University of Glasgow

Security and Wrap-up

Networked Systems 3
Lecture 18

Lecture Outline

- Security considerations
  - Traffic monitoring, confidentiality and authentication
  - Validating input data
  - Buffer overflow attacks
- Wrap-up

Traffic Monitoring

- Possible to intercept traffic on a network
- Many countries monitor traffic, for legal reasons
  - To enable authorised wiretaps by the police, for example
  - Much of this is desirable – the *are* good reasons why law enforcement need to intercept *some* traffic
- Edward Snowden revelations show *pervasive monitoring* is widespread
  - IETF consensus is that “we cannot defend against the most nefarious actors while allowing monitoring by other actors no matter how benevolent some might consider them to be, since the actions required of the attacker are indistinguishable from other attacks” – RFC 7258 “Pervasive Monitoring is an Attack” (https://tools.ietf.org/html/rfc7258)

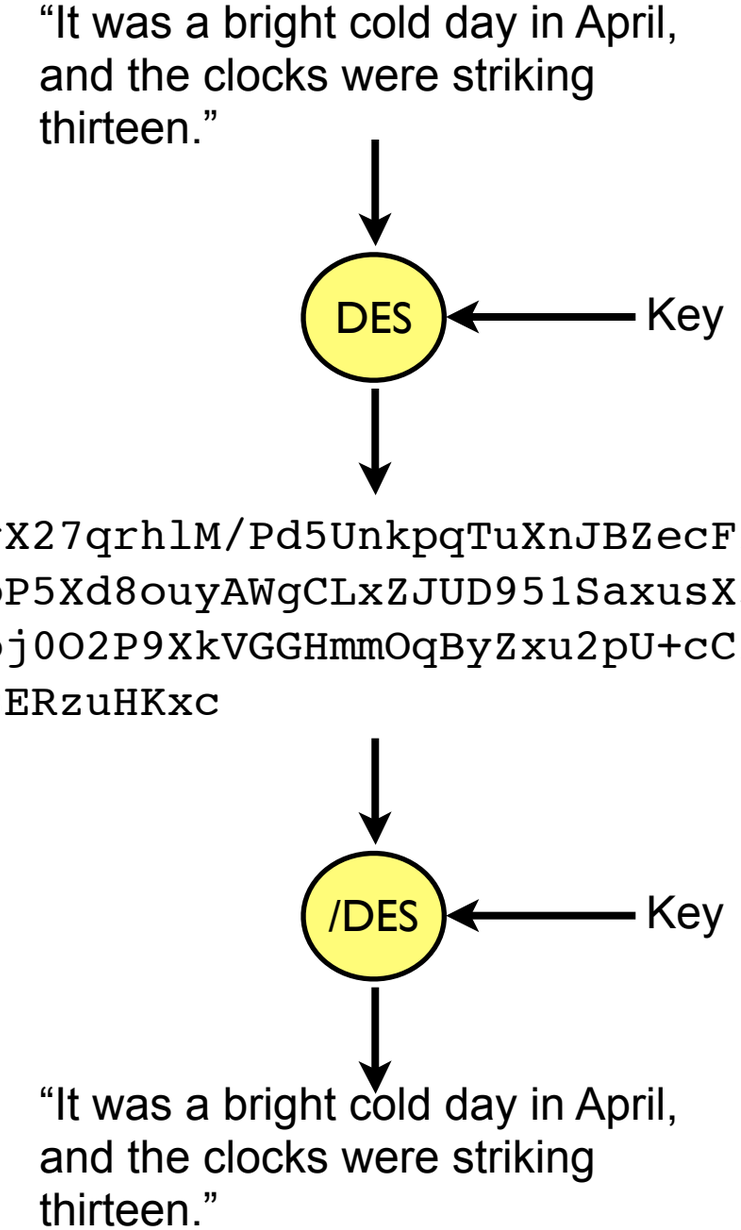
Edward Snowden

Confidentiality

- Must encrypt data to achieve confidentiality
- Two basic approaches
  - Symmetric cryptography
    - Advanced Encryption Standard (AES)
  - Public key cryptography
    - The Diffie-Hellman algorithm
    - The Rivest-Shamir-Adleman (RSA) algorithm
- Complex mathematics – will not attempt to describe

