Refresher: Cryptographic Terms and Concepts

Advanced ccTLD Workshop

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What's our Goal with all this?

(1)-- **C**onfidentiality

(2)-- **I**ntegrity

(3)-- **A**uthentication

- Access Control
- Verification
- Repudiation

(4)-- **A**vailability

1976 Was an Important Year

DES: Adopted as an encryption standard by the US government. It was an *open* standard. The NSA calls it “One of their biggest mistakes.”

But, more importantly for us...

public-key cryptography: Whitfield Diffie and Martin Hellman describe public/private key cryptographic techniques using trap-door one-way mathematical functions. Radical transformation of the cryptographic paradigm.

Review

This is the warm-up for tomorrow and DNSSEC...

You can read RFC 3833, “Threat Analysis of the Domain Name System”:

- http://tools.ietf.org/html/rfc3833

DNSSEC helps us to solve several issues:

- Packet interception
- ID Guessing and Query Prediction
- Name Chaining (“Cache Poisoning”)
- Betrayal by Trusted Server

Terminology

- hashes/message digests
  - md5/sha1
  - collisions
- entropy (randomness)
- keys
  - symmetric
  - asymmetric (public/private)
  - length
  - distribution
  - creation
- Digital signatures
- ciphers
  - block
  - stream
- plaintext/ciphertext
- password/passphrase

All these lead to...

- SSL/TLS
  - Digital Certificates
    - + CSRs
    - + CRTs
    - + PEM files
    - + CAs
- SSH
- PGP
- Secure email with:
  - secure SMTP
    - + SSL
    - + StartTLS
  - POPS, IMAPS
- DNSSEC

Ciphers ==> ciphertext

We start with *plaintext*. Something you can read.

We apply a mathematical algorithm to the plaintext.

The algorithm is the *cipher*.

The plaintext is turned in to *ciphertext*.

Almost all ciphers were secret until recently.

Creating a secure cipher is *HARD*.

Keys

To create ciphertext and turn it back to plaintext we apply a key to the cipher.

The security of the ciphertext rests with the key. This is a *critical* point. If someone gets your key, your data is compromised.

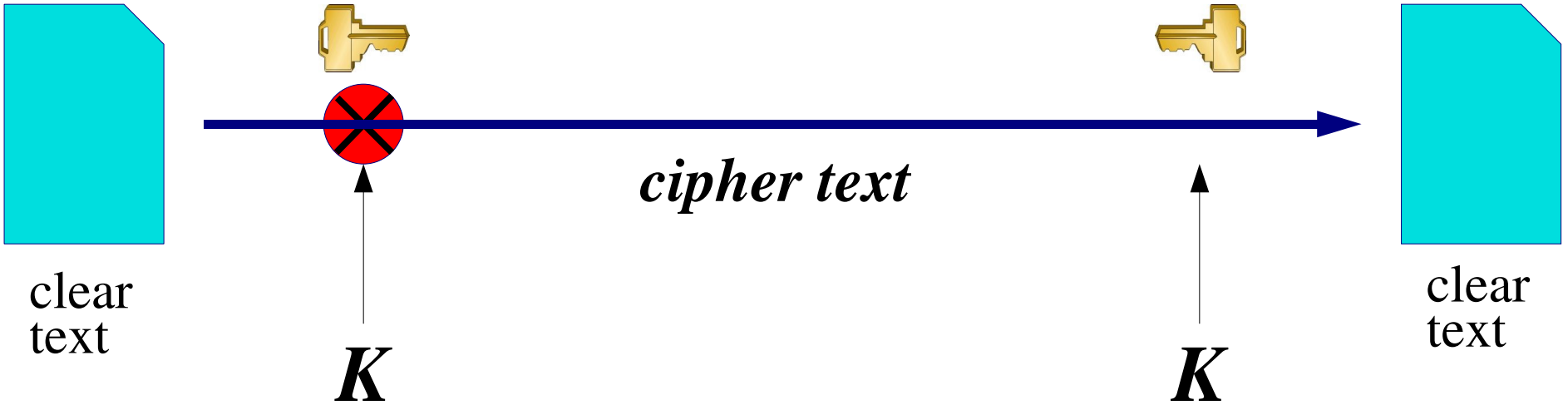
This type of key is called a *private key*.

This type of cipher system is efficient for large amounts of data.

This is a *symmetric cipher*.

