15-410

"..."Windows NT is C2 Secure"..."

Security Overview
Dec. 2, 2015

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Synchronization

Reminder...

- Don't forget to read *your partner's* P3 code
  - Suggestion: read it, then meet with questions

P3 interview/feedback sessions

- Roughly 45 minutes
- Your reader will contact you to set up an appointment during the last week of classes

Synchronization

Today

- OSC Chapter 15, more or less

Next time

- Fun stuff not in the text

Overview

Goals & Threats

Technologies

- Scanning
- Hashes
- Random numbers
- Private-key/symmetric cryptography
- Public-key/asymmetric cryptography
- The mysterious nonce

Next Time

- Applications
- Systems

U.S. DoD “Orange Book” Security Classifications

D – try again

C – authentication, controlled sharing

B – per-object sensitivity labels, user clearances

A – B-class system with formal spec, proofs

Sub-levels

- C2 = C1 + ACLs, audit logs, anti-tamper OS, ...

“Windows NT is C2 secure”

Windows NT is C2 secure

Wimpy old Unix is only C1

Use Windows, it's secure!

“Windows NT is C2 secure”

Windows NT is C2 secure

Wimpy old Unix is only C1

Use Windows, it's secure!

- *Melissa, Code Red, SQL Slammer, SoBig, ...*
- What's wrong with this picture?

“Security Architecture” undermined by implementation

- (default login was superuser!)

Physical security assumed in evaluation

- Locked rooms, floppy booting disabled
- In practice, isolate from Internet!

Goals & Threats

Goal: Authentication

- Threat: impersonation

Goal: Secrecy

- Threats: theft, eavesdropping, cipher breaking, ...

Goal: Integrity

- Threat: cracking

Goal: Signature

- Threats: impersonation, repudiation

...

Goals & Threats

Authentication

- Visitor/caller is Alice

Threat: Impersonation

- Act/appear/behave like Alice
- Steal Alice's keys (or “keys”)

Outcomes

- Maybe you can read Alice's secrets
- Maybe you can send Alice to jail

Goals & Threats

Secrecy (aka Confidentiality)

- Only Bob (or “Bob”) can read Bob's data

Difficult secrecy threats

- Break a cipher (see below)
- Compromise a system (see below)
- Or...

Eavesdropping – get data while it's unprotected!

- Wireless keyboard
- Keystroke logger
- TEMPEST

TEMPEST

Code name for electromagnetic security standard

- The *criteria document* is classified

Problem

- Computers are *radios*
- Especially old-fashioned CRT monitors
  - ~150 MHz signal bandwidth (“dot clock”)
  - Nice sharp sync pulses
  - Surveillance van can *read screens* from 100 feet
- Other scary possibilities for newer equipment

Goals & Threats

Integrity

- Only *authorized personnel* can add bugs to a system
- Or edit bank account balances
- Or edit high school grades

Threats

- Hijacking authorized accounts (impersonation)
- Bypassing authorization checks
  - Boot system in “administrator mode”?
  - Boot some other OS on the machine?
- Modifying hardware

Goals & Threats

Signature

- "Pay Bob $5 for his program" was uttered by Alice

Threats

- Alice repudiates message (after receiving program)
- Charlie signs "Pay Charlie $500 for his program"
  - *... with Bob's signature*

Goals & Threats

Anonymous communication

- "Whistle blowers"
- Secret agents

Threat

- "Traffic analysis"
  - Observe repeated "coincidence"
    - » Node 11 sends a message, Nodes 1-10 attack
  - Which node is a good target?

Goals & Threats

Availability

- Web server is available to corporate customers
- Mailbox contains interesting mail

Threat

- DoS – Denial of Service
  - Flood server with bogus data
  - “Buries” important data
  - SYN flooding, connection resetting

Another DoS Attack

Automated Flight Data Processing System

- Transfers flight arrival/departure data
  - ...between radar tower in Elgin, IL (where's that?)

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  - ...and tower at *O'Hare International*

Fallback system

- paper, pencil, telephone

Another DoS Attack

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Fallback system

- paper, pencil, telephone

Uh-oh...

- Chief engineer quit
  - after deleting *sole copy* of source code

Now What?

Police raided his house

Recovered code!

- Encrypted
  - Cracked – after 6 months

Summary

- http://archives.californiaaviation.org/airport/msg02974.html

Lesson?

- People matter...

