Internet Fundamentals

Lecture-32

Security

Administrative Stuff

- Lab #4 due today
- HW #4 due August 11
- Final exam on Friday
- Wednesday will be review

Final Exam

- Friday (8/13) from 7-10pm in Gates B03
- Closed book
- 2 8.5x11 cheat sheets
- Cumulative
    - Emphasis on material after midterm

Global Functions

- escape(string)
- unescape(string)
- Safe Strings

  ABCDEFGHIJKLMNOPQRSTUVWXYZ

  abcdefghijklmnopqrstuvwxyz

  1234567890

  @ * - _ + . /
- Unsafe Strings => %20, %5c, etc...

Security

Computer Data

- File on your own hard drive (term paper)
- File on networked file system (Leland AFS)
- Data sent to another computer (credit card number to Amazon)

Three Considerations: What do we want?

- Privacy of our data
- Integrity of our data
- Usability of our system/data

Three Concepts

- Confidentiality of data
- Integrity of data
- Authentication of users

What Functionality Is Needed?

- Authentication -- who user is
- Authorization -- who is allowed to do what
- Enforcement -- make sure people do what they are supposed to do

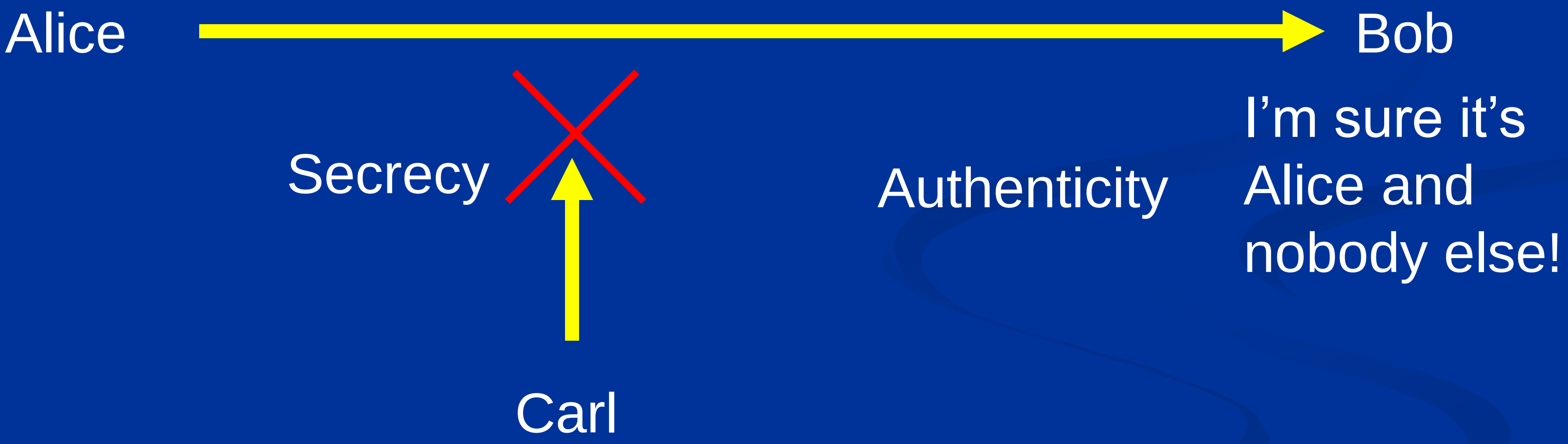
Definitions

- Secrecy (aka Privacy, Confidentiality)
  - Diary Lock
- Authenticity
  - Hi it's Bob.
  - Prove it Dude...

Definition Examples

- Secrecy
  - Alice sends message to Bob. Carl intercepts the message... but can't read
- Authenticity
  - Alice sends message to Bob. Bob can verify that Alice is the sender.

The Big Picture



Alice

Bob

Secrecy

Authenticity

I'm sure it's
Alice and
nobody else!

Carl

Methods

- Cryptography
  - Converting messages to unreadable forms…

    Unconverting it back to the readable form
- Steganography
  - Hiding the existence of a message

Steganography

Null Cipher

Fishing freshwater bends and saltwater coasts rewards anyone feeling stressed. Resourceful anglers usually find masterful leapers fun and admit swordfish rank overwhelming anyday.

Send lawyers, guns, and money.

Invisible Ink

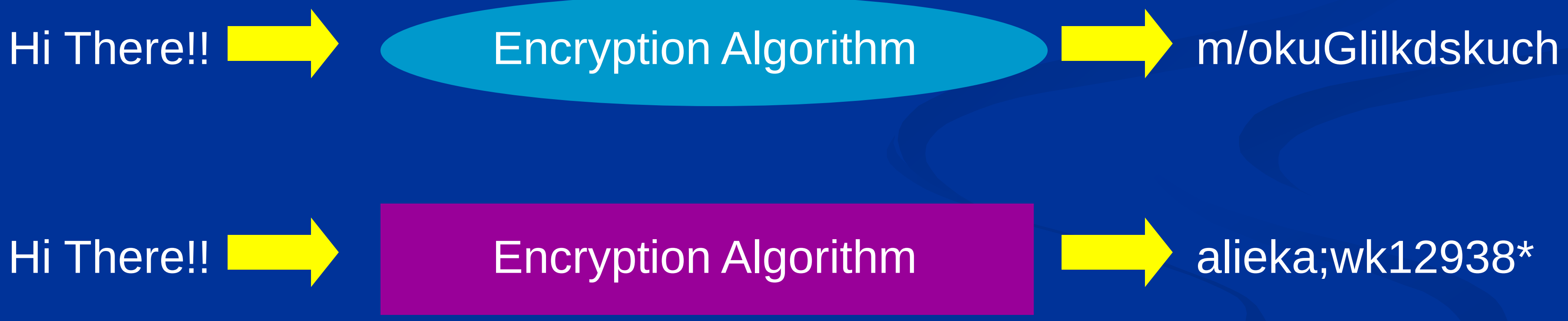
- Write with lemon juice and a toothpick/ cotton swab. Let the paper dry.
- Heat the paper with an iron to reveal the hidden message.

