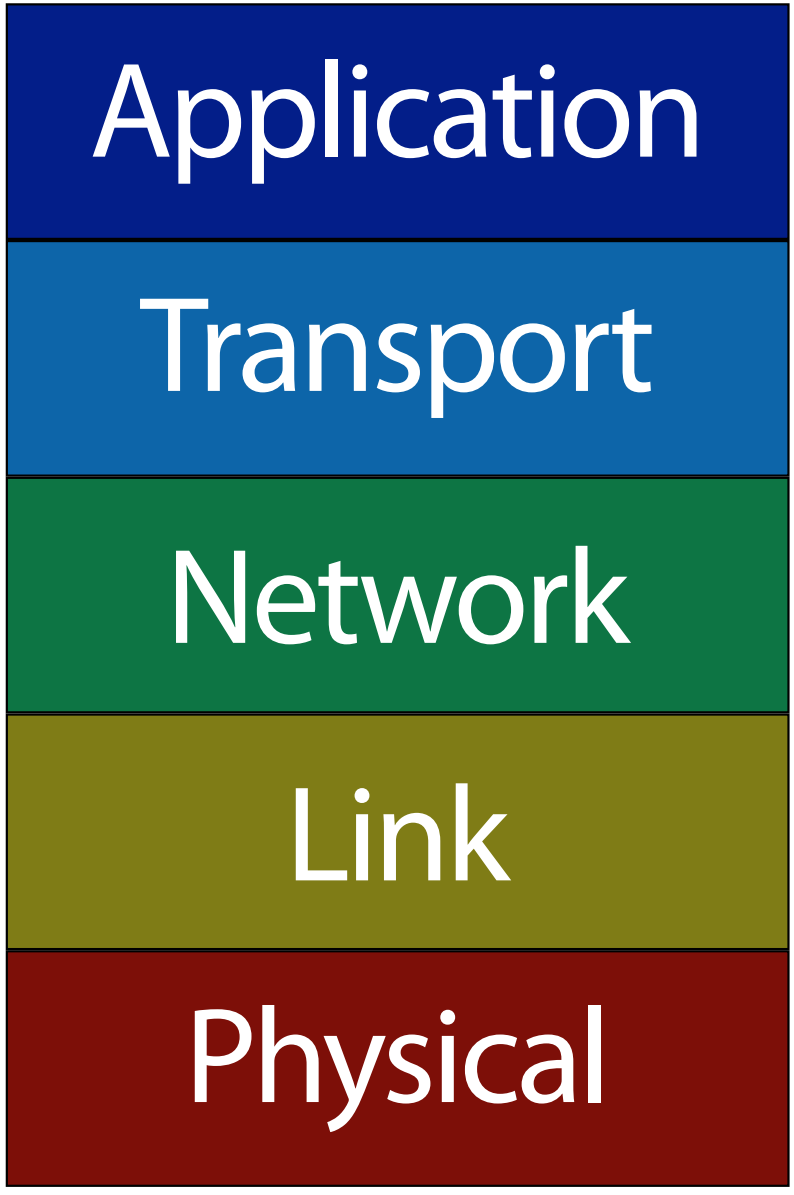
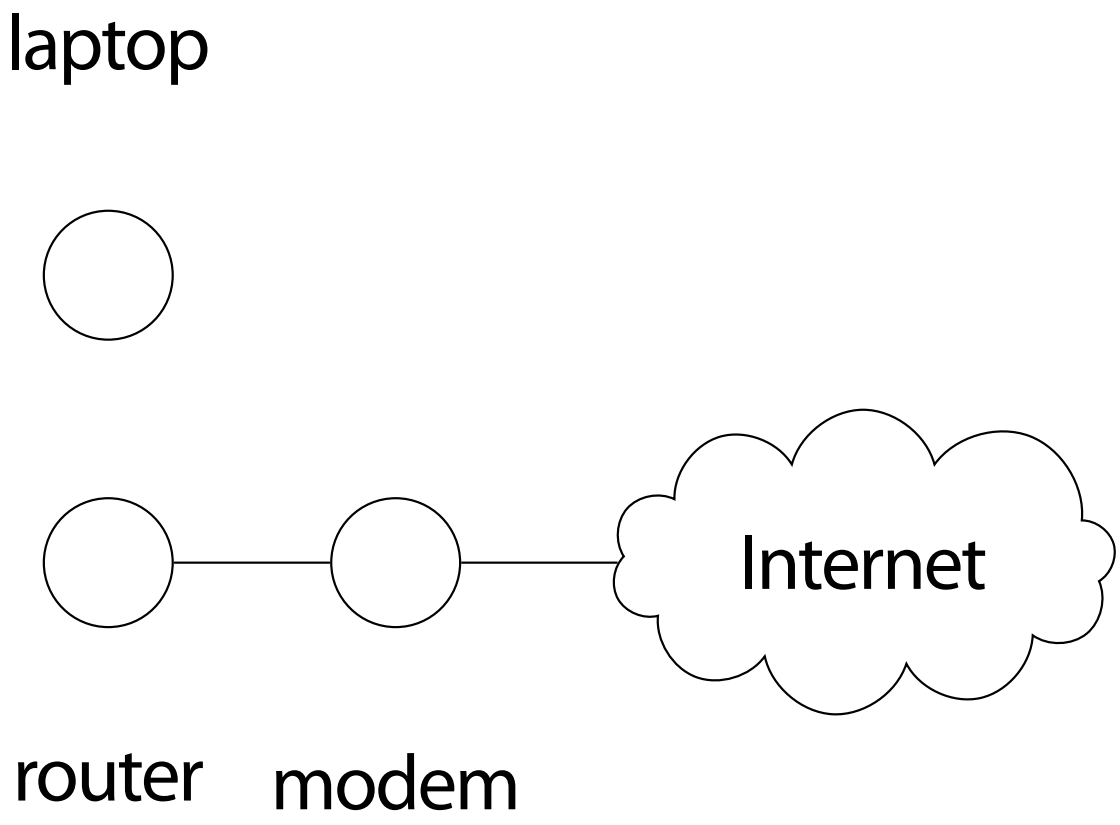
CS2105 Lecture 12
Putting Everything Together

14 April, 2014


Application
Transport
Network
Link
Physical


laptop
Internet
router
modem

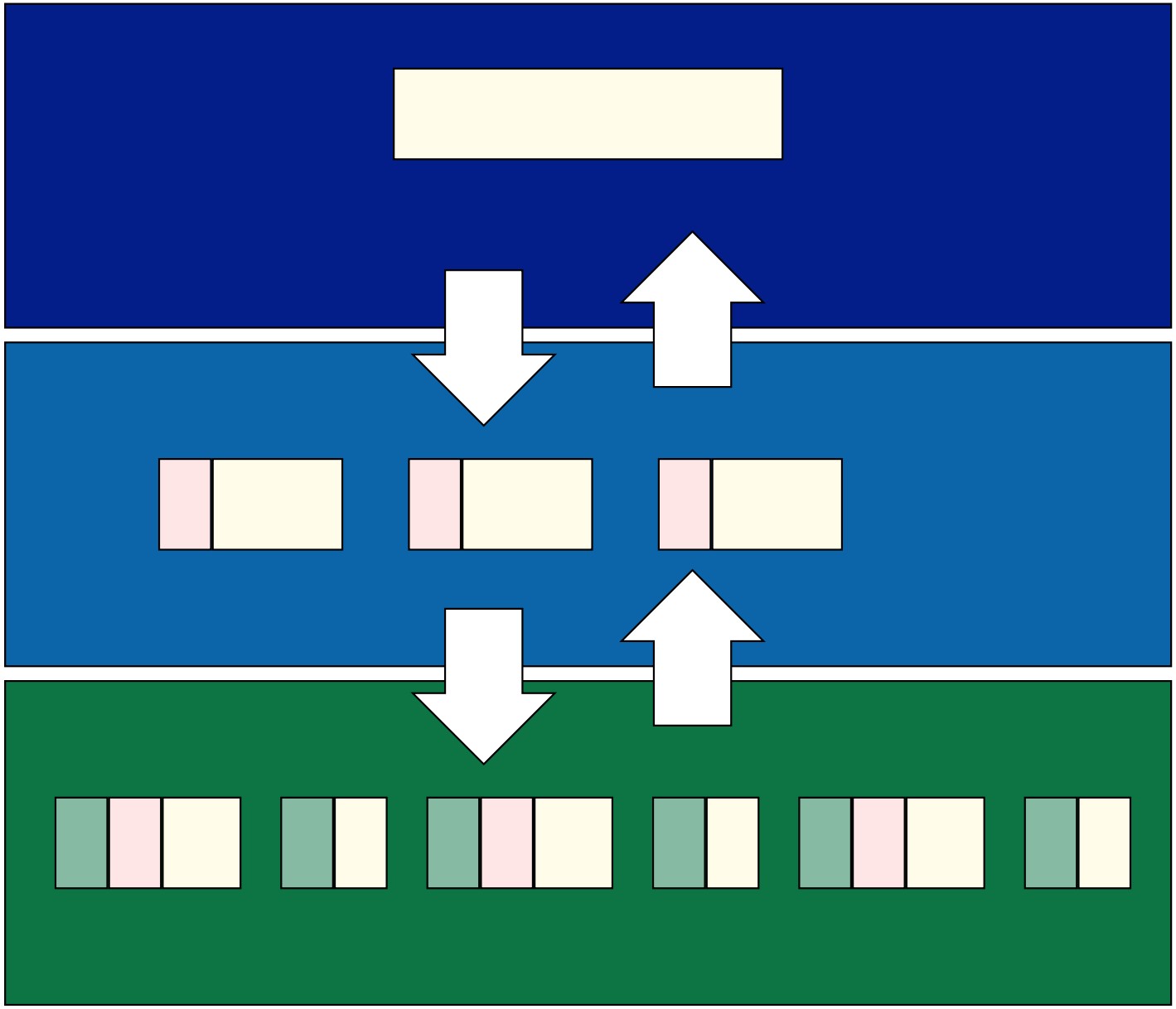
Turn on modem
Turn on router
Turn on laptop
Visit IVLE