Malicious Programs (“malware”)

Buffer overflow

Virus/worm

Trojan horse

Trapdoor

Buffer overflow

```
GET /default.ida?
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
%u9090%u6858%ucbd3%u7801%u9090%u6858%ucb
d3%u7801%u9090%u6858%ucbd3%u7801%u9090%u
9090%u8190%u00c3%u0003%u8b00%u531b%u53ff
%u0078%u0000%u00=a HTTP/1.0
```

Virus/Worm

Virus

- Program which cannot replicate itself
- Embedded in other programs, runs when they do
- Embeds self in other programs

Worm

- Breaks into remote machine
- Launches remote copy
- May not reside permanently on disk

Trojan, Trap Door

Trojan Horse

- Program with two purposes
- Advertised – "Here is the new security update!"
- Actual – Here is a hard-disk-wipe program!

Trap door

- login: anything
- Password: My hovercraft is full of eels!

#insert <reflections_on_trusting_trust>

Technologies

Scanning/intrusion detection/auditing

Hashing

Random numbers

Encryption (1-time, private, public)

The mysterious nonce

Scanning

Concept

- Check your system for vulnerabilities
  - Before somebody else does!

Details

- Password scan
- Scan for privileged programs, extra programs
- Check for dangerous file permissions
- Check that program, config files have correct contents
- Are mysterious programs running?

Intrusion Detection

Concept

- Monitor system in secure state
- Summarize typical behavior
- Watch for disturbing variation

Examples

- Sudden off-site traffic to/from a machine
- Change in system call mix
  - Gee, my web server doesn't *usually* exec("/bin/sh -i")...

Issues – false positive, false negative

Auditing

Concept

- Estimate damage
  - What was taken?
- How to fix system?

Approach

- Log system actions off-board
  - paper printer
  - disk with hardware roll-back

Boring but useful *when* you're in trouble...

Hashing

“One-way function”

- h_1 = f($message_1$)
- Given h_1 “infeasible” to map back to $message_1$
  - Not so hard – “parity sum” is a one-way function!

Hashing

"One-way function"

- h_1 = f(message$_1$)
- Given h_1 "infeasible" to map back to message$_1$
  - Not so hard – "parity sum" is a one-way function!

"Collision resistant"

- Given h_1, "infeasible" to find message$_2$ also hashing to h_1
- "Infeasible" to find any two m_1, m_2 hashing to h_x

Use

- Here is the MD5 hash of the OpenBSD CD-ROM image
- Verify data?
  - Compute hash function on data you have
  - Compare to published official output of hash function run on the official data

Hashing Issues

Say, what *is* the “official version hash”?

- Easy if you're in a room with the OpenBSD release coordinator
- Otherwise, not easy
- Preview of the ***key distribution problem***

Fate of Secure Hashes

Secure hash functions don't last very long

- Some are “found weak” several years after proposal
- NIST SHA (now known as SHA-0) withdrawn almost immediately after standardization

Status (Spring 2004)

- MD5 should be removed from service
- Code under development should use SHA-1

Fate of Secure Hashes

Status (Cryto2004, August)

- MD5 is “blown”
  - Team of Chinese researchers has a method to find collisions
    - » MD4, RIPEMD, HAVAL, MD5...uh-oh...

Status (February 2005)

- SHA-1 is “on life support”
  - Collisions have been found in SHA-0
  - Collisions have been found in “reduced round” SHA-1
  - Collisions can be found in 2^{69} attempts ($\ll 2^{80}$)
- “Schedule SHA-1 for replacement” -- with what??

Fate of Secure Hashes

SHA-1 was widened to yield the "SHA-2 family"

- SHA-224, SHA-256, SHA-384, SHA-512

NIST ran a SHA-3 competition

- Announced 2007-11-02
- Concluded 2012-10-02!
- Winner: "Keccak" (4 European authors)

Status (October 2012)

- "NIST considers SHA-2 to be secure and suitable for general use"
- Keccak provides "an essential insurance policy"
  - If people deploy it *before* SHA-2 runs into trouble
- Keccak may be attractive for embedded/low-power devices

“Random” Numbers

Three concepts

- Pseudo-random number generator (PRNG)
  - `Next = (Previous*L+I) mod M`
  - srand()/random()
  - Next “looks different” than Previous
  - Behaves *the same way every time* - not random *at all*
- Kind-of-random stuff
  - srand(get_timer());
  - Ok for games (where money isn't involved)
- Entropy pool
  - Genuinely random bits

Entropy Pool

Goal (for security) is unguessability

- aka unpredictability, true randomness, entropy

Why “kind-of” doesn't work

- Netscape seeded SSL session key generator with
  - getpid(), getppid(), time of day
  - Time is a globally-known value
  - Process IDs occupy a small space
    - » ...especially if you are on the target's machine!