Cryptography

Greek: kryptos + graphein → hidden writing

Encryption

- Convert normal, readable data into obscured, unreadable data

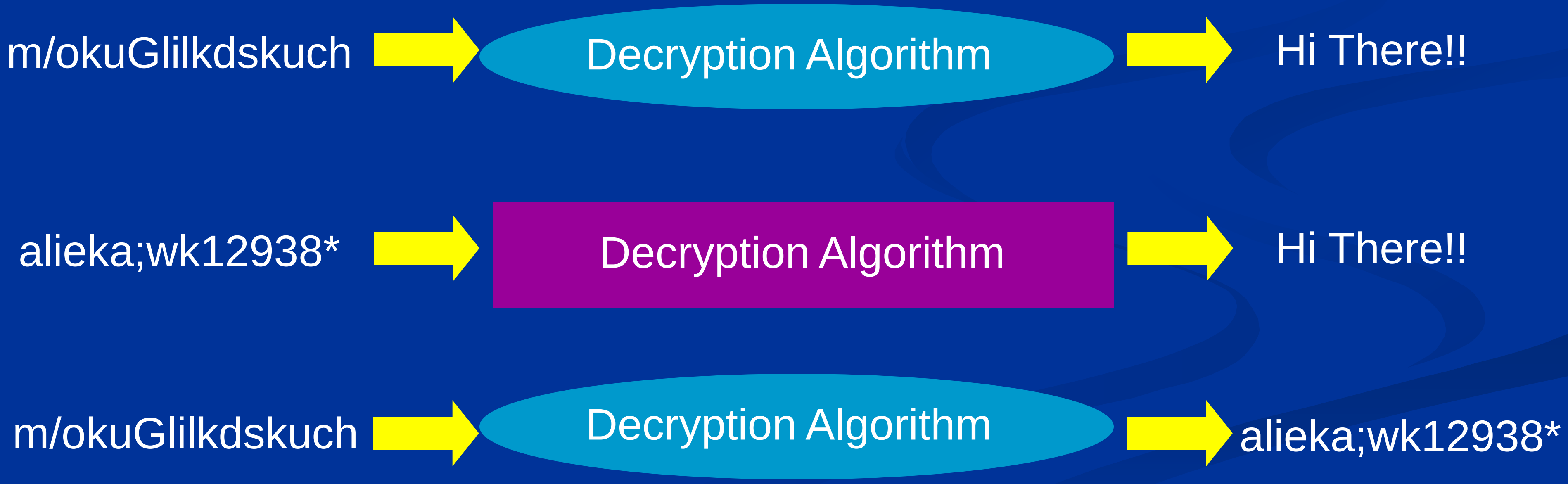


Hi There!! → Encryption Algorithm → m/okuGlilkdskuch

Hi There!! → Encryption Algorithm → alieka;wk12938*

Decryption

- Convert obscured, unreadable data into normal, readable data



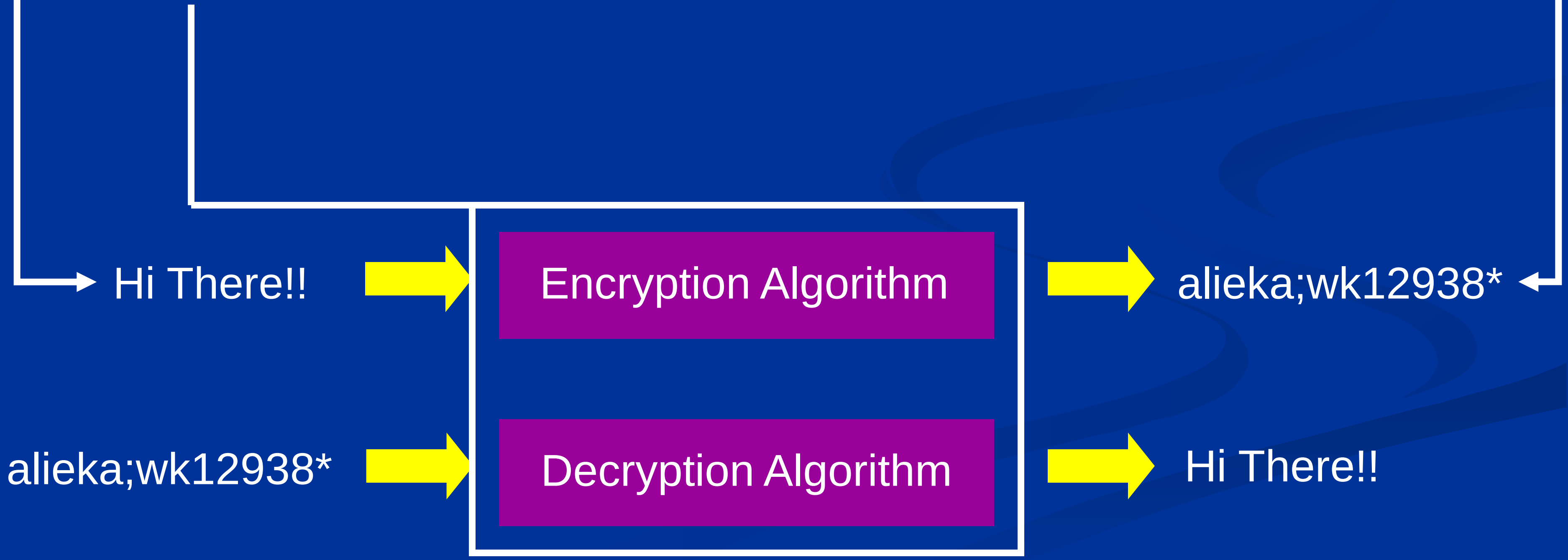
m/okuGlilkdskuch → Decryption Algorithm → Hi There!!

alieka;wk12938* → Decryption Algorithm → Hi There!!

m/okuGlilkdskuch → Decryption Algorithm → alieka;wk12938*

Terminology

- plaintext - clear readable text
- ciphertext - unreadable text
- cipher - algorithm(s) for encryption and decryption



Hi There!! → Encryption Algorithm → alieka;wk12938*

alieka;wk12938* → Decryption Algorithm → Hi There!!

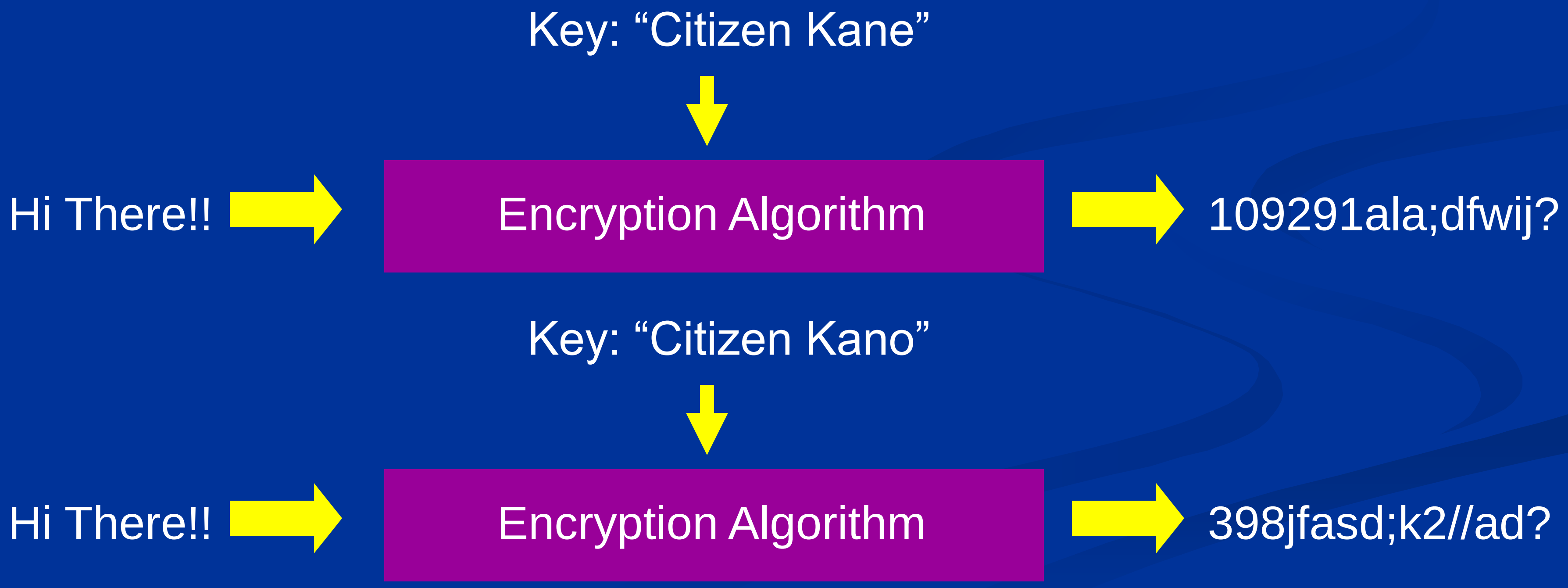
Terminology

- Security through obscurity
  - Don't publish some details of your algorithm... assuming people won't figure it out
  - Like hiding the key under the doormat
- Once your flaw/algorithm is leaked, you're screwed

Optional Reading:
http://slashdot.org/features/980720/0819202.shtml

Terminology

- Key -- a secret piece of information that controls how the encryption algorithm works
- Different keys produce different encrypted results



Key: “Citizen Kane”

Hi There!! → Encryption Algorithm → 109291ala;dfwij?

