15-410

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

Security Overview
Apr. 11, 2012

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Synchronization

Today

- 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!

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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 is 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

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Fallback system

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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?
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
%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"

- $h_1 = f(message_1)$
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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
- "Infeasible" to find/construct malware with that hash

Hashing Issues

Verify data?

- Compute hash function on data you have
- Compare to published official output of hash function run on the official data

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 ($<< 2^{80}$)
- “Schedule SHA-1 for replacement” -- with what??

Fate of Secure Hashes

Status (April 2011)

- SHA-1 is somewhat replaced by the "SHA-2 family" (SHA-224, SHA-256, SHA-384, SHA-512)
  - The "SHA-2 family" is basically SHA-1 with more bits
- NIST is holding a multi-year "Advanced Hash Standard" competition
  - Submissions were due October 31, 2008
  - 64 submissions
  - 51 "first-round candidates"
    - » 10 first-round candidates quickly broken
  - 14 second-round candidates
  - 5 finalists: BLAKE, Grøstl, JH, Keccak, Skein
  - "Third SHA-3 Candidate Conference": March 22-23, DC
  - Expected announcement of winner: 2012Q2
  - http://csrc.nist.gov/groups/ST/hash/sha-3/

“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

$$\texttt{ciphertext} = E(\texttt{text}, K_1)$$

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

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 ⊕ 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 ⊕ pad) ⊕ (m2 ⊕ pad) = (m1 ⊕ 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