Symmetric Cipher

Private Key/Symmetric Ciphers



The same key is used to encrypt the document before sending and to decrypt it once it is received

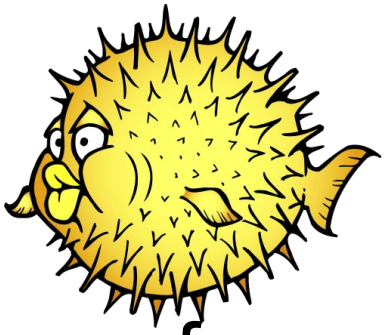
Examples of Symmetric Ciphers

DES - 56 bit key length, designed by US security service

3DES - effective key length 112 bits

AES (Advanced Encryption Standard) - 128 to 256 bit key length

Blowfish - 128 bits, optimized for fast operation on 32-bit microprocessors



IDEA - 128 bits, patented (requires a license for commercial use)

Features of Symmetric Ciphers

- Fast to encrypt and decrypt, suitable for large volumes of data
- A well-designed cipher is only subject to brute-force attack; the strength is therefore directly related to the key length.
- Current recommendation is a key length of at least 90 bits
  - i.e. to be fairly sure that your data will be safe for at least 20 years
- Problem - how do you distribute the keys?

Public/Private Keys

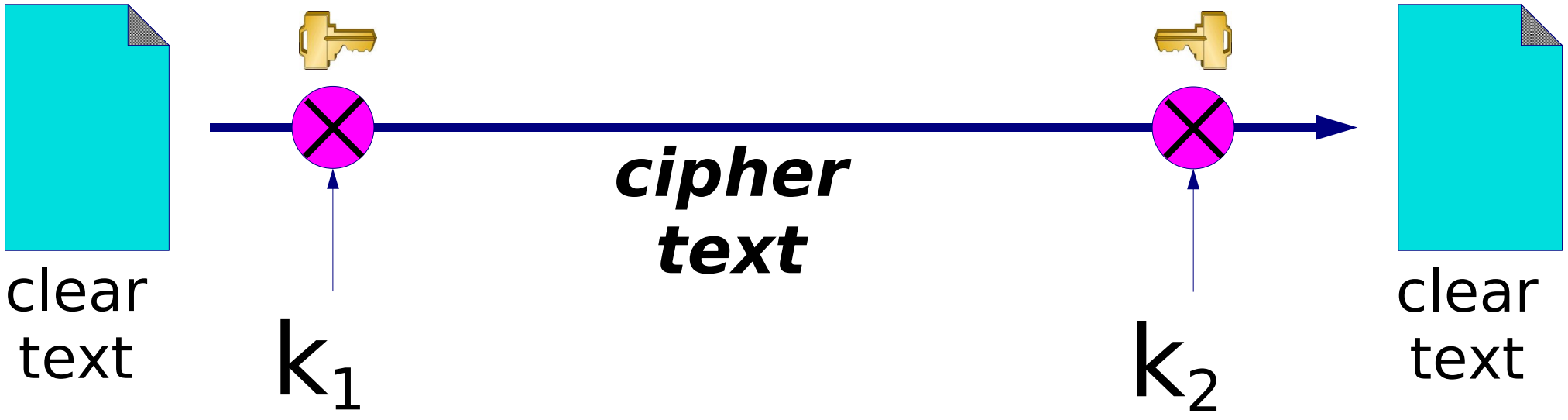
We generate a cipher key pair. One key is the *private key*, the other is the *public key*.

The *private key* remains secret and should be protected.

The *public key* is freely distributable. It is related mathematically to the private key, but you cannot (easily) reverse engineer the *private key* from the *public key.*

Use the *public key* to encrypt data. Only someone with the *private key* can decrypt.

Example (Public/Private Key pair): Not Efficient – Not as Secure



One key is used to encrypt the document,
a different key is used to decrypt it.
This is a big deal!

Why Not Efficient/Secure?

- Symmetric ciphers (one private key) are *much* more efficient. About 1000x more efficient than public key algorithms for data transmission!
- Attack on the public key is possible via chosen-plaintext attack. Thus, the public/private key pair need to be large (2048 bits).

Why Not Efficient/Secure cont.

Mathematically we have:

E = the encryption function

C = ciphertext

P = plaintext

C = E(P)

So, if you know one P encrypted by E, then you can attack by guessing all possible plaintexts and comparing with C. E is public in this case. Thus, you can recover the complete original text.

