INASP: Effective Network Management Workshops

Unit 6: Solving Network Problems

About these workshops

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Objectives

On completion of this session, we hope you will know about:

- Importance of troubleshooting in network management
- Troubleshooting vs. monitoring
- Good troubleshooting technique
- Troubleshooting a rogue DHCP server
- Troubleshooting a slow Internet connection

What is troubleshooting?

- Identify the problem
- By manual, logical deduction
- To help us fix it

Troubleshooting is not monitoring

Once the network is working well, we set up monitoring to:

- warn us if it stops working well
- help us troubleshoot more quickly

The next unit is about monitoring.

For example, if you can't access your mail server, what would you do?

- You troubleshoot, and discover that the mail server has crashed.
- You set up monitoring (Nagios) to alert you if the mail server crashes again, before your users complain, so that you can fix it faster.
- You set up monitoring to find out why the mail server is crashing, for example you enable crash dumps and CPU and memory use logging.

Troubleshooting is not management

Emergency quick fixes (fire-fighting) will not keep the network running well! But it's a necessary part:

- unexpected things will happen
- need to understand to fix them quickly
- and to prevent them happening again
- or detect and resolve more quickly next time

Proper troubleshooting technique

- Prepare for problems (see Unit 4/Disaster Response)
- Responding to a problem
- Identify possible causes
- Eliminate causes

Responding to a problem

You might want to print this out and display on your wall!

- Don't panic
- Find a quick test
- Understand the problem
- Is it plugged in?
- What was the last thing changed?
- What is "known good"?
- Make a backup
- Change one variable at a time
- Do no harm

In more detail:

Don't panic

inform your users of the problem, and set about solving it in a methodical and guided manner.

Find a quick test

Doing something complicated to identify the problem involves more steps, more complexity and makes the whole troubleshooting process more difficult/slower. Find something like the "refresh" button in your browser, or a command-line command such as ping, that tells you whether the thing is working or not, right now.

Understand the problem

If you are troubleshooting a system, that means that it was working at one time, and probably very recently. Before jumping in and making changes, survey the scene and assess exactly what is broken. Historical logs and statistics may help to identify it. Be sure to collect information first, so you can make an informed decision before making changes.

Draw a diagram, or picture in your head, all the steps that are required to make the thing work. One of those steps must be failing. Make a list of them. Quickly check each one:

Is it plugged in?

This step is often overlooked until many other avenues are explored. Plugs can be accidentally (or intentionally) unplugged very easily. Is the lead connected to a good power source? Is the other end connected to your device? Is the power light on? It may sound silly, but you will feel even sillier if you spend a lot of time checking out an antenna feed line only to realise that the AP was unplugged the entire time. Trust me, it happens more often than most of us would care to admit.

Is it apparently OK?

Many things have a quick visual status check:

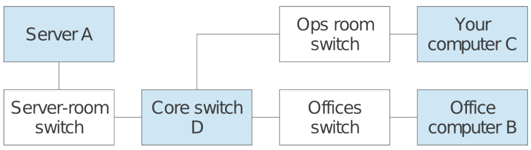
- switches and computers have link lights for network ports;
- a desktop computer should display a graphical screen and respond to mouse movements;
- a server should display a console and respond to keyboard or mouse movements;
- you should be able to open a website such as Google, or an internal server;
- you should be able to ping a server, desktop or managed switch.

What was the last thing changed?

If you are the only person with access to the system, what is the last change you made? If others have access to it, what is the last change they made and when? When was the last time the system worked? Often, system changes have unintended consequences that may not be immediately noticed. Roll back that change and see what effect it has on the problem.

Eliminate possibilities

Try to attack the problem in different ways. If a server appears to be down, try checking from a different point on the network, or “closer” to the server, or “closer” to where the problem is noticeable from.



Imagine a network problem with server A is visible from a user’s computer (point B) and from your computer (point C), which diverge at the core switch (point D). So the paths are A-D-B and A-D-C. It’s unlikely that both D-B and D-C have failed at the same time, so you can “eliminate” them for now, and test the shared path A-D instead.

On the other hand, if the problem is visible from the user’s computer (B) but not from your computer (C), then you know that you’ve tested A-D and D-C by testing from your computer. So the problem must be between D and B.

What is "known good"?

This idea applies to hardware, as well as software. A known good is any component that you can replace in a complex system to verify that its counterpart is in good, working condition.

For example, you may carry a tested Ethernet cable in a tool kit. If you suspect problems with a cable in the field, you can easily swap out the suspect cable with the known good and see if things improve. This is much faster and less error-prone than re-crimping a cable, and immediately tells you if the change fixes the problem.

Likewise, you may also pack a backup battery, antenna cable, or a CDROM with a known good configuration for the system. When fixing complicated problems, saving your work at a given point lets you return to it as a known good, even if the problem is not yet completely solved.

Look at your list of steps again. Which ones can you quickly replace to see what effect that has on the problem?

Change one variable at a time

When under pressure to get a failed system back online, it is tempting to jump ahead and change many likely variables at once. If you do, and your changes seem to fix the problem, then you will not understand exactly what led to the problem in the first place.

