Introduction

ENEE 457

Computer Systems Security

Fall 2019

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Includes material from Prof. Michelle Mazurek and Prof. Dave Levin

- Normally, we care about **correctness**
    - Does software achieve desired behavior?

- Security is a kind of correctness
    - Does software prevent **undesired** behavior?

The key difference is the adversary!

What are undesired behaviors?

- Reveals info that users want to hide
  - Corporate secrets, private data, PII
  - *Privacy/Confidentiality*
- Modifies info or functionality
  - Destroy records, change data mid-processing, install unwanted software
  - *Integrity*
- Deny access to data or service
  - Crash website, DoS,
  - *Fairness*

Why are attacks so common?

- Systems are complex, people are limited

- Many attacks exploit a ***vulnerability***
  - A ***software defect*** that can be manipulated to yield an undesired behavior

- Software defects come from:
  - Flaws in design
  - Bugs in implementation

Why are attacks so common?

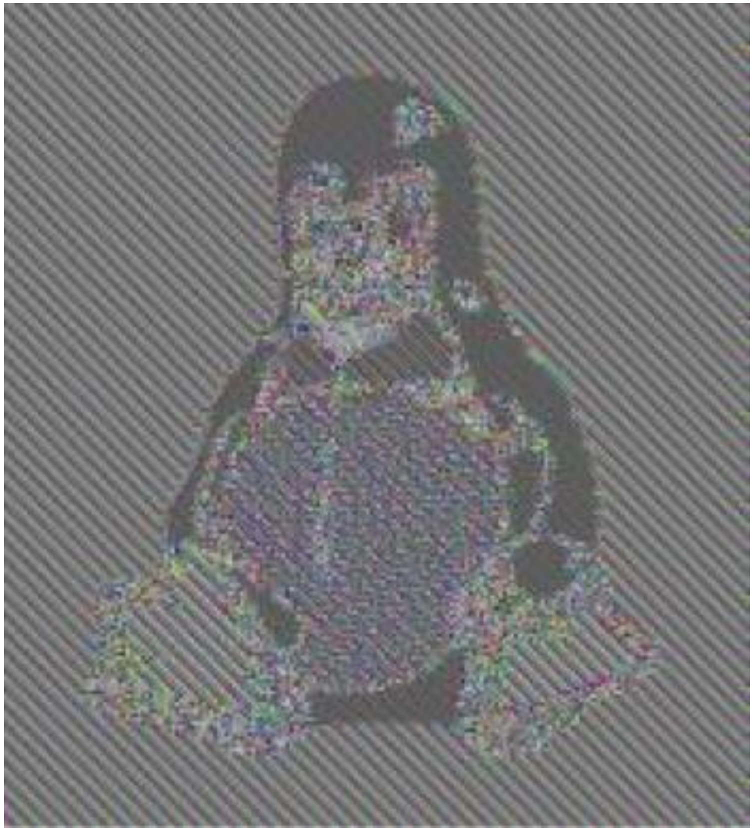
- Normal users avoid bugs
- Adversaries look for them to exploit

Why are attacks so common?

- Because it’s profitable
  - (Or attackers think it is)
- Because complex systems are only as strong as their weakest link

Steps toward more security….

- Eliminate bugs or design flaws, or make them harder to exploit
  - Think like an attacker!
- Deeply understand systems we build
- Be mindful of user-controlled inputs



Today's agenda

- What is security
- Administrivia
- C Refresher (Pointers, Memory Allocation)
- Case Study: Heartbleed Attack
- Course Survey

ADMINISTRIVIA

People

- Me: Dana Dachman-Soled (danadach@ece.umd.edu)

- TAs: Daniel Xing

(dxing97@umd.edu)

Lambros Mertzanis

(lambros@terpmail.umd.edu)

Resources

- Make sure to regularly check the class website:
  - http://www.ece.umd.edu/~danadach/Security_Fall_19/
  - Announcements, assignments, lecture notes, readings
- We will be using the Canvas page for the class
  - Announcements, grades, Project/HW submission, solutions
- We will also use Piazza
  - Class discussion, questions
  - You should have received an email invite

Resources

- Instructor Office hours (IRB 5238):
  - Thursday 3:30-4:30pm
  - Friday 9-10am
  - If your schedule does not allow you to attend OH, email me for an individual meeting.
- TA Office hours: TBD

