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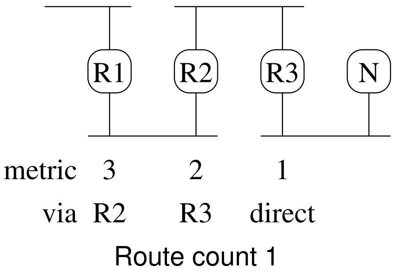
And this can manifest in bad ways

Routing

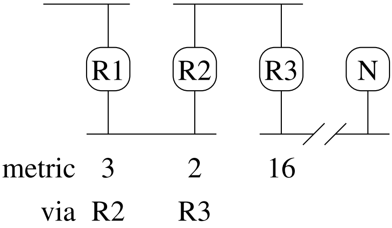
Slow Convergence



R3 knows a route to network N of hop count 1;

Routing

Slow Convergence

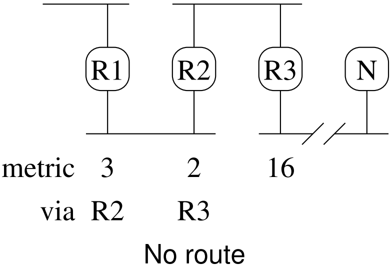


Break in route

After a break in the network R3 finds that route no longer works;

Routing

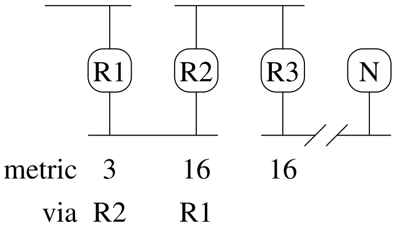
Slow Convergence



So it sends a message to its neighbours (R2) saying “no route to N”. It uses a count of 16, which is interpreted as infinity;

Routing

Slow Convergence

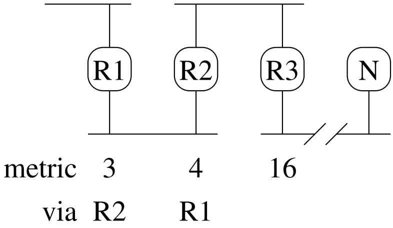


Update routing table

R2 updates its routing table;

Routing

Slow Convergence

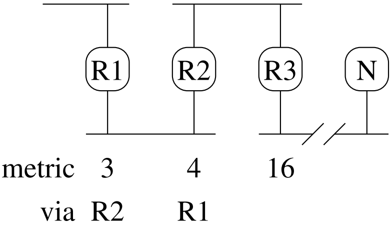


New route for R2?

But R2 also gets a periodic update message from R1 saying "route of 3 hops";

Routing

Slow Convergence

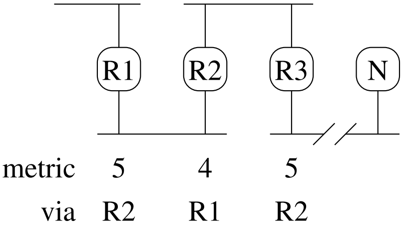


R2 update again

So R2 now thinks the best route is via R1, 4 hops;

Routing

Slow Convergence

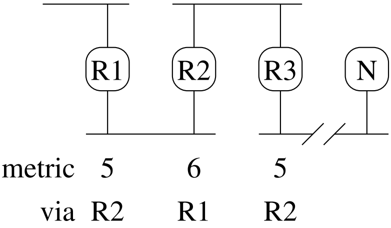


Another broadcast

And when R2 sends its periodic update message “4” to R1 and R3, R1 now thinks there is a route via R2 of 5 hops; and R3 thinks there is a route of 5 hops via R2;

Routing

Slow Convergence

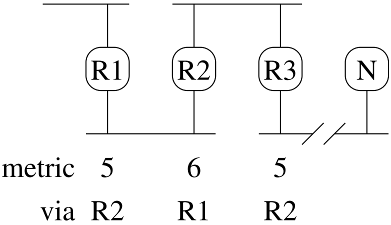


Counts grow slowly

After the next update, R2 thinks there is a route via R3 of 6 hops;