Key: “Citizen Kano”

Hi There!! → Encryption Algorithm → 398jfasd;k2//ad?

Classical Ciphers

- Monoalphabetic substitution
  - Caesar shift
- Polyalphabetic substitution
  - Jefferson

http://www.murky.org/cryptography/classical.shtml

Caesar Shift

PLAINTEXT	a	b	c	d	e	f	g	h	i	j	k	l	m
CIPHERTEXT	D	E	F	G	H	I	J	K	L	M	N	O	P
PLAINTEXT	n	o	p	q	r	s	t	u	v	w	x	y	z
CIPHERTEXT	Q	R	S	T	U	V	W	X	Y	Z	A	B	C

Hello There → khoorwkhuh

Problem

- Monoalphabetic -- Same letter of plaintext always produces same letter of ciphertext
- Even though there are 26! possible substitutions, monoalphabetic solutions are easy to break!
- Use frequency analysis of English language, plus some tricks...

Breaking a Monoalphabetic Substitution

Yxdy pq yjc xzpvpyw ya icqdepzc ayjceq xq

yjcw qcc yjcuqcvrcq.

Xzexjxu Vpsdavs

Breaking a Monoalphabetic Substitution

Yxdy pq yjc xzpvpyw ya icqdepzc ayjceq xq

yjcw qcc yjcuqcvrcq.

Xzexjxu Vpsdavs

Character Frequency: C10, Y8, Q7, X6, J5, P5, V4, D3
A3, E3, Z3, S2, U 2, I1, R1, W2

Breaking a Monoalphabetic Substitution

Yxdy pq yjc xzpvpyw ya icqdepzc ayjceq xq

yjcw qcc yjcuqcvrcq.

Xzexjxu Vpsdavs

Character Frequency: C10, Y8, Q7, X6, J5, P5, V4, D3
A3, E3, Z3, S2, U 2, I1, R1, W2

Alphabet frequency: e t a o i n s r h l d c u m f p g w y b v k x j q z

Breaking a
Monoalphabetic Substitution

Yxdy pq yjc xzpvpyw ya icqdepzc ayjceq xq
Tact is the ability to describe others as

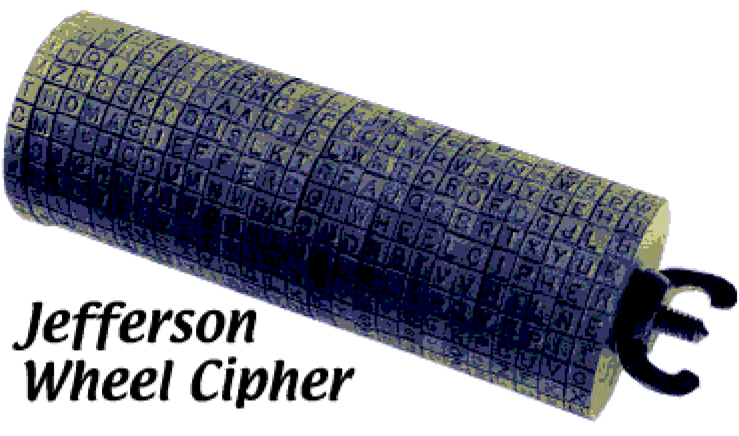
yjcw qcc yjcuqcvrcq.
they see themselves.

Xzexjxu Vpsdavs
Abraham Lincoln

Character Frequency: C10, Y8, Q7, X6, J5, P5, V4, D3
A3, E3, Z3, S2, U 2, I1, R1, W2

Alphabet frequency: e t a o i n s r h l d c u m f p g w y b v k x j q z

Jefferson Wheel Cipher



Computer Era

- Moore's law
- Keys breakable by brute force

Modern Ciphers

- Bigger and bigger keys
- More and more complicated algorithms
- Based on hardcore applied mathematics... and the difficulty of factoring large (i.e. gargantuan) numbers

Terminology

- Symmetric key cryptography
  - Caesar shift, ..., DES, AES
- Asymmetric key cryptography
  - Public/Private key schemes

Symmetric Key Technology

- p = plaintext
- crypt() = encryption/decryption function
- c = cipher text (unreadable)
- k = key (secret; password)

Symmetric Key Technology

- Alice wants to send a private/confidential message to Bob
- Alice computes c=crypt(p,k)
- Sends c to Bob over unsecured wire
- Bob computes p=crypt(c,k)

Symmetric Key Application

- Password login
- Alice sends password to computer to prove identity (authenticity)
- Problem: Sniffing
- Solution: Challenge/response

Shared Secret Key

- Shared secret is great... but how do we distribute it?

Asymmetric Key Cryptography

- Instead of one key, have two
  - public key
  - private key

Asymmetric Key Technology

- Use one key to encode/encrypt
- Use other key to decode/decrypt

Asymmetric Key Technology

- Someone can know public key
- Computing private key from public key is very, very difficult (factoring huge number)

Application: Secrecy

- Bob has Bob.pub, Bob.priv
- Alice has Alice.pub, Alice.priv
- Alice wants to send Bob a secret "I LUV U" note

Application: Secrecy

- Alice finds Bob.pub from his website
- Alice computes c = crypt(p, Bob.pub)
- Sends c to Bob over unsecured wire
- Bob computes p = crypt(c, Bob.priv)

Advantages

- Key distribution not a problem!
- Anyone can send a message to Bob
- Only Bob can decrypt!

Application: Authenticity

- Alice wants to tell Bob the message is really from her!
- Digital signature
- Alice computes c = crypt(p, Alice.priv)
- Alice sends c over unsecured wire
- Anyone can check that Alice is the sender… by computing p = crypt(c, Alice.pub)

Authenticity + Secrecy

Alice
A.priv

“I LUV U”

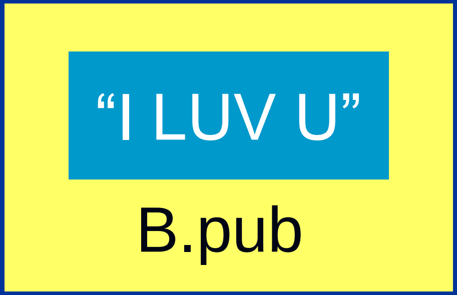
A.pub, B.pub, ...

Carl & Eve
Bad People!

Bob
B.priv

Authenticity + Secrecy

Alice
A.priv



"I LUV U"

B.pub

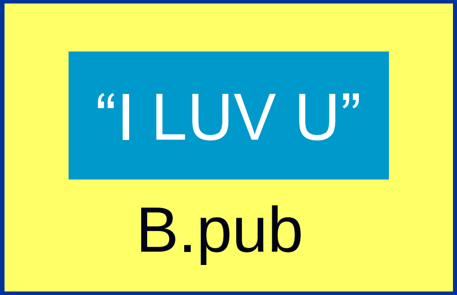
A.pub, B.pub, ...

