CS 360

Application Layer

Chapter 7

SMTP / DNS / DNSSEC

BitTorrent

Regular Expressions

RFC 2396

```
The following line is the regular expression for breaking-down a URI
reference into its components.

   ^(([^:/?#]+):)?(//([^/?#]*))?([^?#]*)(\?([^#]*))?(#(.*))?
    12            3  4          5       6  7        8 9

The numbers in the second line above are only to assist readability;
they indicate the reference points for each subexpression (i.e., each
paired parenthesis).  We refer to the value matched for subexpression
<n> as $<n>.  For example, matching the above expression to

   http://www.ics.uci.edu/pub/ietf/uri/#Related

results in the following subexpression matches:

   $1 = http:
   $2 = http
   $3 = //www.ics.uci.edu
   $4 = www.ics.uci.edu
   $5 = /pub/ietf/uri/
   $6 = <undefined>
   $7 = <undefined>
   $8 = #Related
   $9 = Related
```

http://en.wikipedia.org/wiki/Regular_expression#POSIX_Basic_Regular_Expressions

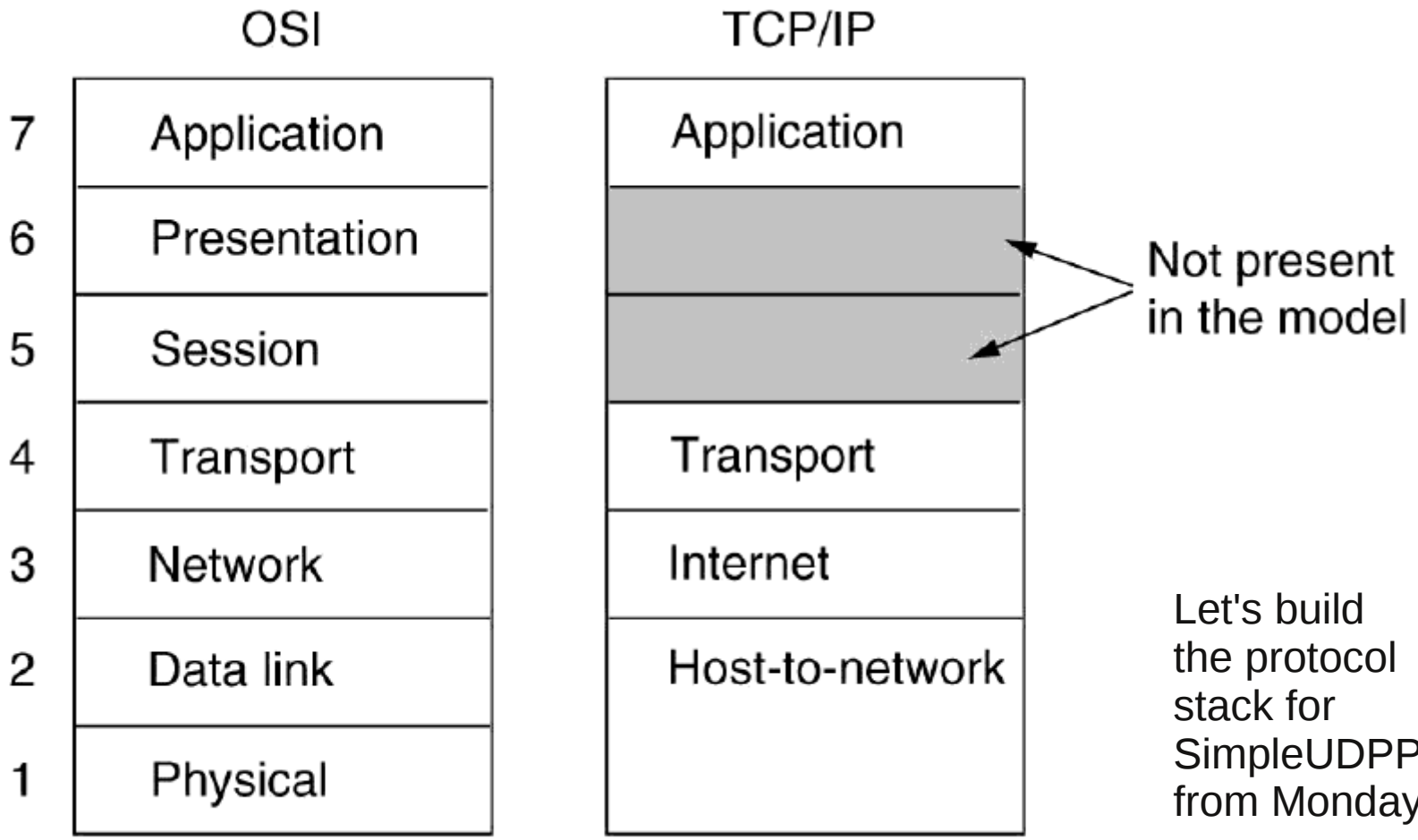
For fun, look up a reg ex to validate email addresses.