Some things are genuinely random

- Which microsecond does the user press a key in?
- “Entropy Pool” is a queue of those events

Encryption

Concept

```
ciphertext = E(text, K1)
text = D(ciphertext, K2)
```

Algorithm E(),D()

- Should be *public*
  - Best known way to achieve strength
  - “Kerckhoff's principle” (1883), “Shannon's Maxim” (1940's)

Keys

- One (or maybe both) kept secret

Encryption: One-Time Pad

Key

- *Truly random* byte string
  - R K N Y Q T I D C E M W X ...

Algorithm

- E(): XOR one key byte, one message byte
  - M ⊕ R = 1F
  - M E S S A G E ⊕ R K N Y Q T I = 1F 0E 1D 0A 10 13 0C 0A
- D(): same process – using the *same random string*
  - Recall
    - » random ⊕ random = 0
    - » msg ⊕ 0 = msg
  - So (msg ⊕ random) ⊕ random = msg

One-Time Pad

Pad must be as long as message

Must be delivered securely

Result: information-theoretic perfect security

- Early Bell Labs result

***Never* re-use pads!!**

- $(m1 \oplus pad) \oplus (m2 \oplus pad) = (m1 \oplus m2)$
- Computationally *very* easy to see if a bit stream is text ⊕'d with other text

Private-Key Cryptography

Concept: ***symmetric*** **cipher**

```
ciphertext = E(text, Key)
text = E(ciphertext, Key)
```

Good

- Fast, intuitive (password-like), small keys

Bad

- Must share a key *(privately!)* before talking
  - This key is called a “shared secret”

Applications

- Bank ATM links, secure telephones

Public-Key Cryptography

Concept: *asymmetric* cipher (aka “magic”)

```
ciphertext = E(text, Key1)
text = D(ciphertext, Key2)
```

Keys are *different*

- Generate *key pair*
  - Two very large bit strings
    - » Related to each other mathematically
    - » Work together
- Publish “public key”
- Keep “private key” *very* secret

Public-Key Encryption

Sending secret mail

- Locate receiver's public key
- Encrypt mail with it
- Nobody can read it
  - *Not even you!*

Receiving secret mail

- Decrypt mail with your private key
  - No matter who sent it

Public-Key Signatures

Write a document

Encrypt it with your private key

- Nobody else can do that

Transmit plaintext *and ciphertext* of document

Anybody can decrypt with your public key

- If they match, the sender knew your private key
  - ...sender was you, more or less

(really: sign msg with E(hash(msg), K_p))

Public Key Cryptography

Good

- No need to privately exchange keys
  - Secret communication without a shared secret!

Bad

- Algorithms are *vastly slower* than private-key
  - kilobits/s vs. megabits/s
- Keys are *vastly longer* than private-key
  - 200X - 1000X
- Must trust key directory