Reading

- No required textbook
- Recommended: textbooks, outside resources
  - Listed on website
  - Share your recommendations on Piazza

Prerequisite knowledge

- Reasonably proficient in C and Unix
  - Refresher on C pointers/memory allocation (today)

- Creative and resourceful

- No prior knowledge in networking, crypto

Grading

- Projects and Demo: 30%
  - Projects: 5%, 5%, 5%, 5%, 5%
  - Final Demo with TAs on one of the Projects: 5%
- Homeworks: 10%
  - Homeworks: 2.5%, 2.5%, 2.5%, 2.5%
  - Mainly on theory portions of the course
- Class Exercises 5%
  - Collaborative class exercises that I will collect. Mainly checking for participation, not graded for correctness.
- Midterm: 25%
  - Tentative date: Monday October 7
- Final: 30%
  - Friday, December 13, 2019, 8am-10am in our regular classroom.

Ethics and legality

- You will learn about, implement attacks
- ***Do not use them without explicit written consent from everyone involved!***
    - Make sure you know who is involved
- If you want to try something, tell me and I will try to help set up a test environment
- Don't violate: Ethics, UMD policies, state and national laws

Read the syllabus

- In general, no late projects/homework accepted.
  - The instructor may allow late homework submission under extenuating circumstances.
  - In this case documentation such as a doctor's note will be requested.
- Excused absences for exams
- Contesting project/exam grade
- Academic integrity
- Extra Credit opportunities

What's in this course?

- Software and Web security
- Crypto
- Network security
- Special Topics (Bitcoin, Side-Channels, and more)

Software security

Memory safety

Malware

Web security

Static analysis

Design principles

What’s in this course?

- Software and Web security
- Crypto
- Network security
- Special Topics (Bitcoin, Side-Channels, and more)

Applied crypto

- What it is (medium-high level)
- How to use it responsibly

Black-box approach

Designing protocols that use crypto

Authentication

Public Key/Symmetric Key

What's in this course?

- Software and Web Security
- Crypto
- Network security
- Special Topics (Bitcoin, Side-Channels, and more)

Network security

- How to build secure networked systems

Attacks on TCP, DNS, Packet Sniffing

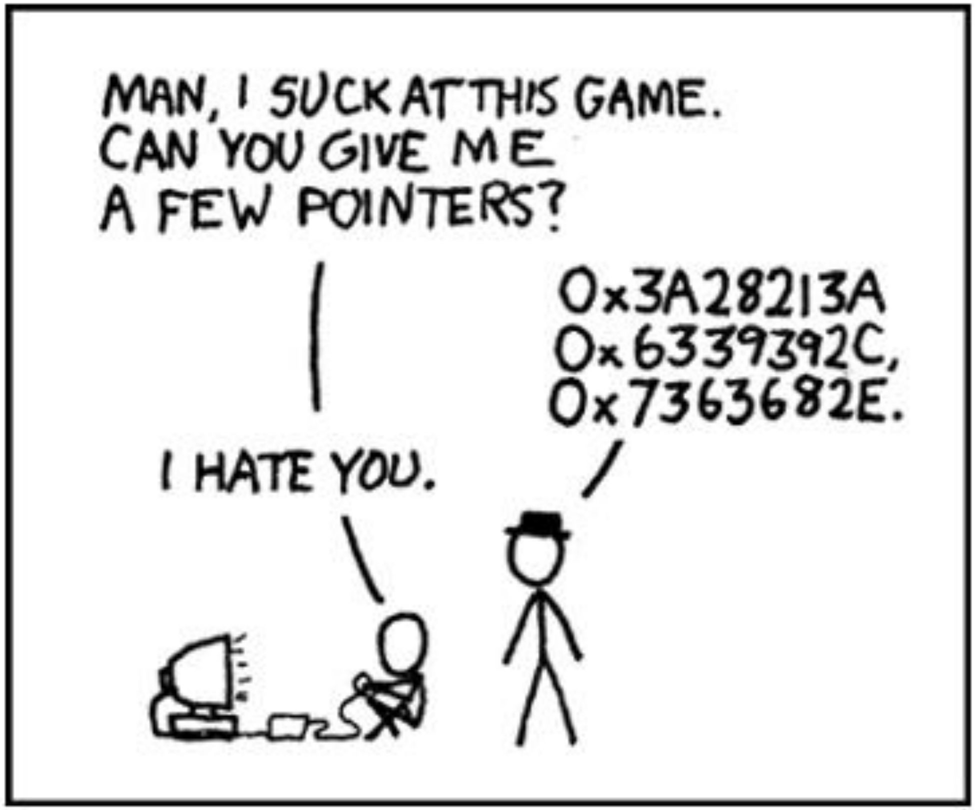
Anonymity

What's in this course?