Grammars

RFC 1034

```
<domain> ::= <subdomain> | " "

<subdomain> ::= <label> | <subdomain> "." <label>

<label> ::= <letter> [ [ <ldh-str> ] <let-dig> ]

<ldh-str> ::= <let-dig-hyp> | <let-dig-hyp> <ldh-str>

<let-dig-hyp> ::= <let-dig> | "-"

<let-dig> ::= <letter> | <digit>

<letter> ::= any one of the 52 alphabetic characters A through Z in
upper case and a through z in lower case

<digit> ::= any one of the ten digits 0 through 9
```

Network Models (to remind us)



Let's build the protocol stack for SimpleUDPPacket from Monday.

Computer Networks, 4th edition, Tanenbaum, page 43.
similar image on page 46 of the 5th edition.

Application Layer

- Where the meaningful work happens
  - SMTP/IMAP/POP3 (mail)
  - DNS
    - DNSSEC (section 8.9.2)
  - Streaming Media (section 7.4)
    - RTP / RTSP
    - digital encoding of media
  - Content Delivery (section 7.5)
    - P2P | BitTorrent | Chord

Client/Server Model

- A server at a **well-known** IP address listens on a **well-known** port
- A client connects, requests data, etc

/etc/services

```
Keyword         Decimal    Description
-------         -------    -----------
echo              7/tcp    Echo
echo              7/udp    Echo
daytime          13/tcp    Daytime (RFC 867)
daytime          13/udp    Daytime (RFC 867)
qotd             17/tcp    Quote of the Day
qotd             17/udp    Quote of the Day
ftp-data         20/tcp    File Transfer [Default Data]
ftp-data         20/udp    File Transfer [Default Data]
ftp-data         20/sctp   FTP
ftp              21/tcp    File Transfer [Control]
ftp              21/udp    File Transfer [Control]
ftp              21/sctp   FTP
ssh              22/tcp    The Secure Shell (SSH) Protocol
ssh              22/udp    The Secure Shell (SSH) Protocol
ssh              22/sctp   SSH
telnet           23/tcp    Telnet
telnet           23/udp    Telnet
smtp             25/tcp    # Simple Mail Transfer
smtp             25/udp    # Simple Mail Transfer
```


http://www.ietf.org/assignments/port-numbers

netstat -a | less

```
Active Internet connections (servers and established)
Proto Recv-Q Send-Q Local Address           Foreign Address         State
tcp        0      0 *:amanda                *:*                     LISTEN
tcp        0      0 *:mysql                 *:*                     LISTEN
tcp        0      0 *:sunrpc                *:*                     LISTEN
tcp        0      0 *:ssh                   *:*                     LISTEN
tcp        0      0 localhost:ipp           *:*                     LISTEN
tcp        0      0 localhost:smtp          *:*                     LISTEN
tcp        0      0 zeus.cs.pacificu.:54632 ada.cs.pacificu.e:ldaps ESTABLISHED
tcp        0      0 zeus.cs.pacificu.ed:ssh 64.59.233.248:45566     ESTABLISHED
tcp        0      0 *:https                 *:*                     LISTEN
tcp        0      0 *:sunrpc                *:*                     LISTEN
tcp        0      0 *:www-http              *:*                     LISTEN
tcp        0      0 *:ssh                   *:*                     LISTEN
```

List of open "files"

```
lsof
```

Which process is using which file/socket?

need to be root

```
fuser -v -n tcp 80      # verbose, tcp, port 80
```

Transport: Connected/Connectionless

- Connectionless:
  - series of unrelated packets
- Connected
  - stream of data

Telnet

- Very basic, TCP application
- Connect to an address and port and type away!
  - just echos to the screen the data it receives
- Insecure
  - sends data and passwords in *clear text*
- Zeus & Lab machines
  - no telnet servers are running!
  - now we use **ssh**!