Worse, your changes may fix the original problem, but lead to more unintended consequences that break other parts of the system.

By changing your variables one at a time, you can precisely understand what went wrong in the first place, and be able to see the direct effects of the changes you make.

Ideally, when you find the change that seems to fix the problem, revert it and check that the problem reappears. Then you can have much more confidence that you've found the real cause.

Configuration Management (covered in Unit 3) can help you to remember exactly what you changed, and revert any changes that you didn't intend to make or that didn't appear to solve the problem.

Do no harm

If you don't fully understand how a system works, don't be afraid to call in an expert. If you are not sure if a particular change will damage another part of the system, then either find someone with more experience or devise a way to test your change without doing damage. Putting a penny in place of a fuse may solve the immediate problem, but it may also burn down the building.

Example: Internet access not working

How would you troubleshoot it?

Some hints:

- Check other websites and applications
- Ping some servers
- Check your DNS
- Traceroute to find the break

It happens all the time. Suddenly, the network isn't working at all. What do you do? Here are some basic checks that will quickly point to the cause of the problem.

First make sure the problem is not just with the one web server you want to contact. Can you open other websites such as www.google.com? If you can open popular web sites but not the one you requested, the problem is likely with the site itself, or with the network between you and the other end.

If your web browser cannot load pages from the Internet, next try to browse to a server on the local network (if any). If local sites are shown quickly, then that may indicate a problem with the Internet connection or the proxy server. If not, then you most likely have a problem with the local network.

If you suspect a problem with the proxy server, try accessing information with a different program, such as an email client. If you can send and receive email, but web browsing still doesn't work, then this may further indicate problems with the proxy server.

Your web browser and mail client can only provide so much information. If nothing seems to be working at all, it's time to switch to a more useful diagnostic tool such as ping.

Try pinging a server on the Internet with a well-known IP address such as `4.2.2.2` or `8.8.8.8`:

```
$ ping 4.2.2.2
PING 4.2.2.2 (4.2.2.2) 56(84) bytes of data.
64 bytes from 4.2.2.2: icmp_seq=1 ttl=247 time=85.6 ms
64 bytes from 4.2.2.2: icmp_seq=2 ttl=247 time=86.3 ms
64 bytes from 4.2.2.2: icmp_seq=3 ttl=247 time=84.9 ms
64 bytes from 4.2.2.2: icmp_seq=4 ttl=247 time=84.8 ms
```

```
--- 4.2.2.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3012ms
rtt min/avg/max/mdev = 84.876/85.436/86.330/0.665 ms
```

If you can ping an IP address then your basic connectivity is working, so the problem may be another setting. If not, the problem may be at your ISP, or your connectivity to them. `traceroute` may help you to identify where the problem is.

Try pinging a well-known web server that responds to pings, such as `www.google.com`:

```
$ ping www.google.com
PING www.l.google.com (66.102.9.99) 56(84) bytes of data.
64 bytes from 66.102.9.99: icmp_seq=1 ttl=243 time=30.8 ms
64 bytes from 66.102.9.99: icmp_seq=2 ttl=243 time=31.6 ms
64 bytes from 66.102.9.99: icmp_seq=3 ttl=243 time=30.9 ms
--- www.l.google.com ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2016ms
rtt min/avg/max/mdev = 30.865/31.176/31.693/0.395 ms
```

If this works as well, it indicates that your network connection is working just fine, and the problem is very likely with your proxy (or your web browser's proxy settings).

If you can ping an IP address but not a domain name, then the network is fine but your computer is unable to convert the domain name (www.google.com) into an IP address (66.102.9.99). Check to make sure that your DNS server is running and is reachable.

If you can't ping an Internet IP address, then it's a good idea to make sure that your local network connection is still working. Does your computer have a valid IP address? Use ifconfig on UNIX or ipconfig on Windows to make sure your IP settings are correct.

If you don't have an IP address then you are definitely not connected to the Internet. Check the cables from your computer (or the wireless settings if using wireless). Also check that your DHCP server is up and running, if you use DHCP. If you have an IP address but it is incorrect, then there are only two possibilities. Either your machine is using the wrong settings, or there is a rogue DHCP server on the local network. Either change your local settings or track down the bad DHCP server.

If you do have a valid IP address, try pinging the gateway's IP address:

```
$ ping 192.168.0.1
PING 192.168.0.1 (192.168.0.1) 56(84) bytes of data.
64 bytes from 192.168.0.1: icmp_seq=1 ttl=64 time=0.489 ms
64 bytes from 192.168.0.1: icmp_seq=2 ttl=64 time=0.496 ms
64 bytes from 192.168.0.1: icmp_seq=3 ttl=64 time=0.406 ms
64 bytes from 192.168.0.1: icmp_seq=4 ttl=64 time=0.449 ms
--- 192.168.0.1 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 2999ms
rtt min/avg/max/mdev = 0.406/0.460/0.496/0.035 ms
```

If you can't ping your gateway then the problem is definitely in your local network — maybe the switch or router needs to be restarted. Check all the cables (both network cables and power cables).