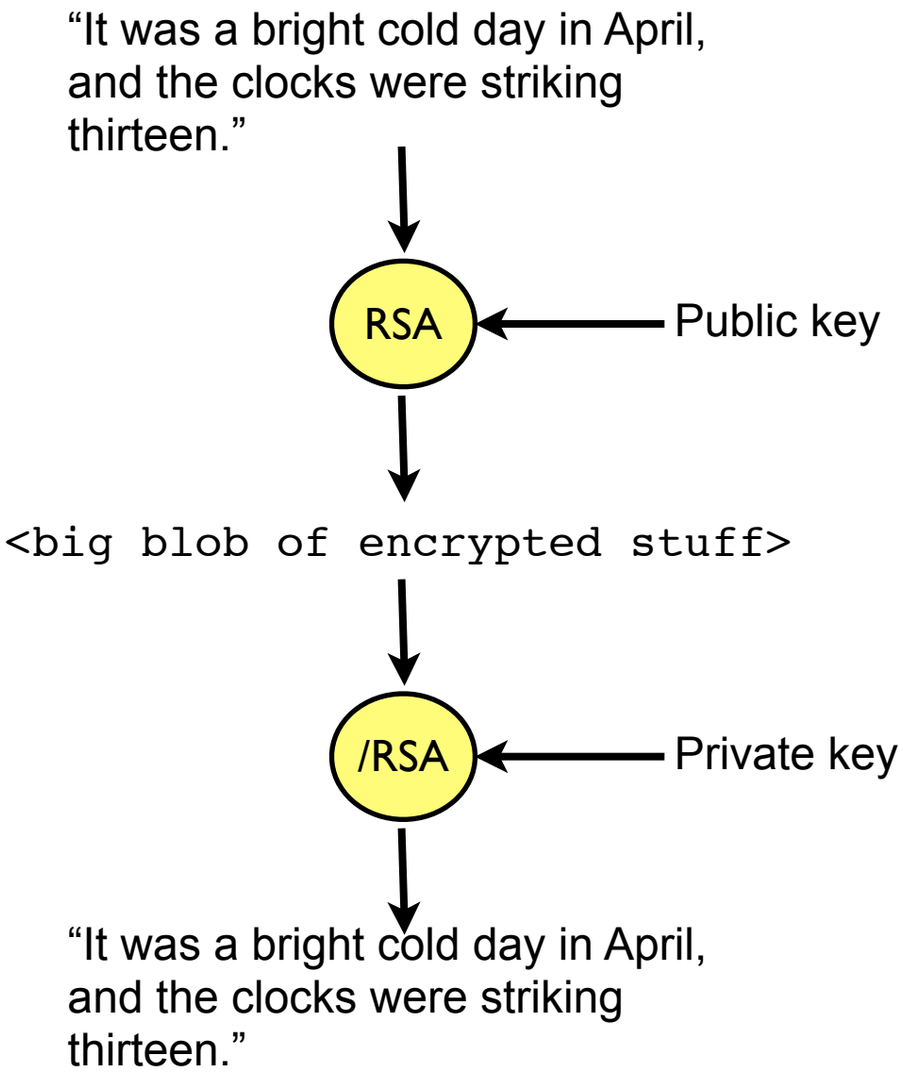
Symmetric Cryptography

- Function converts plain text into cipher-text
  - Fast – suitable for bulk encryption
  - Cipher-text is binary data, and may need base64 encoding
- Conversation is protected by a secret key
  - The same key is used to encrypt as is used to decrypt
  - Key must be kept secret, else security lost – a problem: how to distribute the key?



Public Key Cryptography

- Key split into two parts:
  - Public key – is widely distributed
  - Private key – must be kept secret
- Encrypt using public key → need private key to decrypt
  - Public keys are published in a well known directory → solves the key distribution problem
  - Problem: very slow to encrypt and decrypt



Hybrid Cryptography

- Use combination of public-key and symmetric cryptography for security and performance
  - Generate a random, ephemeral, *session* key that can be used with symmetric cryptography
  - Use a public-key system to securely distribute this session key – relatively fast, since session key is small
  - Encrypt the data using symmetric cryptography, keyed by the session key
  - Examples: PGP for email, SSL for web pages

Authentication

- Encryption can ensure confidentiality – but how to tell if a message has been tampered with?
  - Use combination of a *cryptographic hash* and public key cryptography to produce a *digital signature*
  - Gives some confidence that there is no *man-in-the-middle attack* in progress
- Can also be used to prove origin of data

Cryptographic Hash Functions

- Generate a fixed length (e.g., 160 bit) hash code of an arbitrary length input value
  - Should not be feasible to derive input value from hash
  - Should not be feasible to generate a message with the same hash as another
- Examples:
  - MD5 and SHA-1 (weaknesses found in both – care required!)
  - SHA-256

MD5(“It was a bright cold day in April, and the clocks were striking thirteen”) = 2c794fa2698f4b1bc5aa4e290abdf3a5

Digital Signature Algorithms

- Generating a digital signature:
  - Generate a cryptographic hash of the data
  - Encrypt the hash with your *private key* to give a *digital signature*
- Verifying a digital signature:
  - Re-calculate the cryptographic hash of the data
  - Decrypt the signature using the public key, compare with the calculated hash value → should match

Existing Secure Protocols

- Existing security protocols give confidentiality and authentication:
  - IPsec
  - Transport Layer Security (TLS)
    - An enhancement to the Secure Sockets Layer (SSL)
    - Datagram TLS
  - Secure shell (ssh)
- Use them – don't try to invent your own!