Great for testing out your server (if your protocol is ASCII text)

Telnet to the Web server

Address Port

```
chadd@coffee:~> telnet zeus.cs.pacificu.edu 80
Trying 64.59.233.197...
Connected to zeus.cs.pacificu.edu.
Escape character is '^]'.
GET /chadd/index.html HTTP/1.1
Host: zeus.cs.pacificu.edu
<blank line, just [CRLF]>
HTTP/1.1 200 OK
Date: Fri, 03 Feb 2012 21:21:37 GMT
Server: Apache/2.2.21 (Linux/SUSE)
Last-Modified: Wed, 01 Feb 2012 19:43:57 GMT
ETag: "8c100b-3a16-4b7ec4cf20793"
Accept-Ranges: bytes
Content-Length: 14870
Content-Type: text/html

<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
      "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
```

E-Mail

- RFC 822 – ASCII Email messages
  - http://tools.ietf.org/html/rfc822
  - RFC 2822

- Protocols
  - SMTP: Simple Mail Transport Protocol (RFC 821, RFC 1123)
  - POP3: Post Office Protocol (RFC 1939)
  - IMAP: Internet Mail/Message Access Protocol (RFC 1064)
  - why so many?
- User Agent (mail reader)
- Transfer Agent

SMTP/POP3/IMAP

- How does it all work together?
- Mail server
- User agent / mail reader
- What transport protocol should mail use?

- where does hotmail fit? yahoo mail? gmail?
- why is HTML-ified email the devil?

SMTP

- Creating a new message

```
zeus$ telnet smtp.mailexample.net 25
220 smtp.mailexample.net ESMTP qpsmtpd 0.33-dev ready; send us your mail, but not your spam.
HELO cs360.com
250 mailexample.net says hello to cs360.com
MAIL FROM: <professor@cs360.com>
250 sender ok
RCPT TO: student1138@cs360.com
250 recipient ok
DATA
354 Send mail; end with “.” on a line by itself
From: professor@cs360.com
To: student1138@cs360.com
Subject: Cheap Stuff!
Hello! Would you like to buy something?
.
250 Message accepted
QUIT
221 mailexample.net closing connection
```

- Why does this promote spam?
  - what is spam?
  - what is an open relay?

POP3

- Retrieving messages

```
   zeus$ telnet pop3.mailexample.net 110
+OK POP3 server ready
USER chadd
+OK
PASS iwantmail
+OK login successful
LIST
1 2505
2 14302
.
RETR 1
(send message 1)
DELE 1
QUIT
+OK POP3 server disconnecting
```

- POP3 may use *plaintext* passwords
- TLS or SSL *could* be used to encrypt the session

RFC 822 Email Message Syntax

```
B.1.  SYNTAX

message          =   *field *(CRLF *text)

field            =    field-name ":" [field-body] CRLF

field-name       =  1*<any CHAR, excluding CTLs, SPACE, and ":">

field-body       =   *text [CRLF LWSP-char field-body]
```

Notation:

1*mWORD

WORD must appear in repetition between 1 and *m* times

1*WORD

WORD must appear in at least once, and may be repeated

***WORD**

WORD may be repeated

MIME

base64?
octet?

- Email is ASCII
  - uuencode/uudecode (in the old days)
- Multipurpose Internet Mail Extensions (RFC 2045)
  - allows us to send non ASCII data via email
  - examples?
  - No such thing as a free lunch, what does this cost us?

```
MIME-Version: 1.0
Content-type: image/jpeg
Content-Transfer-Encoding: base64
```

  - where else is this used?
    - where else do we send all data as ASCII?