Applications

- Secret mail, signatures

Comparison

Private-key algorithms

- Fast crypto, small keys
- *Secret-key-distribution problem*

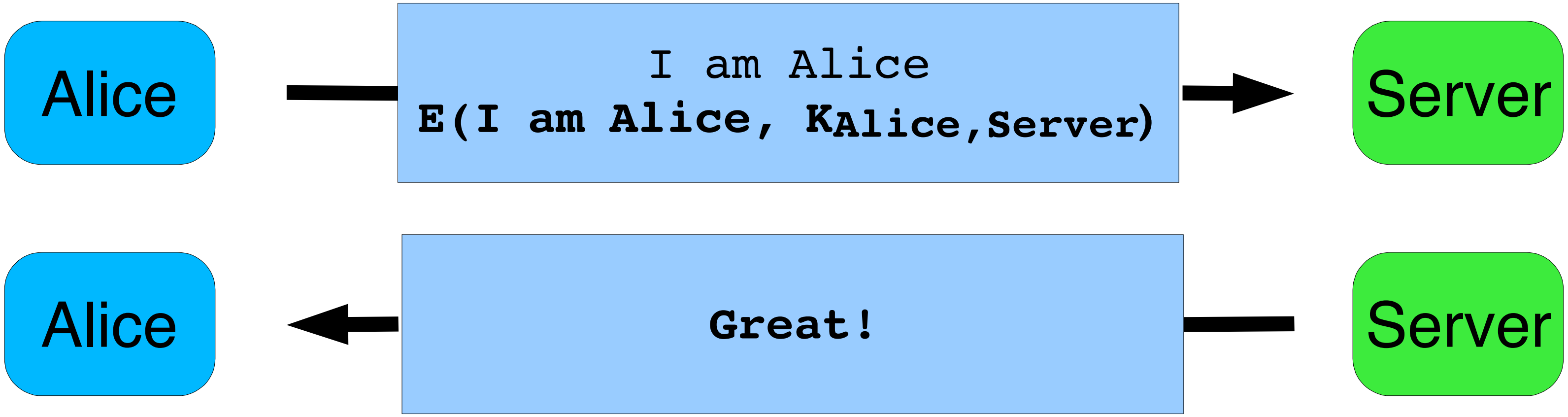
Public-key algorithms

- "Telephone directory" key distribution
- Slow crypto, *keys too large to memorize*

Can we get the best of both?

- Next time!

Secure Network Login



Alice

I am Alice

E(I am Alice, $K_{Alice,Server}$)

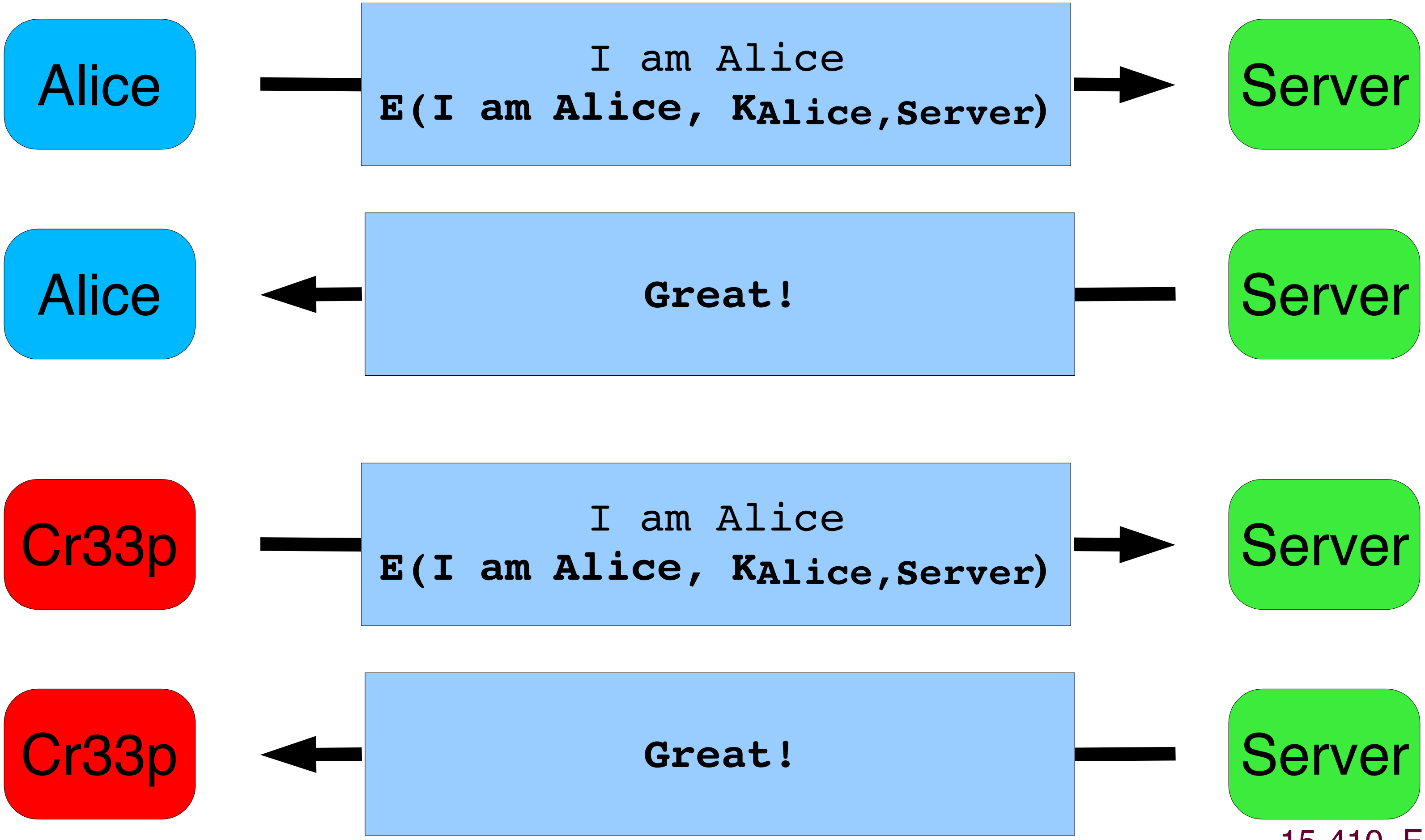
Server

Alice

Great!