Using TLS

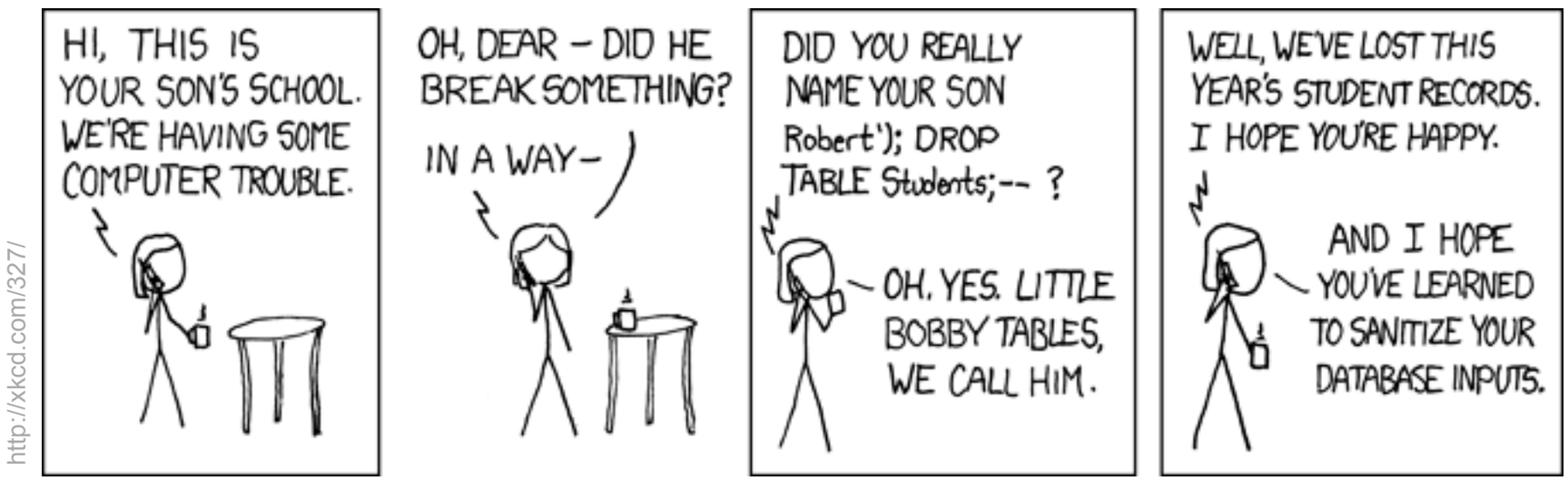
- IETF is developing guidelines for how best to use TLS: https://tools.ietf.org/html/draft-ietf-uta-tls-bcp
  - Expected to be published as an RFC soon
  - Read this if you use TLS in your application

- State-of-the-art in TLS implementations is in flux
  - OpenSSL is popular, but poor quality
  - Alternatives in rapid development as of early 2015 – not clear which is the best long term option

Validating Input Data

- Networked applications fundamentally dealing with data supplied by un-trusted third parties
  - Data read from the network may not conform to the protocol specification
  - Due to ignorance and/or bugs
  - Due to malice, and a desire to disrupt services
- Must carefully validate all data before use

Malicious User Input



http://xkcd.com/327/

- Beware escape characters in user-supplied data!
- Must sanitise all user-supplied data before use
  - Stop malicious users including control characters that might disrupt operation of any scripting language inside your application

Buffer Overflow Attacks

- The C programming language doesn't check array bounds
  - Responsibility of the programmer to ensure bounds are not violated
  - Easy to get wrong – typically results in a "core dump"
  - What actually happens here?

Function Calls and the Stack

```
// overflow.c
#include <string.h>
#include <stdio.h>

static void
foo(char *src)
{
        char dst[12];

        strcpy(dst, src);
}

int
main(int argc, char *argv[])
{
        char hello[] = "Hello, world\n";

        foo(argv[1]);
        printf("%s", hello);
        return 0;
}
```

```
$ gcc overflow.c  -o overflow
$ ./overflow 123456789012
Hello, world
$ ./overflow 1234567890123
Abort trap (core dumped)
$
```

What happens when `argv[1]` is longer than 12 bytes?