http://tools.ietf.org/html/rfc2045#section-6.8

Received: from M.mailexample.net (M.mailexample.net [127.0.127.04])
by circular.mailexample.net (8.12.11.20060308/8.12.5) with ESMTP id l0UIKMEa011117;
Tue, 30 Jan 2007 13:20:22 -0500
Received: from dispatch.mailexample.net (dispatch.mailexample.net [127.0.128.60])
by M.mailexample.net (8.12.10/8.12.5) with ESMTP id l0UIKEAQ022812
for <list@M.mailexample.net>; Tue, 30 Jan 2007 13:20:14 -0500 (EST)
Received: from [127.0.130.105] (wedge.pc.mailexample.net [127.0.130.105])
by dispatch.mailexample.net (8.13.1/8.12.5) with ESMTP id l0UIKClP006424
(version=TLSv1/SSLv3 cipher=DHE-RSA-AES256-SHA bits=256 verify=NO);
Tue, 30 Jan 2007 13:20:12 -0500
Message-ID: <45BF8C5C.8040108@mailexample.net>
Date: Tue, 30 Jan 2007 13:20:12 -0500
From: Da Boss <boss@mailexample.net>
User-Agent: Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:1.7.11) Gecko/20050728
MIME-Version: 1.0
To: list@mailexample.net
Subject: Comments on talk titles
Content-Type: text/plain; charset=us-ascii; format=flowed
Content-Transfer-Encoding: 7bit
X-CSD-MailScanner-Information: Please email staff@mailexample.net for more information
X-CSD-MailScanner: Found to be clean
X-CSD-MailScanner-SpamCheck: not spam, SpamAssassin (score=-1.44,required 5)
X-CSD-MailScanner-From: boss@mailexample.net

Hello! How are you? Do you like the titles of these talks?

Network Stack Review

- Message — Connectionless
- Stream — Connection-oriented

Transport

Internet/Network

- Routing

DNS

- Domain Name System (RFC 1034, 1035, 2181)
  - What is DNS?
  - When do we use it?
  - What is a domain?
  - what does this address mean: zeus.cs.pacificu.edu

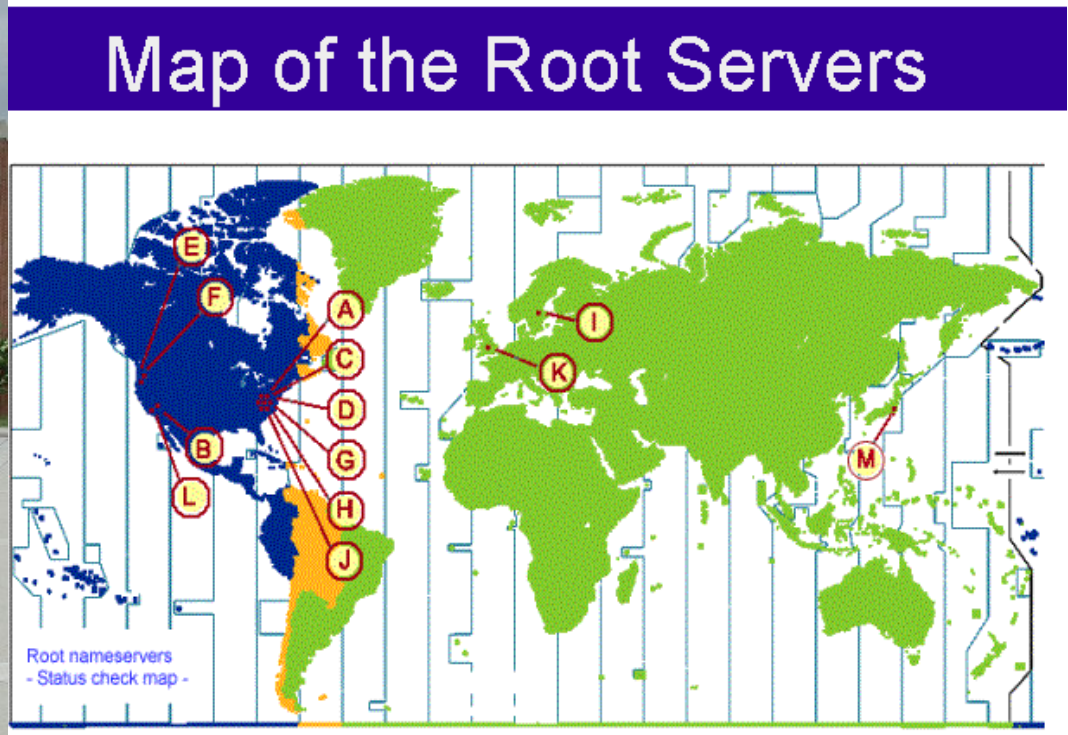
DNS

- How does it work?
  - originally, just ONE file, hosts.txt, that was copied around to all the machines on the Internet (ARPANET) every night
    - /etc/hosts file still exists in UNIX
    - look here first, then queries the DNS server
    - on zeus: `cat /etc/hosts | more`
    - on Windows `system32\drivers\etc\hosts`
    - hmmmm. what havoc could we wreak by writing to this file?