Carl & Eve
Bad People!

Bob
B.priv

Authenticity + Secrecy

Alice
A.priv



“I LUV U”

B.pub

“This is from A”

A.pub, B.pub, ...

Carl & Eve
Bad People!

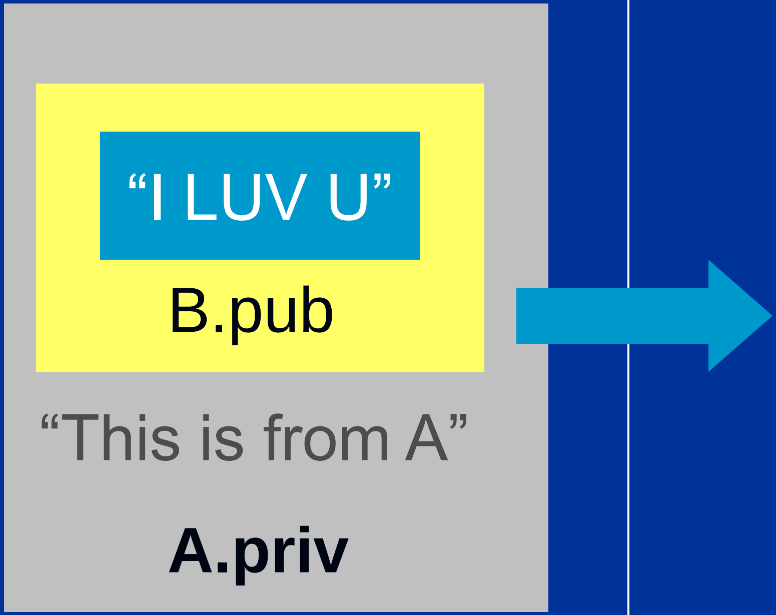
Bob
B.priv

Authenticity + Secrecy

Alice
A.priv

A.pub, B.pub, ...

Bob
B.priv



"I LUV U"

B.pub

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Authenticity + Secrecy

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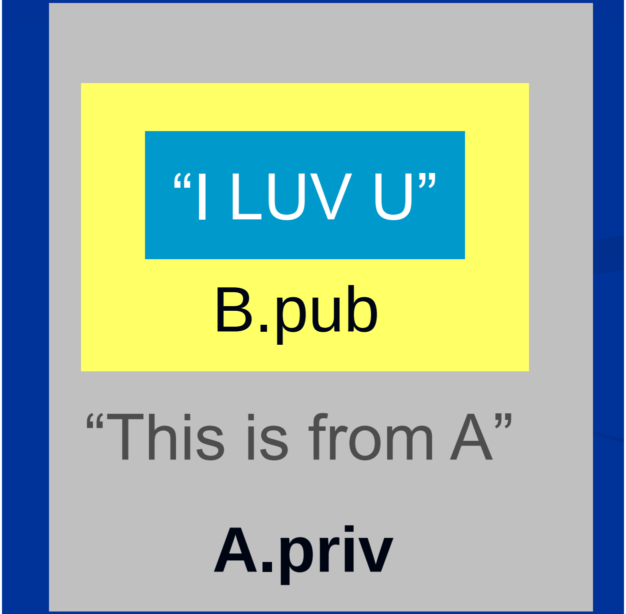

"I LUV U"

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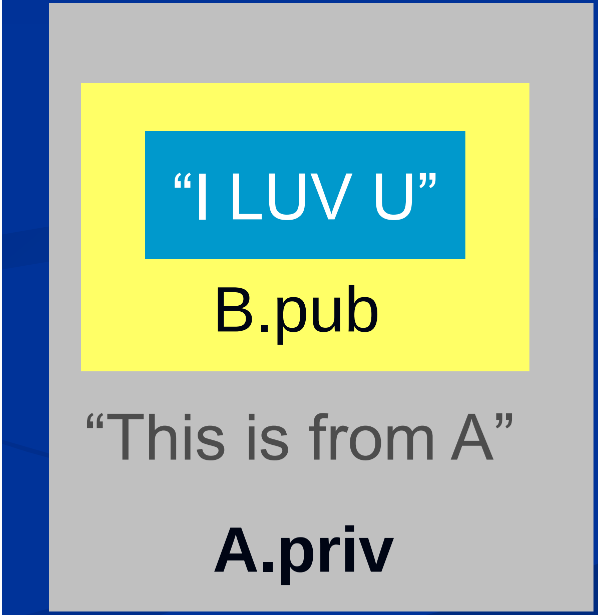

"I LUV U"

B.pub

"This is from A"

A.priv

Carl & Eve
Bad People!

Hash Functions

- h = hash(input)
- Every bit in input affects output
- Hash function not invertible

Error Checking

- Alice wants to send a LONG message to Bob
- Alice computes h=hash($LONG_MSG);
- Sends data to Bob, includes relatively short h at the end of message
- Bob recomputes hash.
- If match, great! Data's correct!
- If not match, either hash or data was corrupted. Resend.

Digital Signatures

- Bob wants to send $data to Alice, with assurances of his identity (authenticity)
  - h=hash($data)
  - Signature = crypt(h, Bob.priv)
- Sends these to Alice
- Alice confirms Bob's identity by
  - h = crypt(signature, Bob.pub)
  - h = hash($data)
  - Compares!

Authenticity + Secrecy

Alice
A.priv

A.pub, B.pub, ...

Bob
B.priv

"I LUV U ……"

Carl & Eve
Bad People!

Authenticity + Secrecy

Alice
A.priv

"I LUV U ……."

hash("I LUV U ...") → 12fea90897bddc

A.pub, B.pub, ...

Carl & Eve
Bad People!

Bob
B.priv

Authenticity + Secrecy

Alice
A.priv

“I LUV U
……”

“This is from A”

12fea90897bddc
A.priv

A.pub, B.pub, ...

Carl & Eve
Bad People!

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B.priv

Authenticity + Secrecy

Alice
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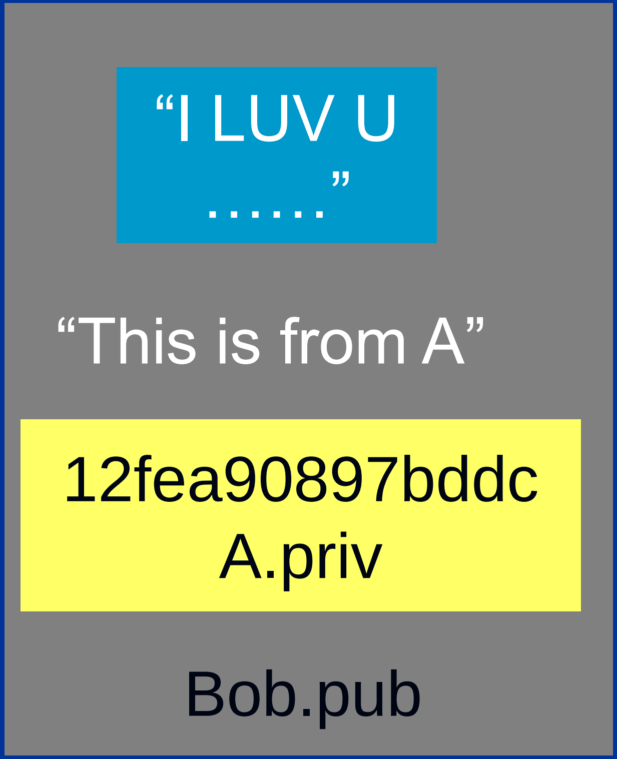
A.pub, B.pub, ...