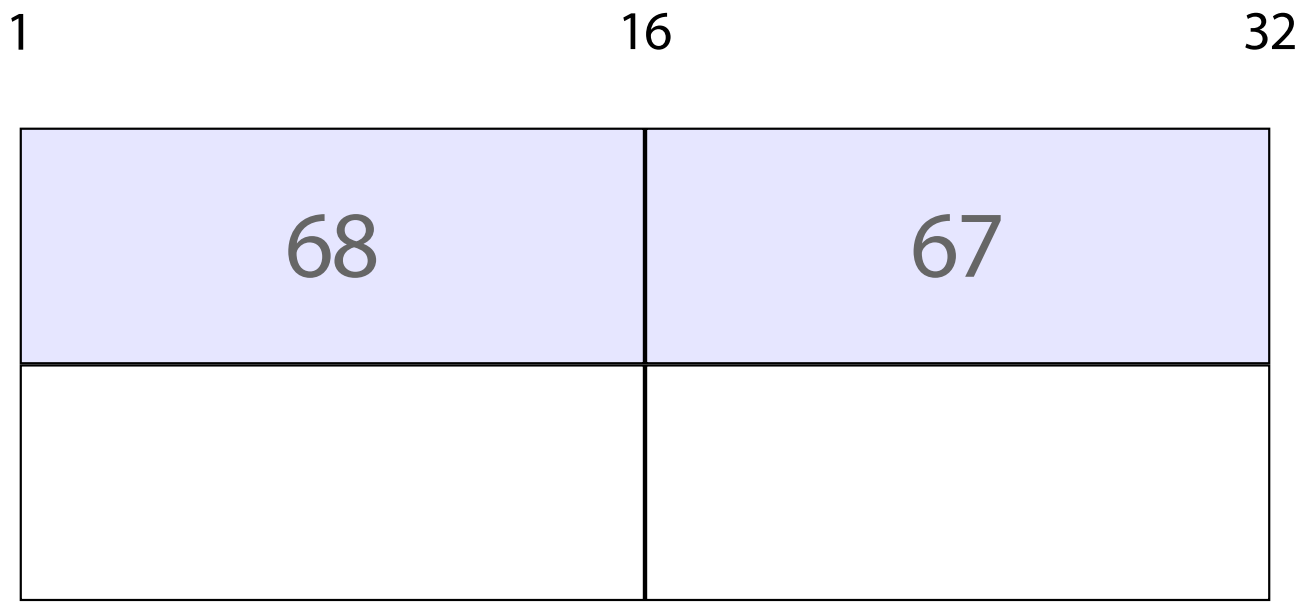
Turn on Modem

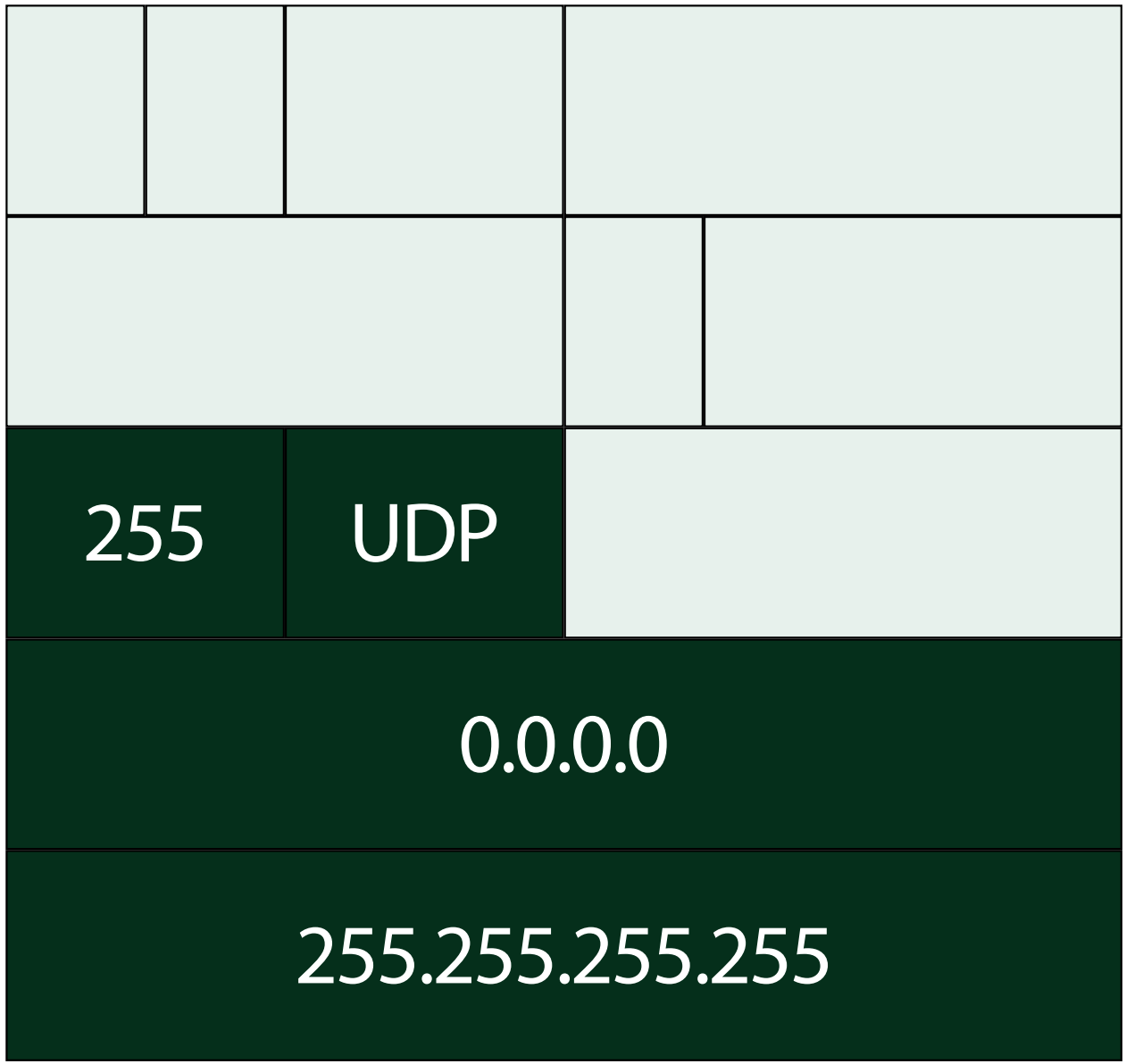
Modulate between Digital (Manchester Coding) and Analog (QAM/QPSK)