- Zones:
  - non-overlapping areas in the DNS
  - each zone as its own Name Server (plus a back up or two)
    - the Name Server contains the *authoritative* records for all hosts in the zone
    - not cached, always correct

DNS Root Servers

- 13 root servers spread across the globe
  - http://d.root-servers.org/
  - University of Maryland, College Park
  - In the basement of the Computer Science Department
  - each “root server” is really a cluster of servers



http://www.icann.org/correspondence/root-map.gif

Need an Address?

/etc/resolv.conf

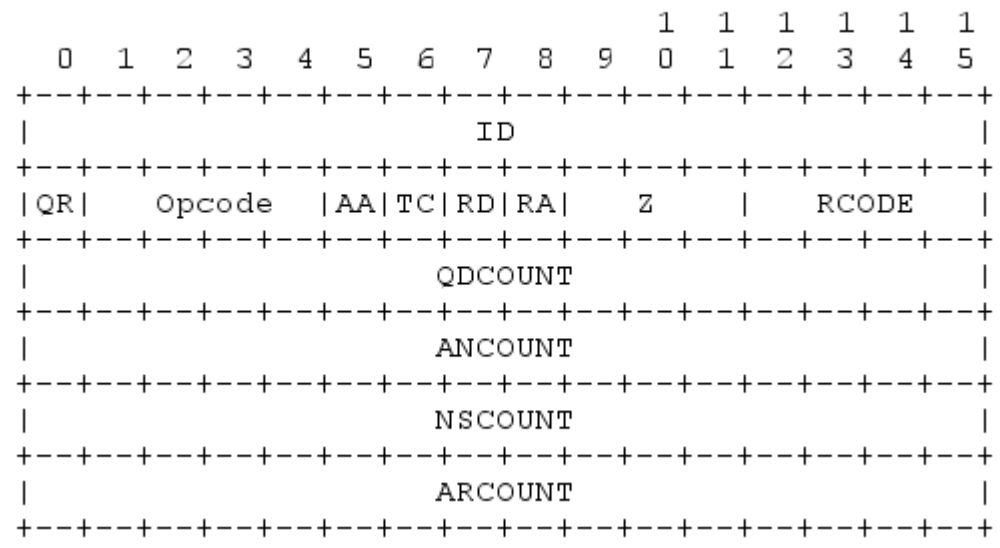
- Need to find an address?
  - Use the *resolver* to look it up via a name
    - *resolver* – a network application distributed as part of an OS
  - UDP packet is sent to the local DNS nameserver
  - UDP packet is sent back with the *Resource Record*
    - why UDP?
- Resource Record
  - **Domain Name**: pacificu.edu (string)
  - **TimeToLive**: How stable is this record (int, seconds)
  - **Class**: In – Internet (string)
  - **Type**: A – IPv4 Address, AAAA - IPv6 Address, SOA – Authority Info, NS – Name Server, MX - mail exchange (string)
  - **Value**: Data (IP address)

DNS Protocol

http://tools.ietf.org/html/rfc1035

```
+---------------------+
|        Header       |
+---------------------+
|       Question      | the question for the name server
+---------------------+
|        Answer       | RRs answering the question
+---------------------+
|      Authority      | RRs pointing toward an authority
+---------------------+
|      Additional     | RRs holding additional information
+---------------------+
```

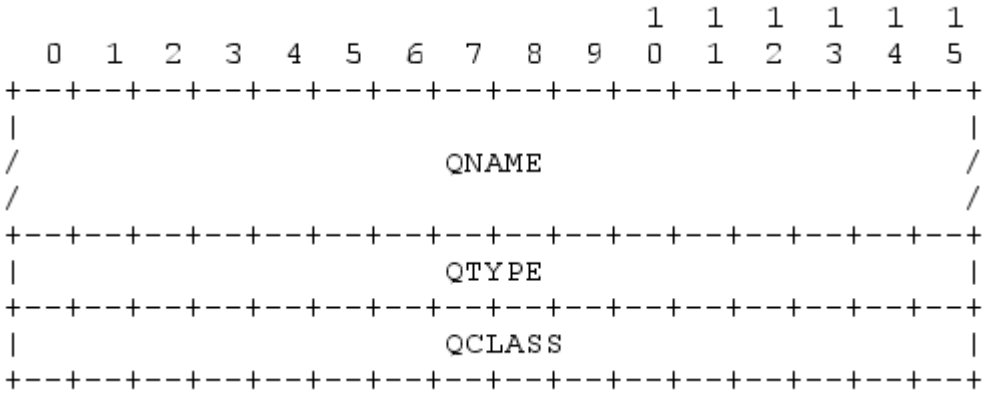
The header contains the following fields:



- ID
- QR
- OpCode
- AA
- TC
- RD
- RA
- Z (Updated: RFC 2065 section 6.1)
- RCode
- xxCount

DNS

Question Section



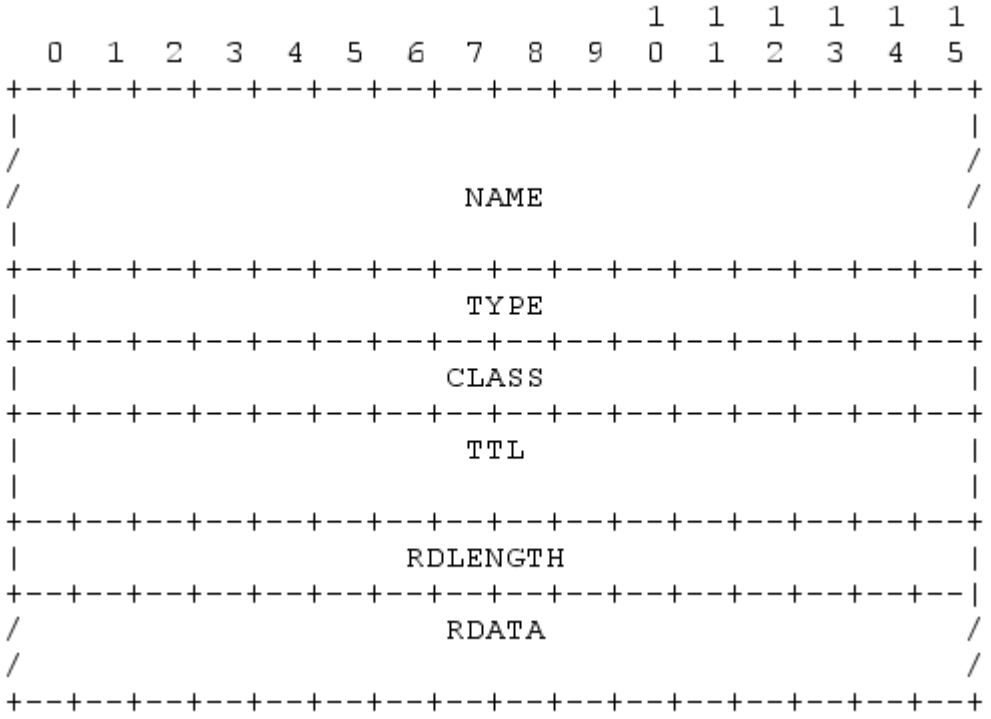
QName

QType

QClass

DNS

Resource Record



Name
Type
Class
TTL
RDLength
RData

Compression.