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

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*

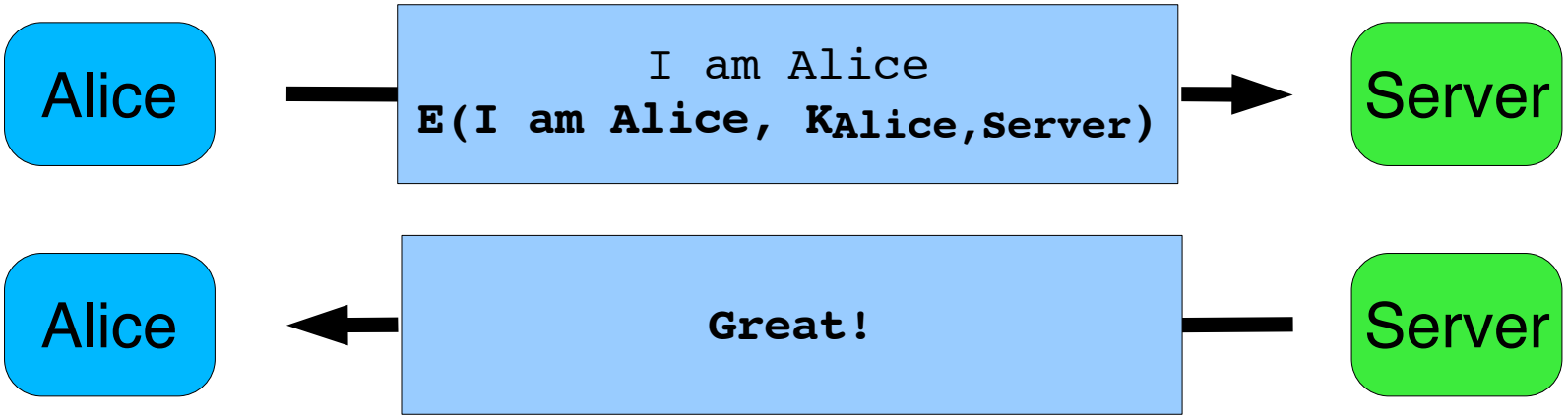
Public-key algorithms

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

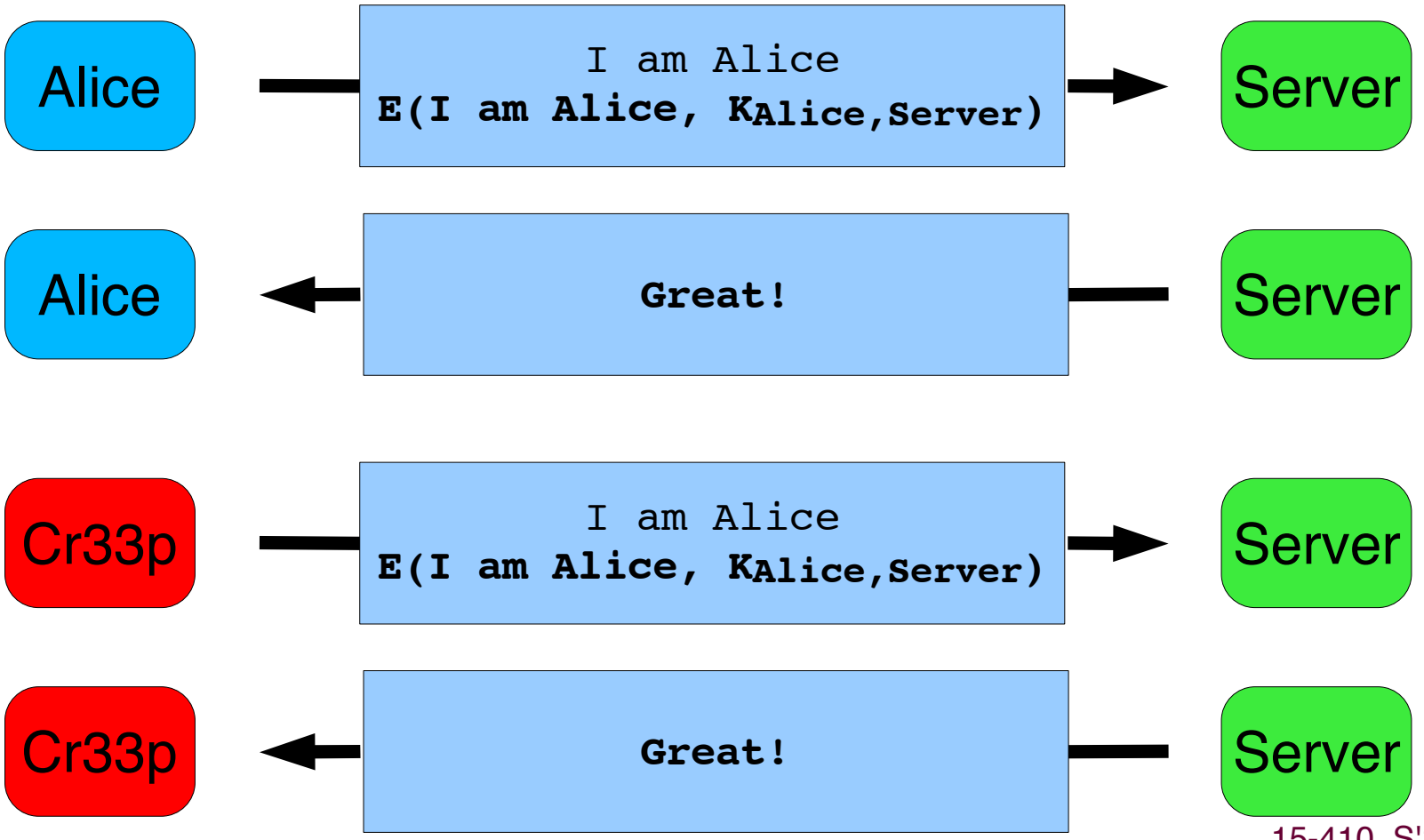
Can we get the best of both?

- Next time!