- Software and Web security
- Crypto
- Network security
- Special Topics (will include some or all of):
  - Bitcoin/Blockchain
  - Adversarial Machine Learning
  - Password Hashing
  - Side-Channel Attacks
  - Differential Privacy

First Topic: Buffer Overflows

Review:
Pointers and Memory Allocation in C



Review:
Pointers and Memory Allocation in C

Consider a compiler where int takes 4 bytes, char takes 1 byte and pointer takes 4 bytes.

```c
#include <stdio.h>

int main()
{
    int arri[] = {1, 2 ,3};
    int *ptri = arri;

    char arrc[] = {1, 2 ,3};
    char *ptrc = arrc;

    printf("sizeof arri[] = %d ", sizeof(arri));
    printf("sizeof ptri = %d ", sizeof(ptri));

    printf("sizeof arrc[] = %d ", sizeof(arrc));
    printf("sizeof ptrc = %d ", sizeof(ptrc));

    return 0;
}
```

Review:
Pointers and Memory Allocation in C

Assume that float takes 4 bytes, predict the output of following program.

```
#include <stdio.h>

int main()
{
    float arr[5] = {12.5, 10.0, 13.5, 90.5, 0.5};
    float *ptr1 = &arr[0];
    float *ptr2 = ptr1 + 3;

    printf("%f ", *ptr2);
    printf("%d", ptr2 - ptr1);

   return 0;
}
```

Review:
Pointers and Memory Allocation in C

```
#include<stdio.h>
int main()
{
   int a;
   char *x;
   x = (char *) &a;
   a = 512;
   x[0] = 1;
   x[1] = 2;
   printf("%d\n",a);
   return 0;
}
```

What is the output? Assume *little-endian* processor.
The **least significant** byte (the "little end") of the data is placed at the byte with the lowest address. The rest of the data is placed in order in the next three bytes in memory.

Review:
Pointers and Memory Allocation in C

What is the output of following program?

```
# include <stdio.h>
void fun(int x)
{
    x = 30;
}

int main()
{
  int y = 20;
  fun(y);
  printf("%d", y);
  return 0;
}
```

Review:
Pointers and Memory Allocation in C

Output of following program?

```
# include <stdio.h>
void fun(int *ptr)
{
    *ptr = 30;
}

int main()
{
  int y = 20;
  fun(&y);
  printf("%d", y);

  return 0;
}
```

Review:
Pointers and Memory Allocation in C

Consider the following program, where are i, j and k are stored in memory?

```
int i;
int main()
{
    int j;
    int *k = (int *) malloc (sizeof(int));
}
```

Review:
Pointers and Memory Allocation in C

Consider the following three C functions :

```
[PI] int * g (void)
{
  int x= 10;
  return (&x);
}

[P2] int * g (void)
{
  int * px;
  *px= 10;
  return px;
}

[P3] int *g (void)
{
  int *px;
  px = (int *) malloc (sizeof(int));
  *px= 10;
  return px;
}
```

Review:
Pointers and Memory Allocation in C

What is the problem with following code?

```
#include<stdio.h>
int main()
{
    int *p = (int *)malloc(sizeof(int));

    p = NULL;

    free(p);
}
```

Review:
Pointers and Memory Allocation in C

```c
# include<stdio.h>
# include<stdlib.h>

void fun(int *a)
{
    a = (int*)malloc(sizeof(int));
}

int main()
{
    int *p;
    fun(p);
    *p = 6;
    printf("%d\n",*p);
    return(0);
}
```