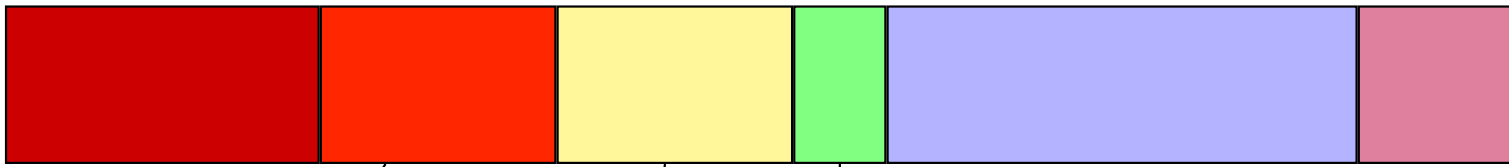
Turn on Router

Router broadcasts DHCP Discover




1
16
32
68
67

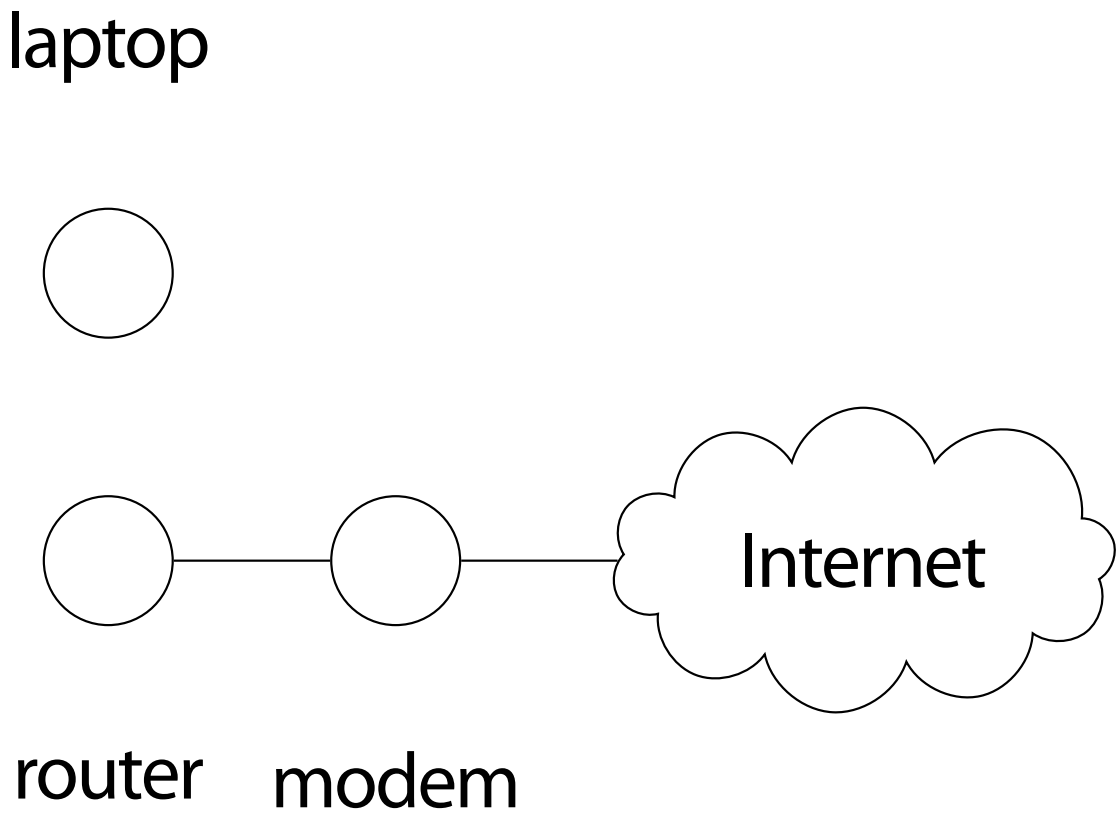

255
UDP
0.0.0.0
255.255.255.255



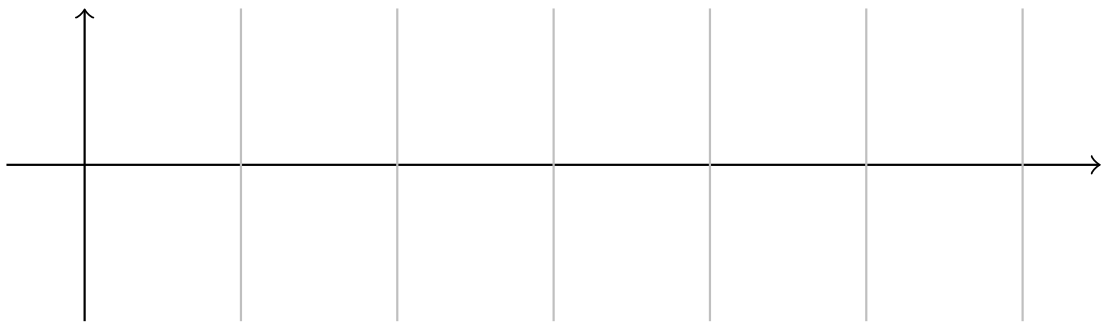
04:42:00:31:98:12

IP

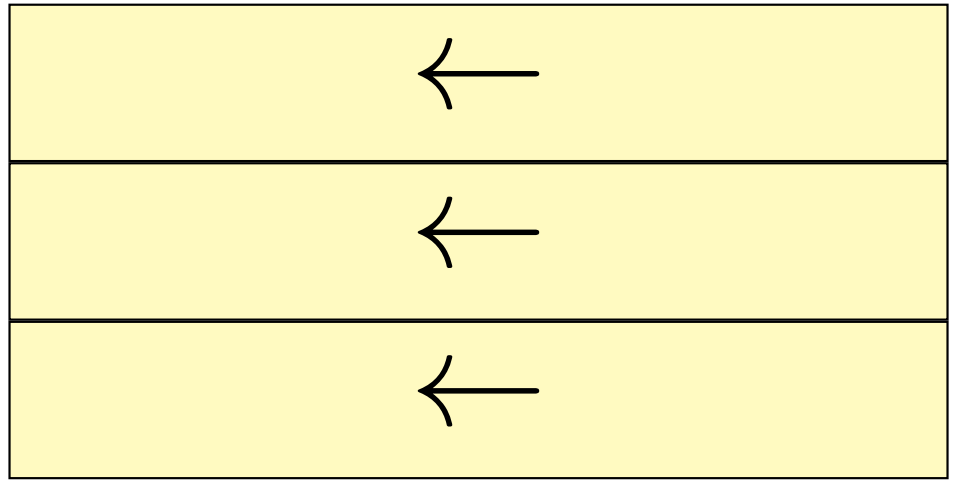
ff:ff:ff:ff:ff:ff

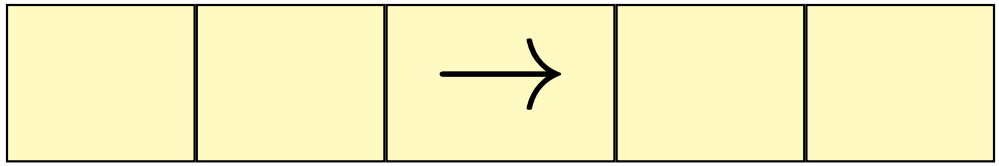

laptop
Internet
router
modem

Manchester

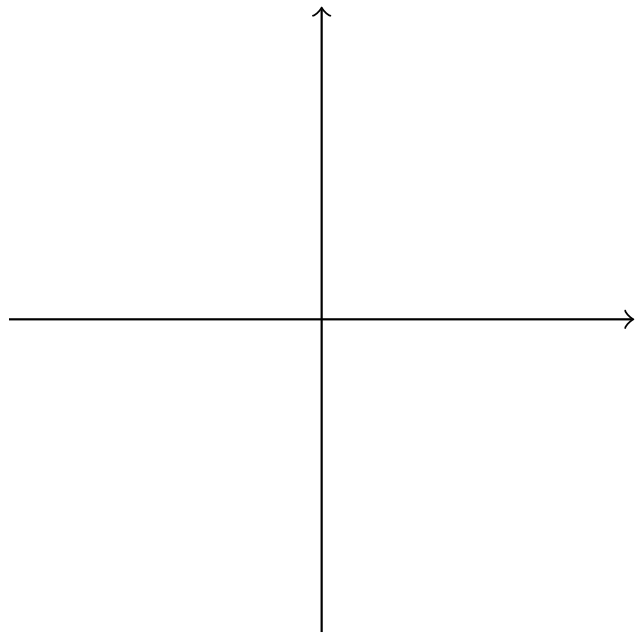


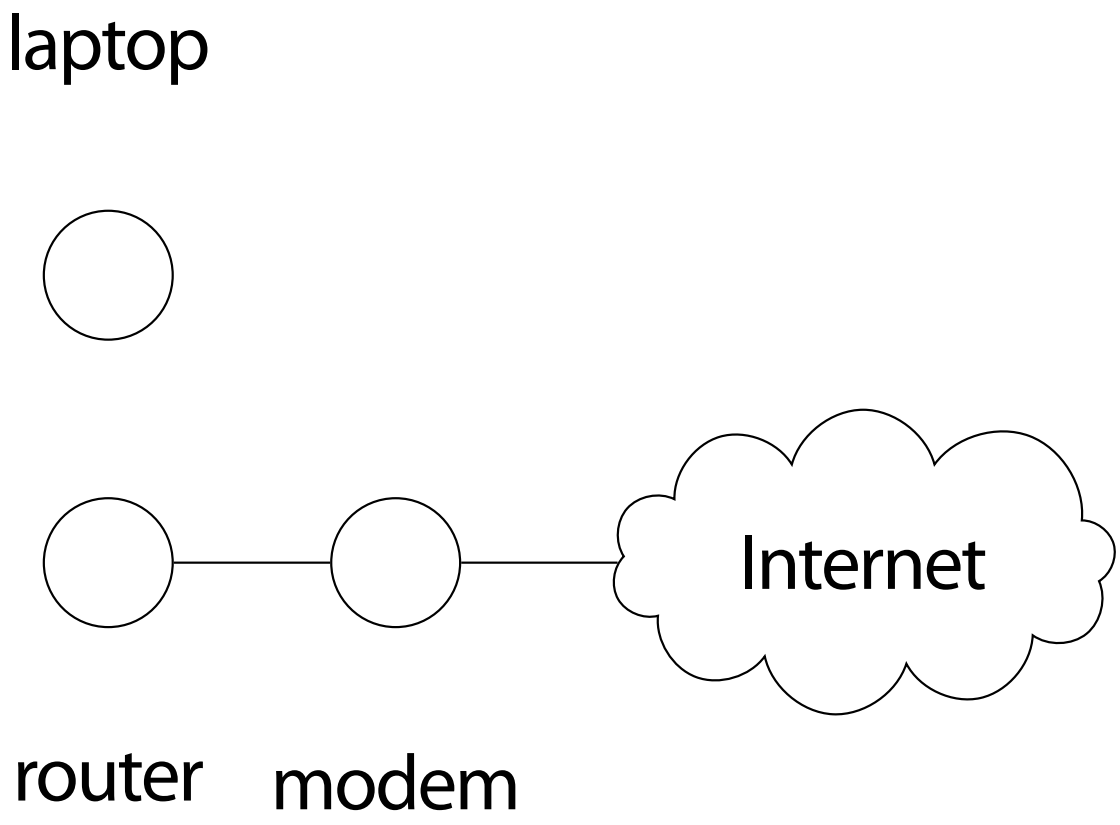
DOCSIS





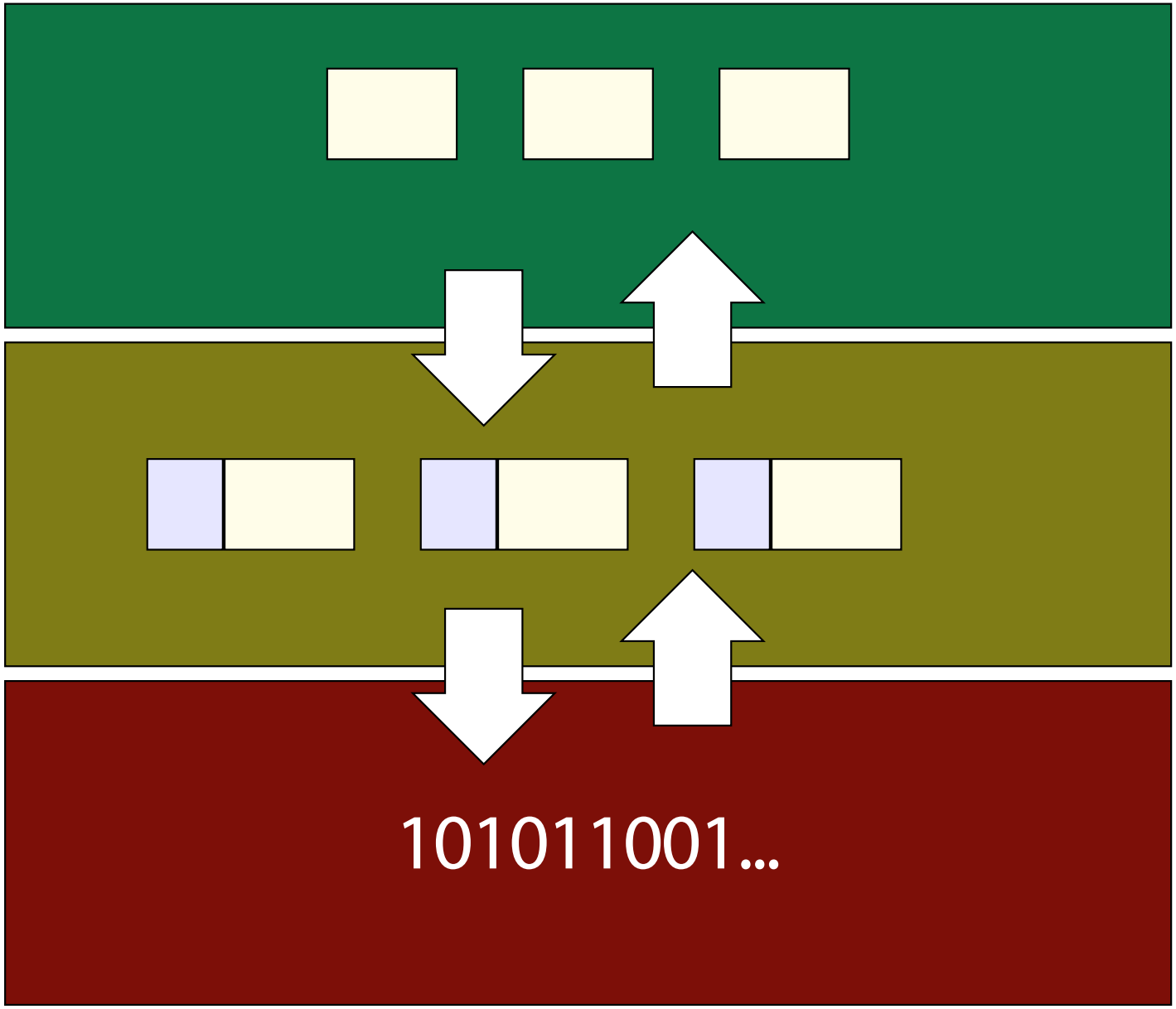
64-QAM

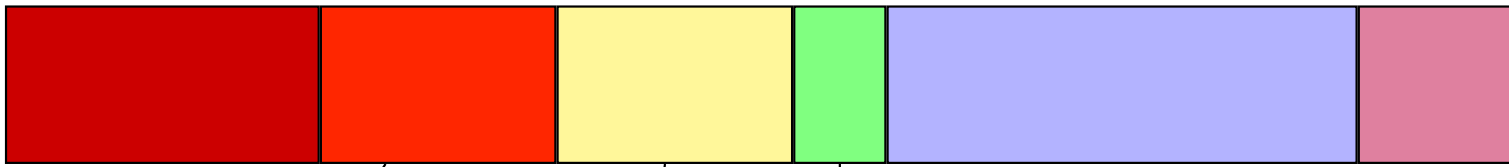



laptop
Internet
router
modem

Router receives DHCP Offer

Router broadcasts ARP Request


1010110001...



