

15-410

“...”Windows NT is C2 Secure”...”

Security Overview Nov. 30, 2016

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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”

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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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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?

**XX
XX
XX
XX
XX
XX
XX**

**%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”

- $h_1 = f(\text{message}_1)$
- Given h_1 “infeasible” to map back to message_1
 - Not so hard – “parity sum” is a one-way function!

Hashing

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“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 (Crypto2004, 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)
 - “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
- Standardized: FIPS 202, 2015-08-05
 - “Should replace” to “new standard” in just 10 years!

“Random” Numbers

Three concepts

- Pseudo-random number generator (PRNG)
 - $\text{Next} = (\text{Previous} * L + I) \bmod M$
 - `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 = $E(\text{text}, K_1)$

text = $D(\text{ciphertext}, K_2)$

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
 - $M \oplus R = 1F$
 - $M E S S A G E \oplus R K N Y Q T I = 1F 0E 1D 0A 10 13 0C 0A$
- D(): same process – using the *same random string*
 - Recall
 - » $random \oplus random = 0$
 - » $msg \oplus 0 = msg$
 - So $(msg \oplus random) \oplus random = msg$

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!!**

- $(m1 \oplus \text{pad}) \oplus (m2 \oplus \text{pad}) = (m1 \oplus m2)$
- Computationally *very* easy to see if a bit stream is text \oplus '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 $E(\text{hash}(\text{msg}), K_p)$)

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*

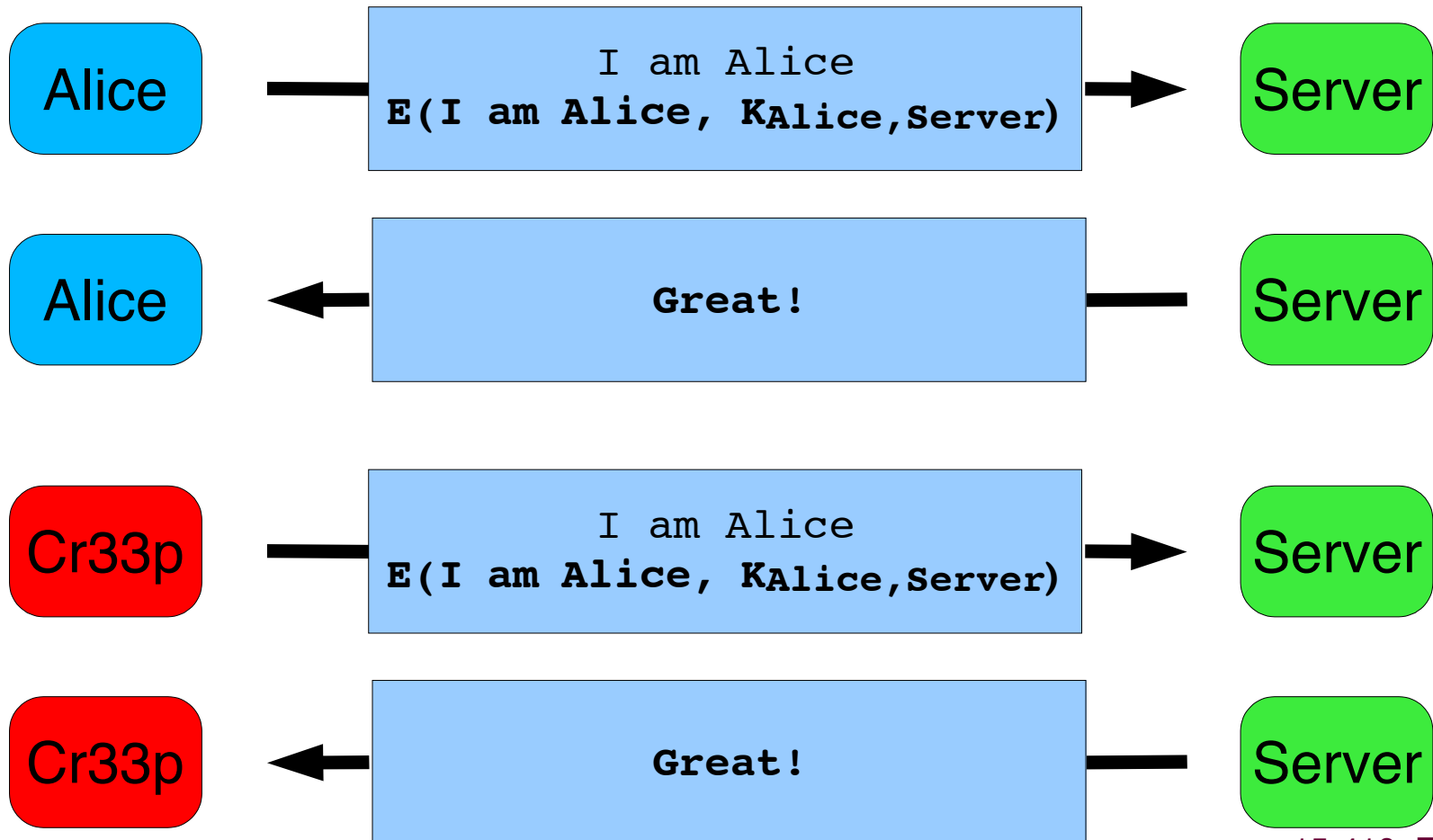
Can we get the best of both?

