparency and disclosure to create a level playing field
Conclusion

- The Internet is so valuable because it is open to anyone, any use, and any business model
  - But participation always required varying levels of payment for varying levels of service between willing parties
- We always need more capacity (and policies to spur more capacity), but more capacity isn’t a substitute for network management
- Network management results in higher performance for everyone at lower prices
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