Hybrid Systems

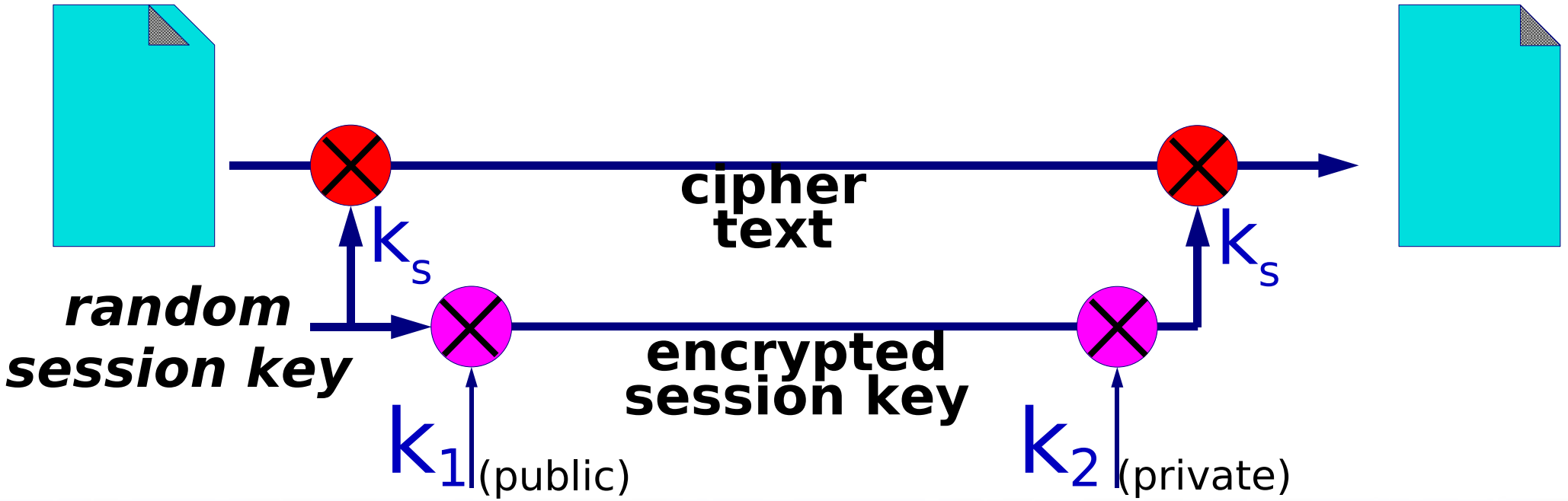
Symmetric Ciphers are not vulnerable in the previous way. The key length can be much shorter.

So, we do this:

- Use a symmetric cipher.
- Generate a one-time private key.
- Encrypt the key using a public key.
- Send it to the other side, decrypt the one-time key.
- Start transmitting data using the symmetric cipher.

Hybrid Systems

Use a symmetric cipher with a random key (the "session key"). Use a public key cipher to encrypt the session key and send it along with the encrypted document.



Hybrid Systems cont…

Two things should (imho) stand out:

1) "*Send it to the other side, decrypt the one-time key.*" How?
2) What about protecting your private key?

Any ideas?

Hybrid Systems cont…

1) "*Send it to the other side, decrypt the one-time key.*" How?

   Use your private key.

2) What about protecting your private key?

   Encrypt it using a hash function.

One-Way Hashing Functions

A mathematical function that generates a fixed length result regardless of the amount of data you pass through it. Generally very fast.

You cannot generate the original data from the fixed-length result.

Hopefully you cannot find two sets of data that produce the same fixed-length result. If you do this is called a *collision*.

One-Way Hashing Functions cont.

Two popular hashing functions include:

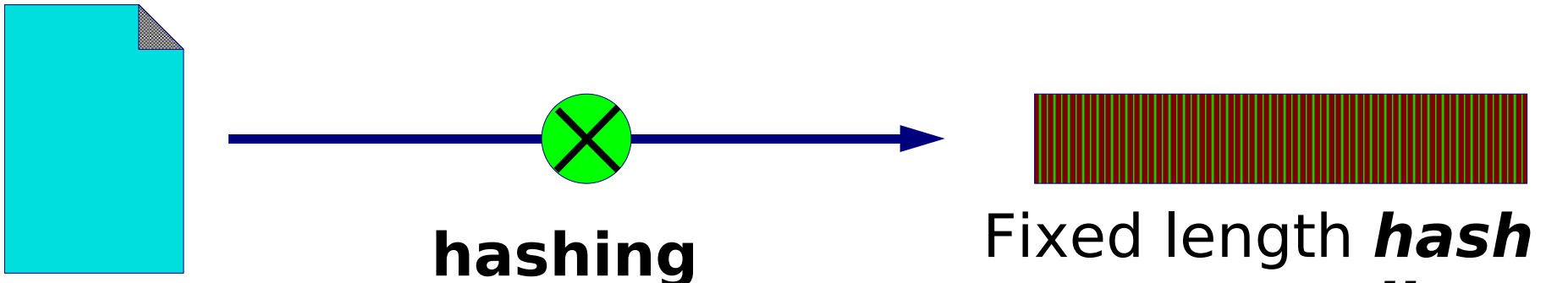
- md5: Outputs 128 bit result. Fast. Collisions found.
- sha-1: Outputs 160 bits. Slower. No collisions yet.

Applying a hashing function to plaintext is called *munging the document*.

The fixed-length result is referred to as a *checksum, fingerprint, message digest,* etc.

Hashing

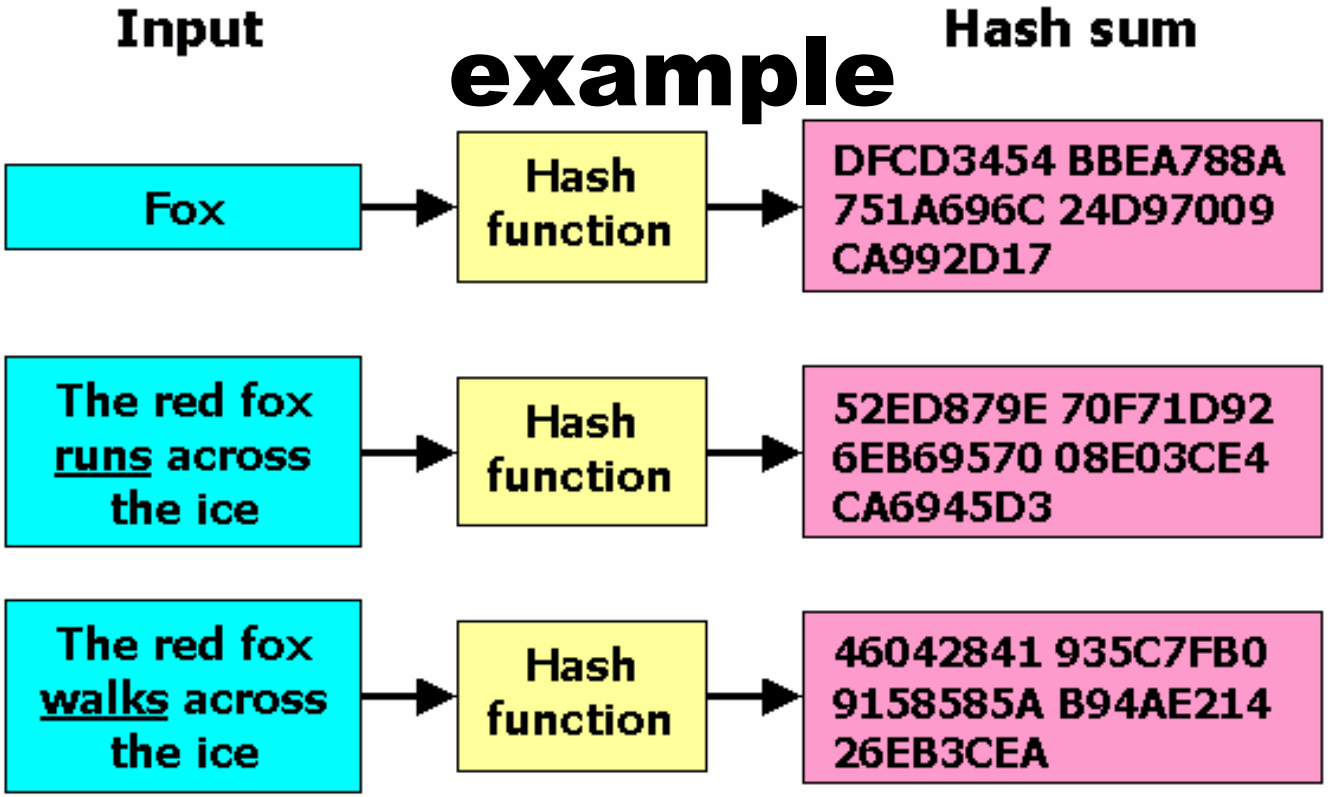
One-Way Encryption



Munging the document gives a short ***message digest*** (checksum). Not possible to go back from the digest to the original document.

