Application Layer V

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Homework #2

• Unlike HTTP, all fields are binary
  – Make sure to refresh pointers
• Question format:

```
<table>
<thead>
<tr>
<th>str1 size</th>
<th>str1</th>
<th>...</th>
<th>strn size</th>
<th>strn</th>
<th>0</th>
<th>Query type</th>
<th>Query class</th>
</tr>
</thead>
</table>
```

• Create classes for fixed headers
  – Fill in the values (flags: DNS_QUERY and DNS_RD, nQuestions = 1)
  – Allocate memory for the packet
  – Fill in various fields into buffer

```
class QueryHeader {
    u_short type;
    u_short class;
};

class FixedDNSHeader {
    u_short ID;
    u_short flags;
    u_short questions;
    ...
};
```
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• High-level operation for DNS questions:

```c
char packet [MAX_DNS_LEN];  // 512 bytes is max
char host[] = “www.google.com”;
int pkt_size = strlen(host) + 2 + sizeof(FixedDNSHeader) + sizeof(QueryHeader);

// fixed field initialization
FixedDNSHeader *dh = (FixedDNSHeader *) packet;
QueryHeader *qh = (QueryHeader*) (packet + pkt_size - sizeof(QueryHeader));
dh->ID = ...
dh->flags = ...
...
qh->type = ...
qh->class = ...

// fill in the question
MakeDNSquestion (dh + 1, host);
// transmit to Winsock
sendto (sock, packet, ...);
```

• If packet is incorrectly formatted, you will usually get no response; use Wireshark to check outgoing packets
Homework #2

• Formation of questions:

```c
makeDNSquestion (char* buf, char *host) {
    while(words left to copy){
        buf[i++] = size_of_next_word;
        memcpy (buf+i, next_word, size_of_next_word);
        i += size_of_next_word;
    }
    buf[i] = 0; // last word NULL-terminated
}
```

• All answers start with an RR name, followed by a fixed DNS reply header, followed by the answer
  - Uncompressed answer (not common)
    0x3 “irl” 0x2 “cs” 0x4 “tamu” 0x3 “edu” 0x00
    `<DNSanswerHdr> <ANSWER>`
  - Compressed (2 upper bits 11, next 14 bits jump offset)
    0xC0 0x0C `<DNSanswerHdr> <ANSWER>`

• For type-A questions, the answer is a 4-byte IP
Homework #2

• To check the header
  – Hex printout on screen
  – Use Wireshark

• What is sizeof(DNSanswerHdr)?
  – The actual size is 10 bytes, but most structures in C/C++
    are aligned/padded to 4 (or 8) byte boundary

• Remember to change struct
  packing of all classes that define
  binary headers to 1 byte

• Caveats (must be properly handled):
  – Exceeding array boundaries on jumps
  – Infinite looping on compressed answers
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- How to check if compressed and read 14-bit offset?
  
  - Suppose array `char *ans` contains the reply packet
  
  - The answer begins within this array at position `curPos`

```
1 1 x x x x x x x x x x x x
```

14 bits

```
char *ans; // points to reply buffer
if (ans[curPos] >= 0xC0)
  // compressed; so jump
else
  // uncompressed, read next word
```

```
char *ans; // points to reply buffer
if ( (ans[curPos] >> 6) == 3)
  // compressed; so jump
else
  // uncompressed, read next word
```

```
// computing the jump offset
int off = ( (ans[curPos] & 0x3F) << 8) + ans[curPos + 1];
```

- These examples are **incorrect**
  
  - Use only **unsigned** chars when reading buffer!
Homework #2

• Note that jumps may appear in mid-answer
  0x3 “irl” 0xC0 0x22 <DNSanswerHdr> <ANSWER>

• Jumps may be nested, but must eventually end with a 0-length word
  – Need to remember the position following the very first jump
    so that you can come back to read the answer

• Replies may be malicious or malformatted
  – Homework must avoid crashing

• If AAAA (IPv6) answers are present, skip
  – Use DNSanswerHdr::len to skip unknown types

• Caution with SuddenLink and dorms
  – Too many malformed packets may raise an alarm
Chapter 2: Roadmap

2.1 Principles of network applications
2.2 Web and HTTP
2.3 FTP
2.4 Electronic Mail
   - SMTP, POP3, IMAP
2.5 DNS (extras)
2.6 P2P file sharing
Domain Flux

- Viruses, trojan horses, rootkits, and various malware affect millions of computers nowadays.
- 20 years ago, viruses mostly performed pranks or corrupted data, but this has changed.
  - Modern attacks are often driven by financial gains.
- Infected hosts are organized into botnets.
  - Large collection of computers under control of a botmaster.
- Early botnets used IRC (Internet Relay Chat) to send and receive commands.