Bob
B.priv



"I LUV U ……"

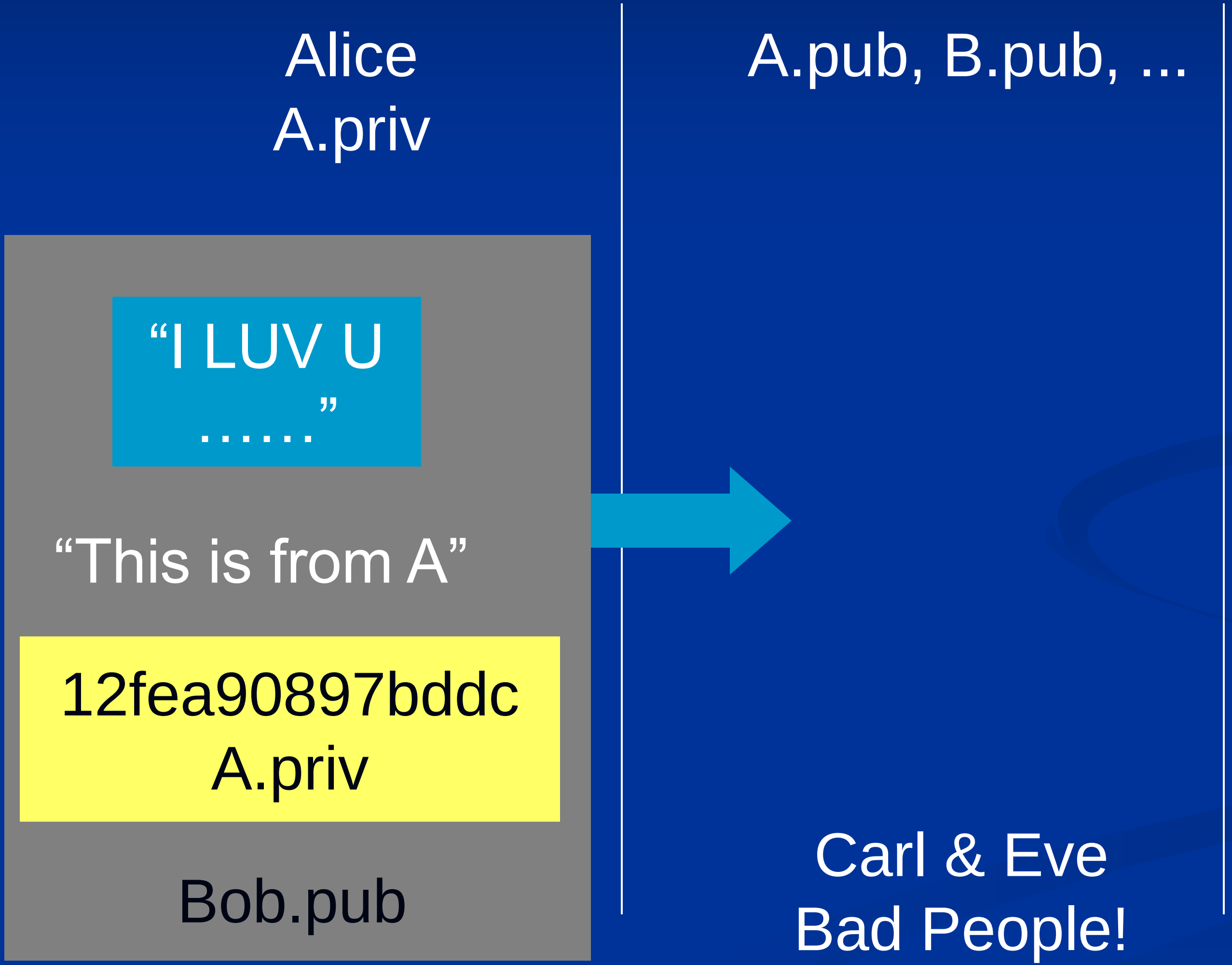
"This is from A"

12fea90897bddc
A.priv

Bob.pub

Carl & Eve
Bad People!

Authenticity + Secrecy



Alice
A.priv

A.pub, B.pub, ...

Bob
B.priv

"I LUV U ……"

"This is from A"

12fea90897bddc
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Carl & Eve
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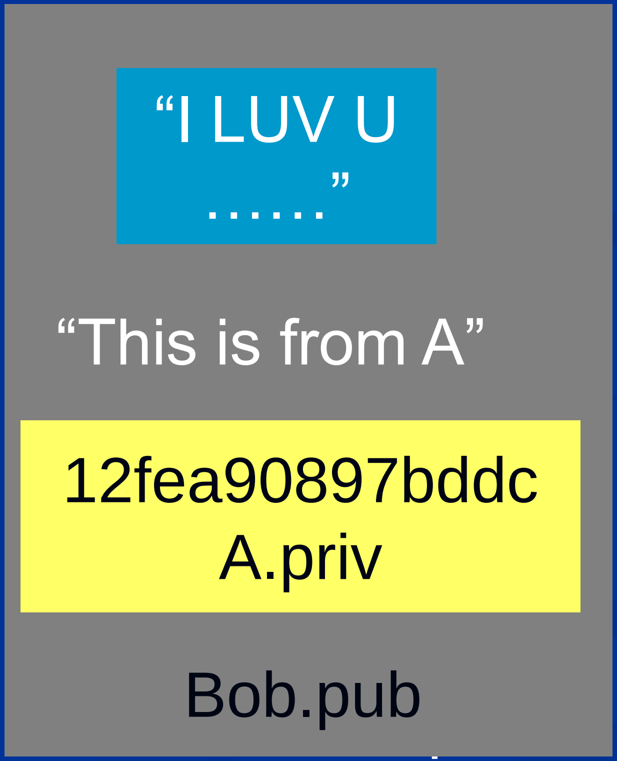

“I LUV U
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“This is from A”

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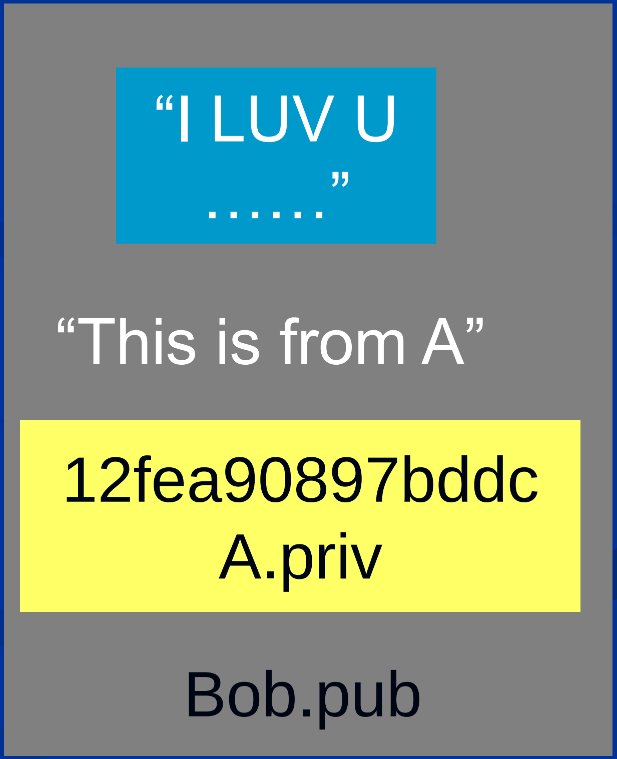

“I LUV U
…….”