Hashing

one-way encryption: another example



Note the significant change in the hash sum for minor changes in the input. Note that the hash sum is the same length for varying input sizes. This is extremely useful.

*Image courtesy Wikipedia.org.

Examples

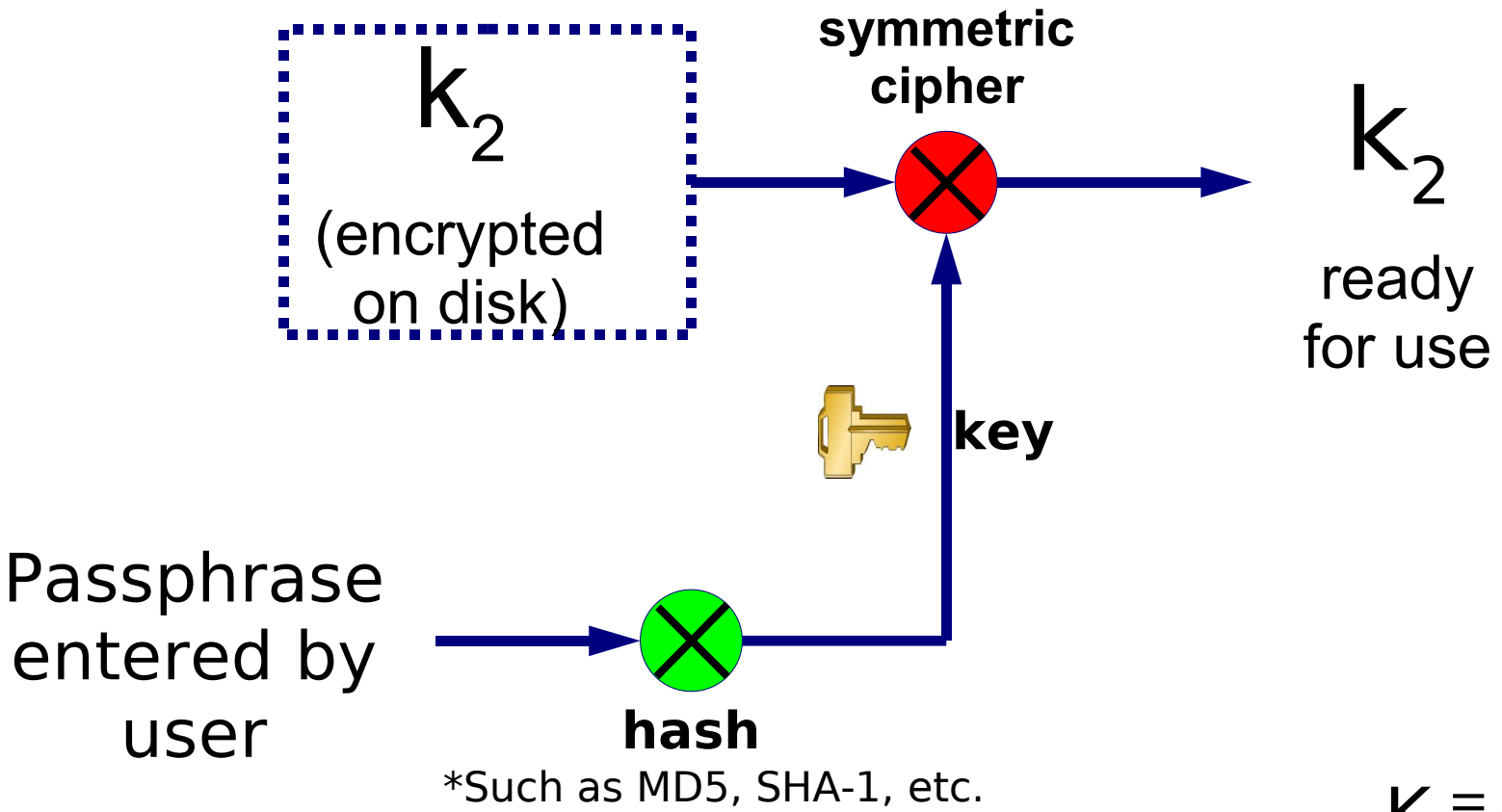
- Unix ***crypt***() function, based on DES (***not secure!)***
- ***MD5*** (Message Digest 5) - 128 bit hash
- ***SHA1*** (Secure Hash Algorithm) - 160 bits
- Until August 2004, no two documents had been discovered which had the same MD5 digest!
  - Such "collisions" are not a major problem as yet
  - No collisions have yet been found in SHA-1
- Still no feasible method to create any document which has a given MD5 digest

What use is this?