Case at hand: Jeremy Jaynes (arrested in 2004) sent an estimated 10M emails/day, pulling $750K/month income.
Domain Flux 2

• Eventually, ISPs started blocking IRC traffic
  – Also, IRC servers were easy targets for shutdown and filtering (e.g., detection of encrypted commands and botnet channels)

• New generation of botnets uses dynamically changing rendezvous points called C&C (command & control)
  – Stealthy because C&C’s IP can rapidly change over time
  – Main problem: how does the botnet find the current C&C?
Domain Flux 3

• **Fast flux** is a method for discovering the IP address of C&C and other resources the botnet may need
  - Botmaster registers a domain (say xyz.com) and updates the A record of www.xyz.com with high frequency
• Botnet contacts nameserver ns.xyz.com and obtains the current IP of the C&C (or multiple ones)
Domain Flux 4

• Main defense against botnet traffic is blocking communication with the C&C
  - Fast Flux makes it much harder since the C&C changes over time and is load-balanced across several hosts
  - When C&C is blocked, botnet learns other locations quickly

• Fast flux can also be used to serve phishing content
  - Suppose email arrives to user with a link to www77.xyz.com
  - Botnet uses DNS to serve this request from a variety of compromised hosts
Domain Flux 5

• Several benefits to serving HTTP content using fast flux
  – Difficult to trace IPs hosting content or block malicious URLs
  – Botnet is failure resilient -- if hosts are cleaned or go offline, there is automatic fail-over to other live hosts
  – Cheap in terms of bandwidth, simple to implement

• However, there is a problem
  – Suppose ISP or SpamAssassin blocks all requests for xyz.com or registrar disables xyz.com?
  – If xyz.com is taken down, the botnet freezes

• Domain flux aims to solve this issue
  – Botnet constantly generates random domain names and tries to resolve them to find the C&C
  – Much more difficult to trace and block

Nowadays, TLD servers auto-detect fastflux and block suspected domains in conjunction with the registrar
Domain Flux 6

• Toy example:
  – Suppose botnet computers generate names using this sequence: 1.com, 2.com, 3.com, 5.com, 8.com, 13.com, etc.
  – Current domain name stays in effect until it is blocked
  – Initially, botmaster registers 1.com and 34.com
  – When 1.com gets blocked, the botnet automatically switches to 34.com, while botmaster registers 144.com, and so on

• In reality, the botnet goes through thousands of failed lookup attempts until it finds an active domain
  – Can be detected from a huge number of failed DNS queries

• Domains may be too random to be human-produced
  – If so, machine-learning algorithms can be used to detect infected hosts that are attempting domain flux
Domain Flux 7

• In some cases, reverse engineering the random generator allows one to predict future domain names
  - By registering these domains, botnets can be hijacked
  - Researchers have shown this is possible in B. Stone-Gross et al., “Your botnet is my botnet: Analysis of a botnet takeover,” ACM CCS, 2009.

• How large are botnets? Some examples:
  - BredoLab (2009): 30M hosts, 3.6B emails/day
  - Conficker (2008): 10.5M hosts, 10B emails/day
  - Cutwail (2007): 1.5M hosts, 74B emails/day
  - Torpig (paper above): 180K hosts (theft of 500K bank accounts, credit cards)
Chapter 2: Roadmap

2.1 Principles of network applications
2.2 Web and HTTP
2.3 FTP
2.4 Electronic Mail
   - SMTP, POP3, IMAP
2.5 DNS
2.6 P2P file sharing
Hybrid P2P

• Napster (1999): novelty in shifting paradigms
  - Client/server architecture is blatantly questioned
  - Unreliable users now play the role of servers!

• Instructive in what it got right… and also wrong
  - Napster had substantial political, economical, technological, and legal implications

• What is it?
  - Service for sharing files
  - Tool for copyright infringement
  - Disruptive technology

• History
  - 5/1999: Shawn Fanning (freshman at Northeastern) founds Napster Online
  - 12/1999: first lawsuit
  - 3/2000: 25% of University of Wisconsin traffic is Napster
  - 2001: 50 million users, 160K simultaneously online
Hybrid P2P

• Operation of Napster
  – Application-layer protocol over TCP
  – Centralized directory server

• Sequence of steps
  – Connect to server, login
  – Upload your IP/port + list of files
  – Give server keywords for search
  – Select “best” answer (ping)
  – Download from peer

• Single point of failure
• Performance bottleneck
• Target for litigation due to copyright infringement
Hybrid P2P

• In 2001, court holds Napster responsible for copyright violations by users
  – Sending it into bankruptcy

• Who should be responsible for actions of users…
  – Company that makes device being used illegally?