If you can ping your gateway, then you should next check the Internet connection. Maybe there is a problem upstream. One good test is to log into your gateway router and try to ping the gateway at your ISP:

- If you cannot ping your ISP's gateway, then the problem is with your Internet connection.

- If you can ping your ISP's gateway but no other Internet hosts, then the problem may exist beyond your ISP. It's probably a good idea to phone your ISP and check if they have a problem, or can help you with troubleshooting.

Is everything still not working? Then it's time to roll up your sleeves and get to work. You should reread the Responding to a problem section and settle down for some slow and methodical work, checking each part of your network bit by bit.

Example: Rogue DHCP server

One of the most common network problems: an unexpected DHCP server causes havoc by assigning users the wrong IP addresses.

A misconfigured DHCP server, either by accident or intentionally malicious, can wreak havoc on a local area network. When a host sends a DHCP request on the local network, it accepts whichever response it receives the fastest. If the rogue DHCP server hands an incorrect address faster than your own DHCP server, it can potentially blackhole some of your clients.

Most of the time, a rogue DHCP server is either a misconfigured server or wireless router. Rogue DHCP servers are difficult to track down, but here are some symptoms to look for:

- Clients with improper IP addresses, netmasks, or gateways, even though your DHCP server is configured correctly.
- Some clients can communicate on the network, others cannot. Different IP addresses are being assigned to hosts on the same network.
- Rebooting a client makes it randomly start working or stop working.
- While sniffing network traffic, you see a DHCP response from a server IP or MAC address that you do not recognise.

Once you have determined the rogue DHCP server's MAC address from a packet trace, you can then make use of various layer 2 tracing techniques to determine the location of the rogue DHCP server, and isolate it.

It's almost impossible to completely prevent rogue DHCP servers from appearing on your network. But there are some steps you can take:

- Educate your users on the dangers of misconfiguring or enabling DHCP services on your local LAN.
- Windows and UNIX systems engineers and users setting up access points on your local LAN should be careful not to place such a service on the local LAN.
- Some switching hardware platforms have layer 2 filtering capabilities to block DHCP responses from network interfaces that should never be connected to a DHCP server. On Cisco switching platforms, you may want to use the "dhcp snooping" feature set to specify trusted interfaces which are allowed to transmit DHCP responses (the ones connected to your DHCP servers). Apply these to server access ports and all uplink ports on your switch fabric.
- Use a network monitor such as Nagios to detect unexpected DHCP server replies on your network and raise the alarm.

Example: Slow Internet connection

What do you need to check?

- DNS speed
- proxy server
- ping times/latency
- available bandwidth
- free bandwidth

How slow is it?

What are response times (latency) for loading external sites?

Measure the speed loading a specific web page, for example http://www.google.com, using the `ab` utility:

```
ab -n 100 http://www.google.com/
This is ApacheBench, Version 2.3 <$Revision: 655654 $>
...
Requests per second:    18.16 [#/sec] (mean)
Time per request:       55.081 [ms] (mean)
Transfer rate:          17.52 [Kbytes/sec] received
```

You need something to compare it to, for example:

- How fast is it when the connection is not busy?
- How fast is it using another ISP?
- Is it less than one second?

Standard are arbitrary, but Jakob Nielsen argues that:

- > 0.1 second delay loses the *instant* feeling.
- > 1.0 second interrupts the user's flow of thought.
- > 10 seconds and you lose the user's attention.

So if web pages load in 0.1 seconds that's really good; less than 1 second is OK, and over 1 second is bad (annoying).

You can automate this test using Nagios and receive an alert by email whenever the speed of web page loading becomes too slow.

What influences page loading speed?

DNS resolution, the available bandwidth *and* the latency are lower bounds:

- if a DNS lookup takes 1 second, the page cannot load in less than 1 second.
- a link with 1 Mbps free cannot load a 1 MB page in less than 8 seconds.
- a link with 3 second latency cannot load any page in less than 9 seconds.

Keep **link latency** and **free bandwidth** under control to ensure that web pages load fast.

DNS responses are cached, but it's worth monitoring how fast they are too, otherwise you can have random long delays which are hard to diagnose.

If you have a **proxy server**, it should be monitored too.

Check the DNS server

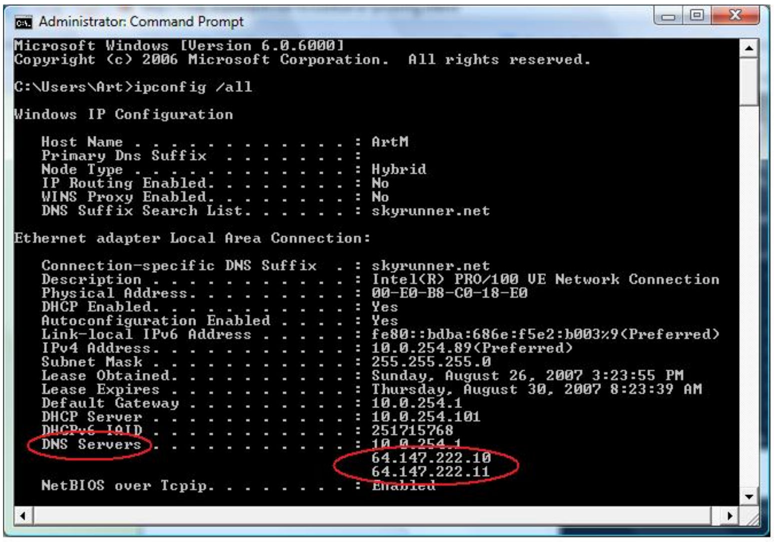
You can check your DNS speed quickly using the UNIX `host` command-line tool, for example:

```
$ host www.google.com
www.google.com has address 173.194.41.180
```