- You can run many megabytes of data through a hashing function, but only have to check 128-160 bits of information. A compact and *unique document signature*.*
- You can generate a *passphrase* for your data – such as your encrypted private key. If someone gets your private key, they still must know your passphrase to decrypt anything using your private key.

* Even with the recent attack, at best the attacker could add some corruption and leave the MD5sum unchanged. They could not insert any data of their own choosing.

Protecting the Private Key



$K_2 = private\ key$

Checking passphrases/passwords

Q.) How do you do this?

A.) It's very simple.

- Type in a passphrase/password.
- Run the hashing function on the text.
- If the message digest matches, you typed in the correct passphrase/password.

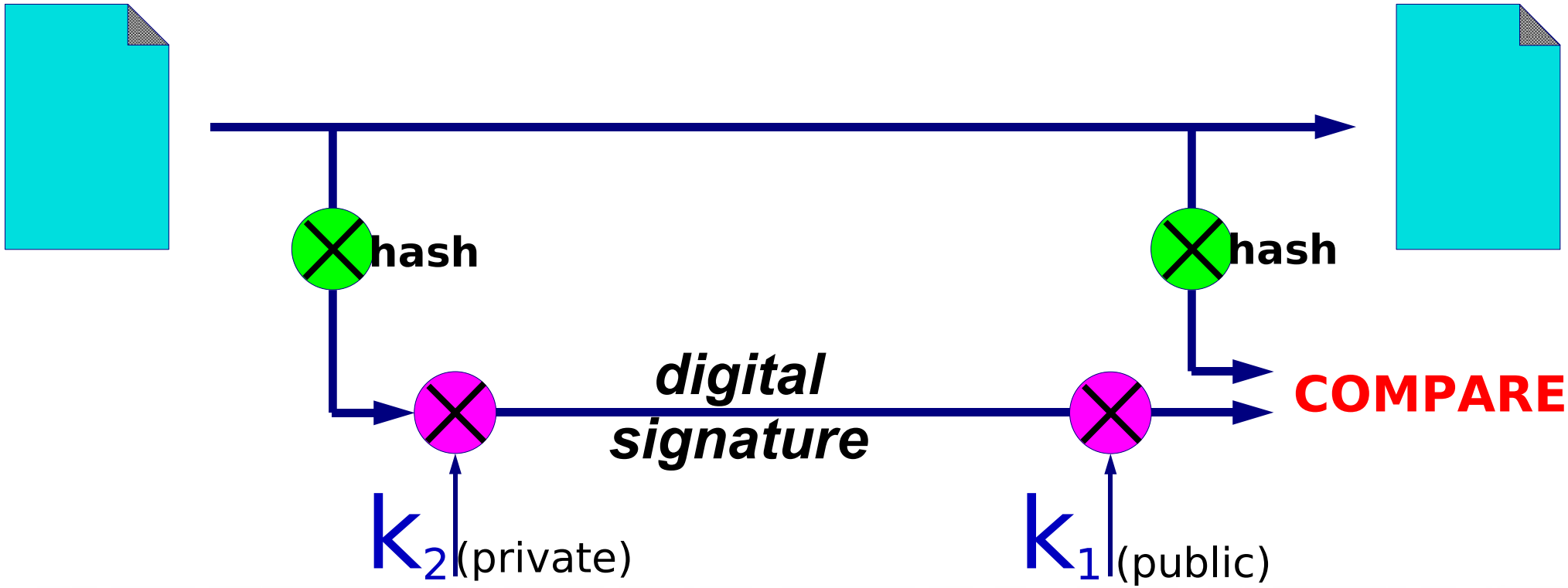
Digital Signatures

Let's reverse the role of public and private keys. To create a digital signature on a document do:

- *Munge* a document.
- Encrypt the *message digest* with your private key.
- Send the document plus the encrypted message digest.
- On the other end munge the document again *and* decrypt the encrypted message digest with the person's public key.
- If they match, the document is authenticated.