- Next time!

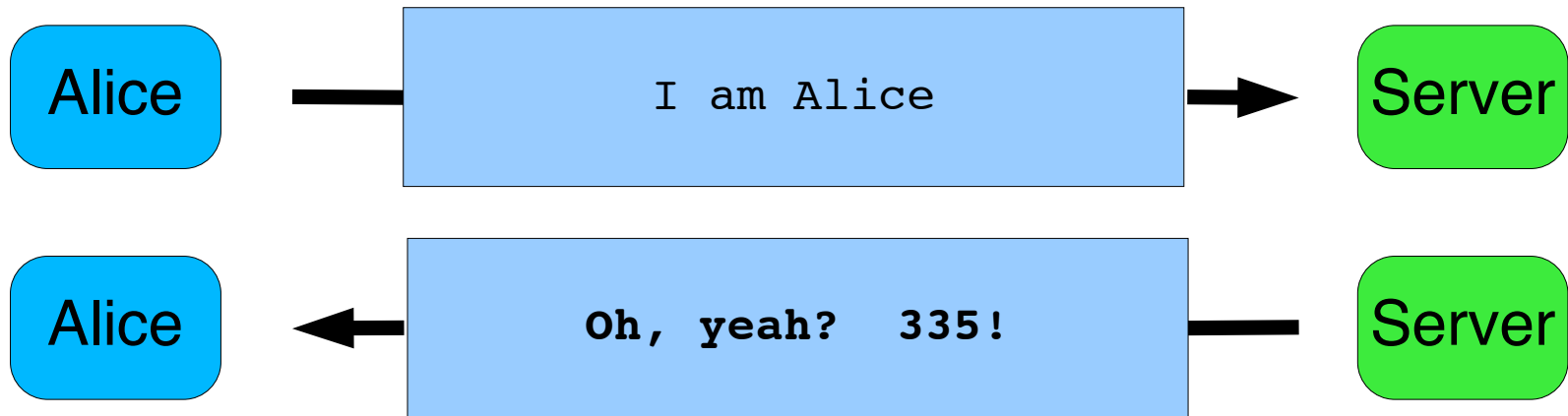
Secure Network Login