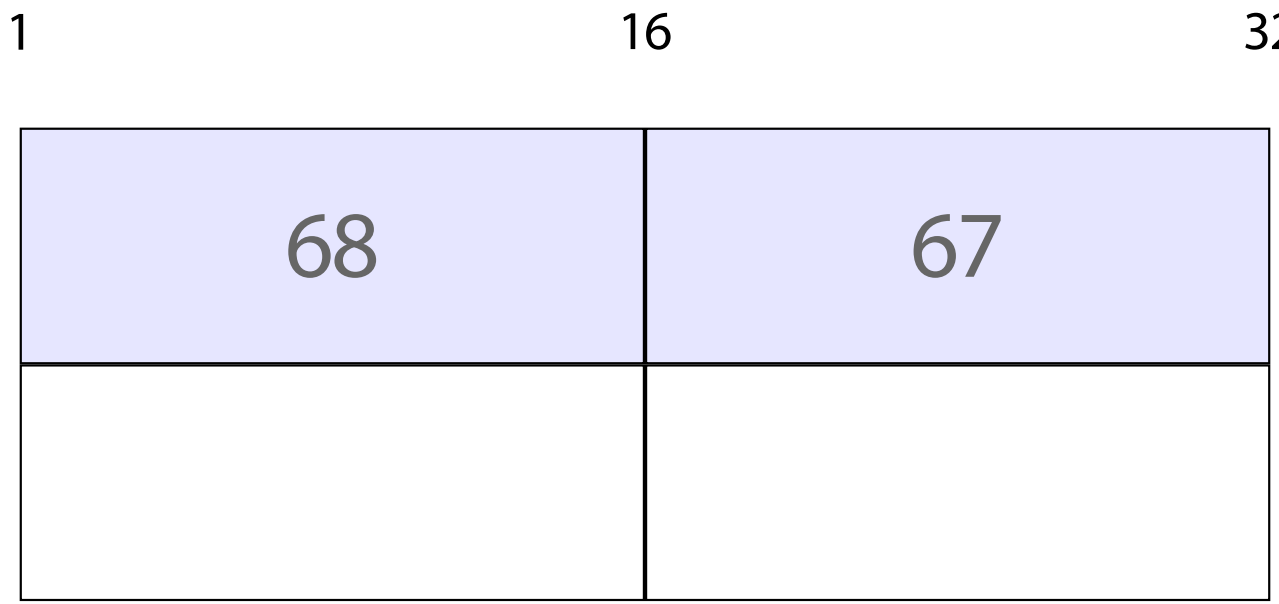
04:42:00:31:98:12

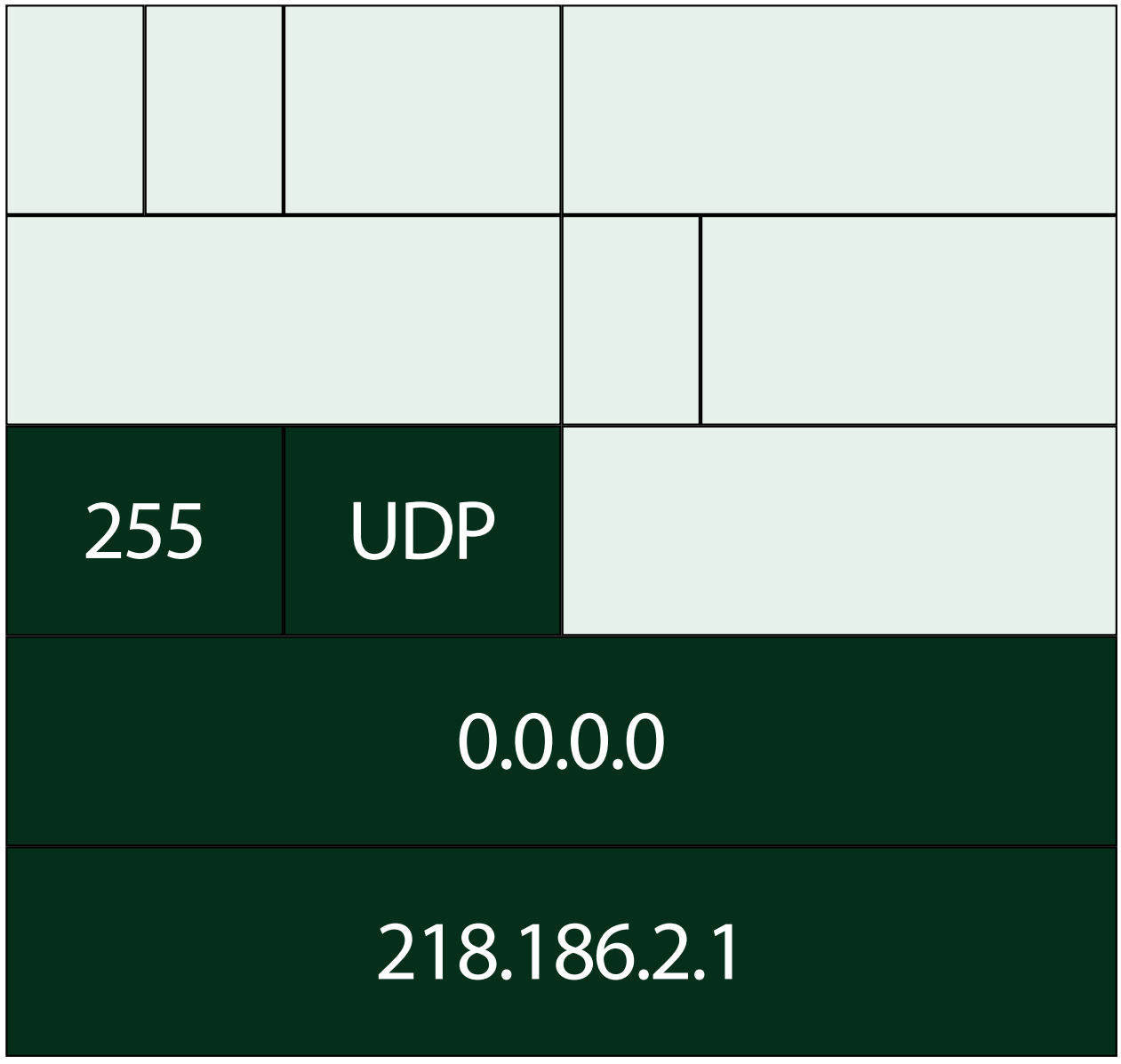
ARP

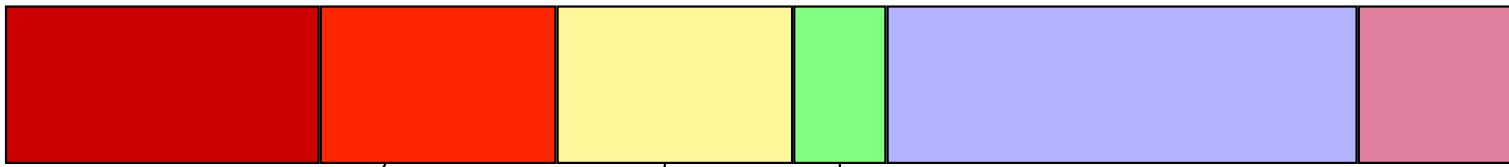
ff:ff:ff:ff:ff:ff

Router receives ARP Respond

Router sends DHCP Request


1
16
32
68
67


255
UDP
0.0.0.0
218.186.2.1

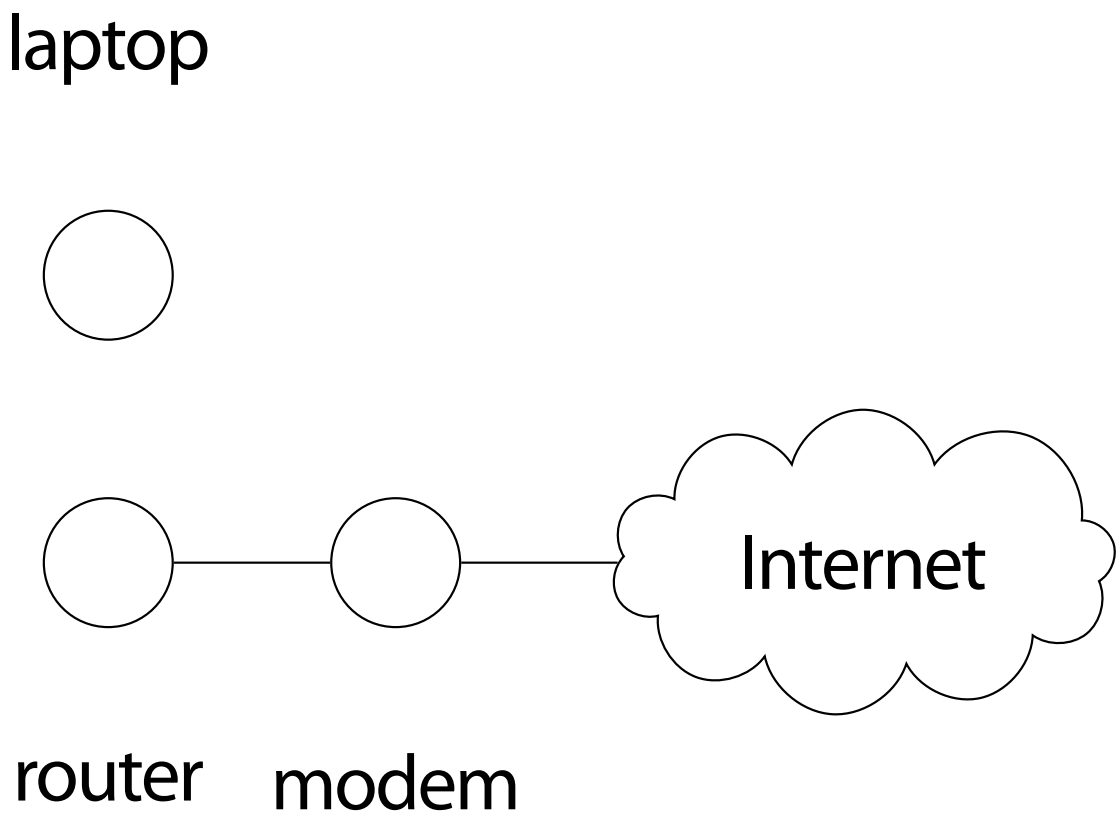


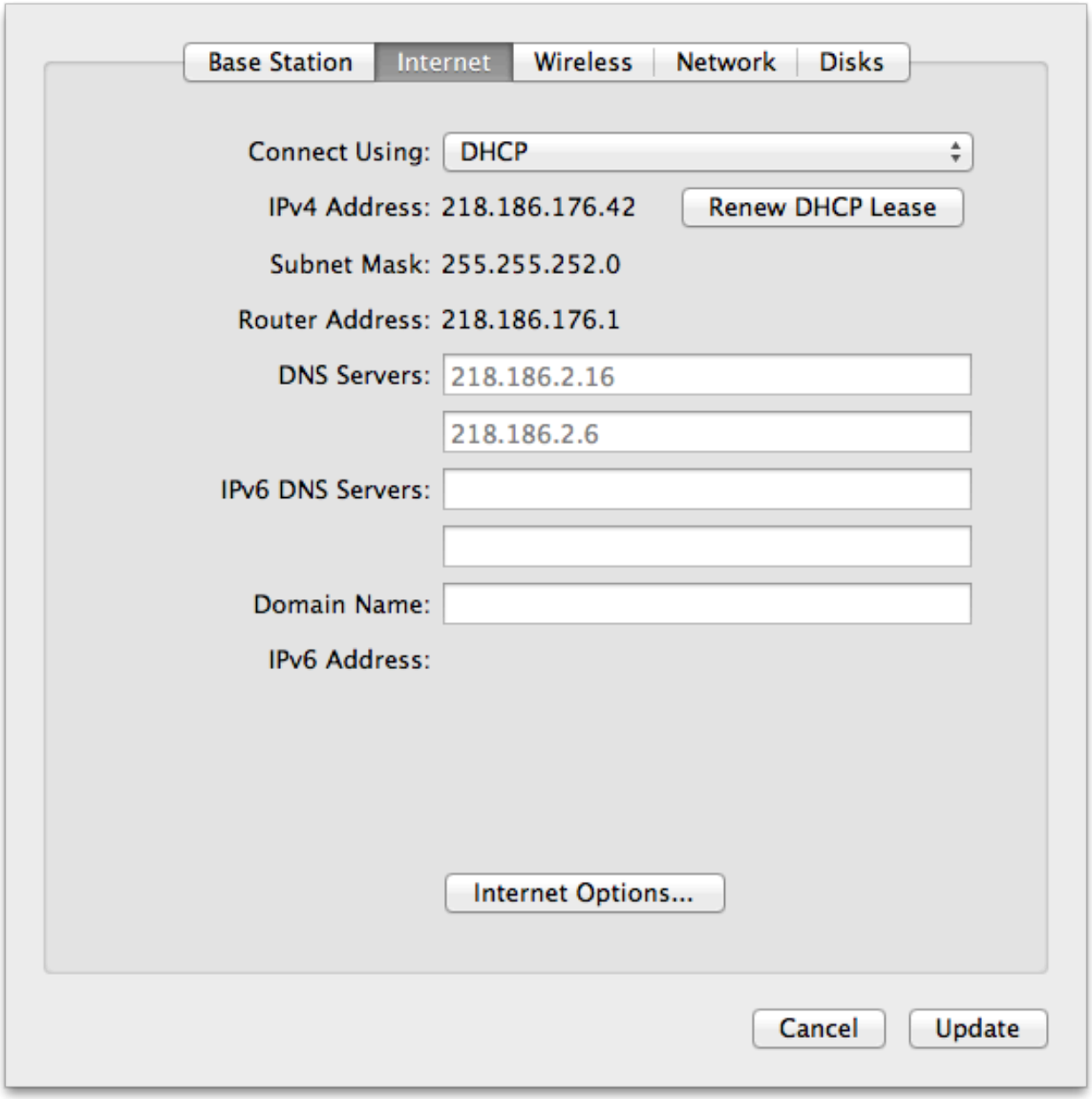
04:42:00:31:98:12

IP

00:1c:f6:03:11:94

Router receives DHCP ACK


laptop
Internet
router
modem

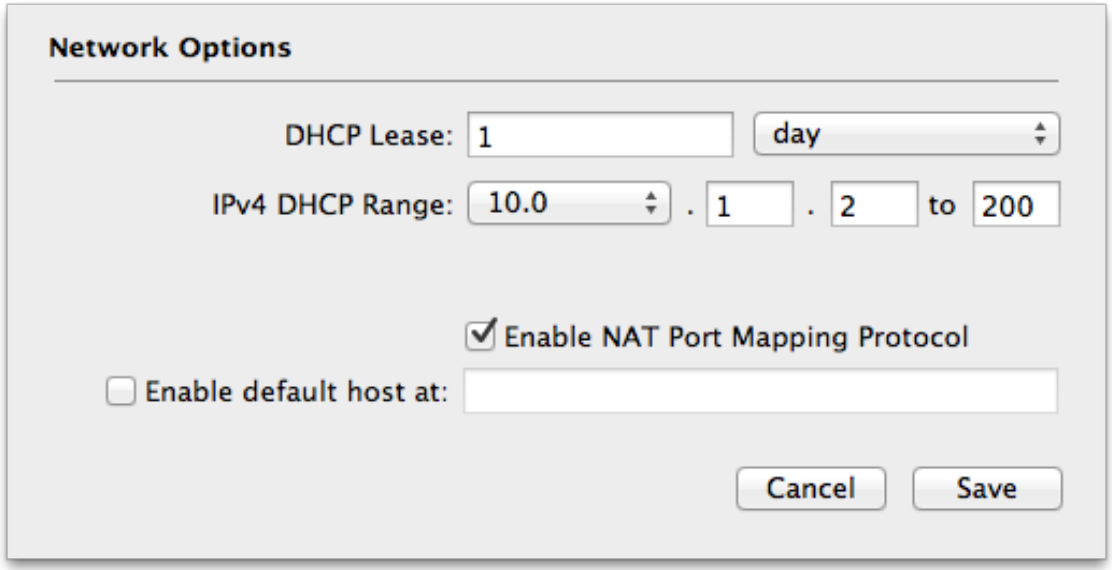

Base Station
Internet
Wireless
Network
Disks
Connect Using:
DHCP
IPv4 Address: 218.186.176.42
Renew DHCP Lease
Subnet Mask: 255.255.252.0
Router Address: 218.186.176.1
DNS Servers:
218.186.2.16
218.186.2.6
IPv6 DNS Servers:
Domain Name:
IPv6 Address:
Internet Options...
Cancel
Update