“This is from A”

12fea90897bddc
A.priv

Bob.pub

Authenticity + Secrecy

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A.pub, B.pub, ...

Carl & Eve
Bad People!

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“I LUV U
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Authenticity + Secrecy

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“I LUV U
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12fea90897bddc
A.priv

Authenticity + Secrecy

Alice
A.priv

A.pub, B.pub, ...

Carl & Eve
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Bob
B.priv

“I LUV U ......”

“This is from A”

12fea90897bddc
==
hash("I LUV U ...") →
12fea90897bddc

Certificates

- Certificate Authority: publishes that a particular identity goes with a particular public key
- Alice gets certificate (identity <=> public key), signed by CA
- So if you trust CA, then you can trust the public key

SSL

- Alice connects to Bob's server
- Bob's server returns certificate (signed by VeriSign), plus something encrypted w/ Bob.priv
- Alice can verify certificate is valid
- Uses public key to decrypt token
- Bob authenticated
- Alice makes one time session key k
- Encrypts w/ Bob's public key, sends to Bob
- Now, can use symmetric key cryptography

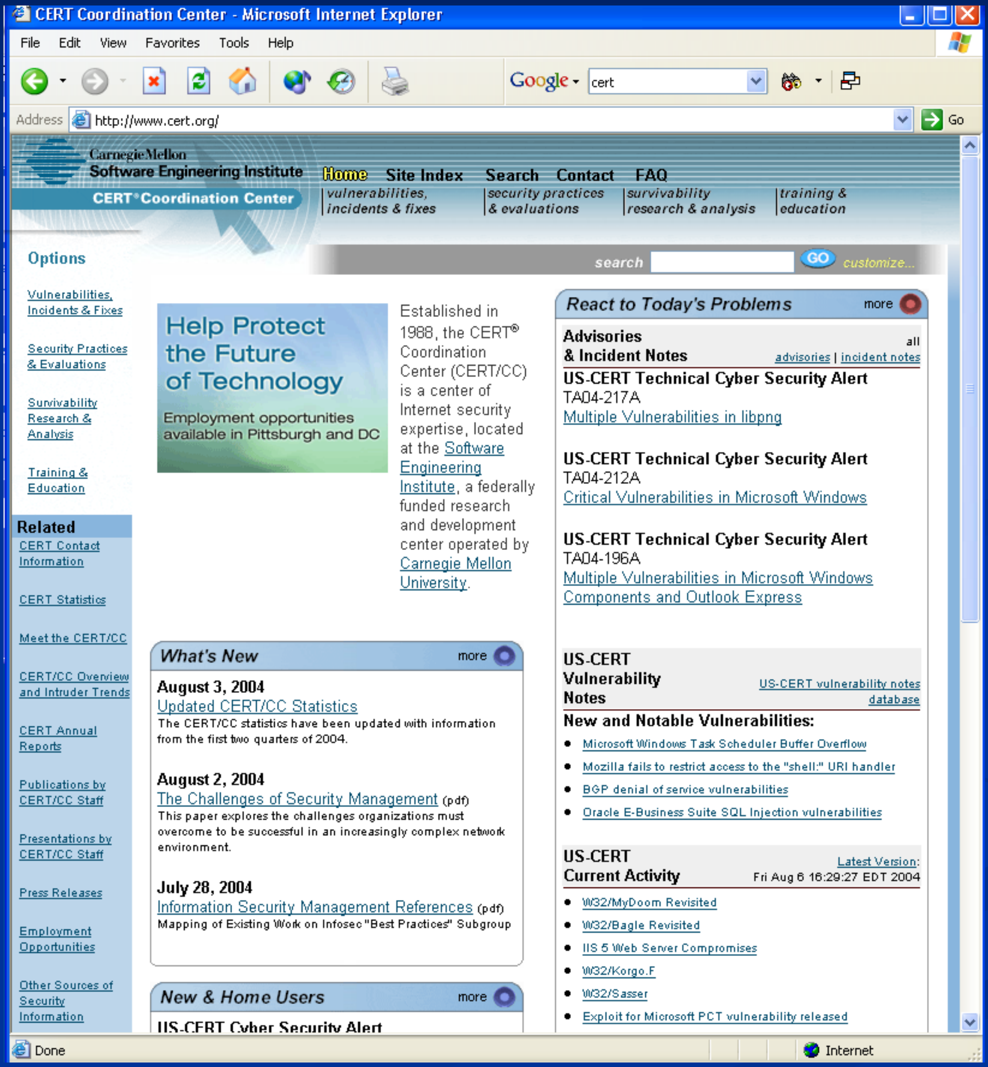
Symmetric vs. Asymmetric

- Symmetric faster but relies on shared secret
- Asymmetric slower but “solves” distribution-of-keys problem

Security History

- If you write it, they will come… to attack it. :o)
- Be aware of most common attacks…
- Learn the basic tricks to writing safer code.

CERT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Address http://www.cert.org/ Go
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Internet

Carnegie Mellon Software Engineering Institute

CERT® Coordination Center

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vulnerabilities, incidents & fixes | security practices & evaluations | survivability research & analysis | training & education

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Established in 1988, the CERT® Coordination Center (CERT/CC) is a center of Internet security expertise, located at the Software Engineering Institute, a federally funded research and development center operated by Carnegie Mellon University.

What's New more

August 3, 2004
Updated CERT/CC Statistics
The CERT/CC statistics have been updated with information from the first two quarters of 2004.

August 2, 2004
The Challenges of Security Management (pdf)
This paper explores the challenges organizations must overcome to be successful in an increasingly complex network environment.

July 28, 2004
Information Security Management References (pdf)
Mapping of Existing Work on Infosec "Best Practices" Subgroup

New & Home Users more

US-CERT Cyber Security Alert

React to Today's Problems more

Advisories & Incident Notes all advisories | incident notes

US-CERT Technical Cyber Security Alert
TA04-217A
Multiple Vulnerabilities in libpng

US-CERT Technical Cyber Security Alert
TA04-212A
Critical Vulnerabilities in Microsoft Windows

US-CERT Technical Cyber Security Alert
TA04-196A
Multiple Vulnerabilities in Microsoft Windows Components and Outlook Express

US-CERT Vulnerability Notes US-CERT vulnerability notes database

New and Notable Vulnerabilities:

- Microsoft Windows Task Scheduler Buffer Overflow
- Mozilla fails to restrict access to the "shell:" URI handler
- BGP denial of service vulnerabilities
- Oracle E-Business Suite SQL Injection vulnerabilities

US-CERT Current Activity Latest Version: Fri Aug 6 16:29:27 EDT 2004

- W32/MyDoom Revisited
- W32/Bagle Revisited
- IIS 5 Web Server Compromises
- W32/Korgo.F
- W32/Sasser
- Exploit for Microsoft PCT vulnerability released

Terminology

- Vulnerability -- some buggy code that can allow bad guys to compromise your machine, or do other bad guy things
- Exploit -- some code or method to take advantage of the vulnerability