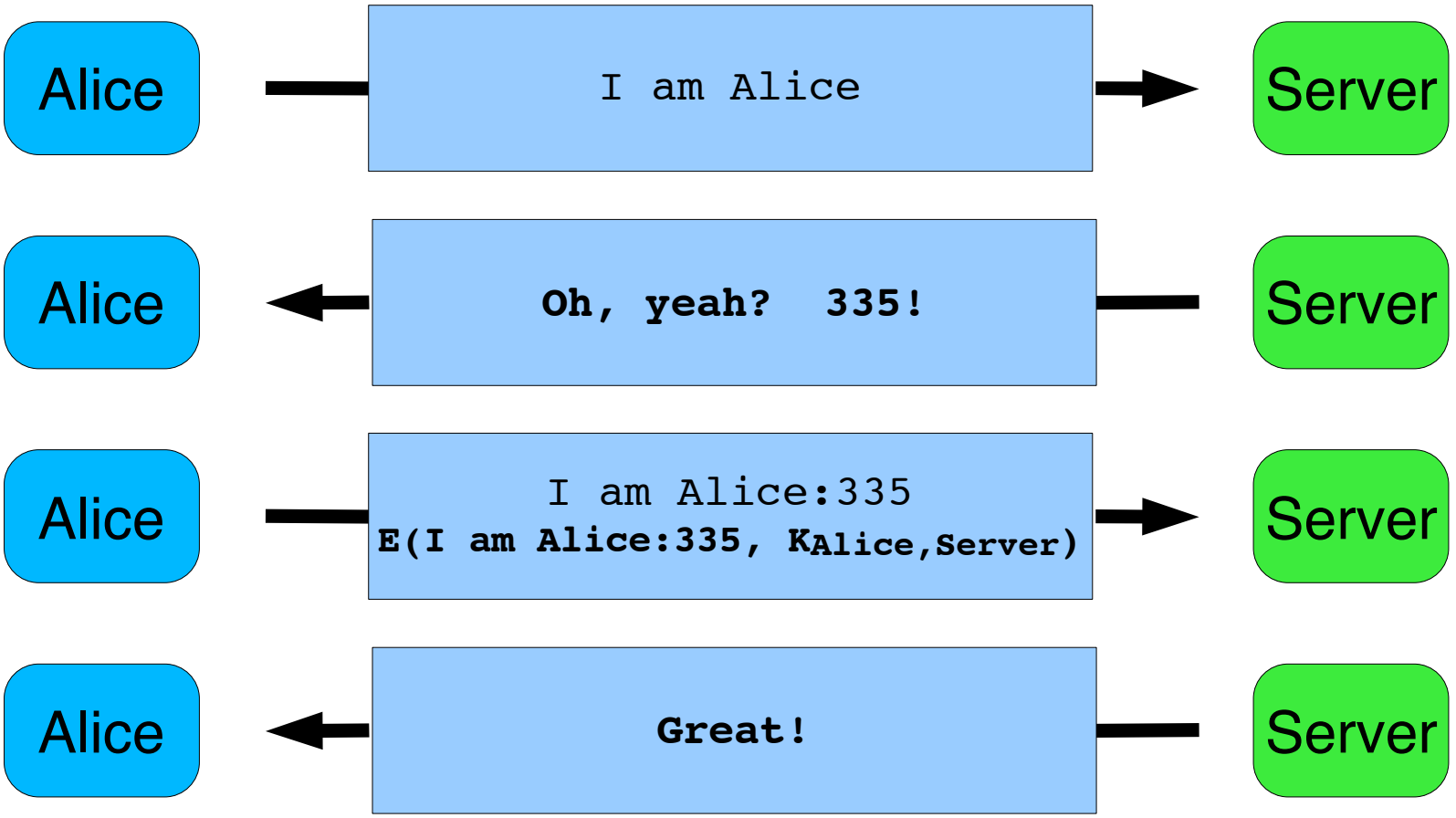
Secure Network Login



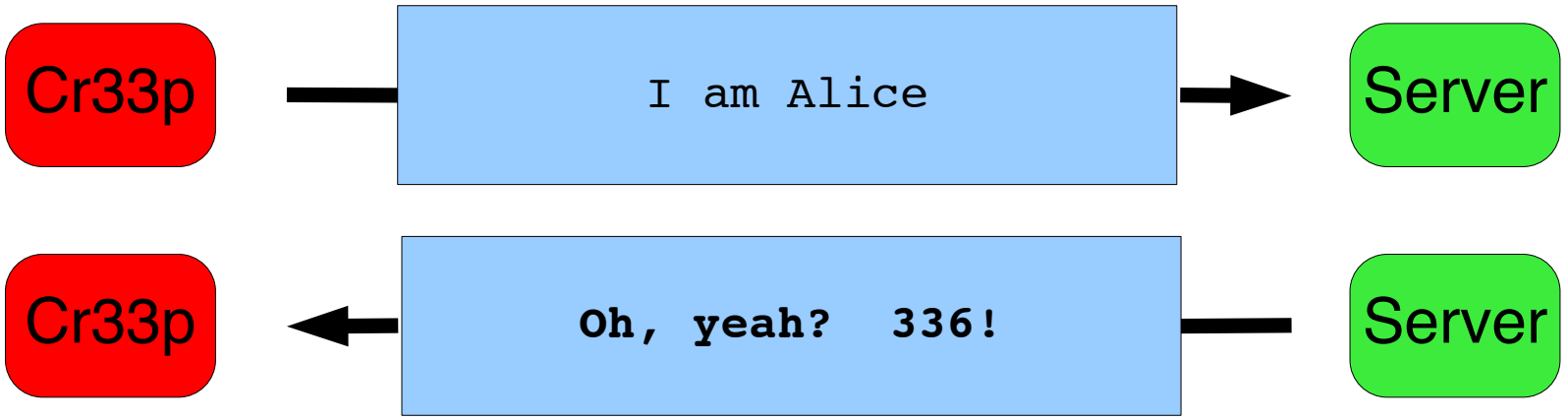
Secure Network Login – Uh-oh...