The reply may take a second if you haven't looked up the site before. After that it should be immediate, because the DNS server should cache it. Try different sites, particularly ones that you haven't visited recently. Try inventing random nonexistent hostnames to test this:

```
$ host ldigvtliyh.google.com
Host ldigvtliyh.google.com not found: 3(NXDOMAIN)
```

If not, which DNS server are you using? The command `ipconfig /all` should tell you:



If you're not using a local, cacheing DNS server, you should be.

Don't use your ISP's DNS servers directly on your computers if you can help it. It's much better to use local cacheing DNS servers. These should be the only computers configured to use your ISP's servers as an upstream.

However you can use the UNIX `host` command to test a specific server, to see if it gives a faster response. For example, if one of your ISP's DNS servers is 192.168.14.40, you can test it like this:

```
$ host www.google.com 192.168.14.40
;; connection timed out; no servers could be reached
```

That means that your ISP's server has crashed. This will cause random slow page loading while your local caches wait for a reply from this server.

You can check all your local DNS servers (the ones listed by `ipconfig`) to make sure that they all reply, and quickly. If any fails to reply, that will cause random, slow page loading. It may mean that:

- your DNS server has crashed; or
- it has the wrong network configuration; or
- it is using the wrong upstream servers; or
- one of the upstream servers has crashed; or
- your Internet connection is down or overloaded.

You can configure a network monitor such as Nagios to warn you if a DNS server stops responding, or takes too long.

Check the proxy server

You can use the UNIX command-line tool `ab` (ApacheBench) to check a proxy server:

```
$ ab -P fen-vz-proxy.aptivate.org:3128 http://www.google.com/
This is ApacheBench, Version 2.3 <$Revision: 655654 $>
...
Complete requests:      1
...
Requests per second:    20.04 [#/sec] (mean)
```

```
Time per request:       49.895 [ms] (mean)
Time per request:       49.895 [ms] (mean, across all concurrent requests)
Transfer rate:          19.34 [Kbytes/sec] received
```

Or you can configure your browser to use the proxy server, and see if you can access web pages.

If that doesn't work (`ab` complete requests is not 1, or the page doesn't load) then try disabling the proxy in your browser, or running `ab` without the `-P` option. This will only work if your firewall allows you to bypass the proxy server, which is not recommended for network security. You may want to temporarily allow direct access, and disable it after testing.

You can configure a network monitor such as Nagios to warn you if the proxy server stops working.

Check ping times (latency)

Ping a server on the Internet, for example `www.bbc.co.uk` or `www.google.com`:

```
$ ping www.bbc.co.uk -n
PING www.bbc.net.uk (212.58.244.69) 56(84) bytes of data.
64 bytes from 212.58.244.69: icmp_req=1 ttl=56 time=19.6 ms
64 bytes from 212.58.244.69: icmp_req=2 ttl=56 time=19.4 ms
64 bytes from 212.58.244.69: icmp_req=3 ttl=56 time=19.2 ms
64 bytes from 212.58.244.69: icmp_req=4 ttl=56 time=19.4 ms
```

As a rule of thumb, time to load a small web page is about 3 round trips. So based on Jakob Nielsen's results above, the ping time should be:

- < 30 ms is really fast (feels instantaneous)
- < 300 ms is noticeable but usable (for web access, not for Skype)
- < 3000 ms to avoid losing the user's attention (unbearably slow)

From a broadband connection in the UK, ping time to `www.bbc.co.uk` would normally be under 30 ms.

You can configure Nagios to warn you if the ping time goes over this threshold.

Interactive applications

- Latency sensitive
- Usually less bandwidth intensive
- May require bandwidth reservation

Interactive applications include:

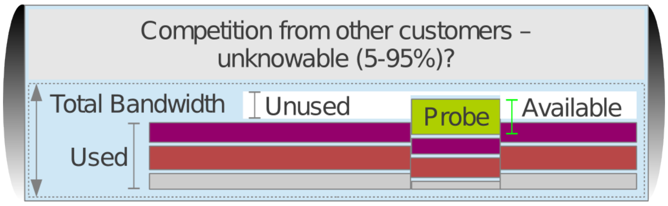
- Real-time Voice over IP (VoIP) and videoconferencing applications, such as Skype;
- Online whiteboards and collaborative tools (Kanban, Trello, games);
- Remote desktop applications (Citrix, Microsoft Terminal Services).