Attack: Social Engineering

- Tricking a naïve person into revealing sensitive data (i.e. his/her password)
  - Hi this is your bank. We need your PIN to fix your account ASAP!
  - Hi this is Amazon. Your order #2333 didn't go through because your credit card was rejected. Tell us another credit card's info, and your order will be good.
  - Dumpster-diving for username & passwords on paper

Bottom Line

- People are the weakest link
- Educate people about computer/Internet Security

Attack: Traffic Sniffing

- Looking at packets on the wire, reading off passwords, etc...
- Problem for authentication mechanisms with cleartext passwords

Traffic Sniffing

- (Somehow) compromise a machine. This is the hard part.
- Set ethernet "promiscuous" mode
- Install a root kit
  - hides hacker activity
  - key logger
  - packet sniffer
  - recompiled versions of programs (passwd, ls)

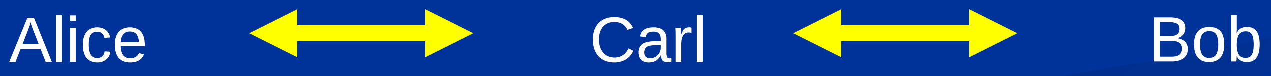
Attack: Spoofer

- One person (hacker) successfully masquerades as another (normal user)

IP Spoofing

- Rewrite headers in IP packets to say they are from someone else
- Launch some other attack. Spoofed IPs prevent good guys from finding you.

Man In the Middle Attack (Spoofing)

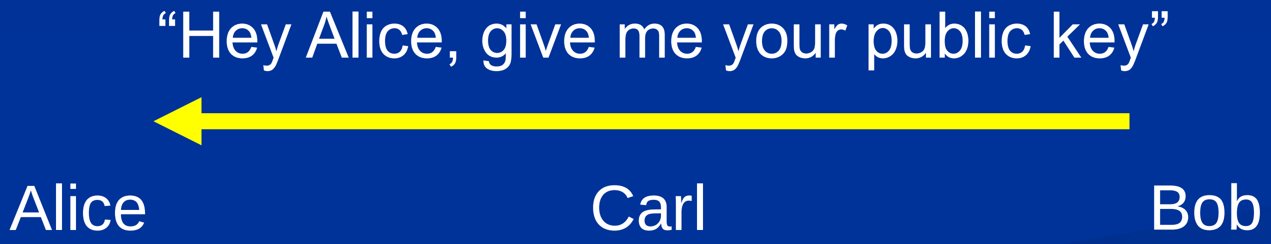


Alice

Carl

Bob

Man In the Middle Attack (Spoofing)



"Hey Alice, give me your public key"

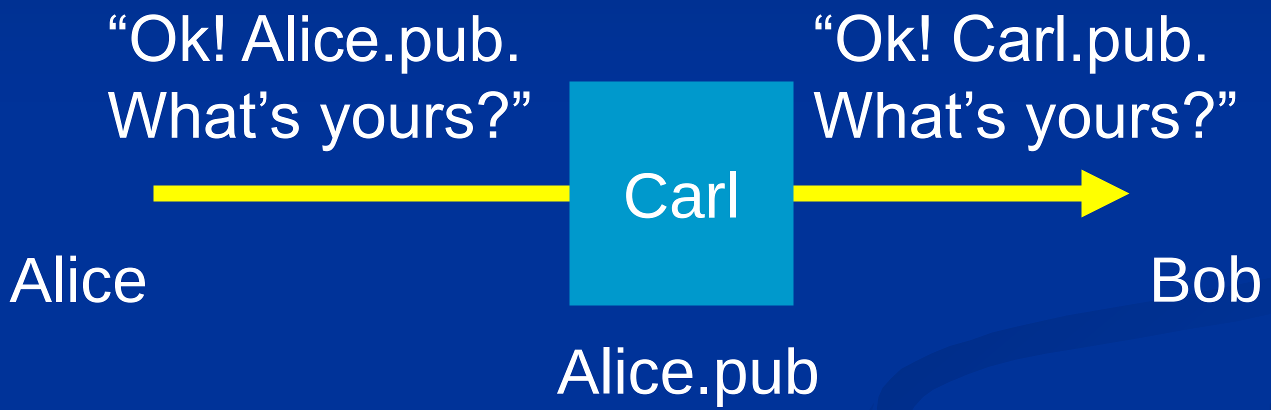
Alice

Carl

Bob

SSL-Like Example

Man In the Middle Attack (Spoofing)



"Ok! Alice.pub. What's yours?"

"Ok! Carl.pub. What's yours?"

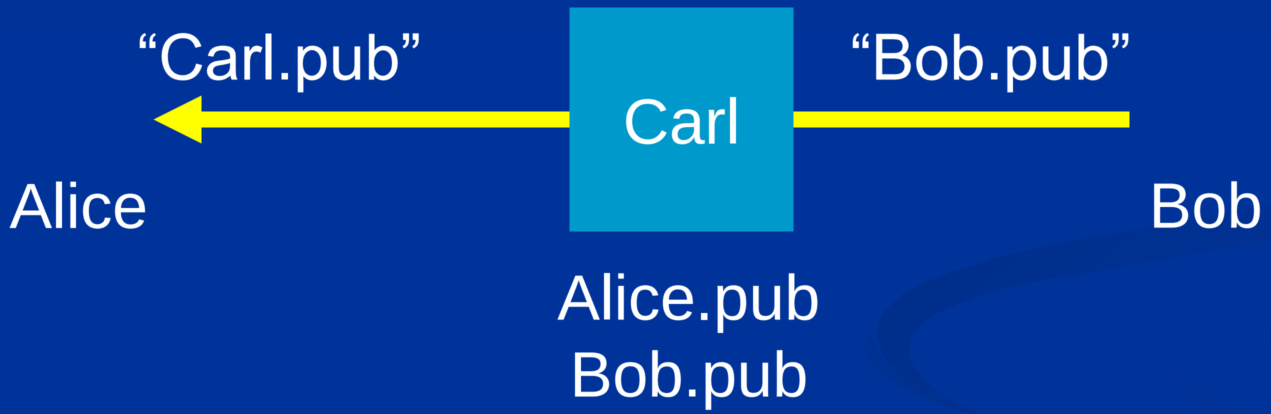
Carl

Alice

Bob

Alice.pub

Man In the Middle Attack (Spoofing)



“Carl.pub”