When authenticating:

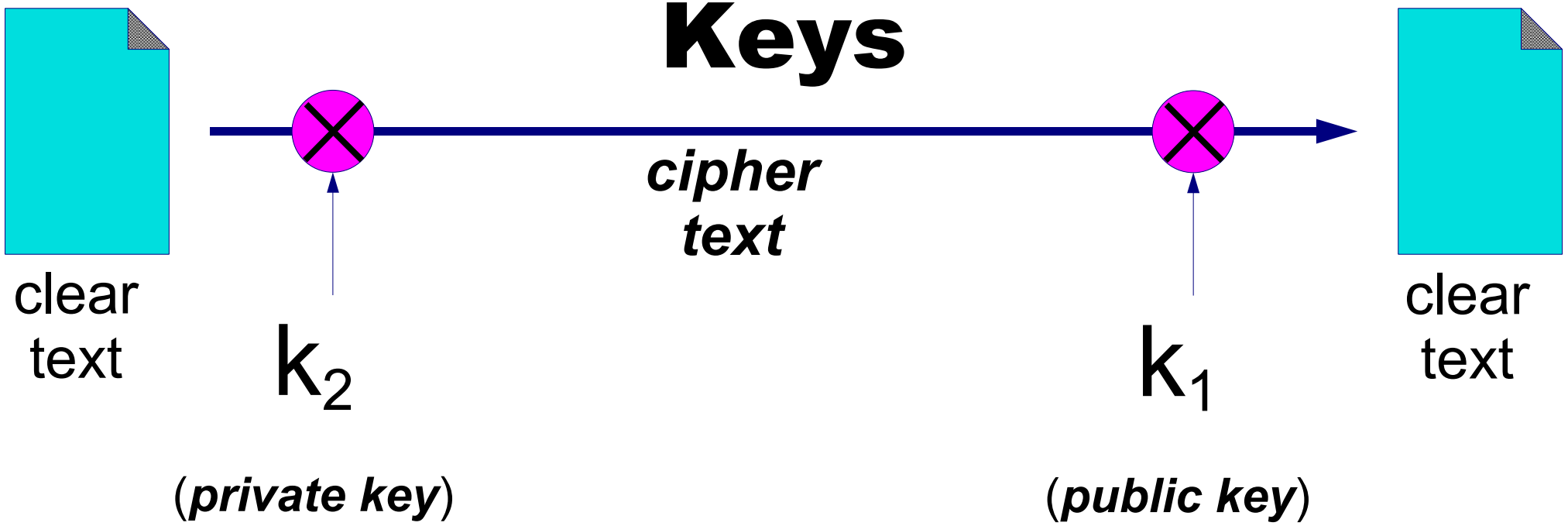
Take a hash of the document and encrypt only that. An encrypted hash is called a "digital signature"



Digital Signatures have many uses, for example:

- E-commerce. An instruction to your bank to transfer money can be authenticated with a digital signature.
- A trusted third party can issue declarations such as "the holder of this key is a person who is legally known as Alice Hacker"
  - Like a passport binds your identity to your face
- Such a declaration is called a "certificate"
- You only need the third-party's public key to check the signature
- We'll talk about this more later.
- DNSSEC

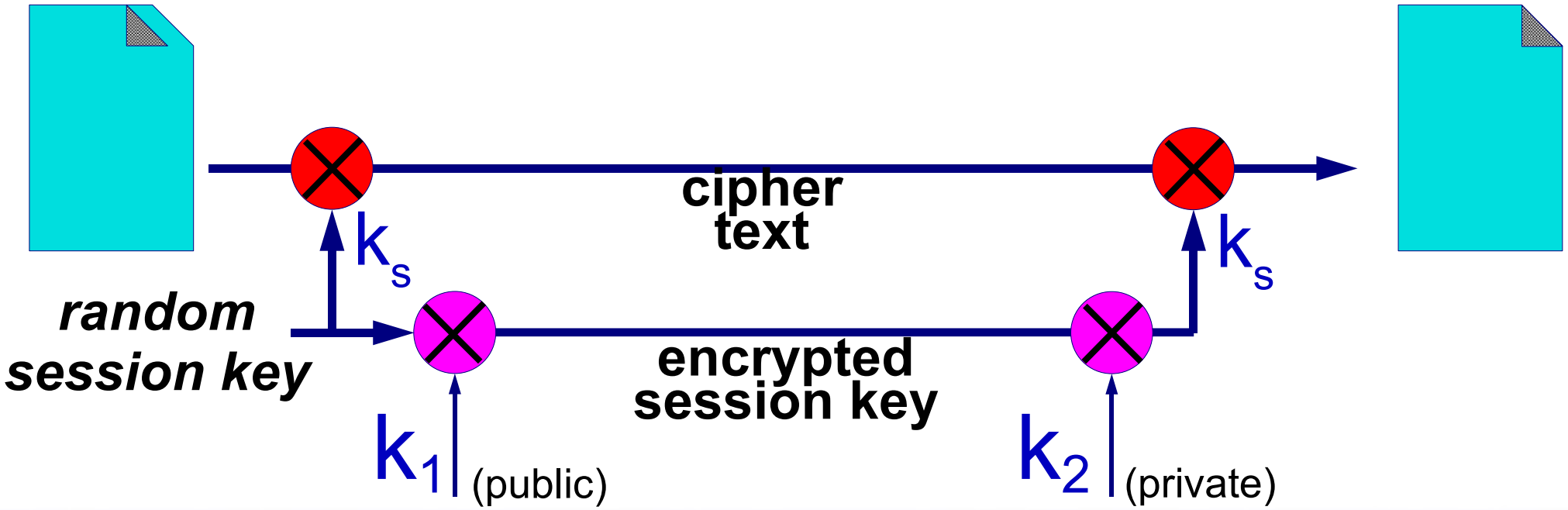
Use for Authentication: Reverse the Roles of the Keys