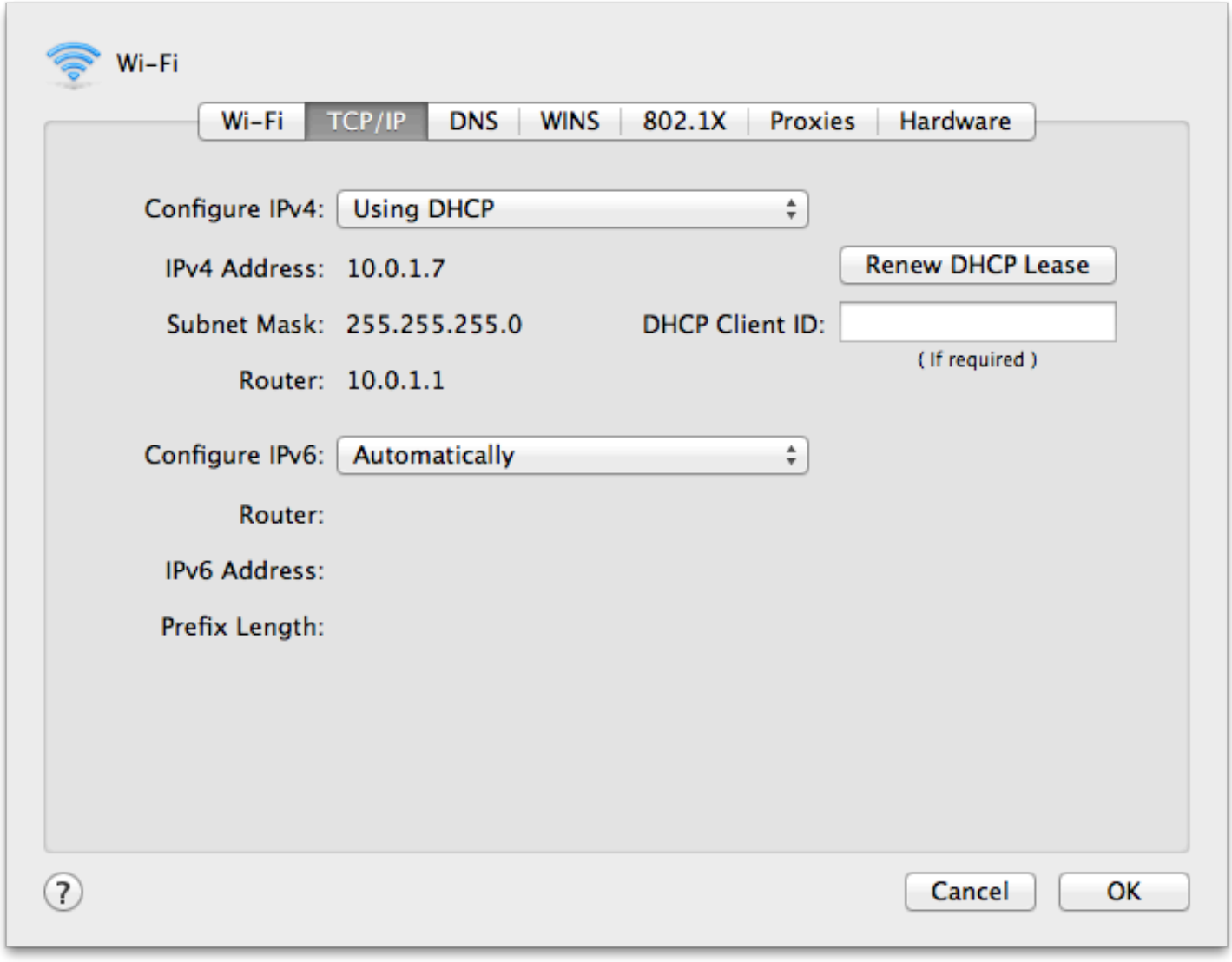
Turn on Laptop and connects to WiFi

Turn on Laptop and connects to WiFi

There are packet exchanges when the laptop associates itself and authenticate itself with the WiFi AP, which we skip here.

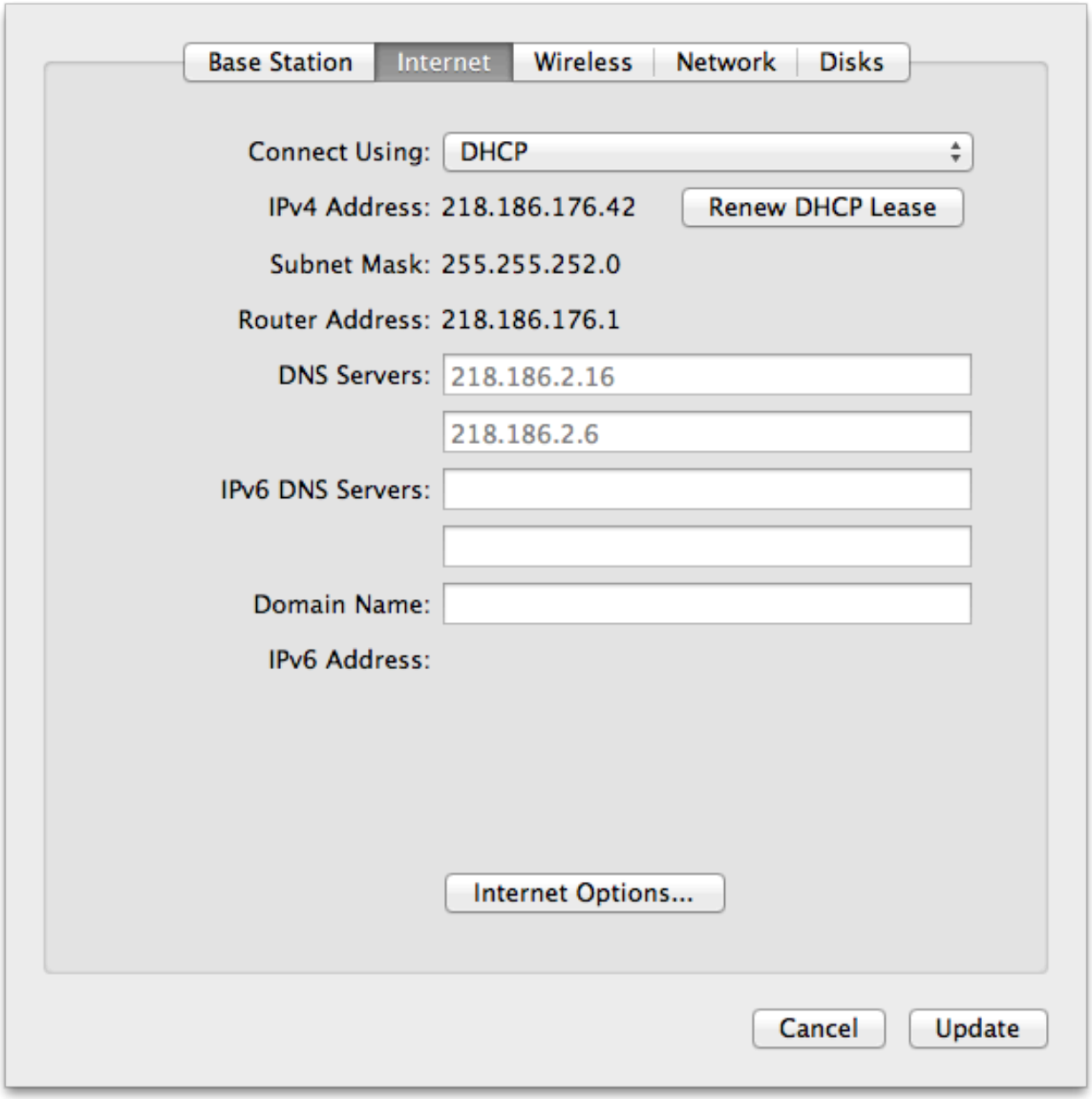
Laptop runs DHCP client
Router runs DHCP server

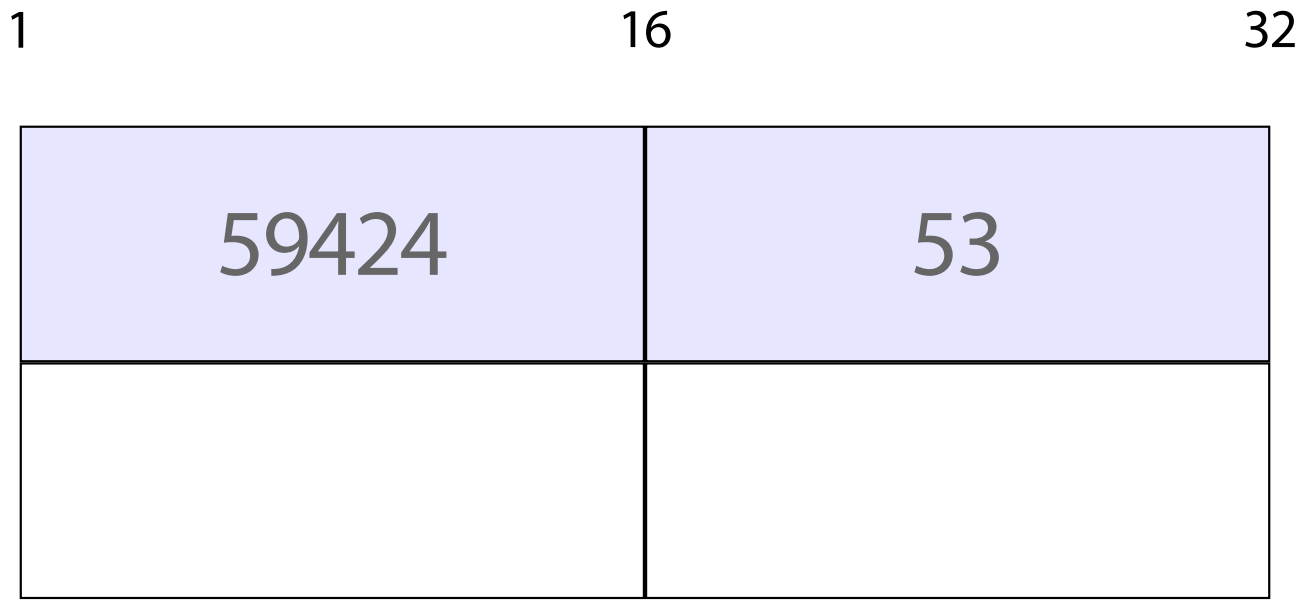

Network Options
DHCP Lease:
1
day
IPv4 DHCP Range:
10.0
.
1
.
2
to
200
Enable NAT Port Mapping Protocol
Enable default host at:
Cancel
Save