Server

Secure Network Login – Uh-oh...



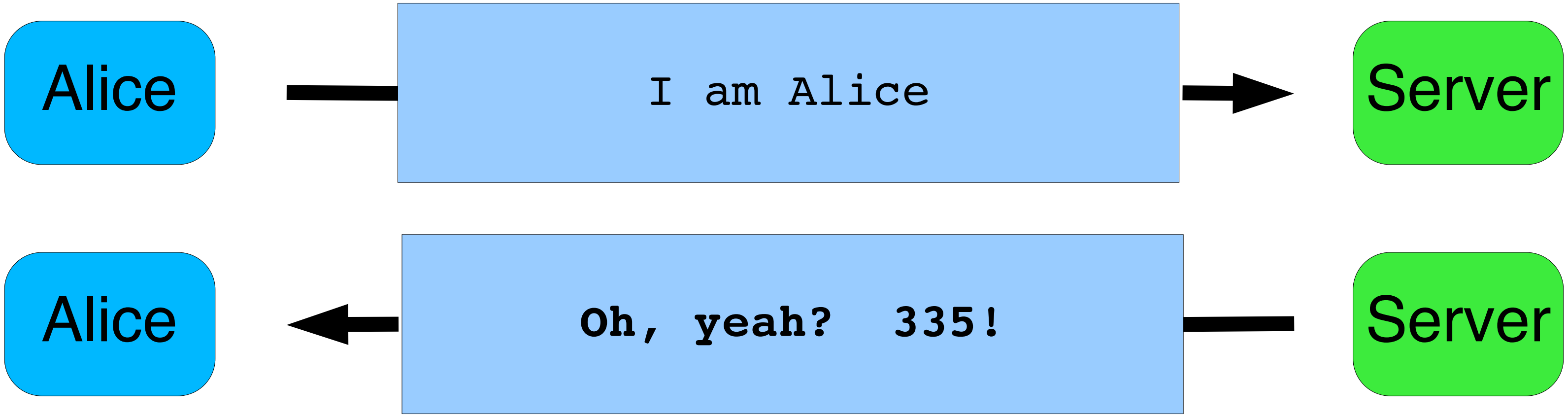
Alice → I am Alice **E(I am Alice, $K_{Alice,Server}$)** → Server