Routing

Slow Convergence

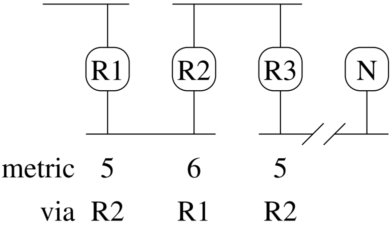


Counts grow slowly

And so on;

Routing

Slow Convergence

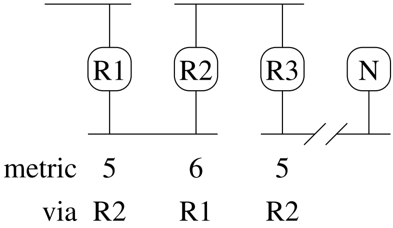


Counts grow slowly

Eventually the hop count reaches 16, i.e., no route, and so this route is dropped;

Routing

Slow Convergence

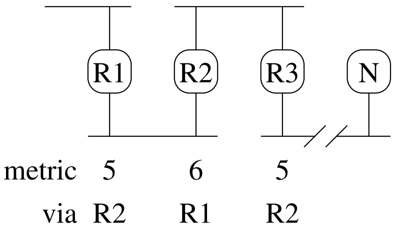


Counts grow slowly

This is called the *count to infinity* problem;

Routing

Slow Convergence



Counts grow slowly

If there was a valid route, it might take a long time to converge to that route

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So RIP should only used on small networks that are fairly stable

Link state protocols, e.g., OSPF, converge faster, but need more complicated graph traversal algorithms to determine best routes

BGP

BGP is a *path vector* variation of distance vector: this includes the path (multiple hops) to the destination, which can be used to spot the loops that lead to count-to-infinity

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Exercise Read about path vector systems

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For example, it would be relatively easy to get BGP to transit data through an evil third party

Also, see the problem with the route to Youtube, earlier

BGP

Exercise Read about the 2018 hack on the cryptocurrency website `MyEtherWallet.com` that started by subverting BGP to send DNS traffic to a rogue server

Exercise Read about the BGP problem of April 2021, where Vodafone Idea (AS55410) published bad routes

Exercise Read about the proposed *Resource Public Key Infrastructure* (RPKI), RFC6810

Exercise Read about the *Mutually Agreed Norms for Routing Security* (MANRS) initiative for ISPs and routing exchange operators

BGP

Exercise Read about RIP

Exercise Read about Dijkstra's algorithm for finding shortest paths in a graph; and OSPF which uses this algorithm

Transport Layer

We now move up a layer: the Transport Layer

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The Internet Protocol has three main protocols that run on top of IP: two are for data, one for control

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Other data protocols exist in this layer, but TCP and UDP are currently the important ones

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Ports

Both UDP and TCP use the concept of *ports*

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A port is just a 16 bit integer: 1-65535

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E.g., an email server may indicate it wants packets addressed to TCP port 25; a browser would listen on port 80 (and 443)

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An analogy: a host as a block of flats. To address a letter to a specific person you need both a building address (IP address) and a flat number (port)

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TCP and UDP are completely separate and do not interact at all (at the transport level)

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Ports

Certain *well-known* ports are associated certain services

- web server on port 80 (or 443 for a secure version)
- email server on port 25
- FTP on port 21
- Microsoft SQL server on 1433
- hundreds of others. See `/etc/services` and RFC6335

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Typically, port numbers under 1024 are reserved for privileged programs

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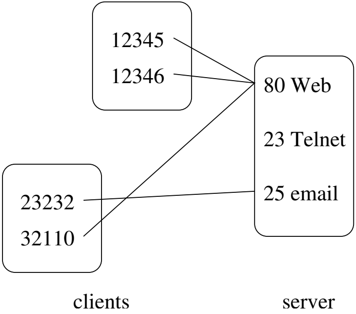
It just means you don't have the extra problem of determining the port for, say, the web server: it is almost always 80 (or 443)