Carl

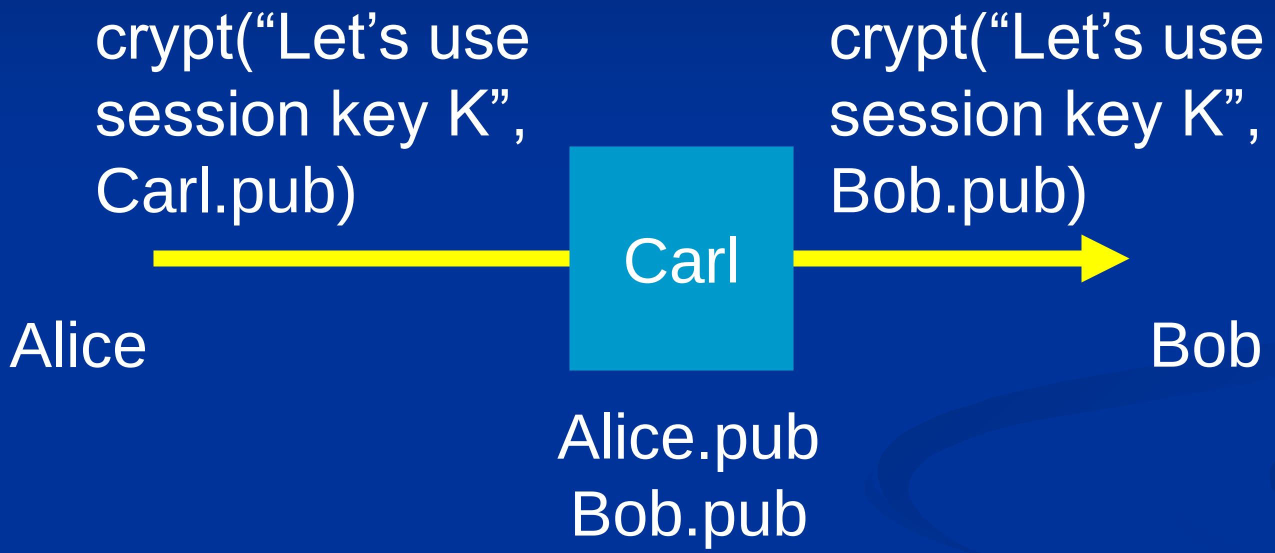
“Bob.pub”

Alice

Bob

Alice.pub
Bob.pub

Man In the Middle Attack (Spoofing)



crypt(“Let’s use session key K”, Carl.pub)

crypt(“Let’s use session key K”, Bob.pub)

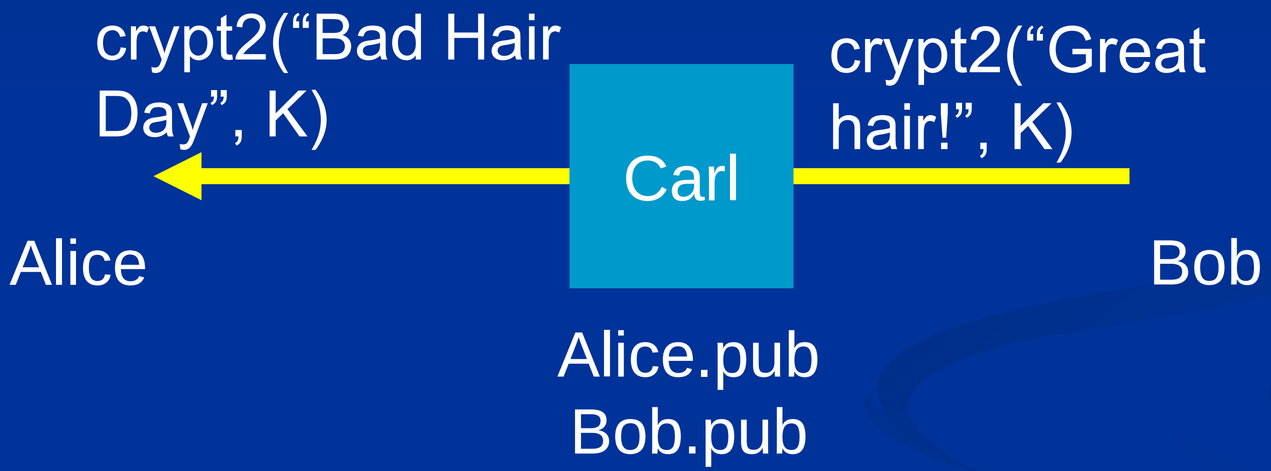
Carl

Alice

Bob

Alice.pub
Bob.pub

Man In the Middle Attack (Spoofing)



crypt2("Bad Hair Day", K)

crypt2("Great hair!", K)

Carl

Alice

Bob

Alice.pub
Bob.pub

Verify Authenticity

- Through digital signatures
- And Certificate Authorities

Attack: DNS Poisoning

- DNS server accepts and uses incorrect info from host with no authority
- Future requests given the incorrect info from that server’s cache

Attack: Password Guessing

- How long is YOUR password?
- Ways to break
  - Dictionary attack (words, names, dates)
  - Brute force
- Solutions
  - Freeze/Turn off account if too many incorrect logins?
  - Wait 2 seconds before logging in/displaying error.

Passwords

- What if your website froze accounts if too many incorrect logins?
- Hacker can still attack your sites users!
- By purposefully guessing login/passwords incorrectly, so that your system locks all accounts!

Solutions

- Longer passwords
- Other forms of authentication
  - Biometric
  - Physical key/card based

Attack: Denial of Service

- Make the service unavailable
- Flood of incoming traffic

  (SYN flood, Malformed Packets)
- Use robot to launch DOS on server. Hard to trace identity of attacker.
- Distributed DOS (DDOS)
  - Take over many machines, launch attack simultaneously from many locations

Smurf DOS

- Bad guy sends ping packets to IP broadcast addresses, source IP spoofed of course
- All hosts on that network perform an ICMP echo reply (reply to the ping)
- Potentially hundreds of replies per packet, can bring network down

External Executables

- Don't trust other people's code
- If Carl can run code on Alice's computer... then Carl can take it over
- Internet Explorer, Safari Vulnerabilities
- “Reflections on Trusting Trust”, Ken Thompson (http://www.acm.org/classics/sep95/)

Attack: Trojan Horse

- Greek allusion (also, remember Monty Python?)
- Innocent looking program, does something malicious
    - OpenSexyPics.exe, Readme.txt.exe
- "recent Trojans include programs disguised as fixes to common computer viruses and those promising free pornographic images."

Attack: Buffer Overflow

- Bad guy sends a huge, over-sized request to a naïvely implemented (aka buggy) program, overflowing the input buffer
- May overwrite data in memory (and/or) program code
- May overwrite the return address on the stack of a program in C, so that the procedure call returns somewhere else

How To Avoid Buffer Overflow

- Write code carefully
- Limit input size; read in small chunks as opposed to reading in whole input
- Use better languages (read: Java)

Attack: Worm

- Self replicating/Spreading computer program

Example

- Morris Worm -- buffer overflow attack on UNIX finger and other programs...
- Robert Tappan Morris, Jr. (CMU student) launched it on Nov 2, 1988 from an MIT computer
- Intended to just spread, but a _bug_ in his code infected computers multiple times, so that computers FROZE after a while
- Infected 6000 UNIX workstations
- CERT created in response to Morris
- Morris now a MIT faculty member

Worms and their Payloads

- Infect computer; send emails to other people... to spread the worm
- Infect computer; install a backdoor program to let bad guy log in... to send mass spam, send more worms, etc

Blaster Worm

- Exploited a buffer overflow in Windows's RPC service
- Programmed to SYN flood windowsupdate.com on August 15 to prevent patches

Attack: Computer Virus

- Attaches itself to a host, another computer program
- Tries to infect other executable files it finds
- When run, it damages resources, files, etc…

Timeline of Viruses and Worms

- May 2004 -- Sasser
  - Delta Airlines canceled many flights, computers down from Sasser
- January 2004 -- MyDoom
  - Attacked MS & SCO Group websites with DDOS

http://en.wikipedia.org/wiki/Timeline_of_notable_computer_viruses_and_worms

Timeline of Viruses and Worms

- 2003 August: Sobig and Blaster
- 2001: Code Red attacks IIS
- 2000: VBS/"I Love You" Worm
- 1999: Melissa Worm

http://en.wikipedia.org/wiki/Timeline_of_notable_computer_viruses_and_worms