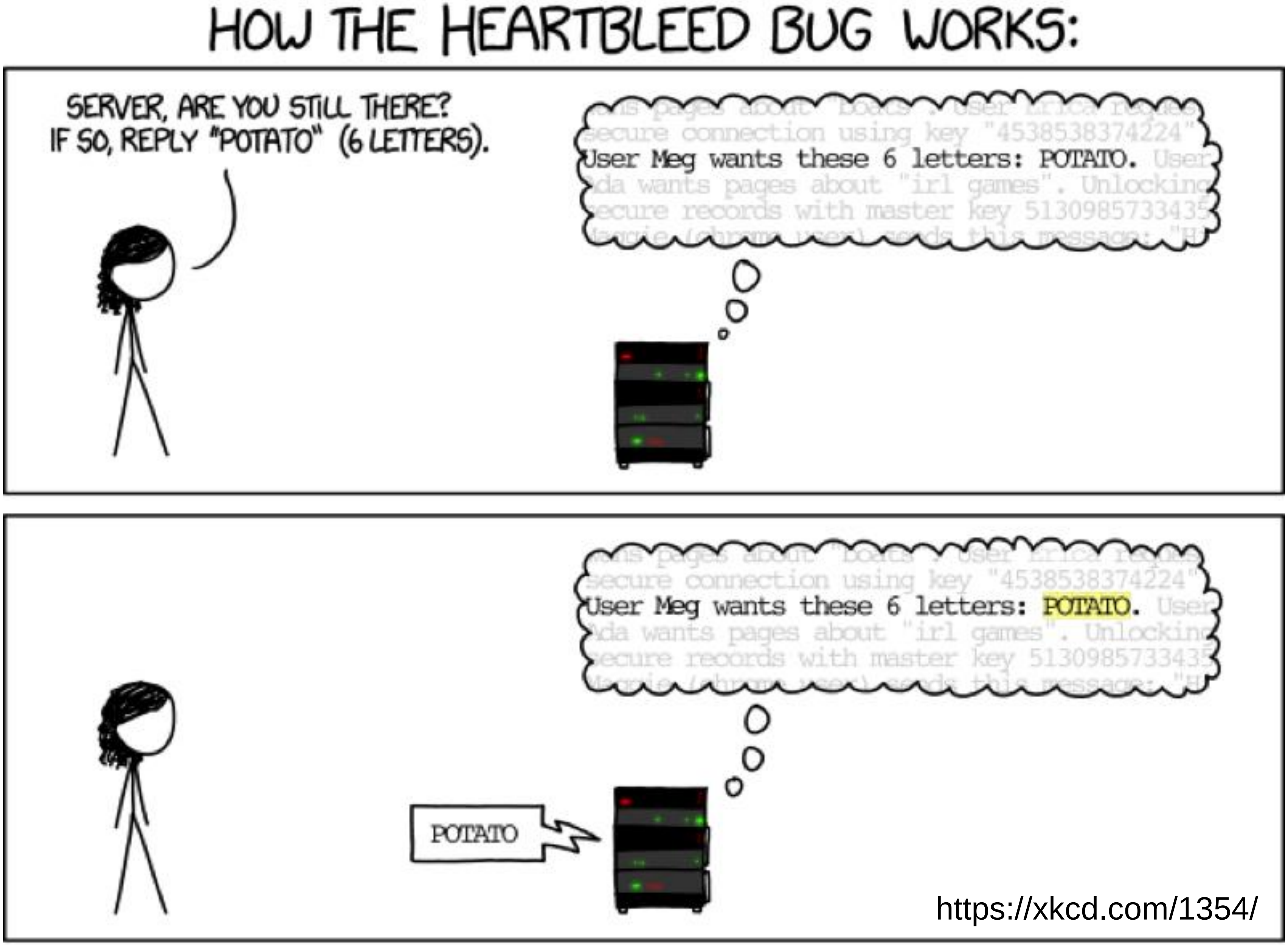
Review:
Pointers and Memory Allocation in C