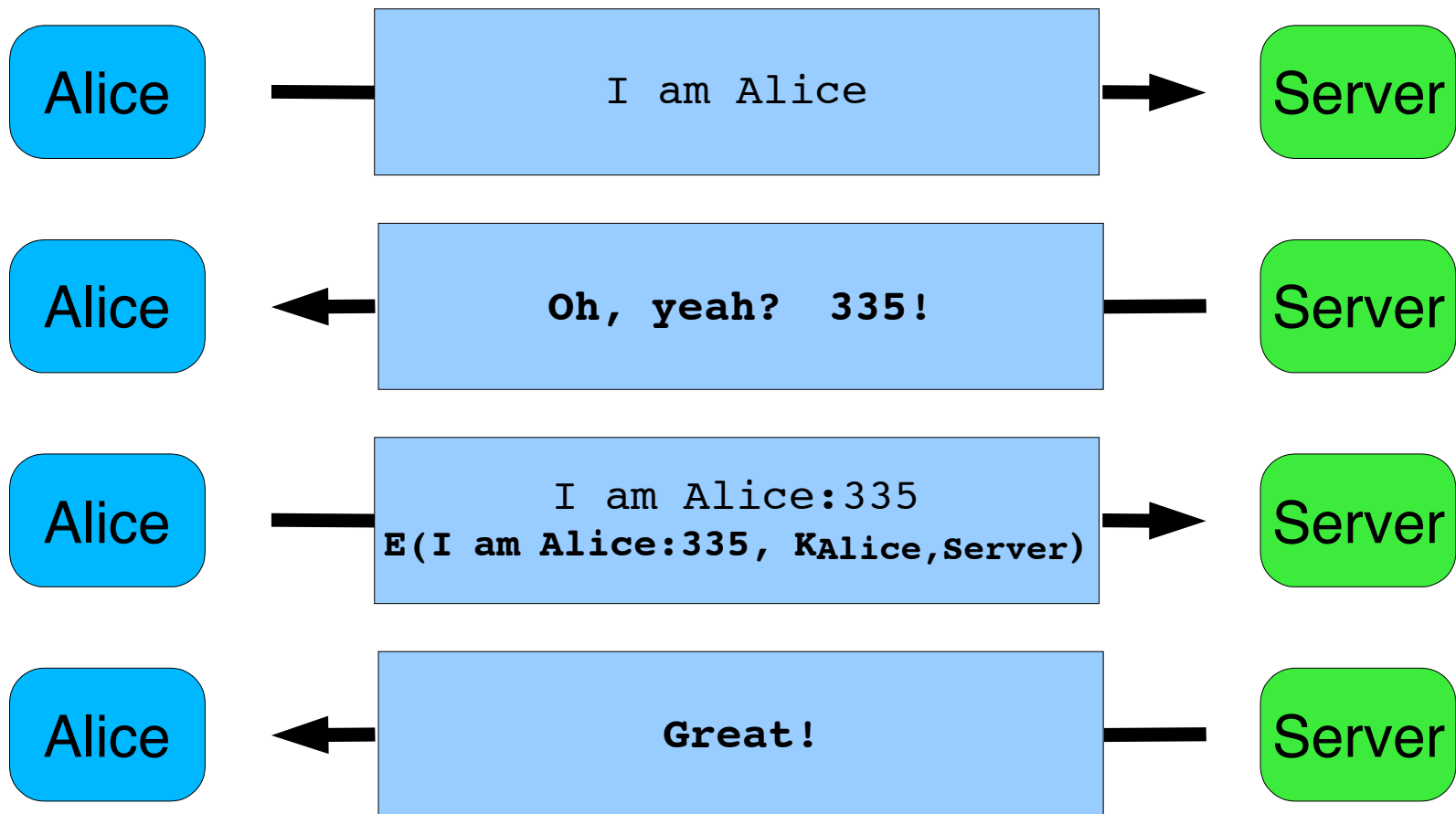
Secure Network Login – Uh-oh...