Function Calls and the Stack

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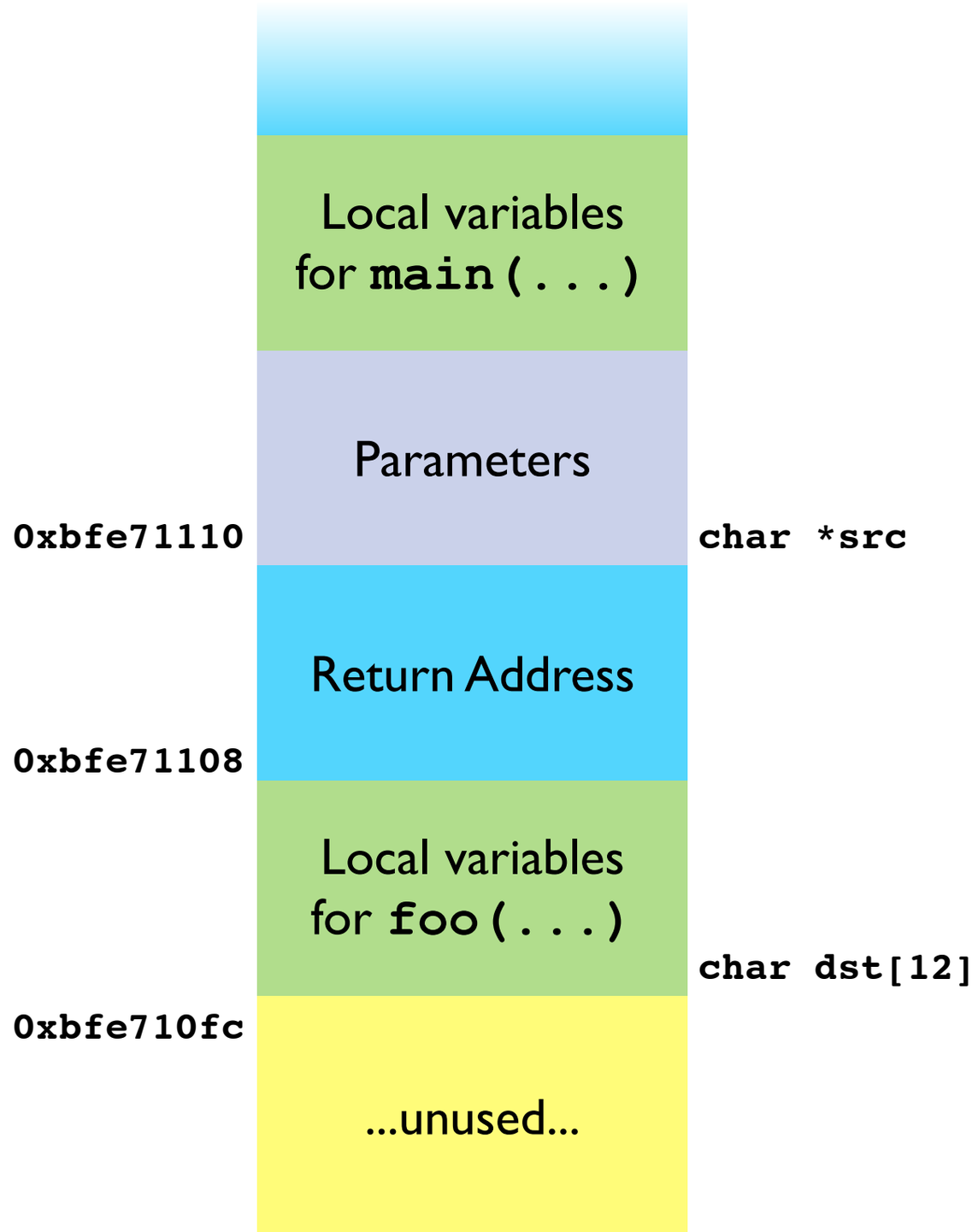
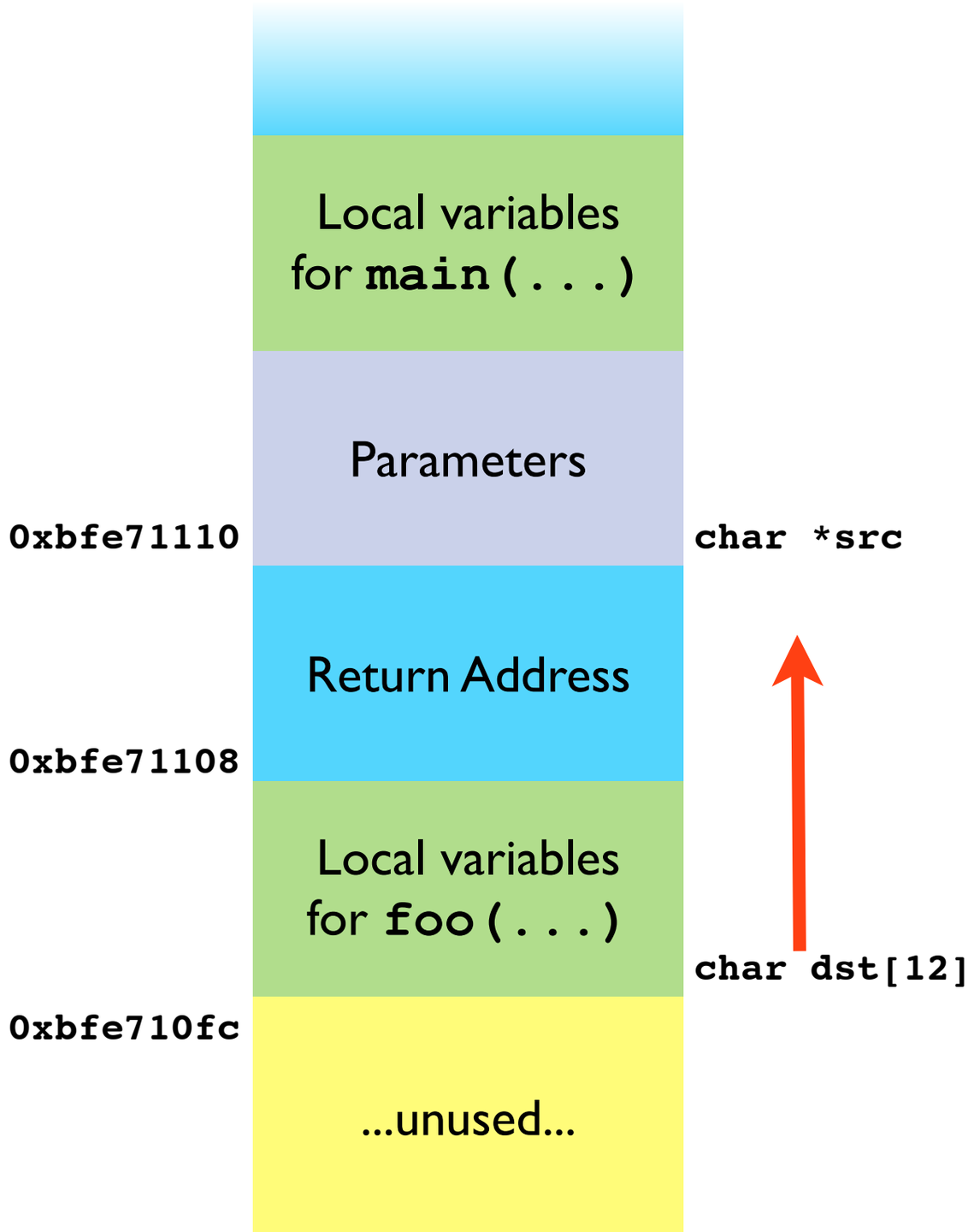