Secure Network Login – Nonce



Secure Network Login – Nonce



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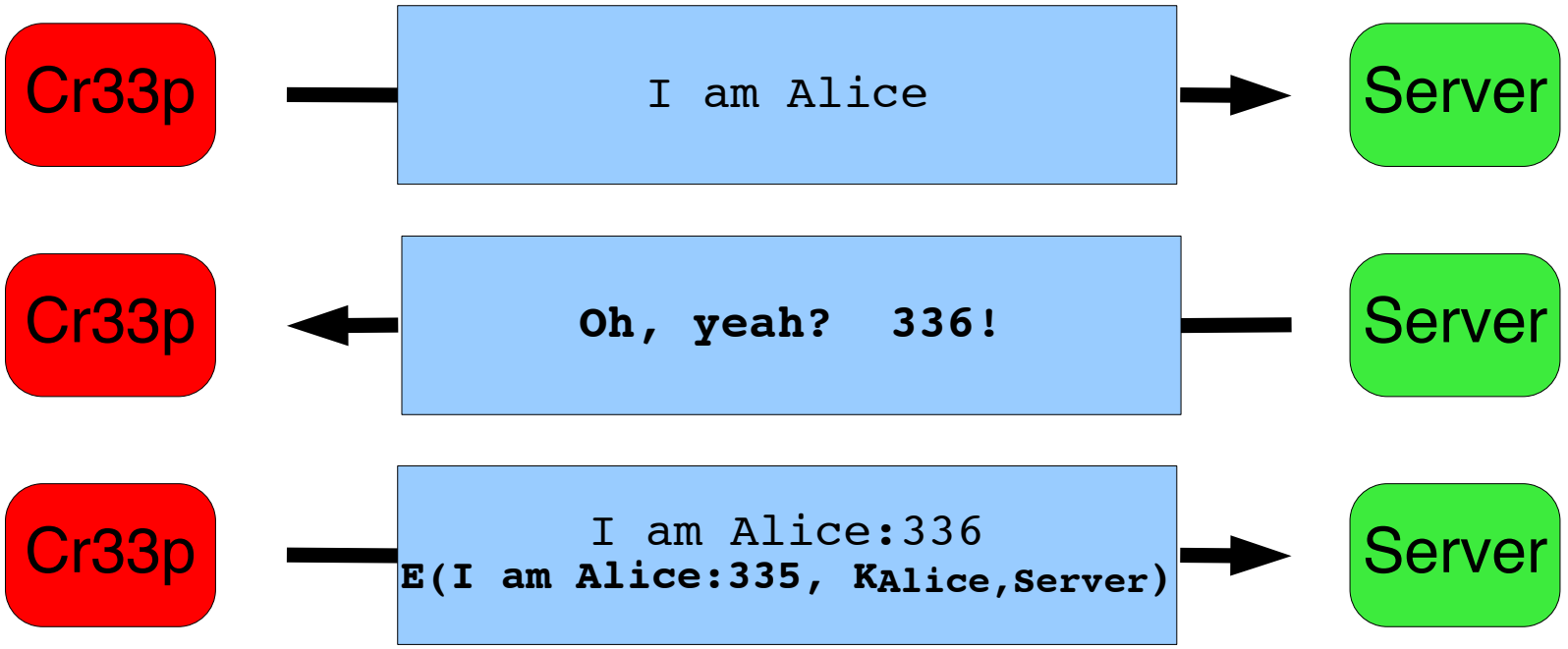
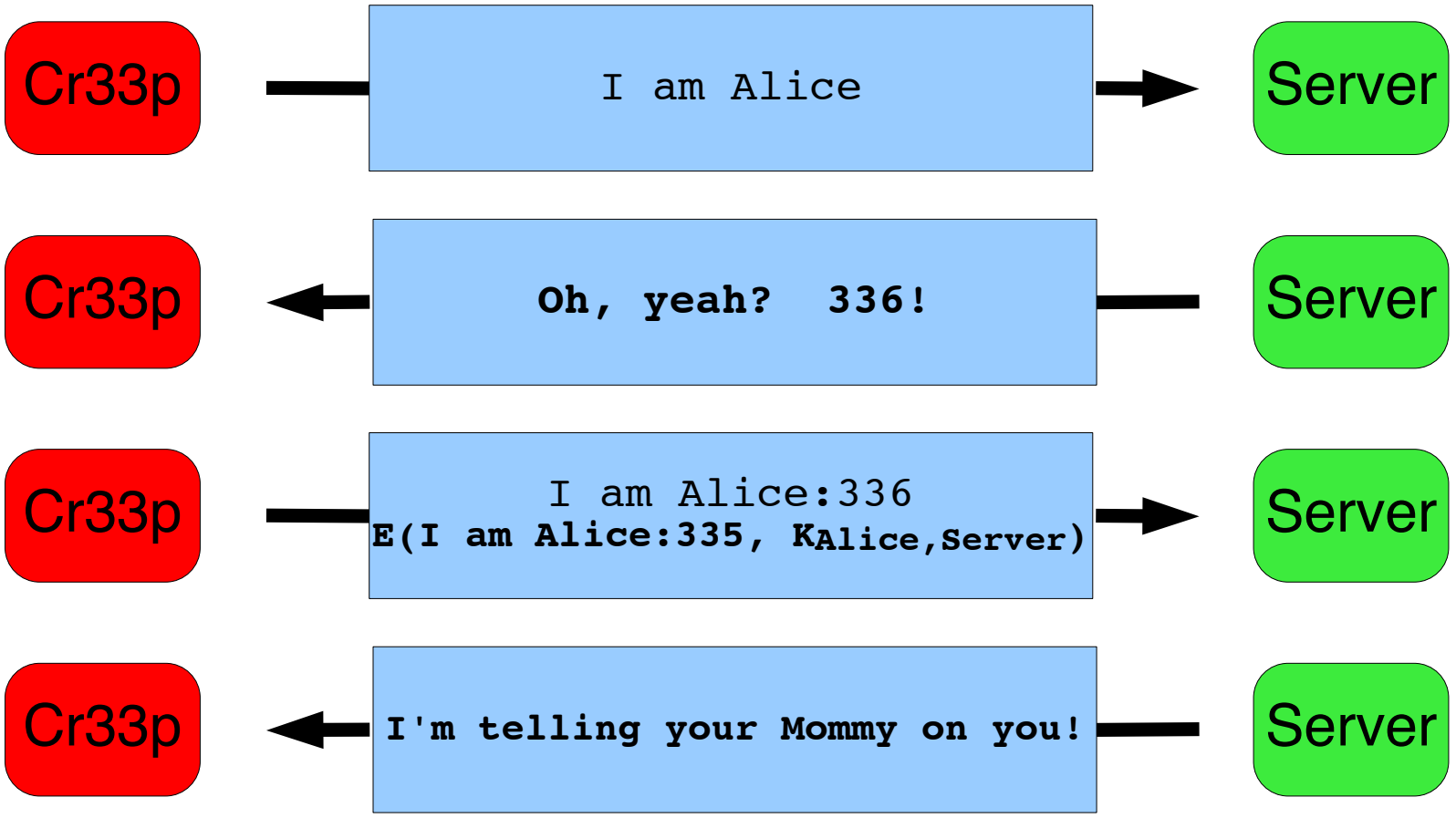


Secure Network Login – Nonce



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

Status of secure hash functions

- MD5 is really dead (fast exploit code available)
  - http://www.schneier.com/blog/archives/2005/06/more_md5_collis.html
  - http://www.schneier.com/blog/archives/2005/03/more_hash_funct.html
  - http://cryptography.hyperlink.cz/md5/MD5_collisions.pdf
- SHA-1 has been seriously wounded
  - http://www.schneier.com/blog/archives/2005/02/cryptanalysis_o.html
  - http://www.schneier.com/blog/archives/2005/02/sha1_broken.html
  - http://www.schneier.com/blog/archives/2005/08/new_cryptanalyt.html
  - Xiaoyun Wang's page
    - » http://www.infosec.sdu.edu.cn/2person_wangxiaoyun.htm

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/