These applications are able to operate with relatively little bandwidth, but are much more sensitive to latency, jitter (sudden changes in latency) and packet loss, all caused by congestion.

You may need to *reserve bandwidth* for these applications to enable them to run effectively.

Available and Total Bandwidth

What do you know? What can you measure?



Total bandwidth

The absolute maximum capacity that your link can deliver (in each direction) right now.

Used bandwidth

The amount of bandwidth (capacity) being used by packets travelling over the link right now.

Unused bandwidth

The total bandwidth minus the amount currently being used.

Available bandwidth

The unused bandwidth, plus how much a new entrant can jostle from other, current users.

The TCP protocol contains a backoff mechanism, which causes it to reduce its bandwidth use when it detects packet loss.

Packet loss is caused by congestion, and randomly affects all flows, so TCP streams tend to share all bandwidth quite fairly between them.

When a new stream (such as a download test) enters the race, it jostles with existing streams, pushing them all to reduce their bandwidth use to some extent. So the **available bandwidth** is more than the **unused bandwidth**.

If you have a guaranteed, uncontended link then you know the total bandwidth. Otherwise, you can only approximately measure it by filling the link, which reduces unused bandwidth to zero.

Notice from the diagram above how inserting the Probe (speed test) into the network reduces the bandwidth of all other flows, and increases the Used bandwidth to nearly 100%.

Available bandwidth testing

There are various sites which offer speed tests:

- http://www.speakeasy.net/speedtest/
- http://www.megapath.com/speedtestplus/
- http://www.speedtest.net/

Or just download a large file.

A speed test will tell you how much *available* bandwidth there is:

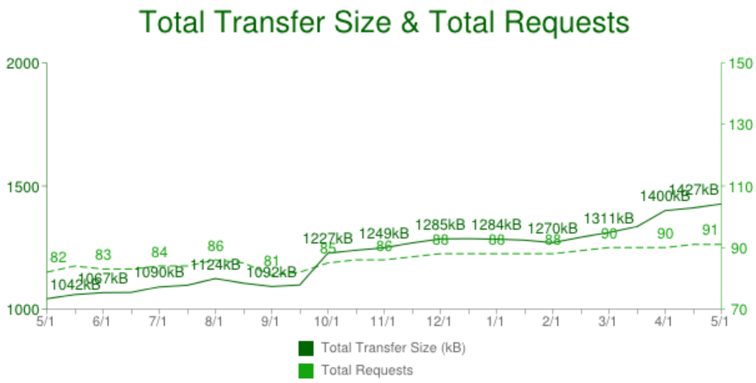
- how much is currently unused, plus
- how much you can jostle for with other users.

This influences page loading speed (along with latency):

- For smaller pages, and large pages with many resources, loading speed is dominated by latency.
- For pages with a few large resource (such as images/flash) and downloads, loading speed is dominated by available bandwidth.

How much free bandwidth do I need?

Average web page was 1.4 MB in April 2013 (~11 Mbit).



HTTP Archive page size trends, May 2012-2013

- To load in 0.1 second, you need 110 Mbps (instantaneous - unrealistic?)
- To load in 1 second, you need 11 Mbps (~UK average broadband, fast)
- To load in 10 seconds, you need 1 Mbps (acceptable)

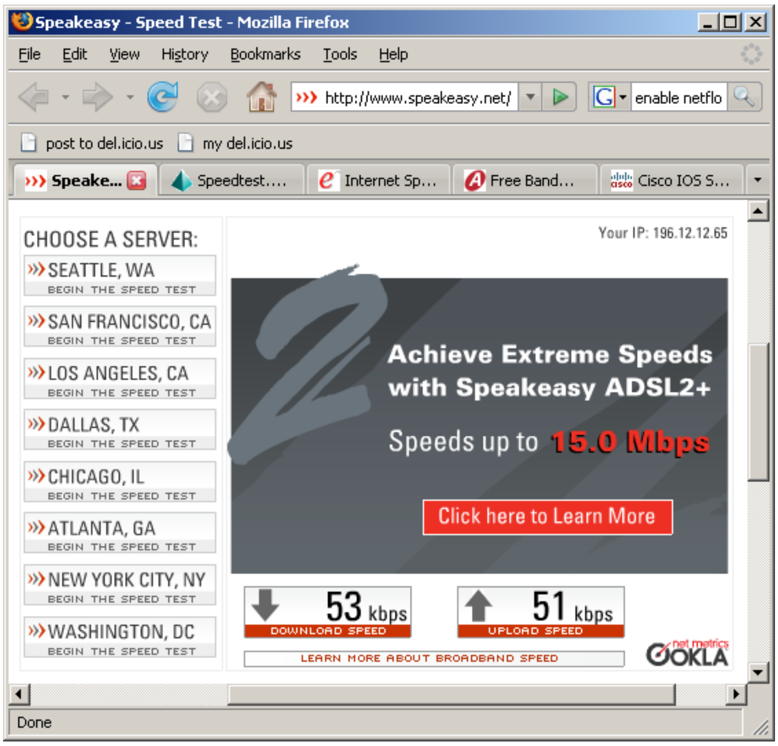
Less than 1 Mbps available: really bad!