Alice ← **Great!** ← Server

Cr33p → I am Alice **E(I am Alice, $K_{Alice,Server}$)** → Server

Cr33p ← **Great!** ← Server

Secure Network Login – Nonce


Alice

I am Alice

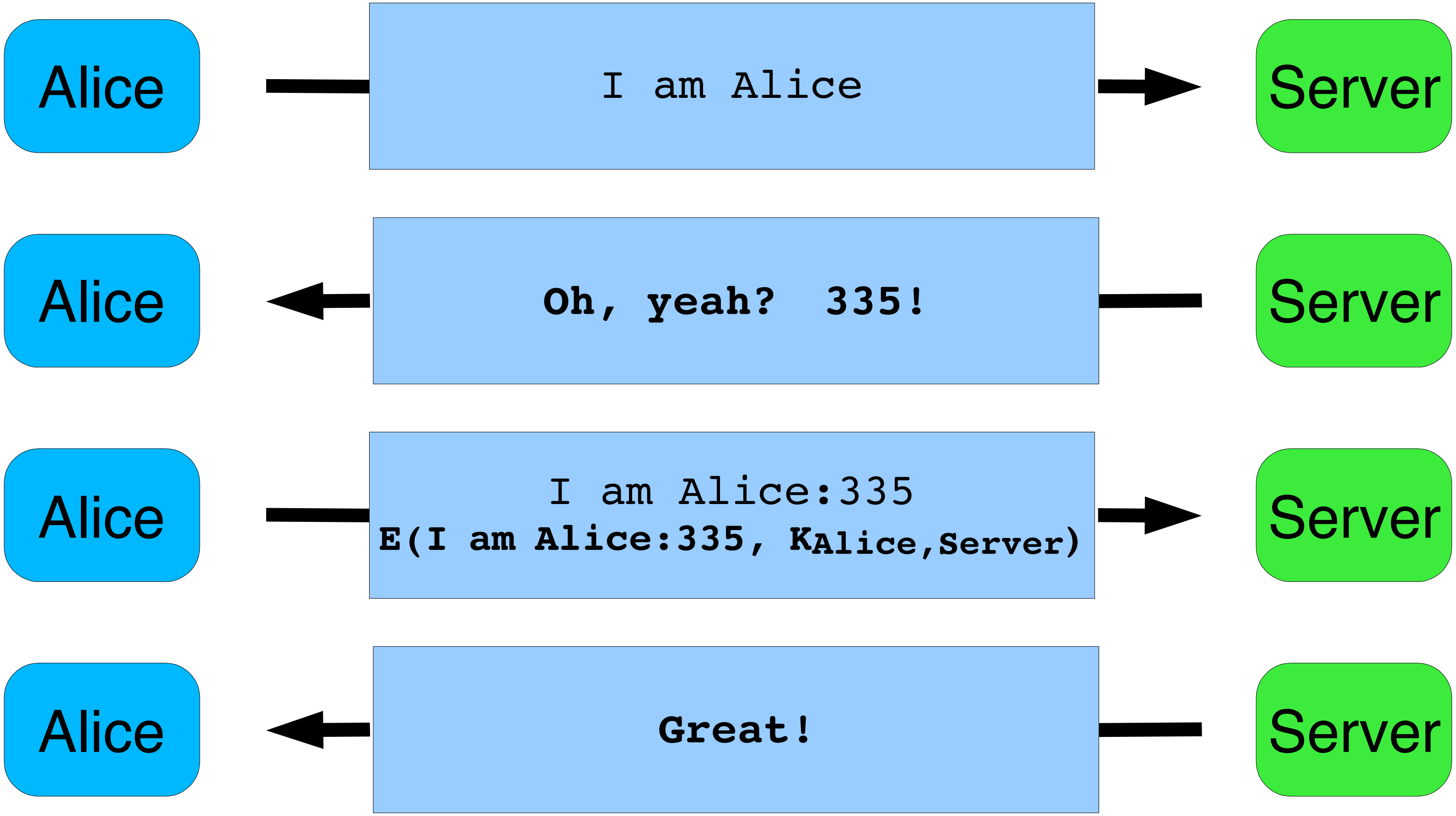
Server

Alice

Oh, yeah? 335!

Server

Secure Network Login – Nonce



I am Alice

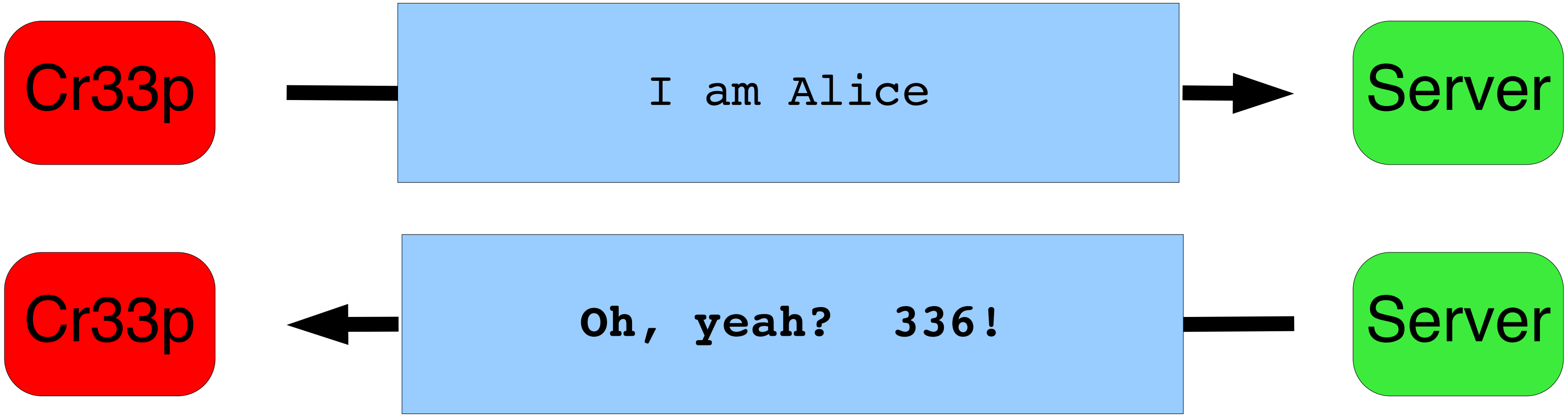
Oh, yeah? 335!

I am Alice:335

E(I am Alice:335, $K_{Alice,Server}$)

Great!