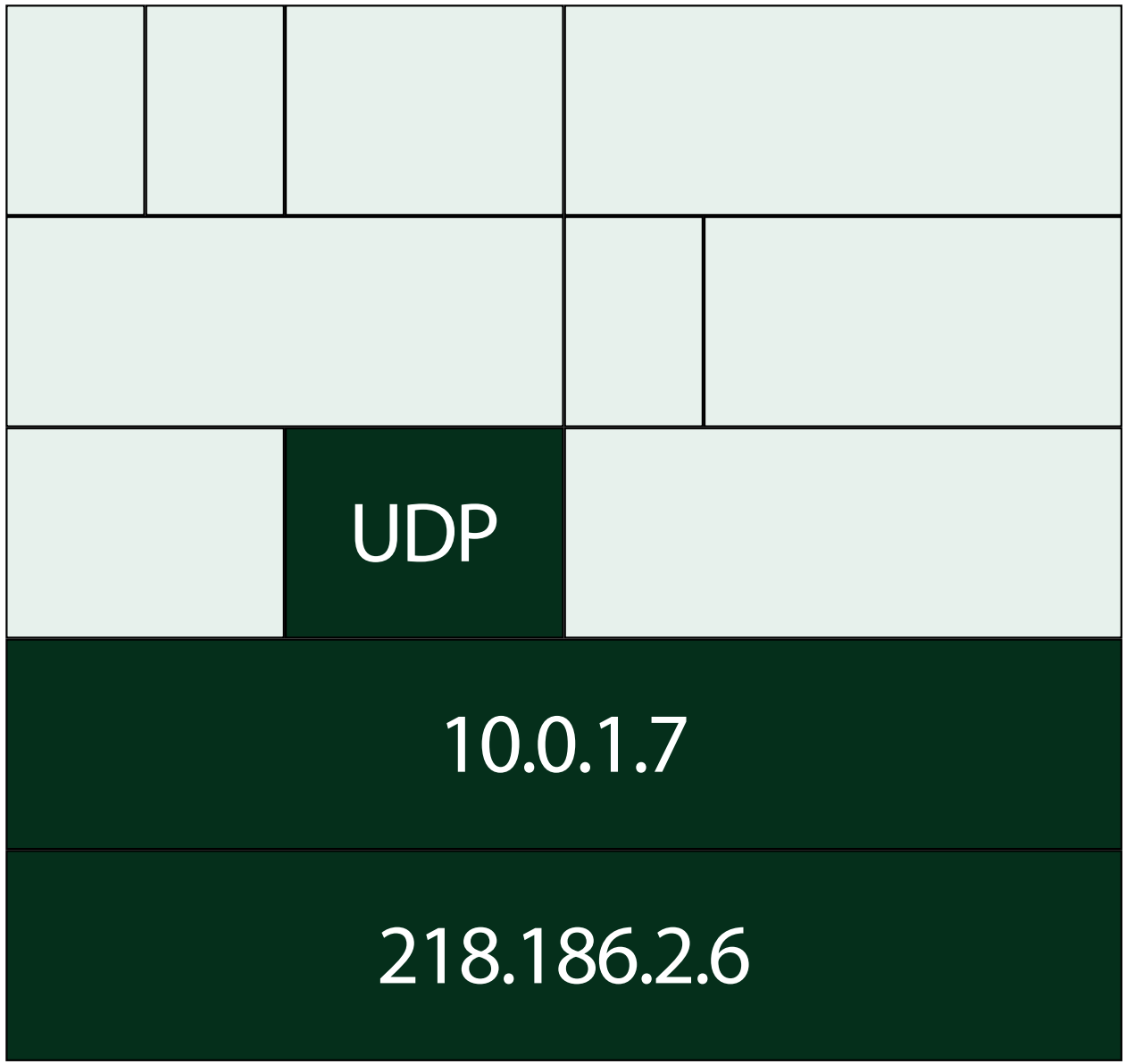

Wi-Fi
Wi-Fi
TCP/IP
DNS
WINS
802.1X
Proxies
Hardware
Configure IPv4:
Using DHCP
IPv4 Address:
10.0.1.7
Renew DHCP Lease
Subnet Mask:
255.255.255.0
DHCP Client ID:
(If required)
Router:
10.0.1.1
Configure IPv6:
Automatically
Router:
IPv6 Address:
Prefix Length:
Cancel
OK

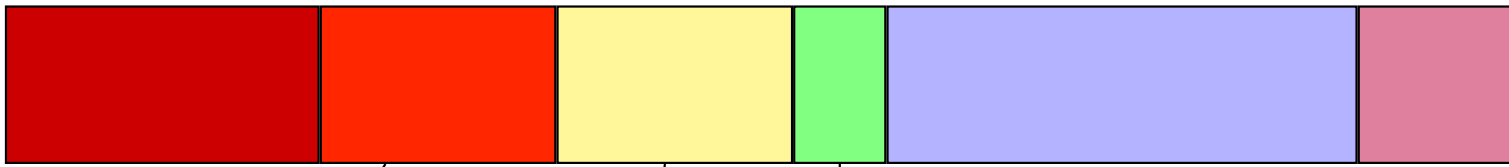
Visit https://ivle.nus.edu.sg/

DNS lookup for ivle.nus.edu.sg


Base Station
Internet
Wireless
Network
Disks
Connect Using:
DHCP
IPv4 Address: 218.186.176.42
Renew DHCP Lease
Subnet Mask: 255.255.252.0
Router Address: 218.186.176.1
DNS Servers:
218.186.2.16
218.186.2.6
IPv6 DNS Servers:
Domain Name:
IPv6 Address:
Internet Options...
Cancel
Update


1
16
32
59424
53


UDP
10.0.1.7
218.186.2.6

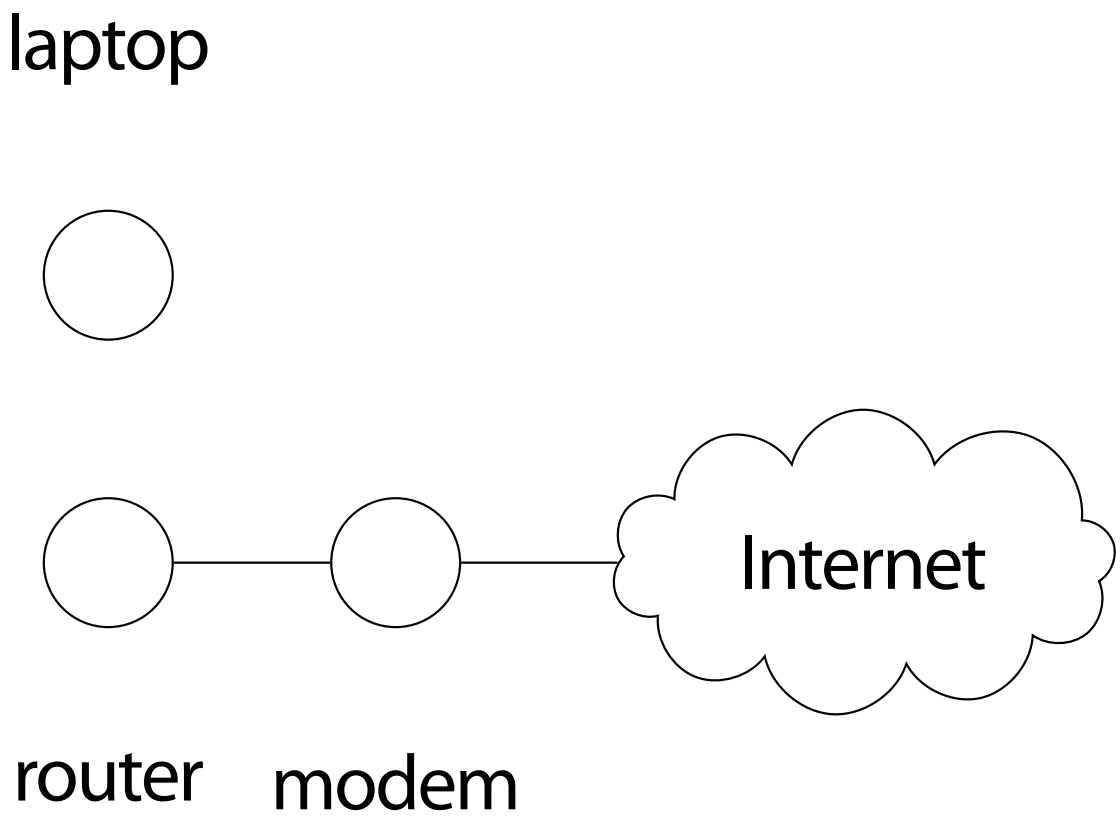


69:1b:04:42:33:12

IP

70:56:81:c7:11:e2

```
laptop:~ ooiwt$ arp -an
? (10.0.1.1) at 70:56:81:c7:11:e2 on en0
? (10.0.1.8) at d0:23:db:47:64:6f on en0
? (10.0.1.255) at ff:ff:ff:ff:ff:ff on en0
? (10.0.1.255) at ff:ff:ff:ff:ff:ff on en1
```


laptop
Internet
router
modem

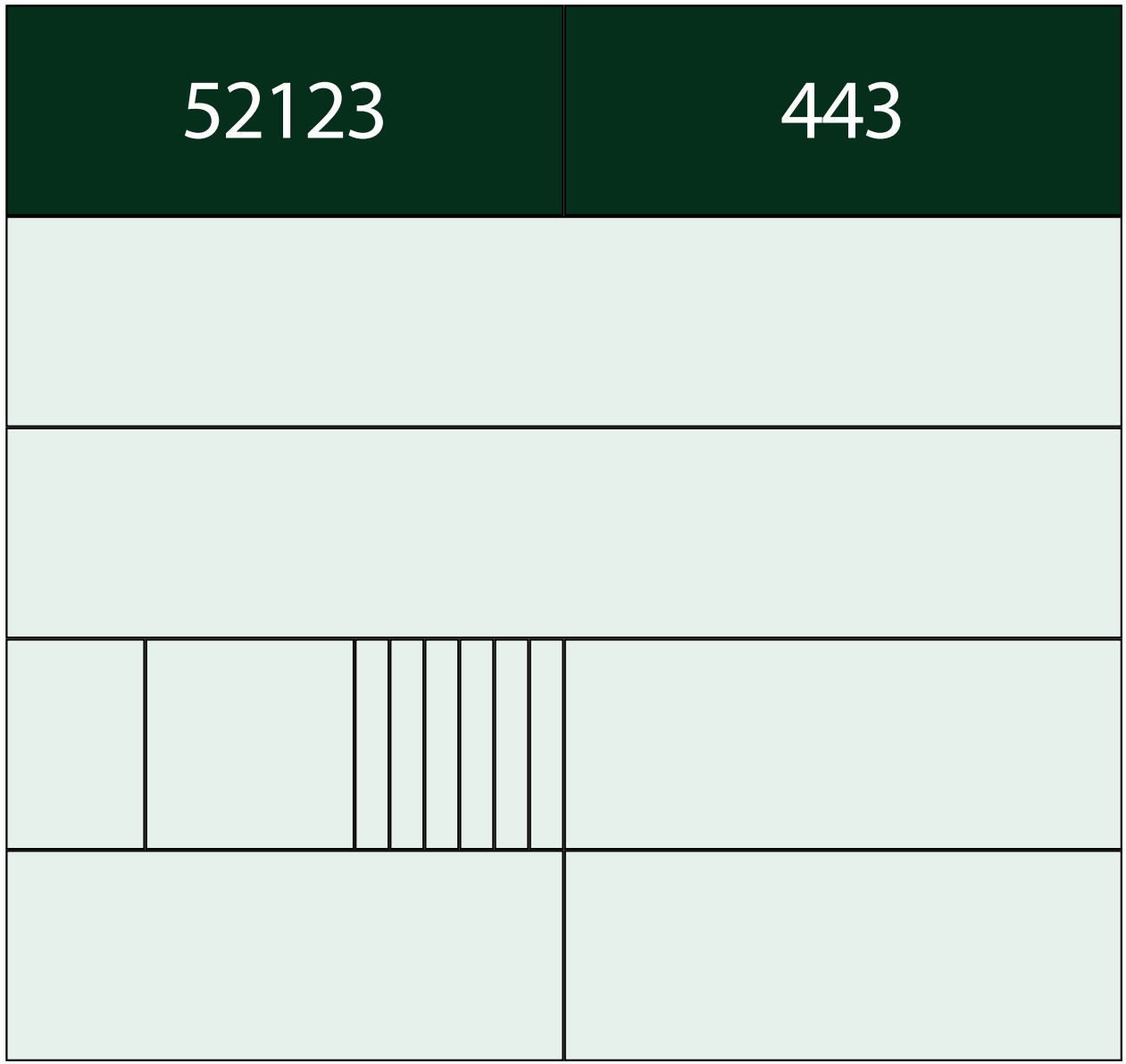
```
traceroute to 218.186.2.6 (218.186.2.6)
 1  10.0.1.1  1.354 ms  0.826 ms  0.913 ms
 2 218.186.176.1 14.015 ms 7.879 ms 12.394 ms
 3 172.20.12.1 11.866 ms 11.813 ms 7.667 ms
 4 172.20.7.82 10.794 ms 15.408 ms 11.775 ms
 5 172.20.7.38 9.464 ms 8.032 ms 11.391 ms
 6 172.20.8.5 12.319.ms 13.101 ms 55.906 ms
 7 218.186.2.6 12.111 ms 11.196 ms 9.436 ms
```