Example of call stack within the call to the function `foo()`

Function Calls and the Stack

- The `strcpy()` call doesn't check array bounds
- Overwrites the function return address on stack, along with the following memory locations
- If malicious, we can write executable code into this space, set return address to jump into our code…



Example of call stack within the call to the function `foo()`

Arbitrary Code Execution

- Buffer overflows in network code are the primary source of security problems
  - If you write network code in C, but *very* careful to check all array bounds
  - If your code can be crashed by network traffic, it probably has an exploitable buffer overflow
- http://insecure.org/stf/smashstack.html

Wrap Up

Examination and Revision

- Exam is worth 80% of course mark
  - Duration: 1.5 hours
  - Rubric: answer all 3 questions
  - Copies of past exam papers are on Moodle

- No revision lecture – email me with any questions

Networked Systems in Level 4

- Three taught modules cover networked systems:
  - Advanced Networking and Communications 4
  - Distributed Algorithms and Systems 4
  - Wireless Sensor Networks 4/M
- Individual projects in networked systems:
  - Look for projects supervised by members of the Embedded, Networked, and Distributed Systems research group
  - Talk to us if you're interested in networking-related projects – we generally have more project ideas than proposed, and can often suggest something that fits with your interests
  - Level 4 projects in this area can lead to MSci/PhD work, if interested

The End