You can measure *available bandwidth* on your network with a speed tester (see Available bandwidth testing).

Note that *streaming video* is very sensitive to available bandwidth. Normally it's encoded at a specific bit rate (e.g. 1 Mbps) and unless your connection can support that bitrate, you will have to download most of the video before it will play, or it will pause continuously to buffer more data.

Available bandwidth and contention

Example speed test on an African network with 512 kbps bandwidth and a 10:1 contention ratio.



Why would your available bandwidth be less than the total:

- Of course, other users sharing your connection may be using it right now;
- And your total bandwidth may be less than expected, because of contention.

Most Internet providers oversell their bandwidth (sell the same bandwidth multiple times). This is called *contention*. It means that you don't get guaranteed or reserved bandwidth, but you have to compete for it with other users (customers of the ISP):

- When nobody else is using it, you get the full rated capacity of your connection.
- When everyone is using their connection heavily, you get the contention ratio, 10% of your full rated capacity in this case (10:1 ratio).

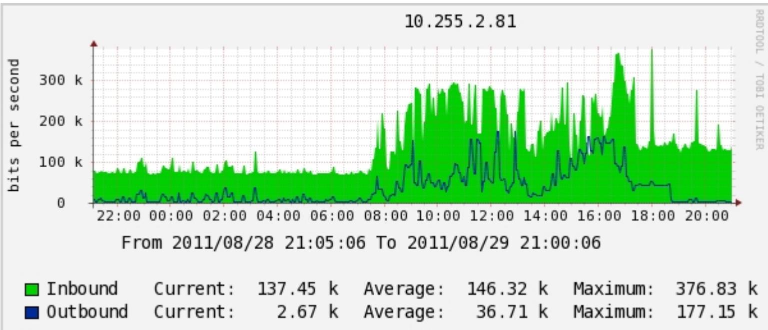
It's difficult to measure your total bandwidth unless:

- You have no contention (guaranteed/reserved bandwidth): then it *should* be the same as your guaranteed bandwidth; or
- You can *fill* it completely and measure average bandwidth used on the router; or
- You can *empty* it completely and then run a speed test (with no competition, total = available bandwidth).

If you report a low speed test to your ISP, they will usually tell you to repeat the test with no other computers connected, to measure the total bandwidth, not the available bandwidth.

Emptying the connection requires you to disrupt it, or switch all users to a backup connection. Measuring the average bandwidth used on the router is less disruptive.

Your Internet provider may be able to provide you with graphs from their side, for example using Cacti:



On a Cisco router you can get the used bandwidth average over the last five minutes with the `show interface` command:

```
r1>show interface GigabitEthernet0/0
GigabitEthernet0/0 is up, line protocol is up
Hardware is BCM1250 Internal MAC, address is 0011.2233.4455 (bia 0011.2233.4455)
Description: link 1
...
Input queue: 0/75/3208/72484 (size/max/drops/flushes); Total output drops: 1373910311
Queueing strategy: Class-based queueing
Output queue: 0/1000/12 (size/max total/drops)
5 minute input rate 79658000 bits/sec, 19312 packets/sec
5 minute output rate 140174000 bits/sec, 21984 packets/sec
```

The output rate on this interface (which might be download or upload, depending on whether it's the inside or outside interface) seems to be 140,174,000 bps (140 Mbps) averaged over 5 minutes. You can change the averaging interval with the `load-interval 30` command, for example to 30 seconds or 10, which is less accurate but more responsive.

You can also set up Cacti yourself, if your router supports SNMP. This is covered in Unit 7, Network Monitoring.

The symptoms of contention are just a reduction in available bandwidth.

Contended bandwidth

Ask yourself:

- When are we likely to use our connection heavily?
- When are other ISP customers likely to use their connections heavily?
- Do we really get what we paid for, or only 10% of it?
- Who benefits from the "fast" connection at off-peak times?

Most Internet providers sell *contended bandwidth*. That means that they buy some bandwidth and sell it several times over.

Why? They guess that each customer won't use 100% of their bandwidth all the time. How much of your bandwidth do you use? For how much of the day?

Contended bandwidth works well for individual users. For example, Zen Internet, an Internet provider in the UK, offers a "Pro" package with 200 GB per month, intended for a single heavy user. This is on an ADSL line with a theoretical maximum speed of 16Mbps, i.e. 2 MB per second or 5,000 GB per month. They expect a "professional" user to use about 4% of their connection (12% if confined to office hours).

Contended bandwidth is not good for multiple users. They compete against each other for the line capacity, *and* against all the other users that their ISP sold the same bandwidth to.

With a contended service, you cannot measure how much bandwidth you actually have available at any time. Nor do you have any control over the other users (customers) of the ISP. So you can't allocate bandwidth fairly between users to guarantee quality of service (QoS) to them.

Contended services cannot be high-quality guaranteed services, ever.

As the speed test result under Available bandwidth and contention shows, when all 10 contending customers use the service at 100% of capacity, they each get about 10% of the bandwidth they expect.