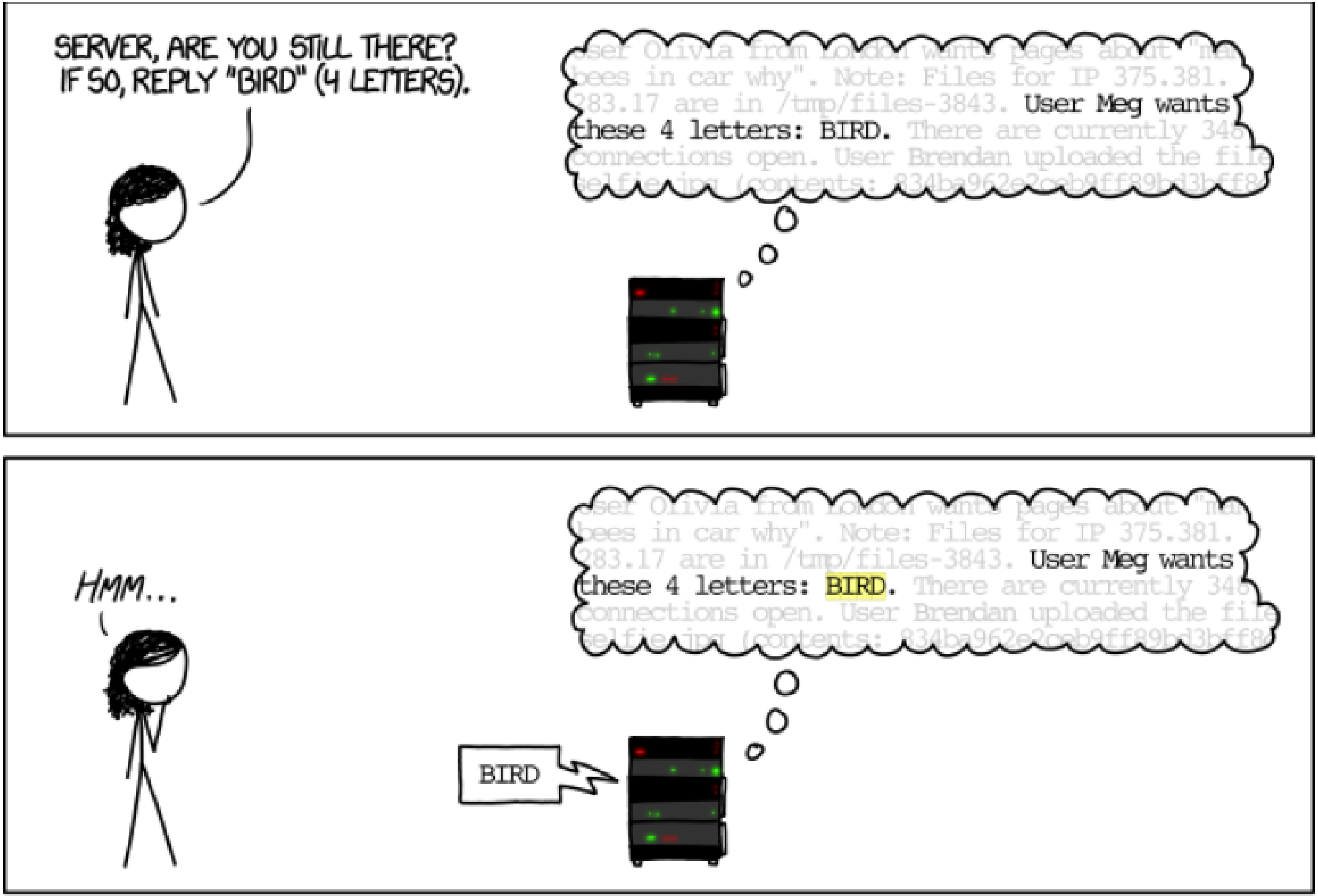
```
X: m=malloc(5); m= NULL;        1: using dangling pointers
Y: free(n); n->value=5;         2: using uninitialized pointers
Z: char *p; *p = 'a';           3. lost memory is:
```

