Network Security

Security aspects of TCP/IP

Radboud University, The Netherlands

Spring 2019

A short recap

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  - Hubs distribute data to everyone (but are largely obsolete)
  - Use ARP cache poisoning on switched Ethernet
  - Wireless LAN behaves a lot like hubbed Ethernet
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- Most threatening in WPA2: bad passphrases, backwards-compatible TKIP

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- *Stop* using TKIP
  - iw dev wlan0 scan | grep TKIP

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- UDP manipulation: attacking transport layer
- What about the internet layer?

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- IP spoofing is today mainly important in a larger attack context

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Countermeasures

- Decrease the SYN-RECEIVED timer
- Increase the size of the queue
- Recycle oldest half-open connection
- Firewalls (later in this course)

Solving the real problem

- SYN flooding countermeasures don't really solve the problem

The recipient will be left with multiple half-open connections that are occupying limited resources. Usually, these connection requests have forged source addresses that specify nonexistent or unreachable hosts that cannot be contacted. Thus, there is also no way to trace the connections back. ... There is little you can do in these situations. ... ***any finite limit can be exceeded****."*

—Practical UNIX and Internet Security, Garfinkel and Spafford (1996)

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- Compute ISN as the client's ISN plus offset of
  - top 5 bits: $t \mod 32$, where t is a 32-bit time counter that increases every 64 seconds
  - next 3 bits: an encoding of a maximum segment size (MSS) selected by the server in response to the client's MSS
  - bottom 24 bits: a server-selected secret function of the client IP address and port number, the server IP address and port number, and t.

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- Enable SYN cookies under Linux:
  `echo 1 > /proc/sys/net/ipv4/tcp_syncookies`

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  - Receiving host will assemble the fragments into a buffer of size 65535
  - Overlong IP packet will overflow this buffer
- This bug was present in UNIX, Linux, Windows, Mac, routers, printers ...
- Trivially easy to exploit with some implementations of `ping`:

```
ping -s 65510 target
```

The return of the ping of death

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- CVE-2016-1409: IPv6 ping of death against Cisco's IOS, IOS XR, IOS XE, and NX-OS software

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When new connections are created, an initial sequence number (ISN) generator is employed which selects a new 32 bit ISN. The generator is bound to a (possibly fictitious) 32 bit clock whose low order bit is incremented roughly every 4 microseconds. Thus, the ISN cycles approximately every 4.55 hours. Since we assume that segments will stay in the network no more than the Maximum Segment Lifetime (MSL) and that the MSL is less than 4.55 hours we can reasonably assume that ISN's will be unique." —RFC 793 (September 1981)

TCP SHOULD generate its Initial Sequence Numbers with the expression: ISN = M + F(localip, localport, remoteip, remoteport, secretkey) where M is the 4 microsecond timer, and F() is a pseudorandom function (PRF) of the connection-id. F() MUST NOT be computable from the outside, or an attacker could still guess at sequence numbers from the ISN used for some other connection. The PRF could be implemented as a cryptographic hash of the concatenation of the connection-id and some secret data; MD5 [RFC1321] would be a good choice for the hash function."

—RFC 6528 (February 2012)

Short comment from the cryptographers

MD5 is NOT a good choice for a hash function.

... in the Linux kernel (4.19)

```
__u32 secure_tcp_sequence_number(__be32 saddr, __be32 daddr,
                 __be16 sport, __be16 dport)
{
    u32 hash[MD5_DIGEST_WORDS];

    net_secret_init();
    hash[0] = (__force u32)saddr;
    hash[1] = (__force u32)daddr;
    hash[2] = ((__force u16)sport << 16) + (__force u16)dport;
    hash[3] = net_secret[15];

    md5_transform(hash, net_secret);

    return seq_scale(hash[0]);
}
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- Can an attacker guess the server's ISN?
- Probably not easily (anymore)
- Keep in mind: No exact guess needed, attacker can try many sequence numbers!

Good sequence numbers are not a replacement for cryptographic authentication, such as that provided by IPsec [RFC4301] or the TCP Authentication Option (TCP-AO) [RFC5925]. At best, they're a palliative measure." —RFC 6528 (February 2012)

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- Attacker can also take over existing, legitimate connection between A and B

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- Details: http://www.cs.ucr.edu/~zhiyunq/pub/sec16_TCP_pure_offpath.pdf

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- Some services announce what they are through a "banner"
- *Internet Assigned Numbers Authority* (IANA) defines list of known ports and services
- Same port for UDP and TCP (but service is not necessarily listening on both)
- List in file `/etc/services`
- It is of course not mandatory to use these ports, but it's what clients assume

Common services and their ports

TCP/UDP port	Service
21	File Transfer Protocol (FTP)
22	Secure Shell (SSH)
25	Simple Mail Transfer Protocol (SMTP)
53	Domain Name Server
80	Hypertext Transfer Protocol (HTTP)
110	Post Office Protocol (POP3)
143	Interim Mail Access Protocol (IMAP)
443	HTTP over SSL/TLS (HTTPS)
465	SMTP over SSL/TLS (SMTPS)
993	IMAP over SSL/TLS (IMAPS)
995	POP3 over SSL/TLS (POP3S)

netstat

- Very important to know and understand: local listening programs/ports
- Various examples:
  - `netstat -tl`: All listening TCP ports
  - `netstat -ul`: All listening UDP ports
  - `netstat -al`: All listening ports (also UNIX ports)
- The `--program` option also shows which process opened the connection
- Run as root to see all `--program` information

telnet, netcat, and openssl

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- `netcat` and `telnet` don't work with SSL connections
- Use OpenSSL's `s_client` instead, e.g.:

  ```
  openssl s_client -connect encrypted.google.com:443
  ```

Port scanning – `nmap`

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- Default scan method for non-privileged user: `connect()` scan:
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- "Filtered" means that a firewall blocks access (more later in this lecture)
- Scan all ports (including high ports) through

```
nmap -p 1-65535 arya
```

SYN, Null, FIN and Xmas scans

- `connect()` scans appear in the servers' log files
- Sometimes a more "stealthy" scan is desired
- Only need a "distinguisher" between open and closed ports

SYN, Null, FIN and Xmas scans

SYN scan

- Send SYN packet
- Receiving SYN/ACK: port is open
- Receiving RST: port is closed
- Send an RST when receiving SYN/ACK to "hang up"
- Connection is never completed (service does not log it)
- Default in nmap with root privileges (or use `-sS`)

SYN, Null, FIN and Xmas scans

Null, FIN, and Xmas scans

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- Any packet without SYN,ACK, or RST can serve as distinguisher
- Null scan: no flags set (`-sN`)
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- Problem: Not all operating systems behave according to RFC 793
- For example, Windows will always send RST (making all ports look closed)

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- With TCP SYN and FIN scans there is still bidirectional communication between scanning and scanned host
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- Idle scan with `nmap`: `nmap -sI zombie`

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- UDP scans in `nmap`: `nmap -sU`

OS fingerprinting

- Important information about target host/network: OS
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- Different operating systems use different parameters
- Investigating those parameters gives information about OS
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- Convenient shortcut: `nmap -A` (`-O -sV -sC --traceroute`)

Portscans – attack or not?

Port scans: no attack

- You only look for offered services
- If you don't want a service to be found, don't offer that service
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Port scans – (part of) an attack

- Why would I want to reveal more about my system than I have to?
- Port scans are a typical first step of an attack
- "If I want you to know about an open service, I'll tell you"
- `nmap` manpage gives a few hints. . . :

```
peter@tyrion: $ man nmap | grep -o attack | wc -l
18
```

NSA/GCHQ Project Hacienda

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- For more details, see
  http://www.heise.de/ct/artikel/NSA-GCHQ-The-HACIENDA-Program-for-Internet-Colonization-2292681.html

Efficient port scanning

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On a typical desktop computer with a gigabit Ethernet connection, ZMap is capable scanning the entire public IPv4 address space in under 45 minutes. With a 10gigE connection and PF_RING, ZMap can scan the IPv4 address space in under 5 minutes."

—https://github.com/zmap/zmap / https://zmap.io

Portknocking

- Some services are meant to be public, e.g., HTTP(S), SMTP(S)
- Other services are (often) only meant for one or very few users, e.g., SSH
- Can run those service on non-standard ports (e.g., 51966): security by obscurity

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- Port scanners won't see port 22 as open
- Can still use SSH from anywhere (if you know the knocking sequence)

More portknocking

- Various ways to implement port knocking:
  - Kernel space vs. user space
  - TCP vs. UDP
  - Inspecting every packet with libpcap vs. lightweight methods (e.g., logfiles)
  - Multi-packet vs. single-packet (Single Packet Authorization (SPA))
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- Nice summary of the reason for port knocking: *"Because you are running network services with security vulnerabilities in them. Again, you are running network services with security vulnerabilities in them. If you're running a server, this is almost universally true. Most software is complex. It changes rapidly, and innovation tends to make it more complex. It is going to be, forever, hopelessly, insecure."*
  —Moxie Marlinspike

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- Compatible with SYN cookies
- Implemented for Linux kernel
- Submitted as an IETF draft: https://datatracker.ietf.org/doc/draft-kirsch-ietf-tcp-stealth/ (but expired)