What is congestion

Congestion = full connection + long queue = unmanaged contention.

Imagine a shop that serves one customer per minute:

- If customers arrive at 0.99 per minute:
    - no queue, and each customer gets immediate attention.
- If customers arrive at 1.01 per minute:

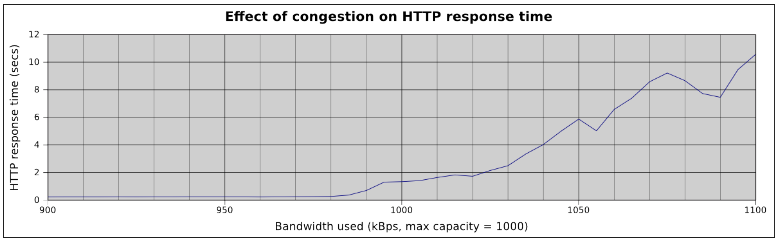
- a queue builds up, customers wait longer and longer, some get bored and leave.

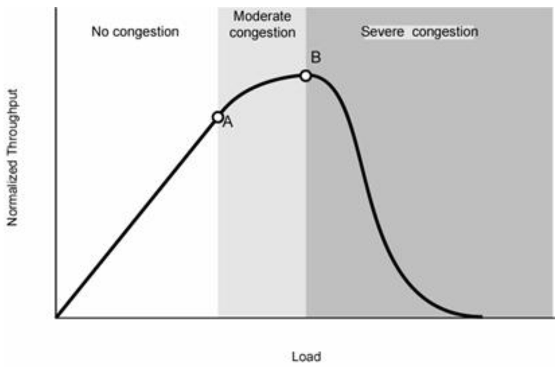
In the second case, the shop makes 2% more money, but the customers experience is completely different!

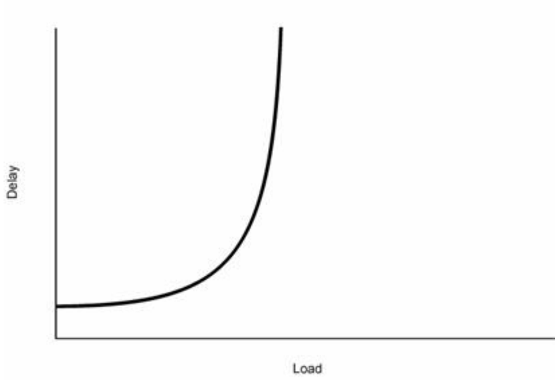
Congestion is related to, but worse than contention. Internet providers carefully manage queue length and fairness policies on their routers to avoid causing congestion when you use the maximum capacity available to you.

Effect of congestion

What happens when a link becomes full?







Tests with a simulated (throttled) link with 1 Mbps bandwidth and 100 ms latency:

- Web page loads very fast (~0.25 seconds) until connection is 98% full.
- At 100% full it takes 1 second
- At 105% full (5% packet loss) it takes 6 seconds

Congestion is closely related to contention:

- full connection + short queue = contention (what your ISP does)
- full connection + long queue = congestion

Your ISP is unlikely to be congested (that would be a sign of bad network management) but it could happen. They should shorten the queue length on their routers.

The symptoms of congestion are:

- a reduction in available bandwidth
- packet loss (should not happen normally)
- an increase in latency (caused by excessive queueing).

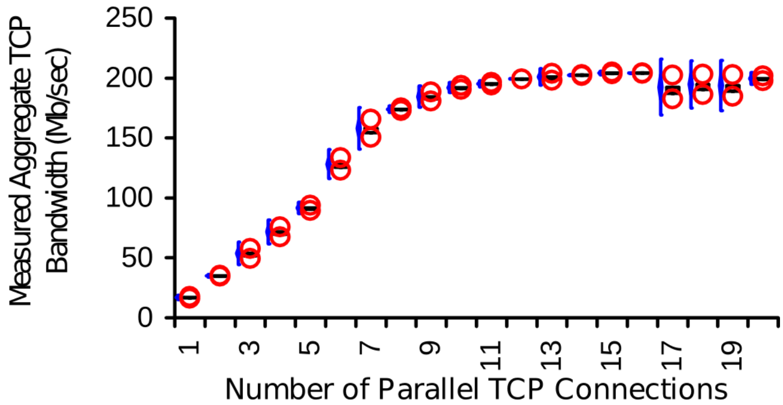
Packet loss and duplicate packets can also be caused by faulty network equipment, or radio interference on a wireless link, so they are not enough to identify congestion by themselves unless you can rule these causes out.

Theoretical predictions show that:

- Actual throughput falls off rapidly as the network becomes congested (packet loss increases)
- Latency/delay climbs exponentially when the load is slightly higher than capacity.