Case study: Heartbleed

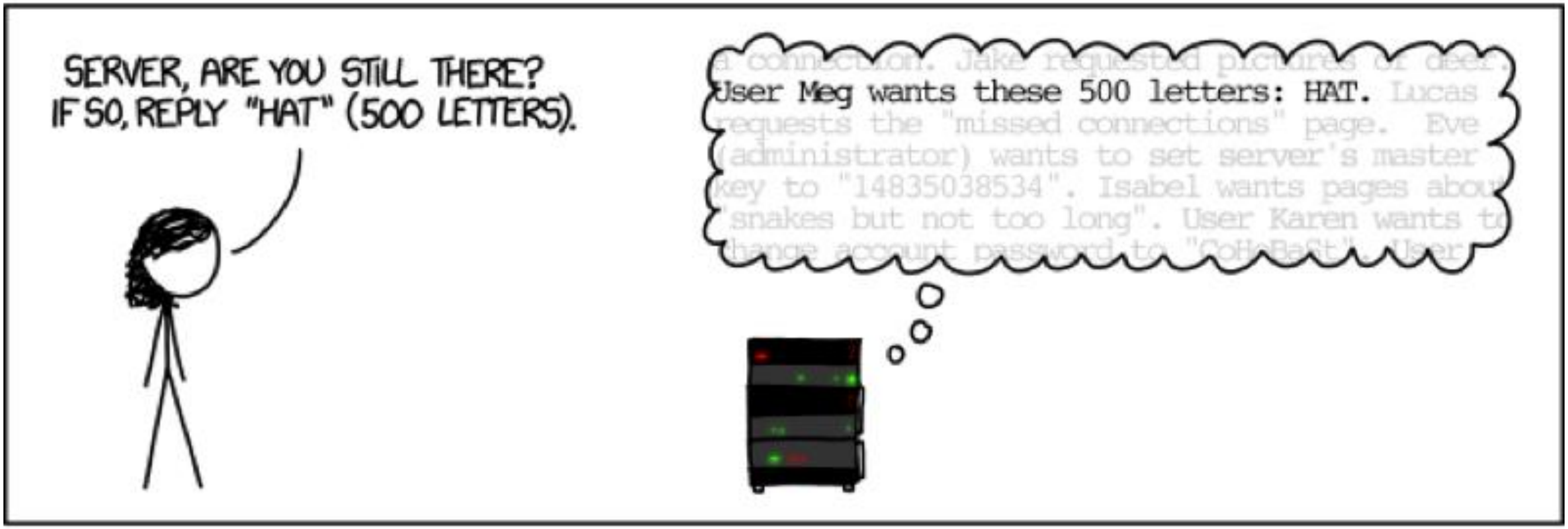
- SSL is the main protocol for secure (encrypted) online communication