You can run a web server on port 25 if you wish: you will just confuse anyone who tries to send you email

Transport Layer



Transport layer ports

Ports also enable multiple simultaneous connections between two machines, e.g., fetching several web pages

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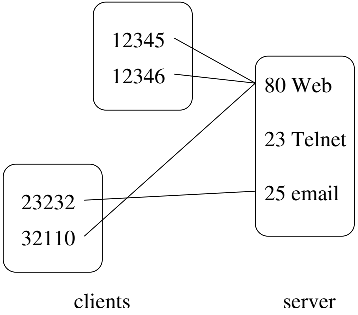

Transport layer ports

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The source port (destination port on the returning packet) allows the client OS to identify which packet belongs to which client program

Transport Layer

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The quad

source address
source port
destination address
destination port

specifies a connection uniquely: the hosts involved and the processes on those hosts

Transport Layer

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Thus the OS can identify which process an ICMP belongs to

And a non-initial IP fragment won’t have such identifying information, so this is why ICMPs are not generated for errors involving such fragments

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NAT and Ports

And ports are how a NAT firewall does its magic of matching returning reply packets to request packets

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It keeps a list of private (internal) socket pairs against public (external) socket pairs

And this is enough to match up replies with requests

Exercise Read about *Port Address Translation*

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Exercise Sometime we wish to allow an external host to initiate a connection with a private host behind NAT. Read about *port forwarding*

Transport Layer

NAT and Ports

Exercise Read about *Port Address Translation*

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Exercise Reflect upon the idea that ports are "process addresses", namely a way to identify a particular process within a destination

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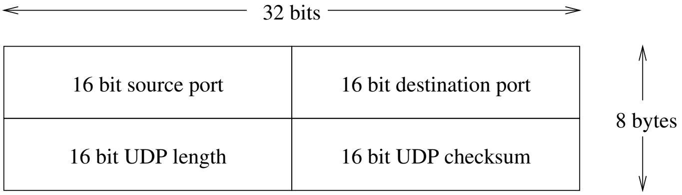
UDP packets are typically called *datagrams* (like telegrams: simple individual messages)

UDP

Header



UDP header

UDP

Header

32 bits

16 bit source port	16 bit destination port
16 bit UDP length	16 bit UDP checksum

8 bytes

UDP header

- Ports: as described

UDP

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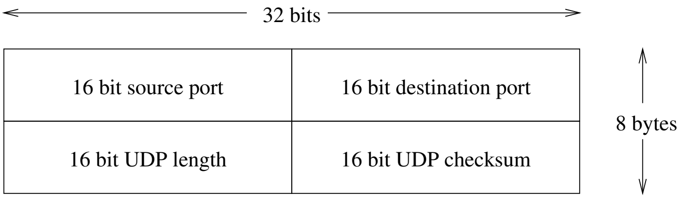

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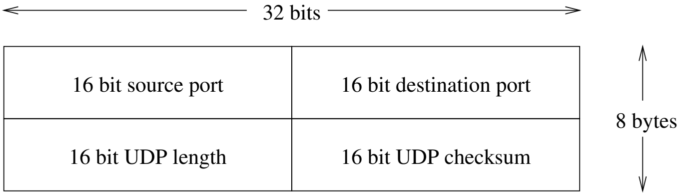

UDP header

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- Checksum: of the UDP header, the data *and some fields from the IP header*

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The checksum is optional: put 0 in this field if you want to save a little time: recall UDP is unreliable!

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It is just about as fast and efficient as IP, with only a small overhead (8 bytes)

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- One shot applications. Where we have a single request and reply. For example, DNS
- Where a fast response is required. We have no overhead in setting up a connection before data can be exchanged (see TCP). E.g., DNS
- Where speed is more important than accuracy. For example, media streaming, where the occasional lost packet is not a problem, but a slow packet is

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Exercise UDP is ideal for streaming video and audio, but a lot of services use HTTP over TCP. What are the advantages and disadvantages of doing this?

UDP

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Thus the need for TCP