• Betamax case (1983)
  – Sony sued by Universal and Disney over legality of VCRs
  – Supreme Court decided Betamax had legal purposes (time shifting, home video)

• Direct infringement
  – Making unauthorized copies of copyrighted work

• Indirect infringement
  – Helping others make unauthorized copies

• Where to draw the line?
  – Device’s intended purpose
  – Lack of effort to prevent illegal activities

• Napster never handled copyrighted files, but…
  – Software was designed with main purpose to illegally distribute music
Decentralized P2P

• Napster folded in 2002, later bought by Roxio, now part of Rhapsody
  – Other P2P systems take over (Gnutella, KaZaA, BitTorrent, eDonkey)
• Gnutella/0.4 (2001)
  – Public-domain protocol
  – Fully distributed design
• Many Gnutella clients implementing protocol
  – Limewire, Morpheus, BearShare

• How to find content?
• Idea: construct a graph
  – Edge between peer X and Y iff there’s a TCP connection between them
• All active peers and edges are called an overlay network
  – Peer typically connected to < 30 neighbors
• Search proceeds by flooding up to some depth
  – Limited-scope flooding
Decentralized P2P

- Queries are P2P
  - Inefficient due to huge volumes of traffic
  - Average degree $k$, depth of flood $d$, overhead $(k-1)^d$
- Downloads are P2P from a single user
  - Unreliable (peer departure or failure kills transfer)
  - Inefficient (asymmetry of upstream/downstream bandwidth)
- Join protocol (bootstrapping)
  - Find an entry peer $X$, flood its neighbors to obtain more candidates, establish connections to those who accept
Hierarchical P2P

- Gnutella/0.4 scaled to about 25K users and then choked
- Alternative construction proposed by KaZaA (2002)
  - Peer is either a group leader (supernode) or assigned to one
- Group leader tracks the content of all its children, acting like a mini-Napster
  - Peers query their group leaders, which flood the supernode graph until some number of matches found
  - Query-hits not routed, but sent directly to original supernode
Hierarchical P2P

• With 150 neighbors, this architecture is 150 times more efficient than Gnutella/0.4 in message overhead
  - With 389M downloads as of 2008, KaZaA was more popular than Napster ever was, accounting for 50% of ISP bandwidth in some regions and running 3M concurrent users

• Gnutella/0.6 soon adopted the same structure
  - Scaled to 6.5M online users, 60M unique visitors per week

• Additional features
  - Hashed file contents to identify exact version of files
  - Upload and request queuing at each user, rate-limiting
  - Parallel downloads from multiple peers
  - Support for crawl requests that reveal neighbors
**Other P2P**

- **Terminology**: user holding a complete file is a **seed**
  - Traditional systems download only from seeds
  - Seed departs, transfer fails
- **Idea**: let non-seeds grab chunks from each other
  - Peers organize into a group (torrent) based on the file they’re downloading
- **Traditional systems** download files **sequentially**
  - Starvation for final blocks

- **Idea**: maximize availability
  - Participants forced to serve chunks they have to others
  - **Rarest** chunk in torrent is always replicated first

- **Known as** **BitTorrent** (2001)
  - Protocol with many implementations
  - Requires **trackers** to keep torrent membership
  - At any time, more concurrent users that YouTube and Facebook combined

- **Built-in incentives to share**
  - Rate-limiting (**choking**) based on upload activity
Other P2P

- Tor (Onion Router)
  - Anonymity network of peers
- Each packet sent through a random chain of P2P nodes
  - Final user relays packet towards destination
  - Return packets processed similarly along reverse path
- Tor can be run thru an API
  - Extremely slow
  - Many exit points are known and blocked by Google
- Roughly 36M users

- Freenet
  - Anonymous information exchange, hiding identities of communicating parties

- Skype chat
  - Video streaming services either directly between users or relayed through non-firewalled peers

- Distributed Hash Tables
  - General class of P2P systems that map information into high-dimensional search space with guaranteed bounds on delay to find content