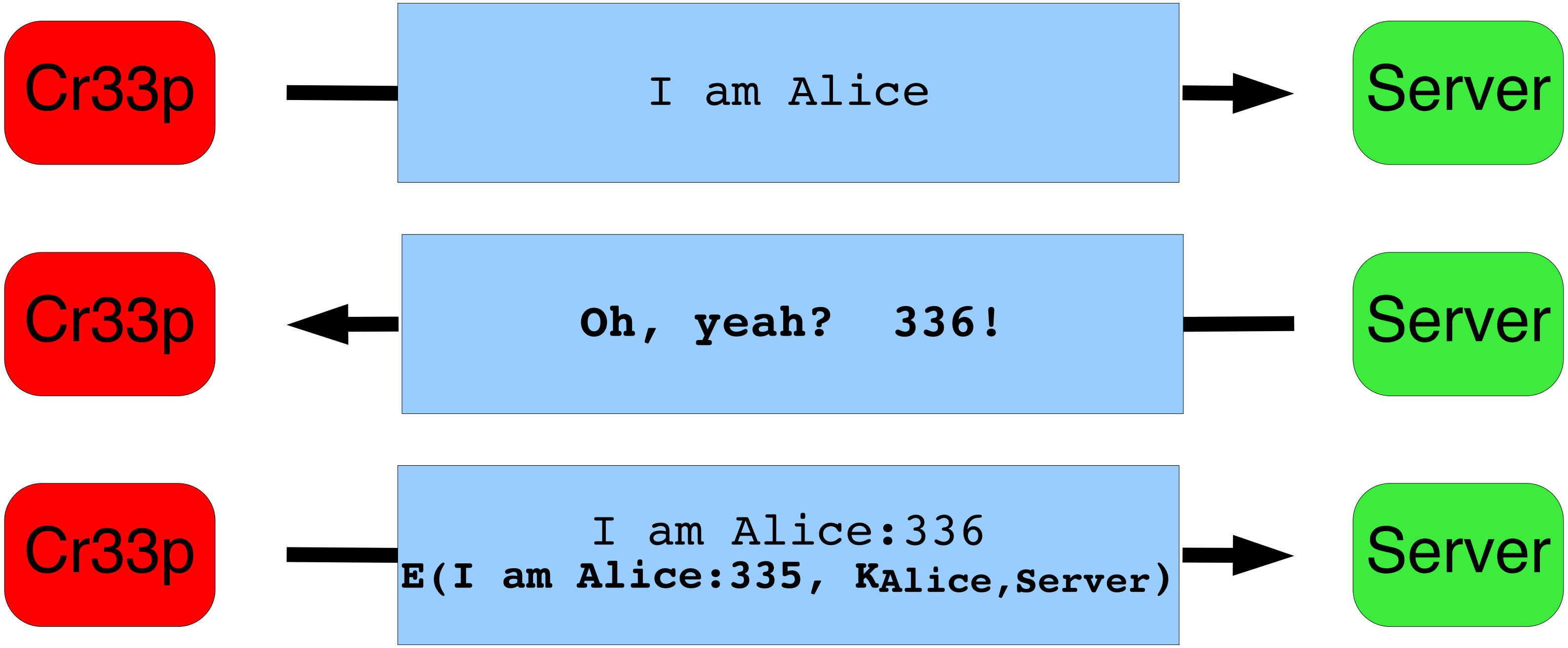
Secure Network Login – Nonce



I am Alice

Oh, yeah? 336!