(Credit: Lancaster University, Vasileios Asloglou, Advanced Networking and the Internet Coursework. Tutorial Topic: Congestion Control techniques. http://www.lancs.ac.uk/postgrad/asloglou/ (dead link))

Note that I could not find the source paper, and I found evidence that contradicts these models, in a paper called The End-to-End Performance Effects of Parallel TCP Sockets on a Lossy Wide-Area Network. This paper appears to show that under some assumptions, multiple simultaneous TCP streams experiencing random fair packet loss will all back off together, and aggregate flow neither increases nor decreases as the number of connections rises:



Is my network congested?

Probably yes if:

- It’s much faster when nobody is using it, or
- Available bandwidth is less than 1 Mbps, or
- Latency is over 300 ms, or
- You see non-trivial levels of packet loss.

Congestion is most likely to be on your weakest link (your Internet connection), but it is possible that your Internet provider has congestion in their network as well/instead.

You can spot congestion by looking for large jumps in latency on a `traceroute`:

```
$ traceroute 10.0.156.214
traceroute to 10.0.156.214 (10.0.156.214), 30 hops max, 60 byte packets
1  10.0.156.130 (10.0.156.130)  52.161 ms  52.150 ms  52.129 ms
2  10.0.156.197 (10.0.156.197)  322.024 ms  322.018 ms  321.968 ms
3  10.0.156.214 (10.0.156.214)  321.949 ms  321.932 ms  321.913 ms
```

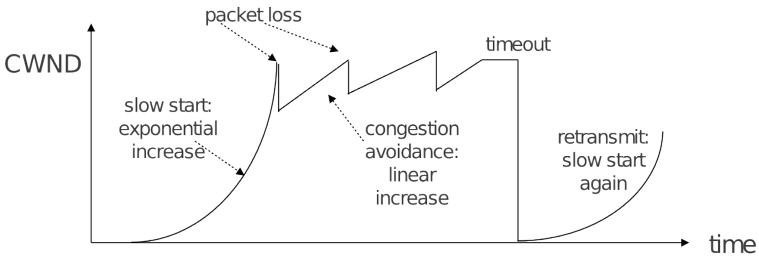
This traceroute has a jump in latency of 270ms between hops 1 and 2, which cannot be explained except by congestion. Compare with the same `traceroute` when the connection is unloaded:

```
$ traceroute 10.0.156.214
traceroute to 10.0.156.214 (10.0.156.214), 30 hops max, 60 byte packets
1  10.0.156.130 (10.0.156.130)  59.295 ms  59.259 ms  59.237 ms
2  10.0.156.197 (10.0.156.197)  119.209 ms  119.233 ms  119.218 ms
3  10.0.156.214 (10.0.156.214)  119.204 ms  119.189 ms  119.173 ms
```

The latency between hops 2 and 3 has dropped from 270ms to 70ms.

What causes congestion

- TCP protocol
- backoff only on packet loss
- ability to saturate connection
- excessive queue length



IP (the Internet protocol standard) includes TCP (Transmission Control Protocol):

- provides reliable delivery of large data streams
- is used by most Internet traffic, including web pages, downloads and videos
- tries to use maximum possible bandwidth
- increases bandwidth use until packets are dropped
- which only happens when a queue is full
- therefore it creates congestion (fills a queue).

So congestion is inevitable if you have limited bandwidth. But you can reduce the effects by carefully controlling queue sizes, as ISPs do.

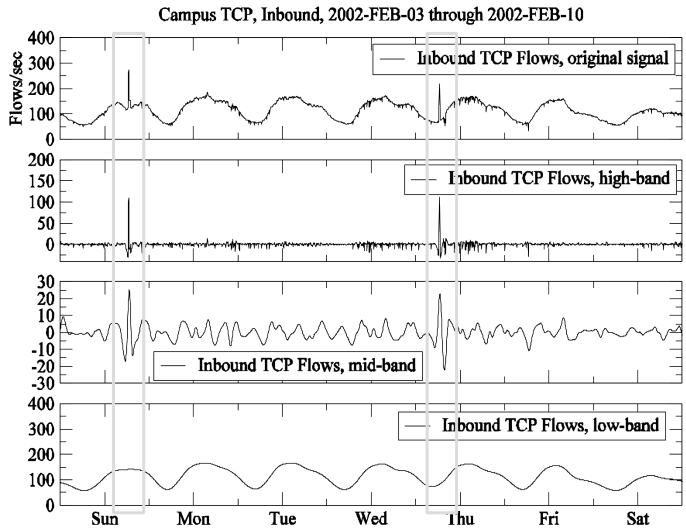
Solving the problem

If available bandwidth is the main problem:

- slow page loading
- slow downloads
- high latency or packet loss
- connection is full (congestion)

Then you need to increase *supply* of bandwidth and/or reduce *demand*. See Unit 9, Making a Difference.

Example: Denial of Service Attack



Graphical tools can spot unusual changes in traffic levels, which may indicate an attack, and pinpoint start and stop times.

Summary

Hopefully you now feel more confident with:

- Importance of troubleshooting in network management
- Troubleshooting vs. monitoring
- Good troubleshooting technique
- Troubleshooting a rogue DHCP server
- Troubleshooting a slow Internet connection

In the next unit, we will cover how to understand in more detail how a connection is being used. That will help us to know whether we can change user behaviour to reduce overloading.