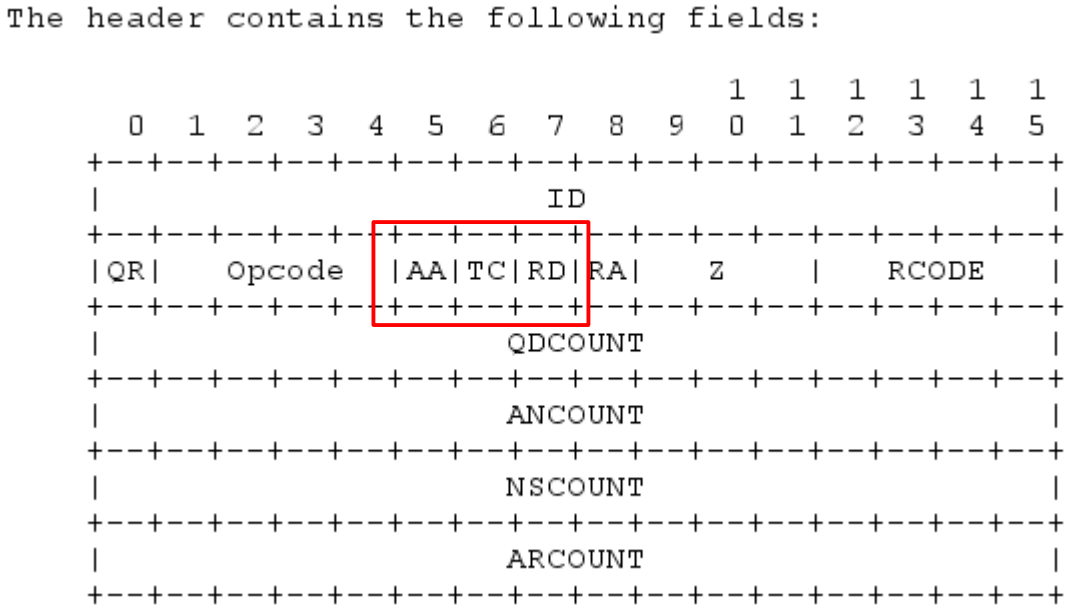
Bit Flipping in Java

| bit-wise OR

& bit-wise AND

>> shift right

<< shift left




```
byte tmpByte;
byte RD=1, TC=0, AA=1;

tmpByte =(byte) ( (AA<<2) |  (TC << 1) | RD);
```

Let's find an address

- resolve(zeus.cs.pacificu.edu);
- query local Name Server for the record
  - if that address is found, return it and stop.
- query (root server) Name Server for .edu TLD Servers
- query (edu server) Name Server for pacificu.edu
- query (pacificu.edu) Name Server for cs.pacificu.edu
- query (cs.pacificu.edu) Name Server for zeus.cs.pacificu.edu
  - *cache* the Resource Records retrieved since you might need them again soon
    - what problems are there with caching?

DNS in action

```
coffee$ nslookup
> cnn.com
Server:         64.59.233.200
Address:        64.59.233.200#53

Non-authoritative answer:
Name:   cnn.com
Address: 157.166.255.18
Name:   cnn.com
Address: 157.166.255.19
Name:   cnn.com
Address: 157.166.226.25
Name:   cnn.com
Address: 157.166.226.26
> set querytype=soa
> cnn.com
Server:         64.59.233.200
Address:        64.59.233.200#53
Non-authoritative answer:
cnn.com
        origin = ns1.timewarner.net
        mail addr = hostmaster.turner.com
        serial = 2012020301
        refresh = 28800
        retry = 7200
        expire = 604800
        minimum = 3600
Authoritative answers can be found from:
ns1.timewarner.net      internet address = 204.74.108.238
```

- What is going on here?
- Why do we have so many answers?
- What is non-authoritative?

- Why is this in the Application Layer, IP does routing, right?

How do I register a domain name?

- Use a company called a *registrar*
  - for a fee, they maintain lists of available domain names
  - you provide an IP address, the provide a DNS Name
  - previously, one company did this: Network Solutions
  - now a huge number of companies do this
    - many of them provide other services (web/mail hosting, etc)

- What about those companies that let you register a domain name for your dialup/DSL connection?
  - www.dyndns.com, www.tzo.com
  - why is a dialup/DSL connection a problem?

DNS: What can go wrong?

- http://news.zdnet.com/2100-1009_22-6156944.html?tag=nl.e589
- Root DNS servers were flooded with traffic (servers: *F, I, M*, G, L)
  - early morning Tuesday (West coast time)

- How can this affect the Internet?

- What mechanisms are in place in DNS to mitigate this type of attack?

- Did you notice a problem?
  - In 2002 a similar attack shutdown 9 of the 13 root servers

Example Code

zeus.cs.pacificu.edu/home/cs360s12/SVNROOT/CS360Utils

Data is tranferred on the network in Network Byte Order; Big Endian

In C, you must use htonl() and ntohl()