Secure Network Login – Nonce

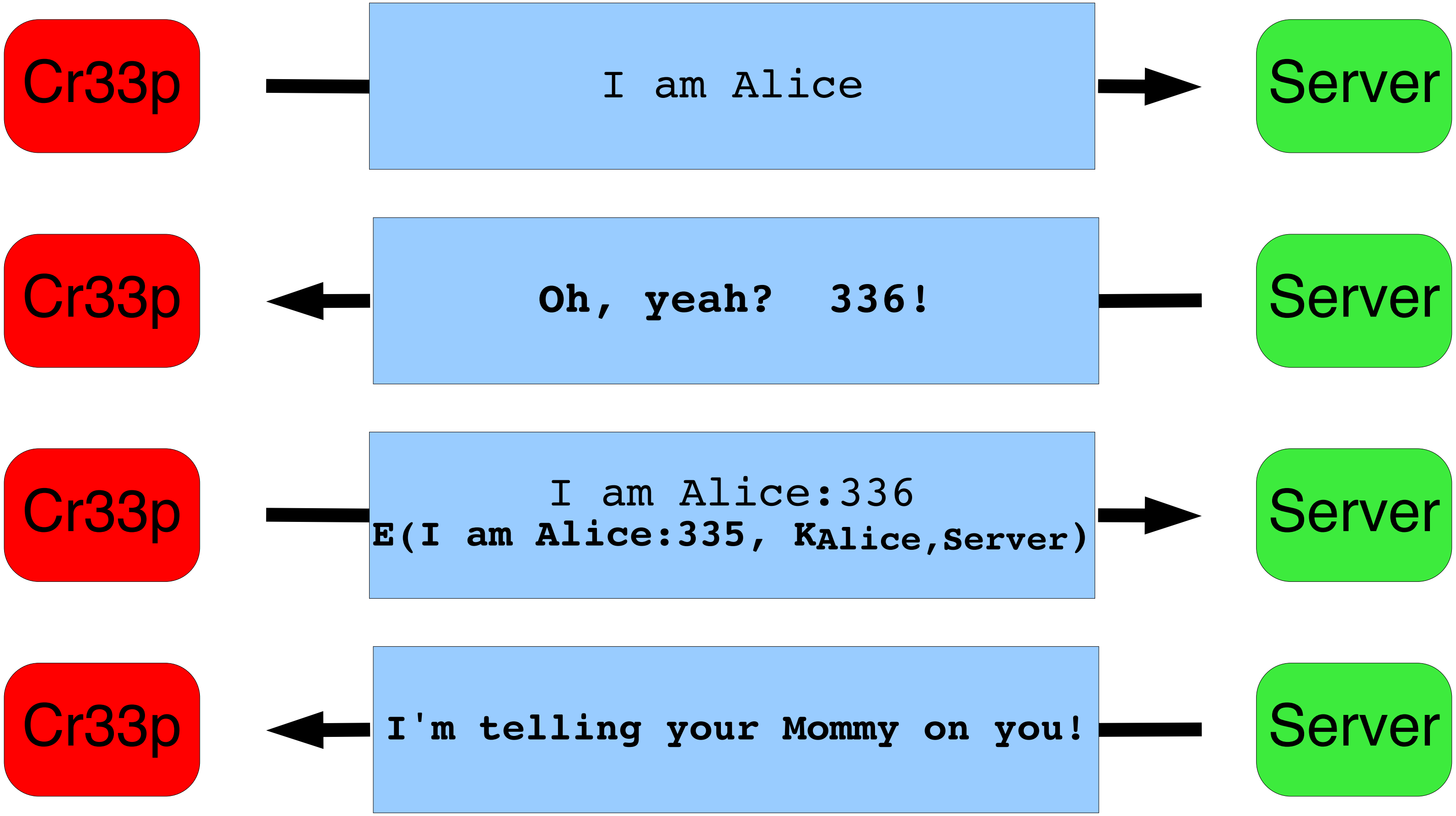


Cr33p → I am Alice → Server

Cr33p ← **Oh, yeah? 336!** ← Server

Cr33p → I am Alice:336 **E(I am Alice:335, $K_{Alice,Server}$)** → Server

Secure Network Login – Nonce



Cr33p → Server: I am Alice

Server → Cr33p: **Oh, yeah? 336!**

Cr33p → Server: I am Alice:336
E(I am Alice:335, $K_{Alice,Server}$)

Server → Cr33p: **I'm telling your Mommy on you!**

Summary

Many threats

Many techniques

“The devil is in the details”

Just because it “works” doesn't mean it's right!

Open algorithms, open source

Further Reading

Soft Tempest: Hidden Data Transmission Using Electromagnetic Emanations

- Markus Kuhn, Ross Anderson
- http://www.cl.cam.ac.uk/~mgk25/ih98-tempest.pdf

Optical Time-Domain Eavesdropping Risks of CRT Displays

- Markus Kuhn
- http://www.cl.cam.ac.uk/~mgk25/emsec/optical-faq.html

Keyboard Acoustic Emanations Revisited

- Zhuang, Zhou, Tygar
- http://www.cs.berkeley.edu/~tygar/papers/Keyboard_Acoustic_Emanations_Revisited/ccs.pdf

Further Reading

Reflections on Trusting Trust

- Ken Thompson
- http://www.acm.org/classics/sep96

Netscape random-number oops

- http://www.cs.berkeley.edu/~daw/netscape-randomness.html

Lava-lamp random numbers

- http://www.LavaRnd.org/

How to destroy somebody who uses a hash table

- http://www.cs.rice.edu/~scrosby/hash/CrosbyWallach_UsenixSec2003/