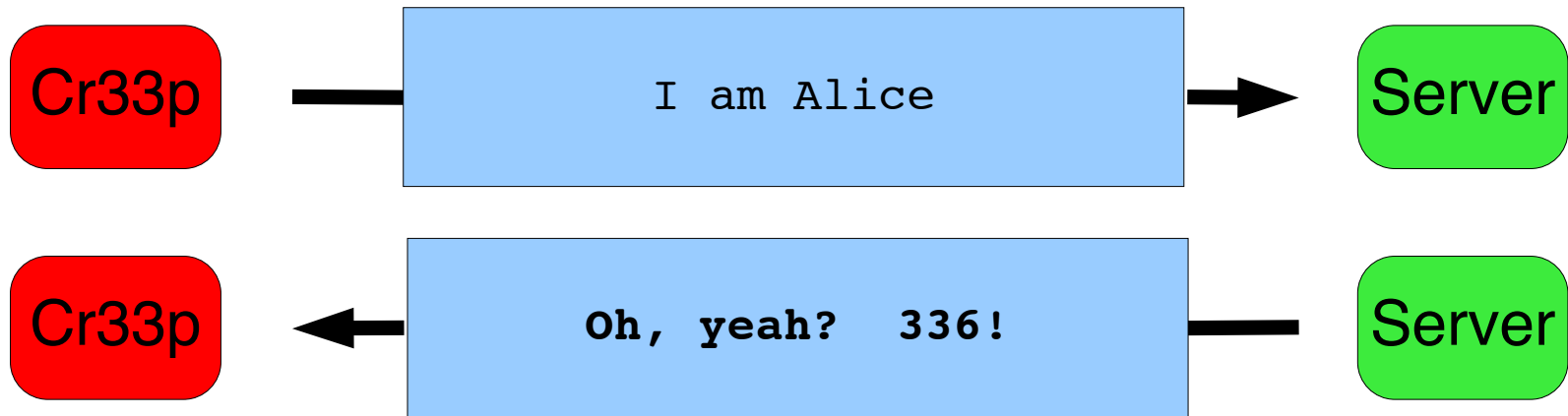
Secure Network Login – Nonce



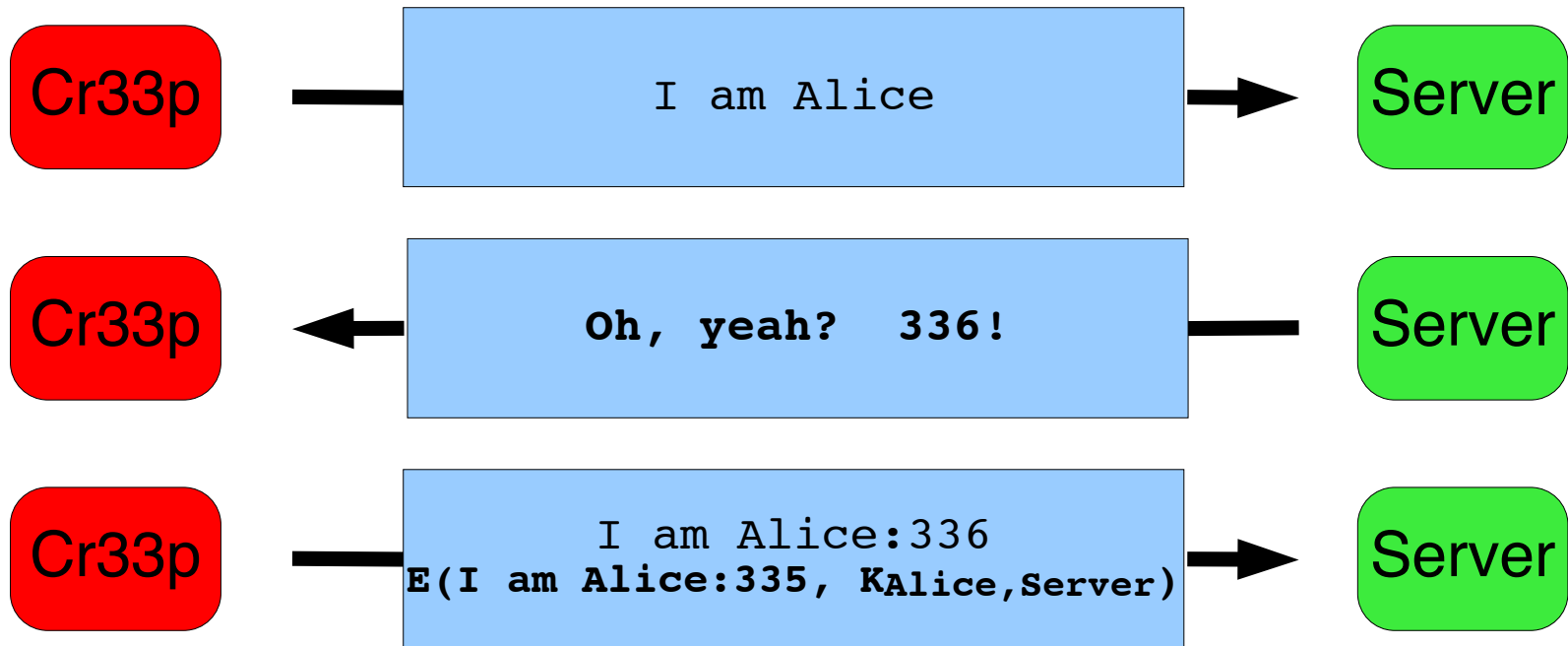
Secure Network Login – Nonce



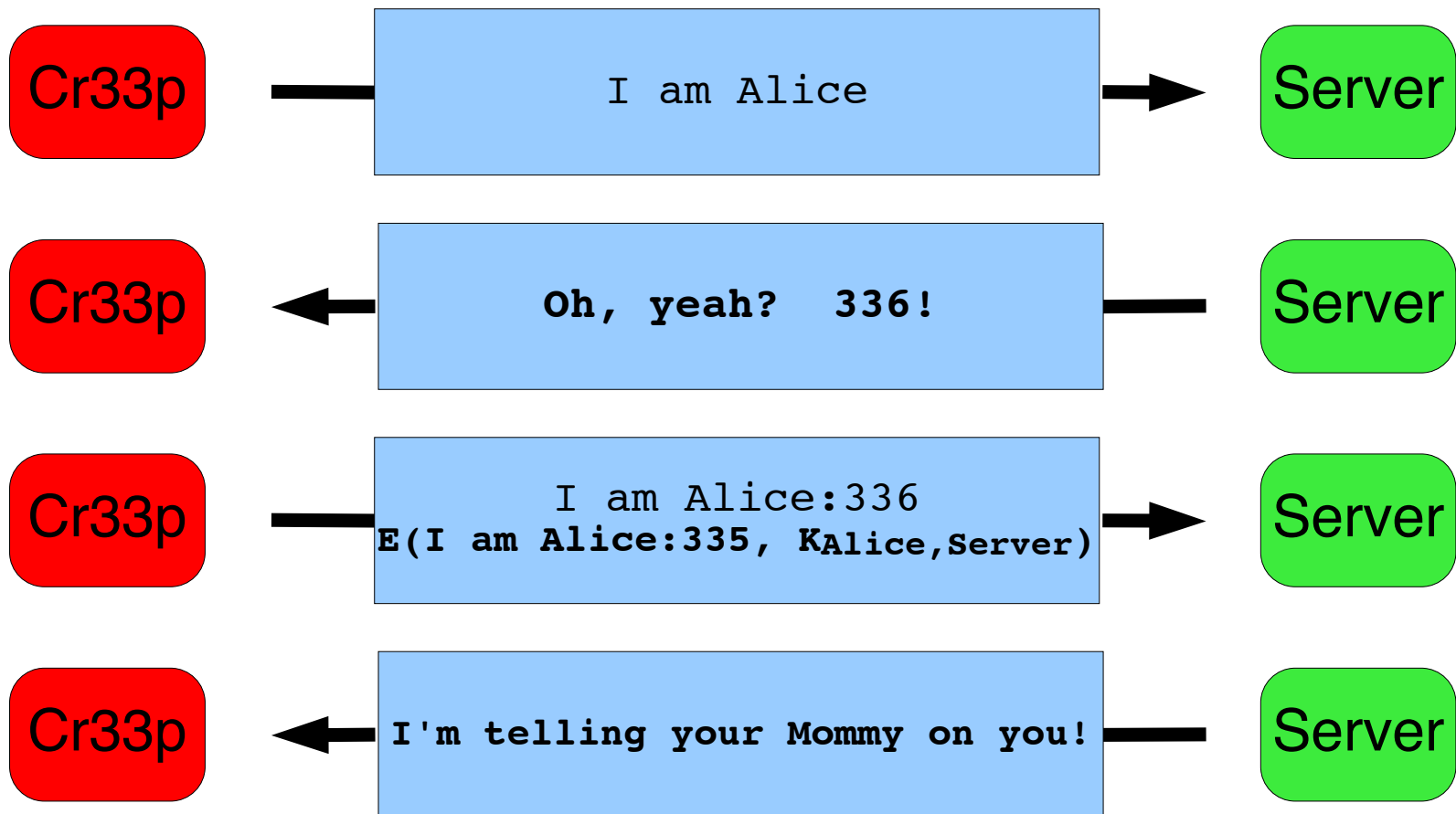
Secure Network Login – Nonce



Secure Network Login – Nonce



Secure Network Login – Nonce



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_UserixSec2003/