- Heartbleed was a vulnerability in the most popular SSL server

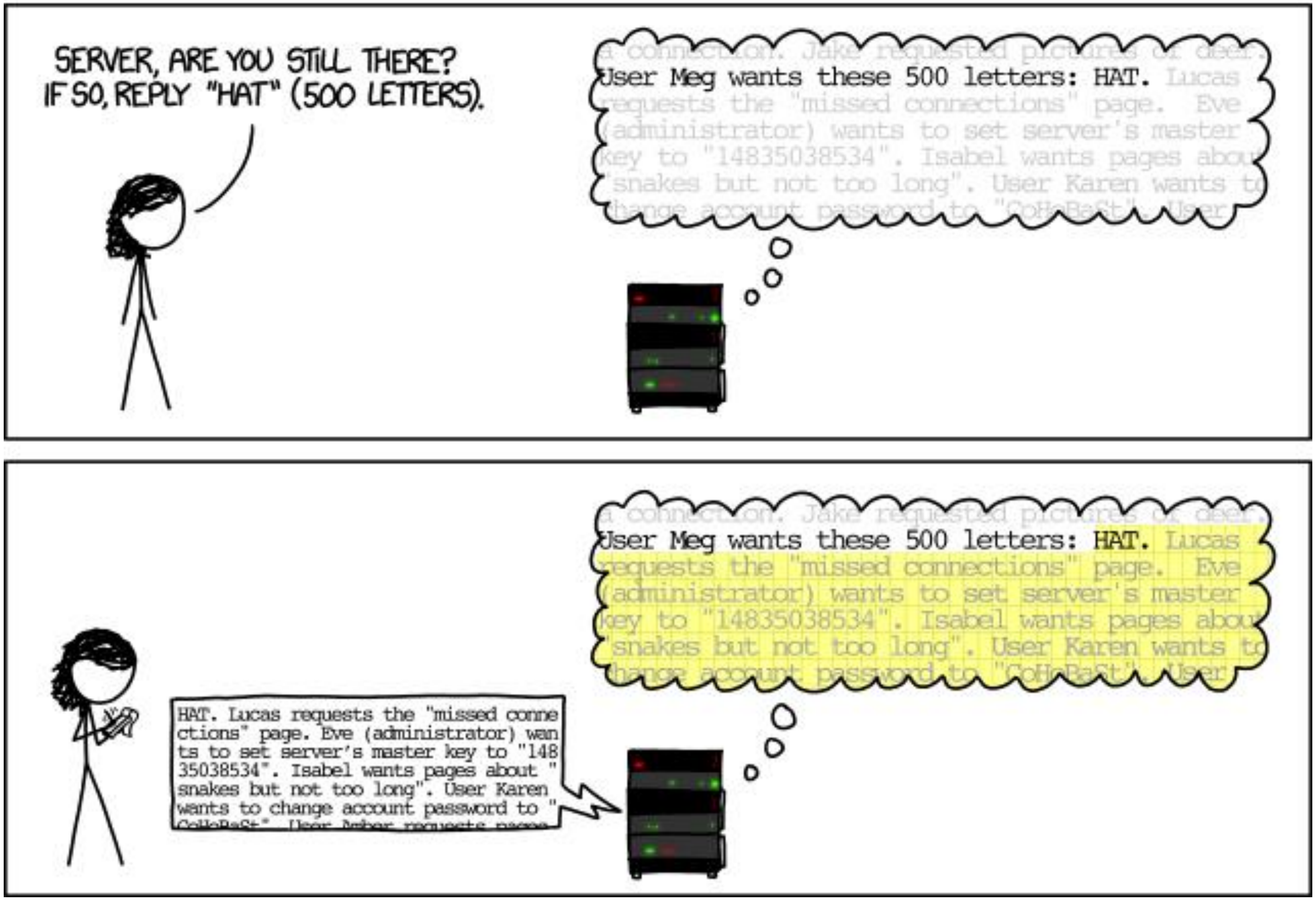

HOW THE HEARTBLEED BUG WORKS:
SERVER, ARE YOU STILL THERE? IF SO, REPLY "POTATO" (6 LETTERS).
secure connection using key "4538538374224"
User Meg wants these 6 letters: POTATO. User
Ada wants pages about "irl games". Unlocking
secure records with master key 5130985733435
secure connection using key "4538538374224"
User Meg wants these 6 letters: POTATO. User
Ada wants pages about "irl games". Unlocking
secure records with master key 5130985733435
POTATO
https://xkcd.com/1354/



SERVER, ARE YOU STILL THERE? IF SO, REPLY "BIRD" (4 LETTERS).
ser Olivia from London wants pages about "ma
bees in car why". Note: Files for IP 375.381.
283.17 are in /tmp/files-3843. User Meg wants
these 4 letters: BIRD. There are currently 346
connections open. User Brendan uploaded the file
HMM...
BIRD


SERVER, ARE YOU STILL THERE?
IF SO, REPLY "HAT" (500 LETTERS).
a connection. Jake requested pictures of deer.
User Meg wants these 500 letters: HAT. Lucas
requests the "missed connections" page. Eve
(administrator) wants to set server's master
key to "14835038534". Isabel wants pages abou
"snakes but not too long". User Karen wants t
hange account password to "CoHoBaSt". User

Heartbleed:
A Closer Look at Buffer Read Overflow



Case study: Heartbleed

- SSL is the main protocol for secure (encrypted) online communication
- Malformed packet allows you to see server memory
  - Passwords, keys, emails, visitor logs …..
- Fix: Don’t let the user tell you how much data to send back!
  - This is a *design* flaw

Heartbleed:
A Closer Look at Buffer Read Overflow

- Read Overflow: A bug that permits reading past the end of a buffer.

Read integer

Read message

Echo back (partial) message

```
int main() {
 char buf[100], *p;

 while (1) {
  p = fgets(buf,sizeof(buf),stdin);
  len = atoi(p);
  p = fgets(buf,sizeof(buf),stdin);
  for (i=0; i<len; i++) {
   if (!iscntrl(buf[i]))
    putchar(buf[i]);
   else putchar('.');
  }
  printf("\n");
 }
 ...
```

len may exceed actual message length!

Heartbleed:
A Closer Look at Buffer Read Overflow

- Sample Output:

```
% ./echo-server
24
every good boy does fine
ECHO: |every good boy does fine|
10
hello there
ECHO: |hello ther|
25
hello
ECHO: |hello..here..y does fine.|
```

OK: input length < buffer size

BAD: length > size !

leaked data