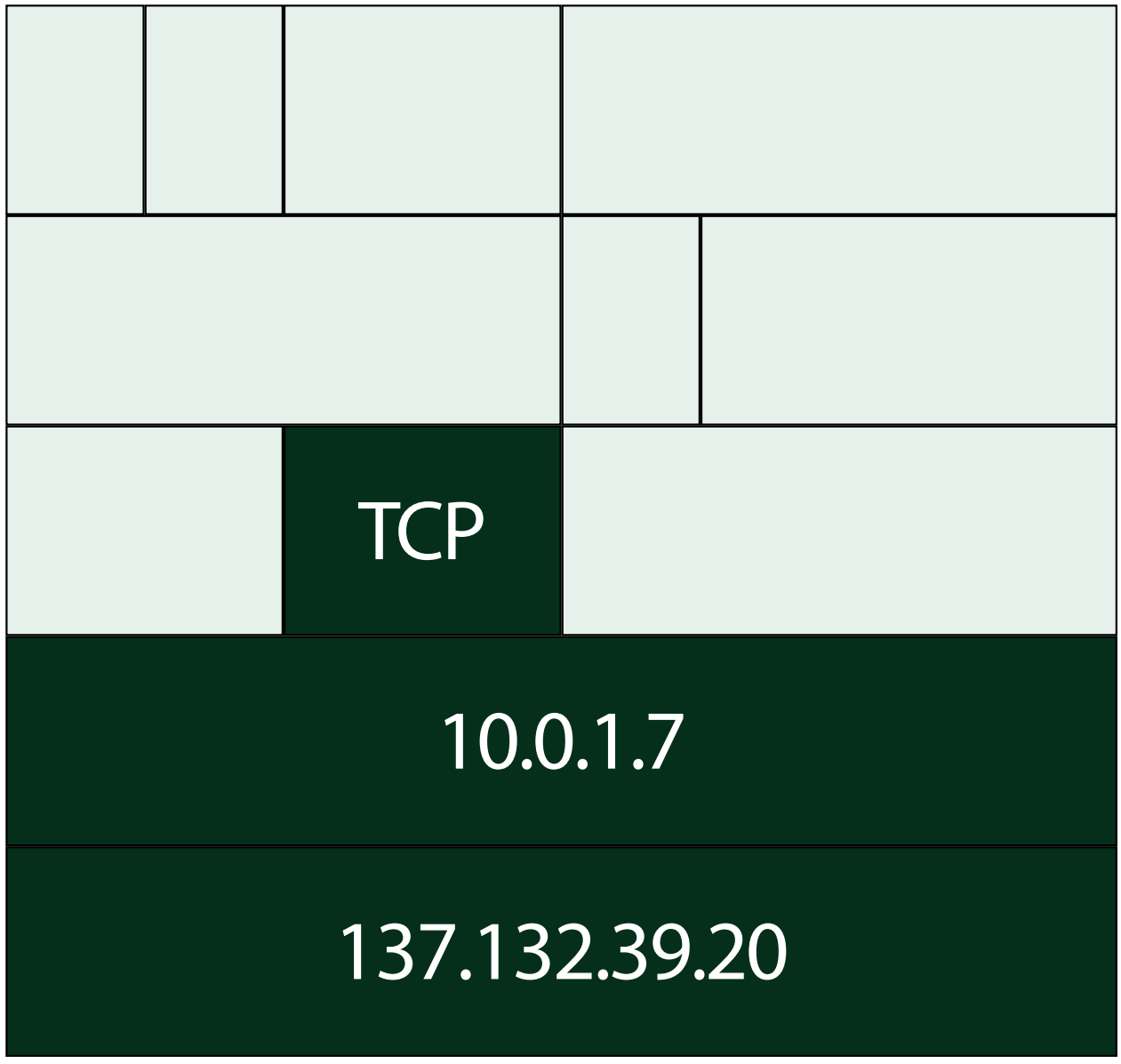
Laptop receives DNS response

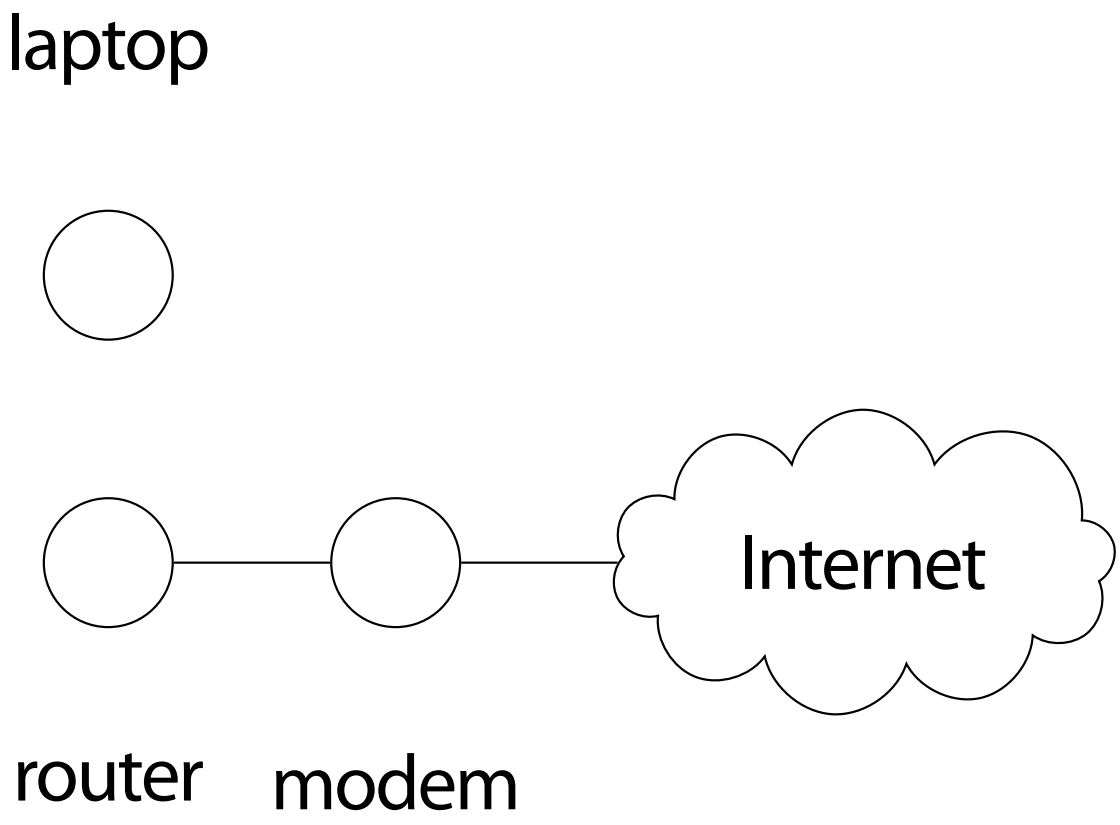
```
;; QUESTION SECTION:
;ivle.nus.edu.sg. IN A

;; ANSWER SECTION:
ivle.nus.edu.sg. 294 IN A 137.132.39.20
```

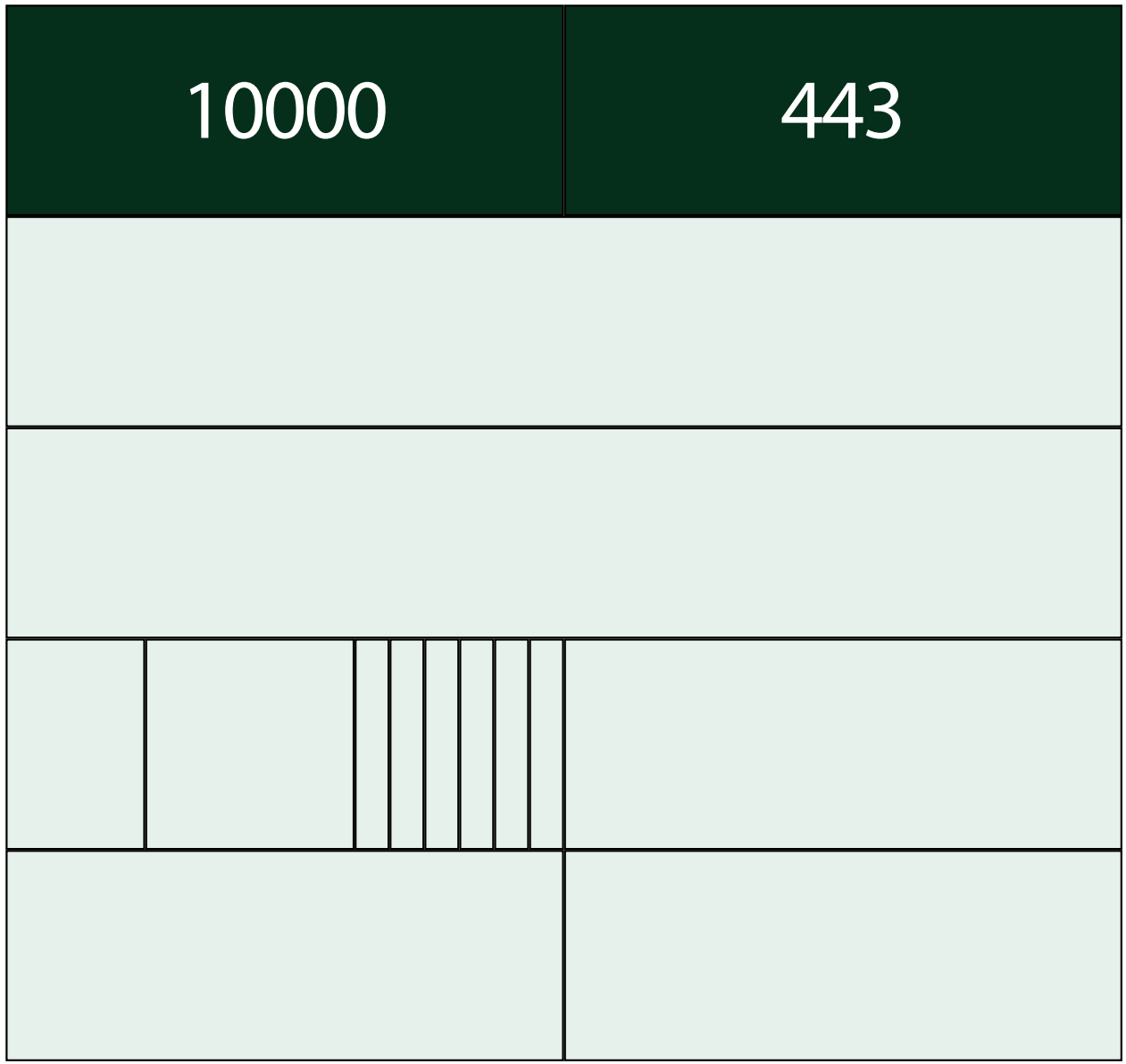
Laptop initiates HTTPS connection (sends TCP SYN to port 443)