If you can decrypt the document with the public key, it proves it was written by the owner of the private key (and was not changed).

Summary

The core idea you should take away from this is how a hybrid cryptosystem works:



Summary cont.

To view this mathematically we have:

E = the encryption function

C = ciphertext

P = plaintext: M=Message (binary data)

D = decryption function

K_1 = encryption key (public)

K_2 = different encryption key (private)

Summary cont.

Symmetric Cipher

$E_{K_2}(M) = C$

$D_{K_2}(C) = M$

With the property that:

$D_{K_2}(E_{K_2}(M)) = M$

And, with different keys (public/private) we have:

$E_{K_1}(M) = C$

$D_{K_2}(C) = M$

$D_{K_2}(E_{K_1}(M)) = M$

Summary cont.

Finally – Remember, we are using *open* cryptosystems. This means that the cipher algorithm is known and available.

The security of your data rests with the key, not with keeping the cipher secret.

All Clear? :-)

Questions?

“Applied Cryptography”

Written by Bruce Schneier. This is, perhaps, the best book around if you want to understand how all this works.

- Crypto-Gram email newsletter
  - http://www.schneier.com/crypto-gram.html
- Counterpane Security
  - http://www.counterpane.com/
- A voice of reason around much of the security hysteria we face today.

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http://www.this-page-intentionally-left-blank.org/

Exercises

Create a public/private key pair and place your public key on your neighbor's machine.

For this exercise here are your neighbors:

pc1 <==> noc

pc2 <==> pc3

pc4 <==> pc5

pc6 <==> pc7

pc8 <==> pc9

Exercises: ssh

Open a terminal window as the admin user (not root!).

```
$ ssh-keygen -b 2048 -t rsa
```

Choose all the defaults. **Don't** enter a password.

First ssh to your neighbor:

```
$ ssh admin@pcN
```

What happened? What does it mean?

Exercises: ssh cont.

Now exit your neighbor's machine

```
$ exit
```

On your machine copy your public key over to your neighbor's admin account.

```
$ cd. ssh
$ scp id_rsa.pub admin@pcN:/tmp/.
$ ssh admin@pcN
$ cd .ssh     [if no .ssh dir create one]
```

Exercises: ssh cont.

$ cat /tmp/id_rsa.pub >> authorized_keys

$ rm /tmp/id_rsa.pub

$ exit

$ ssh admin@pcN

What happened? Why?

Exercises: munging

Let's just prove this concept to ourselves.

You need to be root, so:

```
$ su -
# cat /etc/motd
```

Lots of text, etc... Now we'll munge the document using two hashing functions:

```
# md5 /etc/motd > munge.txt
# sha1 /etc/motd >> munge.txt
```

Exercises: munging cont.

Now make some very minor change to the /etc/motd document:

```
# vi /etc/motd
```

Save your change and exit and we'll munge again (note “>>”):

```
# md5 /etc/motd >> munge.txt
# sha1 /etc/motd >> munge.txt
```

Exercises: munging cont.

Now look at the file “munge.txt”:

```
# cat munge.txt
```

The resultant hashes for /etc/motd should be significantly different.