Your CPU [usually] defines Endianness.
x86 is Little Endian

However:
Java is ALWAYS big Endian.
Some CPUs support both.

```
/* BIG ENDIAN
 *
 * -----------
 * |high| low| VALUE
 * -----------
 * | 00 | 01 | = 0x1
 * -----------
 *    x   x+1  ADDRESS
 *
 * The high value byte is in the LOW address and thus
 * is the first byte read/written when using a ByteBuffer.
 *
 */
```

```
/**
 * Reads two bytes from a ByteBuffer that represent a 16-bit
 * unsigned short in Network Byte Order (Big Endian) and
 * transforms that unsigned short into a 4 byte signed int.
 * @param bb The ByteBuffer to read from
 * @return the signed int representation.
 */
public static final int unsignedShortFromBB(ByteBuffer bb)
{
    int i = 0;

    // get the high value byte
    i = (bb.get() & 0xFF)<< 8 ;

    // get the low value byte
    i = i | ((bb.get() & 0xFF) );

    //System.err.println("VALUE:" +i);

    return i;
}
```

```
/**
 * Writes the int value into the ByteBuffer in the format of a
 * 16-bit unsigned short in Network Byte Order (Big Endian).
 *
 * @param bb the ByteBuffer to write to
 * @param value the value to write to the ByteBuffer
 * @return the int value
 * @throws Exception if the int value to be put into the ByteArray
 * is out of range of 16 bit unsigned int
 */
public static final int unsignedShortToBB(ByteBuffer bb, int value)
        throws Exception
{
    if( value < 0 || value > 65535)
    {
        throw new Exception("Overflow");
    }

    // get the high value byte for writing
     byte b = (byte) ((value & 0xff00) >> 8);
     bb.put(b);

     // get the low value byte
     b = (byte) ((value & 0xff));
     bb.put(b);

     return value;
}
```

Peer to Peer (7.5)

Read all of 7.4 for Monday!

- What is a peer?
- What is a client?
- High level idea?
- Challenges?

How is p2p different than client/server?

How is this similar/different to/from DNS?

Peer-to-Peer

- *Computer Networking: A Top-Down Approach Featuring the Internet, 3rd edition*. Kurose, Ross. In my office if you want to read it.

- Ethical/Legal issues:
  - http://iptps03.cs.berkeley.edu/final-papers/copyright.pdf
  - http://freenetproject.org/papers/freenet-ieee.pdf
  - Legit uses?

Napster

- Very early P2P system
  - 1999
  - shutdown by court order

Pop up and share

- Centralized index
  - upload your list of shared data
  - receive IP address of peers sharing data you want

Gnutella (0.4)

- Decentralized
- Protocol, many clients
  - LimeWire (uses Gnutella and BitTorrent)
  - morpheus, BearShare, Gtk-Gnutella....

- Bootstrap
- Creates an *overlay network*
- Query flooding: send a query to all your peer
  - each peer forwards on the query if they don't have the data
    - max number of hops
    - send response back through the path the query took
  - how is this good?
  - how is this bad?
    - how can we fix it?

Gnutella 0.6

- Add ultrapeers
  - each peer is connected to small number of ultrapeers
  - each ultrapeer is connected to many ultrapeers
    - high out degree
  - Lower max number of hops
  - send results directly to requester

Bit Torrent

- How is this fundamentally different?

- .torrent file?
  - tracker
    - swarm
    - seeder
    - leecher
  - chunks

Reward good behavior

randomly select peers

trade chunks with peers with best performance
unchoked

poor performing nodes will get choked off

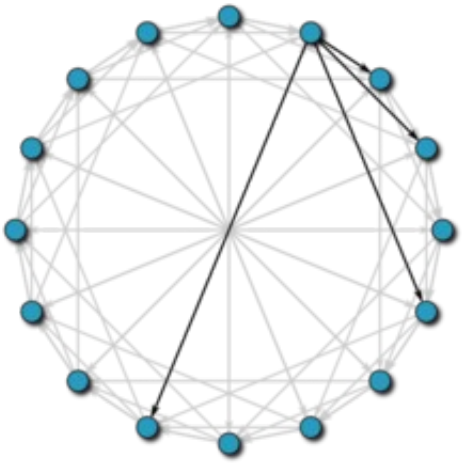
Chord

- Hashtable (key, data)
- DHT (Distributed Hash Table)
  - structured
  - decentralized
  - fault tolerance
  - scalability
- Hash the key to find the containing node
  - move data to correct node
  - store *data* at node *hash(key)*
  - the *data* will outlive you

Built for more persistent storage
Could build a distributed file system
CFS

replicate data amoung nodes
move data as nodes join/leave

overlay network



http://en.wikipedia.org/wiki/File:Chord_network.png

OceanStore

- "OceanStore is a global persistent data store designed to scale to billions of users. ... atop an infrastructure comprised of untrusted servers."

- Uses Chimera
  - an implementation of DHT
  - similar to Tapestry and Pastry