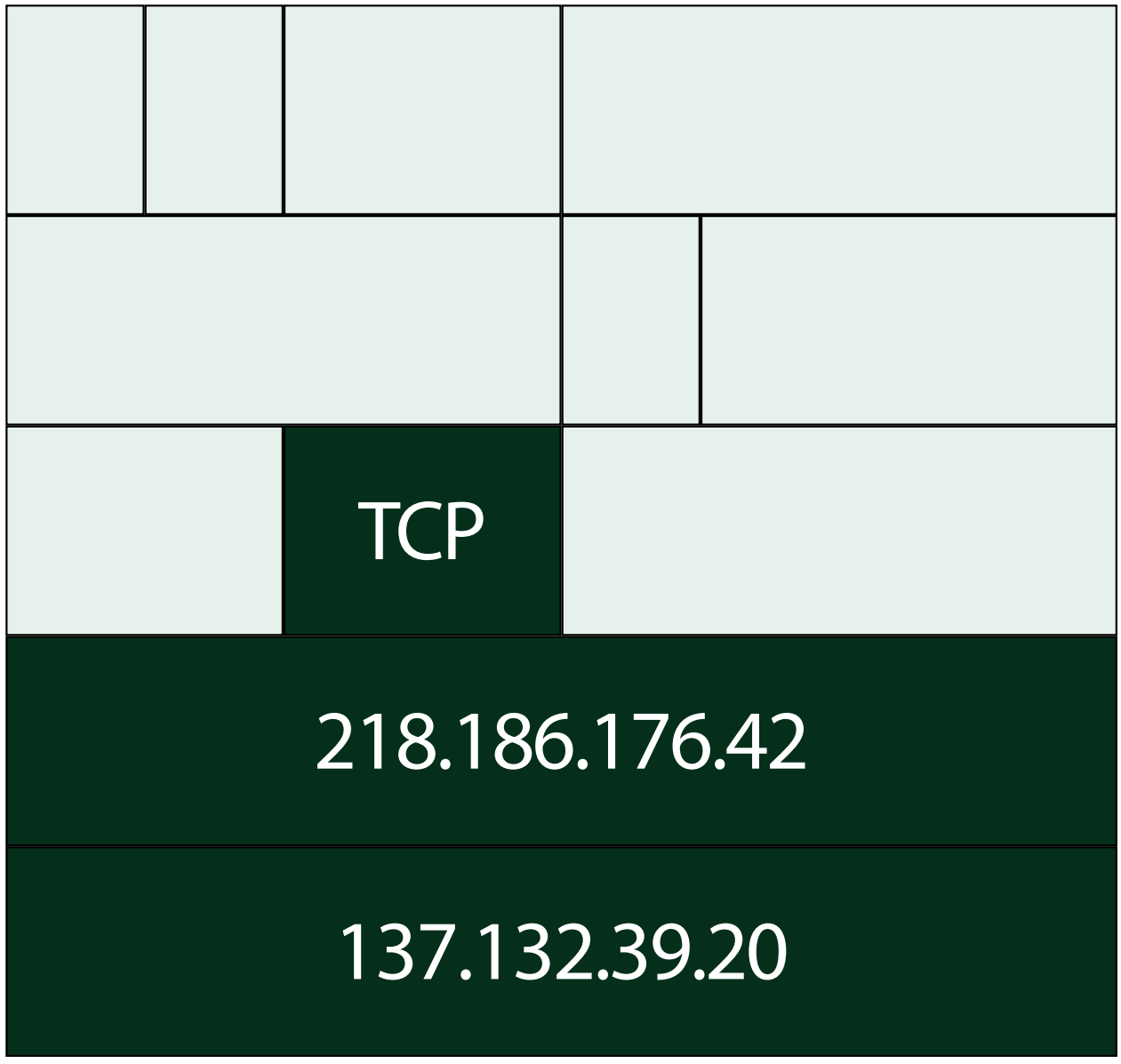

52123
443


TCP
10.0.1.7
137.132.39.20


laptop
Internet
router
modem

Router creates NAT table entry


10000
443


TCP
218.186.176.42
137.132.39.20

```
GET / HTTP/1.1
Host: ivle.nus.edu.sg
User-Agent: Mozilla/5.0
Keep-Alive: 300
Connection: keep-alive
Cookie:__utma=145952555.278120873
```

Transfer data m with sequence number s as m'

$$h = H(m + M_B + s)$$
$$m' = E_B(m, h)$$

Receives m' with expected sequence number s'

$$m, h = E_A(m')$$

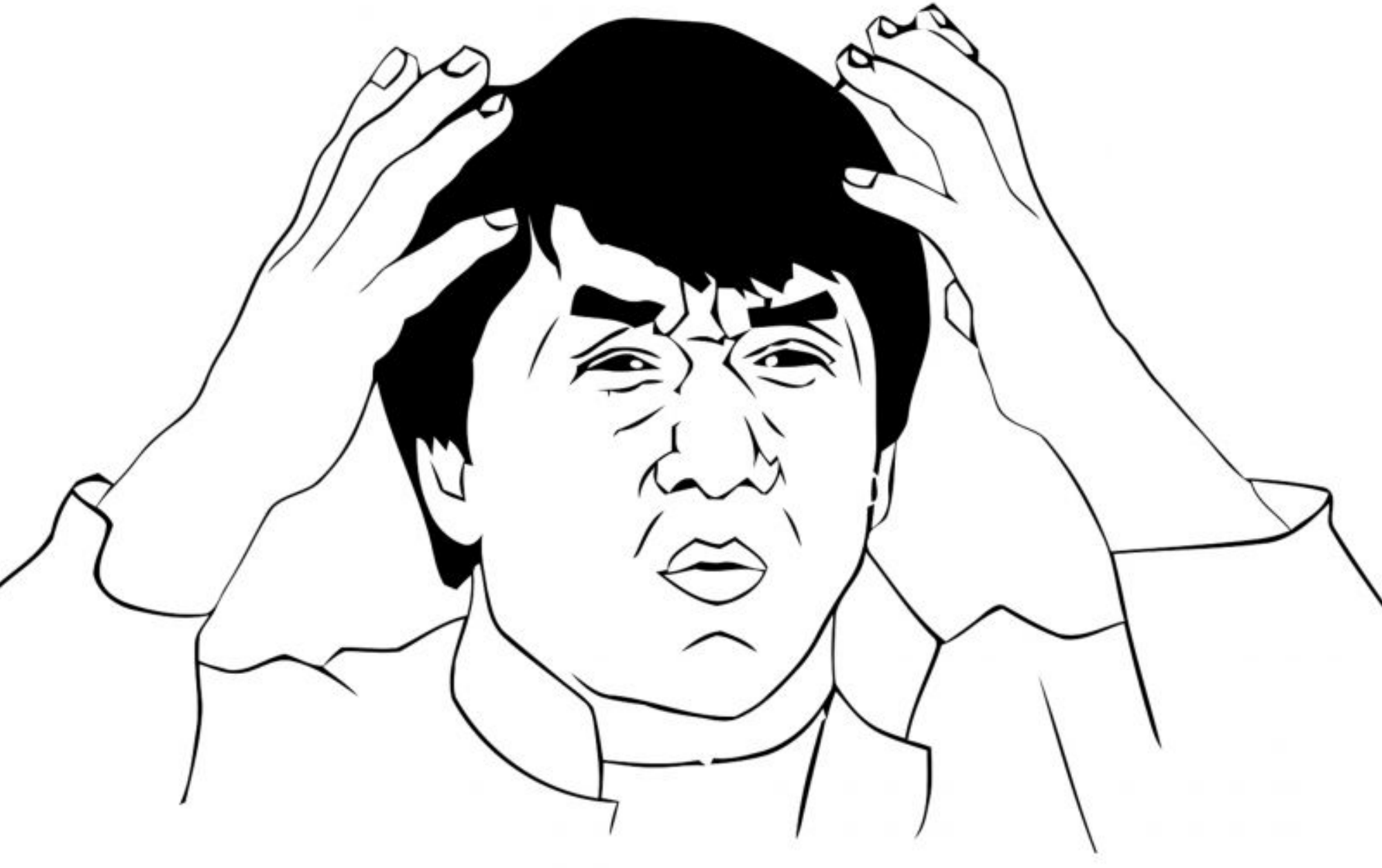
check if $h = H(m + M_A + s')$?

```
HTTP/1.1 200 OK
Content-Type: text/html; charset=utf-8
Server: Microsoft-IIS/7.5
Set-Cookie: ASP.NET_SessionId=jzhnyhv20h..
Date: Thu, 14 Apr 2011 15:58:41 GMT
Content-Length: 39616
Connection: Keep-Alive
```

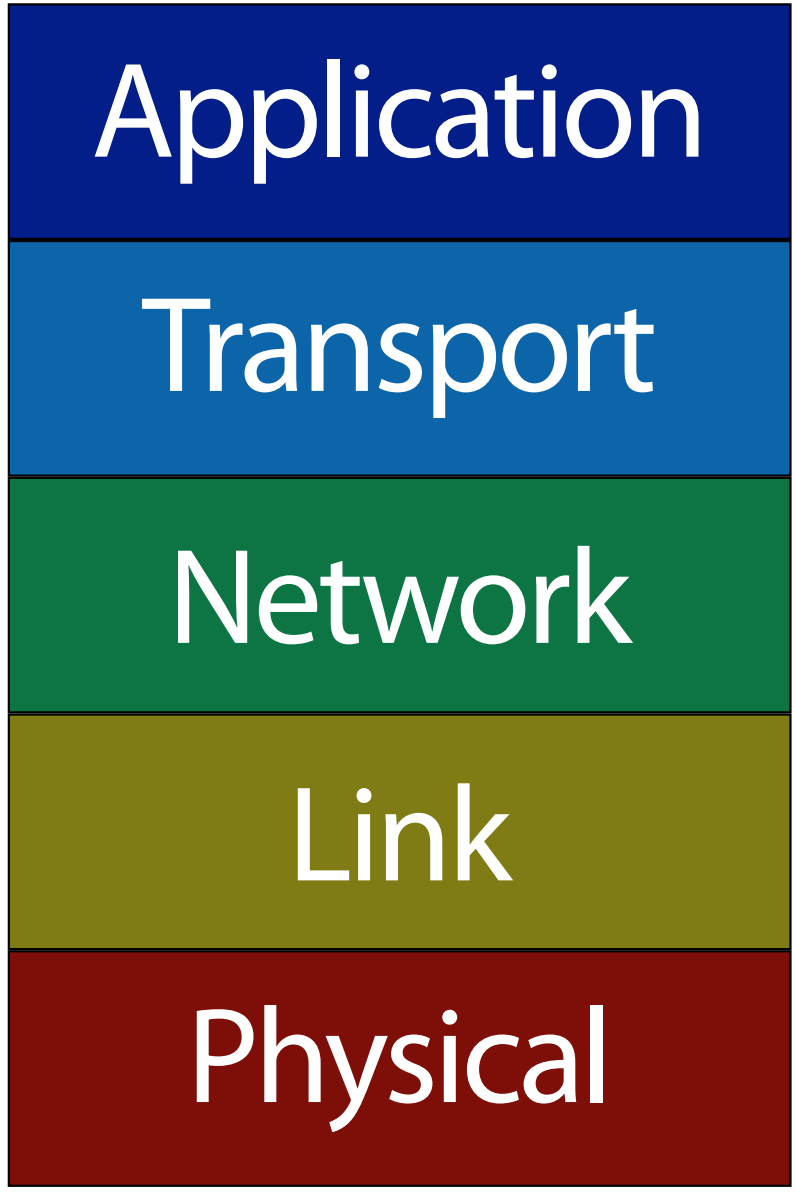
General Lessons from CS2105

How to build a complex system

Many issues to consider, to support different applications running on large number of hosts through different access technology and physical media.



1. Layering


Application
Transport
Network
Link
Physical

- Lower layers hide details from upper layer
- Upper layers make minimum assumptions about lower layer
- Protocols in layers are interchangeable
- Keep lower layer simple, more features at higher layer.

2. Decouple name from address

hostname, cname, IP addr, MAC addr

- Rotate hosts for load balancing
- Change hosts based on geo-location, network conditions
- Replace or move hosts without affecting names

3. Hierarchical Naming/Routing

www.nus.edu.sg

137.132/16

- More organized
- Allow distribution of responsibility
- Allow aggregation of addresses for forwarding
- Other examples: files, zip code

4. Periodically Forget

DNS caches, switching table, DHCP leases, RIP

- Systems adapt quickly
- Prevent stale information automatically

5. Randomization

nonce, TCP sequence numbers, BEB

- Avoid expensive coordination
- Avoid ``coincidence'' (collision, TCP sequence numbers)
- Avoid malicious party from guessing

6. Learn by observation

NAT, Switch, BEB

- Avoid expensive manual configuration
- Adapt to changes automatically

What's Next?

CS2105R 1MC extension
CS3103 Computer Networks and Protocols
CS4222 Wireless and Sensor Networks
CS4274 Mobile and Multimedia Networking
CS4344 Networked and Mobile Gaming
CS5229 Advanced Computer Networks
CS5248 Systems Support for Continuous Media

Acknowledgement

The End